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PREFACE

This proceedings book contains full papers of the ORENKO 2018 – International Forest Products Congress held on September 26-29, 2018 in Trabzon, Turkey. The congress, organized by the Forest Industry Engineering Department at Karadeniz Technical University, has received about 200 abstracts from all over the world including United States, Canada, Australia, Slovenia, Slovakia, Serbia, Romania, Poland, South Korea, Italy, Iraq, Iran, Czech Republic, China, Chile, Bulgaria, Sweden, Bangladesh and Turkey. After an initial review of the submitted abstracts, about 180 abstracts were accepted for oral and poster presentation.

The purpose of this congress is to provide an up-to-date discussion in the field of forest products in general. ORENKO 2018 is focused on the theme "Outlining the Forefront Research in The Field of Wood Science and Engineering". The topics that covered in the congress include wood science, technology and engineering, wood and wood-based products, wood anatomy, wood raw materials, wood composites, wood-plastic composites, engineered wood products, wood drying, biomaterials, wood constructions, physico-mechanical properties of wood and wood-based materials, nanotechnology applications in wood science, nondestructive evaluation of wood, sustainable utilization of forest products, wood preservation, wood modification, wood biomass, wood-inhabiting insects and fungi, marine borers, recycle/reuse/disposal of wood and wood based materials, non-wood forest products, wood chemistry, adhesives and bioresins, formaldehyde and VOC emission from wood based panels, pulp and paper, advanced cellulosic products, fiber resources from non-woody plants, furniture design and manufacturing, wood coatings, wood finishing, archaeological wooden structures, industry 4.0 in forest products industry, forest products economics, forest products marketing, production management and operational research, artificial intelligence in forest product industry, forest products ergonomics, environmental and ecological issues in forest products and occupational health and safety in forest products industry.

Reviewing papers of ORENKO 2018 was a challenging process that relies of the goodwill of those people involved in the field. More than 30 researchers from related fields were invited to review papers for the presentation. We would like thank all the reviewers for their time and effort in reviewing the papers.

Finally, we would like to thank to all person of the organizing committee who have dedicated their constant support and countless time to organize this congress. The ORENKO 2018 is a credit to a large group of people, and everyone should be proud of outcome.

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KEYNOTE ADRESSES

THE INTERNATIONAL FOREST PRODUCTS CONGRESS

Protection of Wood: A Global Perspective on the Future

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Protection of Wood: A Global Perspective on the Future

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ABSTRACT

The current state of wood protection is briefly reviewed, and then the issues that are affecting preservative treatments are summarized. The strategies for addressing these issues are discussed in relation to the role of wood as a renewable building material. The potential for addressing biological attack, ultraviolet light degradation and dimensional stability in a single product are discussed in relation to the need to produce a longer lasting material that retains the environmental attributes of wood.

KEYWORDS: Wood Deterioration, Wood Protection, Preservatives, Barriers, Wood Modification

1 INTRODUCTION

Wood and wood-based materials are among our most important renewable materials with many desirable properties, but susceptibility to damage by combinations of sunlight exposure (primarily ultra-violet light), repeated wetting/drying and biological degradation remain as major negative attributes. The agents of deterioration can combine to markedly shorten the useful lives of many wood based products. Shorter service lives diminish the value of wood as a renewable resource while placing additional pressure on our forests.

While estimates of total global losses to degradation are scarce, Boyce (1961) long ago suggested that 10 % of the timber harvested in the United States was used to replace wood that had failed prematurely in service due to biodeterioration. Extended globally, the UN Food and Agricultural Organization (FAO, 2006) estimated global timber harvests to be 3 billion m3 per year, with 60 % of this production being used for products and the remainder for fuel. The 10 % of harvest figure would translate into 180 million m3 of wood that could be conserved by controlling degradation losses. This does not account for other squandered resources associated with energy consumption during harvesting and processing as well as installation, environmental impacts, and economic effects of the added harvesting. Clearly, limiting degradation can have sizable impacts on both economies and quality of life. While it would be virtually impossible to completely eliminate this loss, it is readily apparent that wood must be used more efficiently and protected more fully if it is to reassume a leading role as a critical structural material. Preservative treatments already contribute to improved wood conservation through extended service life, but there are opportunities for improvement. An important aspect of this effort must be the continued development of effective strategies for protecting wood against physical agents such as UV light, wetting as well as biological attack.

Protecting wood from all of these agents is certainly not new, but the methods used for protection have come under increasing scrutiny from a skeptical public that questions the use of chemicals for all purposes. For almost two centuries, we have depended on heavy duty preservatives such as creosote, pentachlorophenol or heavy metal combinations for wood protection, but public pressures have encouraged substitutions in many applications. Changes has not been uniform globally and examining the various strategies and patterns of change may help us to take a more holistic approach to wood protection. In this paper, we will review the general trends in wood protection in North America with references to activities taking place elsewhere. For the purposes of this review, we will concentrate on long term protection of exterior exposed solid wood products, thereby avoiding the limited market for whole-structure treatments and treated composites. While we recognize that naturally durable wood species have a role to play, they will not be discussed here and we will restrict ourselves to initial wood treatments excluding those used strictly to limit fungal mold and stain attack..

2 CURRENT STATE OF AFFAIRS

Although wood protection is a global need, the vast majority of treated wood is used in temperate climates and the bulk is used in North America (Vlosky and Shupe, 2006). This market constitutes approximately 60 % of the total global market for treated wood. It is unfortunate that the areas with the most critical needs for wood protection tend to employ these technologies, but the higher costs of treatment largely limit their use to developed nations. There remains a critical need for low cost wood protection for developing countries in tropical regions where deterioration rates are more severe.

The North American markets have long been dominated by the so-called heavy duty wood preservatives. Industrially, creosote, pentachlorophenol and heavy metal-based systems remain the dominant preservatives for industrial applications. While there have been challenges to the continued use of these chemicals, the producers have generated the required data to demonstrate that these systems can be safely used with minimal environmental impacts. The U. S. Environmental Protection Agency and Canada's Pesticide Management Regulatory Agency have both reviewed chemicals under their jurisdictions and continue to allow industrial uses (note: there are some differences in chemicals allowed between the two countries). In general, industrial uses of chemicals have been judged on their technical merits and very few chemicals are banned outright, although they may be restricted to specific uses. At the same time, some alternatives for industrial wood protection have emerged, including copper naphthenate and alkaline copper compounds. However, users, who are, by nature, conservative in adopting new systems without long term data, have been slow to adopt these systems.

On the residential side, the market was long dominated by chromated copper arsenate (CCA), but the 2004 decision by the manufacturers to withdraw the use of CCA for residential applications created opportunities for new systems. Much has happened in the intervening decade. The first CCA alternative was alkaline copper quaternary, closely followed by alkaline copper azole. These systems both depend upon copper as the primary biocide with smaller amounts of a carbon-based biocide to protect against copper tolerant organisms. Alkaline copper systems have been touted as more environmentally friendly because they lack arsenic or hexavalent chromium. However, they also contain much higher levels of copper than CCA and this can pose issues with regard to metal migration from the treated product. The high pH of these systems also creates the potential for corrosion of unprotected steel connections, necessitating the requirement for either hot-dip galvanized or stainless steel hardware. Despite their different handling characteristics, the use of these systems rapidly grew and they dominated the residential markets until the recent introduction of micronized copper systems. Micronized systems use finely ground copper suspensions in place of solubilized copper, along with either a triazole or quaternary ammonium co-biocide (McIntyre and Freeman, 2008). Micronized systems are widely used to treat southern pine, which is highly permeable and easily treated, however, these systems are not suitable for more difficult to impregnate species, making them less suitable for treatment of most Canadian wood species as well as woods from the Western United States. The shift to micronized systems has not been without debate because of concerns about the lack of long-term performance data and the lack of standardization by the American Wood Protection Association (AWPA); however, they appear to be performing well when properly applied.

The primary suppliers of wood preservative systems have also been working to develop metal-free alternatives (Morris, 2002). These systems can incorporate mixtures of triazoles, carbamates, quaternary ammonium compounds and various insecticides. While they appear to be working well for non-soil contact applications, they are not yet suitable for direct ground contact. As we will discuss later, the potential for replacing metal based preservative with these organics has largely been muted by their inability to perform well in soil contact. Interestingly, some producers of these colourless products have had to add colourants including small amounts of copper because the public expects treated wood to be coloured.

At the same time, the North American market has seen the emergence of alternative systems including various wood extracts, silanes, and a host of other systems that claim to provide non-biocidal protection. Unfortunately, there is very little publically available data to support these claims. There have also been attempts to introduce acetylated wood and heat treated wood into the market, but these products have not achieved substantial market acceptance, primarily because of higher cost.

Europe has seen the emergence of a host of alternative protection methods including acetylation, thermal modification, and furfurylation. Ironically, both acetylation and thermal modification have roots in North American research dating back to the 1950's.The situation in Europe is a bit different owing to a very different regulatory structure and a public willingness to pay more for wood products coupled with a lower risk of decay in many parts of the continent. This has fostered a willingness to look more closely at alternatives and a seeming willingness to accept some level of reduced performance. This has allowed the development of products with shorter expected service lives. This approach recognizes the tendency of wood users to more often remove wood products from service for changes in appearance rather than any loss in biological performance. However, this approach does have a negative side in that shorter service lives mean that wood products will not perform as well in life cycle analyses. The outcome of shorter service life can be negative when the tree required to replace the product takes longer to grow than the resulting product service life.

Europe has been the center of developments in dimensional stabilization, heat treatment, silanes, and barriers or coatings (Hill, 2006). All of these processes invariably produce materials that are more costly, but these costs do not appear to be a barrier to market entry, perhaps because alternative (non-wood) materials also have higher costs.

3 FUTURE CONCERNS

In order to more fully understand where the use of treated wood is headed, we need to understand why changes are necessary.

There is no doubt that society has a strong desire for the use of less toxic chemicals for all purposes and wood protection is no exception. At the same time, there is increasing public concern about the potential for migration of preservatives into the surrounding environment. Virtually all of the currently used wood preservatives have some degree of water solubility. In addition, these molecules tend to have a much greater effect in aquatic environments because non-target organisms are literally bathed in the chemical. Concerns about preservative migration have led some regulatory bodies to severely restrict the use of treated wood (Brooks, 2011a, b; WWPI, 2012).

Another factor affecting the use of treated wood is disposal. The rules regarding disposal vary widely across the globe. In the U.S., the first recommendation for treated wood that has reached the end of its useful life is to reuse it in a similar application. For example, a utility pole might become a parking barrier or a railway sleeper might become a landscape timber. Ultimately, the wood will no longer be useful in any application. In most of North America, treated wood can be disposed of in lined municipal solid waste facilities (landfills) provided it meets certain criteria. Virtually all wood treated with oilborne preservatives meets these requirements and there is an exemption for water-based systems such as CCA. There is no shortage of landfill capacity in many parts of North America and this has made it difficult to develop alternative disposal options. Most industrial treated wood is given away or reused, while most residential treated wood appears to be placed into landfills.

Despite the lack of a major incentive to avoid land-filling, some options are emerging. Wood treated with oil-based materials contains almost 20 % by weight of oil and represents a valuable energy source. At present, creosoted railway sleepers are burned for energy production, but poles and other products are more difficult to process because of the presence of penta, which has more restrictive combustion permitting requirements. As a result, little penta treated wood is currently burned, but could be a useful bioenergy resource. The other issue related to disposal is the presence of heavy metal treated wood in waste streams that are destined for combustion. The final hurdle to developing alternative methods for resulting or recycling treated wood is the cost of collecting a widely dispersed material with differing degrees of treatment (Smith et al., 2002). Given the current costs of collecting a widely dispersed material, landfilling seems the most viable option in North America, but disposal represents a key lingering issue among wood users.

4 NEW APPROACHES

As with any industry, technologies related to preservative treated wood must continue to advance or alternative materials will be substituted. There are a number of opportunities involving new chemistries, treatment methods, non-biocidal treatments and coatings.

New Chemistries: The process of developing a new wood preservative can vary from as little as 5 to 10 or more years. This includes developing toxicological as well as performance data. In general, it is not economical to develop a chemical solely for wood protection. Many agricultural pesticides have been adapted for wood use as evidenced by the use of triazoles for wood protection. While chemicals are often developed without close public scrutiny until they are released, the time periods required for establishing efficacy of wood protectants generally results in gradual emergence of chemicals for increasingly more aggressive environments (Cabrera and Morrell, 2002; Pernak et al., 2004; Schultz and Nicholas, 2006; Schultz et al., 2004; Zabielska-Metjuk et all., 2004). One disconcerting observation for new wood preservatives is the relative paucity of new chemicals entering major markets over the past few years. The exception has been micronized copper, which has only been commercially available for a few years but now dominates the residential market in the eastern U.S. (Preston et al., 2008; Cookson et al., 2008; McIntyre and Freeman, 2008; Larkin et al., 2008). This system, however, is still dependent on heavy metals and could be viewed as a modification more than a completely new development. The lack of a pool of readily available alternative treatments suggests the need for further development of new chemicals and could be an opportunity for the company that can create the ideal system.

The other area that continues to receive research interest is the potential for using natural products extracts for wood protection (Kawamura et al., 2011; Kondo and Imamura, 1986; Li et al., 2008; Schultz and Nicholas, 2000). Researchers have long sought to use heartwood extractives as potential wood preservatives; however, the approach has two problems. Extractives removed from highly durable woods are rarely as effective when introduced into less durable species. This may reflect that inability to achieve the same micro-distribution that was present in the original wood, as well as the tendency for these chemicals to be water soluble and therefore susceptible to leaching. A more important problem is that many naturally durable species are already in short supply, making it difficult to justify cutting more wood for production of natural preservatives. Extraction of by-products such as sawdust may be possible, but this material contains a mixture of non-durable sapwood and heartwood and may therefore produce lower yields. It may be more useful to employ these by-products for the production of durable composites, provided the materials are compatible with resins.

An alternative to the use of heartwood extracts might be the use of foliar extracts or materials from other organisms (Li et al., 2008). Many plants have evolved to produce foliage that contains an array of compounds designed to discourage attack by bacteria, fungi, and insects. Foliage may be an especially attractive source of biologically active compounds because it can be repeatedly harvested without cutting the tree, or alternatively, it could be collected at the same time the tree is harvested for wood. A number of recent studies suggest that foliage extracts exhibited activity against a variety of fungi and insects, although none of the extracts appears to have the broad spectrum toxicity necessary to function in a natural environment. It may be possible to combine extracts to produce a more effective cocktail of natural products. At the same time, it is important to remember that natural products extracts are, potentially, just as toxic to non-target organisms as synthetic pesticides. As these compounds are explored, it will be essential that they be tested accordingly to ensure that we do not inadvertently introduce more toxic molecules into the system.

Another interesting natural products approach has been the use of chitosans for wood protection (Maoz and Morrell, 2004; Eikenes et al., 2005). These compounds are derived from shrimp-farming operations and are available in large quantities. Modified chitosans have been shown to be effective against a variety of fungi, although their effectiveness against termites remains untested. Nevertheless, they offer the potential for producing anti-microbial compounds from what is largely a waste-product. These examples highlight the potential for developing alternative systems from waste streams produced by other processes.

The search for lower toxicity systems for protecting wood against the diverse array of wood degrading agents will be essential for retaining the viability of wood as renewable construction material in adverse environments.

Non-biocidal Treatments: The protection of wood without biocides has long been a goal of many wood users. The use of glycol to bulk wood and the development of dimensional stabilizers such as acetic anhydride show that wood can made less susceptible to the water uptake that creates conditions conducive to biological attack (Hill, 2006). However, these approaches have drawbacks that include the need to impregnate with large volumes of expensive reactants, lingering odors, and textural changes. These systems also appear to be limited to use on a restricted number of highly permeable wood species.

Alternatively, heat treatments can be used to modify the hemicelluloses in the wood to render the wood less susceptible to fungal attack (Esteves et al., 2007, 2011; Jamsa and Viitaniemi, 1998; Kamdem et al., 2002; Tjeerdsma et al., 1998; Vidrine et al., 2007). However, this process is not completely protective and can reduce wood properties.

Despite their limitations, dimensional stabilization strategies do have some applications. Wood modification clearly limits water uptake and this reduces the risk of fungal decay; however, the process does not appear to alter susceptibility to surface molds or UV degradation (DeVetter et al., 2010a, b; Donath et al., 2004; Dubey et al., 2012, Lande et al, 2004; Mai and Militz, 2004; Metsa-Kartelainen and Viitanen, 2012; Pfeffer et al., 2012; Weigel et al., 2012). Thus, there remains a need for non-biocidal treatments that are more broadly effective against abiotic and biotic agents of deterioration.

New-Treatment Practices: The wood treatment processes employed to impregnate the majority of treated wood used globally date to the middle part of the 19th century. The seeming lack of progress in this aspect of wood protection stems, in part, from the limited ability to overcome the inherent impermeability of heartwood and the overall effectiveness of existing treatment processes. In essence, good performance of properly treated materials has limited interest in investing in entirely new treatment technologies. Despite the overall acceptance of existing processes, there is considerable opportunity for both improving the quality of treatment and placing the chemical in the wood in such a way that it is less likely to migrate outward once in service.

Reducing the risk of preservative migration has become a major concern in some regions, notably where treated wood is used in close proximity to riparian zones. While there is no doubt that some chemical will migrate from treated wood, the goal is to ensure that the levels remain below those capable of inducing a negative environmental effect. Models have been developed that use migration rates for a given volume of treated wood coupled with information about specific waterway conditions such as pH or water current speed to predict total releases over time (Brooks, 2011b). These predictions can then be compared to known minimum effects levels for various organisms. At the same time, treatment practices have been modified to reduce the risk of over-treatment, remove surface deposits of chemical, reduce the risk of bleeding in service and, where ever possible, ensure that preservatives have been immobilized or reacted with the wood. These Best Management Practices are required in many localities across North America (WWPI, 2012).

At the same time, there is still a need for new treatment processes that result in more effective preservative penetration. While much of the coniferous wood species treated globally have thick bands of easily treated sapwood, there are many species that resist impregnation. Developing methods for effectively treating these woods would help improve performance, thereby reducing the need to harvest additional trees. Modifications to existing liquid treatments, with the possible exception of dual treatments involving an initial boron treatment with a diffusion period, following by subsequent over-treatment with a heavy duty wood preservative are limited by the inherent impermeability of the resource. The further development of supercritical fluid treatment processes offers the potential for overcoming the inherent refractory nature of many major wood species (Kjellow and Hendriksen, 2009; Morrell et al., 1997). This process is only commercially used in Denmark and has been explored elsewhere, but the high costs of entry in terms of equipment have largely limited development. Ultimately, SCF impregnation will emerge as a viable technology as we move to carbon-based systems and employ more wood-based composites.

There is a need for continued development of other novel systems for impregnating wood and for limiting the ability of the treatment to migrate outward once installed.

Coatings: While we have developed preservative systems capable of protecting wood against biological degradation for 50 years or more, most treated wood ultimately fails because its appearance declines to the point where the user will no longer accept it. This remains a major problem for wood in exterior applications.

Coatings can reduce damage caused by ultra-violet light as it strikes the wood and also reduce the ability of the wood to sorb water, thereby reducing the wetting and drying that leads to warping, twisting and checking.

UV degradation of lignin on the wood surface, coupled with subsequent removal of other wood components markedly reduces wood appearance (Feist, 1990; Hon and Chang, 1984; Schauwecker et al., 2009). While opaque coatings can reduce this damage, most wood users want to see the natural grain and colour of the wood. Transparent or semi-transparent coatings can provide some protection, but this protection generally declines within 1 to 2 years of exposure. Developing effective treatments that can be impregnated into wood to provide long term UV protection remains a major challenge. Iron oxide pigments, titanium dioxide, or hindered amine light stabilizers are just a few of the many possible surface protectants that have shown some promise, but most are rapidly inactivated by sunlight (Schauwecker et al., 2009; Schmalzl and Evans, 2003; Rowell and Banks, 1985). Water repellency is often produced through the inclusion of various waxes or silicates in the treating solution (Levi et al., 1970; Lesar and Humar, 2011; Sun et al., 2010). These treatments can reduce the rate of water uptake, but add cost to the system and only slow water uptake.

Ultimately, however, wood protection must be considered in a more holistic fashion. Biological performance is important, but so are resistance to water and UV light. The material must not only remain structurally sound, it must look sound as well. If it does not, the wood is replaced prematurely. It is also important to alter the premise that wood has to be the less expensive alternative. Homeowners have shown a willingness to pay 2 to 3 times more for WPC's that promise infinite service life with no maintenance. These materials have their own issues, but they highlight the potential for upgrading wood materials to reach a higher market.

Material specifiers are increasingly comparing the environmental attributes of materials to make specifying decisions. One of the most important emerging tools for these comparisons is life cycle analysis (LCA). The LCA examines all of the inputs required to produce a product including energy and water along with the environmental impacts. There is no correct answer regarding a given material. LCA's allow users to compare the impacts of different materials that can be used for the same application. Wood, by virtue of its renewability, low manufacturing impacts, and ability to sequester carbon, should have a major advantage in these comparisons. However, service life plays a important role in these comparisons. Premature removal of wood sharply increases the overall life cycle impact. Thus, factors such as weathering and wood instability must be considered in performance because they often lead to premature wood replacement.

As a result, biological protectants, water repellents and coatings must all be considered as an integral part of a wood protection system that ensures long term performance. It is also important to consider the inherent attributes of the wood. Another performance component is the original wood. Some species are inherently prone to warping and checking meaning. These species may be effectively protected against biological attack, but will fail prematurely from physical defects. While it is unlikely that species will be replaced, it may be possible to selectively sort lumber for treatment to mitigate the physical limitations. For example, dimensional changes tend to be greatest in the tangential direction in most wood species (flat sawn wood). Selecting materials that are vertically sawn would result in a lower tendency to shrink and swell. Careful material selection to provide properly oriented wood could reduce the tendency of treated wood to check and deform in service.

None of these approaches is without some cost; however, it is also important to avoid the view of wood as the cheapest material. In North America, treated wood is typically the least expensive decking material, followed by naturally durable heartwoods and finally by wood/plastic composites (WPC's). Surveys show that consumers perceive these products in terms of increasing quality in the same order. Purchasers have clearly shown a willingness to pay a premium for products that they perceive to be more durable and less maintenance intensive. At the same time, extensive advertising has convinced them that WPC's are greener. Wood based materials, however, should have more favorable LCA's provided they are properly treated and, consumers have demonstrated their willingness to pay for materials they perceive to combine greenness, durability and low maintenance. There appears to be niche for the development of a durable, more dimensionally stable wood product.

Barriers: Preservative treatment is ultimately a barrier that precludes entry by wood degrading organisms, but there have been recent efforts to develop physical barriers to protect wood. The first successful products originated in South Africa in response to early failures of creosoted utility poles and these products have spread across the globe (Baecker and Behr, 1995; Behr and Baecker, 1994; Behr et al., 1997). In some cases, they encapsulate untreated wood, but generally, they involve coating preservative treated wood. Barriers reduce contact between soil and wood, thereby diminishing the risk of fungal decay and insect attack. They also reduce the potential for preservative migration from wood into the surrounding environment. Barriers clearly reduce the risk of environmental contamination, but they may also have a side benefit. Since less chemical will migrate from the wood and soil is not in direct contact, the barrier may allow the use lower preservative loadings to produce equivalent protection. Barriers can be simple polyethylene barriers or heavy plastic sleeves applied by shrink-wrapping. Other systems spray polyurea on the wood surface to provide a flexible coating whose thickness is based upon the environment to which the wood is exposed. Several barriers systems are currently standardized by the American Wood Protection Association (AWPA, 2017). These systems add cost and users must clearly determine if the added expense is worthwhile, but they help address the issues related to biocide mobility.

5 NEW OPPORTUNITIES

Wood has a long history of use in a variety of applications and preservative treatments have played a major role in the extension of useful life, but there are still other opportunities for growth in the use of treated wood. Among these applications are wood used as solid packing material in global trade, wood used in mass timber structures and a higher end decking product.

Wood pallets seem to be everywhere and most people assume that they have always been used, but palletized shipping only dates back to the Second World War. Pallets make shipping easier and fast, but the lower quality wood used in these pallets and other solid wood packing materials can harbor insects and fungi. These organisms can be inadvertently introduced into new environments during shipping. Nearly all countries require that solid wood packing materials used in global trade be subjected to some type of mitigation treatment. The two most commonly applied treatments are heating to 56 C for 30 minutes or fumigation with methyl bromide. These treatments are not verifiable, nor do they prevent reinvasion. Preservative treatment may provide a more verifiable method for limiting the risk of pest introduction that also provides long term protection against reinvasion. Preliminary tests of solid wood packing material infested with the new house borer (Arhopalus productus) suggested that beetles were not killed by treatment with ACQ, borates or an organic preservative mixture, but also never completed their life cycle (Schauwecker and Morrell, 2008). Clearly, much additional work needs to be completed before preservative treatment is approved as a mitigation tool, but the volumes of wood used in this area are well worth the effort.

Mass timber structures are seeing increasing use in more temperate climates as a part of efforts to compete with concrete and steel in the high rise building market. Cross laminated timber (CLT) is one of the primary products used in this area but other products such as Mass Panel Plywood (MPP) are also emerging as manufacturers begin to innovate. While this material has a number of advantages over alternative materials, it can be wetted and will ultimately need some type of protection against biological degradation (Wang et al., 2018; Morrell et al., 2018). This protection need not entail heavy duty wood preservation, but the fact that all buildings eventually leak means that these structures will experience water intrusion that creates conditions suitable for fungal attack. Some type of treatment will be needed to ensure performance. These appears to be a hesitancy to use traditional wood preservatives in this application, but alternatives such as thermal modification may find applications in applications where the risk of decay is lower and termite attack is absent.

The most promising potential new market for treated wood is decking. Treated wood long dominated this market; however, WPC's have continued to erode market share. Declining market share has been less noticeable because the overall decking market has also grown, masking the change. Wood decks have generally been perceived as lower quality than either WPC or naturally durable decks; however, there is also a general desire to use wood in decks. There is an opportunity to create wood decking products that are both durable and able to remain visually attractive for a longer period of time. Consumers have already shown their willingness to pay more than two times the cost of a treated wood deck for a WPC deck. There is clearly an opportunity to create a better decking product that is cost competitive with WPC products but incorporates features that make it more durable. These features might include a carbon based wood preservative, selection of materials that are more stable (i.e. vertical grain), and application of UV stabilizers to the wood. The resulting product would not compete with traditional lower cost wood decking, but rather with the higher end products.

6 CONCLUSIONS

Wood remains one of our most important renewable building materials. Continued use of this material under adverse conditions will require renewed interest in developing technologies that resist biological and physical damage. Some of these technologies are already available, but remain too costly. Other approaches are under exploration. Effectively protecting wood against biological and physical damage without depending on broad spectrum pesticides must remain a goal if wood is to retain its rightful place in a green society.

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Lignocellulosic-Filled Polymer Feedstocks for Large Scale Additive Manufacturing of Low Cost Composites

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ABSTRACT

Application of large scale 3D printers using extrusion-based processing has demonstrated the potential for the creation of larger, faster and lower cost 3D printed parts by large scale additive manufacturing. The University of Maine Advanced Structures and Composites Center in collaboration with Oak Ridge National Labs is investigating the development and application of low cost lignocellulosic-filled thermoplastic pellets for 3D printing large composite components, initially for use in marine tooling applications. This paper will discuss the results of experiments compounding novel materials with wood flour and cellulose nanofibrils using several thermoplastic polymer resins including poly lactic acid (PLA), styrene maleic anhydride (SMA) copolymer and polypropylene (PP). Each lignocellulosic polymer blend was evaluated to determine the material properties of the materials via mechanical and thermal testing. Promising formulations were selected for 3D printing trials on a high feed rate extruder. Finishing options for the lignocellulosic-filled thermoplastic resins were performed using surface treatments and evaluating coating adhesion of the composite samples. The optimum lignocellulosic-filled thermoplastic formulations were used to print tooling molds for trials by local boat builders.

KEYWORDS: Lignocellulosic, polymer, feedstocks, large scale additive manufacturing, 3D printing

1 INTRODUCTION

1.1 Background on large scale 3D printing

Large scale 3D printing uses an extrusion-based additive manufacturing process methodology commonly referred to as fused deposition modeling (FDM) which is the most common polymer-based 3D printing technique (Gebhardt 2012). The 3D printing process begins with the creation of a digital 3D geometric model of the part to be created which is then converted into a series of 2D layers, or slices, which are printed by extruding and depositing a bead of thermoplastic material from a heated extruder nozzle. The 3D printing parameters constitute the sequence of polymer deposition, the path the extruder head follows during deposition, the dimensions of the deposited material, and properties of the material that is being deposited. The basic adhesion mechanism responsible for the production of parts made by 3D printing is the formation of adhesive bonds via diffusion interactions between the polymer beads being sequentially laid down. The adhesive bonding process is the welding of plastic beads. Limited pressure is applied by a tamper or roller following the extruded beads being applied to produce a part. Large parts can be manufactured via large scale 3D printing including: car chassis, small buildings and tooling molds. Among the polymer 3D printing approaches, a large scale 3D printer is up to 200 times faster than conventional small-scale 3D printing equipment and is able to attain polymer deposition rates comparable to conventional plastic injection and compression molding processes.

1.2 Bio-based polymer feedstocks for large scale 3D Printing

The availability of neat and functionally filled-thermoplastic resins for large scale 3D printing is currently limited because large scale 3D printers have only been available for a few years, and the commercial material supply chain is not well developed for these specific applications. The most commonly used feedstock material for large scale 3D printing is carbon fiber-filled acrylonitrile butadiene styrene (ABS) plastic and that is priced at ~$2.7/Kg. The relatively high cost of carbon fiber-filled ABS provides great impetus to develop low-cost feedstock materials for large scale 3D printing that will be suitable for less demanding part applications. It is anticipated that feedstock materials for 3D printing can be widely varied when considering options for thermoplastic resin types, cellulose filler or biofiber reinforcement type(s), and filler/fiber loading levels. Relevant to 3D printer materials development, UMaine has two decades of experience in the extrusion-based processing of bio-based (wood and lignocellulosic fiber-filled) thermoplastics priced at ~$0.25/Kg, and more recently cellulose nanofiber (CNF)-filled thermoplastics priced at ~$1.4/Kg. It is believed that the bio-based filler technology already existing for profile extrusion should be easily transferrable to the 3D printing with processing and feedstock development.

1.3 Boat tooling applications

Current marine direct composite tool manufacture involves a multi-step construction technique utilizing steel framing, plywood sheathing, a machined polystyrene substrate covered epoxy fiberglass and epoxy-based tooling paste for final machining and coating application. The direct composite tool can then be used as the mold to make low quantities of composite parts or an indirect solid fiberglass tool for high volume composite part construction. Fabrication of marine tooling is a time consuming and expensive process. The global composites tooling market was $316M in 2015, of which 30% is represented by North America (Market Report). Recyclability of marine tooling is low attributable to the multiple materials being used in the manufacturing process. The use of large scale 3D printing to manufacture marine tooling offers a more efficient process of manufacture and final machining and coating application which will reduce tooling creation lead times.

2 OBJECTIVES

The overall goal of this work was to develop and evaluate low cost lignocellulosic-filled thermoplastic composite formulations for application in large scale 3D printing of low cost marine composites tooling. The work reported here is part of a larger research program on large scale additive manufacturing using lignocellulosic-based feedstock materials. The specific objectives were to:

1. Compound wood flour and cellulose nanofibers in thermoplastic resins.
2. Determine the mechanical and thermal properties of the filled thermoplastic resins.
3. Perform surface finishing and coating adhesion on composite samples.
4. Conduct 3D printing process tests on a large scale 3D printer.

3 METHODS AND MATERIALS

Three thermoplastic resins were examined including polylactic acid (PLA), polypropylene (PP) and styrene maleic anhydride (SMA) copolymer. The filler materials examined included wood flour (micron scale) and spray-dried cellulose nanofibrils (CNF). The wood flour was sourced from American Wood Fiber and the

CNF (3 wt.% solids suspension) was produced by the University of Maine Process Development Center from bleached softwood pulp in the one-ton per day pilot plant. The CNF suspension was spray dried according to the methods described by Peng et al. (2012). The lignocellulosic-filled thermoplastic composite formulations are presented in Table 1.

Table 1: Thermoplastic composite formulations examined in this study.

Thermoplastic Resin	Wt. % Wood Flour/wt. % Cellulose Nanofibrils			
Polypropylene	0/0	30/0	0/20	10/10
Styrene Maleic Anhydride	0/0	30/0	0/20	10/10
Polylactic Acid	0/0	30/0	0/20	10/10

Extrusion melt compounding of the thermoplastic composite formulations was done on a Brabender twin screw extruder. The compounded pellets were injection molded into test coupons for mechanical testing following ASTM Standards. Mechanical tests performed included tensile strength and modulus of elasticity (ASTM D 709), compressive modulus of elasticity (ASTM D 695) and Izod impact strength (ASTM D 256). Thermogravimetric analysis (TGA) of the compounded pellets were made from ambient temperature up to 500 ºC to evaluate the thermal stability of the lignocellulosic-filled polymers. Differential scanning calorimetry (DSC) was run on the compounded pellets from ambient temperature to 200 °C to determining melting and crystallization behavior of the materials. Large scale 3D printing tests of candidate thermoplastic composite formulations were performed on the Cincinnati Big Area Additive manufacturing (BAAM) equipment at Oak Ridge National Lab in Knoxville, TN to demonstrate the printability of selected thermoplastic composite formulations. Surface preparation of the composites included sanding abrasion with 120 grit sand paper, surface priming with a thermoplastic adhesion promoter (SEM 39863 Primer) and plasma treatment using a forced air plasma treater (FAPT) following the methods of Oporto et al. (2009). A typical polyester-based marine tooling coating (Duratec 707-002) was used for coating evaluation. Coating adhesion was measured using a DeFesko PosiTEst AT-M tester following ASTM D 4541-02.

4 RESULTS AND DISCUSSION

The tensile strength (modulus of rupture) and modulus of elasticity (MOE) of the lignocellulosic-filled thermoplastic composite formulations are shown in Figures 1 and 2, respectively. The PLA formulations are stronger and stiffer than the PP and SMA. It should be noted that the PLA used in this work is currently used for large scale 3D printing. The SMA has historically been used in profile extrusion and is rubber-modified to support the creation of foam when the maleic anhydride functionality of the SMA reacts with the hydroxyl groups on the lignocellulosic fillers (Han and Gardner 2010). In general, the lignocellulosic fillers appear to contribute to increased tensile properties depending on the loading level. It is interesting that the wood contributes to enhanced tensile strength in the PP and SMA while the CNF provides enhanced tensile strength in the PLA (Figure 1). In contrast, the MOE is enhanced for the CNF-filled SMA while the PLA MOE is increased with the addition of wood flour (Figure 2).

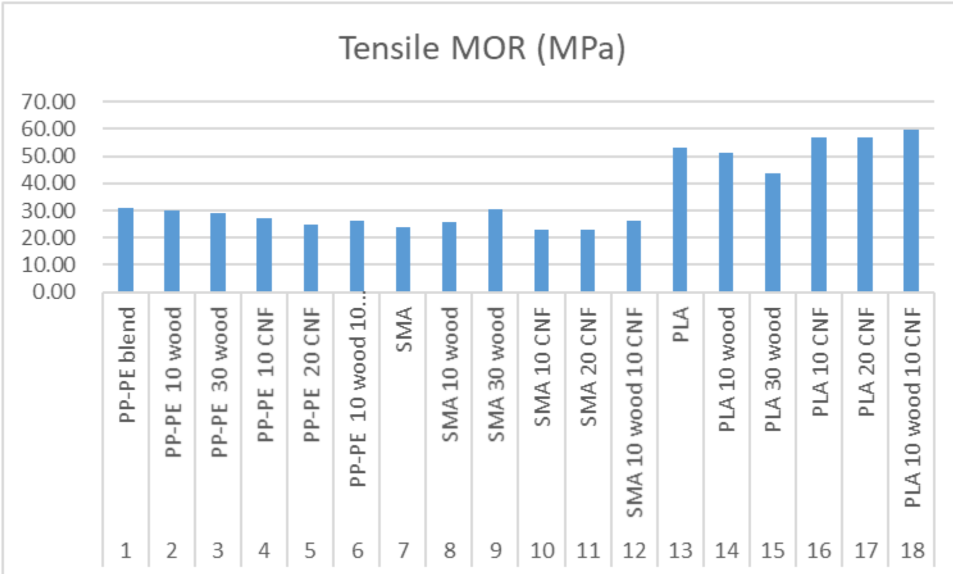


Figure 1: Tensile strength (MOR) of lignocellulosic-filled thermoplastic composite formulations.

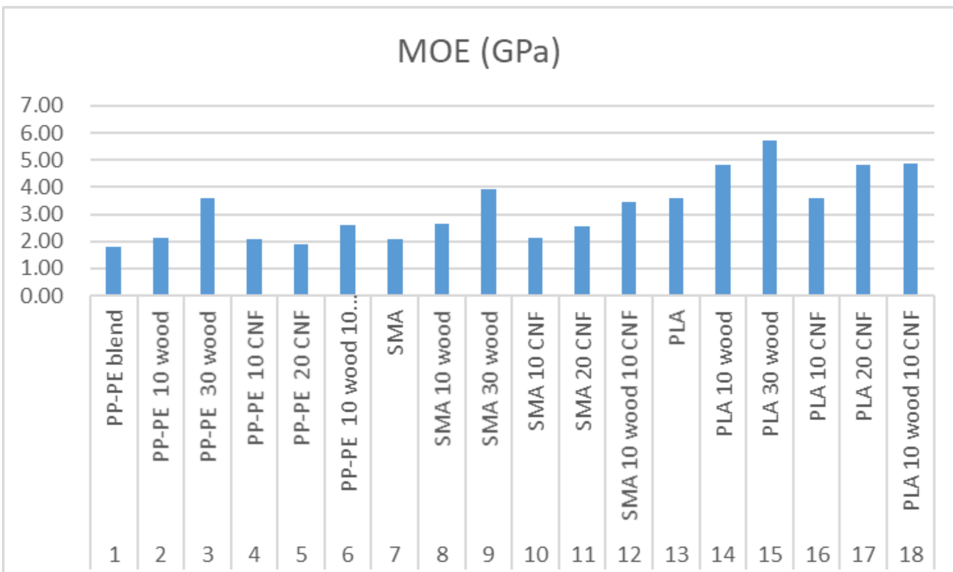


Figure 2: Tensile stiffness (MOE) of lignocellulosic-filled thermoplastic composite formulations.

The compression stiffness (MOE) of lignocellulosic-filled thermoplastic composite formulations are shown in Figure 3. The compression stiffness of the PLA compounds are greater than that of the PP and SMA compounds. It is interesting to note that the combination of 10% wood flour and 10 % CNF in the PLA provided the largest improvement in compression stiffness. Compression stiffness is an important mechanical property for the production of boat molds.

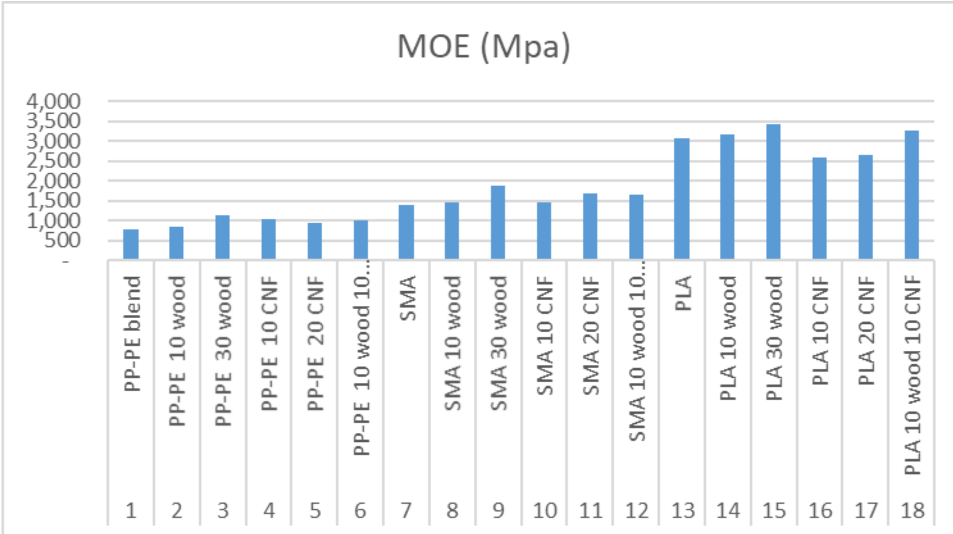


Figure 3: Compression stiffness (MOE) of lignocellulosic-filled thermoplastic composite formulations.

The Izod impact strength (J) of the lignocellulosic-filled thermoplastic composite formulations are shown in Figure 4. The SMA has the highest impact strength compared to the PP and PLA formulations and this is attributed to it being rubber-modified as mentioned earlier. For the SMA, the addition of lignocellulosic filler reduces the impact strength. The impact strength of the lignocellulosic-filled PLA formulations are similar to the neat PLA. This is an encouraging result since the addition of fillers to thermoplastic polymers typically reduces impact strength (Zhang et al. 2003; 2004).

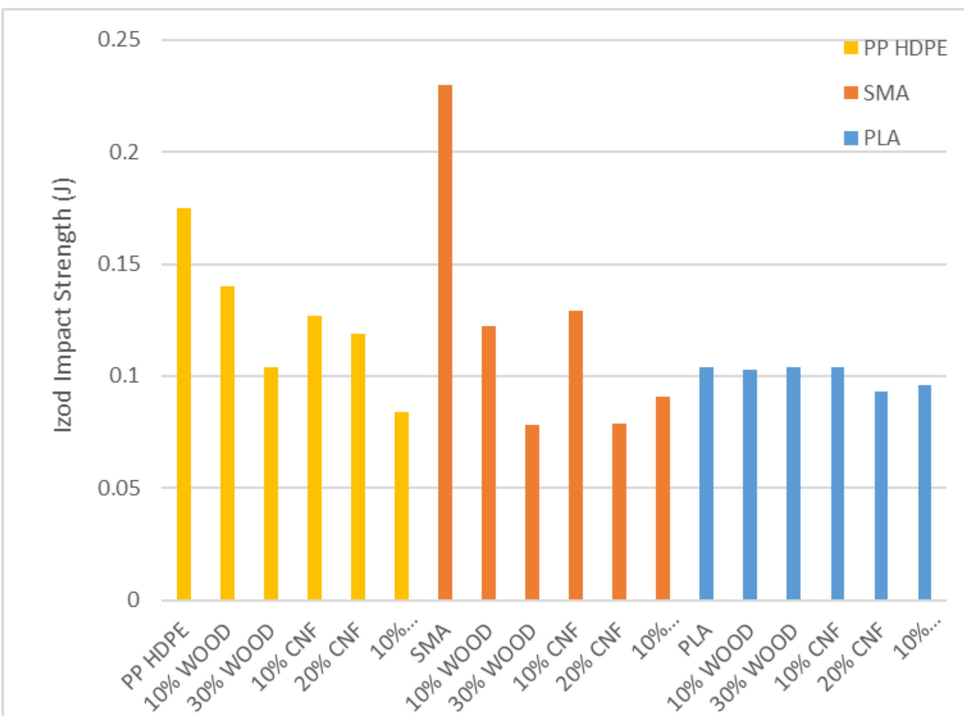


Figure 4: Izod impact strength (J) of of lignocellulosic-filled thermoplastic composite formulations.

The results of the thermogravimetric analysis (TGA) of lignocellulosic-filled thermoplastic composite formulations are shown in Figure 5. The PLA formulations were less thermally stable than the PP and SMA formulations and began to thermally degrade at about 300 ºC whereas the PP and SMA formulations were stable to between 350 and 400 ºC. A more thermally stable formulation for large scale 3D printing may be desirable for a boat mold attributable to the potential exotherms that can be experienced during the curing of thermosetting resins in boat manufacturing.

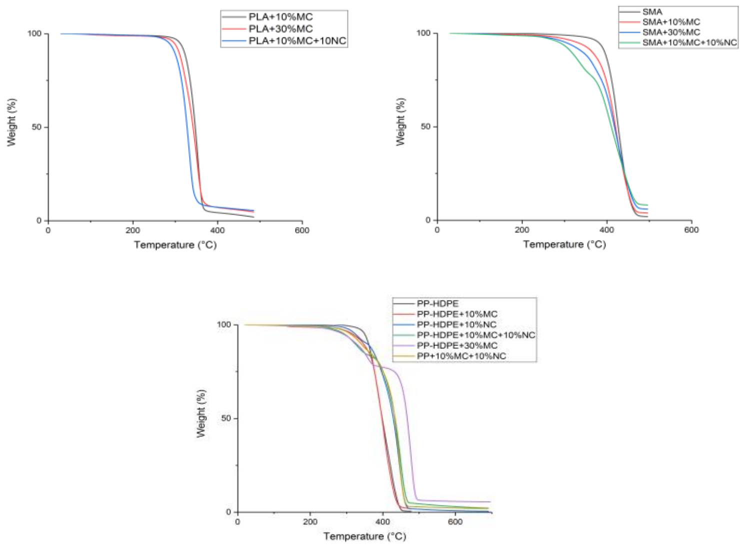


Figure 5: TGA of PLA, PP and SMA lignocellulosic-filled thermoplastic composite formulations.

The differential scanning calorimetry results are shown in Figure 6. The PLA exhibits a glass transition temperature at about 60 °C. An exothermic peak occurs at about 110 °C for the PLA and a melting temperature of 150 °C. The PP samples have a melting temperature of about 160 °C. With the addition of the wood flour or CNF there is a crystallization enhancement at about 140 °C. This can be attributed to the enhanced nucleation through transcrystallization. The SMA compounds don't exhibit any crystallization or melting over the temperature range examined. SMA typically melts at closer to 230 °C

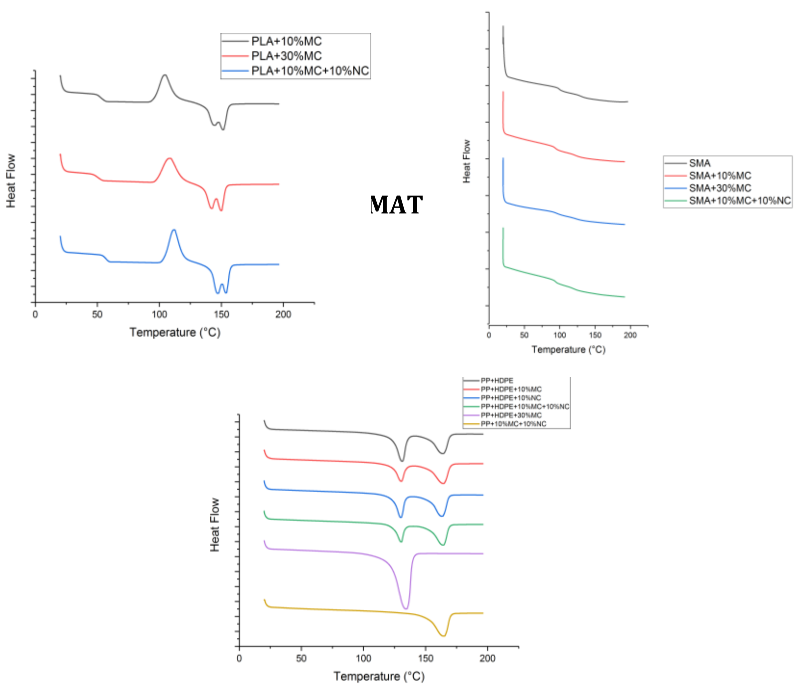
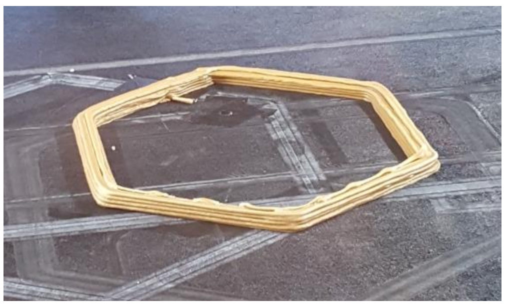


Figure 6: DSC scans of PLA, PP and SMA lignocellulosic-filled thermoplastic composite formulations.

Selected large scale 3D printer test prints of the lignocellulosic-filled thermoplastics are shown in Figure 7. The 10 wt. % wood flour-filled PLA and SMA experienced smooth extrusion of the beads while 30% filled material was too high for smooth extrusion of the feedstock. The 30 wt. % wood flour-filled PP printed well but more work will be needed to address challenges with shrinkage attributed to the crystallization of the PP. Continuing extrusion trials are ongoing to develop adequate process parameters for highly filled thermoplastics by large scale 3D printing. A combination of 20 wt. % wood flour and 1 wt.% CNF in PLA produced encouraging extrusion results for the printing of a test boat tool (Figure 8).

PLA + 10% Wood



PLA + 30% Wood

SMA + 10% Wood Flour

SMA + 10% Wood Flour +10% CNF

PP+HDPE +10% Wood Flour

PP+HDPE +30% Wood Flour

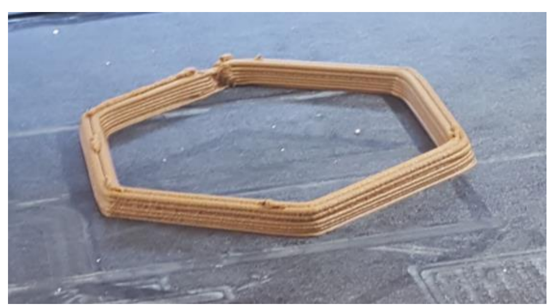


Figure 7: Large scale 3D printer test prints.

Figure 8: Large scale 3D printed boat roof tooling mold made from 20 wt.% wood flour and 1 wt.% CNF in a PLA matrix.

The coating adhesion strength results for the neat polymer, 30% wood flour-filled and 20% CNF-filled polymers are shown in Figure 9. There was little difference between the adhesion strength of the PP and SMA polymers for the different lignocellulosic fillers. The low strength of the 30% wood flour-filled SMA was attributed to cohesive failure in the composite. There was a noticeable increase of the 20% wood-filled PLA which may be attributed to the wood fibers being close enough to the surface to promote adhesion through adsorption. Sanding the surfaces appeared to normalize the coating adhesion across filler types. The forced air plasma treatment only appeared to promote coating adhesion of the PP samples. PP is a low surface energy plastic and FAPT increases the surface energy (Oporto et al 2009). The SMA and PLA already have an adequate surface energy for coating adhesion. There appeared to be a low adhesion strength between the Duratec coating and the SME primer although the primer did increase coating adhesion for the PP samples.

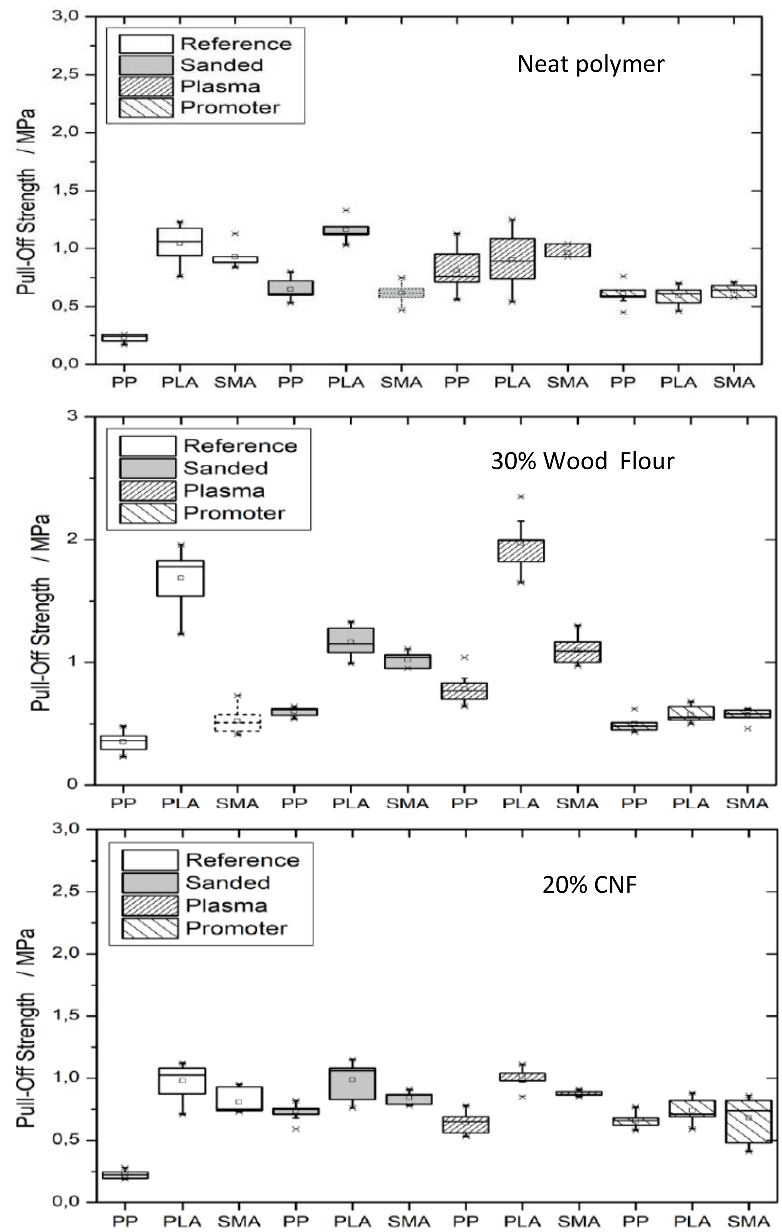


Figure 9: Coating strength of lignocellulosic-filled PP, PLA and SMA polymers.

6 CONCLUSIONS

Lignocellulosic fillers including wood flour and cellulose nanofibrils were compounded in-to PLA, PP and SMA resin for evaluation as feedstocks in large scale 3D printing. The addition of lignocellulosic fillers in some instances provided improved mechanical properties of the thermoplastic resins. The lignocellulosic fillers appear to contribute to increased tensile properties depending on the loading level, and it was interesting that the wood contributes to enhanced tensile strength in the SMA while the CNF provides enhanced tensile strength in the PLA. The Izod impact strength was lowered by the addition of the fillers. The thermal stability of the PP and SMA compounds was better than the PLA compounds. Coating tests indicated that adequate coating adhesion could be achieved with the proper surface treatment regime prior to coating application. The large scale 3D printer test prints showed some encouraging results but additional work is needed to optimize printing parameters when using lignocellulosic-filled thermoplastic polymers.

7 ACKNOWLEDGEMENTS

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Investigation Some Properties of the Wood Treated with Novel Polystyrene-Soybean Oil Copolymer Containing Silver Nanoparticles

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ABSTRACT

In this study, the antifungal effect of wood treated with silver nanoparticles against brown-rot (*Coniophora puteana*) fungi was investigated. In addition, leaching resistance of treated wood was determined. Scots pine (*Pinus sylvestris* L.) sapwood samples were impregnated with Polystyrene-g-soybean oil copolymer-Ag (AgPSbox) nanocomposites and Polystyrene under vacuum process in a small-scale impregnation container.
After impregnation, antifungal effect, leachability, moisture content, weight percent gain, leached formulation (LF) and protection efficiency were analyzed. Structural analysis of the impregnated specimens was characterized by FTIR techniques. The highest value of weight percent gain (WPG) was obtained by AgPSbox (0.78%), while the highest resistance was achieved by PS with a concentration of 0.45 g / l in decay test. However, this effect of treatment seemed to be almost negligible after the leaching test. The FTIR spectra of the specimens impregnated with nanocomposites showed the characteristic signals regarding impregnated components.

KEYWORDS: Antifungal, Decay test, FTIR, Polystyrene-g-soybean oil, Silver nanoparticle

1 INTRODUCTION

Many chemical substances have been used as wood preservers in the wood preservation industry from the past to the present day. some of them were prohibited because of their hazardous effect on environment and human health. Copper chromium arsenic (CCA) is well known a first generation of copper based wood preservative, which is highly effective against the broad spectrum of decay fungi (Bahmani et al., 2015), termites (Lin et al., 2009), and wood boring insects. CCA has been banned in Europe as well as restrictions in the US and Canada because of the environmental concerns (Ellis et al. 2007; Kartal et al., 2015); Therefore, CCA was replaced with the second-generation wood preservatives such as alkaline copper quat and copper azole (Humar and Lesar, 2008).

Since nano-compounds can easily penetrate into the depths of wood cell wall, they may show resistance to leaching and thus may provide higher durability to wood. In recent years, there have been studies conducted on the antifungal activity of silver nanoparticles in wood (Kim et al., 2009; Paril et al., 2017). Mass loss was found less than 5% due to the white rotin some tropical woods treated with nano-silver aqueous dispersion (50 ppm) (Berrocal et al., 2014).

The “greener” environmentally friendly processes in chemistry and chemical technology are becoming increasingly popular and are much needed as a result of worldwide problems associated with environmental contamination. Environmentally friendly methods (ultrasound, magnetic, microwave, biological methods) and substances (vitamins, sugar, plant extracts, biodegradable polymers and microorganisms) are used in the production of metal nanoparticles. With these techniques used silver, copper, gold, iron, metal alloys and oxides are produced in nano-size (Kharissova, et al., 2013).

There are many methods used in order to obtain silver nanoparticles by 'Green' method such as Aqueous extracts of the manna of hedysarum plant and the soap-root (Acanthe phylum bracteatum) plant, culture supernatants Aspergil lusterreus, leaf extract of Euphorbia hirta L., Euphorbia milii, Foeniculum vulgare leaves. In addition, basic amino acids are also used in order to obtain silver nanoparticles such as L-lysine or L-arginine (Hu et al., 2008; Elumalai et al., 2010; Forough and Farhadi, 2010; Singh et al., 2010; de Matos et al., 2011; Bonde, 2011; Li et al., 2012). In another study, silver nanoparticles have been synthesized using Polyalthia longifolia leaf extract (Kaviya et al., 2011). In addition, silver nanoparticles were obtained in the sizes of 13±3 nm using sulphate polysaccharides isolated from Porphyria vietnamensis (Venkatpurwar and Pokharkar, 2011).

Vegetable-oil-based polymers are of great concern by the researchers that can be attributed to some properties of vegetable oils such as biodegradability, renewable resource, environmentally friendly and low price (Shimada et al. 1992; Lligadas et al., 2013). Autoxidation of double bonds causes mostly peroxidation and polymerization leading to macroperoxide initiator to use free radical polymerization of vinyl monomers (Allı et al., 2014; Allı et al., 2016; Ince at al., 2016).

In this work, free radical polymerization of styrene was started by silver-soybean oil macroperoxide in order to obtain polystyrene-soybean oil copolymer containing silver nanoparticles. The aim of this study was to induce the polymerization of silver nano particles with polystyrene. Biological durability and leachability of Scots pine (*Pinus sylvestris* L.) wood treated with polystyrene-soybean oil copolymer containing silver nanoparticles were investigated. Fourier Transform Infrared Spectroscopy (FTIR-ATR) was used to reveal the chemical characterization and the structure of the chemical bonds in the impregnated samples

2 MATERIALS AND METHODS

Scots Pine (Pinus sylvestris L.) specimens of dimensions 5x15x30 mm (heightXwidthXlongitudinal) were prepared from sapwood blocks. of The oven dry density of the samples was 0.42 gr cm-3. Soya oil was a obtained from the company named Çotanak/Altas¸ in Turkey. It contains palmitic acid (11 wt%), stearic acid (4.9 wt%), oleic acid (34 wt%), linoleic acid (42 wt%) and linolenic acid (3.6 wt%). Polystyrene and AgNO3 was supplied from Sigma-Aldrich.

Autoxidized polymeric soybean oil (sbox) was performed according to the modified procedure for the synthesis of gold nanocomposite reported in our previous work (Hazer and Akyol, 2014).

Polymerization of styrene was initiated by oxidized soybean oil polymer with Ag NPs according to the modified procedure described in the cited literature (Hazer and Kalaycı, 2017). For a typical polymerization experiment, the mixture of 0.12 g of Agsbox nanocomposite and 4.52 g of styrene was dissolved in 5 mL of toluene in a reaction bottle. Argon was introduced through a needle into the tube for about 3 min to expel the air. The tightly capped bottle was then put into a water bath at 95 ºC for 6 h. Then, the contents of the tube were coagulated in methanol. The graft copolymer samples were dried overnight under vacuum at 40 ºC (Hazer and Kalaycı, 2017). This product was named as AgPSbox.

Organic solvent-based solutions including chloroform were prepared to impregnation of the wood specimens with polystyrene and polystyrene-soybean oil-Ag nanocomposite. 0.4% of AgPSsbox and PS were dissolved in chloroform. The solutions used in the study were prepared based on weight/ weight. Samples to be treated AgPSbox were stirred in chloroform with magnetic stirrer for 2 h. Afterwards, 2 hours of stirring was carried out again by changing chloroform. Following the stirring process, the samples left in the lab for 2 h, then were dried in a vacuum oven at 40 °C for 4 h. The samples were oven dried at 103 °C subsequently. Control samples also left in to chloroform for 2 hours for comparison with treated samples. Sample were weighted after drying at 103°C for 24 h, and then subjected to the impregnation cycle: vacuum (650 mmHg, 20 min) and atmospheric pressure (1 h). Then the samples were oven dried for 24 h at 103°C and weighed again. The weight percent gain (WPG1) and bulking coefficient (BC) was calculated:

$$WPG1=100[(Mt-Mo)/Mo] \quad (2)$$

where Mo and Mt are the oven dry weights of untreated and treated wood samples, respectively.

$$BC\ (\%) = 100[Vm-Vu]/Vu] \quad (3)$$

where Vu is the volume of the unmodified wood samples and Vm is the volume of the modified wood samples (Hill, 2006).

Leaching procedure was applied according to EN 84 (1997). Wood specimens were placed in a glass beaker filled with deionized water and their floating was prevented by weights. The beaker was put in a desiccator and vacuum (650 mmHg) was applied for 20 min. Wood specimens were maintained in water (water/wood = 5:1) for 14 days with 9 times water changes, and then conditioned to a constant mass. After leaching and conditioning, samples were dehydrated again as previously described and weighed. The WPG after leaching (WPG2), leached formulation (LF), swelling coefficient (S), anti-swelling efficiency (ASE) was calculated after leaching test (Eqs. 4-7):

$$WPG2 = 100[(M1-Mo)/Mo] \quad (4)$$

where M1 is the oven dry weight of leached wood blocks.

$$LF = 100\ [(Mt - M1)/(Mt - Mo)] \quad (5)$$

$$S\ (\%) = 100[(Vws-Vod)/Vod] \quad (6)$$

where Vws is the water-swollen volume of the wood and Vod is the oven-dry volume of the wood (Hill, 2006).

$$ASE\ (\%) = [(Su-Sm)/Su] \quad (7)$$

where Su is the swelling coefficient of the unmodified wood and Sm is the swelling coefficient of modified wood (Hill, 2006).

Decay test was carried out on both leached and unleached specimens according to the principle of EN 113 with modifying dimensions to be 5x15x30 mm (heightXwidthXlongitudinal). Decay test for brown rot fungi, *Coniophora puteana* (Schumach.) P. Karst. was based on mini-block specimens on 48 % malt extract agar in petri dishes. Six replicates were used for each test in the study as specified, with 24 control samples and 24 test samples. Treated and untreated samples were subjected to the decay test for eight weeks in a climate chamber at 23 °C and 70% RH. At the end of the exposure time, the mycelia coverings on the sample surfaces were removed and weighed. The samples were oven-dried at 103 °C and reweighed. The mass loss (ML) was determined based on the oven dry weight before and after the decay test.

Fourier Transform Infrared Spectroscopy (FTIR-ATR) analysis has been used as a technique to obtain information about the structure of the wood constituents and chemical changes taking place in the wood impregnation process. FTIR spectra were obtained by a Shimadzu IRAAffinity-1 equipped with a Single Reflection ATR pike MIRacle sampling accessory. Four accumulated spectra with a resolution of 4 cm^{-1} were obtained for wavenumbers from 700 cm^{-1}-1800 cm^{-1} with 32 scans for each sample. The measurements were carried out on the earlywood section. Spectrum measurements from 8 different points were taken. For each variation, a single spectrum was obtained by calculating the average of the spectra in the device's program.

The results of decay test were analyzed by One-Way Anova test using with SPSS 16.0 program. The significance level ($P < 0.05$) between the variations was compared with Duncan homogeneity groups. Different letters given along with the average values of tested parameters indicated significant difference by Duncan’s homogeneity groups.

3 RESULTS

Table 1 includes the physical properties of control and impregnated samples. Due to the use of low concentration in the impregnation process, the swelling coefficient value of the test samples was close to the control samples. The PS exhibited better performance than AgPSbox on non-leached blocks (10,43% ML), but 72% leaching was observed. The wood samples impregnated with AgPSbox showed only a 29,29% leaching. After the impregnation process, a weight gain value of 0.78% was obtained by AgPSbox and 0.61% by Ps samples. However, after the leaching process, a negative weight gain was obtained by PS samples, while 0.05 was obtained by AgPSbox samples. This can be caused by the silver content of 0.263 ppb remaining in the wood after leaching test (Figure 1). Maximum leaching of silver arised at 48 hours (3023 ppb).

Table 1: Characterization of mini-block impregnated wood

	n	LF (%)	WPG1 (%)	WPG2 (%)	S (%)	ASE (%)	BC (%)
Control	6	-	-	-	18,01		
PS	6	72	0,61 (0,34)	-0,04 (0,49)	17,02	5,50	2,06
AgPSbox	6	29,29	0,78 (0,04)	0,05 (0,11)	17,28	4,05	-1,96

n, Number of replicates; LF, leached formulation; WPG_1, weight per cent gain after impregnation; WPG_2, weight percent gain after leaching; S, swelling coefficient; ASE, anti-swelling efficiency; BC, bulking coefficient, In parenthesis: StD.

ASE was found to be 5.50% in wood impregnated with PS, and 4.05% with AgPSbox.

Modification with cross-linking yields a positive ASE (Ohmae et al. 2002). The reduction in ASE is attributed to bulking of the cell wall by the modifying agent. According to the obtained results, BC values indicated that 2.06% resulted from the samples impregnated with PS and -1.96% from the samples impregnated with AgPSbox .

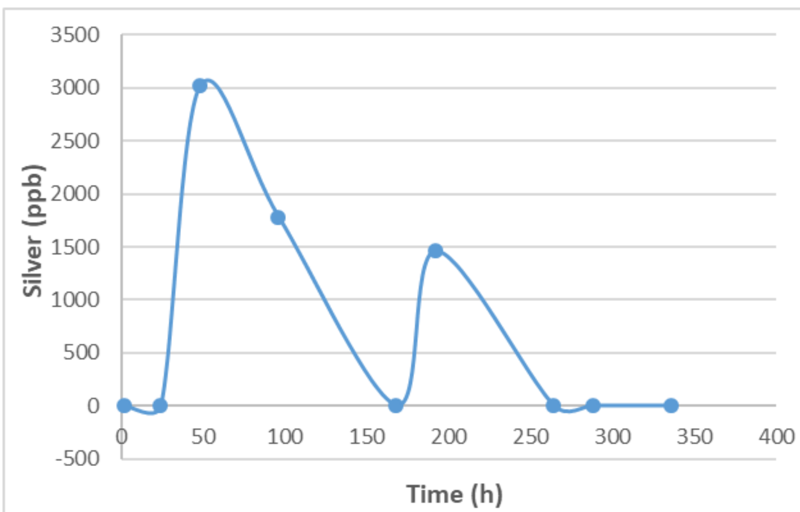

Figure 1. Silver leaching (ppb) from the samples treated with AgPSbox.

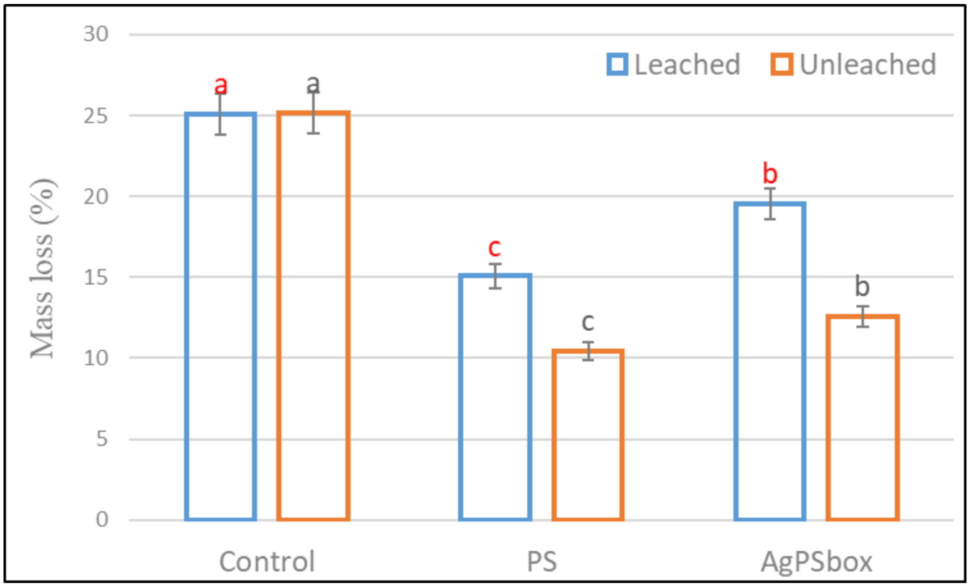

Figure 2. Mass loss of treated and control samples after decay test.

According to figure 2, control leached specimens resulted in mass loss at the rate of 25.08% and similarly unleached specimens resulted in mass loss at the rate of 25.17% at the end of the 2 months decay test. Decay test standard (EN 113, 2006) accounts for the mass loss to be 20% for untreated samples. Our results was a little over standard valueWeight loss was reduced by by modified samples at the rate of 39,91% with PS and 22,09% with AgPSbox for leached samples, as well as 58.56% with PS and 50.14% with AgPSbox for unleached samples respectively.

The results indicate that the decay resistance of wood modified by PS and AgPSbox against brown rot fungus (*C. puteana)*, was remarkably improved, when compared to those of untreated Scots pine.

Polystyrene is a polymer consisting only of long-chain hydrocarbons, which increases the decay resistance of wood because of the synergistic effect of polymer and silver (Raberg and Hafren, 2008). According to Raberg and Hafren (2008), 46% of the weight loss occurred in pine control specimens while those impregnated with polystyrene resulted in 18% of the weight loss. This was evidence of that polystyrene could prevent the mass loss in wood samples in comparison to the control specimens.

Mechanism of silver regarding the resistance to microorganisms has not been yet completely explained. The understanding of intercellular physiology is needed to clarify the action of nano silver particles. Previous authors reported the action mechanism of silver in different ways as follow (Brag and Rainnie, 1974; Kim et al., 2012).

1. Causing the fluid and electrolyte loss on the cell wall make the organism dry and death
2. Diffusion in to the cell wall and affecting the enzymes in terms of respiratory chain cause the degradation of the cell wall
3. DNAs lose their ability to reproduce, enzymes and proteins responsible for ATP production lose their activity.
4. Disrupts the membrane integrity of microorganism, inhibits the damage in wood structure by blocking the enzymes that cause the decomposition of cellulose.

Because, nano silver has significant influence on fungi by destroying the membrane integrity of the fungi (Kim et al., 2009).

The FT-IR spectra of control, and the samples treated with PS and AgPSbox was compared with each other as shown in Figure 3.

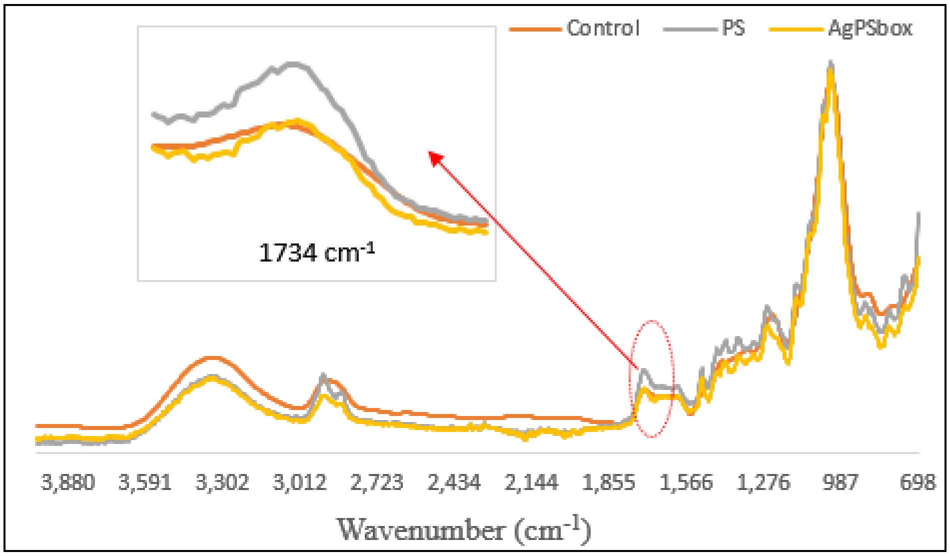

Figure 3. FT-IR spectra of PS and AgPSbox treated and control wood

The peak at 3400 cm^{-1} was assigned to the stretching vibration of hydroxyl group. The peak of both PS and AgPSbox was respectively weaker than that of untreated control. It was considered that the decrease in water content at 3400 cm^{-1} reduced the amount of water needed by the fungi from the wood, and thus lower weight losses were incurred in PS impregnated samples compared to the control samples.

The band at 2924 cm^{-1} was assigned to C-H (CH_2 and CH_3) stretching methyl and methylene groups increased and shifted at 2931cm^{-1}, and the intensity of band (from 0.028154 to 0.030556) was increased 8,53 % by the PS impregnation. Two new characteristic peaks appeared in the samples treated with the PS and AgPSbox. These peaks were increased after the impregnation with AgPSbox. This may have been derived from soybean oil and chemical change in chloroform. Addition of nano compounds caused diverse changes in the intensities of the spectrum band.

It was clearly shown that PS and AgPSbox caused chemical changes in the wood structure. The band at 1734 cm^{-1} indicating an unconjugated C=O stretch in xylan in hemicellulose, increased due to modification of acetyl and carbonyl groups. The increase in the 1734 cm^{-1} peak in samples impregnated with PS. In addition, little increase was observed in AgPSbox impregnated samples (from 0.023963 to 0.024637) in this peak. This group shows olefin regions in soybean oil (Goburdhun et al., 2001; Fabiyi et al., 2011).

The peaks in the range of 1800-700 cm-1 are called "finger print". These absorption peaks reflect the changes occurring in the benzene rings, the basic functional groups in lignin and carbohydrates and the crystallized and amorphous content of cellulose. In our study, the peaks in this range (1506 cm^{-1},1452 cm^{-1}, 1415 cm^{-1}, 1365 cm^{-1}, 1320 cm^{-1}, 1261 cm^{-1}, 1157 cm^{-1}, 1045 cm^{-1}, 1022 cm^{-1}, 891 cm^{-1}) showed an insignificant increase. A slight increase was observed at the peak of 802 cm^{-1}.

4 CONCLUSION

Ag-nanoparticle inhibited fungal decay by *C. puteana* compared to the control samples. The samples of unleached PS was found to be more efficient than Agsbox against decay fungus. Significant changes were observed in wood chemical structure after only PS impregnation. FTIR test showed the methylene and methyl groups generated by impregnation with PS and Agsbox that caused the changes in the chemical structure of the wood. However, further studies are needed to investigate the antifungal, insecticidal and termiticidal effect of Ag nanoparticles in different ratio with other wood species.

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Wettability of Scots pine Coated with ZnO and CeO_2 Stabilized Acrylic Coating after Accelerated Weathering

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ABSTRACT

In this study, influence of nanoparticle stabilized acrylic coating on the contact angle changes of Scots pine wood after accelerated weathering was studied. For this purpose, two metal oxides, nano zinc (ZnO) and cerium oxide (CeO_2), and a water based transparent acrylic coating were used. Commercially available nano wood coating was used as a reference chemical. Both nanoparticles were added to the coating as 5% concentration level based on the solid content of the resin in the coating. The mixtures of 200g/m^2 were applied to the surface of the samples with a brush for three times. The same procedure was also applied for the reference chemical. Then, samples were exposed to accelerated weathering for 1512h in Atlas UV Test machine according to Procedure 1 in ASTM G154 standard. Contact angle was measured with the sessile drop technique using water both for weathered and un-weathered samples. The change in volume of the drop (%) was also calculated.

Results showed that coatings increased surface hydrophobicity of wood. However, weathering decreased contact angle of the samples in comparison to initial contact angle of samples before weathering. Crack formations were observed on the surface of reference samples after 48h of the weathering, and the cracks continued to propagate during the test. In ZnO and CeO_2 treatments, no visible cracks were observed on the surfaces during the weathering period. Advancing contact angles of a water drop were in all cases higher for wood samples coated with nanoparticle stabilized acrylic coating than for coating alone after weathering. Change in drop volume of coated samples was also found to be less than that of controls. The measurements clearly indicated that wood surfaces with ZnO and CeO_2 stabilized acrylic coating formed a hydrophobic barrier on the wood to provide surface protection.

KEYWORDS: Contact angle, nanoparticle, weathering, wettability

1 INTRODUCTION

Wood has to be protected from the outside environment because it is a biological substance and sensitive to weather conditions and biological attacks (Saha et al., 2013). Temperature and humidity variations of the ambient environment subject the wood to wet and dry cycles which result in swelling and shrinking, consequently, create cracks and fissures (Saha et al., 2011). Additionally, wood can absorb electromagnetic radiation in several different wavelengths to initiate photochemical reactions that cause color change. Among the chemical components of wood, lignin and extractives contribute UV absorption of 80-95% and 2%, respectively (Tomak et al., 2018).

In recent years, environmentally friendly products have gained importance due to increased worldwide environmental awareness. The importance of water-based varnishes and paints is increasing since they have low limit values of volatile organic compounds (VOC) in comparison to solvent-based systems (Schaller et al., 2012). Water-based clear coatings are highly efficient, non-toxic and do not cause any change in the appearance of wood (Tomak et al., 2018). Unfortunately, transparent top surface treatments significantly limit the application of these materials to certain areas of use because photodegradation, separation of the coating from the wood surface, cracking and other undesirable effects occur over time in outdoors. For this reason, nano-metal oxides which exhibit UV-resistance on the absorption of UV rays have been used with water-based varnishes and paints (Blanchard and Blanchet, 2011). Nano-metal oxides improve many properties such as scratch resistance and abrasion resistance, impregnability, hydrophobicity, self-cleaning and durability without changing the natural appearance of the wood (Akhtari and Arefkhani, 2010). ZnO and CeO_2 nanoparticles are compared with UV absorbers commonly used to stabilize the color of wood products (Blanchard and Blanchet., 2011). Fufa and Hovde (2010) reported that TiO_2, ZnO and CeO_2 can be used to improve UV resistance. Similar statements were also approved for ZnO by Clausen et al., (2010). ZnO and polypropylene have been found to reduce photodegradation and surface cracks on wood surfaces (Zhou and Li., 2006).

In the previous studies biological resistance, mechanical and physical properties, UV resistance, and color stability of nanoparticles were studied extensively. In this study, wettability of wood coated by ZnO and CeO_2 stabilized acrylic coating after accelerated weathering is investigated. For this purpose, nano zinc and cerium oxide, and a water based transparent acrylic coating were used. Commercially available nano wood coating was used as a reference chemical. Coated samples were exposed to accelerated weathering for 1512h. Contact angle (°) and the change in volume of the drop (%) was measured both for weathered and un-weathered samples.

2 MATERIALS AND METHOD

2.1 Materials

Scots pine (*Pinus sylvestris* L.) sapwood samples with a dimension of 11mm (radial) x 75mm (tangential) x 152mm (longitudinal) were prepared according to ASTM D 358-98 standard. Samples without any visible defects such as cracks, strain and knots were lightly sanded with 180 and 240 grit sandpaper to obtain smooth surfaces, and then conditioned at 20°C and 65% relative humidity for 2 weeks before the treatments. Five replicate samples were prepared for each treatment group. Water based acrylic transparent wood coating with a solid content of 33.5%, and density of 0.98-1.03 kg/m^3 obtained from chemical suppliers. Commercially available nano wood coating (reference chemical), and nano zinc (ZnO, 20 nm; BYK3820) and nano cerium oxide (CeO_2, 10 nm; BYK3810) was supplied from Nanoart and Feza Companies, Istanbul Turkey, respectively.

2.2 Coating of samples

Nano metal oxide containing coatings had 5% nanoparticle concentration. Both nanoparticles were added to the coating based on the solid content of the resin in the coating. The mixtures of 200g/m^2 were applied to the surface of the samples with a brush for three times. Same procedure was also applied for the reference chemical, and the samples coated with reference chemical were labelled as reference samples in this study. After the top coatings, samples were conditioned at 20°C and 65% RH for 2 weeks.

2.3 Natural weathering of samples

An artificial weathering for 1512h was applied to samples in the Atlas UV Test machine according to Procedure 1 in ASTM G154 standard. The weathering cycle involved a continuous light irradiation (340 nm, 0.89W/m2) of 8h at 60°C followed by a condensation for 4h at 50°C. Four replicate samples were exposed to accelerated weathering, and one sample of each treatment group was stored in a dark conditioning room for comparison purposes.

2.4 Contact angle measurement

Four replicates in each treatment group were conditioned at a temperature of 20±2°C with 65% relative humidity for one month before the test. Attension Theta Lite system was used to determine contact angle and drop volume at 1 s intervals for a period of 10s. The measurement technique is based on rapid video capture of images and automatic image analysis. Four drops of 5μl volume were formed automatically using a pump and deposited on the tangential surface of the samples at room temperature. The change in volume of the drop (%) was calculated on the basis of the initial drop volume. Contact angle was measured three seconds after the drop was placed on the wood surface in order to see the actual effect of treatments on contact angle. The measurements were carried out on the tangential surface which exposed to weathering agents.

3 RESULTS AND DISCUSSION

Contact angle (°) values are shown in Figs. 1 and 2 for zinc oxide and cerium oxide stabilized coating, respectively. Average contact angle of the samples and the change in drop volume of the samples (%) are demonstrated in Fig. 3 and 4, respectively. Un-weathered reference samples exhibited higher contact angle than that of others, furthermore the contact angle of reference samples was quite stable over time. These samples had hydrophobic surfaces. Contact angle of coating alone and nanoparticle stabilized coatings is found to be very similar before weathering. These samples also exhibited a water repellent or hydrophobic surface since the observed contact angles were around 90°. Film layer over the sample surface increased hydrophobicity. Zinc and cerium oxide nanoparticles improved water repellency of the wood surfaces.

Weathering caused a decrease on contact angle values of all coatings. The greatest change on contact angle values were observed on reference samples among the other groups after weathering. This could be due to the surface cracks occurred on the reference surface after 1176 h. The cracks can also be observed with the naked eyes on the reference samples after 1512 h of weathering (Fig. 5). Contact angle of coating alone and ZnO stabilized coating was also decreased by weathering factors, in addition, the stability on contact angles over time before weathering was also decreased after weathering. The highest contact angle values after weathering were found to be in order of reference > zinc oxide stabilized coating > coating alone. However, all samples had lower contact angle than 90° (Fig. 1). Decrease on the contact angles over time is attributed to increased surface tension and cracks between the varnish layers. Demirci et al., (2013) reported that deformations on the surface layer of varnishes or coatings caused by UV, temperature and humidity during weathering let an increase on surface roughness of wood. UV radiation could cause photo-oxidation, thermal aging and hydrolysis which could break the strong polymer bonds in the coatings resulting in micro cracks on the surface (Demirci et al., 2013). It is found that the coating thickness decreases with increasing weathering time and a deformation on the coating surface takes place during weathering (Saha et al., 2011). In the case of cerium oxide stabilized coating, contact angle of the coating did not change remarkably, and this coating showed similar contact angle values as before weathering. In this group (Fig. 2), the highest contact angle was in the following order: cerium oxide stabilized coating > reference > coating alone. The surface of cerium oxide stabilized coating were still hydrophobic (90°) even after 1512h of weathering.

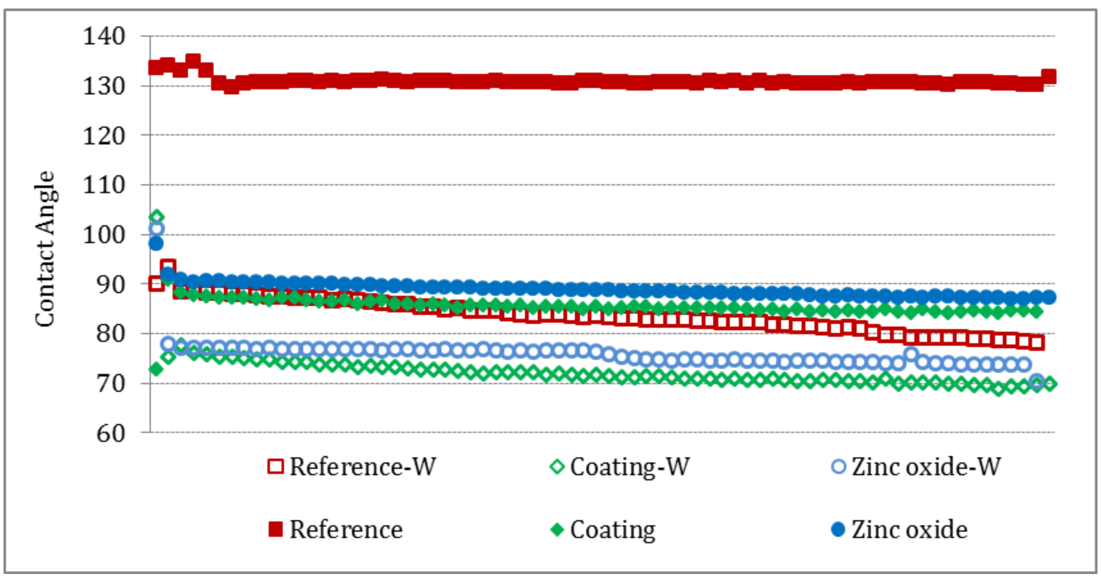


Figure 1: Contact angle of wood with ZnO stabilized acrylic coating

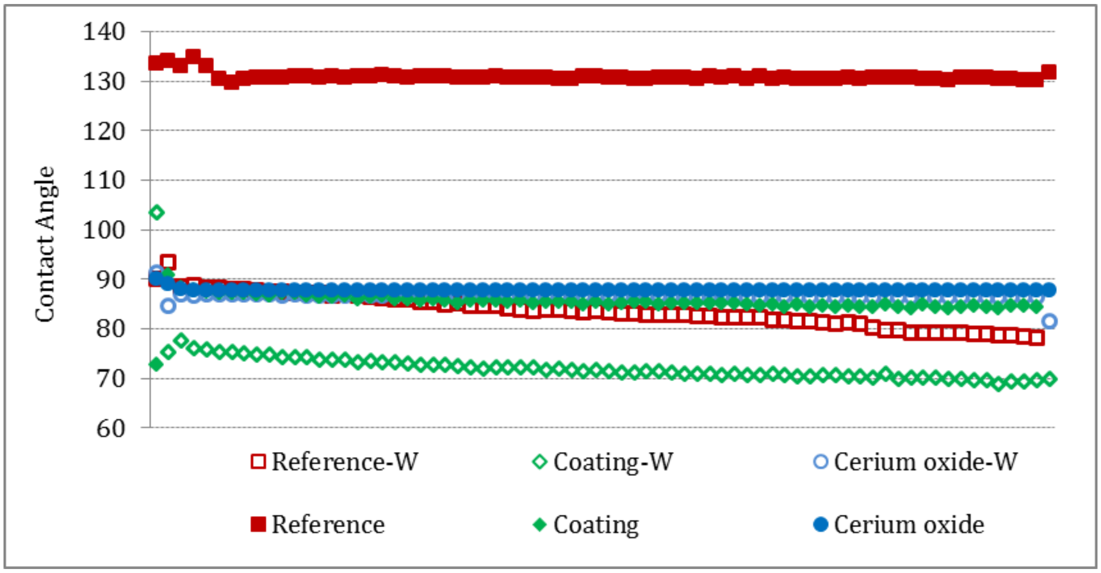


Figure 2: Contact angle of wood with CeO_2 stabilized acrylic coating

Average contact angle of samples (Fig. 3) clearly showed contact angle values before weathering were found to be in the following order: reference > zinc and cerium oxide stabilized coating > coating alone. After weathering the values were found to be in order of cerium oxide stabilized coating > reference > zinc oxide stabilized coating > coating alone. Metal oxide incorporation to wood coating improved surface hydrophobicity. Both metal oxide nanoparticles dispersed in the coating provide long-term UV protection, and this improves the protection of the film and wood without having a significant impact on optical properties such as gloss, coloring, transparency and other physical properties (Web -1, Web- 2.). Fig. 3 also shows the treatment groups which had contact angle higher than 90°. These were cerium oxide and zinc oxide stabilized coating and reference for un-weathered groups, and cerium oxide stabilized coating for weathered groups. Cerium oxide stabilized coating was the only group which had around 90° contact angle after weathering. In general, cerium oxide nanoparticles exhibited better hydrophobicity on the wood surfaces than zinc oxide nanoparticles. The differences between the structures of two nano metal oxides and nanoparticle sizes (Zinc oxide =20nm; cerium oxide=10nm) could be a possible reason for this result. The difference in the penetration characteristic of the coatings might cause the wetting of surfaces. ZnO nanoparticles are photocatalytically active metal oxides like titanium dioxide nano particles (Shang and Zeng, 2013). When these types of particles are exposed to a specific range of electromagnetic radiation, electron hole pairs will be formed and migrate to the surface and eventually react with oxygen, water or hydroxyls to form free radicals (Saha et al., 2013; Tomak et al., 2018). On the contrary, cerium oxides are photocatalytically inactive, and it has a lower refractive index and is rather transparent to visible light compared to titanium oxide and zinc oxide (Fauchadour et al. 2005; Saha et al., 2013; Tomak et al., 2018). As can be seen from the pictures of the samples, these structural differences between the nanoparticles could also play a role on the whitening tendency of surfaces at the end of the weathering period (Tomak et al., 2018). Saha et al., (2011) found that the coating containing titania micro particles wetted the surface most and coating containing zinc oxide nanoparticle containing wetted the surface least. They also found the particle size of the inorganic UV absorber had an effect on the degree of orientation of the acrylic polyurethane coatings. Smaller particles had greater contact angle than bigger particles. This might perhaps be directly related to the surface tension that higher surface tension resulting in the highest contact angle (Saha et al., 2011).

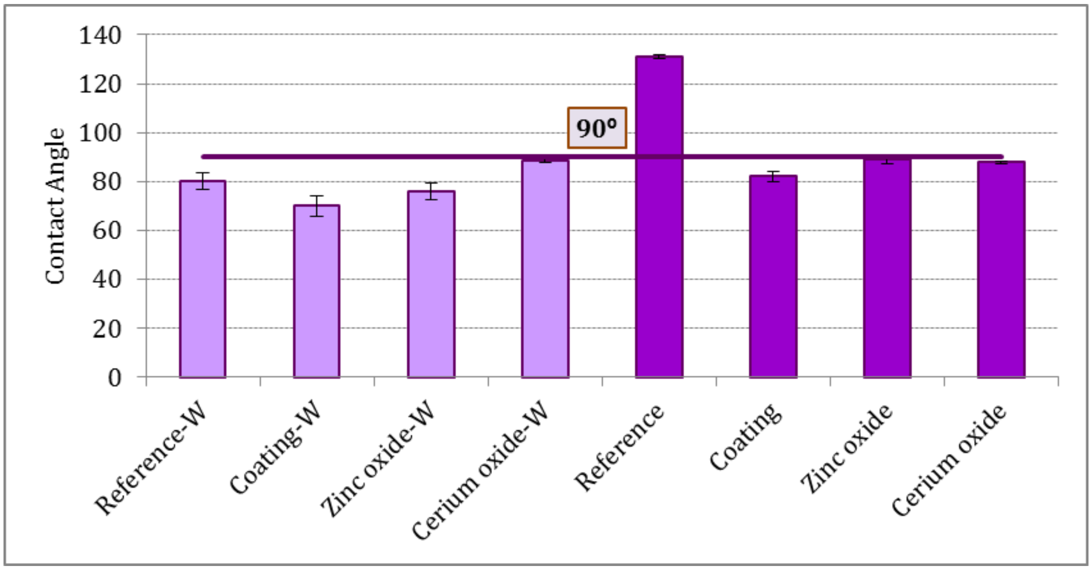


Figure 3: Average contact angle of samples

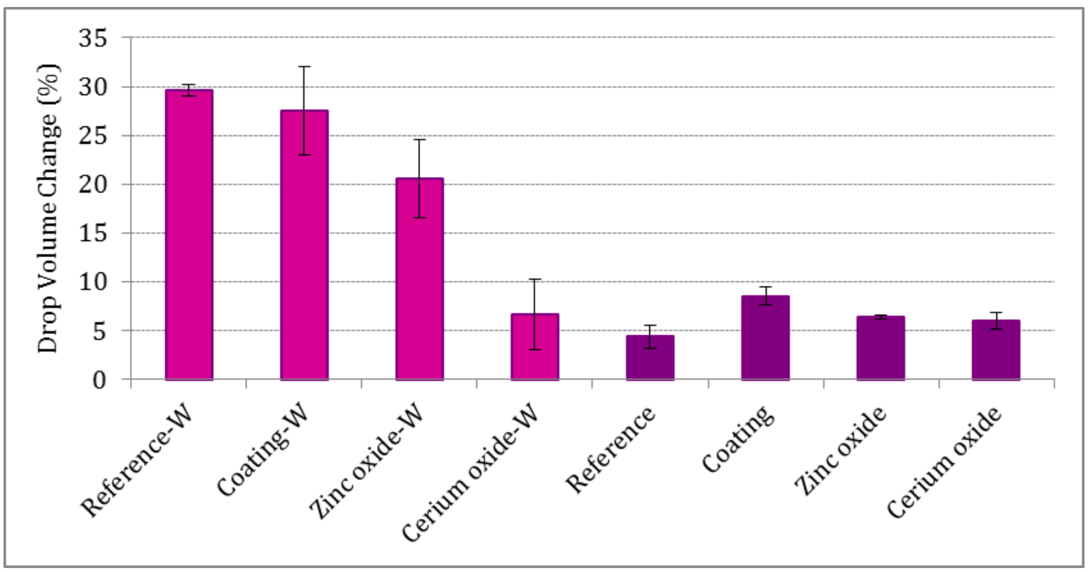
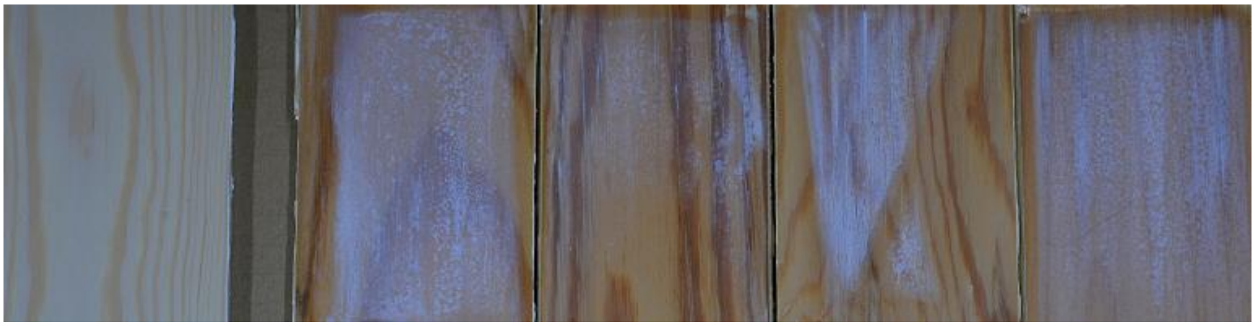


Figure 4: The change in drop volume of the samples (%)

The surface of the weathered reference samples showed the greatest change in droplet volume (Fig. 4). Droplet volume decreased markedly during the experiment showing that water is absorbed by the wood. The quantity of water absorbed by wood and the spreading rate of the droplet were decreased on zinc and cerium oxide stabilized coatings. Droplet volume change of samples were in accordance with the contact angle of samples that clearly showed the drop volume change in weathered samples were in the following order cerium oxide stabilized coating < zinc oxide stabilized coating < coating alone < reference. As been reported above, cracks on the surface occurred by weathering factors probably caused a fast drop spreading on the surface of reference and coating alone. Crack formation was not observed for zinc and cerium oxide stabilized coatings. Beside the contact angle results, cerium oxide stabilized coating had better appearance on the wood surface after weathering than zinc oxide stabilized coating.

Reference



ZnO stabilized coating

CeO2 stabilized coating

Coating alone

Figure 5: Picture of samples after weathering

4 CONCLUSION

The results indicated that reference chemical caused higher hydrophobicity on wood surfaces before weathering in comparison to other coatings however after weathering the efficiency was decreased. This was probably due to cracks on the surfaces occurred by weathering agents. Cracks were also observed on samples coated with the coating without any additives. Metal oxide incorporation to wood coating improved surface hydrophobicity. Crack formation was not observed for zinc and cerium oxide stabilized coatings. Average contact angle of samples before weathering were found to be in the following order: reference > zinc and cerium oxide stabilized coating > coating alone. After weathering the values were found to be in order of cerium oxide stabilized coating > reference > zinc oxide stabilized coating > coating alone. Cerium oxide stabilized coating was the only group which had around 90° contact angle after weathering. Droplet volume change of samples was in accordance with the contact angle of samples. Cerium oxide exhibited better surface appearance and hydrophobicity than zinc oxide.

5 ACKNOWLEDGEMENTS

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Web- 2: https://www.palmerholland.com/Assets/User/Documents/Product/41964/4279/MITM02712.pdf last accessed: 11.06. 2018

THE INTERNATIONAL FOREST PRODUCTS CONGRESS

Changes in Contact Angle of Heat Treated Wood due to Natural Weathering of 2 Years

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ABSTRACT

Heat treatment is one of the environmental friendly wood protection methods since heated wood does not contain any harmful chemicals. Wood polymers are modified by the exposure to high temperature ranges between 160 and 230°C. The main advantages of heat treatment of wood are increased hydrophobicity, improved dimensional stability, lowered equilibrium moisture content, and increased decay and weathering resistance.

In this study, it is aimed to investigate the effect of natural weathering on the wettability of heat treated iroko, ash, Scots pine and spruce wood samples. For this purpose, softwoods were subjected to the heat treatment at 212°C for 90 min while hardwoods were heated at 190°C for 90 min under steam atmosphere, and then all samples including controls were exposed to natural weathering agents in Trabzon for 2 years. Contact angle was measured with the sessile drop technique using water both for weathered and un-weathered samples. The change in volume of the drop (%) was also calculated.

Contact angle measurements after heat treatment showed an increase in wood hydrophobicity. However, weathering increased wettability of the samples probably due to combination of structural and chemical changes of the surfaces. Surface cracks formed during weathering. Cracks were greater in control samples compared to heat treated samples and in softwoods compared to hardwoods. Advancing contact angles of a water drop were in all cases higher for heat treated wood than for control wood after weathering. Change in drop volume of heat treated samples was also found to be less than that of controls showing heat treated wood was less wetted than controls.

KEYWORDS: Contact angle, heat treatment, weathering, wettability

1 INTRODUCTION

Wood is a natural engineering material with many outstanding properties, especially high resistance. Unfortunately, sunlight, moisture, oxygen, atmospheric contaminants, heat, cold, chemicals and biological materials degrade wood components and change aesthetic appearance, and therefore durability is reduced. The effect of these factors shortens service life of wood, and causes economic loss (Yıldız et al., 2013; Tomak et al., 2014). The environmental impacts caused by toxic chemical substances are the main reasons for searching an alternative wood preservation method (Korkut et al., 2015). Heat treatment modifies wood structure without using any harmful chemicals therefore, it is commonly accepted as a cheap and an environmentally-safe method compared with the other modification and/or impregnation techniques (Yıldız et al., 2013). In the heat-treatment process, wood is heated to temperatures of 160–250°C depending on the species used and the desired material properties (Kocaefe et al., 2008). The duration for heat treatment generally vary from 15 min to 24 h depending on the process, wood species, sample size, moisture content of the sample and the desired mechanical properties (Korkut et al., 2007). It was found that the anatomical structure of the wood was little affected during the heat treatment. The main effect of heat treatment is on the chemical and physical properties of wood. Decrease in the amount of hemicellulose, condensation and demethylation of the lignin, and removal of some extracts at high temperatures are attributed to heat treatment (Huang et al., 2012).

Heat treatment is extremely important, especially for industrial applications, because it greatly changes the properties of the wood such as surface quality, dimensional stability and / or anisotropy factor. The temperature creates a variety of changes on the surface of the wood, so its hydrophilic properties and therefore wettability is an important feature to be appreciated when water-based color coatings are designed to be used to protect and reclaim surfaces (Korkut et al., 2015). Quality of wetting is influenced by many factors including wood macroscopic characteristics (e.g., porosity, surface roughness, moisture content, fiber orientation, etc.). Various techniques exist for the measurement of wood wettability. The most well-known and widely used method is the sessile drop technique. In this method, a mathematical expression is fitted to the drop shape and the contact angles are determined by determining the slope of the tangent to the drop at the triple point. The wood is expected to become more hydrophobic with increasing heat-treatment temperature; consequently, the contact angle will increase due to the chemical changes taking place (Kocaefe et al., 2008) Hakkou et al. (2005) reported that the effect of temperature on the wettability changes abruptly for temperatures between 130 and 160°C, and the higher temperatures used for heat treatment are not influenced by the change in wood hydrophilic properties. Gérardin et al. (2007) used contact angles to evaluate the surface energies of heat-treated pine and beech wood, and they attributed the hydrophobic behaviour of wood to hemicelluloses degradation.

Natural weathering of heat treated wood is studied by Nuopponen et al. 2004; Metsa-Kortelainen et al. 2011; Tomak et al., 2014; Metsa-Kortelainen and Viitanen 2015; Turkoglu et al. 2015. The natural weathering studies demonstrated that heat treated wood is more resistant to natural weathering factors than control wood (Nuopponen et al., 2004; Tomak et al., 2014). Heat treated wood had incipient decay while control wood reached failure rating in a lap joint field test for 9 years (Metsa-Kortelainen et al., 2011). Significant differences in durability and moisture content between the heat treated and control samples were found using a modified double layer test after six years of exposure in the field in Finland (Metsa-Kortelainen and Viitanen 2015). Effect of artificial weathering on the wettability of three heat-treated North American wood species (jack pine, aspen, and birch) was studied by Huang et al. (2012). They found that weathering increased wettability of all three heat-treated woods by water.

Ash, iroko, Scots pine and spruce are the main wood species used for industrial scale thermal modification in Turkey. The effect of artificial weathering on chemical composition, surface characteristic and mechanical properties of heat treated these wood species during exposure period of 400–1600 h was studied by Yıldız et al., (2013). Changes in moisture content, color, surface roughness, compression strength parallel to grain, modulus of rupture and modulus of elasticity of heat treated wood species during natural weathering for two years was also investigated by Tomak et al., (2014). To the best of authors' knowledge, wettability of these wood species after natural weathering of 2 years has not been investigated yet. In this study, wettability of these wood samples was investigated. For this purpose, contact angle was measured with the sessile drop technique using water both for weathered and un-weathered samples. The change in volume of the drop (%) was also calculated.

2 MATERIALS AND METHOD

2.1 Materials

Heat treated iroko (*Chlorophora excelsa*), ash (*Fraxinus excelsior* L.), Scots pine (*Pinus sylvestris* L.) and spruce (*Picea orientalis* L.) sapwood lumbers with dimensions of 20mm (radial)×20mm (tangential)×300mm (longitudinal) were supplied from Nova Wood, Gerede, Turkey. Softwood and hardwood lumbers were heat treated at 212 °C and 190 °C for 90 min, respectively under steam in an industrial plant in Turkey. An equal number of unmodified samples (control) with the same dimensions were cut from the unmodified lumbers. Preparation of wood samples for each group was described in detail by Yildiz et al., (2013) and Tomak et al., (2014, 2018).

2.2 Natural weathering of samples

Samples were exposed to outdoor degradation in a randomized complete block design facing South at an angle of 45° to the horizontal and the height of 75 cm from the ground in Karadeniz Technical University campus with an altitude of 170m in Trabzon during the period from October 2011 to October 2013.

2.3 Contact angle measurement

Four replicates in each treatment group were conditioned at a temperature of 20±2°C with 65% relative humidity for one month before the test. Attension theta lite system was used to determine contact angle and drop volume at 1 s intervals for a period of 10s. The measurement technique is based on rapid video capture of images and automatic image analysis. Four drops of 5μl volume were formed automatically using a pump and deposited on the tangential surface of the samples at room temperature. The change in volume of the drop (%) was calculated on the basis of the initial drop volume. Contact angle was measured three seconds after the drop was placed on the wood surface in order to see the actual effect of treatments on contact angle. The tangential surface was chosen for the study since these surfaces were smoother than the radial surfaces which exhibited wavy growth or grain.

3 RESULTS AND DISCUSSION

Figs. 1-3 show the contact angle (°) and change in volume of the drop relative to the initial volume (%). As may be seen from the Figs. 1 and 2, the contact angle of heat treated samples was higher and more stable over time than that of the controls. In systems involving water as the liquid phase, surfaces forming contact angles of less than 90° are said to be wettable or hydrophilic, whereas those giving rise to contact angles greater than 90° are said to be water-repellent or hydrophobic (Koski, 2008). At the end of the contact angle measurement test, heat treated ash, spruce and S. pine samples exhibited a water repellent or hydrophobic surface since the observed contact angles were around 90°. Heat treatment of wood affect wettability and enhance its hydrophobicity (Petrissans et al., 2003; Aydin and Colakoglu, 2007; Petric et al., 2007; Kocaefe et al., 2008; Metsa-Kortelainen and Viitanen, 2012). FTIR spectra of the samples showed some changes, suggesting that thermal modification of the wood components had taken place during heat treatment at 190 and 212°C (Yildiz et al., 2013). A reduction in the number of free hydroxyl groups accessible to water and degradation of hemicelluloses of wood during heat treatment makes wood more hydrophobic (Kocaefe et al., 2008). Heat treated iroko samples exhibited similar contact angle values as the controls did. Extractives in iroko could be a reason for this finding.

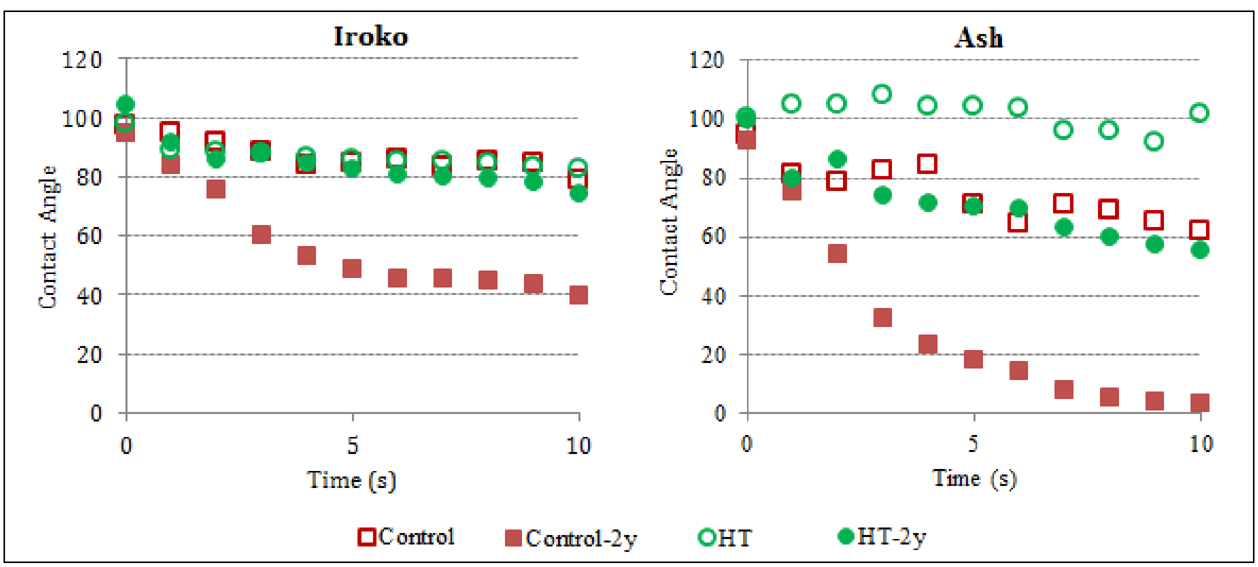

Figure 2: Contact angle of hardwood species

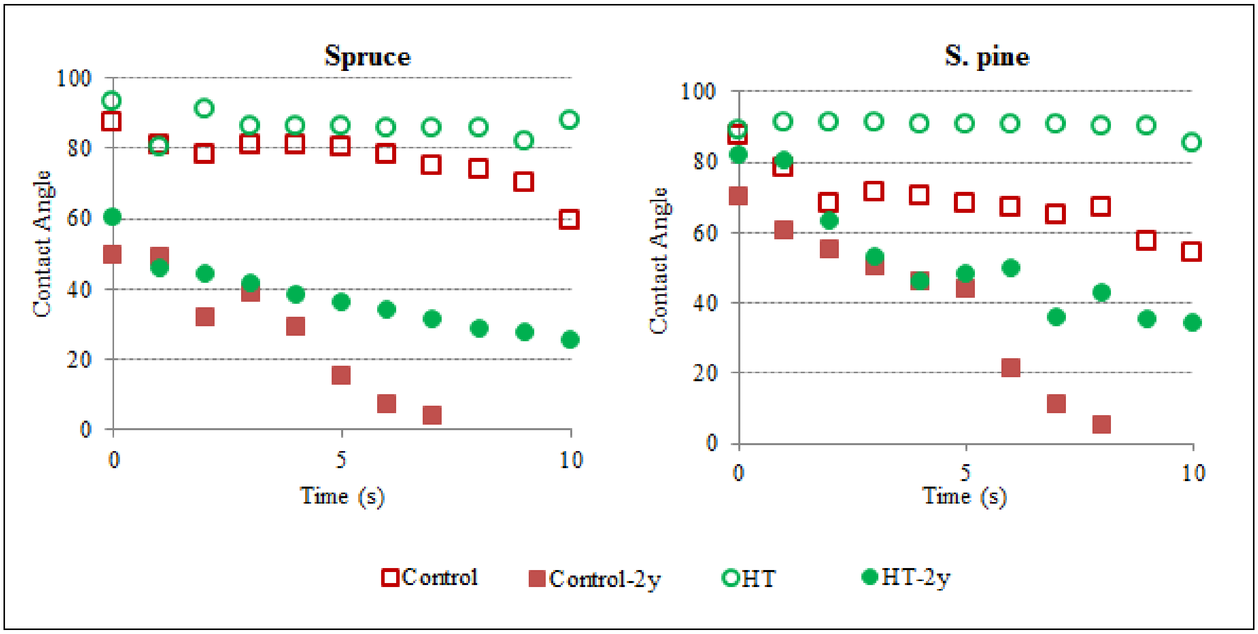

Figure 2: Contact angle of softwood species

As can be seen in two figures, the weathering reduces the hydrophobic behavior of these four heat treated woods; consequently, all the contact angles of weathered - heat treated wood are lower than those of unweathered wood of the same species except for iroko samples. This shows that weathering increases the wettability of wood by water. Heat treated samples exhibited higher contact angles than controls after weathering. Cracks formed on the surfaces due to degradation during weathering (Fig. 4), and controls had deeper cracks than heat treated ones after weathering. As a result, water has easier entry into the cell wall, which consequently increases wettability. Weathering changes wood structural properties (Hon and Feist, 1986; Evans et al., 1996; Huang et al., 2012). The difference in wood surface structure can cause wettability differences of wood surfaces. The changes in wettability during weathering can also be related to changes in the chemical properties of a wood surface (Kishino and Nakano 2004; Huang et al., 2012). It was reported that the presence of cellulose rich layer on wood surface and increasing amount of amorphous cellulose transformed from crystallized cellulose due to weathering results in increase in hydroxyl; consequently, it increases wettability of wood (Huang et al., 2012).

Hardwood species were less wetted than softwood species. Among the heat treated wood species, iroko samples exhibited greater contact angle than others probably related with its hydrophobic extractive contents. The trends observed for both softwood species (spruce and S. pine) are found to be very similar. These results show that the changes in wettability during weathering differ according to heat treatment temperature and type of wood species, and are likely due to combination of structural and chemical changes of the surfaces. Wettability could be affected by the density of wood species. It had been reported that dense wood species are less affected by weathering factors (Anderson et al., 1991a, b).

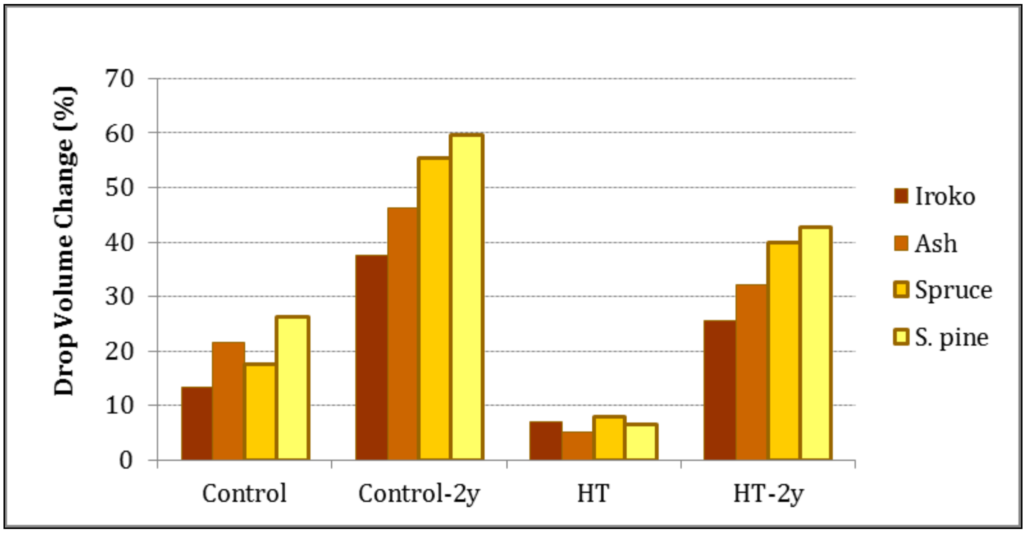

Figure 3: The change in drop volume of the samples (%)

The surface of the weathered control samples showed the greatest change in droplet volume (Fig. 3). Droplet volume decreased markedly during the experiment showing that water is absorbed by the wood. The drop was completely spread after 10s for ash, spruce and pine weathered control samples. Volume changes have a direct influence on the contact angle measurements (Kocaefe et al., 2008). The quantity of water absorbed by wood and the spreading rate of the droplet were decreased on heat treated wood surfaces. Droplet volume change of samples were in accordance with the contact angle of samples that clearly showed the drop volume change in heat treated and weathered samples were in the following order iroko < ash < spruce < S. pine. Extractives in the wood species also play an important role on wettability (Kalnins and Feist, 1993). Many wood properties depend on the density of the wood. As the density of wood increases, its porosity will decrease, and there is a linear relationship between the porosity and uptake of chemicals or water in wood (Bozkurt et al., 1993). Hardwood species may have a lower porosity than softwood species; this may be the reason for the higher wettability of softwood species. In addition, cracks were greater in control samples compared to heat treated samples and in softwoods compared to hardwoods (Fig. 4). SEM analysis is recommended for further explanations on the structural changes of wood surface occurring due to weathering.

Figure 4: Picture of samples after weathering of 2 years.

3 CONCLUSION

The results indicated heat treatment caused a greater decrease in the wettability of wood in comparison to controls. Weathering decreased the contact angle, and therefore the quantity of water absorbed by the wood was increased. In all cases, heat treated samples exhibited more hydrophobic surfaces than controls after weathering. Cracks were greater in control samples compared to heat treated samples and in softwoods compared to hardwoods after 2 years of weathering. Droplet volume change of samples were in accordance with the contact angle of samples that clearly showed the drop volume change in heat treated and weathered samples were in the following order iroko < ash < spruce < S. pine. The greater wettability of weathered wood accelerates deterioration of wooden structures. Heat treatment increases the hydrophobicity of wood surfaces but some additive coatings on heat treated wood may improve its durability in outdoor conditions.

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ABSTRACT

One of the main methods used to protect wooden materials against UV rays is to cut the UV rays and contact with the wood surface of the rain water by applying surface treatments. Within the scope of this project; environmentally friendly new wood preservative surface materials have been developed that protect the wood surface against outdoor conditions. Durability performance of different types water borne acrylic resin with bark extract coatings on wood surface exposed to outdoor conditions was investigated.

The scots pine and oriental beech surfaces were coated with 3 different water-borne acrylic resin coatings. Two different tree (fir and black pine) bark extracts and commercial UV absorber (Tinuvin DW 400) were used in acrylic resin coating formulations. The durability of the coatings (test group) containing these bark extracts were compared with coating (control group) with commercial UV absorber (Tinuvin DW 400). The wood samples coated with test and control coatings were exposed to accelerated weathering testing in laboratory conditions. The surface colour and roughness change values on the wood samples coated with test coatings exposed to the accelerated weathering test (QUV, 2016 h) were compared with the control samples. Microscopic images and dry film thicknesses of the control and test samples prepared before the outdoor test were determined.

The results showed that the protective effect of acrylic coating system containing fir bark extracts in QUV test conditions during 2016 h was better than coating containing commercial UV absorbers. However, the increase of antioxidant effect on the fir bark extract has a positive effect on the beech wood to increase the durability in outdoor conditions, while it has a low preservative effect on the pine wood.

KEYWORDS: Accelerated weathering test, Acrylic resin, Colour change, Tree bark extract, Surface roughness, Wood coating

1 INTRODUCTION

One of the methods used to protect the surface of wood material against outdoor conditions; UV light and water contact with the wood surface is prevented by surface treatments. Today, different wood protective surface products used in outdoor conditions are presented to the market (Decker et al., 2004; Evans et al., 2008; Özgenç et al., 2012). In order to protect wood surface from photodegradation, acrylic resin varnishes and UV absorbers used in car industry are being investigated extensively. According to these investigations, high protection is provided on the surface against photodegradation with the acrylic resin containing organic or inorganic UV absorbers (George et al., 2005; Custódio and Eusébio, 2006; Aloui et al., 2007; Deka et al., 2008). While color stabilization is provided on the surface, lignification is also prevented by protecting the wood surface from washing. Acrylic resin containing UV absorber provides longer protection against outdoor conditions compared to older generation surface treatments. (Forsthuber and Grüll, 2010; Ozgenc et al., 2012; Özgenç and Yıldız, 2016a). Several studies have been carried out on the effects of some bark extracts, high phenol content, or anti-oxidant effects. Chang et al. (2010) investigated the antioxidant activity of the extracts obtained from the bark and heartwood of the acacia tree of Taiwan. Taiwan has determined that the acacia heartwood extract is a more effective antioxidant than bark extract (Chang et al., 2010). Douf et al. (2006), extraction of hazelnut, sumac, Shinopsis lorentzii leaf and pine, mimosa barks by three different methods. As a result, it was determined that the antioxidant capacity of extracts was very high. Jerez et al. (2007) compared antioxidant activity and procyanide components of the extract obtained from maritime pine and red pine barks. Vázquez et al. (2008) investigated potential antioxidant components of chestnut and eucalyptus bark extracts. The extract of the chestnut bark has been shown to have a high molecular weight and the eucalyptus bark has a lower molecular weight. The phenol content and antioxidant activity of barks extracts were found to have a positive linear correlation. The end result of the FTIR spectroscopy analysis revealed that the phenol content of the chestnut bark extract was higher than that of the eucalyptus bark extract. Salem et al. (2014) achieved positive results in antibacterial, antifungal and antioxidant properties of Delonix regia bark extracts known as firewood. There are some studies in the literature on the use of tree bark extracts as organic UV absorbers due to the high antioxidant effect. One of these studies; bark extract, lignin stabilizer, UV absorber and inhibitor amine light stabilizer, compared to the photostabilization effect on the wood surface of the acrylic polyurethane varnish. The highest photosostabilization effect after the accelerated weathering test was determined in heat treated wood surfaces applied with acrylic polyurethane containing bark extract and lignin stabilizer (Kocaefe and Saha, 2012). According to the results of another study, natural antioxidant (bark extract) and lignin stabilizer alone or in combination were mixed into acrylic polyurethane material to increase the durability to the outdoor conditions of the coating material. The color stabilization of acrylic polyurethane containing barks extract coated wood surfaces is increased (Saha et al., 2011). The color stability of the wood coatings based on the combination of epoxy functional containing soybean oil and UV absorber (HEPBP) is very high compared to the wood coatings containing UV absorber containing HEPBP. In addition, the epoxy-based soybean oil combination with UV absorber (HEPBP) provides substantial protection against physical deformation of wood coatings caused by external factors such as UV radiation and rain (Olsson et al., 2012). Saha et al. (2013) examined the outdoor strength of acrylic polyurethane varnishes prepared with three different UV stabilizers (UV absorber, HALS, Anti-oxidant). It has been determined that the strength of the wooden surfaces applied with acrylic polyurethane varnish modified with coniferous tree leaves and leaf extracts increases in outdoor conditions. It has been understood that the antioxidant effect of coniferous tree bark and leaf extracts provides high UV absorption. In the study by Grigsby and Steward (2017), the condensed grain extracted from the tree barks was added to the acrylic resin based varnish as a functional additive. Acrylic resin based varnishes, modified with tannin with high antioxidant effect, provide a very high protection on the surface of wood against outdoor conditions.

In the literature studies, the existing varnishes have been modified using bark extracts. In this study, the durability of water based acrylic based varnish systems containing wood bark extracts in outdoor conditions will be examined. As a test group, bark extracts obtained from 2 different tree species (fir and black pine) and commercial UV absorber (Tinuvin DW 400) were used as a control group. The surface color and roughness changes of the test and control samples exposed to accelerated outdoor testing were analyzed. In addition, the dry film thicknesses of the test and control samples were determined by light microscopy. UV absorber materials used in wood surface varnish systems are imported and are costly products. For this reason, the study will investigate the availability of tree bark extract instead of UV absorber.

2 MATERIALS AND METHOD

2.1 Wood and bark samples

The barks were peeled off from the 20-30-year-old fir (*Abies nordmanniana L.*) and black pine (*Pinus nigra L.*) trees that were cut down in black sea region in the north of Turkey. TAPPI T 257 cm-12 and TAPPI T 264 cm-07standard methods were used for the preparation and chopping tree barks for extraction analysis.

The scots pine (*Pinus sylvestris L.*) and oriental beech (*Fagus orientalis* L.) were used in the study as defect free samples. The wood samples were prepared with dimension of 150mm (longitudinal) by 70mm (tangential) by 20mm (radial) for artificial weathering.

2.2 Bark extraction and coating system process

All tree barks were air-dried at room temperature and then ground by using a laboratory scale Willey mill to obtain 40 to 60-mesh wood powder. To obtain extractives, the bark powders were extracted in a Soxhlet extractor. The bark powder (25 g for each) was soaked in 300 mL of ethyl alcohol:benzene (1:2 v/v). The solvents from each extracts were removed by using a rotary evaporator at 50 ^{o}C and stored in sealed flasks at 4^{o}C until use.

2.3 Application and Preparation of coating systems

The waterborne acrylic based coating system was formulated from the commercial acrylic resin, a poly-(methylacrylate/methylmethacrylate/butylacrylate) copolymer dispersion. In order to increase the effects of other additives on photostabilization, only a small amount of defoamer and 2,2,4-trimethyl-1,3-pentandiolemonoisobutyrate as a coalescending agent were used in the formulation. Acrylic based coating systems containing bark extracts was compared with the control coating groups containing commercial UV absorber. Tinuvin DW 400, also known as commercial UV absorber, is a BASF product with the hydroxyphenyl-s-triazine class (HPT) content.

For the purposes of the artificial weathering test, the back, end-grain and side faces of wood samples were covered with 2-epoxy white paint with a brush, and the front side was left as uncoated for experiments. The commercial water-based impregnation product, having active ingredients of 1.20% propiconazol, and 0.30% iodopropynyl butylcarbamat, was used as a primer for the protection of the samples against biological deterioration, including soft rot and blue stain. The primer was applied to the samples at a spread of 120 g/m^2 using a brush. The first layers of topcoats were also applied to each sample at a spread rate of 100 g/m^2 by brush. Later, the specimens were sanded with a 240 grit size of sandpaper and kept at room temperature for two days before applying the second layer of topcoat.

2.4 Artificial weathering test

All wood samples applied coating systems comprising bark extracts and mineral UV absorber were subjected to an artificial weathering by exposing to 340 fluorescent UV lamps in a QUV/spray accelerated weathering tester (Q-Panel Lab Products, Cleveland, USA) for 2016 h according to TS EN 927-6 standard. The weathering experiment was conducted by cycles of UV-light irradiation for 2.5 h at 60 0C followed by a water spray for 0.5 h followed by a condensation for 24 h at 45 0C in an accelerated weathering test cycle chamber. Samples were removed from the test chamber at 24 h intervals during 48 h, and subsequently colour measurements were performed on the exposed surfaces coated with acrylic and alkyd systems. After the measurements, samples were placed again into chamber and then every 224 h intervals of 2016 h, the samples were removed, and the measurements were repeated on the surfaces. During the 2016 h test period, 11 periodic measurements were performed on the exposed surfaces.

2.5 Colour measurement

The colour measurements were carried out using a Minolta CM-600d spectrophotometer (Konica Minolta, Japan) equipped with an integrating sphere according to the CIE L* a* b* system (ISO 7724 standard). The reflection spectrum of the Konica Minolta CM-600d instrument was acquired from an area measuring an 8 mm in diameter with 100 in the 400–700 nm wavelength range. Five measurements were recorded for each samples.

2.6 Surface roughness measurement

TR100 Surface Roughness Tester was employed for the measurement of surface roughness. The Ra and Rz roughness parameters were measured to evaluate surface roughness of unweathered and weathered (treated and untreated) samples' surfaces according to DIN 4768 (DIN 1990). Ra is an arithmetic mean of absolute values for the profile departures within the reference length and Rz is the arithmetic mean of the 5-

point height of irregularities. The cut-off length was 2.5 mm, sampling length was 12.5 mm, and the detecting tip radius was 5 mm for the surface roughness measurements.

2.7 Determination of dry film thickness using light microscope

The dry Film Thickness is determined by ZEISS Stemi 305 light microscope and ZEISS AxiocAM erC 5s camera at 2X magnification according to EN ISO 2808 (2007) standard. The viscosity of the three different coatings applied in this study was determined by using DIN cup/4mm/20 0 C (ASTM D 1438, 1971).

3 RESULTS AND DISCUSSION

3.1 Colour change of coating systems

The color stabilization of acrylic resin containing tree bark extractives and UV absorbance was evaluated in artificial weathering conditions during 2016 h. The changes in the color as a result of intensive weathering conditions were clearly seen in Fig. 1. In the literature, tree bark extractives provided the best color stabilization based on ΔE values which represents the color change on wood surface against artificial weathering conditions. The high antioxidant activity of tree bark extractive inhibits oxidation reaction which occurs in cell wall components, especially in lignin (Evans et al., 1987; Saha et al., 2011 and 2013). Therefore, tree bark extractives improved weathering resistant significantly. But, in this study, the ΔE values of the control and test samples were different to each other for acrylic coating systems, the least color change was obtained from commercial UV absorber (control) for both pine and beech. While the color changes increased gradually during the 2016 h for bark extracts, the color change in the coating systems containing bark extracts is generally higher than the control coatings containing commercial UV absorber. The Oxidation reactions induced by weathering conditions (combination of UV radiations, high humidity and temperature etc.) cause deformation in the resin structure which influence coating adhesion and cohesion (Perera, 2003, Singh et al., 2001). Therefore, UV rays reach wood surface and degradation occurs. But the color change of the coating system containing fir extract is close to control.

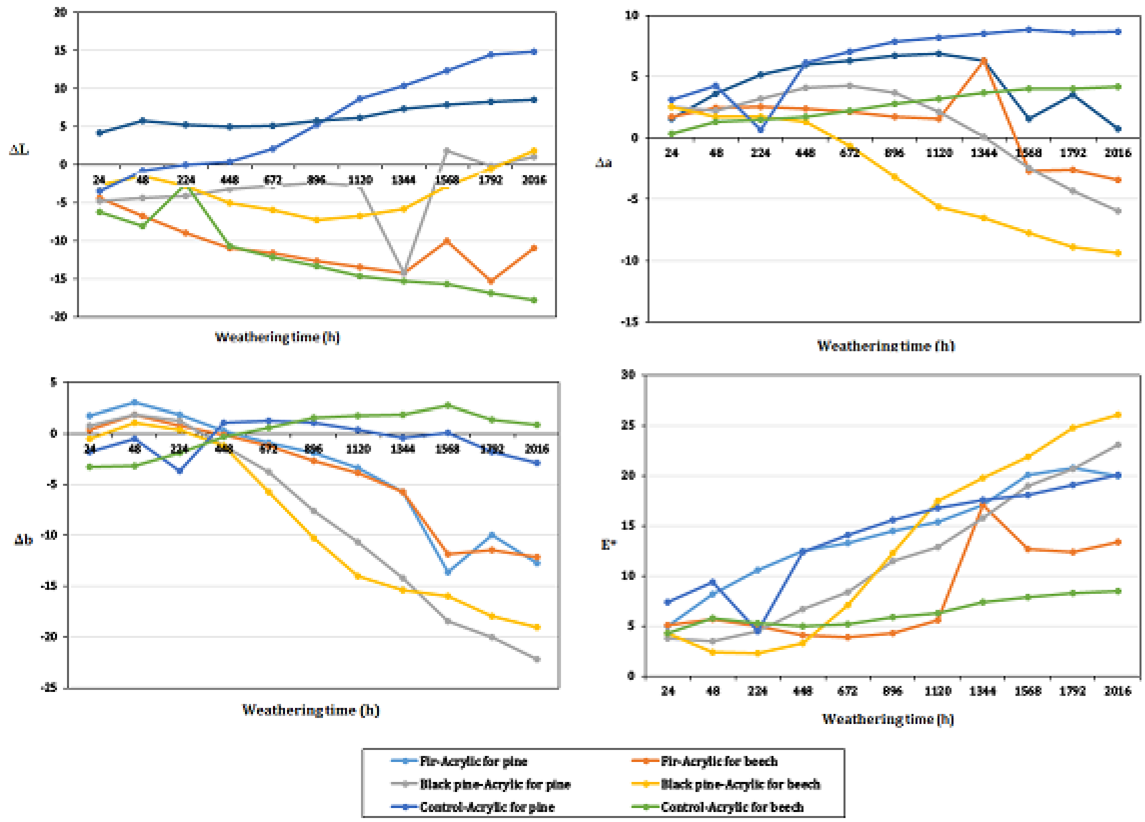

Figure 3: Changes in colour coordinates of wood surfaces applied with acrylic based coating systems.

The positive value of Δb* indicates increasing of the yellowish color on the wood surface, while negative value of that is bluish. As seen in Fig. 1., the color of the test samples changed from yellowish to bluish, compare in the beginning of the artificial weathering test. The highest change was found in black pine bark extractives while the least Δb* value was obtained from control samples. Moreover, Δa* value refers to reddish color for positive value while it is greenish for negative value (Ozgenc and Yildiz, 2016b). The general trend for test coating samples expect for fir bark extract is changing from reddish to greenish during 2016 h. After that time, samples surface tended to be greenish. But control coating samples are positive value of that is reddish. The lowest Δa* values were obtained from fir bark extractives for beech compared to control samples as a commercial product ΔL* values give clues about the surface quality and lightness (Ozgenc et al., 2012). Polymerization of lignin during the weathering test causes wood surface to be dark (Korkut et. al, 2012). ΔL* values of coatings for beech trended toward to be negative during the 2016 hours. Therefore, the beech wood surface was becoming rougher and darker during the artificial weathering test. it was found that in both types of wood, the lowest ΔL*change was observed in coating systems containing black pine extract. The highest color change (E*) was found coating systems containing black pine extract while the lowest one is fir extract for pine. Briefly, in this study, it was determined that the effect of colour stabilization of the fox extract was the potential to be rival to commercial products such as control samples.

3.2 Surface roughness change of coating systems

The surface roughness of wood materials is not induced only by anatomical structure of wood as it is an anisotropic and heterogeneous material. Therefore, some factors must be taken into consideration to evaluate surface roughness, such as earlywood and latewood content in the annual ring, natural growth characteristics (knot, fiber curl, etc.), annual ring wideness, drying temperature, shear direction and angle (Aydın and Çolakoğlu, 2003; Aydın and Çolakoğlu, 2005).

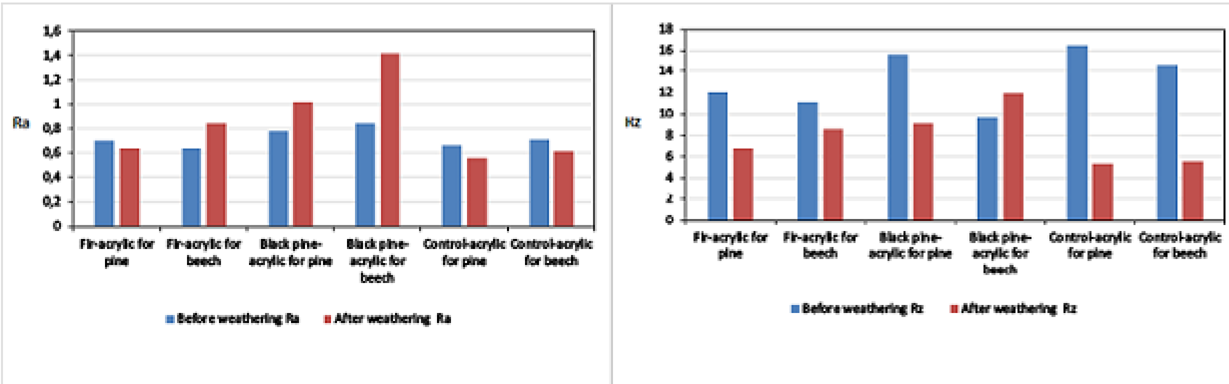

Figure 2: Changes in surface roughness values of wood surfaces applied with acrylic based coating systems.

The surface roughness values of waterborne based acrylic systems containing bark extract and commercial UV absorber were given in Fig. 2. As seen that there is no significant change in the Ra values of the control samples after weathering. On the other hand, the considerable changes arose after weathering in the coating containing bark extracts. In addition, except for the test coating systems applied to pine wood, the Ra values of other test coating systems caused an increase in the weathering test. There is a significant change in the Rz values of all coating systems. While the Rz values of the coating systems containing black pine extract applied to beech wood increased, the decrease in the Rz values of the samples applied to other test and control coating systems was determined. The extensive weathering conditions influence wood surface and some chemical changes take place both coating and wood structures resulted in diminishing of coating adhesion and cohesion (Perera, 2003). The film thickness decreases depending on intensity of weathering conditions in consequence of surface erosion during the exposure period (Decker et al., 2004). Therefore, wood surface deteriorates which leads to create hollow and hills on its surface. Chemical changes occurred in the polymer structure because different changes on the surface (Perera, 1995) which could have resulted in variation for resin types.

3.3 Dry film thickness

In this study, the effects of dry film thickness and viscosity of coating systems on the durability in outdoor conditions were investigated. The dry film thickness measurements were then made at ten locations along the coating using a light microscope equipped with a scale, which was calibrated with a micrometer. A summary of the dry film thickness and varnish viscosity are presented in Table 1. According to the results of this study, there was a significant effect between the dry film thickness and varnish viscosity. Low viscosity varnish constituted low dry film thickness on the surface of the wood. Compared to high viscosity, low viscosity coatings have higher penetration in the wood (Ozdemir et al., 2013). The results obtained in Table 1 show similar results from the literature. But the viscosity is very low in the control coating, the dry film thickness on the beech surface is very low.

Table 1: The dry film thicknesses and viscosity values of acrylic coating systems containing tree bark extract and commercial UV absorber

Coating Systems	Dry film thickness for pine (μm)	Dry film thickness for beech(μm)	Viscosity (s)
Fir-Acrylic	45.36	71.24	100
Black pine-Acrylic	53.73	87.96	120
Control-Acrylic	37.23	65.37	70

All instances of the same amount of coating systems applied to wood. However, depending on the coating viscosity and the variability of the wood types, the penetration in coating thicknesses also varies. Because of coating thickness, different color changes in wood samples after weathering is seen to be different. The low penetration of the acrylic coating systems on the wood surface increases the dry film thickness. When the dry film thickness of coating systems decreases with increasing penetration, the color change on wood surface decreases after weathering (Bulcke et al., 2008; Dawson et al., 2008). In Fig. 3, microscope observations revealed that the penetration behavior was the different in pine and beech wood. It was seen that the color change of pine wood is higher than beech wood due to the coating penetration of beech wood is lower than pine wood. Thus, the high dry film thickness on the beech wood increased the colour stability of the acrylic varnish systems in outdoor conditions.

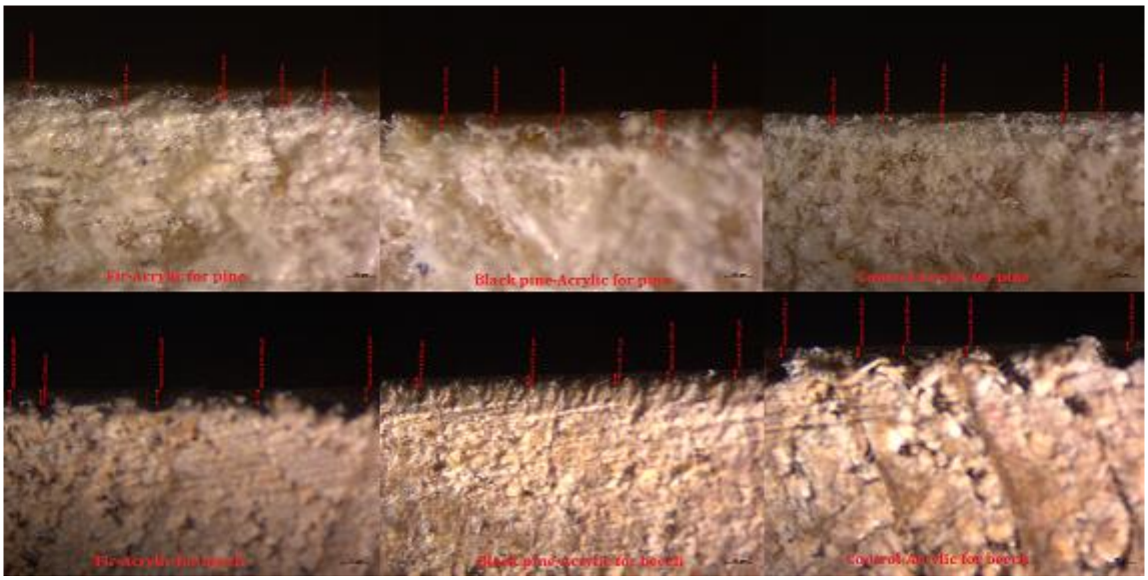

Figure 3: Microscopic screening of acrylic based test and control coating systems applied to beech and scots pine surface.

4 CONCLUSION

In this study, tree bark extracts were evaluated to durability against weathering factors as compared commercial UV absorbance. The high phenol content of tree bark extract has a high amount of UV absorbing ability. Therefore, the colour change on the wood surface was restricted by fir bark extract, close with UV absorbance. The roughness change on the wood surface applied to the coating system containing the fir bark extract after the artificial weathering test was found to be close to the coating system containing the commercial UV absorber. It can be concluded that the viscosity and penetration properties of acrylic varnish system affect the durability on the wood surface exposed to outdoor conditions. The effect of coating viscosity and penetration for coating dry film thickness was investigated by light microscopy. The acrylic varnish system, which has high penetration on the wooden surface, has been found to form low film thickness. The penetration of high viscosity for coating systems on the wood surface is low, resulting in high dry film thickness. As the dry film thickness on the wood surface increases; the colour stabilization of the coating system increases and the variation of the roughness decreases in outdoor conditions.

Consequently, fir bark extracts which have high antioxidant capacity and high phenol content provide photostabilization and protect wood surface against outdoor conditions. So that tree bark extracts have potential to compete with commercial UV absorbance. In future studies, it is recommended to study on the development of acrylic coating systems with different tree bark extracts.

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Comparison of Durability of Different Water-Borne Acrylic Resin with UV Absorber Wood Coating Systems in Natural Weathering

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ABSTRACT

Wood has been used in the construction industry for thousands of years and remains an important material, often protected by surface treatments.

In this study, pine and beech sapwood samples coated with 12 different water-borne acrylic resin coating systems were exposed to natural weathering in Trabzon, Turkey. The natural weathering test continued for 18 months. In these coating systems, water in different proportions, boric acid, two different acrylic resins and three different UV absorbers supplied by BASF were used. The aim was to compare durability of 12 different coating systems in natural weathering in terms of the colour change, surface roughness, and macroscopic evaluation.

These test methods were used to evaluate the appearance and physical properties of the coatings after natural weathering test. The results lead to the selection of the best coatings formulation for the wood durability in natural outdoor conditions. The appearance and physical values after 18 months of weathering test showed that boric acid increases durability of the varnish for usage in outdoor conditions. In addition to, the varnish formulation containing especially acrylic resin and Tinuvin 400 DW provided the highest durability against outdoor conditions.

KEYWORDS: Colour change, Surface roughness, Natural weathering test, Surface roughness, Water borne acrylic varnish, Wood surface

1 INTRODUCTION

The wood surface is protected by surface treatments that prolong the service life from live organisms such as UV light, high and / or varying humidity, mechanical damage, chemicals, fungi, and termite. The wood surface protectants also improve the aesthetics by providing colour or shine. The durability performance of varnishes in outdoor conditions varies based on many factors such as wood types and properties, varnish types and properties, application procedures and outdoor conditions. For this reason, depending on the severity of the outdoor factors, the nature and characteristics of the varnishes, it requires renewal every few years. Surface treated wood can withstand water vapour permeability (Custódio et al. 2006, Teacă et al. 2013, Evans et al. 2015). The use of coating systems containing UV absorbers (acting as filters) minimizes wood degradation with ultraviolet radiation. New generation coatings can also play a role in resistance to biological hazards if they contain additional wood preservatives or if wood pre-treated with a suitable preservative prior to varnish (Stirling et al. 2011). Another requirement for varnish is durability over many years. For this reason, a wood protectant coating should cover your tackiness, flexibility, durability, permeability and ultimate resistance to fungi. Particularly if the varnishes have excellent outdoor durability and provide extraordinary protection against the biodegradation factors for wood, it is not an easy task to formulate it as a highly variable material (Forsthuber et al. 2013a, Grüll et al. 2014, Keilmann and Mai 2016).

On the wood surface used outdoors, with the effect of UV rays, the lignin is first separated into radicals, which then cause decomposition in other chemical components of the other wood. Then, the products of this degradation on the surface of the wood cause the adhesion between the wood surface and the coating to disappear, resulting in delamination in the coating systems (Nkeuwa et al. 2014). The development of nanotechnology allows wood varnishes to develop further, or to achieve new performance characteristics. With the use of different sizes of nano-metal oxides, the UV protection increases the clear varnishes, giving the wood surface scratch resistance and wear resistance. The use of nano-metals with a size of less than 100 nm gives new properties to polymeric surface materials. Transparent iron oxides are generally used as wood preservatives, but they colour the wood structure (Cristea et al. 2012, Fufa et al. 2012). If you want to make the colour clear; organic UV absorbers (benzophenone family, benzotriazoles, triazines, malonates) together with HALS (hindered amine light stabilizers), which exhibit synergistic photoprotection, are widely used. Organic UVA can be degraded by visible light from 500 nm to 17 nm, and UVA is ineffective at this wavelength, while harmful UV energy is converted into warming before reaching the bottom layer, while HALS is cleaning away important free radicals such as lignin. At the right doses, the combination provides good protection, and its protective properties are reduced during prolonged UV exposure. Inorganic UVA-like nanoparticles (typically 5-50 nm) can provide effective UV protection on the long run because they do not dissociate from surface matter in outdoor conditions (Schaller and Rogez 2007, Forsthuber and Grüll 2010, Nguyen et al. 2016).

The most commonly used inorganic nanoparticles as UVA are oxides such as TiO_2, ZnO and CeO_2. These nanocrystalline oxides behave like semiconductors. On the other hand, TiO_2 and ZnO can also exhibit photocatalytic behavior by the formation of reactive free radicals in a reaction mechanism (Schaller and Rogez 2007, Saha et al. 2013). For this reason, photocatalytic behaviour is used in the production of self-cleaning surface materials, but in order to be effective, it is also necessary to protect the inorganic or organic inert substances of UVA nanoparticles with surface treatments. Self-cleaning surfaces are of great interest in numerous applications. Recently, while maintaining high level transparency, inert formation studies based on SiO_2 or silanes suppressing photocatalytic activity have intensified. In the case of CeO_2, the electron generated after stimulation does not move away from the surface at ambient temperature. Recently, while maintaining high level of transparency, inert formation studies based on SiO_2 or silanes suppressing photocatalytic activity have intensified. In the case of CeO_2, the electron generated after stimulation does not move away from the surface at ambient temperature (Cristea et al. 2012, Nikolic et al. 2015, Nguyen et al. 2016, Nguyen et al. 2017). TiO2 in anatase modification; surface materials are a well-known photocatalyst used in the industry because of their efficiency in the decomposition of contaminating organic compounds after exposure to UV radiation. TiO2 as a photocatalyst is remarkable because it is not toxic, it is chemically inert if it is not light and cheap (Forsthuber et al. 2013b, Grüll et al. 2014, Chen et al. 2014, Kotlík et al. 2014).

The durability of the scots pine and oriental beech wood surfaces coated with 12 different coating systems was evaluated evaluated in natural outdoor conditions. These coating systems consist of 2 different acrylic resins, 3 different UV absorbers, distilled water, boric acid and some additives. The change in coating systems exposed to outdoor conditions was determined by color and roughness analysis. Furthermore, the change in sample surface after the natural weathering test was determined by macroscopic evaluation.

2 MATERIALS AND METHOD

2.1 Wood Materials

As a raw material Scots pine (*Pinus sylvestris* L.) and Oriental beech (*Fagus orientalis* L.) were selected and cut into pieces with dimensions of 120 mm in length by 60 mm wide by 10 mm thick from sapwood according to TS EN 927-6 standard. Wood samples were conditioned in a climate room at 23±2 ^{o}C and 65±5 relative humidity until constant weight was attained. One control and three test samples were cut for each variation. Cross sections of wood samples were coated with epoxy paint to increase resistance to weathering conditions.

2.2 Coating Systems

The commercial water-based impregnation product, having active ingredients of 1.20% propiconazol, and 0.30% iodopropynyl butylcarbamat, was used as a primer for the protection of the samples against biological deterioration, including soft rot and blue stain. The primer was applied to the samples at a spread of 120 g/m^2 using a brush. Tinuvin 400 DW as UV absorbers were used in this study. Commercially produced finishing, having acrylic resin, a copolymer dispersion of methylacrylate/methylmethacrylate/ butylacrylate, was used as a topcoat for the specimens. A small amount of defoamer and 2,2,4-trimethyl-1,3-pentandiolemonoisobutyrate, a coalescending agent was added in the topcoat formulation to reduce the effect of other additives on the photostabilization performance. These formulation products were supplied from BASF Company for the wood coatings (Table 3). Three layers of topcoats were also applied to each sample at a spread rate of 100 g/m^2 by brush. Later, the specimens were sanded with a 240 grit size of sandpaper and kept at room temperature for two days before applying the second layer of topcoat. The characteristic features of wood coating materials in the study are given in Table 1 and 2.

Table 1: Acrylic resin types for wood coating systems.

Acrylic resin code	Detailed information
Acrylic Resin 1	Superior weathering resistance, excellent blushing resistance, tack-free films, also for colored aggregates.
Acrylic Resin 2	Exceptional outdoor durability and film elasticity together with outstanding water barrier properties, blocking resistance and wet adhesion.

Table 2: UV absorbers for wood coating systems.

Products	Product Type	Physical form	Active content (%)
Tinuvin 477 DW	UV Absorber	liquid	20
Tinuvin 400 DW	UV Absorber	liquid	20
Tinuvin 5333 DW	UV Absorber	liquid	40

Table 3: The formulations of wood coating systems.

Formulation products	Content (%)	A	B	C	D	E	F	G	H	K	L	P	T
Acrylic Resin 1	73.7	x	x	x	-	-	-	x	x	x	-	-	-
Acrylic Resin 2	73.7	-	-	-	x	x	x	-	-	-	x	x	X
Tinuvin 477 DW	6.0	x	-	-	x	-	-	x	-	-	x	-	-
Tinuvin 5333 DW	6.0	-	x	-	-	x	-	-	x	-	-	x	-
Tinuvin 400 DW	6.0	-	-	x	-	-	x	-	-	x	-	-	X
Film-forming agents	0.67	x	x	x	x	x	x	x	x	x	x	x	X
Defoamers	1.0	x	x	x	x	x	x	x	x	x	x	x	X
Dispersing agent	0.6	x	x	x	x	x	x	x	x	x	x	x	X
Rheology modifier	1.3	x	x	x	x	x	x	x	x	x	x	x	X
Distiled water	16.73	x	x	x	x	x	x	-	-	-	-	-	-
Distiled water with 1% Boric acid	16.73	-	-	-	-	-	-	x	x	x	x	x	X

2.3 Natural Weathering Test

For the purposes of the natural weathering test, 300 x 70 x 20 mm test and control wooden pieces were prepared by removing moisture to prevent decay and painting them with 2-Epoxy white paint in sections as shown by the TS EN 927-3 standard.42 Then, the wood samples were stored for approximately 2 weeks in an environment with temperature of 20^{o}C and relative humidity of 65±5% prior to the natural weathering test.

Natural weathering test assemblies were installed on the coast with various altitude in Trabzon of the Black Sea Region counties of Turkey. The control and test wood samples were placed, as indicated in the TS EN 927-3 standard, in the assemblies installed in Trabzon-TURKEY. The natural weathering test continued for 12 months.

2.4 Colour measurement

The colour measurements were carried out using a Minolta CM-600d spectrophotometer (Konica Minolta, Japan) equipped with an integrating sphere according to the CIE L* a* b* system. The reflection spectrum of the Konica Minolta CM-600d instrument was acquired from an area measuring an 8 mm in diameter with 100 in the 400–700 nm wavelength range. Five measurements were recorded for each samples. The CIE (Commission Internationale de l'Eclairage) colour parameters L∗ (lightness), a∗ (along the X axis red (+) to green (−)), and b∗ (along the Y axis yellow (+) to blue (−)) were calculated by using the Konica Minolta Colour Data Software CM-S100w Spectra MagicTM NX Lite (ISO 7724-2), from which the colour differences ΔE∗ were calculated according to the formula given below:

$$\Delta E^* = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1/2}$$

2.5 Surface roughness measurement

The Mitutoyo Surfest SJ-301 instrument (Japan) was employed for the measurement of surface roughness. The Ra and Rz roughness parameters were measured to evaluate surface roughness of unweathered and weathered (treated and untreated) samples' surfaces according to DIN 4768 (DIN 1990). Ra is an arithmetic mean of absolute values for the profile departures within the reference length and Rz is the arithmetic mean of the 5-point height of irregularities [DIN 4768 (DIN 1990)]. The cut-off length was 2.5 mm, sampling length was 12.5 mm, and the detecting tip radius was 5 mm for the surface roughness measurements.

2.6 Macroscopic evaluation

After the weathering test, macroscopic changes (erosion, checks and cracks) on the sample surfaces were evaluated according to principles ASTM D 660, ASTM D 661 and ASTM D 662 standards. Sample were visiually rated on a scale of 0-10 with 0 indicating surface with high level degradation, and 10 indicating flawless surface with no degradation. Pictures of samples were also taken with NIKON D7500 + AF-S DX NIKKOR 18-105 VR Dijital SLR.

3 RESULT AND DISCUSSION

3.1. Colour change

The colour changes of wood samples with coating for different exposure time are presented in Table 4 according to CIELAB parameters, called ΔL*, Δa*, Δb* and ΔE. The colour changes of the wood samples were determined before the weathering test and the end of the first, 4th, 6th, 9th, 12th of weathering test.
The colour changes rates (ΔE*) were rapid for formulations A and F in beech samples until the end of 4th month of the weathering test, as seen in Fig. 1. However, the colour changes rates diminished slightly for formulations between 4th and 9th months of the weathering test, while it decreased significantly for all formulations on the scots pine surface during weathering time. The highest colour change occurred in formulation K for beech and L for pine, while the lowest colour change was found in formulation E and P for the beech and pine samples.

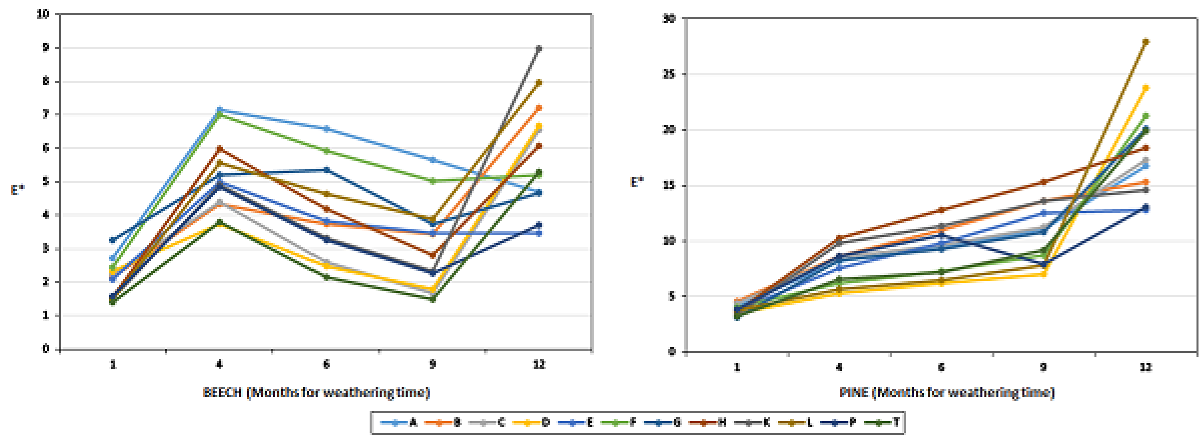

Figure 4: Colour changes (E*) of wood surfaces applied with acrylic based coating systems.

Table 4 demonstrates that the color changes of all formulations on the scots pine and beech samples exposed to natural weathering test during 12 months. As seen, the color changes (ΔE*) are quite different for all formulations. When the Δa* values of the beech samples were examined, it was observed that the colours tended to turn greenish for all formulations, while they turned reddish for all formulations on the pine surface during the natural weathering test. Meanwhile, Δb* values of the colours became bluish for all formulations coated pine and beech samples during 12 months. It is known that ΔL* is an important parameter for the determination of surface quality and overall colour changes (Ozgenc et al. 2012). The light stability (ΔL*) of beech samples for all of the formulations was negative, which pointed out that the wood surface became darker when the exposure time increased. The changes in the light stability ΔL* values tended to negative for all formulations on the beech and pine surfaces. The negative values of ΔL* showed that wood surface changes were darker. However the lignin polymerization and degradation of other cellulosic polysaccharides under the UV radiation results in the darken surface which changes the ΔL* values toward negative (Deka and Petric 2008, Korkut et al. 2012).

It was found higher in the pine wood coated with all formulations than the beech wood, while the color change parameters were also different according to the wood species. The extent of color changes varied based on the wood species. The discoloration of the wood surface is influenced by lignin, carbohydrate, and extractives, which can be oxidized and degraded under UV irradiation (Deka and Petric 2008). The changes in the content of wood components could explain the differentiation between wood species.

Table 4: Colour coordinates of wood surfaces applied with acrylic based coating systems.

		1st MONTH				4th MONTH				6th MONTH				9th MONTH				12th MONTH			
		ΔL	Δa	Δb	E	ΔL	Δa	Δb	E	ΔL	Δa	Δb	E	ΔL	Δa	Δb	E	ΔL	Δa	Δb	E
BEECH	A	-1.87	0.88	-1.48	2.72	-5.19	0.74	-4.86	7.16	-4.94	0.91	-4.26	6.59	-4.51	0.88	-3.26	5.64	2.62	-2.56	-0.2	4.68
	B	-1.93	0.73	-0.5	2.16	-3.59	0.16	-2.31	4.32	-3	0.095	-2.02	3.73	-2.8	-0.05	-1.71	3.43	4.5	-1.42	5.16	7.22
	C	-2.03	0.39	-1.08	2.25	-2.95	-0.04	-3.17	4.39	-1.37	-0.79	-1.89	2.59	-0.31	-1.04	-1.01	1.67	5.57	-3.1	0.83	6.54
	D	-1.89	0.73	-1.16	2.34	-2.46	-0.42	-2.77	3.73	-1.66	-0.86	-1.64	2.49	-1.28	-1.04	-0.68	1.8	-2.12	-4.22	-4.68	6.66
	E	-1.93	0.39	-0.74	2.1	-3.19	-0.08	-3.48	5	-1.17	-0.73	-2.39	3.82	-0.38	-1.23	-1.45	3.48	-1.33	-2.12	2.08	3.48
	F	-2.03	0.55	-1.27	2.45	-4.94	0.48	-4.92	6.99	-4.28	0.13	-4.1	5.93	-3.89	-0.09	-3.17	5.02	-2.78	-2.79	-3.39	5.19
	G	-2.55	0.85	-1.83	3.27	-4.35	0.3	-4.38	5.19	-3.89	0.01	-3.63	5.36	-2.78	-0.36	-2.29	3.73	1.91	-3.26	-2.73	4.66
	H	-1.34	0.58	-0.52	1.56	-4.59	0.51	-3.81	5.99	-2.98	-0.07	-2.91	4.17	2.21	-0.23	-1.73	2.82	5.06	-2.46	2.28	6.08
	K	-1.24	0.52	-0.71	1.52	-3.16	-0.21	-3.66	4.9	-1.51	-0.71	-2.42	3.32	-0.78	-1.03	-1.41	2.32	7.77	-4.42	-0.75	8.98
	L	-1.13	0.49	-0.86	1.5	-3.92	-0.07	-0.81	5.56	-3.4	-0.31	-2.92	4.62	-3.05	-0.51	-1.78	3.9	-3.44	-3.44	-5.72	7.95
	P	-1.45	0.35	-0.54	1.59	-3.2	-0.18	-3.57	4.83	-1.18	-0.93	-2.81	3.25	-0.55	-1.25	-1.76	2.26	0.89	-2.85	1.83	3.70
	T	-1.29	0.34	-0.42	1.41	-2.62	0.015	-2.73	3.81	-1.19	-0.56	-1.55	2.14	-0.76	-0.96	-0.79	1.49	-3.1	-2.43	-2.63	5.30
		1st MONTH				4th MONTH				6th MONTH				9th MONTH				12th MONTH			
		ΔL	Δa	Δb	E	ΔL	Δa	Δb	E	ΔL	Δa	Δb	E	ΔL	Δa	Δb	E	ΔL	Δa	Δb	E
PINE	A	-3.2	2.39	-0.77	4.14	-6.35	3.54	-3.32	8.22	-8.08	4.155	-3.5	9.44	-9.45	4.79	-3.13	11.06	-14.2	6.4	-6.25	16.8
	B	-3.97	2.31	0.18	4.61	-7.36	4.47	-0.11	8.61	-9.26	5.79	1.18	10.98	-11.3	7.13	2.5	13.6	-14.1	6.18	0.67	15.4
	C	-3.63	2.37	0.08	4.36	-7.44	3.98	-1.59	8.59	-8.48	4.47	-1.23	9.68	-9.93	5.14	-1.04	11.27	-15.4	7.29	-2.6	17.27
	D	-2.81	1.87	-0.9	3.5	-4.25	1.87	-2.49	5.31	-5.36	2.7	-1.51	6.21	-6.15	3.2	-1.03	7.03	-20.1	6.42	-11	23.83
	E	-3.29	1.84	0.11	3.77	-6.53	3.74	-0.45	7.55	-8.35	4.96	1.36	9.82	-10.8	5.98	1.92	12.5	-10.6	6.53	3.01	12.8
	F	-3.56	1.78	-0.72	4.05	-4.74	2.46	-3.21	6.23	-6.07	3.09	-2.36	7.25	-7.66	4.05	-1.02	8.72	-19.3	5.59	-7.02	21.3
	G	-2.42	1.8	-0.91	3.17	-6.75	3.68	-2.93	8.29	-7.69	3.94	-3.25	9.25	-9.26	4.68	-3.08	10.8	-16.9	7.31	-8.13	20.12
	H	-2.99	2.05	0.26	3.65	-8.78	5.29	0.91	10.3	-10.6	6.76	2.29	12.78	-12.6	8.06	3.36	15.36	-17.0	7.07	-1.2	18.42
	K	-2.71	1.92	0.76	3.4	-8.66	4.25	-2.05	9.86	-10.1	4.52	-2.76	11.38	-12.1	5.15	-3.41	13.57	-12.9	6.35	-2.09	14.6
	L	-3.1	1.9	-1.02	3.76	-4.56	1.97	-2.6	5.62	-5.62	2.78	-1.72	6.52	-6.91	3.46	-1.16	7.83	-21.5	7.62	-12.2	28.0
	P	-3.32	1.8	0.16	3.86	-7.51	4.12	-0.6	8.61	-9.25	5.07	0.28	10.55	-5.99	2.23	4.45	7.9	-12.3	4.1	-1.53	13.1
	T	-2.71	1.61	-0.52	3.2	-5.28	2.53	-2.96	6.56	-6.07	3.18	-2.01	7.17	-8.07	4.45	-0.15	9.23	-18.1	6.41	-5.4	20.0

3.2. Change of surface roughness values

The change of surface roughness values of waterborne based acrylic coating systems were given in Fig. 5. As seen that there is significant differences after weathering for 12 formulations. However, the rate of change in Ra and Rz values of L formulations for beech wood, L for pine wood was found to be quite low after natural weathering.

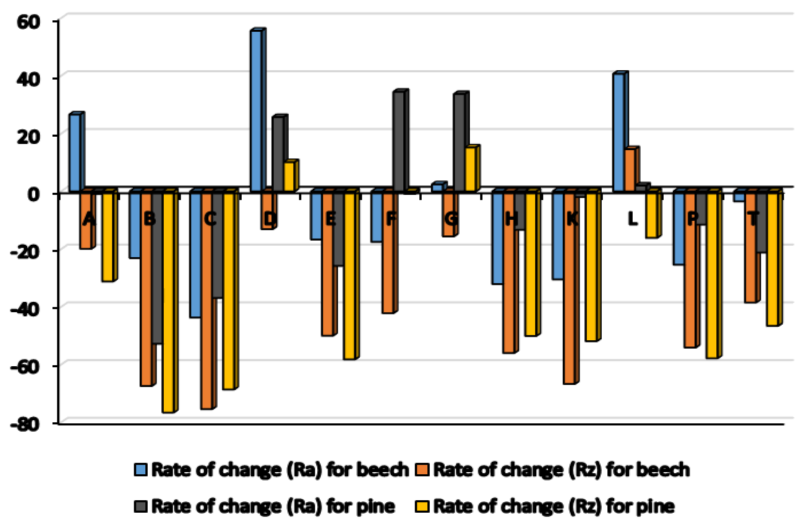

Figure 2: Rate of changes in surface roughness values of wood surfaces applied with acrylic based coating systems.

The surface roughness values of pine and beech wood coated with 12 different formulation before and after the natural weathering test is shown in Table 5. The wood coating systems prevented wood surface degradation and provided an effective preservation against intensive weathering conditions. The smoothest surface was obtained from formulation H, P and K for both of pine and beech samples before the weathering test. When the performance of coatings is considered, formulation K and P provide the smoothest surface for both of wood species after the weathering test. The highest changes in surface roughness values were recorded from formulation D and L for both of pine and beech samples after the weathering test.

The wood species affect the rate of change in the roughness values of coating systems after outdoor testing. It has been determined that the change in the coating systems applied to the surface of the pine wood is rather high compared to beech wood. The wood is anisotropic and composed of heterogeneous materials. As a result of this, tree species, density, moisture content and wood anatomical properties (diameter of vessels and tracheids, and the proportion of early and latewood) affect wood surface roughness (Kiliç et al. 2006, Csanády et al. 2015). When wood is exposed to outdoor conditions. UV rays, humidity, temperature, and oxygen degrade wood surfaces and affect wood surface roughness. The surface wettability and contact angle, which are sensitive against roughness, have a significant effect on coating as well as evaluating the coating performance (Csanády et al. 2015).

Table 5: Surface roughness values of wood surfaces applied with acrylic based coating systems.

		BEFORE WEATHERING			AFTER WEATHERING				BEFORE WEATHERING			AFTER WEATHERING	
		Ra	Rz		Ra	Rz			Ra	Rz		Ra	Rz
	A stsp	0.14	3.87		0.25	2.79		A stsp	0.20	4.73		0.49	6.87
	A	0.79	16.6		1.00	13.3		A	1.10	18.9		1.09	13.0
	B stsp	0.07	2.66		0.05	0.88		B stsp	0.12	3.01		0.06	1.48
	B	0.52	18.9		0.40	6.17		B	0.72	20.9		0.34	4.89
	C stsp	0.08	3.97		0.05	0.72		C stsp	0.33	3.78		0.43	2.85
	C	0.71	27.4		0.40	6.76		C	0.92	23.5		0.58	7.49
	D stsp	0.18	4.59		0.46	3.52		D stsp	0.22	4.67		0.28	4.92
	D	0.99	18.8		1.54	16.4		D	1.05	13.8		1.32	15.2
	E stsp	0.07	3.02		0.09	1.81		E stsp	0.16	3.92		0.08	0.92
	E	0.48	12.1		0.48	6.05		E	0.62	13.9		0.46	5.82
	F stsp	0.32	4.40		0.05	0.89		F stsp	0.08	2.03		0.89	6.56
BEECH	F	0.63	13.1		0.52	7.58	PINE	F	0.58	9.23		0.78	9.15
	G stsp	0.31	5.90		0.35	5.89		G stsp	0.35	4.22		0.48	6.50
	G	1.23	19.2		1.26	16.2		G	0.92	15.0		1.23	17.3
	H stsp	0.11	3.76		0.07	2.66		H stsp	0.04	3.16		0.10	1.42
	H	0.56	15.7		0.38	6.90		H	0.39	11.8		0.34	5.87
	K stsp	0.06	2.75		0.07	0.84		K stsp	0.09	1.50		0.12	1.86
	K	0.59	21.8		0.41	7.25		K	0.51	15.4		0.50	7.42
	L stsp	0.18	3.16		0.35	7.12		L stsp	0.62	4.42		0.16	4.37
	L	1.08	15.3		1.52	17.5		L	1.50	18.1		1.53	15.2
	P stsp	0.21	7.48		0.10	1.23		P stsp	0.07	3.97		0.08	0.78
	P	0.67	14.6		0.50	6.72		P	0.52	12.4		0.46	5.23
	T stsp	0.13	2.25		0.07	1.05		T stsp	0.20	2.95		0.08	1.22
	T	0.58	12.3		0.56	7.57		T	0.66	12.2		0.52	6.52

3.3. Macroscopic evaluation

Due to the fact that such factors as the region altitude, climate conditions, air pollution etc. differ in the deformations of wood surfaces coated with acrylic systems exposed to natural weathering test, the visual evaluation points of samples were found to be different also. After the 12-month weathering test, the visual evaluation performance of beech and pine surfaces coated with 12 formulation was evaluated in Table 6. According to the evaluation performed as per the ASTM D 662-93 standard, the highest point is 10, which means that sample surface has no visible erosion. In comparison to the pine samples, macroscopic evaluation of beech surfaces coated with 12 different acrylic formulation received quite high points (Table 6).

It can be seen from Table 6 that especially wood samples coated with formulation P and K for both of beech and pine received quite high visual evaluation points. It is also seen that formulations H for pine and formulations T for beech provide very high protection after natural weathering testing. According to the results obtained from such studies, the coating treatment with water repelling transparent acrylic resin does not provide effective protection against photo-degradation under natural weather conditions. However, high durability performance of wood surfaces subjected to organic or inorganic UV absorbent acrylic resin coating was determined (Custódio and Eusébio 2006; Schaller et al. 2008; Evans et al. 2008; Forsthuber et al. 2013).

Table 6. Macroscopic evaluation of coated wood samples after artificial weathering test.

Sample Code	Beech	Pine
A	6	6
B	6	7
C	7	7
D	6	5
E	5	6
F	7	6
G	6	5
H	7	8
K	9	9
L	7	5
P	9	9
T	8	7

The beech surfaces coated with formulation B, E and H were found to have deformations on their sides after the natural weathering test, as can be seen in Fig. 3. The pine and beech surfaces coated with formulation A, D, G, L were darkened. In addition, the pine and beech surfaces coated with acrylic varnish due to the air pollution in the outside are also dirtied. The dirty layer forming on the wood surface coated with waterborne acrylic resin containing UV absorber can be cleaned with a slightly damp cloth (Xie et al. 2008; Nejad and Cooper 2011; Nejad 2001).

Figure 3: Wood surfaces applied with acrylic based coating systems.

4 CONCLUSION

The wood surfaces coated waterborne acrylic containing UV absorber or HALS provides quite good protection against the degradation caused by natural weathering conditions. . In this study, we evaluated the performance of 12 different waterborne acrylic wood coating systems against natural weathering conditions. Despite intensive weathering conditions, wood coating systems presented a very good performance. Especially the formulation P for both of wood species improves color stability and significantly prevents the macroscopic deformation and the change in surface roughness. However, for both types of wood E formulation provided very high color stability, but did not provide effective protection for surface roughness and macroscopic deformation. According to the macroscopic evaluation, the formulation P and K completely eliminates such erosion as formation of cracks, tears and fiber stand-up on the wood surfaces exposed to weathering conditions during 12 months. It is thought that the durability performance of the formulation P and K acrylic systems shall be investigated on the heat-treated or pretreated wood surfaces in natural weather conditions. The examination about the durability performance of Formulation P and K systems for the different pretreated wood surfaces under natural weather conditions is suggested as a continuation of this study.

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ABSTRACT

In this study, it was aimed to determine the preferences of gifted children for symmetric-asymmetric furniture and children room's shape and colour preferences. For this purpose, a questionnaire consisting of 20 pairs of symmetric-asymmetric furniture samples and 18 different children's room designs with triangular, square and circular forms and main and intermediate colours were applied to gifted children and their preferences were determined. When the results were evaluated, the rate of symmetric furniture preference was determined to be 65%. It was also determined that the gifted children firstly pay attention to functionality in their symmetric furniture preference and make their choices accordingly and give particular importance to visual quality in asymmetric and functional designs. The most preferred model is square, followed by circle and triangle. When it comes to the colour preferences, cold colours have been determined to be the most preferred colours; blue, purple and green colours have been selected respectively. According to these results, it can be suggested that square model, cold colours and symmetric designs should be preferred for furniture designs for the gifted children.

KEYWORDS: Furniture, Interior architecture, Gifted children

1 INTRODUCTION

A gifted individual is defined as an individual who learns faster compared to his or peers; is at the fore in the capacity related to creativity, art and leadership; possesses special academic skills; understands abstract ideas, likes to act independently of his or her areas of interest and performs at a high level (Bilsem, 2018). It is stated that general mental abilities of the gifted individuals differ from other children in one or more than one area such as special academic skills, creative or productive thinking ability, leadership ability, visual and artistic ability, and psychomotor ability or in harmony with the combination of these areas in terms of showing high achievement and having potential (Çağlar, 1986). The qualities that distinguish gifted children from other children are their special abilities and competence to carry out tasks at a high level. It is seen that these children need differentiated educational programs and services rather than normal school programs in order to be able to contribute to themselves and the community (Clark, 1997). Some of the researches conducted on gifted children are generally related to the social and emotional problems of children (Akarsu and Mutlu, 2017) or the difficulties that their parents face (Karakuş, 2010). In order not to face difficulties or problems because of differences in the developmental characteristics of the gifted children, it is extremely important to be aware of these characteristics and show the appropriate approach (Morawska and Sanders, 2008). Therefore, knowing the characteristics of furniture and colour preferences that gifted children will use in their living environment is considered as significant. How is the furniture form and colour preference of the gifted children who show different characteristics from their peers and have a high level of perception for their rooms? How is the symmetrical-asymmetrical furniture preference of the gifted children who show different characteristics from their peers? It is aimed to contribute to these special talents of the gifted children and support their lives under more comfortable conditions both mentally and physically by increasing their success as a result of determining these preferences and integrating them with the designs that will be made.

2 METHOD

In this study, it was aimed to determine the preferences of gifted children for symmetric-asymmetric furniture and children room's shape and colour preferences. For this purpose, a questionnaire consisting of 20 pairs of symmetric-asymmetric furniture samples and 18 different children's room designs with triangular, square and circular forms and main and intermediate colours were applied to 45 gifted children and their preferences were determined. While the questionnaires were being formed, studies of Uzun et al. (2017) and Sarıkahya et al. (2017) were used. In order to determine the preferences of gifted children for symmetric-asymmetric furniture and children room's shape and colour preferences, colourful printouts were given to the children and their preferences were determined. The data of the survey were collected in Çankırı between April and June in 2017.

3 FINDINGS

Data related to the gender of the children who participated in the research have been given in Table 1.

Table 1: Gender

Gender	f	%
Male	21	46,67
Female	24	53,33
Total	45	100

Accordingly, 53.33% of the children who participated in the research are females. The data on the age of the children who participated in the research have been given in Table 2.

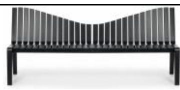
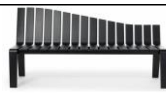
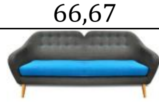
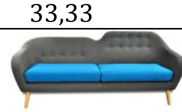
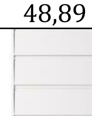
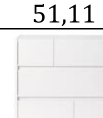
Table 2: Age

Age	f	%
7-10 years	22	48,88
11-13 years	17	37,79
14-15 years	6	13,33
Total	45	100

According to the table, 48.88% of the children who participated in the research are aged between 7-10 years old. Data related to the symmetrical-asymmetrical furniture preference percentages of the children have been given in Table 3.

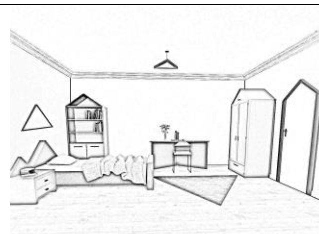
Table 3: Symmetric – asymmetric furniture preference percentages of the children

	Symmetric	Asymmetric		Symmetric	Asymmetric

1		 (Web-1)	11		 (Web-12)
%	73,33	26,67	%	64,44	35,56
2	 (Web-2)	 (Web-3)	12		 (Web-13)
%	48,89	51,11	%	86,67	13,33
3		 (Web-4)	13		 (Web-14)
%	48,89	51,11	%	66,67	33,33
4		 (Web-5)	14		 (Web-15)
%	80	20	%	73,33	26,67
5		 (Web-6)	15		 (Web-16)
%	40	60	%	8,89	91,11
6		 (Web-7)	16		 (Web-17)
%	91,11	8,89	%	95,56	4,44
7		 (Web-8)	17		 (Web-18)
%	66,67	33,33	%	66,67	33,33
8		 (Web-9)	18		 (Web-19)
%	84,44	15,56	%	48,89	51,11
9		 (Web-10)	19		 (Web-20)
%	93,33	6,67	%	44,44	55,56
10		 (Web-11)	20	 (Web-21)	 (Web-22)
%	88,89	11,11	%	17,78	82,22

According to this, the most preferred 13 pairs is symmetrical among 20 pairs of furniture. The model and colours of the teen room used in the research have been given in Table 4.

Table 4: Models and colours used in the research

SQUARE MODEL	TRIANGLE MODEL	CIRCULAR MODEL
		
		
		
		
		
		
		

The preference rates of the models are given in Table 5.

Table 5: Preference rates of the models

Model	f	%
Square	28	62,22
Triangle	2	4,44
Circular	15	33,33
Total	45	100

According to the table, the most preferred model was the square model. Square model was followed by circular and triangular model. The most preferred colour percentages among all models have been given in Table 6.

Table 6: Percentages of the most preferred colours among all models

	f	%
Yellow	4	8,89
Red	5	11,11
Blue	15	33,33
Orange	4	8,89
Green	7	15,56
Purple	10	22,22
Total	45	100

Accordingly, the most preferred colour was blue and blue was followed by purple and green respectively. The most preferred colours of the models have given in Table 7.

Table 7: Most preferred colours of the models

		Yellow	Red	Blue	Orange	Green	Purple	Total
Square	f	4	4	10	1	4	5	28
	%	14,28	14,28	35,71	3,57	14,28	17,85	100
Triangle	f	0	0	0	1	1	0	2
	%	0	0	0	50	50	0	100
Circular	f	0	1	5	2	2	5	15
	%	0	6,67	33,33	13,33	13,33	33,33	100

Accordingly, the most preferred colours of the square model are blue and purple respectively, the most preferred colours of the triangular model are orange and green and the most preferred colours of the circular model are blue and purple. The most preferred models and colours by boys have been given in Table 8.

Table 8: The most preferred models and colours by boys

Model	f	%	Yellow	Red	Blue	Orange	Green	Purple
			0	3	5	1	4	0
Square	13	61,90	0	23,07	38,46	7,69	30,76	0
			0	1	2	2	2	1
Circular	8	38,10	0	12,5	25	25	25	12,5
	21	100						

According to this, 61.90% of 21 male students preferred square model and 38.10% preferred circular model. 38,46% of those who preferred the square model preferred blue colour, 25% of those who preferred the circular model preferred blue, orange and green colours. The most preferred models and colours for girls have been given in Table 9.

Table 9: The most preferred models and colours by girls

	f	%	Yellow	Red	Blue	Orange	Green	Purple
			4	1	5	0	0	5
Square	15	62,5	26,67	6,67	33,33	0	0	33,33
			0	0	0	1	1	0
Triangle	2	8,33	0	0	0	50	50	0
			0	0	3	0	0	4
Circular	7	29,17	0	0	42,85	0	0	57,15
	24	100						

According to this, 62.5% of 24 female students preferred square model, 29.17% preferred circular model and 8.33% preferred the triangular model. 33.33% of those who preferred square model preferred blue and purple colours, 57.15% of those who preferred circular model preferred purple and 50% of those who preferred the triangular model preferred orange and green colours.

4 CONCLUSION

When the results of the research were analysed, it was determine that the preference rate of symmetrical furniture was 65% while the preference rate of asymmetrical furniture was 35%. Sarıkahya et al. (2017) in their study which was conducted on subjects that have average intelligence related to the preferability of asymmetrical furniture found that the most preferred 12 pairs of furniture were asymmetric among 20 pairs of furniture. In other words, the preference rate of asymmetrically designed furniture was 60% (Sarıkahya et al., 2017). Accordingly, it can be said that gifted children mostly prefer symmetrical designs.

According to this study, the most preferred forms are square, circle and triangle. According to the study conducted by Uzun et al. on subjects that have average intelligence, the most preferred form was found to be square with 54.5% which was followed by circular form with 33% and forms which were created based on triangle with 12.5%. It was determined that the gifted subjects and normal subjects had similarities with respect to form preferences and that the most preferred form was square.

According to this study, the most preferred colours of the square model are blue and purple respectively, the most preferred colours for the triangular model are orange and green and the most preferred colours for the circular model are blue and purple. According to the study by Uzun et al. (2017), the most preferred colour for the form which was created based on square is blue, the most preferred colour for triangular forms is purple and the most preferred colour for the circular forms is blue. Blue is the most preferred colour for square and circular forms. Blue brings contentment, good faith, compassion, outspokenness, honesty, flexibility, tendermindedness, agreement, reconciliation, cooperation and peace to mind (Martel, 1995). According to gifted children institute (Web-23), gifted children tend to think flexible; therefore, it is considered that gifted children may like furniture designs which have blue colour or its shades as the blue colour brings flexibility to mind.

It was determined that gifted children firstly pay attention to functionality in their symmetrical furniture preferences and they make their choices accordingly; they attach importance to visuality in asymmetrical and functional designs. Accordingly, it has been proven once again that the gifted children go directly to the target in their preferences, and their perceptions are very high.

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The Effect Of Sub-Zero Application On Parallel Fiber Pressure Resistance Of Thermowood-Treated Sorbus Torminalis

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The Effect of Cryogenic Application On Parallel Fiber Pressure Resistance of Thermowood-Treated Sorbus Torminalis

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ABSTRACT

This study aimed to analyze the possible changes in the pressure resistance values parallel to the fibers(CS) by subjecting heat-treated wood to sub-zero temperatures. Within the scope of the study, test specimens were first prepared by applying thermowood heat treatment at 190 and 212 °C for 1 h to samples of wild service tree wood (Sorbus torminalis). Both the heat-treated samples along with untreated control samples were then kept at -80 °C for 6. 18 and 54 h to obtain the test specimens. When compared to the control samples. Test results showed a difference in the parallel fiber pressure resistance of the heat-treated test specimens held at -80 °C and the values were seen as very positive, especially with the 6-h and 18-h applications. The CS resistance values of the control samples and the heat treated samples as N/mm2 at 190 and 212 °C for 1 h were respectively 56.12. 69.28 and 62.12 for initial; 51,38. 73.25 and 80.55 for 6 h; 50,31. 72.82 and 75.66 for 18 h; 55.85. 60.19 and 62.14 for 54 h.

KEYWORDS: Heat treatment, Cryogenic treatment. Sorbus torminalis. Compression strength

1 INTRODUCTION

Although wood is a widely utilized natural raw material, in a number of applications it exhibits undesirable properties such as dimensional and color changes as well as biological degradation. These features shorten its service life in those areas of application and lead to losses in value (Sahin et al.,2017, Aytin 2013).

Today, various methods and techniques can be employed to improve these stated negative properties of wood materials in those application areas. One example of these is heat treatment (HT), which is a modification technique that can improve the properties of wood material by increasing dimensional stability and resistance to biological degradation in addition to achieving color homogeneity (Srinivas and Pandey 2012, Johansson 2005).

In contrast to the improvements observed in the physical properties of heat-treated wood materials, the values of mechanical properties are generally lower, except for the elasticity modulus and the compression strength parallel to the fiber (CS). There is also an increase in the modulus of elasticity and CS, up to a certain temperature range, and then the values decrease after the heat treatment temperature reaches 205 °C (Anonim, 2003). However, in some studies it has been reported that CS decreases with HT (Çalıova 2011)

Although HT offers significant opportunities for users in the applications of wood materials, mechanical resistance losses are seen as an obstacle to these prospects. It is obvious that allowable safe stresses should be seriously taken into account, especially when a load carrying element is being considered. Hence, in such areas of usage, there is uncertainty in the evaluation of HT wood products compared to natural wood materials. From this point of view, the assessment of potential qualities may actually be quite important for HT wood materials in places where mechanical properties are in the forefront, with preferences for those providing more extensive improvements in physical characteristics.

Cryogenic (Cr) treatment is an application used to increase hardness in steel. In the process for hardened steel, the material is cooled to sub-zero temperatures and held for a certain period of time. It is reported that with cryogenic hardening, steel has higher wear ability and a longer service life (Kam et al., 2016) The application phases of Cr treatment for steel are shown below (Figure 1).

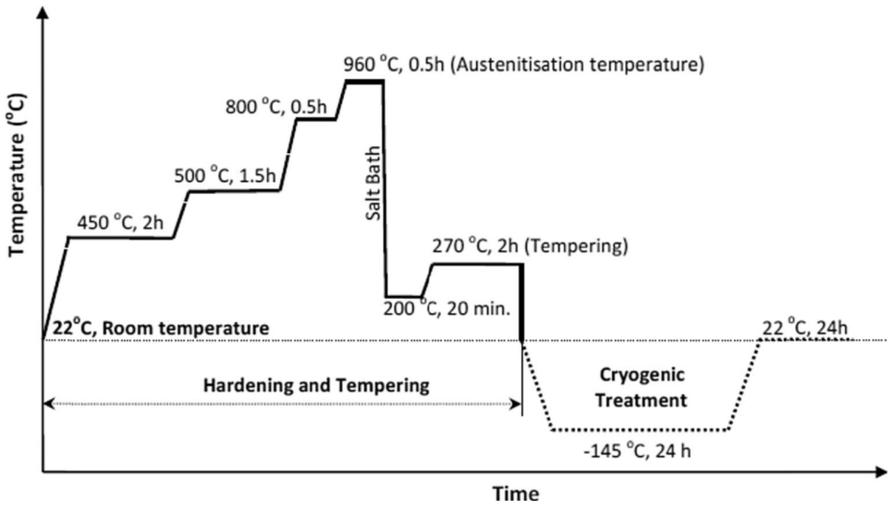

Figure 5: A schematic presentation of the heat treatment schedule consisting of the hardening, tempering, deep cryogenic treatment and tempering cycles of the samples (Aytin 2016)

. It is evident that the increase in hardness and wear capability which cryogenic processing has brought to bear opens up new areas of application. Reviews of the literature show that to date no study has been conducted examining HT and three versions of Cr on wood materials. This study aimed to reveal the relationship between HT and Cr and between natural wood material, HT and Cr in terms of CS.

Thus, this is considered to be an initial study of the consequences of Cr treatment for natural wood and for HT wood.

2 MATERIAL AND METHOD

The S. torminalis trees used in the study were obtained from the Düzce-Odayeri Forest Sub-district Directorate (Duzce. Turkey). Selection of the trees was in accordance with the TS 4176 (1984) standard (7). The trunks of selected trees were cut at the height of 1.30 m from the base and divided into 2-m sections.

Panels with dimensions of 25 mm × 100 mm × 500 mm(thickness. width. length) were prepared from the S. torminalis trees and were subjected to heat treatment in an industrial oven using the ThermoWood method (Novawood Factory. Gerede. Turkey) in accordance with the operational production schedule. The heat treatment was conducted at temperatures of 190 °C and The panels were then subjected to Cr treatment. The HT and subsequent Cr process steps are shown in Figure 2.

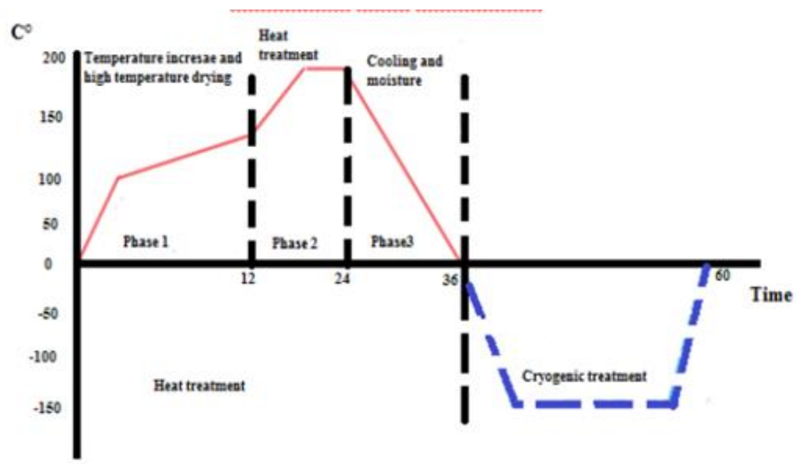

Figure 2: Application stages of HT and Cr in *Sorbus torminalis* wood

The CS test samples were then prepared according to TS 2595 and left to condition. The experimental design used in the study is shown in Table 1.

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Table 2: Experimental design of materials used in the study

Test samples	Abbreviation	Cr (h)
Control	UT	6
		18
		54
190 °C 1 h	TW_1	6
		18
		54
212°C 1 h	TW_2	6
		18
		54

After the study was performed according to the experimental design in Table 1, the results obtained were analyzed using the Windows Evaluation SPSS Version 15.0 program, with significance set at $P \leq 0.05$. Homogeneity groups were examined using the Duncan test.

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3 FINDINGS

The results of the variance analysis of the CS values in the Cr *Sorbus torminalis* specimens are given in Table 2.

Table 2: Results of variance analysis of CS values of *Sorbus torminalis* specimens subjected to cryogenic treatment for different time periods

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	10944.262(a)	11	994.933	12.503	0.000	0.560
Intercept	494268.694	1	494268.694	6211.500	0.000	0.983
Agacturu	6972.133	2	3486.067	43.810	0.000	0.448

Kriyojenik	1392.496	3	464.165	5.833	0.001	0.139
Agacturu * Kriyojenik	2579.633	6	429.939	5.403	0.000	0.231
Error	8593.901	108	79.573			
Total	513806.857	120				
Corrected Total	19538.163	119				

According to the results of the variance analysis in Table 2, among the Cr-applied experimental samples, statistically significant differences can be seen in both the tree species and the cryogenic variations. The Duncan test was applied to determine which groups the differences were between, and the results are given in Table 3.

Table 3: Duncan test results of CS values of *Sorbus torminalis* specimens cryogenically treated for different time periods

Factor	Variations	N	CS		
			A	B	C
Wood types	UT	40	53.4186		
	TW1	40		68.9963	
	TW2	40		70.1213	
Subzero	Control	30	62.5118	62.5118	
	6 H	30			68.3948
	18 H	30		66.2666	66.2666
	54 H	30	59.5415		

The Duncan test results revealed differences in both tree species (UT + heat treatment) and cryogenic (control + 6 h + 1 h + 54 h) CS values. The highest tree species values were reached in the heat-treated specimens and the highest cryogenic values were with the 6- and 18-h applications.

In Table 4, the CS values and Duncan test results are given for each subgroup after the tree species and cryogenic applications.

Table 4: CS values and Duncan test results for each subgroup after tree species and cryogenic applications

Variations	Kriyojenik	CS (N/mm^2)	SS	HG
UT	Control	56.12	5.50	A
	6 h kriyojenik	51.38	10.78	A
	18 h kriyojenik	50.31	11.06	A
	54 h kriyojenik	55.86	7.13	A
TW1	Control	69.29	5.12	AB
	6 h kriyojenik	73.25	12.60	B
	18 h kriyojenik	72.82	12.68	B
	54 h kriyojenik	60.62	6.36	A
TW2	Control	62.12	8.54	A
	6 h kriyojenik	80.55	2.35	B
	18 h kriyojenik	75.66	6.76	B
	54 h kriyojenik	62.14	11.15	A

4 CONCLUSIONS

The CS values obtained in all the cryogenic groups were higher than in the cryogenically untreated (control) samples. The duration of the cryogenic treatment was effective on the CS values. As the time was increased, lower CS values were obtained. For this reason, determining the optimum Cr processing time is an important issue.

With the heat treatment temperature increase, the increasing CS value began to decrease as the temperature rose. Decreases in the CS occurring due to the increased HT temperature can be recovered by Cr application

In Figure 3 CS values are seen for the UT, HT and Cr variations.

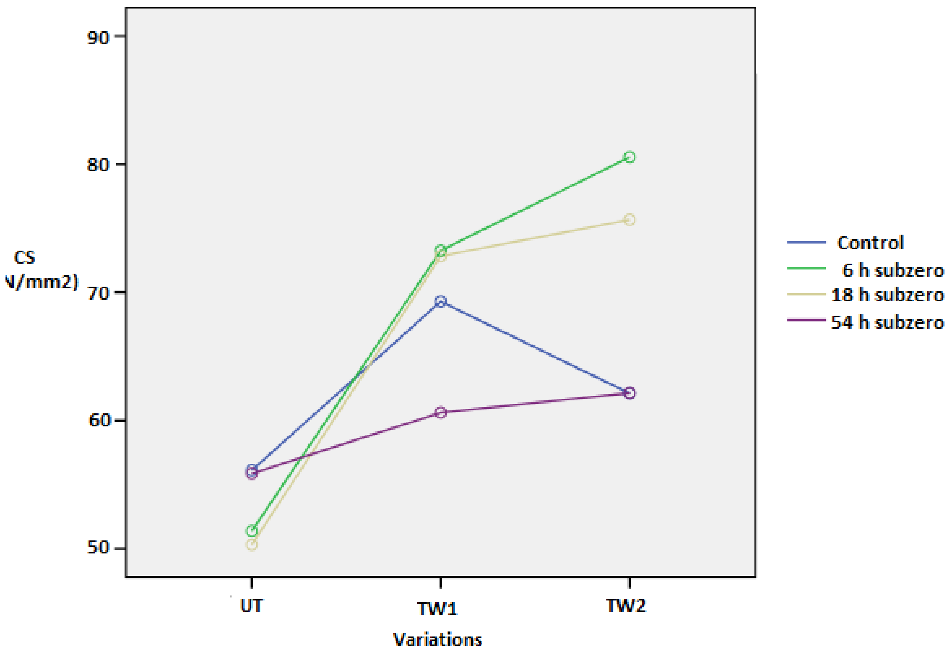

Figure 3: CS values are seen for the UT, HT and Cr variations.

These results show that Cr processing of wood materials is very important after HT and that it is essential to test their threshold values to enable them to be used at the desired locations.

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Dimensional Stability of Wood Bonded with The Bio-Based Phenol-Formaldehyde (PF) Resin

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Dimensional Stability of Wood Bonded with The Bio-Based Phenol-Formaldehyde (PF) Resin

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ABSTRACT

Phenol-formaldehyde (PF) resins have a widely used as adhesive in wood-based product industry. In this study, bio-oil obtained from pyrolysis of wood waste was chemically synthesized with phenol and formaldehyde up to 20 %wt. phenol replacement levels under alkali condition. Afterward, the dimensional stability of wood bonded with modified phenol-formaldehyde (PF) resin was investigated.

Synthesized phenol-formaldehyde resin (lab. PF) was used as reference resin in order to compare the dimensional stability of wood bonded with modified PF resin. As a result of this work, bio-oil can be directly used as chemical feedstock for production of bio-based PF resin.

KEYWORDS: Bio-based adhesives, Bio-oil, Dimensional stability, Phenol-formaldehyde resin

1 INTRODUCTION

Phenol-formaldehyde (PF) resin has been widely preferred as wood adhesive because of its great performance and water resistance. However, PF resin is commonly produced by using petroleum. Therefore, its price depends mostly on petroleum cost. In recent years, the importance of renewable resources has increased. Various studies have been given to the improvement of new adhesives from renewable resources (Stephanou and Pizzi, 1993; Wescott and Frihart, 2004; Zhang et al., 2013; Shahid et al., 2014).

This study aims to analyze the dimensional stability of wood bonded with modified PF resin. Bio-oil obtained from lignocellulosic biomass (pine sawdust) was chemically synthesized with phenol and formaldehyde up to 20 %wt. phenol replacement levels under alkali condition. Afterward, the dimensional stability of bonded wood samples was investigated.

2 MATERIALS AND METHODS

2.1 Biomass

Scots pine (*Pinus sylvestris L.*) sawdust was used as biomass in order to produce bio-oil. Wood sawdust was sieved (less than 2 mm) and dried for 12 h at 103 ± 3 ^{0}C before pyrolysis experiments.

2.2 Wood Lamellas

The lamellas with dimensions of 5 mm x 50 mm x 600 mm were prepared from beech wood (*Fagus orientalis Lipsky*). The planks (60 mm × 120 mm × 3000 mm) were obtained from a commercial company in Karabuk, Turkey. The wood samples were acclimatized in a climate room at 20 ± 2 °C and 65 ± 3% relative humidity.

2.3 Production of Bio-oil

The production of bio-oil was carried out by using pyrolysis method. Pyrolysis process was performed in a reactor, which was heated by an electric furnace under a nitrogen atmosphere. The heating rate and final temperature of pyrolysis process were 15 °C/min and 500 °C, respectively.

2.4 Production of Bio-Based Phenol-Formaldehyde Resin

In synthesis of laboratory phenol-formaldehyde resin (lab. PF), the reactor firstly was charged with phenol and formaldehyde. The temperature was raised up to 60 °C within 30 min., and then sodium hydroxide solution (1/3 of total NaOH weight) was mixed to the reactor. Afterward, the temperature was raised up to 90 °C. The mixture was stirred during reaction period. Eventually, the last part of sodium hydroxide solution was mixed to the reactor. After the process, the mixture was cooled to room temperature. In synthesis of bio-based phenol-formaldehyde resin (bio-oil/lab. PF), the same process was performed by changing the amount of bio-oil in the mixture ranging from 5 to 20 %wt. The experimental design of bio-oil/lab. PF by weight (0/100, 5/95, 10/90, 15/85, and 20/80) were given in Table 1.

2.5 Bonding of Wood Lamellas

Two beech lamellas with dimensions of 5 mm x 50 mm x 600 mm were bonded together with the lab. PF and the bio-based phenol-formaldehyde resins. The resin was applied to one surface of each lamella (approximately 180 g/m^2) by using a hand brush. The bonding process was performed at temperature of 120 °C, applying a pressure of 0.2 N/mm^2 for 15 min.

2.6 Determination of Swelling and Water Absorption

The dimensions of the samples used to determine the swelling and water absorption were 10 mm x 20 mm x 15 mm (thickness, width, length), as given in Figure 1. Firstly, test samples were oven dried at 103 ± 3 ^{0}C until a constant oven-dry weight was obtained. The weights and dimensions were measured to determine the volumetric swelling and water absorption. Then, the samples were immersed in distilled water for three weeks. After the immersion period, weights and dimensions of the samples were measured again. Volumetric swelling (%) and water absorption levels (%) of the samples were determined according to the following Eqs. (1) - (2);

$$a = \frac{SV - DV}{DV} \times 100 \qquad (1)$$

Where:
α: Volumetric swelling of the sample (%),
SV: Saturated volume of the sample (mm^3),
DV: Oven dry volume of the sample (mm^3).

$$WA = \frac{SW - DW}{DW} \times 100 \qquad (2)$$

Where:
WA: Water absorption level of the sample (%),
SW: Saturated weight of the sample (g),
DW: Oven dry weight of the sample (g).

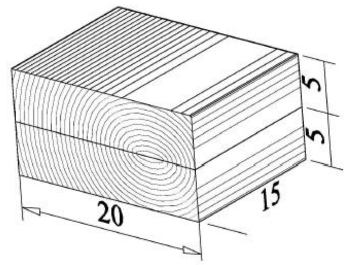

Figure 6: The test sample (dimensions in mm)

3 RESULTS AND DISCUSSION

The volumetric swelling and water absorption levels of the samples bonded with the lab. PF and the bio-based PF resin containing different amounts of bio-oil were given in Table 1.

Table 3: Volumetric swelling and water absorption levels of the samples bonded with modified PF resin

Type of resin	Amount of bio-oil (%wt.)	Volumetric swelling		Water absorption	
		Mean (%)	*Change (%)	Mean (%)	*Change (%)
Lab. PF (Reference)	-	23.70	-	71.74	-
Modified PF 5%	5	24.31	2.57	71.93	0.26
Modified PF 10%	10	22.92	-3.29	68.81	-4.08
Modified PF 15%	15	21.74	-8.27	67.96	-5.26
Modified PF 20%	20	22.18	-6.41	68.15	-5.00

*The changes (%) were calculated by comparing to the reference adhesive

According to Table 1, the volumetric swelling values of the samples increased with the water absorption levels. The highest volumetric swelling (24.31%) and water absorption levels (71.93%) were measured in samples that were bonded with 5% modified PF resin.

The swelling and water absorption levels of the samples bonded with 10 %wt., 15 %wt. and 20 %wt. modified PF resins were slightly lower than those of the samples as compared to the samples bonded with the lab. PF resin. The swelling and water absorption levels were slightly increased in samples bonded with 5% modified PF resin. There were no significant difference in the swelling and water absorption levels of the samples. The results of this study agree with Uysal (2005), Uysal (2006), Toker (2011) and Özbay and Ayrılmış (2016).

4 CONCLUSIONS

The following conclusions can be drawn from the results of this study.

The swelling and water absorption levels of the samples bonded with modified PF resin were slightly lower than that of the samples bonded with the lab. PF resin.

The use of modified PF resin containing bio-oil (up to 20 %wt.) did not considerably affect the volumetric swelling and water absorption levels of the wood samples.

Modified PF resin containing bio-oil can be effective for reducing demand for petroleum.

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Depictions on Wood: Acceptation and Internalization of Wood, which is an Intercultural Interaction Tool, as "A Valuable Object" (The Discovery of Wood is not Over Yet)

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ABSTRACT

As it is accepted and internalized as a valuable material within intercultural interaction, wood, which is most well-known material for its naturality and versatility in the world since ancient times, and which provides solutions for a wide range of different applications, has been depicted in this article in the following 3 original depictions with distinctive compositions constructed with styles and structures as different as possible with a mentality foresight upon the basis of "The Discovery of Wood is not Over Yet".

The implications forming a basis for these depictions were internalized with professional/technical knowledge and in these depictions that were made with a woodlover approach; certain theoretical explanations to strengthen wood awareness and general depictions to introduce wood (considered as an exquisite natural material in intercultural interaction) were made.

KEYWORDS: Wood, Intercultural Interaction, Natural Material, Creativity, Unending Solutions

1 INTRODUCTION

In this article, wood, which is an intercultural interaction tool, have been depicted with distinctive compositions constructed with styles and structures as different as possible with a mentality foresight upon the basis of "The Discovery of Wood is not Over Yet" through 3 original depictions. The focus of this article is to highlight the importance of wood for us in terms of its acceptation and internalization as a valuable object.

2 DEPICTIONS

The implications forming a basis for the following depictions were internalized with professional/technical knowledge and in these depictions that were made with a woodlover approach; certain theoretical explanations to strengthen wood awareness and general depictions to introduce wood (considered as an exquisite natural material in intercultural interaction) were made. The content of each presented depiction has its unique construct and the detail forming the depiction is emphasized in the first line of the depiction.

2.1 The First Depiction: 1091 words

It is obvious that wood, which is a renewable natural and organic material obtained from trees and can be decisively adapted for a wide variety of purposes to meet the needs and requirements of people on a daily basis, is an important and valuable material that has served humanity in the whole world since the beginning of time in the context of its anatomical structure, chemical composition, physical properties and mechanical properties. In this way, wood, which has contributed to the development of civilization from its beginning to the present day, is matchless material for conversion into a wide variety and extensive number of products to satisfy all aspects of human life, even though other competitive materials are almost always available to have many versions of a product from which to choose. In this sense, it is fundamental fact experienced with observational learning or direct experience that wood can be converted into a large numbers of products in different types of purposes and at different levels of demands. This makes it clear that wood is a versatile and functional material for the satisfaction of human needs and aspirations in the major objectives of development and life on Earth since its inception. Curiously, however, the discovery of wood in the context of the all possible appropriate uses is really not over yet as well as all its features, functions and other details. This is not surprising, because the discovery, as an endless process, is an ongoing process since the beginning of human history. Although we are quite familiar with wood today, we have not been able to fully unveil all the features of wood as a versatile and functional natural material.

Just as Ludwig Wittgenstein (1889-1951) has suggested, discovery never ceases. According to Wittgenstein (1922), the problem of life remain completely untouched, even if we feel that even when all possible scientific questions have been answered. If we make a conclusion from Wittgenstein's suggestion, we can clearly state that all questions that are waiting to be answered need to be evaluated thoroughly in the context of science, because scientific investigation is essential for solving a problem and revealing the details of the questions that need to be explained. Science is such that, like the rays of light splashing on a dark surface, it falls on the dark surface in strips to illuminate the darkness and clarify the shaded surfaces. Certainly, science always reveals details in both the light and dark areas of the subject studied. In this context, we can say that while science revealing the details by investigating a research problem in a comprehensive and in-depth manner, it provides a way out the details in the dark area to look better, and it brings out the details rather grey in the light area to see sharp and contrasty. At this point, if we look at this topic from Wittgenstein's point of view, we may conclude that because there are plenty of dark areas in the life, the transformation of darkness into enlightenment takes time as a long-lasting process.

As it is mentioned by Tsoumis (1991), although admirable remarks and curious details on wood are found in the work of ancient writers such as Theophrastus (371–287 BC), a student of Aristotle (384–322 BC), and the pioneer of botanical science with his book "Enquiry into Plants, and Minor Works on Odours and Weather Signs" translated by Arthur Hort in 1916, comprehensive investigations of wood on a scientific basis were undertaken only since the beginning of the twentieth century; while, according to Mantel (1964), Robert Hooke (1635-1703) first discovered cells by looking at cork through a microscope and named the cells in his book "Micrographia: Some Physiological Descriptions of Minute Bodies made by Magnifying Glasses with Observations and Inquiries Thereupon" published in 1667. In this regard, Schmucker and Linnemann (1951) pointed out that while studies on wood seemed to be progressing very fast nowadays, however, only macroscopic and empirical observations have been made for a very long period of time. This statement is very important in terms of the reliability, validity, and representativeness of previous findings about wood in order to ensure the accuracy and adequacy of information. In this frame, as it is expressed by Schweingruber (2007) depending on the context of Schmucker and Linnemann's explanation, it is beneficial to consult old publications for any dendro-ecological and dendro-anatomical research, because there is a fairly large consensus that considerable knowledge in the field of wood science already existed by the end of the nineteenth century. Indeed, despite popular belief to the contrary, and with being overly contentious and being a perfectionist, we need more of it to boost scientific research about wood. This is why, according to Tsoumis (1968), the field of wood science is rapidly progressing through research carried out in universities and specialized research institutions in various parts of the world focusing on understanding the nature of wood, specifically in relation to its complexity, and hence, considerable information has been already acquired about wood dealing with its structure and properties.

According to the preceding paragraphs, scientific research on wood shows us that the end in itself has a value. Thus we can say that advancement of scientific investigations about wood is a very important consideration to humanity or is perhaps the most important gain of taking a broad view of the role of wood in civilization. Moreover, because wood is a source of innumerable products in our contemporary world, and it is also probably the most complicated natural raw material on Earth, further research and studies are needed to shed more light on wood, and also to expand its serviceability with a wider scope of clientele. It is within this context that intelligent utilization of wood material requires not only a thorough knowledge of its anatomical structure, chemical composition, physical properties, and mechanical properties, but also of the machinery and handling processes involved in its manufacture and treatment including design and preparation.

Accordingly it may be said that although wood is an outstanding material that has served all people directly or indirectly since the establishment of the world, it has not yet been fully exploited within the context of possible material properties. It is true that the discovery of wood is not over yet, and hence, wood, which is unrivalled material in the growth and development of civilization, science, technology, economy, culture, education, and arts, continuous to be the essential object of scientific and technological interest, as well as in socio-economic and human sciences along with other issues.

2.2 The Second Depiction: 1032 words

Wood is a versatile and an efficient material facilitating the meeting of basic human needs and a number of requirements that appear as an integral part of daily life activities. In this sense, wood enables to promote comfort and the welfare whether for individuals or societies throughout the world due to its versatility and functionality. Regarding the ability of wood for enhancing the well-being of all members of the communities in terms of its endless possibility by transforming into a large number of goods and items, wood can provide comfort and the welfare of humanity as a whole because each individual member of community is a member of the humanity. Wood, which can be used in many different applications with a wide range of goods and tools within the scope of the needs and requirements that must be met in the ordinary course of everyday life, is very valuable as a material utilized in the mundane routines of daily life directly or indirectly, alone or in combination with other materials. As a general comment it may be said that wood, of course, can be designed for many different types of items and a variety of goods that become an integral part of the regularized activities that constitute everyday life. And it is absolute truth in this context that wood has now become a normalized part of everyday life with its contribution to everyday life at many different levels based on a range of degrees of necessity and of the arbitrary, and at a range of different sizes from the smallest to the largest. An astounding variety of uses of wood is the most prominent and widely recognized phenomenon in our contemporary times, and it is of course inevitable to consider wood as a significant material that has an unpredictable number of usages. In this perspective, to determine what characteristics and features wood has and to investigate whether these characteristics and features can be adapted to needs and requirements is indeed an important issue to reach new horizons.

There is no doubt that the scientific and technological progress has become one of the most important factors in the development of civilization to provide opportunities to better the conditions of human life. It is, of course, wood should be investigated scientifically and technologically to improve the conditions of life of people around the world taking into consideration the fact that wood is a universal material, and can be adapted to many different purposes in order to fulfil a wide variety of needs and requirements that become part and parcel of everyday life. It is clear to see that each scientific and technological attempt can be useful to understand how things that are being questioning in the broadest sense hang together, or to assess reliability and validity of questions about a particular issue of interest, and to have sufficient information to solve a given problem. Therefore, all of possible scientific and technological actions which promote practical applications and the usability of wood help people to live more satisfactory lives. Although many features of wood have been revealed through investigations on wood throughout history, it is necessary to examine the existing properties of wood in terms of applicability to contemporary expectations, and also to determine how many a particular property or a specific set of properties there are in wood as a natural material within the current expectations.

From the point of view of an innovation and discovery, the scientific and technological examination of wood should be carried out with a generic competency framework that supports versatility and functionality. It is worth noting that the competency is not only a specific knowledge or skill area that relates to the ability of someone, but also it is amenability of something that has a particular formation based upon its own characteristics and features. In this statement, therefore, competency stands for the functional competency of the materials that are subject to be used within the field of manufacturing to manufacture different types of products depending on a specific function or set of functions. Because functional competencies of materials may be used for a wide variety of very different purposes within the expectations for how people approach their life as well as what they should done for their achievements and challenges in a normal way of life, the functional competency of wood as a natural material should be modified and improved beyond its current state, if we aim to utilize the full potential of wood, depending on a much wider range of its functional competencies. In this case, both properties and competencies of wood that belong to a particular tree species should be taken much more seriously and considered a special interest deserving of comprehensive research to be conducted to make a list of all possible properties and competencies of a given species in cooperation with universities, institutes, research institutions and organizations all over the world.

From its very beginning science and technology, and arts have benefited each and every society in all possible directions. At this point, it is certain that the development of civilization and its widespread worldwide has been realized with innovations that reveal discoveries. In other words, every new thing revealed in intensive efforts in a planned and organized manner for the progress and benefit to society and humanity is both a discovery and an innovation. Obviously, there are many indications that wood constantly displays a discovery and an innovation while serving the people for necessities and requirements occurring in the ordinary course of day to day life with a large number of applications. It is seen that people who are in a change of attitude and behaviour and beginning to change their feelings and thoughts in the context of organic lifestyle philosophy, which is one of today's prominent approaches, increasingly prefer wood to their daily life. This, of course, causes both wood to be examined in more detail and allows the properties of wood to be handled with a new and different point of view. It looks therefore promising that the usefulness and actual use of wood would be improved with new discoveries and innovations while maintaining its continuance in the ordinary course of life.

2.3 The Third Depiction: 1023 words

Wood, which is perhaps the most important tool of the intercultural interaction because of its contributing to the advancement of civilization, is subtly a part of the greater span of human consciousness, and it has expanded to include various geographic locations traversing cultural barriers throughout the whole world. Since wood is such a universal material that helps people to communicate effectively with individuals who speak another language by transcending the limits of one’s own culture, the role of wood in the evolution and expansion of civilization thanks to the cross-cultural communication and interaction has long been recognized. In this regard, it cannot be denied that connection of wood to all cultures plays a vital role in an increasingly connected world due to globalization which is rapidly becoming vast.

According to Usta (2017), wood is a symbol of civilization which is closely associated with human welfare in order to maintain a life of prosperity both materially and spiritually, and it has always been the most distinguished material in the development of humanity and civilization by enabling individuals to communicate effectively and appropriately with people of other cultures in intercultural environments throughout the history of humanity. As mentioned by Sargut (2010), culture, which is a way the individual or group reading human being and the universe, and is the form of building reality, is an important phenomenon that is very effective in determining the relations with other people through values and symbols. We agree, following Sargut (2010) that, there is a trend towards universalization of cultural values under the influence of science, technology and arts, and hence numerous social values, which have reinforced social awareness in many ways, now become universal values that are recognized and assessed on a global scale. According to Sargut's account of the cultural differentiation, it may be said that communication and interaction, which have become compulsory among societies, remove the prejudices stemming from cultural differences, and despite the developmental differences between the societies, rising values in the face of recent progresses, discoveries, and new approaches affect the whole world.

As it can be understood from the numerous examples that help to clarify the importance of the intensification of the interaction of people on a world wide scale in light of the events and situations in which individuals and communities are participating, the technological changes accompanying scientific discoveries has increased the intensity of communication among societies with different cultures, and has supported to the rapid development of political and economic partnerships that has led to the formation of multicultural structures in manufacturing and marketing around the world. Thereby, wood could be special issue in many different areas of socio-technical research that bring together social, technical and natural environment in order to provide a broader and more comprehensive answer for the potential to enrich its usage to a very great extent. Noting that the term socio-technical is a kind of system theory prospected to cope with organizational change according to Geels and Schot (2007), it focuses mainly on technical innovations, natural environment, and social aspect including interactions with respect to human behaviour and the other elements of a system, and also it aims to help make sense of individual trajectories in order to create flexible and integrated structures to prepare suitable organizational design, and also to provide the satisfaction of everyone within the system involved with human and organizational interactions, wood may be included on a number of scenarios and instances in this topic due to its wide range of uses as a material and an entity.

Wood, which is used every day for a wide variety of purposes, is a universal material that serves the whole humanity, and therefore it is easier for people to communicate each other with the universal power of wood. In this respect, communication, which is at the heart of close relationships between societies and individuals, is critical for everyone to understand each other, and also it is the most important reason for human interaction. At this point, while the technology accompanying scientific discoveries expands the range of communication and causes interaction, likewise wood enables interaction between people communicating with each other by providing an immense variety of products for a diverse assortment of purposes. In this sense, assuming that individual consumers have different wants and needs, wood is not only a material used to produce goods and products including associated services, but also an object used to influence people's thoughts, feelings, emotions, values, beliefs, attitudes, and behaviours. And of course, wood, which is an extraordinary resource for provisioning the greater number of options in everyday life situations, is a very valuable object within a much smoother and effective communication which is a specific way of strong interaction.

In a general way we can say that in order to understand and make predictions about the future, it is necessary to learn from the past by providing historical insights regarding the goods and items made of wood, things made from wood, and applications constructed with wood. This qualification can be elaborated into a long list, considering that wood is a commonly used material in everyday life. This manner is quite useful for gaining reliable knowledge, because all sorts of information from the previous usage history of wood allow us to learn from past behaviours, and understand how they might influence future outcomes. This particular endeavour also helps us to learn and understand the feelings and thoughts, attitudes and behaviours of those who have lived in the past according to the way they use wood as a natural and organic material, and how they value wood as an entity with its own particular characteristics.

Consequently we can say that, even if it is convenient for discussing in detail and is sufficiently plausible for being accepted, there are so many things that need to be investigated about the preciousness of wood in our life as a material and as an entity that is impossible to be counted, so that there really is no limit to the scope of the design subjected to include wood, and there is absolutely no end to the extent to use wood in our lives.

3 CONCLUSION

Wood, which is a natural and organic material obtained from trees grown by sustainable forestry activities, is a fascinating material that touches almost every aspect of our lives with its subjective attributes or qualities, i.e. it has characteristics in terms of anatomical structure and chemical composition, and also features in terms of physical properties and mechanical properties. In other words, wood, which is almost indispensable to our life, is a valuable material that helps us in almost every area of our life from beginning of humankind by making our lives a lot easier, more convenient, and more comfortable thanks to its characteristics and features. Wood, which is widely used in daily life since ancient times, is the most important renewable natural material on Earth, and is the most valuable tool in intercultural interaction throughout history. In this regard, the importance and worth of wood have been well-recognised since the development of human civilisation due to its versatility and wide range of functions in everyday life, and continue to play a prominent role in improving the lives of people throughout the world, likewise play a distinctive role in influencing people's attitudes, behaviour, feelings, and thoughts. Although almost all of the characteristics and features of wood are well-known with the substantial efforts of science and technology, as well as the applied and fine arts, and the artistic experiments, it is necessary to constantly investigate what kind of properties wood has as a material and as an entity due to the new situations arising from new living conditions. Wood, which is the most effective and appropriate material to produce many things that are being used in everyday life, is always subjected to various tests to determine the level of its serviceability by the relevant person or authority, involving ordinary people because wood is a matter of the subjective choice making with multiple objectives.

In summary, research on wood should be carried out with a deeper perspective, including creative and innovative approaches. And of course, scientific, technological, and artistic exertions for wood should continue without interruption to improve its availability for use as a material and as an entity, and to search its potential impact on our lives, and also to develop an even broader understanding of what wood could contribute to the society future in view of the past and present.

This article "The Discovery of Wood is not Over Yet" contains original depictions made by Prof.Dr. İlker Usta within the course "Importance of Wood in Intercultural Interaction" (under the Elective Courses

Coordination Unit, Hacettepe University, Ankara, Turkey), and the perspectives outlined in these essays are elaborated in greater detail elsewhere in the literature.

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Mechanical Properties of Woven Carbon and Glass Fiber Fabric Reinforced Wood Plastic Composites

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ABSTRACT

High mechanical properties are desirable for wood plastic composites (WPC) to compete other conventional composites such as plywood, fibreboard, particleboard etc. Carbon and glass fibers are recognised to have high mechanical properties. In this study, polyvinyl chloride (PVC) based flat-pressed wood plastic composites were reinforced with woven carbon and glass fiber fabric.

The effect of reinforcement with 2 different woven fabrics (carbon and glass fiber) on the mechanical properties of wood plastic composites was investigated. Flexural and tensile strength and modulus elasticity of wood plastic composites were determined to evaluate the effect of reinforcement.

Results showed that reinforcement significantly increased mechanical properties of laminated? wood plastic composites. Thus and so flexural strength was improved up to 162 % when modulus of elasticity was increased up to 40% compared to control samples. The highest increase for flexural strength was obtained from woven carbon fiber fabric, while it was woven glass fiber fabric for flexural modulus. Moreover, similar results were obtained for tensile strength and modulus of elasticity which were also enhanced significantly.

KEYWORDS: Carbon Fiber, Glass Fiber, Mechanical Properties, Reinforcement, Wood Plastic Composites

1 INTRODUCTION

Due to the fact that wood is a renewable and biodegradable material, the demand for wood products is increasing day by day. This is not only due to the fact that wood has many attractive features (aesthetic and high mechanical properties), but also environmental concerns on global scale. The usage of wood resources has to be done more efficiently with regard to sustainability of forest resources due to increasing wood consumption. Meanwhile, wood has also some disadvantages. One of the most important problems is dimensional instability which results in changes its dimension depending on humidity (Hon and Shiraishi, 2001). Wood is affected by outdoor conditions (UV rays, humidity, temperature), and can be degraded under the favourable conditions (Feist and Hon, 1984, Hill, 2007). Variety of composite materials has been produced for this reason. Wood plastic composites (WPC), which are one of them, have been preferred due to the ability to restrain and/or minimize the disadvantages of woody material. Recently, the demand for wood plastic composites in the furniture and building sector has gradually increased. WPC's are usually used as deck, railing, fence, siding, bench, frame, and outdoor/indoor furniture. The WPC's global market share, which was $ 4.06 billion in 2015, has risen to $ 4.37 billion in 2016 and is expected to rise to $ 8.76 billion by 2022 (Web-1, Web-2).

Composite material can be defined as the combination of two or more materials which gives unique properties to the new material that differ from those of existing materials (Pamphlet, 1981). During this process the components are not only mechanically different but also not the same molecular level. The combination of materials occurs when they come together; however, they continue to protect their former structure. The properties of composite materials are better and more developed than the initial properties of the components (Kim and Pal, 2010). WPCs are the general name of composites obtained by combining plastics with lignocellulosic materials (Avci, 2012). Two different types of polymers are used in wood composites: thermoset and thermoplastic. Thermoplastics are polyethylene, polypropylene, polyvinyl chloride, polystyrene, polyamide, polyethyleneterephthalate while thermosetting resins are phenolics, epoxy, alkyd, polyester, amine, allyl resins, and polyurethane foams. The combination of materials is occurred at a certain temperature under the pressure (Güler, 2001, Özmen et al., 2014).

The reinforcement of thermoplastic and thermosetting resins with ceramics, metallic and polymeric fibers have become important recently. As a result of this, more durable, cheaper, and extraordinary properties can be obtained as compared with only polymer matrix. Fiber reinforcement can be described as a physical change rather than a chemical one. Therefore, this makes it cheaper than chemically redesigning of polymer. Moreover, the wood flour added to the thermoplastic polymer reduces the cost of the composite material and provides superior properties compared to the polymer alone. Furthermore, reinforcement has increased strength and bending modulus, flow resistance, weathering resistance, fire resistance, thermal expansion, and electrostatic charge resistance of thermoplastics (Clegg and Colleyer, 1986). The most preferred elements for reinforcement of composites are beryllium (Be), boron (B), carbon (C), magnesium (Mg), aluminium (Al) and silicon (Si) due to being strength, stiff, and lightweight (Zoghi, 2013). Many researchers have been trying to improve even more the technological properties of wood plastic composites in recent years. Various reinforcements such as carbon fiber, glass fiber and aramid fiber have been used in WPCs to obtain hybrid composite materials with superior properties (Boccardi et al., 2015, Russo et al., 2013, Simeoli et al., 2014, Sorrentino et al., 2015).

In this study, it is aimed to increase some mechanical properties of WPCs which is manufactured with thermoplastic polymers (polyvinyl chloride) and wood flour (pine wood) with reinforcement of woven carbon fiber and glass fiber fabrics. Carbon and glass fiber fabric are widely used in reinforcement of thermosetting resins in the literature. Flexural and tensile strength and modulus of elasticity WPCs were determined to evaluate the effect of reinforcement.

2 MATERIALS AND METHOD

2.1 Materials

Polyvinyl chloride obtained from ARE Wood Composites (Isparta) was used as the thermoplastic matrix for manufacturing. Pine flour (40-60 mesh) was used as filling materials. The density of PVC was 1.4 gr/cm^3. A plain weave type woven glass fabric (E-type glass fibers) and carbon fabric with a specific mass of 200gr/m^2 was used as reinforcement.

2.2 Method

Wood flour was oven-dried at a temperature of 70°C until less than 2% moisture content. The wood flour and thermoplastic ratio was adjusted to 1:1 (w/w). The mixture (thermoplastic and wood flour) was mixed using tumbling mixture. The 15% of wood flour and plastic was stacked and woven fabric was laid. Then the 70% of mixture was stacked and second woven fabric was laid. Finally, rest of the mixture (15%) was stacked. The draft was hot pressed for 30 minutes. The target density of board was 1.3 g/cm^3. Pressing pressure was 24-26 kp/cm^2, and temperature was 165°C.

Test samples were conditioned according to ASTM D618. The flexural strength and modulus was measured in a three-point bending test according to ASTM D790. The tensile strength and modulus was measured according to ASTM D638-99.

3 RESULTS AND DISCUSSION

The mechanical properties of carbon and glass fiber reinforced wood plastic composites are given in Table 1. According to results, flexural strength and modulus of elasticity in flexural were significantly improved compared to control samples. The highest flexural strength was obtained from carbon fiber reinforced WPC samples. Glass fiber is widely used in the polymer composites applications due to its low cost while carbon fibers give much more resistance to materials in contrast with its high cost (Frederic, 1992, Zoghi, 2013). In recent years, polymer composites were reinforced with short carbon fiber and glass fiber.

Rezaei et al., (2008) reported that carbon fiber significantly increased flexural strength and modulus of elasticity. In another study, the increasing carbon fiber content affected the flexural strength and modulus of elasticity and improved up to 49%, and 59%, respectively (Tufan et al., 2016).

Recently, woven glass fiber fabric has been used to produce the laminated composites (Boccardi et al., 2015; Russo et al., 2013; Simeoli et al., 2014; Sorrentino et al., 2015). According to studies, flexural strength was improved up to 500%. As can be seen in Table 1, the carbon fiber improved flexural strength by 162 % while glass fiber was by 102 % as compared to control. Unlike flexural strength, the highest modulus of elasticity was obtained from glass fiber. The glass fiber increased flexural modulus up to 40% while carbon fiber was by 29% as compared to control. According to DIN 68 761 standards, the minimum flexural strength for particleboards produced by flat pressed method (up to 13 mm thickness) is 16-18 MPa while for middle density fiber boards (MDF) is 11-16.5 MPa (Talavera, 2007). The results meet the DIN standards and the reinforced wood plastic composites could be also evaluated even that where higher strength is required.

Table 4: Mechanical properties of reinforced wood plastic composites

Groups	Flexural Strength (MPa)	Flexural Modulus (MPa)	Tensile Strength (MPa)	Tensile Modulus (MPa)
Control	35 (3)	3241 (135)	16 (2)	1837 (191)
Carbon Fiber Reinforced	92 (9)	4183 (102)	68 (3)	2520 (153)
Glass Fiber Reinforced	71 (6)	4564 (386)	28 (2)	2804 (293)

Note: Values in the parentheses are standard deviations.

Fu et al., (2000) reported that short carbon fiber increased tensile strength up to 90% when glass fiber was by 60%. Similarly, polypropylene composites reinforced with short carbon fiber improved tensile strength and tensile modulus approximately 100% depends on fiber length and content (Razaei et al., 2008). Meanwhile glass fiber also improved tensile strength by 65%, to a lesser extent, carbon fiber. As seen in Table 1, there is a significant difference between control and reinforced WPC samples for tensile strength. Carbon fiber reinforcement increased tensile strength up to 325 % while glass fiber is 75 %. Although there is not a remarkable change in the tensile modulus, it was enhanced up to 53 %. However, unlike tensile strength, the highest tensile modulus was obtained from glass fiber reinforcement.

4 CONCLUSION

The increasing pressure on the environment increases the demand for natural products. Wood plastic composites as a relatively natural product have drawn an attention which grows up its product range. Mechanical properties of wood plastic composites could sometimes be insufficient in the usage. The reinforcement of WPC with natural and/or artificial fibers has come up to obtain durable, cheap and high properties in recent years. For this purposes, woven carbon and glass fiber fabrics were evaluated to increase WPC's mechanical properties in this study. The reinforcement with woven fibers results in increasing of mechanical properties due to their high strength. Lamination with woven fabric improved flexural and tensile strength significantly. Especially, the highest increase obtained from carbon fiber woven fabrics. Even though not as much as flexural and tensile strength, there is also improvement for modulus of flexural and tensile modulus. According to obtained results, it could be stated that, reinforcement with woven fiber fabric provides enhancement in some mechanical properties and allow WPC'S to be evaluated for a wider range of utilization.

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The Performance of Water-Borne Acrylic Coating Systems on Flat-Pressed Wood Plastic Composites

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ABSTRACT

The colour change of surface in the outdoor conditions is one of the prominent obstacles for wood plastic composites. In this study, 2 different water-borne acrylic resin with UV absorber coating systems were implemented on polyvinyl chloride based flat-pressed wood plastic composites.

The effect of water-borne acrylic coating systems application on the performance of polyvinyl chloride based flat-pressed wood plastic composites in outdoor conditions is evaluated in this study. The uncoated (control) and coated (test) wood plastic composites were exposed to artificial weathering test during the 200 hours (ASTM G 53-96). The changes in the colour and surface roughness on the uncoated and coated wood plastic composites were determined after the weathering test. Visual examination of wood plastic composites exposed to accelerated weathering was carried out by light microscopy (LM) to determine the weathering effect.

The result shows that water-based coating systems enhanced the surface quality of wood plastic composites. The colour changes of surface decreased as a result of UV absorb ability of coating systems. LM images show that colour changes increased significantly in consequence of severe weathering conditions. Moreover, surface roughness of wood plastic composites also improved compared to control samples.

KEYWORDS: Weathering Resistant, Wood Plastic Composites, Acrylic Resin, Colour Changes, Surface Roughness

1 INTRODUCTION

Wood plastic composites (WPC) have a history of about 80 years. The first industrial applications were carried out with thermosetting resins such as phenol formaldehyde. The use of thermoplastics began in the late 1960s (Gardner and Murdock, 2010). WPC's are manufactured by combining of thermoplastic polymers and wood flour as binders. The wood flour referred to herein includes not only wood materials but also all lignocellulosic materials such as annual plants and other agricultural wastes (Klasov, 2007). Therefore, wood plastic composites can be called as composite materials produced from recycled/virgin plastics and lignocellulosic wastes. The cost is reduced and extraordinary properties can be obtained as a result of combining the plastic polymer with the lignocellulosic material as filler (Kim and Pal, 2010). As a result of being environmentally friendly, WPC's are usually evaluated in decking, railing, fencing, timber, sidings, benches, window door frames, indoor furniture, etc. (Fabiyi and McDonald, 2010; Kim and Pal, 2010; Stark and Matuna, 2007).

The increase in demand for WPC's has resulted in the expansion of the market. Particularly WPC's have frequently been used in decking, siding, and railings recently. Therefore, they are under the influence of different factors (UV rays, humidity, temperature, exhaust gases, rain) in outdoor conditions. As a result of this, some chemical changes occur in the structure resulted in discoloration (Fabiyi and McDonald, 2010). Additionally, the mechanical properties are reduced by the combination of surface oxidization, crystallization of the matrix, and reduction of binding between matrix and lignocellulosic material due to moisture (Stark, 2004). Depending on the severity of degradation, the mechanical properties and aesthetic appeal disappear immediately (Fabiyi and McDonald, 2010, Stark and Matuana, 2007, Stark, 2006).

It is generally recognised that chromophoric groups are responsible for absorbing of UV light which initiates photo-oxidation. The photo-dissociation and photo-oxidation have taken place for the most organic-based polymer in the both outdoor (exposure to sunlight) and indoors (exposure to fluorescent light) (Ito and Nagai, 2008). Chromophoric groups such as the carbon-carbon double bond (C = C) and carbonyl groups (C = O) of the polymers have the capacity to absorb ultraviolet (UV) energy and are involved in photoreactions which results in the degradation of the polymer (Bajracharya et al., 2014).

The increased amount of wood in the composite material makes it more susceptible to degradation, as well as being a more natural material. As known from the previous studies, lignin, which makes the wood material sensitive against weathering conditions, is the one that degrade under the UV rays (Özgenç, 2014). Chromophore groups in the lignin absorb UV rays and initiate degradation (Feist and Hon, 1984). The presence of moisture also significantly affects wood plastic composites in the outside. The surface of wood plastic composites is whitened and cracked as a result of moisture and UV rays (Stark and Matuna, 2007). Therefore, they also cause the wood particle to break off the surface.

The objective of this study was to investigate the performance of water-borne acrylic coating systems on wood plastic composites against artificial weathering conditions. For this purpose, wood plastic composites were manufactured via flat-pressed method and coated two different water-borne acrylic resin with UV absorber. The WPC specimens were exposed to artificial weathering conditions for 200 hours according to ASTM G 53-96. The surface roughness, colour changes was evaluated as compared with control samples. The visual examination was also performed by using light microscopy (LM).

2 MATERIAL AND METHODS

2.1 Materials

Polyvinyl chloride obtained from ARE WoodComposites (Isparta) was used as the thermoplastic matrix for manufacturing. Pine flour (40-60 mesh) was used as filling materials. The density of PVC was 1.4 gr/cm^3.

The raw material of acrylic coating systems' products were supplied from BASF Company in Turkey, and formulations was seen in Table 1 and 2, respectively. The coatings were applied to samples at three times with a brush and each layer was 100 gr. The waiting-period was 24 hours for drying of each layer.

Table 1. The raw material of coating systems

Pruducts	Description	Physical form	Active content (%)
Resin	Pure acrylic	liquid	50
Resin	Acrylic emulsions	liquid	42
UV absorber	UV Absorber	liquid	40

Table 2. Formulations of coating systems

Formulation products	Content (%)	X	Y
Acrylic resin	73.7	X	-
Acrylic emulsions	73.7	-	X
UV absorber	6.0	X	X
Film-forming agents	0.67	X	X
Defoamers	1.0	X	X
Dispersing agent	0.6	X	X
Rheology modifier	1.3	X	X
Distiled water	16.73	X	X

2.2 Methods

2.2.1 Production of WPC

Wood flour was oven-dried at temperature of 70 ^{0}C until less than 2% moisture content. The wood flour and thermoplastic ratio was adjusted to 1:1 (w/w). The mixture (thermoplastic and wood flour) was mixed using tumbling mixture. The draft was hot-pressed for 30 minutes using flat-press methods. The target density of board was 1.4 g/cm^3. Pressing pressure was 24-26 kp/cm^2, and temperature was 165 ^{0}C.

2.2.2 Artificial Weathering Test

Artificial weathering was performed in a QUV/spray accelerated weathering tester (Q-Panel Lab Products, Cleveland, OH, USA) equipped with 313 nm fluorescent UV (UVB) lamps; the temperature in the chamber was approximately 60 ^{0}C (ASTM G 154-12a). The weathering experiment was carried out in cycles of UV light irradiation for 4h followed by condensation temperature of 50 ^{0}C for 4h in an accelerated weathering test cycle chamber over 200 h. Four replicate samples for each coating system were prepared for each artificial weathering test condition.

2.2.3 Color measurement

The color measurements were carried out using a Minolta CM-600d spectrophotometer (Konica Minolta, Japan) equipped with an integrating sphere according to the CIE L* a* b* system. The reflection spectrum of the Konica Minolta CM-600d instrument was acquired from an area measuring an 8 mm in diameter with 100 in the 400–700 nm wavelength range. Five measurements were recorded for each samples.

2.2.4 Surface roughness test

A Mitutoya SurfTest SJ-301 instrument was employed for surface roughness measurements. The Ra and Rb roughness parameters were measured to be evaluated the surface roughness of the surface of unweathered and weathered coated particleboard and uncoated particleboard samples according to DIN 4768. Ra is the arithmetic mean of the absolute values of the profile departures within the reference lenght, and Rz is the arithmetic mean of the 4-point height of irregularities (DIN 4768). The cut-off length was 2.5 mm, the sampling length was 12.5 mm, and the detector tip radius was 10 μm in the surface roughness measurements.

2.2.5 Visual Examination

The surface investigation of wood composite samples was carried out by Zeiss Stemi 305 light microscopy and Zeiss AxiocAM erC 5s camera.

3 RESULT AND DISCUSSION

3.1 Artificial Weathering Performance

The artificial weathering performance of acrylic coating systems on wood plastic composites was investigated based on Δa*, Δb*, ΔL*, ΔE* values during 200 hours. The colour changes of WPC samples exposed to artificial weathering was seen in Table 3. When examined the ΔE* values which is refer to general colour changes of samples, the highest colour change was obtained from control samples, as expected. Meanwhile, acrylic based coatings decreased the colour changes as compared control samples and protected samples surface. Therefore, formulation X provided the highest protection which resulted in the lowest colour change. The changes rate in the colour was proportional between the exposure periods. ΔL* values give information about the surface quality and lightness of samples (Ozgenc et al., 2012). All of the ΔL* values were negative which indicates rougher and darker surface for WPC samples. The more process temperature, the darker sample surface (Fabiyi et al., 2008; Stark, 2015). Similarly the highest ΔL* value was obtained from control samples, while the lowest one was formulation X. Although formulation Y is lower than control samples, there is a not significant difference between them.

Table 3. The colour changes of WPC's exposed to artificial weathering

	Formulation X				Formulation Y				Control			
Hours	**Δa***	**Δb***	**ΔL***	**ΔE***	**Δa***	**Δb***	**ΔL***	**ΔE***	**Δa***	**Δb***	**ΔL***	**ΔE***
24th	0,28	-0,21	-0,56	1,11	0,45	-0,45	-0,65	1,93	0,36	-0,20	0,45	1,30
72th	0,60	-0,02	-0,79	1,35	0,81	-0,40	-0,82	1,86	0,41	-0,91	0,16	1,82
144th	0,86	0,20	-0,76	1,49	0,81	-0,46	-1,39	2,32	0,41	-1,3	0,64	2,68
200th	0,72	-0,71	-0,73	1,83	0,97	-0,17	-2,04	2,67	0,18	-0,96	-2,17	4,03

Δa* values were positive for all of the samples which means that surface colour tended to change toward reddish. However, the highest Δa* value was obtained from coated samples as compared to control. However, the lower one was found formulation X between them. Furthermore, Δb* values were negative which demonstrate that samples prone to be blue for all samples (Ozgenc and Yildiz 2016). Even though all of Δb* values are similar, the highest one was found control samples.

3.2 Surface roughness

Surface roughness is an important parameter for classification, quality, gluing, coatings (Aydın and Çolakoğlu, 2003; Csanady et al., 2015). Surface texture is affected by anatomical properties of wood (annual ring proportion, early and late wood content, diameter of tracheids and vessel), density, and wood species, (Csanady et al., 2015; Özgenç and Durmaz, 2017). Wood flour is used as filler in the WPC and therefore influences the surface texture.

The surface roughness values of coated and uncoated samples were given in Table 4. Weathering factors (UV rays, humidity, spray) affect coating systems and result in changes in the material surface (Kotnarowska, 1999). Therefore, the extensive weathering conditions ruined surface quality in this study. The heterogeneity of WPC results in higher surface roughness when exposed to extensive weathering conditions because of lower adhesion between wood flour and polymer (Gupta et al., 2007). As seen in Table 4, Ra and Rz values increased as a result of artificial weathering. However, Rz value for formulation X decreased.

Table 4. The surface roughness values

Samples	Before weathering			After weathering	
	Ra	**Rz**		**Ra**	**Rz**
Formulation X	1,02 (0,17)	29,61 (10,30)		1,35 (0,23)	16,87 (5,12)
Formulation Y	0,38 (0,12)	7,40 (3,12)		0,77 (0,60)	9,98 (6,57)
Control	1,76 (0,64)	14,58 (4,34)		2,67 (0,67)	20,67 (4,21)

Note: Value in the parentheses is standard deviations.

3.3 Visual Appearance

Visual examination of WPC samples exposed to artificial weathering was carried out by light microscopy. The images of WPC's were given in Fig. 1. As seen, the colour changes as a result of extensive weathering conditions were remarkable. Especially, surface roughness and darkness increased for control samples after 200 hours of accelerated weathering. According to colour measurement, the highest colour change took place for control samples which support this situation. Weathering conditions also resulted in remove of wood fiber from the surface which increases roughness. As compared to control samples, the colour changes in the acrylic based coatings are relatively lower. Surface texture is comparatively smoother compare with uncoated control samples.

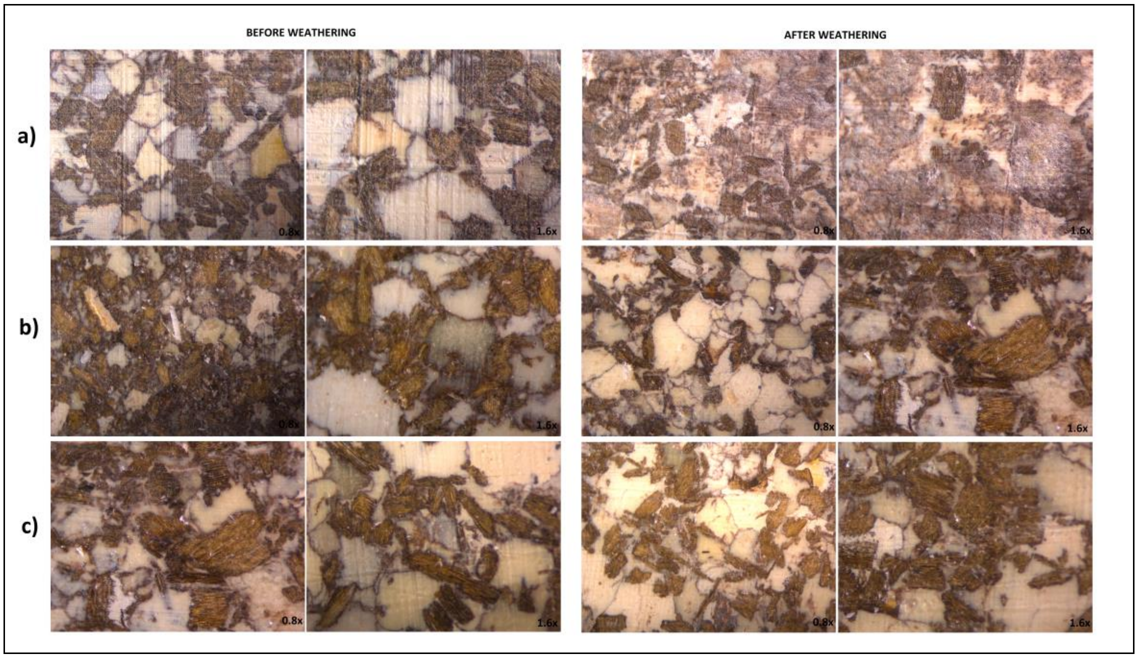

Fig. 1. Visual examination of WPC's exposed to accelerated weathering; a) control samples, b) formulation X, c) formulation Y

4 CONCLUSION

The colour change on the surface of wood plastic composites exposed to weathering is inevitable. Recently, researches have been conducted to improve the wood plastic composites surface quality. In this study, acrylic based coating systems containing UV absorber were applied WPC's surface to improve weathering resistance. After 200 hours of accelerated weathering, although control samples changed colour and surface quality deteriorated, acrylic coated samples resisted and were less affected by extensive weathering conditions. Therefore, coating systems restrained the weathering effect and improved the WPC's surface quality. Formulation X, however, indicated the best performance rather than formulation Y. The findings from color measurement, surface roughness, and visual appearance proved that UV absorber in the acrylic coating systems is effective to reduce weathering detrimental effect and improve the WPC's surface quality.

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Dimensional Stability of Wood Bonded with The Phenol-Formaldehyde/Waste Tyre Pyrolytic Oil Blend Adhesive

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ABSTRACT

Phenol formaldehyde adhesive, whose price depends heavily on petroleum cost is widely used in the wood industry. A large amount of tyre waste is created every year all over the world. Many studies have been carried out on the re-use of tyre waste in the industrial area. In this study, the dimensional stability of commercial phenol-formaldehyde (Com. PF) adhesive containing different amounts of waste tyre pyrolytic oil was investigated. The com. PF adhesive was gradually substituted by increasing amount of waste tyre pyrolytic oil up to 30 %wt. Afterward, the effects of blend ratio on dimensional stability of bonded-wood were determined. The commercial phenol-formaldehyde resin was evaluated as reference resin in order to compare the dimensional stability of wood bonded with modified PF resin. The test results showed that the swelling values of the samples bonded with the PF adhesives containing up to 15 %wt pyrolytic oil were about the same as that of com. PF adhesive.

KEYWORDS: Waste tyre, Tyre pyrolytic oil, Phenol–formaldehyde, Dimensional stability, Wood

1 INTRODUCTION

Every year, a large amount of scrap tyre is generated all over the world. The issue of scrap tyre pollution has turned into a growing environmental threat. Pyrolysis is the thermal decomposition process used in order to produce the valuable chemicals and resources from the waste tyre. The production of waste tyre pyrolytic oil from pyrolysis method has created remarkable interest. Various studies have been conducted on the re-use of tyre waste (Ramarad et al., 2017; Umeki et al., 2016; Miranda et al., 2013; Mirmiran et al., 1992; Williams, 2013; Mazloom et al., 2009; Senneca et al., 1999).

Phenol formaldehyde (PF) adhesive has been commonly used in wood industry due to its bonding performance and water resistance. However, PF adhesive depends mostly on petroleum cost. Many researches have been given in order to modify the PF adhesive with various resources (Aslan et al., 2015; Wescott and Frihart, 2004; Sukhbaatar et al., 2009; Zhang et al., 2013; Wang et al., 2009).

This study aims to evaluate the dimensional stability of wood bonded with the PF/waste tyre pyrolytic oil blend adhesive. The commercial PF adhesive was partially replaced with pyrolytic oil up to 30 %wt. The dimensional stability of bonded wood samples was investigated by the volumetric swelling test.

2 MATERIALS AND METHODS

2.1 Materials

The commercial PF (Com. PF) adhesive provided from POLİSAN company in Izmit, Turkey was considered as reference adhesive. The density (20 °C) of the PF adhesive was 1.201 g/cm^3. Waste tyre pyrolytic oil was supplied from EN-TEK company in Bilecik, Turkey.

The beech wood planks (*Fagus orientalis Lipsky*) tested in this study were purchased from a timber company in Karabuk, Turkey. The lamellas with dimensions of 5 mm x 50 mm x 600 mm were cut from the planks. The wood lamellas were acclimatized in a climate room at 20 ± 2 °C and 65 ± 3% relative humidity prior to bonding.

2.2 Methods

The tyre pyrolytic oil was filtered through the filter paper to eliminate the dust and particles prior to use. In the preparation of the adhesives, the PF/pyrolytic oil mixture was stirred by the magnetic stirrer to make it uniform. The contents of pyrolytic oil are 0 %wt (reference), 5 %wt, 10 %wt, 15 %wt, 20 %wt, 25 %wt, and 30 %wt.

In the bonding process, two lamellas were bonded together with the com. PF and the PF/pyrolytic oil blend adhesives. The adhesive was applied to one side of lamellas at the application amount of approx. 180 g/m^2 with a hand brush. The bonding was performed at a temperature of 120 °C, applying a pressure of 0.2 N/mm^2 for 15 min.

The volumetric swelling tests were carried out in order to evaluate the dimensional stability of samples bonded with the commercial PF/tyre pyrolytic oil mixtures. The thickness, width, and length of the test samples were 10 mm, 20 mm and 15 mm, respectively. In the volumetric swelling tests, samples were firstly oven dried at 103 ± 3 ^{0}C until a constant oven-dry weight was obtained. Afterward, the samples were soaked in a distilled water for three weeks. Volumetric swelling (%) of the samples were calculated according to the following Eq. (1);

$$\beta = \frac{Vs - Vd}{Vd} \times 100 \qquad (3)$$

Where:

β : Volumetric swelling of the sample (%),

Vs : Saturated volume of the sample (mm^3),

Vd : Oven dry volume of the sample (mm^3).

3 RESULTS AND DISCUSSION

Table 1 presents the volumetric swelling (%) of the samples bonded with the com. PF and the PF/waste tyre pyrolytic oil blend adhesives.

Table 5: Volumetric swelling of the samples bonded with blended PF adhesive

Type of adhesive	Volumetric swelling	
	Mean (%)	*Change (%)
Com. PF (Reference)	23.59	-
PF/pyrolytic oil (%) (95/5)	23.23	-1.55
PF/pyrolytic oil (%) (90/10)	24.02	1.79
PF/pyrolytic oil (%) (85/15)	23.88	1.21
PF/pyrolytic oil (%) (80/20)	24.61	4.14
PF/pyrolytic oil (%) (75/25)	25.61	7.89
PF/pyrolytic oil (%) (70/30)	24.64	4.26

*The changes (%) were calculated by comparing to the reference adhesive

There is no significant difference between the swelling values of the samples bonded with com. PF, 5 %wt pyrolytic oil blended, 10 %wt pyrolytic oil blended and 15 %wt pyrolytic oil blended PF adhesives (Table 1). Thus, the volumetric swelling values were not affected by the pyrolytic oil mixture up to 15 %wt replacement level. Further increment in the pyrolytic oil content (above 15 %wt) increased the swelling of the samples. The highest swelling with a value of 25.61% was found in the samples bonded with the PF adhesive containing 25 %wt pyrolytic oil.

4 CONCLUSIONS

In this study, the effects of the PF/waste tyre pyrolytic oil blend adhesive on the wood dimensional stability was investigated. The test results revealed that the swelling values of the samples bonded with the PF adhesives containing up to 15 %wt pyrolytic oil were about the same as that of com. PF adhesive.

As a result of this work, waste tyre pyrolytic oil could be partially blended (up to 15 %wt) with commercial PF adhesive.

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Antioxidant, Antimicrobial and Anti-Quorum Sensing Activities of *Usnea filipendula* and *Viscum album*

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ABSTRACT

Many plants contain a variety of bioactive components. Therefore, it is important to know the bioactive properties of plant materials in order to be a reference for later researchers. In this study, it was investigated the antioxidant, antimicrobial and anti-quorum sensing activities of *Usnea filipendula* and *Viscum album*'s methanol extracts. To determine the antioxidant properties of the extracts; total phenolic, flavonoid and condensed tannin contents and ferric reducing antioxidant power analyses were performed. The antibacterial potential of plant extracts was tested by agar well diffusion method against *Staphylococcus aureus* ATCC 25923, *Escherichia coli* ATCC 25922, *Enterococcus faecalis* ATCC 29212, *Pseudomonas aeruginosa* ATCC 27853, *Salmonella Typhimurium* ATCC 14028, *Klebsiella pneumoniae* ATCC 13883, *Proteus mirabilis* ATCC 7002, *Listeria monocytogenes* ATCC 43251, *Candida parapsilosis* ATCC 22019 and *Candida albicans* ATCC 10231 microorganisms. Anti-quorum sensing activity was investigated on *Chromobacterium violaceum* ATCC 12472 bacteria. The highest total phenolic and ferric reducing antioxidant power was determined in *U. filipendula* extract. This extract inhibited the growth of *S. aureus, K. pneumonia* and *L. monocytogenes* microorganisms. The highest flavonoid and condensed tannin was observed in *V. album extract*. This extract was also able to prevent the growth of *K. pneumonia* and *L. monocytogenes*. None of the extracts showed anti-quorum sensing activity.

KEYWORDS: Antioxidant, antimicrobial anti-quorum sensing, *Usnea filipendula*, *Viscum album*

1 INTRODUCTION

The plants can be described as 'a gift of nature' because they are therapeutic. Many kinds of them have played an active role in the treatment of different diseases for centuries (Farombi, 2003). Although many drugs or medical methods have been applied to treat diseases by the development of technology and science, some governments have made it compulsory to consume natural products for many aims (Ertürk et al., 2004). Plants produce secondary metabolites in their bodies and it has been proven by many scientific studies that secondary metabolites have antioxidant, antimicrobial, anticancer, antidiabetic, etc. properties (Rao and Kingston, 1982; Mensor et al., 2001; Srinivasan, 2005;González-Lamothe et al., 2009).

Some chemical reactions in body tissues produce free radical molecules under certain conditions. Free radicals occur naturally in every step of the duration. These molecules cause metabolic problems and play a role in bringing damage to tissues. However, these unstable electron-laden chemicals are largely destroyed or removed by natural antioxidant defence systems normally found in the body. The use of antioxidant plants/foods supports the body's antioxidant defence mechanism (Gate et al., 1999; Srinivasan, 2005). Antioxidants can be considered as two major groups; synthetic and natural, generally. Despite the synthetic ones have been used in many places, there is still suspicion about their reliability (Hoand Shahidi, 2005; Taghvaei and Jafari, 2015) because of their possible toxic/side effects especially during long-term intake (Taghvaei and Jafari, 2015). On the other hand, it has been indicated that many natural additives have more antioxidants property and thermal stability than the synthetic ones.

Increased technology, unlimited consumption demand and pollution have also increased/diversified the disease. As it is known some plants species have been used to overcome the microorganisms that cause diseases. The therapeutic effects of plants are related to the synergistic effect of a large number of compounds. It has been reported that the herbal combinations provide more effective treatment against the resistance of microorganisms that are difficult to kill with a single antibiotic. (Sree et al., 2010;Nazri et al., 2011).

While quorum sensing (QS) is the communication system between the bacterial cells by the signaling molecules, anti-quorum sensing is the name of the stopping this communication mechanism (Alvarez et al., 2012). Over the past few years, QS has become a very extensive field of research because of its promising results for the utilizations in industry, medicine and biotechnology (Taganna et al., 2011). According to research of some scientists that “plants are rich natural resource of quorum sensing agents” (Choo et al., 2006; Kohand Tham, 2011; Mohamed et al., 2014; Al-Haidari et al., 2016). The most likely benefit of the QS researchers is to disrupt the signal communication between microorganisms’ communities and to keep their growth under control. It was seen that there is not much study in the literature about the quorum sensing-disrupting activity of plants. Therefore, this study will reveal whether the lichen and mistletoe plants investigated in this article have anti-quorum sensing activity or not.

It has been known that the lichens and mistletoe have some special bioactive properties. Bioactive natural products obtained from lichens have been utilized for medicinal and cosmetic purposes. Six lichen species involving usnic acid in various amounts were found to be effective against various (Cansaran et al., 2006; Yıldız, 2017). On the other hand, biologically active components of mistletoe have been reviewed (Ochocka and Piotrowski, 2002). Ertürk et al. (2004) investigated anti-microbial properties of mistletoe (*Viscum album* L.) against a fungus and six bacteria species. They explained that different concentration of n-hexane extract of mistletoe was effectual against micro-organisms analysed.

The phenolic components of plant origins have attracted attention because of their functional, useful and nutritional properties including antioxidant and antimicrobial capacity, in recent years (Bubonja-Sonje et al., 2011). The plants that are found in abundant quantities and inexpensive such as lichen or mistletoe need to be investigated, firstly. In this study it was examined the antioxidant, antimicrobial and antiquorum sensing activities of *Usnea filipendula* and *Viscum album*’s methanol extracts.

2 MATERIAL AND METHODS

2.1 Material

Lichen (*Usnea filipendula*) was collected from wild areas in Trabzon province, Tonya district (Fig. 1). Mistletoe (*Viscum album* L.) was collected from *Pinus sylvestris* host tree in Trabzon province, Sürmene district (Fig. 2), located in the north-eastern of Turkey (Table 1). The plants were brought to laboratory for extraction process.

Table 1: Investigated plant samples

Sample	**Scientific classification**	**Collected place**	
		Province	**District**
Mistletoe	*Viscum album* L.	Trabzon	Tonya
Lichen	*Usnea filipendula*	Trabzon	Sürmene

Figure 1: Lichen (*Usnea filipendula*) Figure 2: Mistletoe (*Viscum album*)

2.2 Sample preparation

Whole of lichen and twigs of mistletoe were used for the analyses. Samples were dried in an oven at 60°C at 24 hours before grinding. A laboratory scale Wiley mill was utilized to grind. Approximately 5 g powdered samples were dissolved in 50 mL methanol (99%). The mixture was continuously stirred using a shaker (Heidolph Promax 2020, Schwabach, Germany) at room temperature for 24 h. Particles were removed using Whatman No. 4 filter paper (pore size 20-25 μm). Then the solutions were filter sterilized using 0.45 μm hydrophilic polyvinylidene fluoride (PVDF) filters.

2.3 Antioxidant properties

2.3.1 Ferric Reducing Antioxidant Power (FRAP)

The antioxidant capacity was determined using ferric reducing antioxidant power (FRAP). This method is based on the reduction of tripyridyltriazine complex (Fe $(TPTZ)^{3+}$) to blue colored $Fe(TPTZ)^{2+}$ by antioxidants in acidic medium (Benzie and Strain, 1996). FRAP values were expressed in wet weight of the samples as μmol of ferrous equivalent Fe (II) per g of sample.

2.3.2 Determination of phenolic contents

The polyphenolic contents of the methanol extracts were evaluated by three different ways; total phenolic contents (TPC), total flavonoids (TF) and condensed tannin (CT) contents. For the determination of the total phenolic contents, the Folin-Ciocalteau procedure was employed and gallic acid was used as standard (Slinkard and Singleton, 1977). The results were expressed as mg Gallic Acid Equivalent (GAE) per g of methanolic extracts.

2.3.3 Determination of flavonoid contents

The concentration of the total flavonoid content in the methanol extracts was measured using a spectrometric assay. The total flavonoid concentration was expressed as mg equivalents of quercetin (QE) per g of sample (Fukumotoand Mazza, 2000).

2.3.4 Determination of condensed tannins contents

The concentration of condensed tannins was determined according to the method previously used by Julkunen-Titto (Julkunen-Tiitto, 1985). The results were expressed as mg catechin equivalent (CE) per g of sample.

2.4 Antimicrobial activity

The extracts were tested for antimicrobial activity by agar-well diffusion method according to the Clinical & Laboratory Standards Institute (CLSI) guidelines (Wayne, 2002) against *Staphylococcus aureus* ATCC 25923, *Escherichia coli* ATCC 25922, *Enterococcus faecalis* ATCC 29212, *Pseudomonas aeruginosa* ATCC 27853, *Salmonella typhimurium* ATCC 14028, *Klebsiella pneumoniae* ATCC 13883, *Proteus mirabilis* ATCC 7002, *Listeria monocytogenes* ATCC 43251, *Candida parapsilosis* ATCC 22019 and *Candida albicans* ATCC 10231. The microorganisms were obtained from Department of Medical Microbiology, Faculty of Medicine, Karadeniz Technical University, Trabzon, Turkey. Bacteria and yeast were cultured in Luria Bertani (LB) and Sabouroud Dextrose agar (LABM, UK), respectively. Fresh cultures (18 h) of bacteria and yeast were used to make suspension in 5 mL of sterile isotonic sodium chloride and turbidity was adjusted to 0.5 McFarland. Agar plates were filled with suspension and 0.6 cm agar wells were cut out using a sterile pipette tip. 50 microliters of extracts were transferred into each agar well and cultures were incubated at 37°C for 24 hours. Ampicillin, gentamicin, cefotaxime, tetracycline and amphotericin B solutions and DMSO were used as positive and negative controls, respectively. The antimicrobial activity was determined by visual inspection and measurement of the diameter of inhibition zones around the agar-wells. The minimal inhibitory concentration (MIC) of the extracts showing a positive antimicrobial activity was determined using the liquid microdilution test method. The well with the lowest concentration that did not show any microbial growth was considered to be the MIC of the tested extract.

2.5 Anti-Quorum Sensing activity

Anti-quorum sensing activity was determined using microdilution method as described for the antimicrobial activity test above (Damte et al., 2013). The anti-QS activity of the extracts has been tested against *Chromobacterium violaceum* ATCC 12472, a violacein-producing strain. Briefly, MIC of each extract was determined as described above and sub-MIC concentrations were used for the inhibition of pigment production of *C. violaceum*. For anti-QS assay, to the fresh culture of the strains in LB broth was added for each extract and incubated for 24 h. At the end of the incubation, 1 mL of culture was centrifuged and pellet was resuspended in 1 ml of DMSO and vortexed at the high speed for pigment extraction. Supernatant was removed and absorbance values of the pigments were determined at OD 585 nm using a microplate reader (Damte et al., 2013; Norizan et al., 2013). Vanilla extract was used as positive control (Choo et al., 2006).

2.6 Statistical analysis

The data were presented as means and standard deviations of three replicates for total phenolic content and antioxidant properties and ten replicates for metal composition analyzed by using Statistical Package for Social Sciences (SPSS version 23.0). The data were analyzed by ANOVA and tests of statistical significance were performed using Duncan's multiple range tests.

3 RESULTS AND DISCUSSIONS

3.1 Antioxidant activity

3.1.1 Ferric Reducing Antioxidant Power (FRAP)

In this study, antioxidant capacity was determined using ferric reducing antioxidant power (FRAP) method. The results are given Figure 3.

As shown in Figure 3, antioxidant capacity of *U. filipendula* (54,4 µmol$FeSO_4.7H_2O$/g) was found higher than antioxidant capacity of *V. album* (51,45 µmol$FeSO_4.7H_2O$/g). Vicas et al. (2009) investigated the hydrophilic and lipophilic antioxidant activities of *V. album.* For this purpose, they collected the *V. album* leaves and stems from five host trees (*Acer campestre, Malus domestica, Fraxinus excelsior, Populus nigra* and *Robinia pseudoacacia*) and determined the antioxidant activity of methanol and acetone extracts of all collected samples. They reported that methanol extract of *V. album* leaves collected from *M. domestica* exhibited the highest activity.

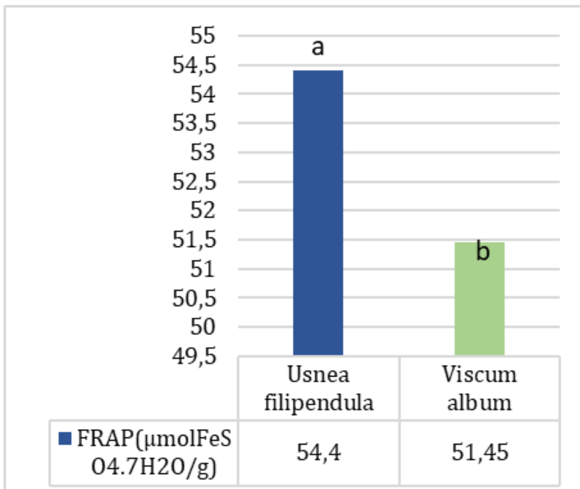


Figure 3: Antioxidant capacity of samples

Önay-Uçar et al. (2006) found that *V. album* living in different trees had different antioxidant activity. So, they reported that *V. album* extract's antioxidant capacity can vary depending on the plant's harvest time and the configuration of the main tree at the same time. In this study, *V. album* was collected from *P. sylvestris* host tree. Therefore, it can be concluded that antioxidant capacity of *V. album* collected from different host tree can be differ from our results. In a study, the reducing power activity of *V. album* crude alcoholic extract was reported at 0.10 equivalent 1mM $FeSO_4$ by (Papuc et al., 2010). It was noticed that extracts of *V. album* obtained from cashew tree demonstrated a stronger Fe chelating ability (Oluwaseun and Ganiyu, 2008).

Oran et al. (2016) studied the antioxidant capacity of different lichen species' (*Usnea intermedia, Usnea filipendula* and *Usnea fulvoreagens*) methanol and ethanol extracts. They reported that methanol extracts of lichen species showed higher antioxidant capacity from the ethanol extracts.

All the previous studies and the present study are evaluated together, it can be concluded that the antioxidant capacity is affected many factors such as extract type and method, extract concentration, plant harvesting time, host tree (for mistletoe) etc.

3.1.2 Total phenolic contents

In this study, the polyphenolic contents of the methanol extracts were evaluated by three different ways; total phenolic content, total flavonoids and condensed tannin contents. The polyphenolic contents of the methanol extracts of samples are given in Figure 4.

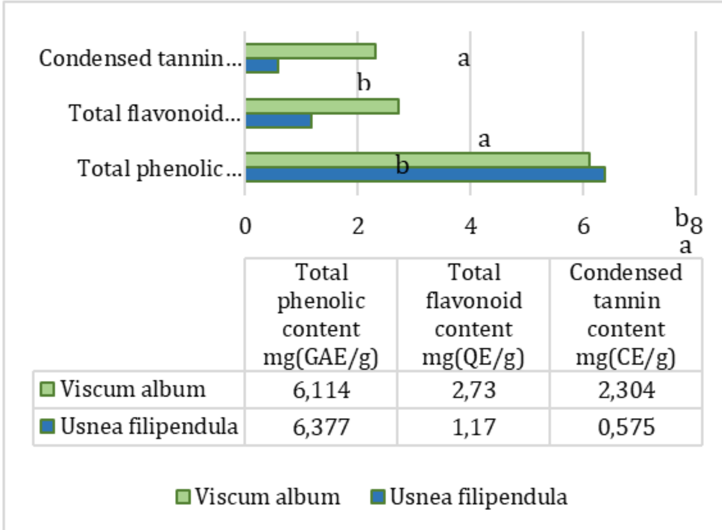


Figure 4: The polyphenolic contents of the methanol extracts of samples

In this study, total phenolic contents of *V. album* and *U. filipendula* was determined as 6.114 and 6.377 mg (GAE)/g, respectively (Fig. 4) and the results were found to be statistically significant each other ($p<0.05$).

In a study, total phenolic contents of *V. album* methanol extract were determined as 19.43 mg GAE/g dried weight (Sengul et al., 2009). Vicas et al. (2009) reported that the total phenolic content of *V. album* methanolic and acetonic extracts' which collected from 5 host tree were between 0.40-0.65 mg GAE/g fresh weight and 0.002-0.015 mg GAE/g fresh weigh, respectively. It can be concluded that the total phenolic content of the mistletoe collected from different host trees is also different. (Papuc et al., 2010) informed that the polyphenols of *V. album* ethanolic extracts as 6.33 mg/g dry plant. Our results are comparable with just mentioned study. Total phenolic content of *U. filipendula* acetone, ethanol and methanol extracts was reported that 329.7, 197.4 and 291.5 mg GAE/100 g^{-1} of dried lichen, respectively (Oran et al., 2016).

3.1.3 Total flavonoid contents

Flavonoids are aromatic pigment compounds found in fruits, vegetables and some beverages. They have been intensively investigated by researchers (Kesarkar et al., 2009). Flavonoids have been shown to play a crucial role in the obstruction of many diseases such as cancer (Serafini et al., 2006). In this study, total flavonoid content of *V. album* and *U. filipendula* was calculated as 2.73 and 1.17 mg (QE/g), respectively (Fig. 4). In a previous study, it was (Papuc et al., 2010) reported that the flavonoid content of *V. album* ethanolic extracts was 9.72 mg/g dry plant. It can be said that the solvent type affects the flavonoid content. There are some studies in the literature reported that some lichen species have important flavonoid contents (Kosanić et al., 2011).

3.1.4 Condensed tannins contents

Tannins whose main characteristics are binding to proteins, starch and digestive enzymes are often evaluated to be nutritionally undesirable (Goel et al., 2005). On the other hand, many studies reported that tannins have positive effects on animals by anthelmintic, anti-microbial properties especially in ruminants. Condensed tannins consist of flavonoids are presented in many plants such as some tree species, as well as pasture species such as *Lotus* spp. (Hassanpour et al., 2011).

In this study, condensed tannin content of *V. album* extract (2.304 mg (CE/g)) was found 4 times higher than the *U. filipendula* extract (0.575 mg (CE/g).

When all the polyphenolic contents and antioxidant capacity of methanol extracts of studied samples are evaluated together, the higher total phenolic content and antioxidant capacity was determined in *U. filipendula* extract while the higher total flavonoid content and condensed tannin content was determined in *V. album* extract.

3.2 Antimicrobial activity

The antimicrobial activity of studied samples and used antibiotics are given Table 2.

Table 2. Antimicrobial activity and used antibiotics

Agar Well Diffusion (mm zone diameter)							
	V. album	*U. filipendula*	Ampicillin	Gentamicin	Amphotericin B	Tetracycline	Cefotaxime
S. aureus	0	4	> 30	-	-	-	-
E. coli	0	0	16-17	-	-	-	-
P. aeruginosa	0	0	-	21-22	-	-	-
E. faecalis	0	0	>30	-	-	-	-
C. albicans	0	0	-	-	30		
C. parapsilosis	0	0	-	-	-	-	-
S. typhimurium	0	0	27	-	-	-	-
P. mirabilis	0	0	-	-	-	-	37
K. pneumoniae	2	1	-	-	-	-	-
L. monocytogenes	2	1	-	-	-	25	-

As can be seen in Table 2, *V. album* methanol extract inhibited *K. pneumoniae*, L. *monocytogenes* and *U. filipendula* methanol extract inhibited *S. aureus, K. pneumoniae* and L. monocytogenes microorganisms. Also, *V. album* extract was shown better antimicrobial zone than *U. filipendula* extract against *K. pneumoniae and L. monocytogenes* microorganisms.

Minimum inhibition concentration (MIC) values of extracts which show antimicrobial property are given in Table 3.

Table 3. Minimum inhibition concentration (MIC) values of extracts (µg/mL)

	V. album	*U. filipendula*
S. aureus	-	312.5
K. pneumoniae	1250	1250
L. monocytogenes	625	625

The lower MIC value means the stronger antimicrobial effect of extract. In this study, *U. filipendula* methanol extract has the best antimicrobial activity against *S. aureus* microorganism with 312.5 µg/mL concentration. It can be said that *V. album* extract was more effective than *U. filipendula* extract, because when same MIC values of extract was tested (Table 3), *V. album* extract showed higher (twice times) antimicrobial activity (mm zone diameter) from *U. filipendula* extract (Table 2).

Sengul et al. (2009) reported that both methanol and aqueous extracts of *V. album* inhibited many organisms. Methanol extracts showed better antimicrobial activity than aqueous extracts. In a study, it was investigated the antimicrobial activity of different extracts (acetone, petroleum ether, ethyl acetate, chloroform, ethanol, methanol, water) of *V. album* collected from Rialy, Muzaffarabad Azad Jammu and Kashmir. According to the reported results all extracts inhibited many of studied microorganisms except from acetone and petroleum ether extracts (Hussain et al., 2011). In another study; it was investigated that antimicrobial activity of *V. album* against 6 bacteria and 1 fungus (*Bacillus subtilis, Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, Enterobacter cloacae*, *Proteus vulgaris* and *Candida albicans*). The results showed that the different concentrations of n-hexane extract of mistletoe were effective against micro-organisms analyzed (Ertürk et al., 2003).

Oran et al. (2016) reported that the MIC values of all analyzed extracts ranged from 64 µg/mL to 512 µg/mL for all the bacterial strains and all the Fluoro quinolone-resistant Escherichia coli isolates (except for E101) were sensitive to the methanol extracts of the three *Usnea filipendula*. In another study, it was reported that *U. filipendula* have antimutagenic and antigenotoxic effects.

3.3 Antiquorum sensing activity

The communication mechanism between microorganisms has called "quorum sensing" (QS). Anti-QS activity charts of positive control (vanilla) and *U. filipendula* and *V. album* are given Figure 5-7, respectively.

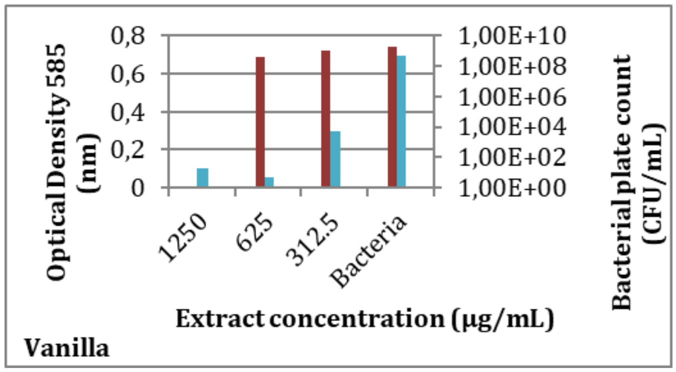
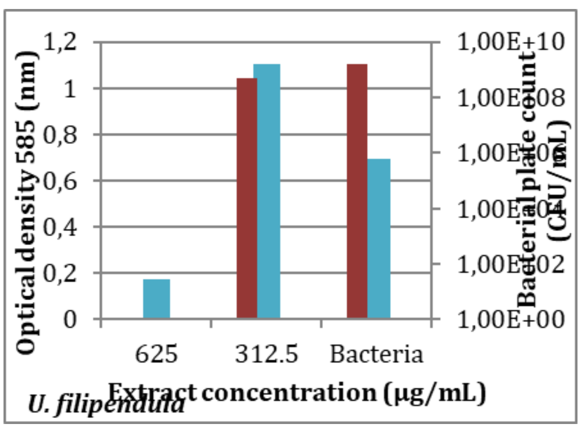


Figure 5: Anti-QS activity chart of vanilla



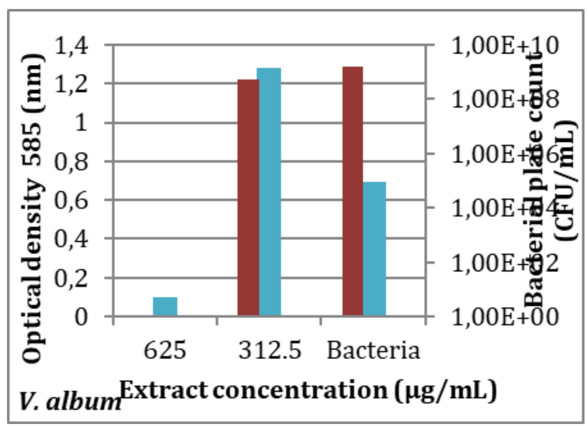


Figure 6: Anti-QS activity chart of *U. filipendula*

Figure 7: Anti-QS activity chart of *V. album*

Bacteria used in this study (*C. violaceum*) for anti-QS assay produces the purple pigment. If the extract we use is not killing bacteria or killing very little, the intensity of pigment production is not reduce, or if it is very low, it can be considered that used extract have anti-QS activity. A good functioning of this mentioned state is seen in the positive control extract (Fig. 5). Vanilla showed anti-QS activity from 312.5 to 625 µg/mL while inhibited the bacteria when 1250 µg/mL. In this study, both of *U. filipendula* and *V. album* inhibited the *C. violaceum* at 625 Mg/mL extract concentration so they did not show anti-QS activity.

Kenar et al. (2016) investigated that the methanolic and dicloromethanolic extracts of fruits, leaves, and stem of *V. album*. They used agar well and disc diffusion assay for anti-QS activity using *Chromobacterium violaceum* (CV12472 and CVO26) strains. They reported that the effect of *V. album* extracts on anti-biofilm and anti-QS was very effective over biofilms produced by pathogens and these extracts were good sources for new antimicrobial components.

4 CONCLUSION

In this study antioxidant, antimicrobial and anti-quorum sensing activities of *U. filipendula* and *V album*'s methanol extracts were investigated. The important findings of this study can be listed as follows;

- The higher total phenolic content and antioxidant capacity was determined in *U. filipendula* extract
- The higher total flavonoid content and condensed tannin content was determined in *V. album* extract.
- *U. filipendula* methanol extract has the best antimicrobial activity against *S. aureus* microorganism with 312.5 μg/mL concentration.
- *V. album* extract was more effective than *U. filipendula* extract against *K. pneumoniae* and *L. monocytogenes.*
- Both of extracts inhibited *C. violaceum*, they did not show anti-QS activity.

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THE INTERNATIONAL FOREST PRODUCTS CONGRESS

Application of DES (Deep Eutectic Solvent) to Wood Extractives

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ABSTRACT

Deep eutectic solvents (DES), known as environmentally friendly, recyclable, nonpoisonous, low volatility, non-flammability and harmless are first found by Abbott et al. in 2003. In the last decade, scientists are working with DES in different areas. Mainly, they focus on isolation of cellulose and lignin. Regard to extractives, to the best of our knowledge DES was not studied before. In this study, it was aimed to determine the extractive composition of Scotch pine with deep eutectic solvents.

Pinus sylvestris L. was used as wood material. As deep eutectic solvent (DES) Choline chloride (Merck 5.00117), ethylene glycol (Merck 1.00949) and urea (Merck 1.08487) were used with molar ratio of choline chloride; ethylene glycol (1:2 m/m), and choline chloride: urea (1:2 m/m). Sequential soxhelet extraction was performed first with n-hexane and then acetone-water with 5 g wood sample for 6 hours. With DES two extractions were performed in an ultrasonic (UB) and hot-water bath (HWB) at 60°C for 30 min. 0.05 g wood samples were used for these extractions. Identification and quantification were done with Shimadzu GCMS-QP2010 GC-MS and Shimadzu GC 2010 FID-GC.

Similar results were obtained with DES and organic solvents. Fatty acids, resin acids and stilbenes are the main chemical groups. Oleic acid (1.4-9%), linoleic acid (1.6-8%) and levopimaric acid (0.6-17.7%) are dominant compounds, found in all extracts. Also, monomethyl pinosylvin (51.5%) was found in acetone:water mixture. DES can be an alternative to organic solvents in wood extraction.

KEYWORDS: Deep Eutectic Solvents(DES), Extractives, *Scots pine*

1 INTRODUCTION

Deep eutectic solvents (DES) are the mixtures of two or more compounds with a low melting point then preliminary compounds (Soares et al., 2017). They composed of hydrogen bond donor and hydrogen bond acceptor which support the dissolution (Li and Row, 2016). Hydrogen bond acceptors are generally quaternary ammonium salts while hydrogen bond donors involves amines, carboxylic acids, alcohol, polyoses or carbohydrates (Shishov, 2017). DES has some advantages compared to organic solvents; easy to prepare high purity compounds with low cost and biocompatibility (Hayyan et al.2013). Studies point out that DES are environmentally friendly, recyclable, nonpoisonous, low volatility, non-flammability and harmless solvents (Abbott et al., 2004; Jhong et al., 2009; Hayyan et al., 2012; Singh et al., 2012; Wu et al., 2012 Lynam et al. 2017).

DESs was used in the following processes: the determination of bioactive compounds (Gu et al., 2014), the extraction of anthocyanins (Bosiljkov et al., 2017),the removal of aromatic hydrocarbons from aliphatic compositions (Hou et al., 2015), the analysis of volatile substances (Nie et al., 2017), the analysis of sugar amount in the corncob (Procentese et al., 2015), the increment of the cellulose derivation from the corn stoves for the butanol fermentation (Xu et al., 2016), the fractionation of lignocellulosic biomass (van Osch et al., 2017).

DES are mainly applied on cellulose and lignin (Lynam et al., 2017; Liu et al., 2017). To the best of our knowledge, isolation of low molecular compounds (fatty-resin acids) from wood with DES was not studied before. In this study, it was aimed to determine the extractive composition of Scotch pine with deep eutectic solvents.

2 MATERIAL AND METHOD

2.1 Material

Pinus *sylvestris* L (Scots pine), a widely studied wood species, was used as a wood material. Samples were taken from 630 m altitude of Hasankadi-Bartin province of Turkey and prepared according to TAPPI T 257- cm-02. After debarking and cutting in to matchstick size, samples were dried in a freeze dryer and grounded in the Wiley mill.

Choline chloride (Merck 5.00117), ethylene glycol (Merck 1.00949), glycerin (Merck 1.04092) and urea (Merck 1.08487) were used as deep eutectic solvent (DES). Eutectic mixtures molar ratio was as; choline chloride; ethylene glycol (1:2 m/m), choline chloride:glycerol (1:2 m/m) and choline chloride: urea (1:2 m/m). Also organic solvents n-hexane and acetone were used.

2.2 Extraction Methods

Three different extraction procedures, was applied. Traditional successive soxhlet extraction was performed with n-hexane and acetone-water respectively. 5 g wood sample was extracted 6 hours with each organic solvent. The other two extractions were performed in an ultrasonic (UB) and hot-water bath (HWB) at 60°C for 30 min. with deep eutectic solvents. 0.05 g wood samples were used for these extractions. 500 µl of aliquot from each extract was taken to a test tube and 1 ml of acetone has added. 700 µl of acetone phase was evaporated under nitrogen and was silylated.

2.3 Identification

Identification of compounds were performed with Shimadzu GCMS-QP2010 GC-MS equipped with TRB-5MS column (30 m x 0.25mm (0.25 µm thickness). Temperature program was started at 120 °C set for 1 min. then rised to 310 °C with a 6 °C/min. waiting for 20 minutes. The injection temperature was set to 260 °C, with 1:25 split mode, ion source was 200 °C and ionization energy 70eV. Wiley and NIST libraries were used. For quantitative analysis, Shimadzu GC 2010 FID-GC was used with TRB-5 column (30 m x 0.25 mm (0.25 µm thickness). Temperature program was set as above.

3 RESULTS AND DISCUSSION

Extractive composition of Scots pine wood was analyzed with organic solvents applied classically (soxhlet) and by new biodegradable deep eutectic solvent (DES). The results are represented in Table 1. Fatty acids, resin acids and stilbenes (pinosylvin monomethyl ether) are the main chemical groups identified.

Total amount of fatty acids concerning palmitic acid, oleic acid and linoleic acid were found 19% in hexane extract. Except ChCl-Gly with HWB (19.6 %) the amount of total fatty acids was low (13.9-17%) with other solvents and extraction method. Oleic acid was found to be the major fatty acid in hexane. The results are in agreement with literature (Yildirim and Holmbom, 1978). Thus the ratio of this acid was 5.5%, 4.9% and 5.4% in ChCl-EG, ChCl-Gly, ChCl-Urea respectively in UB. With HWB, amount of oleic acid was low.

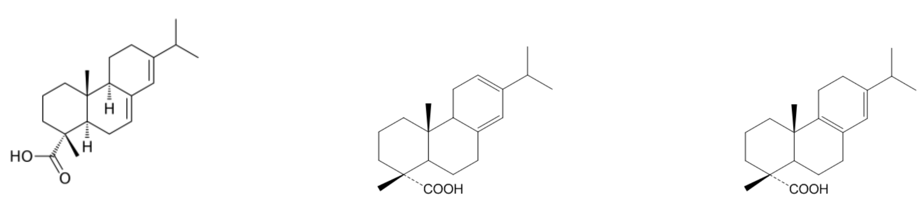
Table 1. Extractives of P. slyvetris wood obtained by organic and DES solvents (%)

	RT	Compound	H	A-W	ChCl-EG (1:2 molar)		ChCl-Glycol (1:2 molar)		ChCl-Urea (1:2 molar)	
					UB	HWB	UB	HWB	UB	HWB
1	15,12	Palmitic acid	0.1	-	0.4	0.9	1.0	3.8	0.7	2.2
2	16,54	Heptadecanoic acid	-	-	0.3	0.5	0.8	0.8	1.9	1.4
3	17,86	α-Linolenic acid	2.0	0.8	2.1	2.1	2.0	1.9	2.1	1.9
4	18,14	Linoleic acid	8.0	1.6	5.9	6.4	5.2	6.7	5.5	6.7
5	18,22	Oleic acid	9.0	1.4	5.5	4.7	4.9	6.4	5.4	4.8
6	19,48	Monomethyl pinosylvin	3.2	**51.5**	**12.0**	**15.5**	**16.4**	**16.1**	5.9	10.9
7	19,72	Pimaric acid	7.1	0.3	6.3	5.3	4.9	4.5	7.7	4.9
8	19,97	Sandracopimaric acid	1.1	-	1.3	0.8	1.0	1.5	1.3	0.9
9	20,14	Isopimaric acid	3.3	**-**	5.6	6.1	**10.2**	7.5	5.7	7.5
10	20,16	n.i.	-	**41.0**	-	-	**-**	-	-	-
11	20,45	Palustric acid	**14.3**	0.5	**12.4**	**11.6**	**11.0**	9.3	**12.5**	**13.9**
12	20,76	Levopimaric acid	**16.5**	0.6	**12.7**	**11.3**	**10.7**	**9.5**	**17.7**	**11.5**
13	20,88	Dehydroxyabietic acid	7.1	0.9	**10.4**	9.0	8.6	8.5	6.1	9.5
14	21,30	Abietic acid	**15.0**	0.8	**14.5**	**14.8**	**13.1**	**14.1**	**13.0**	**14.7**
15	22,63	Neoabietic acid	**13.0**	0.5	**10.7**	**10.9**	**10.1**	**9.5**	**14.5**	9.3

H: Hexane; A-W: Acetone-water; UB:ultrason bath; HWB: Hotwater bath; n.i: not identified.

Resin acids, more than 70% of total extracts composed of pimaral and abietal type of acids (Fig.1). The most abundant compounds were levopimaric acid (16.5%) and abietic acid (15%) in hexane. With DES solvents amount of levopimaric acid varied between 9.5-17.7% and abietic acid 13-14.8%. UB method showed better result than HWB at 60^0C. As known resin acids have antiviral, antibacterial and antifungal effects (Savluchinske-Feio et al, 2006) and used in pharmacy and food industry. Specially for food industry residue of organic solvent is a big problem. With DES more secure extracts can be obtained. The amounts of total resin acids are almost compatible with hexane.

Pinosylvin and pinosylvin monomethyl ether which have an inhibition factor against some fungus and effect the decay resistance of wood (Venäläinen et al. 2004, Vainio-Kaila et al.2015) was found 51.5% in acetone:water extract. Sequential extraction was applied with organic solvents to recover first fatty and resin acids and then to extract pinosylvin monomethyl ether (Fang et al, 2013). With DES, the best results were obtained with ChCl:Glycol treated samples. The amount of pinosylvin monomethyl ether with ChCl:Glycol was 14.4% and 13.2% in ultrasonic and hot water bath respectively. In other DES applications hot-water bath give better results.



Abietic acid Levopimaric acid Palustric acid

Figure 1. Some resin acids found in the *P. slyvetris* wood.

Ultrasonic (UB) and hot-water bath (HWB) two different method applied to DES. As seen in Fig.2 total amount of resin acids were 5% more with UB compared to HWB at 60^{0}C. However, with fatty acids the situation was reverse. Fatty acids gave better results with HWB. The structure of fatty acid is, linear long chains and HWB application seems to be enough. Resin acids forms from ring structures with one or more double bonds. UB was more effective for these structures.

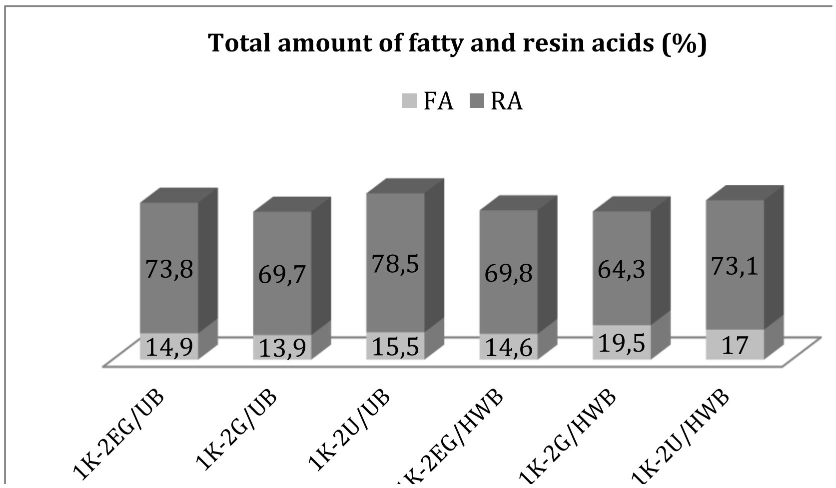


Figure 2. Total amount of fatty and resin acids with DES (%)

4 CONCLUSION

Organic solvents (hexane, acetone, ethanol, toluene etc.) are used in the extraction procedures. These are petroleum-based solvents and have some environmental problems with high-cost. Deep Eutectic Solvents (DES) are cheap and eco-friendly green chemicals used since 2003. This study showed that, DES can be used for the wood extraction. For fatty and resin acids, DES can be an alternative for organic solvents. Also, extraction procedure decreased to 30 min. with ultrasonic bath. Choline chloride: urea combination gave better results.

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The rehabilitation possible of chair frames made from sycamore (*Platanus orientalis*), pine (*Pinus eldarica*) and poplar (*Populus nigra*) using Glass fiber-reinforced polymers

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The rehabilitation possible of chair frames made from sycamore (*Platanus orientalis*), pine (*Pinus eldarica*) and poplar (*Populus nigra*) using Glass fiber-reinforced polymers

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ABSTRACT

Two elements of furniture frames are usually separate at glue line. The stress of front to back loading are concentrated in this part of furniture frame. Failure location for chair under front to back load occurred at the joint between the back post and side rail, and it less located at the joint between the front post and side rail. The aim of this research was to rehabilitate a chair that broken by force from front to back. To achieve this goal, the separated joints can be reinforced with Glass fiber-reinforced polymers. In this study, six different types of chairs were used. For each treatment, the test was repeated three times. Chairs are custom type that made from species wood of sycamore (*Platanus orientalis*), pine (*Pinus eldarica*) and poplar (*Populus nigra*). Front to back load tests were conducted by mechanical universal testing machine in accordance with DIN EN 1729-2 standard. After the loading test, destroyed chairs were reformed with Glass fiber-reinforced polymers, and then again, front to back load applied. Front to back loads of control samples are compared to resulted loads of reformed chairs. The results of the experiment showed that differences between the control samples and reformed chairs were not significant. The first type chairs were broken at the load about 1010 N, but the reformed type chairs at about 841 N. The chairs strength of made from species wood of sycamore (*Platanus orientalis*), pine (*Pinus eldarica*) and poplar (*Populus nigra*) against applied loads are 1172, 911 and 693 N, respectively. Wooden chairs made of sycamore have a super performance when compared to other samples.

KEYWORDS: Wooden chairs, the maximum front to back load, Chair rehabilitation

1 INTRODUCTION

The supply of massive wood has been decreased in recent years. The demand for wood product has been increasing with increasing population of the world which is adversely influencing the sustainable utilization of lignocellulosic resources. The reuse and rehabilitation of chair frames obtained from plantation trees such as sycamore (*Platanus orientalis*), pine (*Pinus eldarica*) and poplar (*Populus nigra*) can be deserves option because of increasing demand of wood, decreased supply of raw materials and environmentally friendly issues. Product and part reuse is not a new concept, but, there is advantageous influencing the sustainable utilization of forest resources. In the other hand, due to access to forest plantation and the lack of forest resources, furniture durability must be increased against external loads, in order that the lack of raw material at furniture industry is resolve. In now, plantation trees woods are used in furniture industry. A few of research have been presented that why length of service life and ultimate strength of products obtained from these species increase (Eckelman and Haviarova 2006, Bayatkashkoli and Hemmati 2015, Bayatkashkoli et al., 2017, Uysal et al. 2015).

Length of service life is one of the most important considerations in the design of furniture, and in most cases, it is a function of joint construction (Eckelman and Haviarova 2006). Chairs have a different failure location that due to different force distribution. Also, joints and design of chair are very important to manufacture chairs with higher performance, and can be affect its strength and service life. The mechanical strength of a chair made from poplar wood is affected by number of joints in its component parts and surfaces of the glue line. Failures have occurred in the glue line within the mortice or finger joint (Bayatkashkoli and Hemmati, 2015). The custom chair joints made from poplar wood that fail most frequently occur between the back post and the seat rail. Failures usually occurred at the glue line. The component parts with joint types are less strong than without joint. The removal of the joints of frame is one of the methods for the frame reinforcement. Stretcher types (box stretcher and cross stretcher) and wood shelf brackets were used to reinforce chair frames. Stretcher type and brackets changed the failure location at the joint between the back or front post and side rail (Bayatkashkoli et al., 2017). Finally, failure of wood structures mainly occurs in the joints that located between back post and side rail, or otherwise, located between side rail and front post.

The cyclic durability, ease of disassembly, repair, and reuse of parts of wooden chair frames were comprised by Uysal et al. (2015). Glued round and rectangular mortise and tenon joints had the highest levels of cyclic load durability whereas bed bolts had the least. Chairs constructed with knockdown joints were easiest to repair, whereas chairs constructed with glued joints were the most difficult to repair. the longest possible service life, easily repaired and reusable parts so that broken or discarded furniture (that cannot be simply repaired) such as legs, rails, and stretchers can be recycled, i.e., incorporated into a new generation of furniture are important at furniture designs. Ease of repair is largely a function of how easily the chair can be disassembled. This study is also of special interest to humanitarian groups involved in the production of school furniture and the repair of broken furniture especially in the developing world.

One way to increase the length of service life of the furniture frame corners is to use GFRP (Glass fiber-reinforced polymers), and or, the rehabilitation possible of chair frames with it. The effect of joint rehabilitation of chair frames and its reinforcement methods against front-to-back loading less considered. GFRP can be increase the structural performance of chair under front-to-back loading. Losses strength of chair frames can be reinforced by GFRP. GFRP used as reinforcement material in structures members. The published data had emphasized to strengthen comparison of structures with GFRP, but the effect of rehabilitation and repair methods of failure after applied loads less considered.

Glass fibers are having excellent properties like high strength, flexibility, stiffness and resistance to chemical harm. Classification and physical properties of various glass fibers indicated that E glass type has a higher strength and electrical resistivity (Sathishkumar et al., 2014). Epoxy resins have been widely used for glass fibers different applications. Epoxy resins have high chemical/corrosion resistance properties, low shrinkage on curing. The capability to be processed under various conditions and the high level of crosslinking epoxy resin networks led to brittle material (Hameed et al., 2007). Connection strength increases as the number of layers of fiberglass reinforcement increases. The ultimate strength of a three-layer reinforced connection was 33 percent greater than the nonreinforced connection for parallel-to-grain loading, and more than twice the strength for perpendicular-to-grain loading (Soltis et al., 1998). GFRP and wood materials have a positive combined effect. These failure modes consist of the local buckling of the GFRP and the compression failure of the GFRP skin (Qi et al., 2015). Durability of wooden member with carbon fiber reinforced plastics evaluated by Hojo, (2013). As a result of observing the destructive situation by a bending test, in almost all the examination object, carbon fiber material was not detached from the wood. The specimen after outdoor exposure is gradually decreased adhesion strength, it is considered that the reinforcing effect of the bending stiffness is reduced due to the decrease in adhesive strength.

The effect of rehabilitation of chair frames made from plantation trees on the front-to-back loading was not evaluated yet. Quantitative studies of reuse and rehabilitation of chair frames, fore example, repair and reuse of parts of wooden chair frames by Uysal et al. (2015), have been conducted. The study objectives are listed as follow. Determine which plantation trees woods are best suited for reconstruction of chairs. Determine the front-to-back load capacity of frames constructed with three types of wood of plantation trees. A comparison of the front-to-back load capacity of frames rehabilitate with GFRP and the front-to-back load capacity of custom chair that is rehabilitation possible of chair frames.

2 MATERIALS AND METHODS

2.1 Manufacturing of custom chair

Wooden chairs are manufactured with different designs in workshops and factories. The design used in the research is a chair design with stretchers that is largely produced. Tenon and mortise joint is largely applied in wooden chairs. The chairs are often produced in workshops and factories of Iran. The dimensions of the chair and its components are based on a field survey, Published data (Noll, 2007; Jackson and Day, 1995; Horwood, 1999) and the DIN EN 1729-1. The patterns of manufacture of the chair and their dimensions are shown in Figure 1.

Sycamore (*Platanus orientalis*), pine (*Pinus eldarica*) and poplar (*Populus nigra*) species were used in the study. Wooden chairs were constructed with stretchers, tenon and mortise joint, sycamore, pine and poplar woods. Polyvinyl acetate glue was used as an adhesive. The characteristics of the adhesive are presented at table 1.

Table 1. The characteristics of the polyvinyl acetate glue

Properties	Test result
appearance	Milky white, smooth and free of foreign particles
pH	3.2
Film forming properties	Smooth and colorless and transparent
Minimum film forming temperature	20° C
Storage time	6 months
Solid materials	32%
Assembly time	10 minutes
Preparation	Not need

The final assembly of the chairs was accomplished with Polyvinyl acetate glue and manufacture with three different species. The chairs were kept at normal atmospheric conditions for a period of 24 hours for the adhesive used in the joints to become completely cured.

2.2 Rehabilitation of custom chair frames

First, Polyvinyl acetate glue was applied to the surfaces of the dimension parts that its joints are loosed, and then the parts were assembled and clamped for 24 h. Subsequent, loose joints of chair frames reinforced with Glass Fiber-Reinforced Polymers. The upper surface of loose joint was coated with GFRP. The reinforcement process of joints is follow;

The loose joint surfaces were cleaned and smoothed. Initially, unsaturated polyester resin containing curing additives was applied in the joint surfaces by using flexible-blade knives. The glass fiber was placed on the resin and fully wetted. A scraper was used to make full wetting of fiber in resin. A final sealing layer of resin was poured on the fiber. Over the period of time, the laminated composite was fully hardened. The chair frames with GFRP were cured at 60 C for 24 h, during the

curing process pressure wasn't employed on the joints. Only 1-ply sheet of glass fiber was saturated by epoxy resin.

The style of glass fiber was E glass that used on the joint surfaces. The woven-mat glass fiber was saturated with epoxy resin and hardener. The product name of glass fiber was Kor-GFW420 that strength and stiffness of fiber, areal weight and fabric thickness are 2300 Mpa, 76 Gpa, 420 g/m2, 0.16 mm, respectively. The product name of epoxy resin was EPIKOTE 828 that has a medium viscosity liquid epoxy resin produced from bisphenol A and epichlorohydrin. The product name of hardener was EPIKURE F205 that has a low viscosity, modified cycloaliphatic amine curing agent. The weight ratio epoxy resin to hardener was 10:5.8.

2.3 Performance test of chair frames-front-to-back load tests

Front to back load was applied on the prepared chairs by Universal Testing Machine according to the DIN EN-1729-2:2006 Standard and Eckelman (1999). All tests were performed on a computer-controlled INSTRON machine (Model DANP4). The loading speed was set at 6.5 mm/min to measure the maximum load. The chair was fixed on the machine's span. The fixed chair does not slide when loading from front to back. Loading method applied from front to back on the chair. The experimental error decreases for uniform conditions of construction, including the same of glue line thickness, size of dimensions parts and joints size. The specimens were placed on the test station in accordance with the loading model given in figure 1.

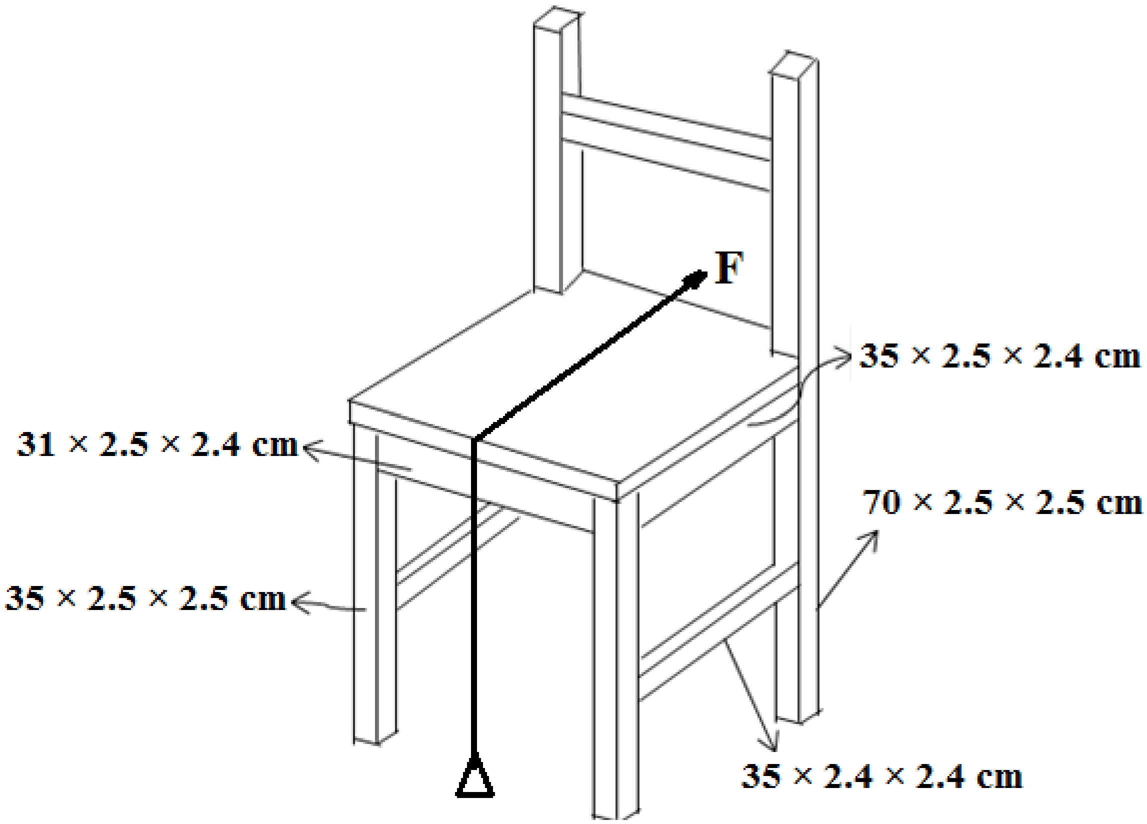

Figure 1. The pattern of manufacture of the custom chair and size of its component parts and loading method applied from front to back on the chair

2.4 Analysis of the data

The study has six treatments under front to back loading that included chair frames made from wooden species types and chair frames repaired with GFRP. Three samples were made from each group. The maximum loading test was designed according to a completely randomized design (CRD). The SPSS package program was used in the statistical analysis of the data. A one-way analysis of variance (ANOVA) was performed on the data. The differences between means were tested was according to the Least Significant Difference (LSD) test at a 95 percent level of protection.

3 RESULTS AND DISCUSSION

The means values of the physical and mechanical qualities of sycamore, pine and poplar wood is shown in table 2. The means values of the maximum load, standard deviation and standard error of chairs under front to back loads is shown in table 3. Univariate analysis of variance for treatments is shown in table 4. Univariate analysis of variance and Least Significant Difference (LSD) results showed that there were statistical differences between maximum loads of the chairs with sycamore wood and poplar woods at the 95% confidence level.

Table 2. Physical and mechanical qualities of sycamore, pine and poplar wood

Species	Physical properties	Mechanical properties		
	Density (gr/cm^3)	Maximum load (N)	MOE (Mpa)	MOR (Mpa)
Sycamore	0.61	2436	64661	114
Pine	0.54	1703	63333	80
Poplar	0.38	1415	95961	66

Table 3: The means values of the maximum load of chairs and its statistic scales

Chair with:				
wooden species	**Treatment type**	**Mean (N)**	**Std. Deviation**	**Std. Error**
Sycamore	Control	1230	450	260
Sycamore	Rehabilitation	1113	207	119
pine	Control	1032	51	29
pine	Rehabilitation	790	60	35
poplar	Control	767	224	129
poplar	Rehabilitation	618	231	133

Table 4: The statistically significance of variables effects resulted of univariate analysis of variance at 95 percent confidence level.

Source	Sig.
Species	0.017
Rehabilitation	0.166
Species * Rehabilitation	0.898
R Squared	0.540
Adjusted R Squared	0.348
Based on the observed means.	

Generally, the results of LSD are showed that the mean differences of treatments are significant at the 0.05 level. The Multiple Comparisons of the maximum loads of chair type by LSD test are observed in Table 5. While multiple comparisons of the maximum loads of treatment have not a significant difference, its LSD results aren't present at Table 5.

Table 5: The results of multiple comparisons of Least Significant Difference test related to maximum loads of specimens

Comparing chair type;		
First chair	**Second chair**	**Sig.**
Control sample with sycamore wood	Rehabilitation sample with pine wood	0.047
Control sample with sycamore wood	Control sample with poplar wood	0.038
Control sample with sycamore wood	Rehabilitation sample with poplar wood	0.010
Rehabilitation sample with sycamore wood	Rehabilitation sample with poplar wood	0.028
The mean difference is significant at the 0.05 level, and Std. Error is 198.5		

Loading diagram and failure position of chair types are shown in Figure 2. The behavior of rehabilitation chair with GFRP and control chair under front-to-back loading were different as seen in Figure 2. The failure modes of chairs were changed due to rehabilitation with GFRP, and failure types are shown in Figure 3 and 4.

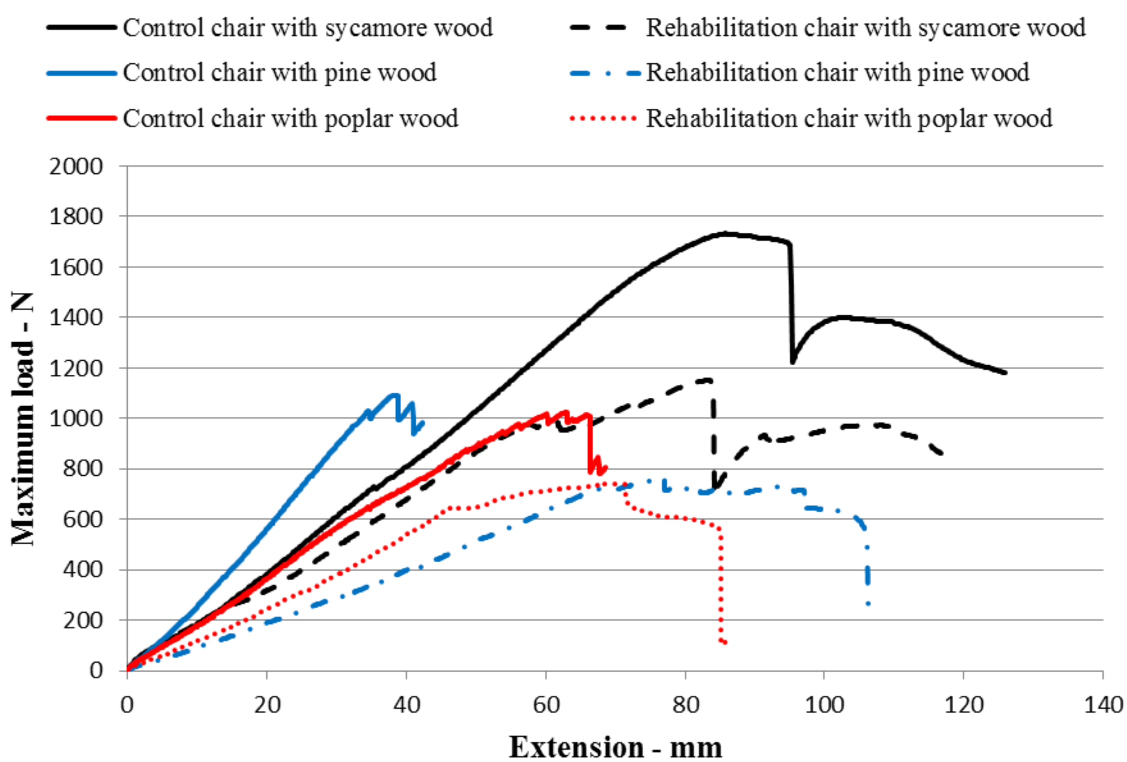

Figure 2: Loading diagram and failure behaviors of chairs

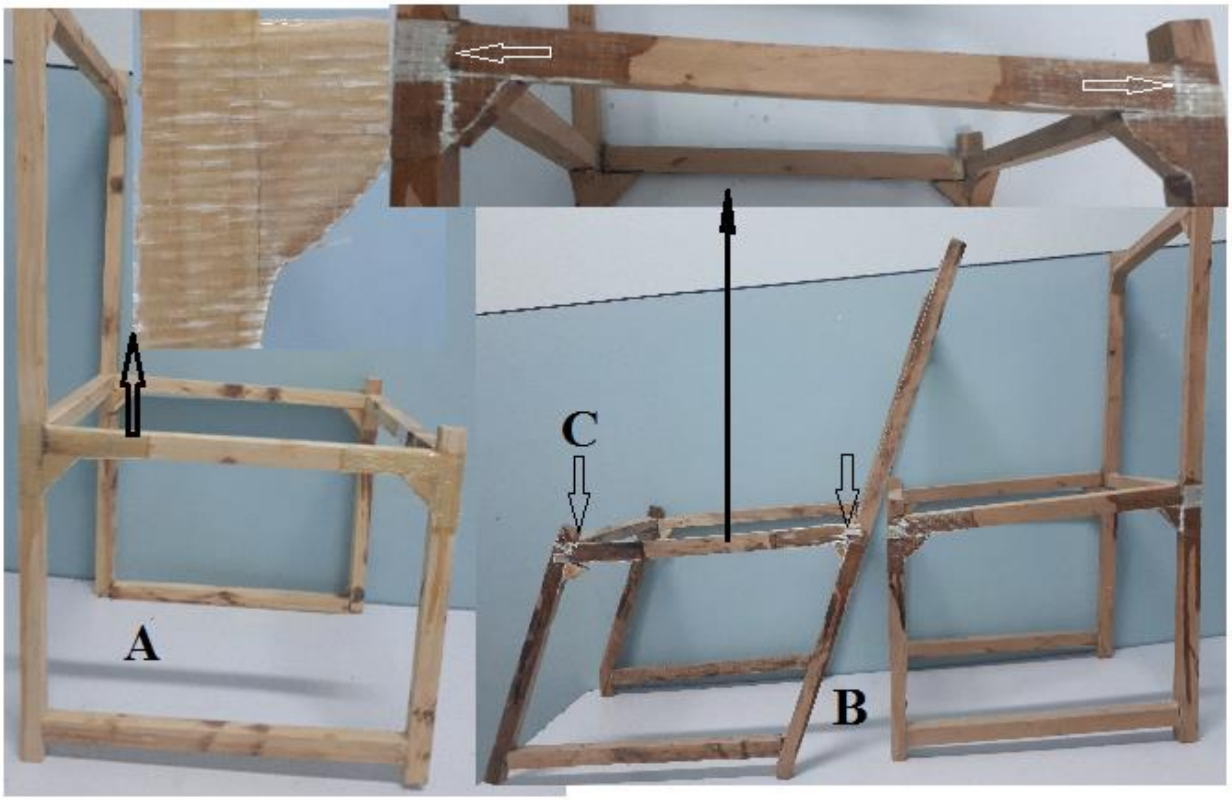

Figure 3: Rehabilitation chair with poplar wood and its repaired joint (A), Failure locations that occurred at repaired joints of rehabilitation type chair with sycamore wood (B), Failure locations that occurred at the repaired joint between the back or front post and side rail (C)

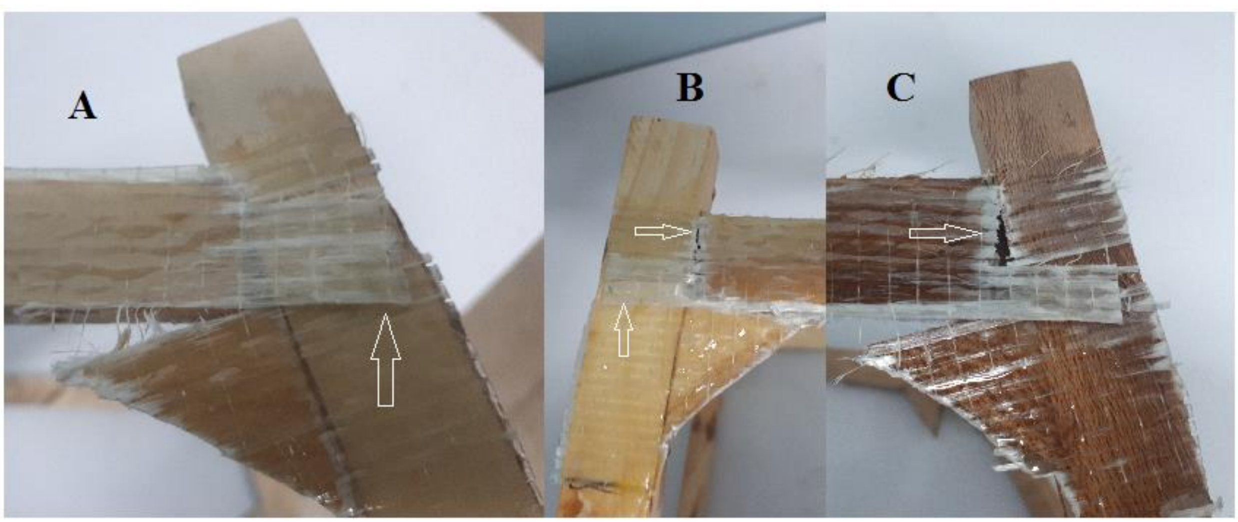

Figure 4: Failure modes of repaired joints with GFRP: failure modes of frame joint with poplar wood (buckling failure)(A), failure modes of frame joint with pine wood (Bursting and Buckling failure) (B), and failure modes of frame joint with sycamore wood (Bursting failure) (C)

This study result shows that the following treatment groups have the highest to the lowest strength, respectively: chair with solid wood made from sycamore wood, chair with solid wood made from pine wood, chair with solid wood made from poplar wood (figure 2 and table 3). The results showed that the maximum load was 1010 N for the control chairs made from solid wood. The strength of the chairs repaired with GFRP was 841 N. The weak chairs such as rehabilitation chair with poplar woods have minimum standard loads on the basis of DIN EN 1729-2 (2006), and these chairs are still strong enough to use (Table 3). Threshold values are related to functional dimensions. Functional dimensions of chairs are varied. Threshold values of back loads are equal to 50–180 N for small to large size of chair, and also, back static loads are 410–700 N, respectively. Threshold value of back static load is equal to 700 N for the size of school chair.

This results the rehabilitation chair of not only an environmentally friendly but also provides an excellent performance against applied load. The maximum loads of control chair is often same the rehabilitation chair. The supply of massive wood has been decreased in recent years. Reuse of wood products can be replaced with forest products because of increasing demand of wood products, decreased supply of raw materials and environmentally friendly issues. Strengthen of rehabilitation chair against front-to-back load can be caused to increase interest in remanufacturing. The rehabilitation chair would be replaced with chairs from massive wood.

Failure locations for control chair and rehabilitation chair under front to back load occurred at the joint between the back or front post and side rail. Uysal et al. (2015) argue that the parts' recovery with rectangular mortise and tenon joints was high when tenons were replaced with inserted tenons. In this study, wooden chairs were constructed with tenon and mortise joint that the parts' recovery with this joint was high.

Failure or separation types of GFRP are different on the surfaces of various wooden species. Separation of GFRP layers on the sycamore wood surfaces has seen as tear or bursting (figure 3B-C and figure 4C). The high level of crosslinking epoxy resin networks is responsible for this failure type (Hameed et al., 2007). But, separation of GFRP layers on the poplar wood surfaces have often seen as peeling that argued by Qi et al. (2015) (figure 4A). Loose texture and raised grain of poplar wood surfaces are caused to peeling separation of GFRP layers. Brittle failure and local buckling of the GFRP layers on the pine wood surfaces are seen together simultaneously (figure 4B). These failure types are also due to pitch streak or mineral pockets and mismatch texture. Since, if the number of layers of fiberglass reinforcement increases in three wooden species, only connection strength of GFRP layers on the sycamore wood surfaces will increase basis of published data (Soltis, et al., 1998) and also wood texture quality.

Chair with sycamore wood had superior performance based on the results of tests. Results of front to back load test showed that the rehabilitation chair with sycamore wood had better maximum load compared to the rehabilitation chair with poplar wood (Table 5). Also, their failure types showed the remarkable effect of wooden species type on the maximum load of rehabilitation or control chair (Figure 2 and 3). The mechanical strength of a wooden chair is affected by wooden species of component parts (Table 4). Chairs made from sycamore woods were stronger (1172 N) than other chairs made from pine woods (911) and poplar woods (693 N). The surfaces of the glue line are responsible for this decreased strength (Bayatkashkoli, and Hemmati, 2015). If the joint elements have a smooth surface, the contact angle between the glue and surface is low and glue line very clearly show the superior performance. Therefore, the strength of the structure frame increases against applied stress at the glue line. Generally, sycamore wood has a smooth surface is because the high density and condenser texture when compared with samples of pine and poplar woods (Table 2). Since, samples of sycamore wood have a better glue line performance than pine and poplar woods. Density and mechanical properties of sycamore wood have a more values when compared to other woods (Table 2). Chairs made of sycamore species are stronger than those made of pine and poplar species, because the mechanical and physical properties of sycamore wood are better than those of pine and poplar woods. Hence, chairs made of sycamore species are more resistant to the applied load, and chairs made from sycamore and other woods, are significantly different.

Repaired joints changed the failure behaviours at the chairs. The applied loads charts of rehabilitation chairs have uniform increased, and then its failure slope is low. But, line slope of failure chart at chair with solid woods is smooth more. The stress concentration is located in the joint line between back post and side rail. Since, chair with solid woods have a one-stage-failure. But, the front to back load is transferred by the GFRP to other parts of the rehabilitation chair. Subsequently, the front to back load is again concentrated in the joint between back or front post and side rail, and the glue line is split in this position. Therefore, repaired chair with GFRP have a two-stage-failure. Generally, chairs have a different failure that is due to different force distribution. Front to back load on the chair frame caused to the shear strength and axial forces occurred, and the load is transferred to side rail and joint line. It is useful to use the GFRP which increase the shear strength in the chair frame exposed to destructive loads.

Sycamore (*Platanus orientalis*), pine (*Pinus eldarica*) and poplar (*Populus nigra*) can be available as forest plantation. Availability of plantation trees is advantage, but its low quality is disadvantage. The chair performance can be decreased by low quality of plantation trees woods. Length of service life is one of the most important considerations in the design of furniture (Eckelman and Haviarova 2006). Length of service life can be increased with GFRP which used to repair the loose joints of chair frame. Since, plantation trees woods can be used for furniture manufacture, and rehabilitation of chair frame caused to increase the length of service life.

4 CONCLUSIONS

Glass fiber-reinforced polymers are considered as useful rehabilitation substance to destroyed chair made from plantation trees woods, though, plantation trees products woods that have a low quality and mismatch texture. The GFRP as reinforcement materials can improve the length of service life of these chairs. Rehabilitation with GFRP cause increasing resistant of chair frames against applied loading. Wooden species types and GFRP can impart helpful effects on repaired joints of chair frames. The results of the front-to-back loading tests showed that significant differences were found between the six different chairs. Chairs made of sycamore wood have the highest strength, because physical and mechanical properties of sycamore woods are better than poplar wood. Sycamore wood has a higher density, denser texture, smooth surface and more suitable adhesive bonding or GFRP bonding, and hence, its glue line or GFRP bonding occurred firm. Sycamore wood has a tight texture and chair frames made from this wood is able to increase the front to back load. But, pine and poplar woods have a low strength and these woods are not able to increase the GFRP bonding quality. Sycamore woods have a smooth surface that caused to increase the adhesion of GFRP bonding and also decrease its layers separation. Wood texture is one of the effective ways to enhance the joint strength. The strength deficiency of loose joint is compensated by GFRP. Chair made from sycamore wood had higher maximum load when compared to others because of density and stiff surface, and also, the chair made of poplar wood had less front-to-back load than others due to the presence of raised grain. From this study it can also be concluded that the performance of chair is strongly dependent on the wooden species types. High quality chair cannot be obtained from poplar or pine wood and its rehabilitation chair, but the plantation trees woods have the capacity for chair production with high quality. It is possible that the chairs made from plantation trees woods with acceptable strengths, as well as repaired chair by GFRP. The maximum front to back load of the chairs exceeds the standard value. The technique used which plantation trees woods can be used in furniture industry. The chair repairing process offers long of service life to chair significantly. The rehabilitation chair is considered as an environmentally friendly with increasing efficiencies in the uses plantation trees woods. All of the wood products would have some potential to be reused.

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ABSTRACT

In this study, it is aimed to determine bonding strength and combustion characteristics of structural laminated wood material reinforced with carbon fiber (CFRP). Laminated sheets were obtained using moisture curing polyurethane and two component epoxy adhesives prepared from Oriental beech (*Fagus orientalis* L.) wood samples. In this study, while bonding strength test was made according to BS EN 204 and BS EN 205 standards, combustion test was applied according to ASTM E-69 standard.

As a result of bonding tests, the highest bonding strength value (22.77 N/mm^2) was obtained in laminated sheets bonded with epoxy adhesive and reinforced with carbon fiber (CFRP). In combustion test, while the highest weight loss (31.38%) was found in experimental samples bonded with polyurethane adhesive, the highest temperature value (551.23 ^{0}C) was obtained in laminated sheets bonded with epoxy adhesive and reinforced with carbon fiber.

KEYWORDS: Laminated wood material, bonding strength, combustion characteristics, carbon fiber (CFRP), adhesive.

1 INTRODUCTION

The lamination technique allows the wood material to be used free from imperfections and the quality properties of the produced material are better than those of the massive wood material. Laminated wood materials are not only perfect but also aesthetic because they can be made from wood materials of different thickness and color in laminated layers (Keskin and Togay, 2004).

Nowadays, thanks to lamination technique applied to wood materials; it is increased the physical strength of the wood material and it is possible to obtained much longer single piece wood. In this technique, various materials such as various impregnation materials, special adhesives and carbon fiber (CFRP) can be added to around or layers of the wood material to increase the bonding strength of the wood material and increasing the burning time.

Luggin and Bergmeister (1998) investigated shear strength of glulam test specimens glued with epoxy resin and reinforced with carbon fiber. They found that shear strength of glulam test specimens were increased about 32%. Ogawa (2000) studied bending strength and combustion characteristics of wood reinforced with carbon fiber. Results showed that bending strength and combustion characteristics of wood material were improved about 300%.

In this study, it was aimed to investigate bonding strength and combustion of laminated sheets reinforced with carbon fiber and epoxy adhesive.

2. MATERIAL AND METHOD

2.1. Material

2.1.1. Wood Material

As a test material, Oriental beech (*Fagus orientalis* L.) was used. It is a material that full-dry density (D_0) 0. 68 g/cm^3, air-dry density (D_{12}) 0.72 g/cm^3. Also, its elasticity module is 15700 MPa, bending strength (σE) is 120 MPa, tensile strength in parallel with the fibers (σg) is 132 MPa, and the compression strength parallel to the fibers (σB) is 60 MPa (Bozkurt and Erdin, 2000).

2.1.2. Adhesives

Epoxy adhesive was provided by Dost Kimya Industrial Raw Materials Industry and Trade. Ltd. Co. It is a double component adhesive which is used for adhering solid materials to glossy surfaces, resistant to chemicals, providing excellent adhesion to concrete, wood, steel and plastic materials and reaching the desired mechanical strength very quickly. It was used with carbon fiber for the bonding of epoxy concrete elements, iron, steel and similar metals, types of wood and glass and assembly operations exposed to heavy and medium loads. Its density is 1.5 g / cm^3 at 20 ^{o}C and its viscosity is 1100 mPas. Usage of 200 g/m^2 in compliance with the company's proposal (Web-1).

Moisture curing polyurethane adhesive was provided by SBC Kimya Industrial Raw Materials Industry and Trade. Ltd. Co. It has resistant to water and moisture, solvent-free, one-component polyurethane based. Also, it is preferred in sea and lake vehicles, metal and wood parts of the installation and repair. Its density is 1.11±0.02 g/cm^3 at 20 ^{o}C and 14,000 ± 3,000 mPas at 25 ^{o}C. It hardens in 30 minutes at 20 ^{o}C ±2 temperature and 65±3 relative humidity environment. According to the manufacturer's recommendations, this adhesive is recommended to be applied to the package viscosity and to the surfaces at a rate of 150 g/m^2 until the absorption is high, as well as slightly moisturizing the dried surfaces (Altinok, 1988).

2.1.3. Carbon Fiber (CFRP) Material

In this study, the carbon fiber building materials have a density of 300 g / m^2 with 1.2 mm thickness in the dimension and form suitable for the strengthening work to be carried out. This material was provided by Dost Kimya Industrial Raw Materials Industry and Trade. Ltd. Co. It is a high abrasion resistance and extremely rigid material that high resistance compared to steel, very low density compared to metal. In addition, chemical resistances are high, light and unlimited size is suitable for production. Carbon fiber reinforced composite materials are generally used for used in aircraft industry, in rocket and satellite construction, in automotive industry, and in the construction of many sporting goods (Yildizhan, 2008).

2.1.4. Preparation of Experimental Samples

Experimental samples are provided according to TS 2470 standard by 'Random selection' method from timber enterprises in Karabük industry. Then, laminated sheets were obtained adding moisture curing polyurethane and two component epoxy adhesives and carbon fiber construction material. Component a (resin) and component b (hardener) of the two component epoxy adhesive used in the study were mixed 1/1 rate until a light gray color and applied with a spatula to the applied surface at 200 g / m^2. At the same time, care has been taken to cut the carbon fiber material properly with a modeling knife for the purposes of the fibers do not break off. The cut carbon fiber construction material was bonded with epoxy adhesive between and around of laminated sheets. The samples were subjected to press 2.5 kg/cm^2 press pressure, 20 ^{0}C degree temperature and under 60 minutes wait period. Then, the specimens were brought to the intended dimensions in appropriate standards for each test group. Ten replicates were used for each treatment groups.

2.2. Test Method

2.2.1. Air-Dry Density

The moisture content of the test samples was determined according to TS 2471, densities was determined according to TS 2472 standards. The test specimens were weighed on a 0.01 g precision scale after waited until being allowed to reach constant weight at 20 ± 2 ° C and 65% relative humidity in cabinet. After, the dimensions were measured by caliper in ± 0.01 mm sensitivity. Air-dry density (δ_{12}) value was determined in the following formula that according to air-dry weight (M_{12}) and air-dry volume (V_{12}) values.

$$\delta_{12} = \frac{M_{12}}{V_{12}} = g/cm^3 \tag{1}$$

2.2.2. Bonding Test

Bonding test specimens were prepared according to BS EN 204 and BS EN 205 standards and measuring 10x20x150 mm. The samples were tried to be pulled from the adhesive line by applying tensile strength to the bonding surface at a loading rate of 3 mm / min. The maximum force (Fmax) at break is determined and the bonding strength (σy) is calculated by the following formula:

$$\sigma y = \frac{Fmax}{A} = N/mm^2 \tag{2}$$

Here in;
A = axb = bonding surface area (mm^2)
F_{max} = applied force (N/mm^2). Example of bonding test is shown in Figure 1.

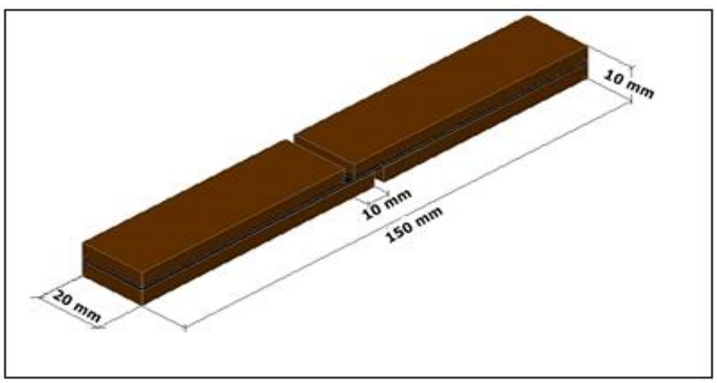

Figure 1: Example of bonding test

2.2.3. Combustion Test

Combustion test specimens were prepared according to ASTM E-69 standard and laminated at 9x19x1016 mm dimension. The samples were maintained for a total of 10 minutes for 4 minutes flame welding and 6 minutes flame-free combustion. At the end of the combustion, weight loss (g) and temperature (^oC) values were determined by the combustion test mechanism. The combustion test sample is shown in Figure 2.

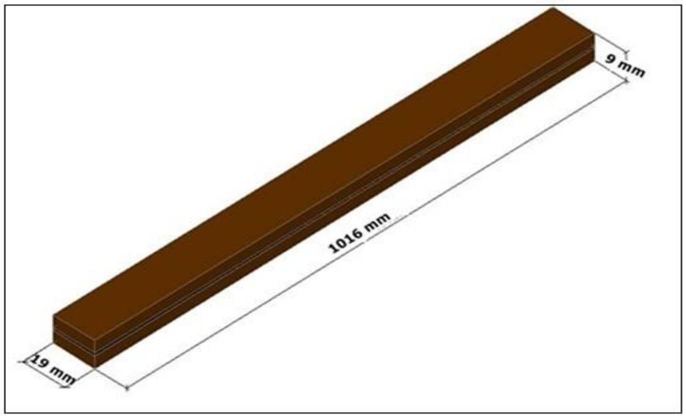

Figure 2: Example of combustion test

Statistical Evaluation of Data

Mechanical test results were evaluated by a computerized statistical program composed of analysis of variance and following DUNCAN test at the 95% confidence level. Statistical evaluations were made on homogeneity groups (HG), of which different letters reflected statistical significance.

3. RESULTS AND DISCUSSION

3.1. Results of Air-Dry Density

The mean values of air-dry density for the laminated samples are given in Table 1.

Table 1: Mean values for air-dry density

No	Sample type	Average (g/cm^3)
1	Epoxy between layers and CFRP around layers	1.79
2	Polyurethane between layers and CFRP around	1.68
3	CFRP and epoxy between layers (CFRP+epoxy)	1.77
4	Epoxy between layers (control)	1.72
5	Polyurethane between layers (control)	0.78

As a result of the experiments, the highest air-dry density value (1.79 g/cm^3) was obtained in laminated sheets bonded with epoxy between wood layers and covered with carbon fiber around wood layers. The lowest air-dry density value (0.78 g/cm^3) was found in laminated sheets bonded with polyurethane between wood layers (control).

3.2. Results of Bonding Test

The average values for the groups laminated as a result of the bonding test is given in Table 2.

Table 2: Arithmetic mean values for the bonding test (N/mm²)

No	Sample type	Bonding strength (N/mm²)	Standard deviation	Homogeneity group
1	Epoxy between layers and CFRP around layers	21.09	1.82	A
2	Polyurethane between layers and CFRP around layers	20.03	1.22	A
3	CFRP and epoxy between layers (CFRP+epoxy)	22.77	1.15	A
4	Epoxy between layers (control)	12.82	1.61	B
5	Polyurethane between layers (control)	10.60	10.9	B

The highest bonding strength values of the laminated samples were obtained (22.77 N/mm²) for samples bonded with carbon fiber and epoxy adhesive between wood layers (CFRP+epoxy). The minimum value (10.60 N / mm²) was found for samples bonded with polyurethane adhesive between wood layers. The adhesive type used in the laminated layers did not show any effect on the laminated samples without carbon fiber coating.

Ozcifci and Okcu (2008) studied bonding strength of oak (*Quercus petreae* L.) and chestnut (*Castanea sativa* Mill.) woods impregnated with borax and zinc chloride and bonded with moisture curing polyurethane. As a result, they were stated that these materials have a negative effect on bonding strength. They have found that the reason for this is due to the weakening of the bonds between surface and adhesive layer of the impregnation materials.

In this study, we obtained higher bonding strength with the epoxy than the polyurethane adhesive. In general, the wood material laminated with carbon fiber construction material and epoxy adhesive showed similarity to the information in the literature reinforcing bonding strength. The reason is that epoxy adhesives can harden rapidly at low and high temperatures, adhere very well to wood surfaces, and the strength values of oriental beech wood used in the work are high. However, it can be said that the carbon fiber has high tensile strength and it is used between epoxy resin and laminated layers to increase bonding strength. In addition, polyurethane (control) between wooden layers and epoxy (control) between wooden layers samples were found in the same homogeneity group. The results of the variance analysis to determine the effect of carbon fiber adhesive on bonding strength are given in Table 3.

Table 3: Variance analysis of the bonding test

Variance source	Sum of squares	Degrees of freedom	Average of squares	F (Account)	P value ($p \leq 0.05$)
Interaction	4621.41	1	4621.41	4498.16	0.00
Adhesive	25.89	1	25.89	25.20	0.00
Coating	3042.72	2	1521.36	1480.78	0.00
Adhesive * Coating	25.89	1	25.89	25.20	0.00
Error	46.23	45	1.02		
Total	7801.24	50			

According to the results of the analysis of variance, the effect of coating, adhesive and adhesive-coating interactions on bonding strength was found to be important in the 95% confidence interval.

3.3. Results of Combustion Test

3.3.1. Weight Loss Values (g)

The weight loss values for the combustion test are given in Table 4.

Table 4: Mean weight loss values for the combustion test (g)

No	Sample type	First weight (30 second)	Flame welded weight (240 second)	Final weight (600 second)	Homogeneity group
1	Epoxy between layers and CFRP around layers	97.75	64.05	15.21	B
2	Polyurethane between layers and CFRP around layers	96.73	66.18	16.24	C
3	CFRP and epoxy between layers (CFRP+epoxy)	97.56	78.19	17.74	B
4	Epoxy between layers (control)	94.19	62.01	1.49	A
5	Polyurethane between layers (control)	96.65	81.03	31.38	B

At the end of flame welding, the lowest weight loss average value (62.01%) was determined in epoxy (control) adhesive samples, while the highest weight loss value (81.03%) was found in polyurethane (control) adhesive samples. Köse (2008) studied the average weight loss of laminated materials by adding phenol formaldehyde, melamine urea formaldehyde, and urea formaldehyde adhesives to the impregnated Scotch pine and poplar woods with various chemical substances. According to the results, the highest weight loss (91.90%) was found in the samples with urea formaldehyde glue, while the lowest weight loss (86.88%) was detected in the samples with phenol formaldehyde glue. Borax, boric acid, borax + boric acid, and ammonium phosphate chemical substances used here in may have increased combustion resistance of the samples. In addition, the samples laminated with epoxy (control) and polyurethane (control) adhesives were statistically different but no significant difference was found between the polyurethane (control) samples and carbon fiber and epoxy adhesive samples (CFRP+epoxy) between wood layers.

The results of the variance analysis to determine the effect of carbon fiber and adhesive on weight loss are given in Table 5.

Table 5: Variance analysis of weight loss values for combustion test

Variance source	Sum of squares	Degrees of freedom	Average of squares	F (Account)	P value ($p \leq 0.05$)
Interaction	550300.36	1	550300.36	9277.83	0.00
A: Sample type	10537.526	2	5268.76	88.82	0.00
B: Measurement time	106179.232	19	5588.38	94.21	0.00
A*B	2423.72	38	63.78	1.07	0.00
Error	5931.34	100	59.31		
Total	724341.79	160			

According to the variance analysis results, when the sample type and measurement time were examined separately, the effects on the weight loss mean values (p≤0.05) were found to be significant. However, measurement time and sample type interactions were found to be significant.

3.3.2. Temperature Values (g)

The temperature values for the combustion test of the laminated groups were given measurements every 30 seconds are given in Table 6.

Table 6: Average temperature values for the combustion test (°C)

No	Sample type	First temperature (30 second)	Flame welded temperature (240 second)	Final temperature (600 second)	Homogeneity group
1	Epoxy between layers and CFRP around layers	133.45	225.13	548.86	C
2	Polyurethane between layers and CFRP around layers	132.18	222.34	546.45	C
3	CFRP and epoxy between layers (CFRP+epoxy)	131.03	219.86	551.23	B
4	Epoxy between layers (control)	150.94	238.07	305.72	B
5	Polyurethane between layers (control)	101.09	202.02	320.64	A

The highest temperature value measured at the end of flame welding (240 second) was found in epoxy (control) adhesive between wooden layers (238.07 °C), while the lowest temperature value was found in samples laminated with polyurethane (control) adhesive between wooden layers (202.02°C). At the end of combustion (600 second), the highest temperature value was detected in the carbon fiber and epoxy adhesive (CFRP + epoxy) samples (551.23 °C) between wooden layers, the lowest temperature value was obtained in epoxy (control) adhesive samples (305.72 °C) between wood layers. The carbon fiber and epoxy adhesive samples (CFRP + epoxy) between wooden layers and epoxy (control) adhesive samples between wooden layers were found in the same homogeneity group.

The results of the variance analysis made to determine the effect of sample types on the temperature values are given in Table 7.

Table 7: Variance analysis of temperature values for combustion test

Variance source	Sum of squares	Degrees of freedom	Average of squares	F (Account)	P value (p≤0.05)
Interaction	1.01	1	1.01	2265.58	0.00
A: Sample type	278415.28	2	139207.64	31.29	0.00
B: Measurement time	1187725.46	19	62511.86	14.05	0.00
Interaction A*B	399763.33	38	10520.08	2.36	0.00
Error	444786.80	100	4447.86		
Total	1.25	160			

According to the results of the analysis of variance, it was determined that the effect of the sample type and the measurement time on the average temperature values of the samples in the combustion (p≤0.05) was significant. It was also found that the interaction of measurement time and sample type was significant in the 95% confidence interval.

4. CONCLUSIONS

As a result of the bonding test, it was determined that the average bonding strength was the highest (22.77 N/mm^2) in the sample types laminated with carbon fiber building material and epoxy adhesive (CFRP +epoxy) between the wood layers. It also increased by 114,81% compared to control groups. Therefore, it can be used for strength damaged parts of wood structures and restoration workings by using carbon fiber and epoxy adhesive. It can be said that extends the wear time of the wood as a result of bonding the laminated wood material with high strength of epoxy adhesive.

As a result of combustion test, the highest weight loss in weight loss mean values was found in polyurethane (control) adhesive samples at 31.38%, while the lowest weight loss value was determined in samples laminated with epoxy (control) adhesive at 1.49%. In addition, the highest temperature value was determined in the samples laminated with carbon fiber building material and epoxy adhesive (CFRP + epoxy) between wooden layers, while the lowest temperature value was determined in the samples bonded with epoxy adhesive.

As a result of the work, carbon fiber can be preferred especially for timber construction elements due to the fire retardant effect. When carbon fiber and epoxy adhesives are used together on the exterior and interior fronts of wooden houses, it can extend the duration of the effects of any kind of dangers such as fire.

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Investigations on Wood Destroying Marine Borers in The Turkish Coastal Waters

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INVESTIGATIONS ON WOOD DESTROYING MARINE BORERS IN THE TURKISH COASTAL WATERS

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ABSTRACT

Wood is used in the marine environment for several purposes such as groynes, wharves, jetties, dolphins, and navigational posts. It is also important material in the boat construction in many countries due to the wide availability, ease of fabrication, repair and maintenance, strength and elasticity properties. In the marine environment, wood is susceptible to attack and deterioration by marine wood-borers. Temperature and salinity of the seawater influence the distribution of wood-boring organisms. Most studies on wood durability in the marine environment involved in using of tropical timbers as well as wood preservatives or modified wood in different test sites in the world. Although Turkey is surrounded on three sides by the sea, less attention has been given to the marine borers and protection of wood in the marine conditions. The existence of *Teredo navalis* (shipworm) in the deep waters of Marmara was reported by early investigations. *T. navalis* was also found to be dominant species in the Western part of the Black Sea, heavily destroyed the Scots pine samples in one year. Investigations revealed that CCA and creosote shoved resistance to marine borers while the performance of copper azole was promising in the Black Sea. From the tropical wood species, wenge, douka, azobe and paduk showed great resistance to marine borers in the Turkish coastlines. Test sites in Trabzon, Ereğli and İskenderun exhibited the highest boring activity in comparison to the other test locations. *Bankia carinata*, *Nototeredo norvagica*, *Teredo navalis*, *Lyrodus pedicellatus* and *Limnoria tripunctata* were found in the wood samples in the Southern coasts of the Turkey. *Teredothyra dominicensis* was identified as an invasive species in the coast of Kaş in Antalya. DNA barcoding study proved that there was no difference in the barcodes of *N. norvagica* collected from the Atlantic and the Mediterranean Sea.

KEYWORDS: Marine wood-borers, Teredinids, Limnoriids, Turkish coastal waters

1 INTRODUCTION

Wood material has been used for centuries to meet the needs of human beings. Because, wood has unique characteristics compared to alternative materials such as renewability, the aesthetic appearance, its performance from past to today, the design and flexibility in use and manufacturing, easy repair and maintenance, high strength and elasticity under load.

Due to the wide availability and easy of fabrication and repair, wood has been the main resource used in the construction of rafts, boats, ships and maritime structures (Borges 2014a; Cragg et al., 2001). Liphschitz and Pulak (2007) investigated the identification of wood species used in ancient shipbuilding in the Eastern Mediterranean. Lebanese cedar, Calabrian pine, Corsica pine and Turkey oak were the main wood species used in wooden shipbuilding in their report.

In the marine environment, wooden materials are susceptible to attack by wood borers. Although microorganisms decay the surface of wood in the sea water, marine borers molluscs and crustaceans are the cause of the wood destruction. The superficial decay of microorganisms accelerates the settlement of marine borers on the wood surface (Eaton 1985). The boring organisms include Bivalvia (Teredinidae and Pholadidae), Isopoda (Limnoriidae and Sphaeromatidae), and Amphipoda (Cheluridae).

Wood is generally impregnated with preservatives or tropical species is used against marine borers, another alternative is the using of physical barriers. Impregnation of wood with creosote or chromated copper arsenate provided resistance to marine borers and this application was found economically viable. However, such these traditional preservatives has been limited by European Commission (2003) in marine structures due to the environmental concerns. Naturally durable timbers from tropics are widely used in marine structures, but a few species particularly has a high demand because of their reputation in this field. For example, tropical species such as turpentine and greenheart shows resistance against teredinids are not immune to attack by limnoriids (Borges et al., 2008).

Wood-boring organisms cause economic damage to the structures such as wharves, piers, groynes, lock gates, house stilts and other facilities used in the marine (Cragg et al., 1999). The damage to submerged coastal structures was estimated to be $1 billion annually in the USA, and crustacean borers was mainly shown as responsible for this cost (Boyle 1988). Estimated economic loss was reported to be ranged from 300 to 3000 million Rs. annually due to the wood borers in India (Karande and Chongdar 2001). The cost of damage by limnoriids has been estimated to be of the order of billions of Euros worldwide (Borges et al., 2014b).

Marine borers are also a major threat to the cultural heritage under water. For example, shipworm, Teredo navalis can cause great destruction to wooden archaeological remains in the marine environment. (Eriksen et al., 2016).

The activity of marine wood-borers is still of great concern in Europe. Several factors including climatic change, physiological and ecological mechanisms probably have an effect on the increasing of the wood-borer attack. For this purpose, an exploratory workshop on "Marine wood borers: new frontiers for European waters" was held in Venice in 2013. The main output of this workshop was to establish a research network that coordinates scientists with a global perspective, to create new research areas on wood-boring organisms and to cooperation in the future (Tagliapietra et al., 2013).

The aim of this paper is to introduce marine wood-borers, take attention to the destructive effect of these organisms in wooden structures, and present investigations performed in the Turkish waters.

2 MARINE WOOD-BORERS

There are four kinds of wood-boring organisms living in the sea, two of which are crustaceans and the other two are molluscs. The destruction of wood in the sea is mainly carried out by wood-boring molluscs and crustaceans and their diagnostic methods are given by Turner (1971a) and Kühne (1971).

2.1 Molluscs

The molluscs comprise the species belonging to teredinids and pholads. Although the teredinids are widespread throughout the world, the distribution of pholads is limited and live in temperate and salty tropical waters (Eaton 1985).

Teredinids or shipworms are bivalve molluscs and Lyrodus, Bankia, Teredo and Nausitora are known the members of Teredinids. Teredinids can attack wood from mud-line to mid-tide, but the most severe attack is near the mud-line. The shell in these organisms is small and covers the front of the animal act as a rasp in the boring of wood. Teredinids release microscopic larvae in the sea water, become active between 1 and 30 days depending on the development stage and can grow up to two meters in length (Cookson 1986). Most of the teredinids are grown feeding in the wood and at the same time filter feed. Cellulolytic nitrogen-fixing bacteria were also isolated from teredinids (Waterbury et al., 1983).Distribution of the larvae can take place by the way of currents or ballast water in the ship. Even, the adults of *T. navalis* can be spread by driftwood (MacIntosh et al., 2012).

If the larvae settle on a substrate like untreated wood, begin to bore for entry holes. These holes on the wood are hardly visible since the larvae are too small. Therefore, the surface of the wood may appear sound but the interior is riddled. After settlement, a larva develops in to adult form, wormlike in the burrow where the calcareous substance secreted by the borer is deposited. Shipworms contain a pair of siphons and a pair of calcified pallets at the posterior of the body. The function of the siphons is the intake of seawater and the expulsion of the waste while the pallets close off the burrow to protect the borer from the predators. The structure of the pallet is of great importance due to the identification of the species (Johnson 1986).

Another group of molluscs is the pholad, destroying wood in the sea and *Martesia striata* L., is the most well-known species, which causes significant damage in the wood. *M. striata* live in tropical and subtropical waters with high salinity, and is fed by filtering the water like Sphaeroma species. They do not feed with wood, only burrow wood and produce pear-shaped tunnels (Turner and Johnson 1971). Pholads are not as destructive as teredinids for some reasons such as less widely distributed, have no ability to close off burrows by their pallets and do not burrow deeply (Johnson 1986).

Researches on marine trials stated that the increase in temperature in the sea water led to an increase in the numbers and activities of marine wood-borers. In addition, another factor that affects the distribution of marine wood-borers is the salinity in the sea water (Turner 1971b).

2.2 Crustaceans

The most important species of wood-boring crustaceans are Limnoria, Sphaeroma and Chelura. While Limnoria species spread throughout the world from cold water to warm water, Sphaeroma live in mild salty water. The diagnosis of these organisms is made on the basis of their external morphological characteristics (Eaton 1985).

Limnoria are from small crustaceans, 1-4 mm in length, and borrow the wood for feeding. They are from the group of invertebrates and degrade the cellulose in wood without the aid of any microorganisms since they produce own cellulase enzyme. They form small ventilation holes in the longitudinal direction in borrows, close the wood surface. Limnoria can attack wood anywhere from mud-line to mid-tide, rarely seen in the areas where the salinity is below 25 parts per thousand. Important species of Limnoria are *L.tripunctata*, *L.quadripunctata* Holthuis and *L. indica* Becker and Kampf. *L.tripunctata* Menzies is a widely studied species of limnoriid in the world (Barnacle et al., 1983).

Sphaeroma species are from crustaceans, larger than Limnoria, and can grow up to 8-14 mm in length. Among these species, three important wood-boring are *S.terebrans* Bate, *S.quoyanum* Milne Edwards and *S. Treste* Heller. Sphaeroma species can tunnel in the wood, sandstone, weak concrete and polystyrene materials. The cavities are small and in the same direction with the surface. Sphaeroma species produce an appearance like hourglass in the destruction of the wooden poles, can destroy wood in the waters where the salinities ranging from 10 to 35 parts per thousand (Cookson 1986).

Sphaeroma species are fed by filtering the seawater. They burrow wood, but do not feed with wood. However, the data obtained from the laboratory feeding experiment showed that *S. terebrans* had the ability to use the wood as food source. *S. terebrans* is widespread in tropical and subtropical estuarine waters and may burrows in cypress, cedar, palm, and pine (Benson et al., 1999).

Three species of chelurids *Chelura terebrans*, *Chelura insulae* and *Chelura brevicauda* were introduced by Kühne (1971). From these species, *C. terebrans* shows worldwide distribution in temperate and subtropical regions. Chelura attack is usually associated with limnoria in the maritime timbers in which chelura generally occupies the outer region whereas limnoria is found interior of the wood. The chelurids have less tolerance than limnoriids with regard to environmental change such as low salinity or low-oxygen conditions. Thus, the chelurids are the least important of the crustacean borers (Eaton and Hale 1993).

3 TEST METHOD AND EVALUATION IN THE MARINE TRIALS

For the marine exposure, Scots pine (*Pinus sylvestris*) is used as a reference sample. Wood samples are prepared to 25 × 75× 200 mm in size according to the EN 275 standard (1992). Wood is drilled on the center to a connection hole of 25 mm diameter. At least 5 replicates samples are used for each protection system and test site, and also 5 for control. Full-cell process is required for the samples to be impregnated.

The test specimens should be deployed within 6 meters below the waterline into a medium height. The samples should be inspected every year for a five-year testing period. Assessment of the samples is carried out based on the X-ray inspection and visual evaluation. In the X-ray inspection, each sample is rated according to damage by marine borer attack from 0 to 4. In this system, zero (0) indicates no attack, 1 little damage, 2 moderate damage, 3 severe destruction and 4 means complete destruction.

4 MARINE TRIALS IN THE TURKISH WATERS

First investigation was held in the Marmara Sea where *T. navalis* was identified in Turkey (Demir 1954). Berkel reported that maritime structures around Istanbul was destroyed by teredinids in a short period. Sekendiz (1981), examined the *T.navalis* damage in the Black Sea and drew attention to the presence in the Turkish waters.

In the earlier times, a considerable study was conducted by Pınar (1997), covering the test sites in the Black Sea, Marmara, Aegean and the Mediterranean Sea in 1968. Test sites were selected in Amasra, Istanbul, Çanakkale, İzmir and Mersin where the test material exposed to marine borers for 12 months. Observations on the untreated black pine panels revealed that *Noroteredo norvagica*, *Limnoria tripunctata* and *Chelura* *terebrans* were the identified species. The activities of these organisms were found to be very high in all test stations except İzmir. The activity of *T. navalis* in Amasra and *L. tripunctata* in Mersin were found to be more active.

Effectiveness of the creosote and CCB (Copper, chrome, Boron) wood preservatives against marine borers by using Scots pine, fir, beech and oak wood species was studied by Bobat (1994). Control and impregnated samples were left at the test stations located in İzmit (Derince) and Mersin (Erdemli) and in Trabzon port for 14 months. At the end of the marine trial, it was determined that the samples in the Marmara Sea were not destroyed. Control samples excluding oak wood in the Mediterranean and the Black Sea were totally destroyed by marine wood-borers, while oak control specimens were found more durable than the others. A few mollusc were seen in the Scots pine and oak samples impregnated with CCB in the Mediterranean and the Black Sea, and the best results was obtained by the creosote treated samples. In the control samples exposed to the Mediterranean Sea, marine wood-borers *Lyrodus pedicellatus*, *Teredo utriculus* and *Bankia carinata* were recorded, while in the Black Sea only *T. navalis* was encountered in the control samples.

Scots pine sapwood and heartwood, oak and chestnut samples impregnated with CCA were tested in the Black Sea (Amasra) for twelve months. A heavy attack of *T. navalis* occurred in the Scots pine control panels. However, CCA treated Scots pine samples showed great resistance to marine borers, while treated samples of oak and chestnut were moderately attacked. In addition, dynamic MOE measurement indicated good correlation between untreated wood and treated wood in the assessment of borers attack (Sivrikaya et al., 2012).

Copper azole wood preservative, free of chromium and arsenic, was performed against marine borers in Amasra for 7 and 14 months intervals. *T. navalis* has been the only species, as it was in the earlier study, identified on wood panels. No damage was observed on the impregnated Scots pine and fir samples except for a few specimens at the end of 7 and 14 months exposure period. All control panels were attacked heavily, while moderate attack was seen on the black pine impregnated panels (Sivrikaya et al., 2016).

Industrial wood species used in wood yacht, boat and harbour constructions have been tested against wood-boring organisms in the Mediterranean Sea. In this context, Scots pine, oak and chestnut species were exposed to marine conditions over five months in Erdemli. During the study, the activity of teredinids was found to be very high and the most damage was observed in Scots pine sapwood and heartwood panels and followed by oak and chestnut respectively. Approximately half of the identified teredinids were *T. navalis*, one-fourth were *B. carinata* and the other one-fourth were *N. norvagica*. From crustaceans, chelura sp., economically less important than other species, found only in the chestnut panels (Sivrikaya et al., 2009).

A comprehensive study was carried out by Şen et al. (2009) in the Turkish waters covering the Black Sea, Mediterranean, Aegean and Marmara Sea, determining the performance of 18 wood species from Europe and 15 from tropical woods against marine borers for 14 months. From the European species hornbeam, elm, Austrian pine, Scots pine (*Pinus sylvestris*), ash (*Fraxinus excelsior*), beech (*Fagus orientalis*) alder (*Alnus glutinosa*) and fir (*Abies nordmanniana*) were severely attacked by marine borers while olive wood samples were slightly damaged. Tropical species such as wenge (*Millettia laurentii*), douka (*Tieghemella heckelii*), azobe (*Lophira alata*) and paduk (*Pterocarpus soyauxii*) showed high resistance to boring organisms. From the commercial ports, Trabzon, Ereğli and İskenderun showed the highest boring attack. However, slight attack was shown in the marinas of Bandırma, Alaçatı and Finike. In overall experiments, 5 wood-boring organism species and 26 fouling species were identified. When compared to test stations, *T. navalis* and *L. pedicellatus* were exist in all test sites, whereas *N. norvagica* was only found only in Trabzon and İskenderun ports and *B. carinata* only in İskenderun port. From the crustaceans, *L. tripunctata* was only identified in the test sites in Finike and İskenderun (Şen et al., 2010).

To draw attention to the destruction of wooden shipwreck under water, the replica of the historical Uluburun (III) shipwreck was built, made of *Pinus brutia* including sapwood and heartwood, and deliberately sunk in the Kaş in the Eastern Mediterranean Sea in 2006. Neither wood preservatives nor surface protection was applied in the building of the replica. The degradation of the shipwreck was monitored by several dives throughout four years. The survey revealed that the hull planks and other wooden parts and frames were heavily destructed by shipworms at the end of the October 2009. The complete destruction took place in August 2010. The only remaining parts of the wreck were the mast, frame and keel, found scattered along the seabed. The obtained shipworms from the wreck concluded that the ship was infested by *N. norvagica* and *Teredothyra dominicensis*. *T. dominicensis* was the dominant species representing 92% of the shipworms collected, has previously never been reported in the Mediterranean Sea before. This wood borer was previously reported in the Caribbean Sea and The Gulf of Mexico (Shipway et al., 2010).

Identification of wood-boring teredinids according to their morphological characteristics is quite difficult. Because, the shell morphology of teredinids shows high intra-species variability, so their diagnosis is made according to the palette morphology.

To obtain precise result, Borges et al. (2012) conducted a research in which morphological evidence and mitochondrial and DNA sequences were combined to obtain a taxonomic solution in some species of teredinids. Specimens were collected in France from three areas, from Erdemli in Turkey, and the other specimens were obtained from a shipwreck site in Kaş, Turkey. According to obtained results, DNA barcodes of Atlantic and Mediterranean populations of *L. pedicellatus* diverged by 20% indicated the cryptic species. The low intra-species divergence in barcodes of *N. norvagica* specimens suggests that the Atlantic and Mediterranean forms are the same species. *T. dominicensis* was detected for the first time in the Mediterranean, and it was reported that this was the same species found in the Caribbean Sea. It was also mentioned that *B. carinata* from the Mediterranean and Caribbean may indicate cryptic species.

In addition, first occurrences of the warm-water shipworm *Teredo bartschi*, collected from Mersin, Turkey, and Olhão, Portugal was examined. It was estimated that this species found in Mersin came by rafting from the Red Sea along the Suez Canal. This was the first time that the existence of this species in the Mediterranean and the North East Atlantic was reported by Borges et al. (2014c).

Recently, biogeographic distribution of marine wood-borers in Europe has been conducted by the scientists from Eurolag and European network. Scots pine panels were exposed simultaneously in lagoons, estuaries and harbours. Experiments were carried out in 21 sites spread over 13 Countries, covering from the South Mediterranean to the Baltic and from the Black Sea to the Atlantic Ocean. Zonguldak port in Western part of the Black Sea was one of the test sites where wood borer *T. navalis* only identified. This result has confirmed again the domination of this species in the Black Sea (Guarneri et al., 2018).

5 CONCLUSIONS

Turkey is surrounded by the sea on three sides and wood is used for boat and yacht building and for various purposes such as construction of piers and docks. Marine borers either molluscs or crustaceans are the main biological hazards for wood in the marine environment. In addition, invasive species, originating from the other parts of the world increase the biodiversity and also threat to the facilities or materials, even cultural heritage made of wood under the sea water.

Therefore, more attention should be paid to the presence of marine wood-borers and distribution of them in the Turkish waters. On the other hand, researches are needed to develop novel protection methods, environmentally friendly, against marine wood-borers.

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Examination of Working Capital Determinants of Companies Operating in Forest Products, Furniture, Paper-Paper Products and Printing and Publishing Sectors

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ABSTRACT

Working capital is of great importance to companies for the following reasons. These: (1) to start production, (2) to continue their activities, (3) to not fall into a difficult situation financially, (4) to meet their obligations on time.

In this study, it was aimed to determine the factors affecting the working capitals of companies operating in the forest products, furniture, paper-paper products and printing and publishing sectors traded on Istanbul Stock Exchange (BIST). 12 different ratios and values of 18 companies with the help of the 2016 data were used for analysis. As a result of using multiple regression and correlation methods, factors affecting the working capital have been determined

KEYWORDS: Working Capital, BIST, Forest Products-Furniture-Paper- Paper Products-Printing and Publishing Sectors

1 INTRODUCTION

In production environments where resources are scarce and limited, financial management, which aims to maximize company value, has to capture the optimum level in asset structuring. In the asset structuring consisting of the combination of fixed and current assets, the weights of the two main elements can changed according to the sector, size, economic conditions and many different factors. Financial management, which focuses attention on long-term financial decisions and long-term financial investments, may have shortcomings in taking short-term financial decisions (Arslan, 2003; Büyükşalvarcı and Abdioğlu, 2010). The supply of fixed assets is mostly financed by long-term resources and equity resources and they can also be rented (Nazir and Afza, 2008), but such an alternative is not possible for the current asset structure, which requires daily activities and short-term preferences.

The working capital, representing a significant portion of the current asset structure, represents the amount of capital that fulfils the function of working with fixed assets and meeting short-term needs of companies. The sustainability of short-term activities that constitute a key element of long-term success requires a successful working capital management. Working capital, which has significant effects on the profitability, risk situations and values of the companies, ensures that companies operate at full capacity, they can continue their production without interruption, they can increase their credit value and they do not have in financial difficulty (Erdinç, 2018). The working capital, which will ensure that companies are ready for all the changes that will take place in the production environment can be achieved through successful financial management. The reason for the success and long-term high profit levels of the companies is the success of the working capital (Appuhami, 2008).

2 MATERIAL AND METHOD

This study was carried out in order to determine what variables affect the working capital requirements of the Forest Products Industry and Paper and Paper Industry Sectors operating in the BIST. BIST has 4 companies in the forest products and furniture industry and 14 companies in the paper and paper products industry.

Forest Products and Furniture Industry
Doğtaş Kelebek Mobilya Sanayi ve Ticaret A.Ş.
Gentaş Genel Metal Sanayi ve Ticaret A.Ş.
Orma Orman Mahsulleri İntegre Sanayi ve Ticaret A.Ş.
Yonga Mobilya Sanayi ve Ticaret A.Ş.
Paper and Paper Products, Printing and Publishing Industry
Saray Matbaacılık Kağıtçılık Kırtasiyecilik Ticaret ve Sanayi A.Ş.
Bak Ambalaj Sanayi ve Ticaret A.Ş.
Doğan Gazetecilik A.Ş.
Duran Doğan Basım ve Ambalaj Sanayi A.Ş.
Doğan Burda Dergi Yayıncılık ve Pazarlama A.Ş.
Hürriyet Gazetecilik ve Matbaacılık A.Ş.
İhlas Gazetecilik A.Ş.
Kaplamin Ambalaj Sanayi ve Ticaret A.Ş.
Kartonsan Karton Sanayi ve Ticaret A.Ş.
Olmuksan International Paper Ambalaj Sanayi ve Ticaret A.Ş.
Prizma Pres Matbaacılık Yayıncılık Sanayi ve Ticaret A.Ş.
Mondi Tire Kutsan Kağıt ve Ambalaj Sanayi A.Ş.
Viking Kağıt ve Selüloz A.Ş.
Alkim Kağıt Sanayi ve Ticaret A.Ş.

In the study, which is based on the data of the companies in the year of 2016, the values that are considered to affect the working capital needs of the companies as a result of the literature search were determined and the variables decided to be used for the analysis were obtained from the official web site of the Public Lighting Platform (Web-1). The 11 variables identified are defined in Table 1.

Table 1: Variables used for analysis

Variables	Definitions
Working Capital Requirement (WCR)	$\frac{(Trade\ Receivables + Inventories) - (Trade\ Payables + Other\ Payables)}{Total\ Assets}$
Leverage Ratio (LR)	$\frac{(Short\ Term\ Debt + Long\ Term\ Debt)}{Total\ Assets}$
Return on Asset Ratio (RAR)	$\frac{Net\ Profit\ for\ The\ Period}{Total\ Assets}$
Equity Profitability Ratio (EPR)	$\frac{Net\ Profit}{Equity}$
Earnings Before Interest, Tax and Depreciation (EBITD)	*Company's Profit Margin Before Interest, Tax and Depreciation*
Percent Sales Growth (PSG)	$\frac{Current\ Period\ Net\ Sales\ (t)}{Prior\ Period\ net\ Sales\ (t-1)}$

Stock Turnover Ratio (STR)	$\frac{Cost\ of\ Goods\ Sold}{Average\ Invertory}$
Receivables Turnover Ratio (RTR)	$\frac{Net\ Sales}{Average\ Trade\ Receivables}$
Gross Profit Margin (GPM)	$\frac{Gross\ Sales\ Profit}{Net\ Sales}$
Fixed-Asset Turnover Ratio (FATR)	$\frac{Fixed\ Asset}{Total\ Assets}$
Tobin's Q Value (TBQ)	$\frac{(Trade\ Payables + Market\ Value\ of\ the\ Company)}{Total\ Assets}$
Natural Logarithm of The Company's Market Value (LNM)	*Natural Logarithm of Current Year Market Value*

The hypotheses used to determine the variables affecting the working capital requirement are given below.

H_{01}: There is no significant relationship between the companies' working capital requirement and the leverage ratio.

H_{02}: There is no significant relationship between the companies' working capital requirement and the return on asset ratio.

H_{03}: There is no significant relationship between the companies' working capital requirement and the equity profitability ratio.

H_{04}: There is no significant relationship between the companies' working capital requirement and the profit margin before ınterest, tax and depreciation.

H_{05}: There is no significant relationship between the companies' working capital requirement and the percent sales growth.

H_{06}: There is no significant relationship between the companies' working capital requirement and the stock turnover ratio.

H_{07}: There is no significant relationship between the companies' working capital requirement and the receivables turnover ratio.

H_{08}: There is no significant relationship between the companies' working capital requirement and the gross profit margin.

H_{09}: There is no significant relationship between the companies' working capital requirement and the fixed-asset turnover ratio.

H_{010}: There is no significant relationship between the companies' working capital requirement and the Tobin's Q value.

H_{011}: There is no significant relationship between the companies' working capital requirement and the natural logarithm of market value.

The econometric model created to test the hypotheses was shown below. The least squares method was used to estimate the generated model.

$$WCR_x = ß_0+ß_1LR_x + ß_2APR_x + ß_3EPR_x + ß_4EBITD_x + ß_5PSG_x + ß_6STR_x+ß_7RTR_x + ß_8GPM_x + ß_9FATR_x+ ß_{10}TBQ_x + ß_{11}LNM_x + \epsilon_x$$

The variables and their expression in the model are as follows;

WCR: the "x" company's working capital requirement

LR: the "x" company's leverage ratio

RAR: the "x" company's return on asset ratio

EPR: the "x" company's equity profitability ratio

EBITD: the "x" company's profit margin before interest, tax and depreciation

PSG: the “x” company's percent sales growth
STR: the “x” company's stock turnover
RTR: the “x” company's receivables turnover
GPM: the “x” company's gross profit margin
FATR: the “x” company's fixed-asset turnover ratio
TBQ: the “x” company's Tobin’s Q value
LNM: logarithm of the “x” company's market value
Є: Error term

3 FINDINGS AND CONCLUSION

Whether there is autocorrelation among the variables used in the model which generated for determining what variables affect the working capital requirement of the Forest Products Industry and Paper and Paper Industry Sectors operating in the BIST was determined by the Durbin-Watson test. If the Durbin-Watson test values are between 1.5 and 2.5, it indicates that there is no autocorrelation between variables (Kalaycı, 2006). When the tables showing the model results for the analyses are examined below, it is understood that the model does not have autocorrelation because the Durbin-Watson test values are between the limits mentioned above.

According to a result of the correlation analysis (Table 2) conducted for the existence of the problem of multiple linearity among the variables used in the model, it can be said that there is no linearity problem among the variables. Because the correlation coefficient values are not equal to 0.9 or above. When the correlation results are examined, it is seen that there is a negative relationship between the working capital requirement and the leverage ratio at 1% significance level.

Table 2: Correlation between variables

	LR	RAR	EPR	EBITD	PSG	STR	RTR	GPM	FATR	TBQ	LNM
WCR	-0.705**	0.405	0.433	0.086	-0.106	0.02	0.064	-0.067	-0.465	0.026	0.133
LR		-0.553*	-0.451	-0.22	0.175	-0.278	-0.135	-0.07	0.12	-0.255	-0.488*
RAR			0.281	0.809**	0.055	0.436	0.233	-0.015	-0.285	0.202	0.268
EPR				0.076	-0.36	0.074	-0.065	-0.06	-0.333	0.082	0.229
EBITD					0.13	0.632**	0.047	-0.006	-0.102	-0.161	-0.009
PSG						-0.151	0.138	-0.07	-0.133	0.313	0.307
STR							-0.103	0.614**	0.025	-0.292	0.134
RTR								-0.143	-0.001	0.307	-0.14
GPM									-0.132	-0.064	0.222
FATR										-0.352	0.026
TBQ											0.469*

* represents a significant relationship at the 5% significance level
** represents a significant relationship at the 1% significance level

Descriptive statistical data related to dependent and independent variables for 18 companies constituting our study material were given in Table 3.

Table 3: Descriptive Statistical Information

Companies	N	Minimum	Maximum	Mean	Standard Deviation
WCR	8	-0.33	0.40	0.0571	0.21914
LR	8	0.09	1.00	0.4752	0.29165
RAR	8	-0.11	0.18	-0.0034	0.08045
EPR	8	-48.85	0.21	-2.8438	11.48950
EBITD	8	-48864907.00	100848755.00	7539535.7222	31273348.48065
PSG	8	-0.22	0.23	0.0598	0.11454
STR	8	1.70	137.99	16.0512	32.16463
RTR	8	1.07	19.82	4.8634	4.16108
GPM	8	0.05	0.40	0.2066	0.10227
FATR	8	0.09	0.69	0.4707	0.16775
TBQ	8	0.59	3.87	1.5445	0.78083
LNM	8	16.80	20.52	18.8441	1.20616

When the descriptive data of the 18 companies included in the study are examined, it is seen that the working capital requirements are at the level of 5.71%. The leverage ratio is 47.52% and the growth ratio is 6%.

According to the results of the analysis in Table 4, the leverage ratio and the Tobin's Q value from the independent variables are statistically significant in the 95% confidence interval, and they have a negative effect on the working capital requirement (dependent variable) by 56.4% and 15.1%, respectively. It was found that rate of influence of independent variables used in the model on dependent variables is 88%.

Table 4: Initial model results of working capital requirement

MODEL	R^2	Adjusted R^2	Durbin-Watson	F	Sig.
WCR	0.888	0.682	1.562	4.31	0.043*
MODEL	Unstandardized Coefficients		Standardized Coefficients	t	
WCR	ß	Standard Error	ß		Sig.
CONSTANT	1.917	1.081		1.774	0.126
LR	-0.564	0.172	-0.751	-3.284	0.017*
RAR	2.147	1.476	0.788	1.455	0.196
EPR	0.0000061	0.004	0.000	0.002	0.999
EBITD	-0.0000000071	0.000	-1.012	-1.585	0.164
PSG	0.647	0.533	0.338	1.214	0.270
STR	0.001	0.003	0.193	0.450	0.669
RTR	-0.006	0.011	-0.110	-0.516	0.624
GPM	-0.544	0.604	-0.254	-0.902	0.402
FATR	-0.559	0.312	-0.428	-1.792	0.123
TBQ	-0.151	0.063	-0.539	-2.401	0.049*
LNM	-0.051	0.062	-0.279	-0.812	0.448

* represents the 5% significance level

It has been identified that the other independent variables (return on asset ratio, equity profitability ratio, profit margin before interest, tax and depreciation, the percent sales growth, stock turnover ratio, receivables turnover ratio, gross profit margin, fixed-asset turnover ratio and natural logarithm of market value) have no statistically significant effect on the working capital requirement.

It was seen that although there was a positive relationship between working capital requirement and return on asset ratio, equity profitability ratio, growth ratio in sales and stock turnover ratio, there was a negative relationship between working capital requirement and profit margin before interest, tax and depreciation, receivables turnover ratio, gross profit margin, fixed-asset turnover ratio and natural logarithm of market value. The independent variable that affects most of the working capital requirement is realized as the return on asset ratio.

According to the results of multiple regression analysis, the regression model obtained as the dependent variable of working capital was formed as follows.

$WCR_x = 1.917 - 0.564*LR_x + 2.147*RAR_x + 0.0000061*EPR_x - 0.0000000071*EBITD_x + 0.647*PSG_x + 0.001*STR_x - 0.006*RTR_x - 0.544*GPM_x - 0.559*FATR_x - 0.151*TBQ_x - 0.051*LNM_x + \epsilon_x$

Independent variables that are statistically insignificant in multiple regression analysis were excluded from the equation, respectively and it was formed again regression equation. The final regression equation in which all the independent variables are statistically significant was given below (Table 5).

$WCR_x = 0.766 - 0.549*LR_x - 0.645*FATR_x - 0.094*TBQ_x + \epsilon_x$

Table 5: The working capital requirement

MODEL	R^2	Adjusted R^2	Durbin-Watson	F	Sig.
WCR	0.736	0.679	2.046	12.987	0.000**
MODEL	Unstandardized Coefficients		Standardized Coefficients	t	
WCR	ß	Standard Error	ß		Sig.
CONSTANT	0.766	0.145		5.286	0.000**
LR	-0.549	0.107	-0.730	-5.137	0.000**
FATR	-0.645	0.192	-0.494	-3.363	0.005**
TBQ	-0.094	0.042	-0.334	-2.212	0.044*

* represents the 5% significance level
** represents the 1% significance level

According to the results of the analysis, the leverage ratio, fixed-asset turnover ratio and Tobin's Q value are statistically significant in the 95% confidence interval and they have a negative effect on the working capital requirement by 54.9%, 64.5% and 9.4%, respectively. The independent variable with the highest influence on the working capital requirement was realized as the fixed asset ratio. The rate of influence of independent variables on dependent variables is 73.6%.

According to the results of the study made on 18 companies operating in the Forest Products and Furniture and Paper and Paper Products, Printing and Publishing sectors traded on BIST, 5.7% of the total assets of the companies constitute working capital. When calculated on an average basis, the leverage ratio is 47.52%, the stock turnover ratio is 16.05 and the receivables turnover ratio is 4.86. However, leverage ratio, fixed-asset turnover ratio and Tobin's Q value have a significant effect on the working capital requirement. The working capital requirement, which is in a negative interaction with all three values decreases with increasing of these ratios. If there is a positive interaction, the working capital requirement increases.

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Appendix-1: The companies traded on BIST

Sectors	Companies	Ratios											
		LR	RAR	EPR	EBITD	PSG	STR	RTR	GPM	FATR	TBQ	LNM	WCR
Forest Products and Furniture	Doğtaş Kelebek	0.211	0.087	-1.53	-42108245	0.059	1.862	4.875	0.329	0.452	2.541	20.402	-0.1
	Gentaş	0.315	0.072	0.106	30327916	0.212	2.439	3.172	0.205	0.365	0.955	19.04	0.35
	Orma	0.803	-0.114	0.583	-674197	-0.006	4.731	2.113	0.111	0.681	0.858	17.283	-0.33
	Yonga	0.252	0.045	0.061	2106352	0.006	4.606	19.818	0.142	0.48	1.831	17.796	0.22
Printing and Publishing	Saray	0.704	-0.032	-0.11	4006007	0.023	1.826	6.171	0.124	0.393	0.954	16.799	0.12
	Bak	0.629	0.033	0.09	25204971	0.081	4.653	4.189	0.176	0.445	1.223	19.074	0.04
	Doğan Gaz	0.101	0.176	0.197	100848755	-0.004	137.99	4.39	0.395	0.554	0.589	19.444	0.03
	Duran Doğan	0.867	-0.047	-0.357	8564458	0.145	5.303	5.406	0.208	0.547	1.45	17.997	-0.21
	Doğan Burda	0.51	-0.073	-0.149	-4297826	0.086	43.787	2.649	0.373	0.086	1.718	18.009	0.29
	Hürriyet	0.553	-0.092	-0.208	-48864907	-0.053	26.52	2.535	0.404	0.693	1.21	20.233	0.008
	İhlas	0.156	-0.004	-0.005	3290641	0.036	12.911	1.065	0.052	0.627	1.512	19.853	0.23
Paper and Paper Products	Kaplamin	0.811	-0.009	-0.047	4086062	-0.095	9.38	3.188	0.167	0.388	1.78	18.058	-0.15
	Kartonsan	0.161	0.008	0.01	12013885	0.188	4.641	7.543	0.114	0.635	2.518	20.521	0.15
	Olmuksan	0.463	-0.03	-0.056	-11356796	0.147	6.582	2.912	0.16	0.326	1.176	19.596	0.26
	Prizma	0.085	0.02	0.022	1275230	-0.218	1.7	1.742	0.174	0.485	0.984	17.457	0.4
	Mondi Tire	0.664	0.003	0.011	19884472	0.072	6.841	2.883	0.167	0.429	1.361	19.679	-0.08
	Viking Kağıt	0.998	-0.087	-48.854	546441	0.226	7.43	6.007	0.228	0.691	1.274	17.727	-0.31
	Alkim	0.271	0.156	0.214	30858424	0.172	5.72	6.883	0.189	0.195	3.867	20.226	0.11

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ABSTRACT

Planning and targeting is the first step in the management function in enterprise. The success of management activities in every enterprise goes through effective planning and targeting. Top executives in an enterprise can have more time for planning and targeting than other functions. The junior administrative officer can have more time for other management functions. Priorities should be defined when determining processes in an enterprise. The first step in planning and targeting is to determine where you want to be reached. Also, the procurement and selection of all kinds of sources that will achieve these targets are included in planning and targeting.

In this study, it was tried to determine how much the managers in the management stages of different forest industry industries operating in İstanbul had an important role in achieving the success of the enterprise in terms of planning and targeting function. In the study, a scale consisting of 31 expressions was set up for the planning and targeting to the employees in the enterprises. The number of surveys evaluated was 271. The results obtained from managers and other employees in different forest products sectors have been tested in SPSS statistical program with some other factors and the results are presented in detail.

Keywords: Planning, Targeting, Forest Products Industry

1 INTRODUCTION

As in any industry, enterprises operating in the forest products industry should attach importance to "management" concept to increase their profits, maximize their sales and survive in a competitive environment. A good management is the most important element in the success of a business.

It is relatively new that the management emerged as a scientific discipline even though the management event is based on as old as human history. But concepts related to management science have not been fully clarified and a common management definition has not yet been reached among the authors (Şimşek 2010). Therefore, management can be understood as a process, the elements of this process that people and groups, a certain information society, and decision-making and leadership activities (Saltürk 2008).

According to thinkers who tend to perceive management as a process, can be expressed as a process involving the whole of the efforts of directing a group of people towards designated objectives and coordinating them with cooperation. It should not be forgotten that the result is not achieved by using only human resources in management. Because, in the concept of management, it is mentioned that all production factors, including the first human element, are used effectively and efficiently in accordance with the targets determined at the planning stage (Şimşek 2010).

As a process, the functions need to be handled one by one for management to review it as required. In traditional sense, these management functions are divided into five. These are planning, organizing, directing, coordinating, and controlling (Şimşek and Çelik 2014). In this study, it was informed only about planning in those functions.

Planning, the first and most important of the management functions, in the simplest terms, is a bridge between the present situation and the future. In a general sense, it is a conscious process that has the qualities of choosing and developing the best course of action to achieve an objective. At this stage, answers to the following questions are sought. These questions are "What?", "When?", "How?", "Where?", "Why? "," By whom? "," What cost? " (Akmut et al. 2003; Bakan et al. 2013; Tengilimoğlu et al. 2012).

Planning is done for a variety of reasons. The most important of these reasons is that scarce resources are used efficiently and profitably. Beside this, there are a number of reasons for planning (Özevren 2009). These (Özevren 2009);

- To determination of the criteria for effective control,
- To guide the enterprise,
- To predict the future of the business more accurately,
- To direct other functions of the management,
- To prevent repetition of activities in enterprise,
- To respond more quickly to sudden changes for enterprise,
- To increase efficiency and effectiveness.

It should not be forgotten that some important points should be taken into consideration when making the planning which is important for enterprise. These are "who made the planning", "time dimension", "resource need", "alternative cost of the plan", "making alternative plans", "basing planning on real events and scientific predictions", and "the effect of environmental factors" (Özevren 2009).

It is collected a number of pieces of information by planning function in order to determine what the objectives of the enterprises will be and what their strategies will be. Accordingly, the planning activities involves a number of stages until the plan is clear, starting with the collection of information. One of these stages is to determine the objectives (Tutar 2005).

In the objective stage of the planning process, it is determined what and how much the enterprise wants to realize in the future and where it wants to be. The uncertain objectives make practitioners unsuccessful. The objectives may also be comprehensive enough to cover all enterprise. Main (general) objectives are determined at the upper levels of the organization, while objectives for activities at lower levels. In order to the objectives to be carried out effectively and efficiently, everyone should be aware of the basic and special objectives and adopt these objectives (Tengilimoğlu et al. 2012; Şimşek and Çelik 2013; Şimşek and Çelik 2015).

In this study, the perceptions of the employees related to expressions about objective setting and planning were investigated. It was determined by using one-way variance analysis (ANOVA) that whether there was a significant difference between the positions of employees and expressions about objective setting and planning.

2 MATERIAL AND METHOD

The scope of our study constitutes forest products enterprises operating in the Anatolian side of Istanbul. The survey form was planned to be applied to large and/or small scale enterprises in the Forest Products Industry and all the employees (lower, middle, upper and workers) in these enterprises. The survey form contains questions about the demographic characteristics and questions about objective setting and planning. 31 questions were prepared in accordance with a 5-point Likert-type scale (never:1, very little:2, undecided:3, normal level:4, high level:5) about objective setting and planning. The expressions prepared about objective setting and planning were given in Table 1. The surveys were applied by performing face to face interviews with people.

Table 1: Expressions about objective setting and planning

	Expressions
1	The objectives in our enterprise are clear.
2	Awareness of the objectives and plans increases the motivation of employees in the enterprise.
3	The objectives and plans in our business form a guide for the activities.
4	The objectives and plans in our enterprise form the basis for the decisions of the managers.
5	The objectives and plans in our enterprise are the success standard.
6	The market share to will be owned in our objectives and plans in our enterprise is investigated.
7	In our enterprise, new methods and product innovations are included in the objectives and plans.
8	Profitability is the forefront in objectives and plans in our enterprise.
9	In our enterprise, the cash flow in determining objective and plan is important.
10	In our enterprise, physical and financial resources are important in objectives and plans.
11	In our enterprise, importance is given to productivity performance in objectives and plans.
12	In our enterprise, managerial and organizational growth is prioritized in objectives and plans.
13	In our enterprise, social responsibilities towards customers and society are in the forefront in objectives and plans.
14	The objectives in our enterprise were often digitized.
15	The objectives and plans in our enterprise are carried out on the main activities.
16	The objectives in our enterprise are very real.
17	The objectives and plans in our enterprise are realized within a certain period of time.
18	Planning is a financial burden for enterprise.
19	Planning is necessary for the sector we are in.
20	Planning increases the number of staff.
21	Planning limits the freedom of movement of managers.
22	Planning contributes to regular communication.
23	With the planning, the hierarchical system works properly from top to bottom.
24	Planning in our enterprise facilitates the transfer of authority.
25	Our enterprise has policies.
26	The methods available in our enterprise are used.
27	The rules and bases are obeyed in our enterprise.
28	There are always the desires for planning in our enterprise.
29	Alternative plans in our enterprise are constantly being developed.
30	The flexibility principle in planning in our enterprise is implemented.
31	Teamwork is fully implemented in our enterprise.

The following sample determination formula was used to determine the total number of participants to whom the surveys would be applied (Naing et al. 2006):

$$n = \frac{N.Z^2.p.q}{N.d^2 + Z^2.p.q} \quad (1)$$

In formula;
n: sample size;
N: universe size;
p: p-value (0.5) ;
q: q- value (0.5);
Z: Z-score at 95 % confidence interval (1.96);
d: margin of error (0.05)

According to the Istanbul Chamber of Commerce, there are 1750 enterprises in the Forest Products Industry operating in the Istanbul where the study will be applied. The "p" and "q" values were taken as 0.5 in a way that would enable the sample size to be more in our study. The error margin was accepted as 5%. As a result, the sample size was determined to be 315. However, a total of 271 surveys were achieved. Then, all the survey forms were numbered and the numbered data were entered into the SPSS for Windows package program. One-way variance (ANOVA) analysis was used for determine whether there was a significant difference between the positions of employees and expressions about objective setting and planning. Abbreviations for the positions of the employees used in the analyzes were given in the table below.

Table 2: The positions of employees and abbreviations

The positions of employees in enterprises	**Abbreviations**
Senior managers	SM
Middle-level managers	MLM
Lower-level managers	LLM
Labor-officer employees	LOE

3 RESULTS

3.1. Results regarding demographic characteristics

According to Table 3, 77.9% of personnel who participated in the survey are male, 22.1% are female. The majority of participants (42.1%) are in the age range 26-33. Majority of participants (80.8%) are working at same enterprise less than 10 years. More than half of the participants (57.2%) work in the manufacture department. While 61.6% of enterprises participating in the survey are operate in the furniture sector, other enterprises operate in the lumber (19.9%) and corrugated board sector (18.5%). The majority of enterprises are limited liability companies. The vast majority of enterprises participating in the survey are small and medium-sized enterprises. 4.1% of the respondents are senior managers, 16.2% of them are middle-level managers, 8.5% of them are lower-level managers and 71.2% of them are labor-officer employees.

Table 3. The demographic characteristics of the participants

Demographic characteristics		**Frequency**	**Percentage (%)**
Gender	Male	211	77.9
	Female	60	22.1
Age	18-25	42	15.5
	26-33	114	42.1
	34-41	80	29.5
	42 and over	35	12.9
Position	Senior manager	11	4.1
	Middle-level manager	44	16.2
	Lower-level manager	23	8.5
	Worker, officer	193	71.2

Legal structure	Limited company	195	72
	Joint stock company	35	12.9
	Others	41	15.1
Total working time in enterprise	0-5 year	128	47.2
	6-10 year	91	33.6
	11-15 year	38	14
	16 year and over	14	5.2
Total number of employees in enterprise	0-9 people	111	41
	10-49 people	94	34.7
	50-99 people	30	11.1
	100 people and over	36	13.3
Department where the participants work	Manufacture	155	57.2
	Sales & Marketing	76	28
	Financial and administrative affairs	35	12.9
	Enterprise owner	5	1.8
The sector in which the enterprise is located	Furniture	167	61.6
	Timber	54	19.9
	Corrugated cardboard	50	18.5

3.2. Statistical analysis results

It was determined that whether there was a significant different between expressions about objective setting and planning and perceptions of managers. For this, one-way variance (ANOVA) analysis was used and the results obtained were given in Table 4.

Table 4: Results regarding planning and targeting

	Manager type	**Mean**	**F**	**p**
Expression 1	SM	4.18	0.971	0.407
	MLM	3.98		
	LLM	4.00		
	LOE	4.19		
	Total	4.09		
Expression 2	SM	4.36	0.509	0.676
	MLM	4.05		
	LLM	4.13		
	LOE	4.17		
	Total	4.18		
Expression 3	SM	4.36	1.205	0.308
	MLM	3.95		
	LLM	4.09		
	LOE	4.20		
	Total	4.15		
Expression 4	SM	4.55	0.923	0.430
	MLM	4.09		
	LLM	4.22		
	LOE	4.17		
	Total	4.26		

Expression 5	SM	4.45	0.727	0.537
	MLM	4.09		
	LLM	4.26		
	LOE	4.22		
	Total	4.26		
Expression 6	SM	4.27	2.252	0.083
	MLM	3.82		
	LLM	4.30		
	LOE	4.11		
	Total	4.13		
Expression 7	SM	4.45	0.767	0.513
	MLM	4.07		
	LLM	4.22		
	LOE	4.19		
	Total	4.23		
Expression 8	SM	4.45	3.737	**0.012***
	MLM	3.86		
	LLM	4.26		
	LOE	4.25		
	Total	4.21		
Expression 9	SM	4.45	3.206	**0.024***
	MLM	3.86		
	LLM	4.17		
	LOE	4.24		
	Total	4.18		
Expression 10	SM	4.64	1.851	0.138
	MLM	3.95		
	LLM	4.13		
	LOE	4.17		
	Total	4.22		
Expression 11	SM	4.27	1.468	0.224
	MLM	3.86		
	LLM	3.91		
	LOE	4.12		
	Total	4.04		
Expression 12	SM	4.36	4.065	**0.008****
	MLM	3.73		
	LLM	4.35		
	LOE	4.16		
	Total	4.15		
Expression 13	SM	4.18	1.761	0.155
	MLM	3.82		
	LLM	4.26		
	LOE	4.12		
	Total	4.10		
Expression 14	SM	4.09	2.004	0.114
	MLM	3.66		
	LLM	4.13		
	LOE	3.98		
	Total	3.97		

Expression 15	SM	4.36	0.528	0.663
	MLM	4.05		
	LLM	4.09		
	LOE	4.16		
	Total	4.17		
Expression 16	SM	4.45	0.855	0.465
	MLM	3.98		
	LLM	4.04		
	LOE	4.09		
	Total	4.14		
Expression 17	SM	4.55	1.824	0.143
	MLM	3.86		
	LLM	3.91		
	LOE	3.99		
	Total	4.08		
Expression 18	SM	3.82	2.308	0.077
	MLM	3.52		
	LLM	3.96		
	LOE	3.96		
	Total	3.82		
Expression 19	SM	4.00	1.916	0.127
	MLM	3.93		
	LLM	4.39		
	LOE	4.20		
	Total	4.13		
Expression 20	SM	4.18	1.349	0.259
	MLM	3.75		
	LLM	4.13		
	LOE	3.98		
	Total	4.01		
Expression 21	SM	4.18	1.426	0.236
	MLM	3.64		
	LLM	3.83		
	LOE	3.98		
	Total	3.91		
Expression 22	SM	3.91	1.274	0.284
	MLM	3.80		
	LLM	4.09		
	LOE	4.06		
	Total	3.97		
Expression 23	SM	4.45	8.473	**0.000*****
	MLM	3.61		
	LLM	4.35		
	LOE	4.11		
	Total	4.13		
Expression 24	SM	4.00	1.236	0.297
	MLM	3.86		
	LLM	4.13		
	LOE	4.12		
	Total	4.03		

Expression 25	SM	4.73	3.048	**0.029***
	MLM	3.93		
	LLM	3.96		
	LOE	4.13		
	Total	4.19		
Expression 26	SM	4.64	3.200	**0.024***
	MLM	3.89		
	LLM	4.00		
	LOE	4.16		
	Total	4.17		
Expression 27	SM	4.45	2.165	0.093
	MLM	3.93		
	LLM	4.13		
	LOE	4.23		
	Total	4.19		
Expression 28	SM	4.36	3.005	**0.031***
	MLM	3.77		
	LLM	3.87		
	LOE	4.15		
	Total	4.04		
Expression 29	SM	4.09	2.561	0.055
	MLM	3.70		
	LLM	4.22		
	LOE	4.11		
	Total	4.03		
Expression 30	SM	4.18	2.167	0.092
	MLM	3.70		
	LLM	3.87		
	LOE	4.09		
	Total	3.96		
Expression 31	SM	4.36	4.808	**0.003****
	MLM	3.68		
	LLM	4.13		
	LOE	4.25		
	Total	4.11		

*, p<0.05; **p<0.01; ***, p<0.001

As a result of the research, the findings regarding managers' perceptions about objective setting and planning are as follows. According to one-way variance analysis, it was found that there was significant different between the eight expressions about objective setting and planning and the opinions of the managers. The expressions that were found significant differences are 8, 9, 12, 23, 25, 26, 28 and 31. Senior managers said that more attend to the expressions, which were found significant differences,. At the same time, when we examine Table 4, the majority of the senior managers who participated in the survey said that our enterprise has policies (expression 25). The majority of the middle-level managers who participated in the survey said that their enterprise does not attach much importance to objective setting and planning. Because the vast majority of the expressions are below 4. The lower-level managers who participated in the survey said that planning is necessary for the sector we are in (expression 19). The officer-workers said that profitability is the forefront in objectives and plans in our enterprise (expression 8) and teamwork is fully implemented in our enterprise (expression 31). When we examined the results in general, the majority of the respondents said that the objectives and plans form the basis for the decisions of the managers and the objectives and plans are the success standard.

4 CONCLUSION

In this study, the perceptions of the employees related to expressions about objective setting and planning were investigated. Also, it was determined that whether there was a significant difference between the positions of employees and expressions about targeting and planning. In this study, the following results were obtained:

(1) The vast majority of participants are male.

(2) The age range of the majority of the participants were 42 years and below.

(3) The position of the majority of the participants in the enterprise is the worker or officer.

(4) The majority of participants is working in small-scale enterprises and the majority of enterprises are in the status of limited liability company.

(5) The majority of the employees participating in the study are employed by enterprises operating in the furniture sector. Because there is the most furniture sector in the forest products industry in the Anatolian side of Istanbul.

(6) The majority of employees is working in manufacturing departments in their enterprises.

(7) According to opinion of managers, it has been found that some expressions from expressions related to planning and targeting are significant differences. These expressions are 8, 9, 12, 23, 25, 26, 28 and 31. In other words, the answers given with the change of the manager type varied.

(8) The majority of participants said that their enterprises are paying attention to planning and targeting.

In order to ensure the continuity of the enterprises and to keep the enterprises standing, the enterprises are necessary to give importance to targeting and planning. Therefore, more extensive research can be done for future studies

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Evaluation of Managers in Forest Products Industry Enterprises According to Three Features and Managerial Skills Approaches

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ABSTRACT

Today, social and economic developments are very fast and this is closely related to all enterprises. Regarding of this rapid change and development, enterprises need to give more importance to the concepts of management and manager. In terms of the growth and development of the enterprises, how and to what extent the people who work in the management part of the enterprises have the managerial characteristics and how subordinates perceive their managers are very important.

How the properties that should be found in upper management of the forest products industry enterprises operating in Istanbul province were perceived by the employees at the subordinate level were tried to be revealed with three features and managerial skills approach. Face-to-face survey method was used in the study. The survey is composed of three parts. The numbers of persons surveyed were 271. The questions prepared according to the 5-point Likert scale were analysed in the SPSS statistical program and the results were given in detail.

KEYWORDS: Manager, Managerial skills, Forest Industry Engineering

1 INTRODUCTION

The forest products industry, which is defined as primary and secondary manufacturing industry groups, provides raw materials for a large number of industries and gives employment opportunities to about 300,000 people. Moreover, this sector was also influential in the development process with the products it transferred to the employment and production processes and it led to the development of economic activities (Akyüz 2006; Akyüz 2000; Şahin 2016).

As in any industry, enterprises operating in the forest products industry should attach importance to "management" concept to increase their profits, maximize their sales and survive in a competitive environment. Also, the role of the manager in the enterprises should increase. A good management or good manager is the most important element in the success of a business.

There are different opinions about the concept of management. According to economists, management is one of the factors of production. According to management science, management is an authority system. According to society scientists, management is a class and prestige system (Ataman 2001). According to another definition, management is a system in which the objectives are carried out effectively and efficiently (Gürüz and Gürel 2006).

Management in the enterprises is a characteristic that is intertwined with other functions. These functions, which constitute a management process, are a system that affects each other. Therefore, the success of a management can be achieved by coordinating these functions, effectively and efficiently. The fact that these functions are not managed is also the most important reason behind the failures in the enterprises (Dinçer and Fidan 1996).

Management work is performed by the managers. So the manager can be defined as the person who performs the management work. According to another definition, the manager is someone who operator in harmony and co-operation the people assigned to his or her command for reach a certain goals (Eren 2003). Managers must have a number of qualities and characteristics to be able make to functions, effectively and efficiently. These characteristics can be examined under three characteristic approaches. These are intellectual, characteristic and social characteristics (Paşaoğlu et al. 2013).

In this study, the properties that should be found in upper management of the forest products industry enterprises operating in Istanbul province were how perceived by the employees at the subordinate level were investigated.

2 MATERIAL AND METHOD

The scope of our study constitutes forest products enterprises operating in Istanbul located in Marmara Region. The study was limited to the Anatolian side since it is not possible to conduct a survey on the forest products operating in all the districts of Istanbul in terms of cost and time. The survey form was planned to be applied to large and/or small scale enterprises in the Forest Products Industry and all the employees (lower, middle, upper and workers) in these enterprises and questions were prepared in this direction. The survey form contains questions about the demographic characteristics and questions about the characteristics that managers should have. The characteristics that managers should have were examined in three categories. These are intellectual, characteristic and social. 15, 12 and 7 question was prepared about the intellectual, characteristic and social characteristics, respectively and 5-point Likert scale (never: 1, very little: 2, undecided: 3, normal level: 4, high level: 5) was used while preparing the questions. The expressions prepared for these characteristics were given in Tables 1, 2 and 3. The surveys were applied by performing face to face interviews with people.

Table 1: Questions about the intellectual characteristics

	Expressions
1	General culture
2	Specialization in many subjects
3	Logicalness
4	The spirit of analysis
5	To analyze the causes of an event analytically
6	Synthesis spirit
7	To put variables of an event together to form a solution or plan
8	Intuition power
9	Being able to anticipate opportunities and threats
10	Imagination
11	To visualize possible developments in the future
12	Judicial power
13	The ability to distinguish "good from bad" and "right from wrong"
14	The ability to focus ideas on issues and problems
15	The ability to express ideas clearly.

Table 2: Questions about the characteristic features

	Expressions
1	Balance between mind and emotion (harmony between objectivity and subjectivity)
2	Be able to adapt to changing circumstances and environments and to people in different personalities
3	Carefulness
4	Prudence
5	Assertiveness (courage to take risks)
6	Memory power (to keep important events, people and variables in mind)
7	Dynamism (monitoring and taking precautions on many issues and events on-site and on time)
8	Perseverance and persistence (to be standing in the face of danger and difficulties)
9	Tidiness and regularity
10	To use methods which have usefulness
11	Rapidness
12	Seriousness (to not underestimate the danger and problems)

Table 3: Questions about the social characteristics

	Expressions
1	Physical appearance
2	The ability to appeal
3	The ability to understand group structures, common purposes, values and feelings (sociability)
4	The ability to deal with work discipline and bad habits
5	The ability to help and cooperate with every person who works with him
6	The ability to move in a balanced way
7	The ability to fair, persuasive, and trustworthy

The following sample determination formula was used to determine the total number of participants to whom the surveys would be applied (Naing et al. 2006):

$$n = \frac{N.Z^2.p.q}{N.d^2 + Z^2.p.q} \quad (1)$$

In formula;
n: sample size;
N: universe size;
p: p-value (0.5) ;
q: q- value (0.5);
Z: Z-score at 95 % confidence interval (1.96);
d: margin of error (0.05)

According to the Istanbul Chamber of Commerce, there are 1750 enterprises in the Forest Products Industry operating in the Istanbul where the study will be applied. The "p" and "q" values were taken as 0.5 in a way that would enable the sample size to be more in our study. The error margin was accepted as 5%. As a result, the sample size was determined to be 315. However, a total of 271 surveys were achieved. Then, all the survey forms were numbered and the numbered data were entered into the SPSS for Windows package program. Chi-Square (X^2) test was used for determine whether there was a significant difference between characteristics that managers should have and positions of employees. Abbreviations for the positions of the employees used in the analyzes were given in the table below.

Table 4: The positions of employees and abbreviations

The positions of employees in enterprises	Abbreviations
Senior managers	SM
Middle-level managers	MLM
Lower-level managers	LLM
Labor-officer employees	LOE

3 RESULTS

3.1. Results regarding demographic characteristics

77.9% of personnel who participated in the survey are male, 22.1% are female. A great majority of participants (87.1%) are under the age of 42. Only 31.7% have university graduate. 73.4% of the participants are married. Majority of participants (80.8%) are working at same enterprise less than 10 years. While 61.6% of enterprises participating in the survey are operate in the furniture sector, other enterprises operate in the lumber (19.9%) and corrugated board sector (18.5%). The majority of enterprises are limited liability companies. 4.1% of the respondents are senior managers, 16.2% of them are middle-level managers, 8.5% of them are lower-level managers and 71.2% of them are labor-officer employees.

3.2. Statistical analysis results

It was determined that whether there was a significant relationship between the intellectual characteristics that managers should have and manager types. For this, Chi-Square (X^2) was used and the results obtained were given in Table 5.

Table 5: Results regarding the intellectual characteristics

	Manager type	Mean	X^2 (Chi-square)	
Expression 1	SM	4.36	0.764	Insignificant
	MLM	4.11		
	LLM	4.04		
	LOE	4.01		
	Total	4.04		
Expression 2	SM	4.18	0.697	Insignificant
	MLM	3.98		
	LLM	3.70		
	LOE	3.97		
	Total	3.96		
Expression 3	SM	4.09	0.530	Insignificant
	MLM	4.09		
	LLM	3.87		
	LOE	4.01		
	Total	4.01		
Expression 4	SM	4.18	0.863	Insignificant
	MLM	3.95		
	LLM	3.87		
	LOE	4.03		
	Total	4.01		
Expression 5	SM	4.09	0.583	Insignificant
	MLM	4.07		
	LLM	3.83		
	LOE	4.05		
	Total	4.04		

Expression 6	SM	4.18	0.563	Insignificant
	MLM	4.18		
	LLM	3.78		
	LOE	4.06		
	Total	4.06		
Expression 7	SM	4.18	0.776	Insignificant
	MLM	4.30		
	LLM	3.96		
	LOE	4.20		
	Total	4.19		
Expression 8	SM	3.82	0.400	Insignificant
	MLM	4.11		
	LLM	3.96		
	LOE	4.21		
	Total	4.15		
Expression 9	SM	4.45	0.727	Insignificant
	MLM	4.02		
	LLM	4.00		
	LOE	4.04		
	Total	4.05		
Expression 10	SM	4.09	0.400	Insignificant
	MLM	4.07		
	LLM	3.87		
	LOE	4.12		
	Total	4.09		
Expression 11	SM	3.91	0.028	**Significant**
	MLM	4.14		
	LLM	3.96		
	LOE	4.23		
	Total	4.18		
Expression 12	SM	4.09	0.903	Insignificant
	MLM	4.16		
	LLM	4.13		
	LOE	4.11		
	Total	4.12		
Expression 13	SM	4.18	0.864	Insignificant
	MLM	4.14		
	LLM	4.35		
	LOE	4.03		
	Total	4.08		
Expression 14	SM	4.27	0.694	Insignificant
	MLM	4.00		
	LLM	4.04		
	LOE	4.16		
	Total	4.13		
Expression 15	SM	4.09	0.951	Insignificant
	MLM	4.09		
	LLM	4.35		
	LOE	4.23		
	Total	4.21		

As a result of the research, the findings regarding the intellectual characteristics of the managers are as follows. According to the chi-squared test, it was found that there was only significant relationship between "expression 11 (to visualize possible developments in the future)" and "manager types". The officers-workers more said that senior managers should have this expression. At the same time, when we examine Table 5, the senior managers who participated in the survey said that the intellectual characteristic that senior managers should have most is the ability to anticipate opportunities and threats (expression 9). The middle-level managers who participated in the survey said that the intellectual characteristic that senior managers should have most is to put variables of an event together to form a solution or plan (expression 7). The lower-level managers who participated in the survey said that the intellectual characteristic that senior managers should have most is the ability to distinguish "good from bad" and "right from wrong" (expression 13). The officer-workers said that the intellectual characteristic that senior managers should have most is the ability to express their ideas clearly. When we examined the results in general, the majority of the respondents said that senior managers should express their ideas clearly.

It was determined that whether there was a significant relationship between the characteristic features that managers should have and manager types. Analysis results were given in Table 6.

Table 6: Results regarding the characteristic features

	Manager type	**Mean**	**X^2 (Chi-square)**	
Expression 1	SM	4.36	0.932	Insignificant
	MLM	3.89		
	LLM	4.17		
	LOE	4.01		
	Total	4.01		
Expression 2	SM	4.64	0.238	Insignificant
	MLM	4.11		
	LLM	4.00		
	LOE	4.10		
	Total	4.11		
Expression 3	SM	4.82	0.222	Insignificant
	MLM	4.18		
	LLM	4.17		
	LOE	4.20		
	Total	4.22		
Expression 4	SM	4.73	0.179	Insignificant
	MLM	3.86		
	LLM	3.96		
	LOE	4.10		
	Total	4.07		
Expression 5	SM	4.55	0.171	Insignificant
	MLM	4.07		
	LLM	3.91		
	LOE	4.12		
	Total	4.11		
Expression 6	SM	4.27	0.652	Insignificant
	MLM	4.02		
	LLM	3.91		
	LOE	4.10		
	Total	4.08		
Expression 7	SM	4.27	0.256	Insignificant
	MLM	4.02		
	LLM	3.91		
	LOE	4.18		
	Total	4.13		

Expression 8	SM	4.45	0.179	Insignificant
	MLM	4.27		
	LLM	3.83		
	LOE	4.21		
	Total	4.20		
Expression 9	SM	4.55	0.717	Insignificant
	MLM	4.14		
	LLM	4.30		
	LOE	4.30		
	Total	4.28		
Expression 10	SM	4.64	0.906	Insignificant
	MLM	4.16		
	LLM	4.22		
	LOE	4.11		
	Total	4.15		
Expression 11	SM	4.64	0.426	Insignificant
	MLM	4.16		
	LLM	4.00		
	LOE	4.23		
	Total	4.22		
Expression 12	SM	4.64	0.017	**Significant**
	MLM	4.32		
	LLM	4.04		
	LOE	4.33		
	Total	4.31		

According to Table 6, there was only significant relationship between “expression 12 (seriousness (to not underestimate the danger and problems)) and “manager types”. Senior managers more said that senior managers should have this expression. The senior managers who participated in the survey said that the characteristic feature that senior managers should have most is the ability to prudence (expression 4). The middle-level managers and the officer-workers who participated in the survey said that the characteristic feature that that senior managers should have most is to not underestimate the danger and problems (expression 12). The lower-level managers who participated in the survey said that the characteristic feature that senior managers should have most is tidiness and regularity (expression 9). When we examined the results in general, the majority of respondents said that senior managers should not underestimate problems and dangers.

It was determined that whether there was a significant relationship between the social characteristics that managers should have and manager types. Analysis results were given in Table 7.

Table 7: Results regarding the social characteristics

	Manager type	**Mean**	**X^2 (Chi-square)**	
Expression 1	SM	4.18	0.711	Insignificant
	MLM	4.09		
	LLM	4.09		
	LOE	4.12		
	Total	4.11		
Expression 2	SM	4.36	0.987	Insignificant
	MLM	4.09		
	LLM	4.00		
	LOE	4.11		
	Total	4.11		
	SM	4.45		

Expression 3	MLM	4.14	0.852	Insignificant
	LLM	4.04		
	LOE	4.14		
	Total	4.14		
Expression 4	SM	4.55	0.836	Insignificant
	MLM	4.09		
	LLM	4.04		
	LOE	4.21		
	Total	4.19		
Expression 5	SM	4.45	0.894	Insignificant
	MLM	4.07		
	LLM	4.17		
	LOE	4.18		
	Total	4.17		
Expression 6	SM	4.36	0.277	Insignificant
	MLM	4.00		
	LLM	4.00		
	LOE	4.16		
	Total	4.13		
Expression 7	SM	4.73	0.323	Insignificant
	MLM	4.11		
	LLM	3.74		
	LOE	4.24		
	Total	4.20		

According to Chi-Square results, it was found that there was not a significant relationship between the social characteristics that managers should have and manager types. Although not a significant relationship between social characteristics and manager types, the senior managers and the officer-workers who participated in the survey said that the social characteristic that senior managers should have most is the ability to fair, persuasive, and trustworthy (expression 7). The middle-level managers who participated in the survey said that the social characteristic that senior managers should have most is the ability to sociability (expression 3). The lower-level managers who participated in the survey said that the social characteristic that senior managers should have most is the ability to help and to cooperate with every person who works with him (expression 5). When we examined the results in general, the majority of participants said that senior managers should have fair, persuasive, and trustworthy.

4 CONCLUSION

In this study, how the properties that should be found in upper management of the forest products industry enterprises operating in Istanbul province were how perceived by the employees at the subordinate level was investigated. In this study, the majority of participants said that senior managers should have characteristics such as the ability to express their ideas clearly, the ability to seriousness and the ability to persuasion. The ability to express their ideas clearly is one of the intellectual characteristics that managers should have. The ability to seriousness is one of the characteristic features that managers should have. The ability to persuasion is one of the social characteristics that managers should have. In addition, there was a significant relationship between the expression of the ability to visualize possible events in the intellectual characteristics that manager should have and manager types. In the same way, there was a significant relationship between the expression of seriousness in the characteristic features that manager should have and manager types. It has been tried to determine the characteristics that managers should have by the restricted factors in the study. More extensive research can be done for future studies and the characteristics that managers should have can be compared to different sectors.

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Estimation of Wood Biomass for Anatolian Black Pine Stands (A Case Study in Akçay Region)

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ABSTRACT

Wood is an indispensable raw material in human life because of its superior properties. Rapidly developing industry and technology together with the growing population, it causes an increase in the demand for wood raw material. As a result, the need for natural resources and energy is increasing day by day. In addition to destroying forest areas for people's needs, global warming and various environmental damage cause the need for protection of forest areas, as a result restrictions on the production of wood raw materials. These restriction are an obstacle to the forest products industry, which supplies raw materials from forest areas. Therefore, it is necessary to consciously use the obtained wood raw materials and rationally evaluate the used raw materials.

In this study, Anatolian Black Pine is selected which having the widest distribution area after oak and brutian pine and one of the most economically important species in Turkey. What's demand for raw materials of Anatolian Black Pine forest products industry has been put forward and tried to determine the wood biomass. For this purposes Akçay Planning unit was selected for study area.

KEYWORDS: Wood biomass, Wood raw materials, Anatolian black pine

1 INTRODUCTION

Increasing population, urbanization and rapidly growing industrial activities parallel to the developing technology are increasing the pressure on environment and natural resources. In order to meet the increased needs, it is benefited from the nature without considering the ecological processes. As a result of these activities, various ecological problems such as global warming, desertification and erosion, reduction of biological diversity, environmental pollution (soil, air and water) are the most important problems facing human beings and nature. These ecological problems mentioned threaten ecosystems that have not yet lost their naturalness. Forests are also at the forefront of these natural ecosystems. Forests offer a wide range of services to humans such as forest product production, water production, erosion prevention, climate regulation (including oxygen generation and carbon sequestration), community health, nature conservation, aesthetics, recreation, national defense and scientific functions. Besides these benefits to people, forests are also home to many plants and animals. The most important ecological problems of recent years in terms of prevention of global warming and climate change, the nature of the carbon pool is not further increase the importance of forests.

Nowadays, it is possible to benefit from the forest versatile, more than about ten thousand products obtainable only from wood. The consumption of wood, which has such a wide usage area, is increasing day by day with the increasing world population (Bozkurt, 1979). Demand for wood materials is increasing day by day due to its easy processing, insulator, texture due to natural structure, color and aesthetics. In order to meet this demand for wood raw material should be considered as an economic and rational (Erdin, 2003).

Turkey has significant advantages in the forest products industry because it can grow 22.3 million hectares of forest and a wide variety of tree species. However, only 57% of this forest area is productive. The coniferous 48%, 33% decidious, 19% of the mix (coniferous+decidious). Turkey forest standing volume is 1.6 billion m^3 , accounted for 1.09 billion m^3 of coniferous trees (OGM, 2017).

It is one of the sub-sectors of the manufacturing industry which consists of thousands of small and medium sized forest products industry, which aims at contributing to the national economy by evaluating the forest area covering 28.6% of Turkey land area. This industry is also divided into sub-classes or groups in their activities. According to international standard industrial classification, forest products industry, which is a dual sub-industry group of manufacturing industry; among the industries producing intermediate, consists of the furniture industry, which is located among the industries producing wood and mushroom products and consumer (Roman, 1991, Gedik, 2010). This sector; the primary and secondary raw products obtained from the forests are processed in a semi-finished or finished product, in particular by changing, changing or changing the form of the wood in the form of splitting, cutting, mowing and peeling, chipping or separating the fibers, without using or using pressurizing, evaporating, drying, impregnating, it is an industrial branch that produces goods, uses the product of one of them as raw material when necessary and performs integrated level production (Akyüz, 1995).

The annual consumption of wood in Turkey is about 31 million m^3. approximately 21 million m^3 of which is produced by General Directorate of Forestry, while the rest is covered by private sector and imports in Table 1. An average of 10 million 90 thousand m^3 of industrial wood was produced in 2005-2009 period. This figure has reached 13 million 526 thousand m^3 in 2010-2012 period and 15 million 560 thousand m^3 in 2013-2017 period as seen in Table 2 and 3. Annual firewood production is; the development of the alternative assessment in the industry is showing a decreasing tendency with changing consumer preferences in the social and economic structures of consumers. This trend is expected to continue in the coming period (OGM, 2017).

Tablo 1: 2013-2017 Years Wood Sales Quantities (OGM, 2017)

	Unit	**2013**	**2014**	**2015**	**2016**	**2017**
Industrial Wood	Thousand m^3	11.677	11.745	12.402	13.452	12.294
Fire Wood	Thousand Ster	5.263	5.257	2.363	2.206	4.270
Standing Sales	Thousand m^3	3.542	3.986	4.163	4.606	4.087

Tablo 2: 2013-2017 Years Wood Production Amount (OGM, 2017)

	Unit	**2013**	**2014**	**2015**	**2016**	**2017**
Standing Stump	m^3	16.888.766	19.276.052	21.240.509	21.128.942	20.196.476
Industrial Wood	m^3	13.667.987	14.923.209	16.637.597	17.009.998	15.521.622
Fire Wood	Ster	5.981.703	5.257.994	5.022.986	4.877.067	4.359.646

Tablo 3: 2013-2017 Years Industrial Wood Production Amount (m^3) (OGM, 2017)

	2013	**2014**	**2015**	**2016**	**2017**
Log	4.629.829	5.001.861	5.904.015	5.786.107	5.474.260
Wire Pole	32.641	37.527	54.257	57.574	60.610
Mine Pole	541.771	570.156	663.689	632.168	561.967
Industrial Wood	701.688	728.972	764.010	835.157	752.253
Paper Wood	2.196.434	1.966.963	2.375.172	2.486.595	2.169.059
Fiber Chip Wood	5.551.397	6.608.416	6.866.356	7.201.462	6.494.371
Pole	14.227	9.314	10.098	10.935	9.102
Total	13.667.987	14.923.209	16.637.597	17.009.998	15.521.622

The population growing, consumption preferences vary with technological advances. This causes the diversification of the products and needs of the forest products. Countries have to meet the needs of people with their assets and resources and raise the level of prosperity. In many countries, however, energy demands are rising, especially due to rapid industrialization and urbanization. Keeping energy consumption at the lowest possible level requires energy to be used in the most cost-effective and efficient way. In recent years, it has been recognized that the prosperity of energy is better understood by the societies, even the standard of living of an country, the economic, cultural and scientific levels of the countries are proportional to the amount of energy they produce and use. In the world there are about 6 billion people, 1 billion people living in developed countries consume about 60% of the total energy used, while 5 billion people living in developing countries consume only 40% of the total energy (Veziroğlu, 2000).

A large part of the energy needs of Turkey in the world as it is supplied from fossil sources. Besides irreversible harm to the environment rapidly depletion of these resources with a certain reserve and lead people to search for new energy sources. Renewable energy sources such as water, sun, wind, geothermal and biomass have come to the fore as alternative energy sources.

Due to its geographical location, Turkey has a very good potential in terms of new renewable energy sources that we can classify as water, sun, wind, geothermal and biomass. Biomass energy has a great potential in alternative energy sources, not intermittent like wind and solar, is a resource that can provide continuous power. The production of new and renewable energy sources in Turkey has the second highest production after total coal production. Approximately three percent of these resources are biomass. The remaining three-quarters of the renewable energy source is the majority of hydroelectric energy. Understandably for Turkey biomass is a special precaution.

Biomass can also be defined as the total mass at which a living organism belonging to a species or a collection of various species at a given time.

Main components; carbohydrates, vegetable and animal origin are all biomass energy source, and the energy obtained from these sources is defined as biomass energy. Biomass energy can be considered in two groups, classical and modern. First traditional, firewood obtained from forest and also used as fuel plant and animal waste. Second, the modern biomass energy; energy forestry and forest-wood industry wastes, vegetable wastes in agriculture, municipal wastes, industrial wastes based on agriculture (Web-1).

Today, biomass is widely used because it is easy to grow, store easily and economically. Biomass can be used directly by burning, it is evaluated in energy technology by increasing fuel quality by various processes and obtaining alternative bio-fuels (easily portable, storable and usable fuels) (Çetinkaya and Karaosmanoğlu, 2003). In Figure 1, it is shown schematically areas where biomass is used.

Biomass potential in the world is given in Table 4. According to this, despite the fact that most of the oceans cover the surface, the utilization of this is limited and the most used ones are forest biomass.

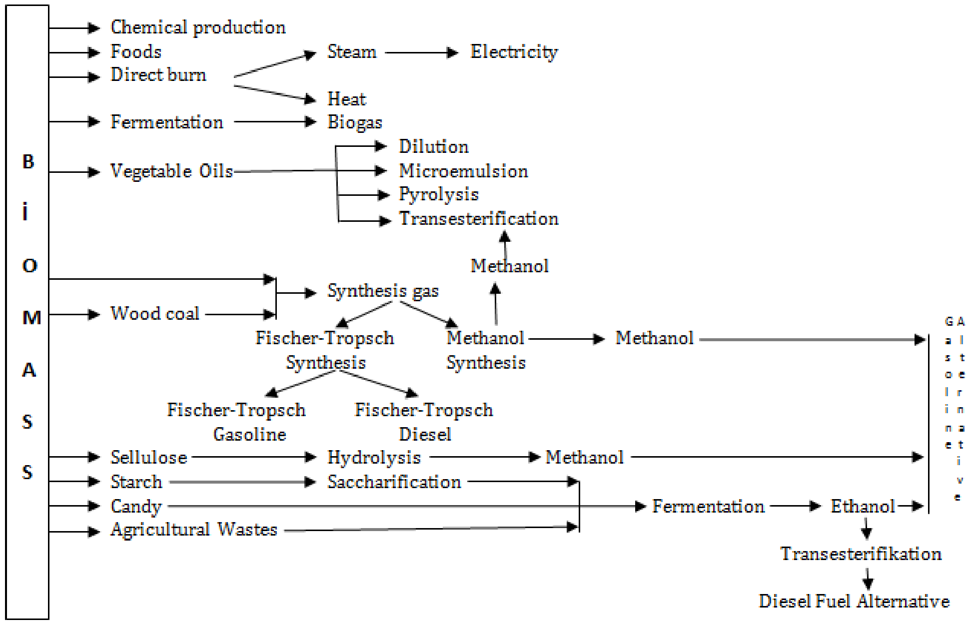

Figure 1: Using Areas of Biomass (Othmer, 1980).

Tablo 4: Biomass Potential in the World (Acaroğlu and Ültanır, 2000).

	Area (%)	**Biomass production (%)**
Forests	11	44
Groves	5	1
Grassland-Meadow	5	9
Agricultural Areas	3	5
Desert	5	0
Lake and Rivers	1	3
Oceans	70	38

In developing countries in particular, biomass, such as firewood, continues to be the greatest energy source of today. Globally, firewood accounts for approximately 64% of the combustible renewable energy sources in its various forms, the estimated total world supply (Demirbaş, 2009). Worldwide estimated biomass annual electricity production is about 185 TWh, of which about three quarters are produced from solid biomass, 14% from biogas and 12% from municipal solid wastes. If we consider the part of the world by contributing to the total energy production from biomass, this rate is less than 2% (WEC, 2007). According to Turkish Statistical Institute data, 8.6% of the electricity produced in Turkey in 2016 was obtained by using renewable energy sources. Since the early 2000s there is a significant increase in the quantity of electricity produced using renewable energy sources and it is expected to increase further in the coming years (Table 5).

Tablo 5: Electricity Generation and Shares by Energy Resources (TUIK, 2017)

Year	Total (GWh)	Coal	Liquid fuels	Natural Gas	Hydro	Renewable Energy(1)
2005	161.956	26,6	3,4	45,3	24,4	0,3
2006	176.300	26,4	2,4	45,8	25,1	0,3
2007	191.558	27,9	3,4	49,6	18,7	0,4
2008	198.418	29,1	3,8	49,7	16,8	0,6
2009	194.813	28,6	2,5	49,3	18,5	1,2
2010	211.208	26,1	1,0	46,5	24,5	1,9
2011	229.395	28,8	0,4	45,4	22,8	2,6
2012	239.497	28,4	0,7	43,6	24,2	3,1
2013	240.154	26,6	0,7	43,8	24,7	4,2
2014	251.963	30,2	0,9	47,9	16,1	4,9
2015	261.783	29,1	0,9	37,9	25,6	6,5
2016	274.408	33,7	0,7	32,5	24,5	8,6

(1)Renewable energy and waste includes geothermal, solar,wind, solid biomass, biogas and waste.

Turkey's forest areas covering almost 30% of industrial wood while meeting today, also provides a significant contribution to the energy needs of human communities. For this reason, taking into account the intensive forestry approach and forestry principles, the realization of forestry activities reveals both the protection of our forests and the necessity of processing the products obtained from the forests in the most accurate and rational way. As a result of forestry activities, it is necessary not only to determine the amount of round wood, but also to determine and quantify the amounts of wood components such as branches, leaves and bark.

In this study, Anatolian Black Pine which having the widest distribution area after oak and brutian pine which is 4.444.921 hectares in Turkey, we tried to determine the amount of raw material needed by the forest products industry. As the study area, Akçay Forest Management Chiefdom of the Vezirköprü Forest Management Directorate, which is located in the forefront of forestry production activities in Turkey, was selected.

2 MATERIALS AND METHODS

2.1 Research Area

In this study, Akçay Forest Planing Unit was selected as a study area in Figure 2. Akçay plan unit is located between $41^\circ 19' 52''$ and $41^\circ 7' 21''$ north latitudes and $35^\circ 40' 51''$ and $35^\circ 24' 48''$ east longitudes. Altitude of this area range from 195-1082m (Hacıosman Tepe) above the sea level. Study area is 25523 ha. forested area is abut 12915 ha and 12608 ha without forests. The vegetation type is forest vegetation and the dominant tree species of the vegetation are anatolian black pine and brutian pine but scotch pine and oaks are also included.

Figure 2: The Study Area

2.2 Fields Studies

In this study, the data obtained from the inventory study carried out in 2009 for Forest Management Planing. From the various age and site classes, 76 sample plots were measured. Areas of rectangular plots varied from 400m^2 and 800m^2. In each sample plots, all trees diameter at breast height (*dbh*), height, age, and bark thickness was measured.

34 sample trees from anatolian black pine stands in Akçay planing unit were selected. Sample trees were selected from each diameter classes with an effort to equal allocation. For each diameter class, efforts were made to include every height classes. Trees have living, whole crown, single body and healty speciallty.

The aboveground portion of each sample tree was divided into components and the fresh weight of each component was measured. All 34 trees were felled and weighed. Sample trees were cut down from 30 cm heigth, stem were measured from bottom to top 2 meter sections. Sample disc with 5 cm thickness were taken from the middle of all stem. The diameter and height of all live branches on the tree were measured on all sample trees. A branch to represent the tree was cut down as a sample branch. Branches were separated from their needles and bagged individually. Then, each tree component was measured for fresh weight. To determine dry weight, samples of different tree components were weighed in a laboratory before and after desiccation. Distribution of sample trees in diameter and height clases is given in Table 6.

Table 6: Distribution of Sample Trees in Diameter and Height Clases

H / **dbh**	**3**	**5**	**7**	**9**	**11**	**13**	**15**	**17**	**19**	**Total**
6	*	*	*							3
10			**	*	*					4
14				**	*					3
18				*	**					3
22						**	*			3
26						**	*			3
30							*	**		3
34							**	*		3
38							*	**		3
42						*	*		*	3
46							**	*		3
Total	1	1	3	4	4	5	9	6	1	34

2.3 Laboratory Studies

All data taken from sample trees were brought laboratory for measurement. Firstly, each tree component was measured for fresh weight. The Huber's formula was used to determine the volume of sample trees and the stem wood samples were taken from different heights. The stem wood and branch samples were oven-dried during 96 hours, needle sample 24 hours at 65 °C and weighed using an electronic scales. After desiccation all measurements were made again for determine volume and dry biomass.

Using the data obtained, fresh and dry weights of aboveground components of each sample tree and living tree biomass were calculated. The total aboveground components of each sample tree biomass allometric regression equations were developed using SPSS version 23.0 (SPSS, 2017). The independent variable was dbh. The total biomass of a sample plot was obtained by multiplying the weighted biomass by the number trees.

3 RESULTS AND DISCUSSION

Various models have been tried to determine the relationship between the biomass of the tree components and dbh and R square and standart error criteria have been used to determine the most appropriate equation. As a result of the regression analysis, the model that best describes the relationship between the biomass of tree components and dbh is given in Table 7 and Figure 3. The amount of biomass of the tree components of each sample tree were calculated and given Table 8.

Tablo 7: Allometric Relationship Between Biomass of Tree Components and Diameter at Breast Height for Anatolian Black Pine

		b_0	b_1	R^2	Std. Error	Sig. Level
Stem	$y = b_0 x d^{b_1}$	0,036	2,541	0,983	0,219	*P<0.001*
Branch	$y = b_0 x d^{b_1}$	0,008	2,762	0,919	0,530	*P<0.001*
Needle	$y = b_0 x d^{b_1}$	0,036	1,856	0,805	0,591	*P<0.001*
Bark	$y = b_0 x d^{b_1}$	0,015	2,129	0,962	0,273	*P<0.001*
Living tree	$y = b_0 x d^{b_1}$	0,070	2,502	0,979	0,240	*P<0.001*

Tablo 8: Biomass of Tree Components (kg)

	Minimum	Maximum	Mean	Std. Deviation
Stem	1.5	669.6	194.9	±185,6
Branch	0.5	626.3	112.5	±151,2
Needle	0.7	82.4	20.5	±21,8
Bark	0.4	69.6	18.9	±16,8
Living tree	3.0	1362.0	346.8	±355,6

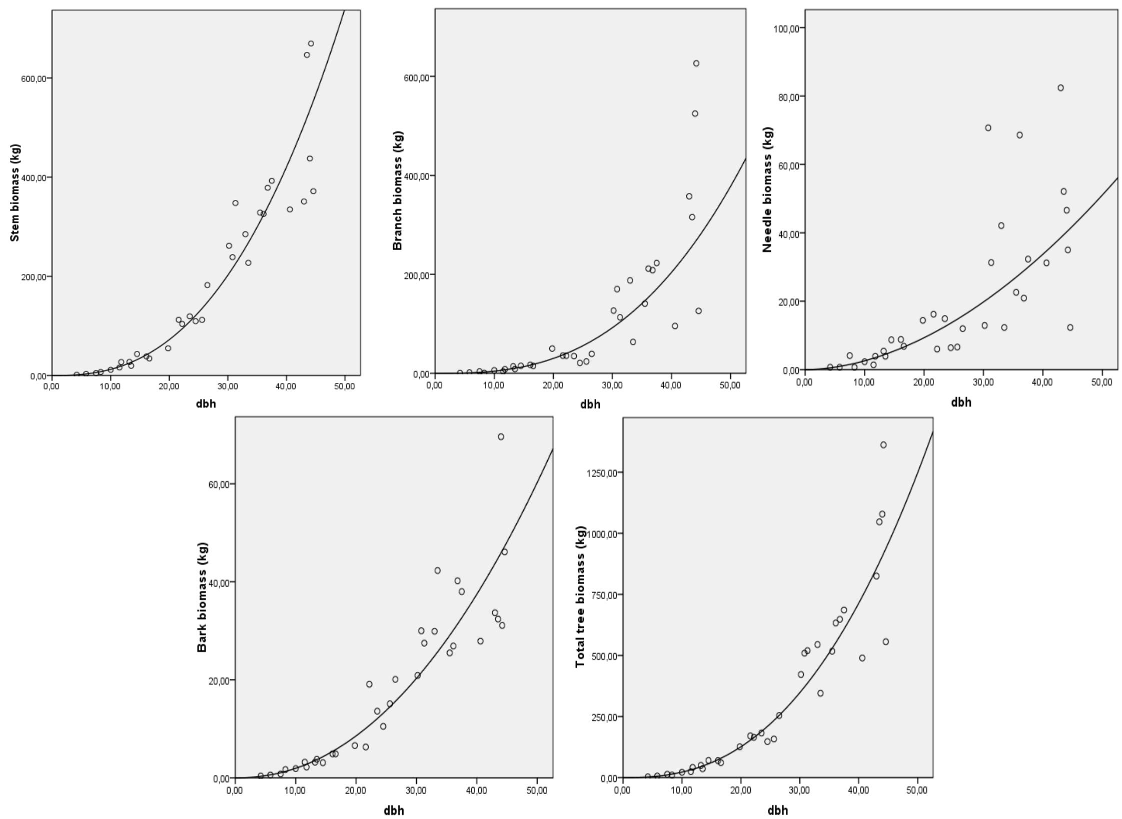

Figure 3: Relationship Between Biomass of Tree Components and dbh

Biomass of all tree components were calculated using developed biomass models. The stem, branch, needle, bark and living tree minimum and maximum biomass of anatolian black pine stands were 4,8-96.5 t/ha, 1.7-46.3 t/ha, 0.9-9.1 t/ha, 0.8-9.6 t/ha ve 6.8-163.9 t/ha, respectively. The amount of biomass in the forests varies according to the stand type and site classes. There are 10 different stands types in the Akçay planning unit where pure anatolian black pine are found. Total of 76 sample plot were taken from different stand types. The amount of biomass in each stand type in the planning unit was determined and given in Table 9.

Tablo 9: Biomass of Stand Types (t/ha)

		Stem			Branch			Needle			Bark			Living Tree		
Type of Stand	Num. of Samp. Area	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Çkab3	3	4,8	17,6	11.2	1,7	6,7	4,2	0,9	3,4	2,2	0,8	2,7	1,7	8,5	31,2	19,8
Çkb2	4	14,9	15,9	15.,6	5,9	6,5	6,3	2,43	2,54	2,47	2,0	2,2	2,1	26,1	27,8	27,2
Çkbc1	4	3,9	16,6	9.5	1,7	7,6	4,1	0,5	1,9	1,2	0,5	1,9	1,1	6,8	28,5	16,3
Çkbc3	12	24,0	96,1	50.4	10,9	46,3	22,9	2,8	9,2	5,8	2,7	9,7	5,7	41,2	16,3	86,4
Çkc1	6	6,6	42,4	23.3	2,9	20,5	11,1	0,8	3,9	2,3	0,7	4,2	2,4	11,3	71,9	39,6
Çkc2	12	19,6	40,8	31.7	8,6	19,4	14,7	2,4	4,6	3,4	2,3	4,6	3,4	33,7	70,1	54,1
Çkc3	3	49,2	83,3	68.2	23,3	37,7	31,6	4,8	9,5	7,2	5,1	9,3	7,3	83,7	143,0	116,5
Çkcd1	13	11,1	50,8	34.0	5,6	24,3	16,5	0,9	4,9	3,1	1,0	5,1	3,4	18,7	86,3	57,6
Çkcd2	12	34,7	73,4	49.5	16,5	35,7	23,7	3,4	6,6	4,7	3,6	7,2	4,9	59,1	124,3	84,0
Çkcd3	7	43,1	96,5	68.5	20,2	46,3	32,8	4,5	9,1	6,5	4,6	9,6	6,9	73,6	163,9	116,3

There are 4718.2 hectares of pure anatolian black pine stands in Akçay planing unit. Total biomass of anatolian black pine stands in planing unit was 1636,3 ton as an average. As a result of forestry activities in the year 2017, 13.000 m^3 wood was produced in the Akçay planning unit.

The wood raw material produced as a result of forestry activities is stem wood which constitutes about 57% of the total dry weight of a tree. 43% part of the tree is left to decay in the forest. Materials left in the forest, to trigger fires and increases the flame temperature. To prevent fire risk, these materials should be used in different industries, instead of coal. By using the materials left in the forest, significant contributions can be made to the energy closure of Turkey by obtaining energy.

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The Effects of Nano-TiO_2 and Nano-Boron on the Thermal Properties of Wood Plastic Composites

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ABSTRACT

Wood polymer composites are preferred due to their different properties in many fields. The ability to modify properties during production is one of the most important properties of wood polymer composites. Like all materials, wood polymer composites have also negative aspects. These properties can be improved with different support materials during production. In this study, wood plastic composites which are composed of cellulose fiber (CF) and polypropylene (PP) were supported with nano sized boron (NB) and titanium dioxide (TiO_2) during production. Thermal properties of produced wood plastic composites (TGA, DTA, DTG) have determined.

It was determined that T10% and T50% values of composites obtained after addition of cellulose fibers at 10% and 20% of pure polypropylene were lower than those of pure polypropylene, whereas T90% and residue amounts were increased after cellulose addition. After the addition of Boron and Titanium, thermal properties were generally found to be lower than that of pure polypropylene. When the DTA curves were taken, it was determined that the Tm values varied between 155.6 and 167.5 ° C and the Td values were between 446.5 °C and 449.4 °C.

KEYWORDS: Thermal characterization, Nano-boron, Nano -TiO_2, Wood Polymer Composites (WPC)

1 INTRODUCTION

The tem of wood polymer composite was born as a modern concept in Italy in the 1970s and became popular in North America in the early 1990s. In the early 21st century, it spread to India, Singapore, Malaysia, Japan, and China (Pritchard, 2004). The wood polymer composites (WPCs) are very promising and sustainable green materials to provide endurance without using any toxic chemicals. The term WPC refers to any composite containing plant fibre and thermoset or thermoplastic. Compared to other fibrous materials, plant fibres are materials generally suitable for strengthening plastics with high strength and hardness, low cost, low density, low CO2 emission, biodegradability and every year renewability properties (Ashori, 2008). The plastics industry has traditionally used talc, calcium carbonate, mica and glass or carbon fibres in order to change the performance of the plastics (Eckert, 2000). Significant industries such as aviation, automotive, construction or packaging industries have shown great interest to the development of new composite materials (Alemdar and Sain 2008).

Plant fibres have many traditional advantages and disadvantages. Their ecological properties, biodegradability, low cost, non-abrasive nature, safe fibre use, high filling levels, low energy consumption, high specific properties, low density and a wide variety of fibre types are very important factors for them to be accepted in large volume markets such as automotive and construction sectors. In addition to all, the public generally regards the products, which are made from renewable raw materials, as environmentally friendly (Lundquist et al., 2003; Kim et al., 2006; Bismarck et al., 2006).

Academic studies conducted have also increased based on increasing production and usage areas of wood polymer composites. Bledzki et al. (1998) supported polypropylene (PP), polyethylene (PE) and polyvinyl chloride (PVC) polyolefin with wood fibres and compared their properties with fibreboard (MDF). As a result of the study, it was determined that bending and tensile resistances of samples containing 55% wood fibre and 45% PP were higher than MDF samples. Ayrilmis et al. (2014) reported that the hexagonal nanoboron, which they had used as coupling agents in the wood polymer composites produced with PP and high density polyethylene (YYPE) ethylene, increased the bending resistance and modulus of elasticity. Stark and Rowlands (2007) reported that in the wood polymer composites (WPC) produced with wood flour classified using four different sieves, the bending resistance, tensile resistance and modulus of elasticity of these resistances also increased by increasing aspect ratio. In the same study, they compared the wood flour and wood fibre at the proportion of 20% and 40% in OPKs, which they had produced, separately and determined that the composites produced with fibre performed better than the composites produced with wood flour.

The production methods and methods used in analyses have influence on the properties of wood polymer composites. Migneault et al. (2009) reported that wood polymer composites demonstrated different properties produced by extrusion and injection moulding method. In another study, Jeske et al. (2012) used two different polypropylenes; polymer and copolymer (ethylene) in a study that it examined the thermal properties of wood polymer composites produced using wood flour. Within the scope of the study, individual TG analyses (thermogravimetric analysis) of polymers were conducted using nitrogen and oxygen. When using oxygen, the co-polymer polypropylene begins to decompose at the temperature of 225 °C, while this temperature is at 350 °C when using nitrogen. For this reason, the decomposition temperatures may vary depending on the method used in the TG analyses. As a result of the study, it was also stated that the copolymer (ethylene) polypropylene demonstrated higher thermal properties than the polymer propylene.

2 MATERIAL AND METHODS

Polypropylene (EH241) used as a polymer matrix in the production of wood plastic composites was obtained from Petkimya Holding AŞ and its properties are given in Table 1.

Table 1. General properties of polypropylene (EH241)

Properties	Value
Melt flow index, g/10 min (at 230 °C/2.16 kg)	5 to 20
Density (g/cm^3)	0.92
Water absorption, (%)	0.1
Processing temperature, (^{0}C)	160-170
Tensile strength, MPa (MPa)	35
Flexure modulus (GPa)	1.5
Izod impact, (kJ/m^2)	2

The wood fibres used as filler material were supplied as glueless from the MDF (Medium Density Fibreboard) plant of Kastamonu Entegre Agac Sanayi A.S. from the 50% leaved-wood and 50% coniferous wood in the production process in which they are used. After the wood fibres were supplied, the wood were brought to full dry weight (0% moisture) in the stove at the temperature of 103 ± 2 °C. The wood fibres used as filler were used at 10% and 20% in proportion to the total mixture weight.

TiO_2 used as a nanoparticle is supplied from the MK Nano Corporation (Canada) and nanoboron (NB) is supplied from the BORTEK® Boron Technologies and Mekatronik San. Tic. AS. The nanoparticles used in the study were used at 0.5% and 1% in proportion to the total mixture weight. The materials and proportions used in the production of wood polymer composites are given in Table 2.

Table 2. Materials and ratios used in the study

Filling material	Amount of PP (gr)	Amount of filling material (gr)	Amount of nano material (gr)	Mixture Weight (gr)	Nano Material Type	Sample Code
Cellulose fiber	1000	-	-	1000	-	Control
	900	100	-	1000	-	CF10
	800	200	-	1000	-	CF20
	895	100	5	1000	NB	CF1B0.5
	890	100	10	1000	NB	CF1B1
	895	100	5	1000	TiO_2	CF1T0.5
	890	100	10	1000	TiO_2	CF1T1
	795	200	5	1000	NB	CF2B0.5
	790	200	10	1000	NB	CF2B1
	795	200	5	1000	TiO_2	CF2T0.5
	790	200	10	1000	TiO_2	CF2T1

2.1 Preparation of composites

The materials, of which the definitions and quantities are given in Table 2, were mixed in a closed container for 5 minutes by means of a four-arm mechanical mixer. The obtained composites were processed through a single screw extruder with a speed of 50 rpm using extrusion method. The temperature of the extruder was set between 160 ^{0}C-170 ^{0}C and the pressure was between 5 and 10 bar throughout the production process. The mixture extracted from the extruder was cooled with water and granulated by grinding through a grinder. The granulated mixture was left in the stove at the temperature of 103±2 °C, until it reached its full dry weight (24 hours). The granulated mixture, which reached its full dry weight, was subjected to injection moulding process in order to obtain mechanical test samples.

The thermal stability of all the composites was investigated using a TGA/DTA and DSC (Perkin Elmer, TA Instruments, USA). In TGA/DTA, the samples were heated from 25 °C to 600 °C with a heating rate of 10 °C/min and a nitrogen flow of 100 mL/min. The samples weighing about 10 mg were used for the tests. Degradation temperatures at 10% weight loss (T%10) and 50 % weight loss (T%50), maximum degradation temperature in the derivative thermogravimetric peaks (DTGmax), and mass loss of the samples in the TGA cures were measured and compared with the results obtained. The differential scanning calorimeter (DSC) tests were performed on a DSC 2920 (Perkin Elmer, TA Instruments, USA) at a heating rate of 5 °C/min under a nitrogen atmosphere (Myers, 1991; Sozen et al., 2017).

3 RESULTS AND DISCUSSION

Thermal properties of wood polymer composites were carried out using TGA/DTG analysis. According to TGA results adding cellulose fiber to pure PP has decreased the thermal stability of samples. The fastest moss losses were observed in samples containing 10% cellulose fiber and 1% nano boron (CF1B1). As sees in Figure 1, it can be said that no significant difference occurred in TG analysis between CF10 and CF20 during degradation. However, rates of residue of CF10 and CF20 are 99.91% and 90.81, respectively.

The thermal degradation data for the samples revealed that most of the degradation events occur between 300 and 500 °C. The cellulose fiber containing samples are degraded at a lower temperature than the pure PP, but the slow charring reaction of wood still continues into the temperature range of PP degradation. The WPC samples showed two degradation steps, corresponding to degradation of the pure PP at around 470 °C and of cellulose at around 390 °C (Bouza et al. 2008).

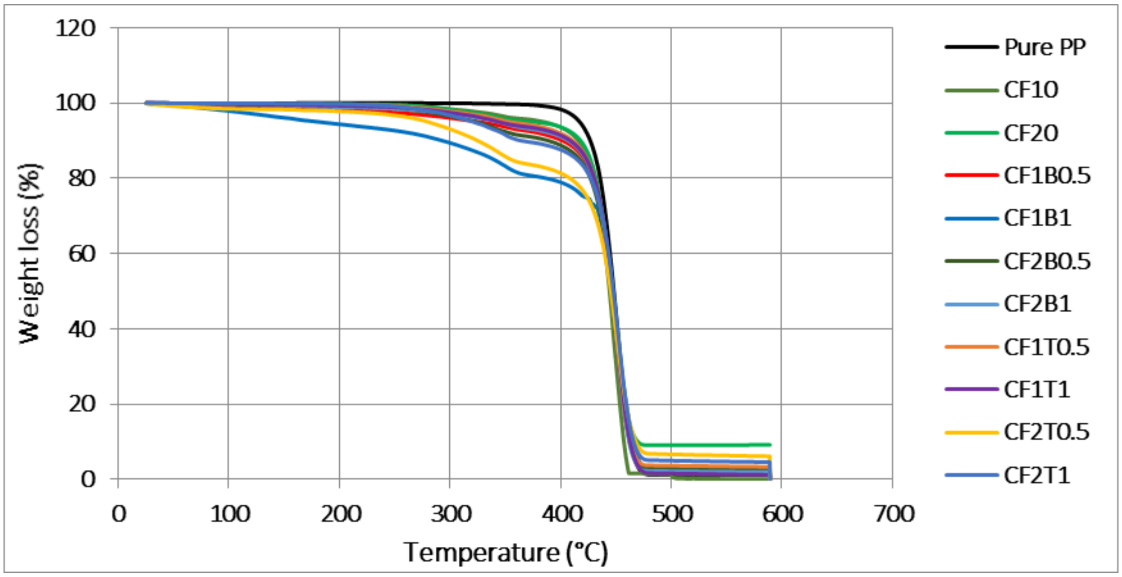

Figure 1. TGA curves of samples

All nano particles have decreased thermal stability of samples. Actually, it has been reported by Laachachi et al. (2005) and Deka and Maji (2011) that nano boron and TiO_2 have a positive effect on the thermal properties. It appears that nanoscale materials are often used with coupling agent materials in practice. In some applications it is reported that nanoparticles or matrices have been used by modified (Deka and Maji 2011).

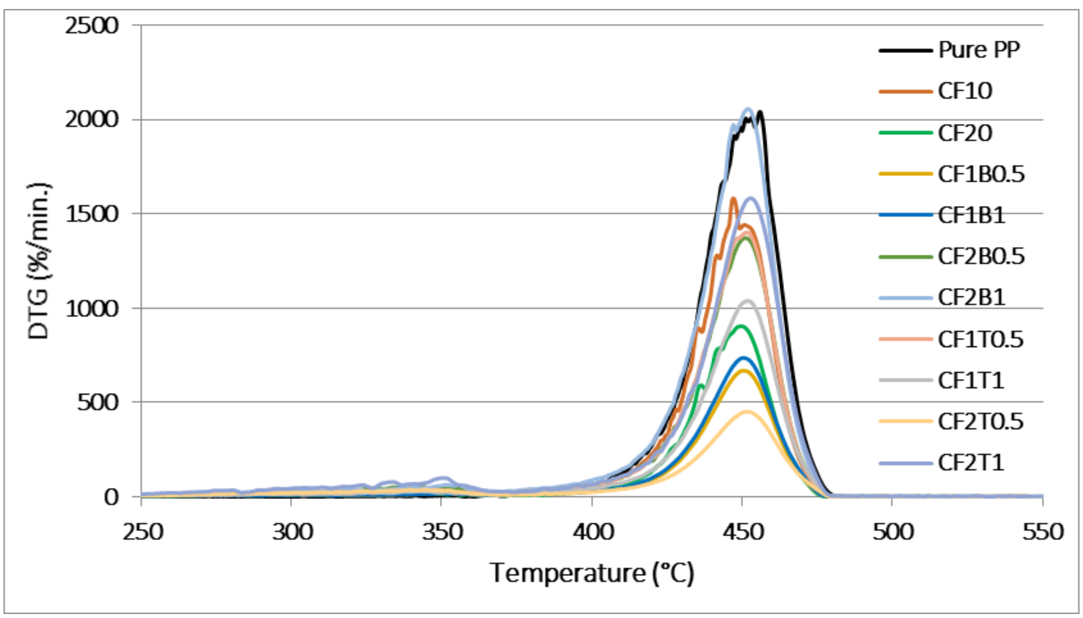

Figure 2. DTG curves of samples

DTG curves in Figure 2 showed maximum degradation at 468 °C for CF2T0.5 samples, and the peaks of the composites were found to be between 345 °C and 475 °C. CF2B1 and pure PP have shown similar peek point. In Table 3, summary of TG analysis is given. According to Table 3, the lowest Tm values were obtained in CF20 and CF10 samples, respectively. Adding nanoparticles to CF/PP composites have increased the Tm values of composites. Bouza et al (2008) have been explained that the increasing thermal energy necessary for the PP degradation may be due to entry of the PP into wood capillaries.

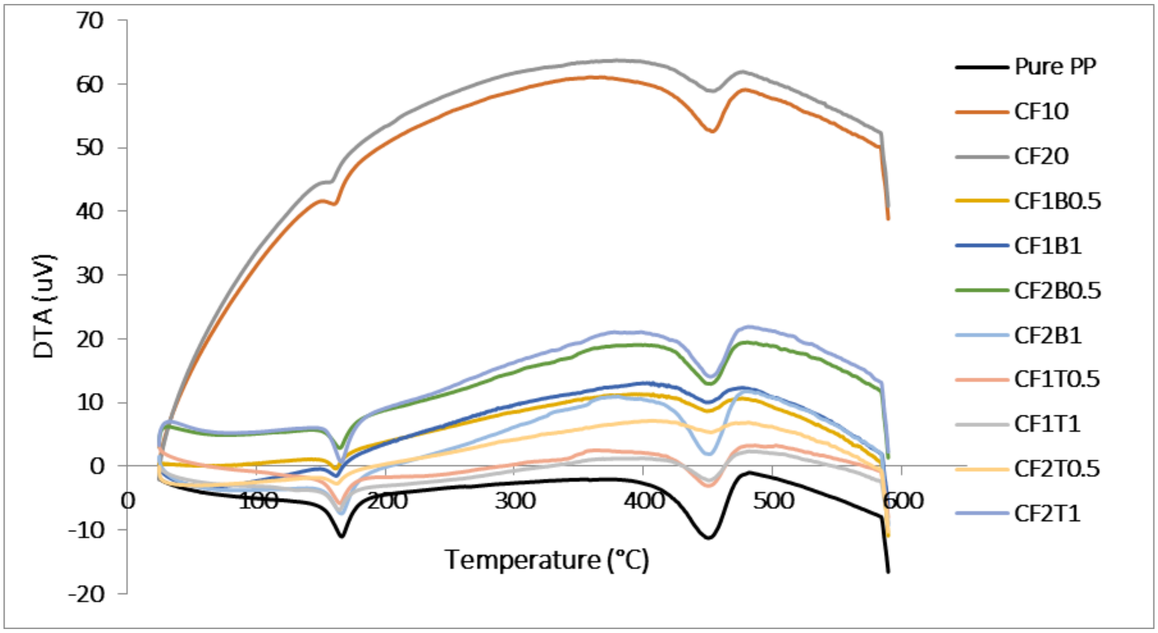

Figure 3. DTA curves of samples.

According to Fig. 3, the addition of nano-fillers increased the melting temperature (Tm) for all composites, whereas; the degradation temperature (Td) decreased with the presence of the nano-fillers as comparison with polymer containing with cellulose fibers. As seen as Tab. 3, the maximum and minimum values for Tm and Td were found to be 155,62 (CF20) and 167.48 (CF2T1), and 446.48 (CF1B1) and 454.05 (CF10), respectively.

Table 3. Summary of thermogravimetric analysis

Samples	T10% (°C)	T50% (°C)	T90% (°C)	Residue (%)	DTGmax (°C)	Tm (°C)	Td (°C)
Pure PP	426,95	448,21	463,22	98,73	456,02	163,28	451,77
CF10	416,09	444,23	457,28	99,91	447,07	158,11	454,05
CF20	418,19	446,33	470,06	90,81	449,69	155,62	453,03
CF1B0.5%	401,62	446,25	462,45	98,33	450,45	161,07	446,82
CF1B1%	292,99	446,57	465,69	97,90	450,45	164,35	446,48
CF2B0.5%	389,00	446,02	462,70	97,30	451,10	167,41	452,87
CF2B1%	406,85	446,33	461,98	98,10	451,94	167,41	448,29
CF1T0.5%	411,12	446,65	463,05	96,70	451,60	164,27	447,88
CF1T1%	322,97	446,99	462,88	98,80	452,03	164,43	449,04
CF2T0.5%	364,30	445,36	468,18	93,80	451,85	164,68	449,36
CF2T1%	426,95	447,79	466,05	95,40	452,95	167,48	452,87

4 CONCLUSION

10% and 20% cellulose fiber (CF) and polypropylene (PP) wood polymer composites were produced by melt compounding and these composites were investigated for two nanoparticles and two loading rates based on the thermal properties of CF/PP composites. The results indicated that adding nano particles to CF/PP composites have decreased the degradation temperature. It is believed that this situation caused due to no using of coupling agent. Cellulose fibers increased Td values while decreasing Tm values. When the residual mass ratios were examined, a significant difference was found between CF10 and CF20 samples. This unexpected difference is thought to be due to the inadequacy to provide a homogeneous mixture during production. The study results showed that the use of nanoparticles with coupling agent is important for integrating the desired properties.

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Gamma Irradiation of Wood Incorporated with Orthophtalitic Unsaturated Polyester Resin with Styrene: Physical and Biological Properties

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ABSTRACT

The irradiation of wood incorporated with liquid monomers, using high-energy radiation such as gamma (γ) rays from a ^{60}Co source is one of the new developments in wood protection, consolidation and restoration areas. The various properties of wood can be thus modified by polymerizing several impregnated monomers with γ-radiation. In the study, improvements in physical properties and biological performance against decay and mold fungi of wood by radiation-induced *in situ* copolymerization of three types of low viscosity-unsaturated polyester resin with styrene were studied. Radiation polymerization of orthophtalitic unsaturated polyester resins with styrene in a viscous system was performed at ambient temperature by using γ-rays. Water absorption and dimensional stability of the modified wood specimens were determined after modifications. Chemically-modified and γ-irradiated-wood specimens were then subjected to laboratory decay and mold resistance tests. Results after 24-immersion of modified wood specimens in water showed that more than 70% of water repellent effectiveness was obtained in the wood specimens after modifications with the three formulations of tested chemical mixtures; however, the highest anti-swell efficiency values (nearly 66%) were seen in the specimens treated with the only one type of treating mixtures (48% styrene + 52% UP resin T3). Mold resistance tests showed that the treating mixtures tested were not completely inhibited mold growth on the specimens' surfaces; however, some improvements in regard with decreasing mold scores were seen in comparison with control wood specimens. Decay resistance tests revealed that after modifications, the specimens showed increased resistance against the fungi tested.

KEYWORDS: Irradiation, polymerization, unsaturated polyester, styrene, wood, decay, termite, modification

1 INTRODUCTION

Modification process for wood is employed to improve a number of properties of the wood material primarily related to its hygroscopicity, dimensional stability, deterioration and degradation by fungi and insects. Due to increased environmental considerations, wood modification processes are currently facing major developments. Various novel technologies and modifying agents such as thermal modification, acetylation, furfurylation, and different impregnation and polymerization processes as well as new monomer and polymer systems, and resins have been successfully introduced in the market as modern technologies (Sandberg et al. 2017).

In lumen modifications, wood is first vacuum impregnated with liquid monomers, then *in situ* polymerized, and the polymer is finally located almost solely in the lumens of the wood. In these modifications, unsaturated polyester (UP) resins are most often used in combination with other monomers, making them less expensive and improving their properties. Many polyester resins are available as commercial products. Polyester and styrene were generally polymerized individually and in combinations by gamma radiation or benzoyl peroxide. Styrene is frequently mixed with polyester resins to reduce viscosity, thus enabling better penetration into the wood (Ibach and Rowell 2013). Jurkin and Pucic (2006) have stated that the UP resins are most widely used thermosetting resins and are being increasingly applied for various purposes because of their balanced mechanical and chemical characteristics and a low cost (Aziz et al., 2005). The UP resins are being used as the polymer matrix for composites and, recently, nano-composites. Essentially, the UP resins include polyester coils swollen to some extent in a vinyl monomer as a solvent and crosslinking agent.

UP resins are the condensation products of unsaturated acids or anhydrides and diols with/without diacids and the unsaturation part provides a site for cross-linking (Dholakiya 2012). Cao and Lee (2003) have discussed that UP resins are commonly used in the composite industry and provide exceptional mechanical and chemical properties, improved chemical and weather resistance, and they are cost effective. The cross-linking reaction between UP resins and vinyl monomers, i.e. styrene, allows one polymer chain to connect with other polymer chains, and to produce a three dimensional network. These reactions finally convert the whole resin system to a hard, thermoset solid.

The crosslinking reaction of UP resins is generally initiated by various curing methods such as thermal or redox initiator; however a number of concerns regarding these methods i.e. uncompleted conversion, difficulties of homogeneous mixing with UP resin, release of residual styrene and unwanted odor are available. The alternative way of curing UP resins is radiation technology with many advantages over the traditional curing methods. In radiation techniques, no further catalyst or additives are needed to start the reaction and whole curing process can be performed at low temperatures (Jurkin and Pucic (2006). Gamma irradiation is one of the radiation techniques for wood modification by monomers. Since wood material is a mixture of high molecular weight polymers, exposure to high-energy radiation will depolymerize these polymers and free radicals to initiate polymerization are formed (Ibach and Rowell 2013).

Numerous types of UP resins have been successfully used for wood preservation and consolidation with styrene since the volatilization of the polymer mixture is notably decreased from the matrix (Mahmoud et al. 2001). The aim of the present work was to improve dimensional stability, water absorption and decay resistance of Scots pine wood by impregnating with UP resin and styrene under gamma irradiation process. This paper represents some test results that are part of a larger research project carried out with the cooperation of Turkish Atomic Energy Authority (TAEK). The project basically focuses on application of radiation techniques for protecting cultural heritage and property such as wood, paper, textiles etc. The application of ionizing radiation for the disinfection of cultural heritage artifacts has been successfully demonstrated in recent years. The project deals with evaluating the effect of irradiation on the functional properties of such artifacts' base materials and minor constituents, as well as on post-irradiation effects and appropriate irradiation procedures for wider use of the technique. In the project, various consolidation processes are applied to cultural heritages by radiation processing.

2 MATERIALS AND METHODS

2.1 Wood specimens

Wood specimens were prepared from sapwood portions of a Scots pine log (*Pinus sylvestris* L.) harvested from Artvin Province, Turkey. The specimens were cut from planed strips with a cross-section of 25 mm 9 15 mm, on which the growth rings ran in any direction except completely tangential on the broad faces. The longitudinal faces were parallel to the direction of the grain. Transverse cuts were made neatly to produce sharp edges. The specimens were exclusively from sapwood containing little resin and having between 2.5 annual growth rings per 10 mm and 8 annual growth rings per 10 mm. The proportion of late wood in the annual rings did not exceed 30 % of the whole. The wood specimens were free from cracks, stain, decay, insect damage or other defects based on the BS EN 113 and BS EN 84 standard test methods (BS EN 1997a,b). All specimens were conditioned in a conditioning room at (20 ± 2) °C and 65 ± 5 % relative humidity (RH) for 30 days before treatment.

2.2 Treatments

Styrene and orthophtalitic unsaturated polyester (UP) resin were obtained from Toteks Dış. Tic. Tekstil San. Ltd. Şti. – UniGrup, Istanbul, Turkey. Styrene is a colorless, combustible liquid and soluble in ethanol and insoluble in water. Styrene is commonly used in mixtures with other polymerizable substances such as unsaturated polyester resins for the consolidation of wood. UP resins are colorless to pale yellowish, viscous liquids and used usually with irradiation curing for the consolidation purposes (Unger et al. 2001).

Wood specimens were weighed, and then vacuum-treated with the UP resin and styrene mixtures based on the BS EN 113 standard test method (BS EN 1997a).

The used mixtures by weight (w/w) were as follows:

MIX A: 48% styrene + 52% UP resin T1

MIX B: 48% styrene + 52% UP resin T1 UV

MIX C: 48% styrene + 52 UP resin T3

After treatments, the specimens were dry-blotted and weighed again to determine preservative uptake as kg/m^3. Retention of the resin mixtures and weight gain were calculated by specimen weights after the treatments.

The treated specimens were then immediately exposed to gamma irradiation process. In the processes done at TAEK, Ankara, Turkey, the specimens were irradiated to 25kGy dose by using Isotope Ob-Servo Sanguis Co^{60} gamma irradiator at a fixed dose rate of 1.714 kGy/h at ambient temperature and atmosphere. The specimens were then re-dried at 60 ± 2 °C for 3 days.

2.3 Water absorption, volumetric swell, water repellent effectiveness and anti swell efficiency of modified and gamma irradiated specimens

Water absorption (WA) was evaluated according to the below equation (Eq. 1):

$$WA\ (\%) = ((W_2 - W_1) / W) \times 100 \quad (1)$$

where W_2 is the weight after immersion in water for either 2 or 24 h (g), and W_1 is the oven-dried weight before immersion in water (g).

Volumetric swelling (VS) was determined by measuring the oven-dried and wet dimensions of the specimens using the below equation (Eq. 2):

$$VS\ (\%) = ((V_1 - V_0) / V_0) \times 100 \quad (2)$$

where V_1 is the wet volume of the specimen after immersion in water for either 24 or 48 h (mm^3), and V_0 is the oven- dried volume of the specimen (mm^3).

Water repellent effectiveness was calculated based on the water absorption values of the specimens as follows: (Eq. 3)

$$WRE\ (\%) = 100 \times (WA_1 - WA_2) / WA_1 \quad (3)$$

where WA_1 is water absorption of untreated wood specimens, while WA_2 is water absorption of modified wood specimens.

Anti-swell efficiency was then calculated based on the volumetric swell values of the specimens as follows (Eq. 4)

$$ASE\ (\%) = 100 \times (ASE_1 - ASE_2) / ASE_1 \quad (4)$$

where ASE_1 is anti swell value of untreated control specimens while ASE_2 is anti swell value of modified wood specimens.

2.4 Fungal decay resistance of modified and gamma irradiated specimens

Wood decay tests were performed according to the Kolle flasks test method based on the BS EN 113 standard test method (BS EN 1997a). For each treatment group, 12 wood specimens were inoculated with *Trametes (Coriolus) versicolor* (MAD 697) and *Fomitopsis (Tyromyces) palustris* (TYP 6137) fungi. After 12 weeks of incubation in a conditioning chamber at 20 ± 2 °C and 65 ± 5 % RH, mycelium was removed from the specimens prior to drying at 60 ± 2 °C to weight constancy. Weight losses in the specimens were then calculated based on the initial constant weights.

2.5 Mold resistance of modified and gamma irradiated specimens

Modified and untreated control specimens were evaluated for resistance to mold fungi according to a modification of the ASTM D4445 standard test method (ASTM 2012). Three mold fungi, *Aspergillus niger* ASN 6275, *Trichoderma harzianum* Rifai, FS19 and *Penicillium fellutanum* F66 were grown and maintained on 2% malt agar at 27 ± 2°C, and 80 ± 5% RH. A mixed spore suspension of the three test fungi were prepared by washing the surface of individual 2-week-old Petri plate cultures with 10–15 mL of sterile DI water. Washings were combined in a spray bottle and diluted to approximately 100 mL with DI water to yield approximately 39107 spores mL^{-1}. The spray bottle was adjusted to deliver 1-mL inoculum per spray. Specimens were sprayed with 1 mL of mixed mold spore suspension and incubated at 27 ± 2°C and 80 ± 5% RH for 4 weeks. Following incubation, specimens were visually rated on a scale of 0–5, with 0 indicating the specimen was completely free of mold growth, and 5 that it was completely covered with mold growth.

3 RESULTS AND DISCUSSION

Uptake of the treating solution mixtures by wood specimens after modifications is given in Table 1. The table also represents weight gain of the specimens after modifications. The uptake values of modified specimens much lower than that of distilled water-treated control wood specimens (723 kg/m^3). This suggested that the high viscosity (about 200-400 cP) and molecular size of the compounds for modifications played an important role in obtaining less retention levels when compared to distilled water.

Table 2 shows water absorption and volumetric swell values of control and modified wood specimens as well as the effect of the modifying agents and gamma irradiation on water repellent effectiveness and anti swell efficiency. The values were obtained from the specimens immersed in distilled water for 24 and 48h. Results revealed that water absorption and volumetric swell were greatly improved in modified and gamma irradiated specimens when compared to control specimens. Interestingly, gamma irradiation in untreated wood specimens (without the resin and styrene) resulted in considerably less water absorption (around 52% for 24 h immersion; 45% for 48 h immersion) in comparison with untreated specimens without gamma irradiation. However, volumetric swell values in gamma irradiated control specimen were higher than those in control specimens without gamma irradiation (around 25% for 24 h immersion; 18% for 48 h immersion). The best results among the modified and gamma irradiated specimens were obtained in the specimens treated with 48% styrene + 52% UP resin T3 formulation. In these treatments, water repellent effectiveness was nearly 78%; while anti swell efficiency was 66% when compared to untreated and non-radiated specimens for 24 h immersion. These results suggest that gamma irradiation may have caused some chemical changes in particularly in the hemicelluloses and cellulose components of wood that are responsible for water absorption.

Table 1: Uptake and weight gain in the specimens

Test specimens	Treatment code	Uptake of modification compounds (kg/m^3)*	Weight gain after chemical modification (%)*
Control specimens	-	-	-
Gamma irradiated unmodified control specimens	-	-	-
Modified wood specimens	MIX A (48% styrene + 52% UP resin T1)	454,00 (46,46)	87,43 (15,12)
Modified wood specimens	MIX B (48% styrene + 52% UP resin T1 UV)	442,00 (59,96)	82,43 (15,41)
Modified wood specimens	MIX C (48% styrene + 52% UP resin T3)	402,00 (88,09)	72,06 (13,78)

*Each number is average of 120 specimens. Values in the parentheses are standard deviations. For comparisons, distilled water uptake of unmodified control specimens was 723,00 (±67,22) kg/m^3.

The majority of the accessible OH groups of the cell wall are associated with the hemicellulosic constituents of wood cell. Hill (2006) states that the OH groups associated with the cell wall polymeric constituents are very important in determining many of the properties of wood. Many of the material properties of wood depend upon the presence of these groups and, in particular, hydrogen-bonding interactions between the molecular components of the cell wall. Moreover, the OH groups are also responsible for absorption of moisture (leading to dimensional instability). Despot et al. (2012) reviewed that the break down of cellulose component in gamma-irradiated wood is very typical and holocellulose portion of cell walls is degraded by gamma irradiation. Even small doses of gamma radiation lead to a destruction of hemicelluloses' pentose creating new compounds and new chemical bonds (Seifert 1964). The dose of 500 kGy results in increased wood solubility due to depolymerization and destruction of hemicelluloses (Chawla 1985). Borysiak (2010) investigated that the content of cellulose in wood was similar during the initial stage of gamma radiation at the dose range 20–300 kGy; however, when the doses increased above the level of 500 kGy then the cellulose content decreased rapidly. The highest irradiation dose (9 MGy) resulted in the total destruction of wood. Katsumata et al. (2007a, b) showed a reduction on the degree of polymerization of cellulose by increasing the dose up to 100 kGy in *Cryptomeria japonica* wood. The decrease in water absorpti on and volumetric swell in modified specimens is because the hydrophobic polystyrene shields the wood surfaces and remains in the cell wall and lumen, resulting in less water penetration into the wood (Cao and Lee, 2003). There was a significant improvement of water repellence between the untreated and treated wood. Wood of different types impregnated with a polymer mixture containing an macro-monomer and styrene had improved water repellency, compression and bending strength (Baki et al., 1993). Mahmood et al. (2001) showed that the use of the unsaturated polyester/styrene mixtures resulted in a higher water repellent effectiveness, and anti-swelling efficiency. Devi et al. (2003) also found that chemical modification by styrene and methacrylate improved the volumetric swelling and anti-shrink efficiency in rubber wood.

Table 2: Dimensional stability and water absorbance test results

Specimens/ Treatments	**Immersion duration**	**Water absorption (WA) (%)***	**Volumetric swell (VS) (%)***	**Water repellent effectiveness based on water absorption WRE (%)***	**Anti swell efficiency based on volumetric swell (ASE) (%)***
Modified and gamma irradiated wood specimens - MIX A (48% styrene + 52% UP resin T1)	24 h	21,56 (2,11)	9,47 (3,22)	74,46 (12,09)	13,93 (2,65)
Modified and gamma irradiated wood specimens - MIX B (48% styrene + 52% UP resin T1 UV)	24 h	19,18 (3,04)	6,92 (2,00)	77,28 (13,45)	37,16 (7,45)
Modified and gamma irradiated wood specimens - MIX C (48% styrene + 52% UP resin T3)	24 h	18,90 (2,90)	3,70 (1,45)	77,61 (11,10)	66,36 (5,89)
Gamma irradiated unmodified control specimens	24 h	40,75 (9,34)	13,80 (3,33)	-	-
Untreated control specimens	24 h	84,41 (11,43)	11,01 (2,09)	-	-
Modified and gamma irradiated wood specimens - MIX A (48% styrene + 52% UP resin T1)	48 h	29,99 (3,45)	10,79 (3,02)	66,15 (8,88)	18,21 (3,01)
Modified and gamma irradiated wood specimens - MIX B (48% styrene + 52% UP resin T1 UV)	48 h	26,85 (7,21)	11,31 (1,87)	69,69 (14,32)	14,22 (2,22)
Modified and gamma irradiated wood specimens - MIX C (48% styrene + 52% UP resin T3)	48 h	25,99 (4,44)	6,96 (0,76)	70,66 (10,87)	47,23 (7,43)
Gamma irradiated unmodified control specimens	48 h	48,37 (9,43)	15,57 (4,77)	-	-
Untreated control specimens	48 h	88,59 (11,09)	13,19 (2,32)	-	-

*Each number is average of 15 specimens. Values in the parentheses are standard deviations.

Table 3 gives mold scorings in the specimens exposed to mold fungi for 4 weeks. Results suggested that no modifying agents and gamma irradiation resulted in complete inhibition of mold growth on the wood specimens even though mold ratings in modified specimens were smaller than those in untreated controls. Irradiation in control specimens caused a slight increase in mold growth.

Table 3: Mold ratings after 5-week-exposure to mold fungi

Test specimens	Treatment code	Mold rating*
Control specimens	-	4,5 (0,9)
Gamma irradiated unmodified control specimens	-	4,8 (0.7)
Modified and gamma irradiated wood specimens	MIX A (48% styrene + 52% UP resin T1)	3,0 (1,2)
Modified and gamma irradiated wood specimens	MIX B (48% styrene + 52% UP resin T1 UV)	2,5 (1,7)
Modified and gamma irradiated wood specimens	MIX C (48% styrene + 52% UP resin T3)	4,3 (1,1)

*Each number is average of 15 specimens. Values in the parentheses are standard deviations. On a scale of 0–5, with 0 indicating the specimen was completely free of mold growth, and 5 that it was completely covered with mold growth (0: no growth, 1: 20 %, 2: 40%, 3: 60%, 4: 80%, and 5: 100% coverage with mold fungi).

Table 4 indicates the weight losses occurred in the specimens subjected to fungal resistance tests by the two *Basidiomycetes* fungi in laboratory conditions. When compared to untreated specimens (no radiation), gamma irradiation resulted in increased weight losses in gamma irradiated control specimens exposed to *T. versicolor*, a white rot fungus. However, slight decrease was observed in these values when *T. palustris*, a brown rot fungus, was employed. No complete inhibition by the modifications and gamma irradiation was observed in the decay resistance tests; however, important decreases in weight losses were seen after the modifications. The lowest weight losses were obtained in the specimens with the Mixture C with T3 type resin. Despot et al. (2012) states that as gamma radiation causes break-up of cellulose to shorter chains, which are water-soluble, and that leads to an "opening of additional micro-cracks", in which water molecules can easily penetrate. Consequently, gamma irradiated wood is also more accessible to enzymes of wood decaying fungi. Unger et al. (2001) discusses that depending on the dosage applied, the gamma irradiation causes formation of radicals and ionization of molecules, thus, chemical bonds are broken, cellulose chains become shortened and functional groups are changed in wood. Due to chemical changes in wood after radiation, acceleration of aging can lead to increased susceptibility to biological attack. For increased biological resistance to fungi, filling lumens with polymers is an important issue since polymerization makes the cell walls inaccessible to moisture and decay organisms. On the other hand, the amount of polymer in the cell wall is also crucial factor for decay resistance. Some protection against biological degradation is possible at cell wall polymer contents of 10% or more (Ibach and Rowell 2013). Sandberg et al. (2017) reviews that modified wood has generally lowered equilibrium moisture content and fungi hardly obtain the moisture required for decay. Such wood also physically blocks the entrance of decay fungi from the micro pores of the cell walls and inhibits the action of specific enzymes (Hill 2006; Rowell et al. 2009; Rowell 2016).

Table 4: Fungal decay resistance tests results

Test specimens	Treatment code	Weight loss (%) by *T. palustris**	Weight loss (%) by *T. versicolor**
Control specimens	-	51,98 (6,48)	42,76 (10,05)
Gamma irradiated unmodified control specimens	-	50,47 (11,53)	49,01 (7,00)
Modified and gamma irradiated wood specimens	MIX A (48% styrene + 52% UP resin T1)	19,09 (7,10)	9,24 (1,58)
Modified and gamma irradiated wood specimens	MIX B (48% styrene + 52% UP resin T1 UV)	17,10 (5,58)	6,98 (2,61)
Modified and gamma irradiated wood specimens	MIX C (48% styrene + 52% UP resin T3)	12,14 (7,34)	3,46 (1,13)

*Each number is average of 12 specimens. Values in the parentheses are standard deviations.

4 CONCLUSION

UP resins are most often used in combination with other monomers, making them less expensive and improving their properties. UP resin and styrene are generally polymerized in wood by gamma radiation. In this study, modifications by styrene and UP resin with different formulations and gamma irradiation greatly improved water absorption and volumetric swell of wood specimens when compared to unmodified control specimens. Even though such modifications did not inhibit completely mold growth and decay fungi in the specimens, weight losses is decay resistance tests by *Basidiomycetes* fungi decreased considerably while mold scorings with two formulations of modifying agents were smaller than those occurred in control specimens. Results suggest that modifications by styrene + UP resin along with gamma radiation improves water absorption, in turn, decay resistance against decaying and mold fungi.

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ABSTRACT

Lignocellulose materials are considered as suitable raw materials to production low cost adsorbents . In this work , activated carbon was prepare from wood branches for several types of tree (*Calistemon viminalis , Thuja orentalism , Cupressus sempervirens , Pinus brutia* and *Bauhinia variegata*) which are usually left in the forest land after being separated from timbers or through pruning process . Chemical carbonization at 500˚C for 1.30 hr. was used to prepare carbon , KOH solution for 24 hr. was used to activated the carbons . The results indicated that characteristics (Soild yield, burn off, density, moisture content, ash content, pore volume, porosity percent, Iodine number and removal percent of methyl blue) for all activated carbon were compared with commercial activated carbon. The result showed that activated carbon for all wood types using KOH solution has good adsorption properties (removal blue dyes % and iodine number mg/g) . This Low cost activated carbons can be used for waste water treatment .

Keywords : Activated carbon, wood type, chemical activation, adsorbents.

1 INTRODUCTION

Carbonic materials that has an advanced surface area with porous tissue . It is an amorphous form of carbon that is processed for the purpose of forming a structure with highly developed internal pores and a large area of surface reach in some types to 3000 m^2/g of adsorbents (Alhamed , 2006 & Ahmed , 2011). In nature, it is mostly amorphous and in which a high degree of porosity is developed through the a process of manufacturing and treatment (Abechi et al. , 2013) . This process is done by creating pores and controlling functional groups that facilitate absorption of pollutants from their streams (Sunanda et al. , 2013).

Activated carbon production is carried out through carbonization of raw materials which is activated at high temperature to obtain the final production (Pragya et al. , 2013) . Studies on the production of activated carbon used agriculture wastes, fruit stones, hard shell of fruit stones, bagasse, manure compost, oil palm waste, agriculture residue from sugarcane, saw dust, rosa canina spp. seeds , sewage sludge, ...etc. (Shrestha , 2011) . Coconut husk, palm shells, saw dust and tropical wood are among the most agriculture residues used to produce activated carbon (Pragya et al. , 2013). In previous years, waste from various wood industries and oil palm residues formed the main source of biomass , currently due to the lack of wood material supply , wood residues convert to activated carbon (Lam & Zakaria , 2008) . Commercial activated carbon is expensive , because of the use of non - renewable , high cost starting materials such as coal , which are difficult to use in pollution control application . therefore, in recent years attention has been paid to the production of activated carbon to remove various pollutants using renewable and cheaper materials (I.A.W., 2008).

The furnace is used as a common heating device for the manufacture of activated carbon, the heat is transferred through conduction and convection, the outside surface of the sample is in contact with the generated heat , which is rapidly diffused in to the interior (Hui & Zaini , 2015). Production process divided in to three steps (dehydration , carbonization and activation) , there are two process type of activation (physical & chemical) process , Physical activation involves two phases (carbonization process follow with activation by an activated gas such as CO_2 & H_2O) , it involves oxidation of raw materials at a high temperature reduction (800 - 1000) ° C in the presence of an oxidizing agent (Hirunpraditkoon et al. , 2011 and Bae et al. , 2014) . Chemical activation consists of a single step using chemical agents such as ($ZnCl_2$, H_3PO_4 , KOH and $CaCL_2$) which have dehydration and oxidation properties for activation purposes (Hirunpraditkoon et al. , 2011 and Zainulabdeen , 2016) .

Chemical activation is performed using a lower temperature than physical activation as it improves the development of pores in the carbon structure of the chemical affect , also the yield are higher than physical activation (zainulabdeen , 2017) . Hirunpraditkoon et al. (2011) said that chemical activation gives activated carbon (central area , limited identification and a much better helper than physical activation) , different activation agent provide activated carbon with different properties .

Increasing pollution of municipal and industrial sewages by toxic compounds due to industry development and growth is a concerning issue. Adsorption is a process during which a soluble material accumulates on the surface of another substance . In fact , adsorption is the function of transferring from liquid phase to solid phase . Adsorption is an important phenomenon in many physical , chemical and biological processes in the nature . Adsorption is also widely used in water and wastewater treatment (Abechi et al. , 2013 and Dowlatshahi et al. , 2014) .

One of the most important application of activated carbon are (separation of gases , recovery of solvent , removal of organic pollutant from drinking water and a catalyst in many other processes (sugawara et al. , 2007 and Yacob et al., 2008) , also in removal of infusion , decontamination and gas respirators for protection against toxic gases (shalna and yogamoorthi , 2015) .

Types of trees (*Galistemon viminalis* , *Thuja orentali s*, *Cupressus sempervirens* , *Pinus brutia* and *Bauhinia variegata*) are among the most species planted in recent decades in different parts of Iraq . These species produce large quantities of Cutting of wood annually through branch pruning and mitigation or as residues for various commercial processes (Dawood ,1979) .

For this purpose , this study was conducted to consider the possibility of producing active carbon from the logging of these species using the chemical method using KOH solution as an active substance for activating , also study of their properties and a comparison between the types of activated carbon produced from these types of wood in terms of productivity and absorbability .

2 MATERIALS AND METHODS

SAMPLE PREPARATION

The samples were taken from the lower tree branches of (*Galistemon viminalis* , *Thuja orentalis* , *Cupressus sempervirens* , *Pinus brutia* and *Bauhinia variegata*) trees planted in different areas of the city of Kirkuk . The selection of these trees was free from insect , fungal infections also the age and diameter of the branch almost convergent . The samples were cut 5 cm long with 5 samples per tree (Figure 1) , then dried in temperature of between (90 – 110) ^{o}C until reach to constant weight and weighed to be ready to prepare activate carbon .

Figure 7: Samples of different tree branches used in preparation of activated carbon

The density of different wood samples has been measured to be used as an indicator of the amount of wooden material they are experiencing by Equation (3) .

CARBONIZATION

Samples are putted in the furnace at the temperature 500˚C for time 1.5 hr. (Mansooreh and Kaghazchi 2014) and (Patil et al 2013) at which all of the materials were completely carbonized, the carbonized materials were cooled, crushed and kept in containers (Figure 2), to find the solid yield by Equation (1) and the burn off by Equation (2) :-

Solid yield %= (Wc / Ws)*100 .... (1)

Burn off%= ((Ws-Wc) / Ws)*100... (2)

Ws = weight of the sample before of carbonization (g.)

Wc = weight of carbon after carbonization (g.)

Figure (2) : Carbonization Samples after cooling & Crushing

CHEMICAL ACTIVATION OF CARBON

Chemical activation of carbon KOH 25% are used by saturation process to activated all wood carbons, weighted (25 g) of KOH , mixed with (25 g) of each samples , then added 100 ml of distillate waters and mixed it , left for 24 hr. (zainulabdeen , 2017) . After 24 hr. , the samples were washed by distillate water (8–10) times and use pH meters for test washed water until the pH meter reads (6.5- 7.5) . Then dried the activated samples in 70˚C for 24 hr. in electric normal furnace to be ready to study the characteristics of activated carbons.

CHARACTERIZATION OF ACTIVATED CARBON

1- BULK DENSITY

The bulk density of activated carbon is defined as the weight of a unit volume of the sample in air. The sample put in cylinder of (10 ml) and then weighted . The density of activated carbon depends on the shape, size and density of the individual particles of samples, it can calculate by Equation (3) (Zainulabdeen , 2017) .

ρ = Mc/Vc …………………….. (3)

Where: ρ = bulk density (g/ml) , M= mass of activated carbon (g) & V= volume of activated carbon (ml) .

2- MOISTURE CONTENT

Moisture content of activated carbon was determined by heating process for weighted samples in oven at 120˚C for 3hr. , after heating the sample until the weight constant , then is allowed to cool to the room temperature by placed in a desiccators and weighted . The moisture content determined by the following equation (Sunanda et al. , 2013) :

Moisture % = ((Wi – Wf) / Wi)*100 .... (4)

Where: Wi = initial weight of activated carbon before heating.

Wf = final weight of activated carbon after heating.

3- pH

The pH value of activated carbon was calculated by weight 1 g. of dry activated carbon , then washed for 5 minute with 30 ml. The distillate water filtered with filter paper and pH of filtrate was measured (Rhoda and Ideyonbe , 2015) .

4- ASH CONTENT

For the purpose of estimating the total content of the ashes placed 1gram of activated carbon to a crucible and reweighted together, then heated in a muffle oven at 650˚C for 3 hr. , after that the activated carbon was cooled and reweighted . Ash content calculated by equation (5) (Zainulabdeen , 2017) .

Ac = (F-G) / (B-G) *100 ……….. (5)

Where : G = weight of empty crucibles in g.

B = weight of the crucible plus dry samples in g.

F = weight of crucible plus ash sample in g.

5- IODINE NUMBER

Iodine number is very important characteristic of activated carbon , put 1g. of activated carbon in the conical flask 250ml and add 10ml. of HCL (5%) . Then heated the contents for half hour , at after cooled add 100ml of iodine solution 0.1N , and shaking the mixture for 30 min. Initially 20 ml. of the filtrate was cancelled and take 50ml titration by (0.1N) of sodium thiosulfate until the colour of solution change from the orange to yellow color then added (2ml.) of starch solution were added and the titration was carried on until a colorless solution was produced, the iodine number is calculated from the Equation (6) (Zainulabdeen , 2017) :

$I_n = \frac{X}{M} A$ ………………….. (6)

Where : X = mg. of iodine adsorbed by the activated carbon.

X = (12.692 N_1) -(279.246 $N_2 * V$)

N_1 = normality of iodine solution.

N_2 = normality of solution thiosulphate solution.

V = volume of sodium thiosulphate solution in ml.

M = mass of activated carbon (g).

A = correction factor.

6- METHYLENE BLUE NUMBER

The methylene blue value is defined as the number of millilitres standard methylene blue solution decolourized by 0.1 g. of activated carbon. Prepare 1000 ml. (1500 ppm) of methylene blue stay for 24hr , at the same time prepare 5 sample of methylene blue (5ppm , 10ppm , 15ppm , 20ppm , 25ppm) stay for 24hr also . Then take 0.1g from each sample and putted in 100 ml. (20ppm) methylene blue and put them in the shaking device for mixing for 30 minutes until absorbed. The calibration of five samples of methylene blue of different concentration putted in the U.V. spectrometer to read absorbance value and draw the relation between the concentration and absorbency shown in (Figure 3) .

After 30 minutes we read the absorbency of samples in U.V. and it must be cleaned the test container by alcohol and distillate water between each sample then we can read the residual concentration for each sample from (Figure , 3) and find the removal percentage (R%) of dye by the adsorbents and amount of dye adsorbed at equilibrium (q_e) (mg/g) were calculated by the following equation respectively (Velmurugan et al. , 2011) .

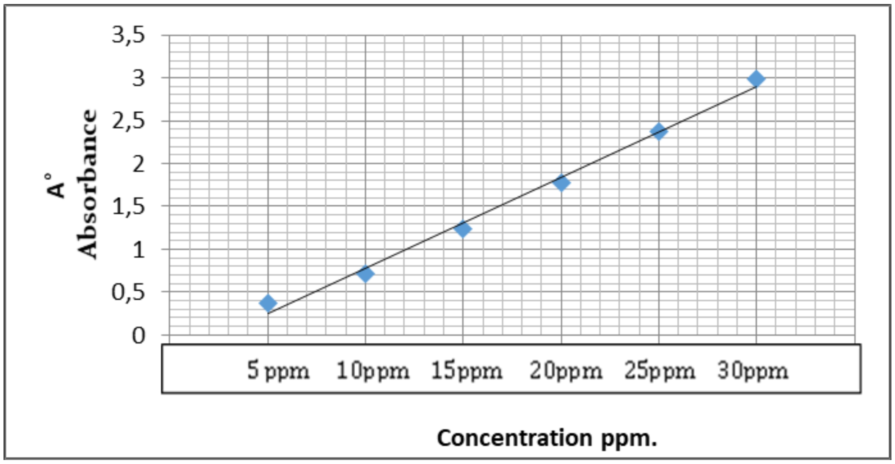

Figure 3 : the relation between concentration & absorbance

Removal % = ((Co-Ce) / Co)*100.. (7)

q_e = (Co-Ce)V / W ……………... (8)

Where: Co = the initial concentration of prepared M.B solution (mg. /l)

Ce= the residual concentration of M.B solution (mg. /l)

V= volume of solution in litters.

W= amount of adsorbent used (activated carbon) (g) .

7- PORE VOLUME AND POROSITY

The pore volume of activated carbon determined by weight one gram of samples , transferred into a measuring cylinder of 10 ml. and recorded the volume of the particles . Then the sample was placed in to a beaker containing 20ml. of distillate water and boiled for five minutes for displaces air in the sample , then the beaker contain was dried and reweighted . The increase in activated carbon weight divided by density of water give the pore volume for activated carbon . The porosity of the same sample was calculated by dividing the pore volume of particle of the total volume of activated carbon particles (Rhoda and Ideyonbe , 2015) . Results and discussion

The density of the used wood species was included in (table 1) , there was a variation in the density of the studied species (*Galistemon viminalis* , *Thuja orentalis* , *Cupressus sempervirens* , *Pinus brutia* and *Bauhinia variegata*) were reaching (0.62 , 0.44, 0.47, 0.52, 0.66) g/cm^3 respectively .

3 RESULT AND DISCUSSION

SOLID YEILD % AND BURN OFF %

Solid yield values are an indication of the amount of solid material produced by a carbonization process , so it is an economic indicator of the actual quantity produced of activate carbon (zainulabdeen , 2017) . Figure (4) showed the results of Solid yield % of the five species (*Galistemon viminalis* , *Thuja orentalis* , *Cupressus sempervirens* , *Pinus brutia* and *Bauhinia variegata*) , it were (33.498 , 30.408 , 31.960 , 34.058 and 35.566) % respectively .

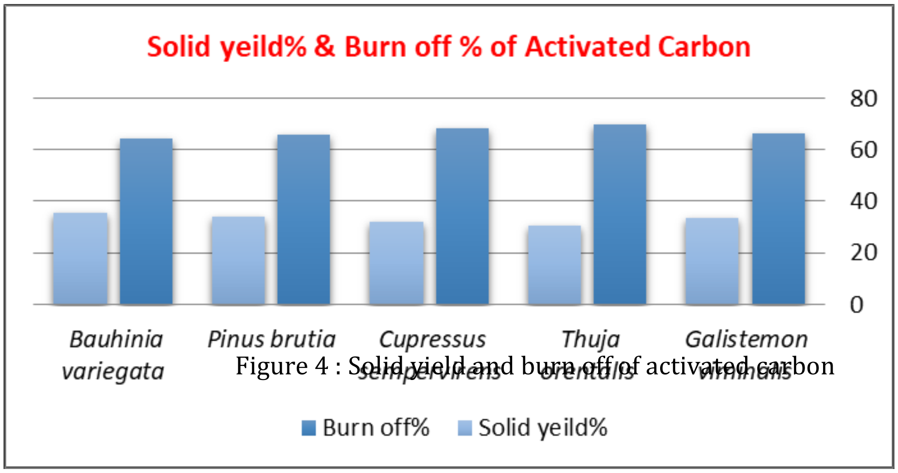

Figure 4 : Solid yield and burn off of activated carbon

These values are relatively close , with an advantage in qualitative productivity of *G. viminalis* & *B. variegata* . When comparing the solid yield values with the density of the species, high density species gave higher yield values due to their content of wood materials , Burn off % also showed in figure (4) .

ACTIVATED CARBON CHARACTERISTICS

Result of the activated carbon characteristics are given in table (1) . The results were obtained with the results of samples of industrial active carbon available in local markets of Iraq to show the preference .

Table 1 : Characteristics of activated carbons

Activate carbon type	Wood Density g/cm^3	A. C. Density g /ml	Moisture content %	pH	Pore volume ml.	Porosity %	Ash %
Galistemon viminalis	0.62	0.398	1.375	7.1	1.687	10.22	2.88
Thuja orentalis	0.44	0.359	1.566	7.0	1.753	13.49	2.07
Cupressus sempervirens	0.47	0.217	1.247	7.0	2.810	13.38	2.22
Pinus brutia	0.52	0.220	1.762	7.1	1.858	13.73	1.99
Bauhinia variegata	0.66	0.246	1.956	7.0	3.592	17.96	1.39
I.A.C. *	-	0.30 – 0.70	0.80 *	-	0.6 – 1.8	-	2.0 - 10.0

* I.A.C. = Industrial Activated Carbon (commercial) .

Density : It is important properties indicates the amount of material within the volume unit that will absorb (zainulabdeen , 2017) , Value showed that *Thuja oreintalis* & *Galistemon viminalis* Activated carbon's density given high numbers (0.359 & 0.398) g/ml. respectively between other species , when low value get to *Cupressus sempervirens* (0.217g/ml.) , The high density of the wood branches , type of the raw materials , the production & activation process and the activity of the final product may be resulted in high densities of some activated charcoal . Othman (2008) indicate that high density provides great volume activity and usually indicates better carbon activation .

Moisture Content % : Activated carbon prices generally depend on moisture - free basis . Moisture content does not affect the energy supply of activated carbon , but it lower carbon efficiency (Madu & Lajide , 2013) . The range of M.C. % in this study were between (1.375 -1.956) % . It be observed that higher density's activate carbon given lower humidity adsorption .

pH value : For five types of activated carbon showed pH approximate and moderate acidity values (7.0 - 7.1) , this result is good in terms of the effect on the efficacy of activated carbon performance and is consistent with what is mentioned by (Madu & Lajide , 2013) that activated carbon is more effective at low pH value .

Pore volume and porosity : Results of pore volume and porosity showed that *Bauhinia variegata* activate carbon recorded higher pore volume and porosity (3.592 ml. , 17.96 %) followed by *Pinus brutia* (1.858 ml. , 13.73 %) which they have lower density value for their activate carbons , this direction will aggregate with (zainulabdeen , 2017) .

Ash : Ash content ranged between (1.39 - 2.88) % for all activate carbon's type , *Bauhinia variegata* showed lower ratio of ash content (1.39 %) . The presence of ash at high rates leads to the blockage of pores and thus reduce the surface area of activated carbon (Maulina & Iriansyah , 2017) .

Iodine number : Iodine number is the most fundamental parameter used to characterize activate carbon performance. It is the standard measure for liquid phase applications . Figure (5) showed that higher value of Iodine number get from *Bauhinia variegate* (495 mg/g) followed by *Thuja orentalis* (485 mg/g) .

Although the two types were superior in value , they did not reach the required values , where both of (Shashank & Raman , 2011 and zainulabdeen , 2017) refer that the general range of iodine number of a good quality of activated carbon is from (500 – 1200) mg/g.

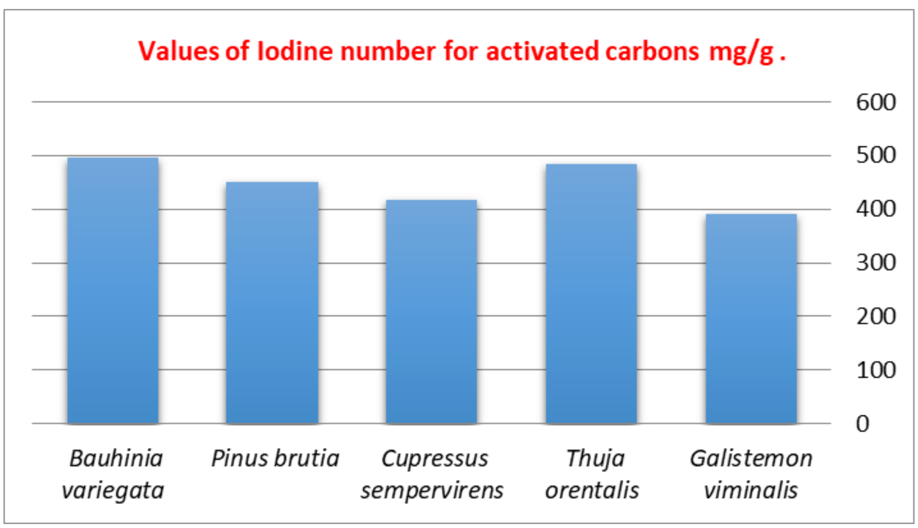

Figure 5 : Iodine number of activated carbons mg/g.

Removal % : Table (2) shows value of Removal % which means the percentage of vision to remove dyes from solutions (blue dye) , which is an important feature determination the extent of active charcoal to absorb. *Thuja oreintalis* given higher value of removals (50%) followed by *Cupressus dempervirens* and less value get from *pinus brutia* activated carbon.

Table 2 : methyl blue number properties at constant initial concentration

Activated carbon type	Ce mg /l	qe mg /g	R %
Galistemon viminalis	11	9	45
Thuja orentalis	10	10	50
Cupressus sempervirens	10.5	9.5	47.5
Pinus brutia	12	8	40
Bauhinia variegata	10.8	9.2	46

4 CONCLUSION

Through the results obtained from activated carbons sample tests for different wood types and compare them with the recommendations of the researchers referred in the result & discussion section, also with the results of industrial activated carbons (commercial), it was concluded :

1- The possibility of activate carbons productions of wood branches of the five tree types used in the study .

2- Most of the tested results traits are close to the permissible limits with superiority of *Thuja oreintalis* & *Thuja orentalis* activated carbon in adsorption.

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Combined Non-Destructive Test Methods for Predicting Flexural Properties of Turkish Black Pine (*Pinus Nigra Var. Pallasiana* Arnold) Structural Lumbers

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ABSTRACT

Aim of this paper is evaluating stress wave and screw withdrawal resistance as non-destructive test (NDT) methods to predict density and flexural properties such as static elasticity of modulus (MOEs) and static modulus of rupture (MOR) of Turkish Black Pine structural lumbers (*Pinus nigra var. pallasiana* Arnold) for using the methods in-situ estimation in wooden buildings. In this study, commercially preferred fifty-three structural lumbers were used. NDT methods were performed with using related devices from Fakopp co. and MOEs and MOR of the lumbers were determined in structural size in accordance with EN 408. In order to analyse the obtained data, the relationships between the following parameters were examined; (1) screw withdrawal force vs. density, MOEs and MOR, (2) stress wave measurements vs. density, MOEs and MOR, (3) combined values of screw withdrawal force and stress wave velocity vs. MOEs and MOR.

Results showed that the best compliance for withdrawal force were found with density (R=0,7414), while correlations with MOR and MOEs were found lower (R=0,6256 and R=0,5288, respectively). The best compliance for stress wave velocity were found with MOEs (R=0,6804), while correlations with MOR and density were found lower (R=0,3148 and R=0,4158, respectively). On the other hand, combination of NDT methods gave higher correlations with destructive values (MOR (R=0,679) and MOEs (R=0,772)). In the light of the results, it is suggested that NDT methods as acoustic based, hardness devices etc. can be combined with together for better correlations.

KEYWORDS: Non-destructive test methods, Stress wave, Screw withdrawal resistance, Turkish black pine, Structural lumber.

1 INTRODUCTION

Regardless of species and size, lumber even if sawn from the same log, may show great variations in physical and mechanical properties due to its fibrous structure and the presence of irregularities. This is especially important for structural applications where the engineers are often frustrated with the performance variability found in structural members. In addition, even if the best quality lumbers had been used, performance of the members can change with several reasons from nature or living people in lifetime of the structure. Therefore an increasing amount of resources are being devoted to repair and rehabilitation of existing structures rather than to new construction.

As more resources are devoted to repair, an increasing emphasis must be placed on the in-place assessment of structures. But conventional test methods are not suitable assessing the structural members, due to several reasons such as destructive measurement principle, laboratory condition requirement etc. Many researchers and organizations have conducted research to develop nondestructive testing (NDT) techniques for assessing the condition of wood members and the techniques allow in-place evaluation of wood members at many places in structures (Ross and Pellerin, 1994).

Acoustic-based methods are most commonly used NDT methods especially good correlations and practical applications. Stress wave is one of them that employs stress wave NDT technology utilizes simple time-of-flight type measurement systems to determine speed-of-wave propagation. The use of stress wave equipment to detect rot, other defects and their extent in timber bridges and other structures is practical. Even though the stress wave velocity can vary with moisture content, grain orientation, temperature and extent of pressure treatment, those variances can be discounted in field use as they are minor compared with variances due to unsound conditions of the timber (Pellerin et al., 1994). Good correlations with modulus of elasticity (MOE) of lumbers were found in many studies (Bell et al., 1954; Galligan and Courteau, 1965; Porter and Kusec, 1972; Pellerin and Galligan, 1973; Gerhards, 1982).

Another useful and practical NDT method is screw withdrawal resistance (SWR) test which can be a variant of mechanical tests with its relationship to strength (ASTM, 1996; Winandy, 1998). SWR test is an important strength predictor, especially for in-situ strength estimation of in-service wooden beams. SWR and pick - or probing types tests which can be described inexpensive techniques provide information about a member at a point and are consequently of limited value for inferring strength for large members.

However, this predictor is not sensitive to the wood defects of timber because it is a local value but useful in the shear modulus and density estimation (Divos and Tanaka, 1997). They are useful for detecting surface damage of members and the SWR tests were initially found to be simple indicators of biological degradation (Talbot, 1982). In the study, several small Douglas-fir beams that were in various stages of degradation as a result of exposure to decay fungi were used. It is found that a correlative relationship between withdrawal resistance and residual strength is exist. After that he used this test in conjunction with stress wave techniques to assess the extent of damage to the solid-sawn timbers of Washington State University's football stadium

It is confirmed by experiments that specific gravity, compression capacities, MOE and MOR of wood are correlated to screw withdrawal resistance of wood. Reduction of specific densities is good indicators to evaluate the degradation of wood members for wood engineers, but compression capacity, MOE and MOR are better indicators for degradation of wood members for structural engineering because structural engineers are required to evaluate damage of structures from the damage of members (Yamaguchi, 2011).

Therefore studies continue to increase correlation especially combination with another NDT methods. The Fakopp Enterprise, a commercial company, represents that screw withdrawal method can be an indicator the wood material strength, density and shear modulus. The force is a local parameter, but selecting a representative location on a beam, it can be a useful information in wooden structure evaluation. It is told that the method has relatively high correlation coefficients with bending strength, density and shear modulus (respectively 0.72, 0.79 and 0.86) (Fakopp, 2010).

Divos and Tanaka (1997) told that using the screw withdrawal force and the velocity of stress wave the following empirical strength predictor equation ($B_{in\text{-}situ}$) is the best strength predictor where the applied units in the equation (Eq. 1) are $B_{in\text{-}situ}$ (MPa), F_{screw} (kN) and V_{stress} (km/s):

$$B_{in-situ} = 0.1154\, F_{screw}\ x\ V_{stress}^3 + 9.29 \tag{1}$$

The correlation coefficient between bending strength and $B_{in\text{-}situ}$ is 0.74 and the SEE is 7.51 MPa.

In other study, Divos et al. (2001) used screw withdrawal force (F_{screw}) and velocity of stress wave (v) to propose the following empirical strength predictor equation (Eq. 2) for coniferous species:

$$MOR_{est} = 0.809\, F_{screw}\ x\ v^2 + 26.8 \tag{2}$$

The applied units in the equations are: bending strength MOR_{est} (MPa), F_{screw} (kN) and V (km/s). The correlation coefficient between the bending strength and MOR_{est} is 0.74.

The empirical equations obtaining screw withdrawal resistance from specific density are used in design specifications. Cai et al. (2002) examined the relationship between screw withdrawals and density of wood.

As seen in studies, NDT techniques have good correlations but they aren't good enough to give reliable decisions for structural members. Aim of this paper is to research for increasing correlations with combining two NDT techniques. Stress wave and screw withdrawal resistance methods were used to predict static elasticity of modulus (MOEs) and static modulus of rupture (MOR) on Turkish Black Pine structural lumbers (*Pinus nigra var. pallasiana* Arnold.) with using the methods in-place estimation in structures.

In order to analyze the obtained data, the relationships between the following parameters were examined; (1) screw withdrawal force measurements vs. density, MOEs and MOR, (2) stress wave measurements vs. density, MOEs and MOR, (3) screw withdrawal force and stress wave velocity measurements together vs. MOEs and MOR.

2 MATERIAL AND METHODS

2.1 Material

In this study, 53 various structural lumbers of Turkish Black Pine (*Pinus nigra* var. *pallasiana* Arnold.) with the dimension of 6×8-10 cm (width×depth) and 2-m-length were obtained commercially. The moisture content of the lumbers were measured using electrical resistance equipment by following the procedure defined in the EN 13183-2 standard (2002). The average moisture content of the lumbers was determined as 15.4%.

2.2 Stress Wave Method

First NDT technique, stress wave method was used to measure the dynamic MOE (MOEds) of lumbers. The method was carried out using a Fakopp Microsecond Timer (23kHz). This is a portable microsecond stress-wave timer with two piezoelectric-type transducers equipped with 60 mm long spikes. The spike probe fixes the transducer into the wood and also functions as a wave guide. The stress wave is induced by a simple hammer impact and the output displayed on the meter is the time-of-flight (ToF) in microseconds (Figure 1).

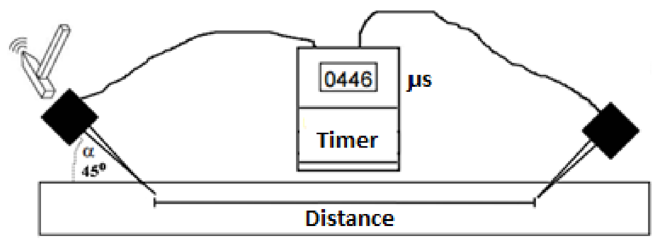

Figure 1: Set up for Fakopp microsecond timer

Stress wave velocity (V, in m/s) was calculated using distance between the transducers (L, in m) and the time-of-fligth (ToF) the pulse from the transmitting transducer to the receiving transducer (t, in µs) by the following equation (Eq. 3):

$$V = (L/t).1000 \tag{3}$$

Later, dynamic elasticity of modulus (MOEds, in MPa) was calculated using the specimen's density (d, in g/cm^3), by the following equation (Eq. 4):

$$MOEd = V^2 .\ d/1000 \tag{4}$$

2.3 Screw Withdrawal Method

As a second NDT technique, screw withdrawal method was used to measure screw holding capacity of lumbers. The method was carried out using a Fakopp Screw Withdrawal Resistance Meter that a portable device with a load-cell. The standard screw size of 4mm diameter and 18mm length (for softwood) put in the lumber and caught by the fork of the force transducer. Later the handle was turned clockwise until the screw is removed with the following speed: half turn in 3-4 seconds as described in user guide. The maximal force (SWR, in N) was read on the display unit Rinstrum N320 (Figure 2).

Figure 2: Screw Withdrawal Resistance Apparatus

Due to the force measuring area of screw withdrawal method is so small, three area (from two sides and middle) were measured and the mean value was evaluated.

2.4 Destructive Tests

Following the nondestructive tests, the static modulus of elasticity (MOEs) and modulus of rupture (MOR) were determined on the timbers in structural size in accordance EN 408 standard (2010) (Figure 3). The tests were carried out with the universal testing machine, which was equipped with load cell of 100 kN.

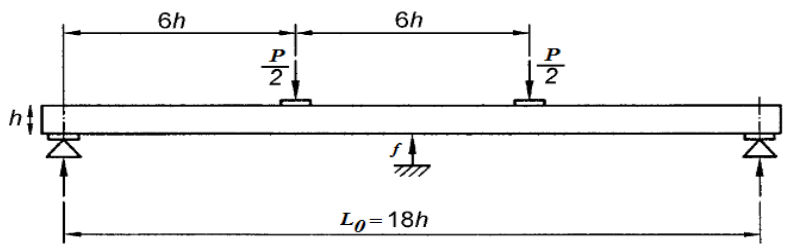

Figure 3: Static Four Point Bending Test Arrangement According to EN 408

The static modulus of elasticity (MOEs, in MPa) was calculated using effective span distance (L_0, in mm), respectively 10% and 40% of maximum load (P_1 and P_2, in N), respectively deflection at 10% and 40% of maximum load (f_1 and f_2, in mm), distance between loading point and nearest support point (a, in mm), width (b, in mm) and height (h, in mm) by the following equation (Eq. 5):

$$MOEs = \frac{(L_0)^3.(P_2-P_1)}{b.h^3.(f_2-f_1)}.[\left(\frac{3a}{4L_0}\right)-\left(\frac{a}{L_0}\right)^3] \quad (5)$$

Modulus of rupture (MOR, in MPa) was calculated using maximum load (Pmax, in N) by the following equation (Eq. 6):

$$MOR = \frac{Pmax.a}{b.h^2/3} \quad (6)$$

2.5 Density

After breaking the lumbers, they were sawn to 2cm x 2cm x 3cm dimensions to measure density values according to TS 2472 standard (1976). The density (d, g/cm^3) was calculated using weight of the sample (W, g) at same moisture content with big-sized samples and sample volume (Vol, cm^3) (Eq. 7):

$$d = {}^{W}/_{Vol} \tag{7}$$

In order to analyze the obtained data, the relationships between the following parameters were examined; (1) screw withdrawal force vs. density, MOEs and MOR, (2) stress wave measurements vs. density, MOEs and MOR, (3) screw withdrawal force and stress wave velocity measurements together vs. MOEs and MOR. In additionally, effect of the anatomical differences (sapwood-heartwood and blue stain existence) were examined.

3 RESULTS

Table 2 shows the relationship between non-destructive and destructive test results; (R is regression coefficient, while R^2 is correlation coefficient).

Table 2: Relationship between non-destructive and destructive test results

Independent	Dependent	R^2	R	Equation
Stress Wave Velocity (V)	Density	0.0991	0.3148	y = 0.0548x + 288.14
	MOEs	0.4629	0.6804	y = 5.8099x – 17139
	MOR	0.1729	0.4158	y = 0.0245x – 58.999
Screw Withdrawal Resistance (SWR)	Density	0.5496	0.7414	y = 0.1238x + 231.32
	MOEs	0.2796	0.5288	y = 4.3290x + 794.42
	MOR	0.3914	0.6256	y = 0.0353x – 29.966

As seen in Table 2, especially stress wave velocity correlation coefficients are low. Screw withdrawal force has higher coefficients but only it has good correlation with density. To obtain better correlations, non-destructive test results were combined and compared statistically with multiple regression (Table 3, Table 4 and Table 5).

Table 3: Multiple regression results for static modulus of elasticity with

Equation:	MOEs= 4.975 V + 3.096 SWR – 21302.843
Std. Error of the Estimate:	1749.89260
ANOVA (Sig.) (p<0,05):	0.000
R^2 =	0.596
R =	0.772

Table 4: Multiple regression results for static modulus of rupture

Equation:	MOR= 0.016 V + 0.031 SWR – 101.150
Std. Error of the Estimate:	13.94483
ANOVA (Sig.) (p<0,05):	0.000
R^2 =	0.461
R =	0.679

Table 5: Multiple regression results for static modulus of elasticity with all NDT combination

Equation:	MOEs= 4.573 V + 1.028 SWR + 17.517 D – 23568.013
Std. Error of the Estimate:	1641.90416
ANOVA (Sig.) (p<0,05):	0.000
R^2 =	0.652
R =	0.807

4 DISCUSSION AND CONCULUSION

Results showed that the best compliance for screw withdrawal force were found with density (R=0.7414), while correlations with MOEs and MOR were found lower (respectively R=0.5288 and R=0.6256). The results were obtained expectedly due to measurement principle of screw withdrawal method.

The test area of screw comprises of wood material. The strength of the material is strongly correlated with anatomic structure and naturally density. However evaluating volume is so small when compared the all sample and it only considers test area, not possible defects on the sample. Therefore, screw withdrawal resistance method should be combined with other methods due to evaluating comparatively small area. Although flexural properties are affected from defects, screw withdrawal method is not efficient (successful) to detect and to evaluate some defects.

The best compliance for stress wave velocity were found with MOEs (R=0.6804), while correlations with density and MOR were found lower (respectively R=0.3148 and R=0.4158). This result is outgrowth that the flexural properties are controlled by different mechanism of wood components. The mechanism of determining maximum force that material can be resist is different and it is significantly effected by defects while modulus of elasticity is effected less. On the other hand correlations aren't good enough to use predicting structural members strength.

For better correlations, two NDT methods were combined using multiple regression. It was seen that both of the correlations with MOEs (R=0.772) and with MOR (R=0.679) increased. Moreover triple-combination has better correlation with MOEs (R=0.802). This correlation is better than the studies of Divos and Tanaka (1997) and Divos et al. (2001).

Consequently, it is suggested that NDT methods can be combined for better correlations. If either or both from stress wave and screw withdrawal resistance methods will be used, defects should be considered for better bending strength prediction.

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Assessment of the Processing Roughness of Black Alder Surfaces

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Assessment of the Processing Roughness of Black Alder Surfaces

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ABSTRACT

The objective of the study was to compare the surface quality of the processed samples made of black alder (*Alnus glutinosa* L.) wood when using two milling cutters endowed with different cutting plates. Defect free samples provided by a local company were used. They were processed by longitudinal milling under laboratory conditions when applying various cutting schedules. The surface quality of the resulted samples was expressed by the most relevant processing roughness parameters. The roughness of the specimens was measured with the help of a specific profilometer device of FRT type with white light.

The results of this study showed that the two milling cutters generated smooth surfaces with no or low fuzzy grain and such quality of the processed surfaces can be obtained when using low feed speeds and light cutting depths. Findings of this work could help to use more efficiently the wood of black alder in the furniture sector.

KEYWORDS: black alder, cutting schedule, milling, roughness

1 INTRODUCTION

Mechanical processing of wood represents those processes that can change the shape and dimensions of wood without changing its chemical composition. It is said that no cutting tool is more versatile than a milling cutter which can produce various and specific surfaces. Routers, machines for planing and straightening as well as for tenoning and vertical milling machines are widely used in the furniture sector.

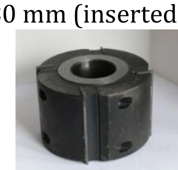
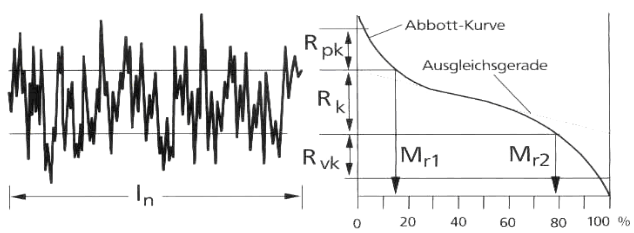
Various research studies performed during last decade have shown the pragmatic character of wood milling as regard to the most important factors that affect the quality of a processed surface, such as: wood species, type of milling, characteristics of milling cutter, and cutting schedule especially (Hynek et al., 2004; Kilic et al., 2006; Keturakis and Juodeikienė, 2007; Goli et al., 2010; Azemovik et al., 2014; Hernandez et al., 2014; Gaff et al., 2015; Kvietkova et al., 2015; Bendikiene and Keturakis, 2017). The feed speed and cutting depth have a high impact on the wood surface roughness. The higher the feed rate is, the rougher the processed surface becomes (Salca, 2015; Sogutlu, 2010). Low feed speeds and light cutting depths were proved to generate smooth wood surfaces after milling (Hernandez and Cool, 2008; Pinkowski et al., 2016). In order to obtain a superior quality of a wooden finished product different types of milling cutters with inserted plates are recommended. But common milling tools with brazed cutting plates are still used as well.

Therefore the objective of the present study was to compare the surface quality of the processed samples made of black alder (*Alnus glutinosa* L.) wood when using two milling cutters of same diameter but endowed with different cutting plates. It is expected that findings of this work could help to use more efficiently the wood of black alder in the furniture sector.

2 MATERIAL AND METHOD

Commercially flat sawn timber of black alder (*Alnus glutinosa* L. Gaertn.) wood supplied by a local company in Buzau County, Romania was used in this study. A total of 80 defect free samples were cut at 1000 mm length. Table 1 presents the complete design of experiments, variables, parameters and equipment.

Table 6: Design of experiments, variables, parameters and equipment

Processing direction / machine		Longitudinal milling / MNF 10 vertical machine				
Number of samples		20 specimens / each milling process and rotation speed				
Milling cutters		D=80 mm (brazed carbide) 		D=80 mm (inserted carbide) 		
Cutting schedule	Rotation speed, rpm	6620 and 9732				
	Feed speed, m/min	4.5	9	13.5	18	22.5
	Cutting depth, mm	1	2	3	4	5
	Cutting width, mm	20	25	30	35	40
Roughness parameters	R_k, µm	 *R_k=Parameter for the processing roughness evaluation*				
	R_{pk}, R_{vk}, µm	*R_{pk}, R_{vk}=Parameters for the fuzzy grain and anatomical roughness evaluation, respectively*				
Scanning parameters	Scanning mode	Scanning speed	Points per line	Evaluation length	Sampling length	Resolution
	2D	750 µm/s	10000	50 mm	2.5 mm	5 µm
Roughness measurement	Along the processing direction					
Roughness device	MicroProf FRT Optical Device					

All specimens were processed on their longitudinal edges on the vertical milling machine of MNF 10 type under laboratory conditions by employing a mechanical feed device (Salca, 2015). Two milling cutters of 80 mm diameter endowed with cutting plates made of brazed and inserted sintered carbide were used for the milling process. The factorial experiment with three variables (feed speed, cutting depth, cutting width) was applied per each milling and rotation speed. Such algorithm enables various cutting schedules with only 20 samples per process. The moisture content of all samples prior to processing was 8%.

2.1 Roughness Measurement

In this study a specific roughness device of MicroProf FRT type was used for roughness measurement. The scanning parameters and roughness parameters under evaluation are presented in Table 1. Two out of three parameters of R_k family (R_k, R_{vk} and R_{pk}) were selected, namely R_k and R_{pk} according to ISO 13565 2: 1996 standard. In this study R_{vk} was excluded because the anatomical roughness was not removed. The roughness core depth, R_k, is considered by far the most representative processing roughness indicator (Gurau et al., 2005). A Gaussian filter was automatically applied.

2.2 Data Processing

Specific software programs have been used for data processing, such as *Visual Basic*, *DataFit* and *Delphi*. A non-linear regression was applied by respecting an equation of 2nd degree type with three variables, expressed by Eq. (1).

$$Y = a + bx_1 + cx_2 + dx_3 + ex_1x_2 + fx_1x_3 + gx_2x_3 + hx_1^2 + ix_2^2 + jx_3^2 \quad (1)$$

in which the three variables x_1, x_2, and x_3 were the feed speed (u), cutting depth (h) and cutting width (b), respectively. The real experiment did not benefited by enough representation values and thus some extreme values have been removed from the analysis. The cutting width has relevance for the dynamic elements only and it does not influence the surface quality. Therefore in this study three feed speeds (9, 13.5 and 18 m/min) and three representative cutting depths (1, 2 and 3 mm) were evaluated along the cutting width of 30mm.

3 RESULTS AND DISCUSSIONS

The software used in this study provided 3D response surfaces representing the variation of the two roughness parameters under evaluation for all the processed surfaces as a function of cutting schedule. Figure 1 presents the variation of roughness parameter, R_k, as a function of all three cutting variables after the longitudinal milling when using the inserted carbide milling cutter at 9732 rpm rotation speed.

Figures 2 and 3 present the variation of roughness (R_k) depending on variable cutting schedules for a cutting width of 30 mm after the longitudinal milling when using two types of milling cutters at 6620 and 9732 rpm rotation speeds, respectively. For both types of milling processes performed with the two milling cutters at the rotation speed of 6620 rpm the R_k roughness values gradually increased once the feed speed and cutting depth increased. The best surface quality expressed by the processing roughness parameter (R_k) using both types of milling cutters was obtained for the longitudinal milling at the rotation speed of 6620 rpm, for a feed speed of 9 m/min and a cutting depth of 1 mm, while at the rotation speed of 9732 rpm, for same feed speed of 9 m/min but a cutting depth of 3 mm.

The processing roughness values ranged between 14.13 to 20.32 μm in case of processing with the brazed carbide milling cutter and from 16.33 to 22.7 μm in case of using the inserted carbide milling cutter.

For both types of milling at the rotation speed of 9732 rpm a slow increase of the processing roughness (R_k) with the increase of feed speed at a constant cutting depth was noticed, while at same feed speed for an increase of cutting depth, the roughness values slowly decreased.

The most reduced value for the fuzzy grain roughness parameter (R_{pk}) of about 6.35 μm was determined in case of using the brazed carbide milling cutter at a rotation speed of 9732 rpm and a feed speed of 9 m/min for a cutting depth of 3 mm.

Almost a similar value for such fuzzy grain expression of about 6.43 µm was determined using the inserted carbide milling cutter at the rotation speed of 6220 rpm and same feed speed of 9 m/min but for a light cutting depth of 1 mm. In this respect it is worth to mention that all samples presented either no or less fuzzy grain given the low values of the specific roughness parameter, R_{pk}, ranging from 6 to 9 µm, as presented in Figure 4.

Both milling cutters generated by processing fine surfaces which indicated how smooth the milling process run. But based on the criteria of minimum roughness parameters which express the surface quality after processing, it can be concluded that for low feed speeds and light cutting depths, the inserted carbide tool is recommended for a rotation speed of 6620 rpm while the brazed carbide tool generates the best surface quality for a rotation speed of 9732 rpm. Such findings are in accordance with the specialty literature (Sogutlu, 2010).

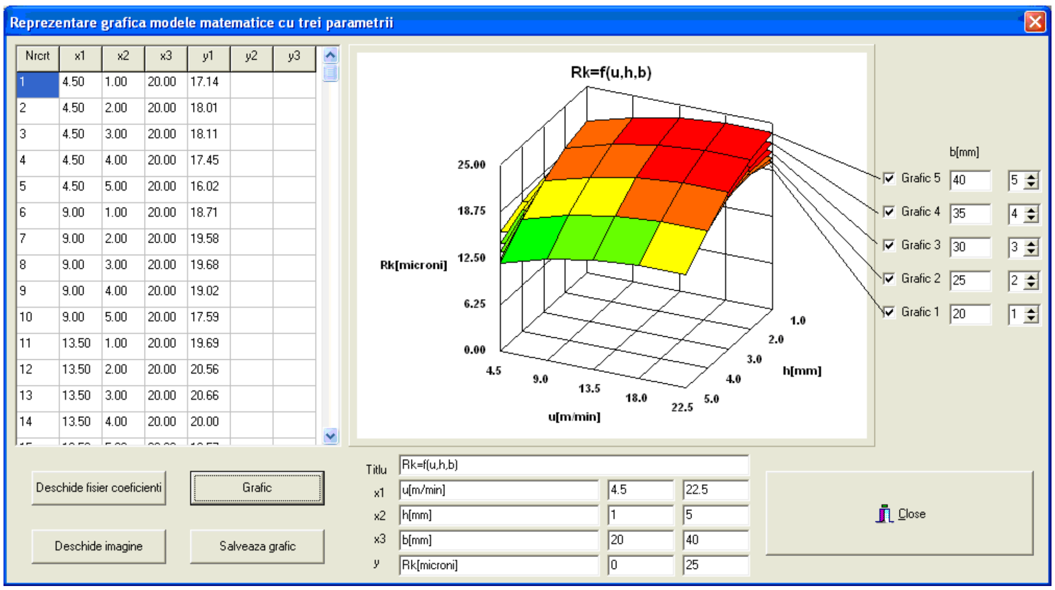


Figure 1: 3D Surfaces - Variation of Roughness (R_k) depending on feed speed (u), cutting depth (h) and cutting width (b) after the longitudinal milling by using the inserted carbide milling cutter at 9732 rpm rotation speed

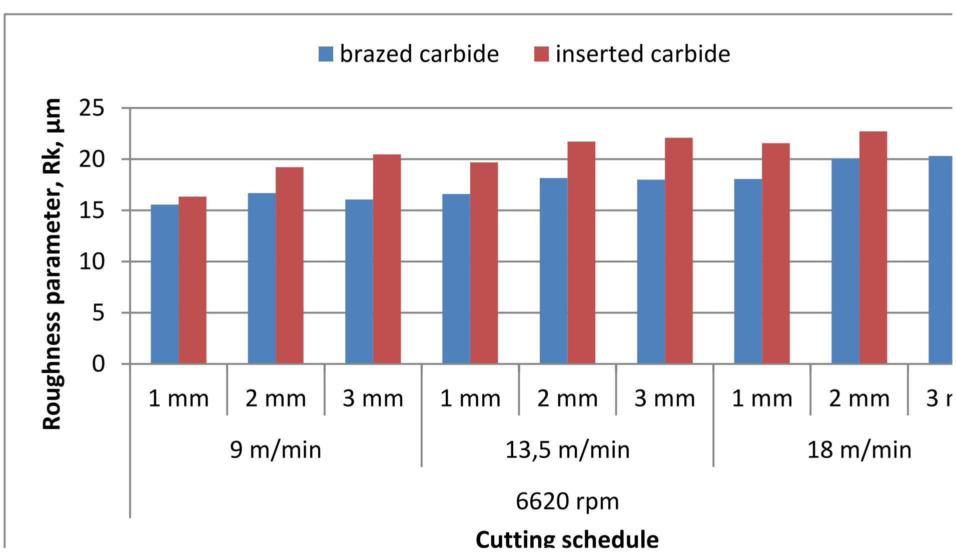


Figure 2: Variation of roughness (R_k) depending on the cutting schedule for 30 mm as cutting width after the longitudinal milling by using two types of milling cutters at 6620 rpm rotation speed

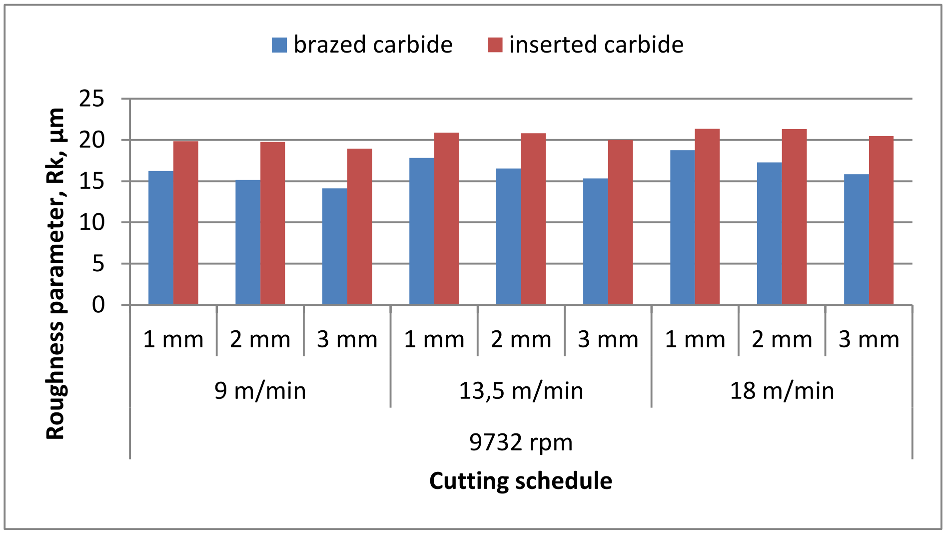


Figure 3: Variation of roughness (R_k) depending on the cutting schedule for 30 mm as cutting width after the longitudinal milling by using two types of milling cutters at 9732 rpm rotation speed

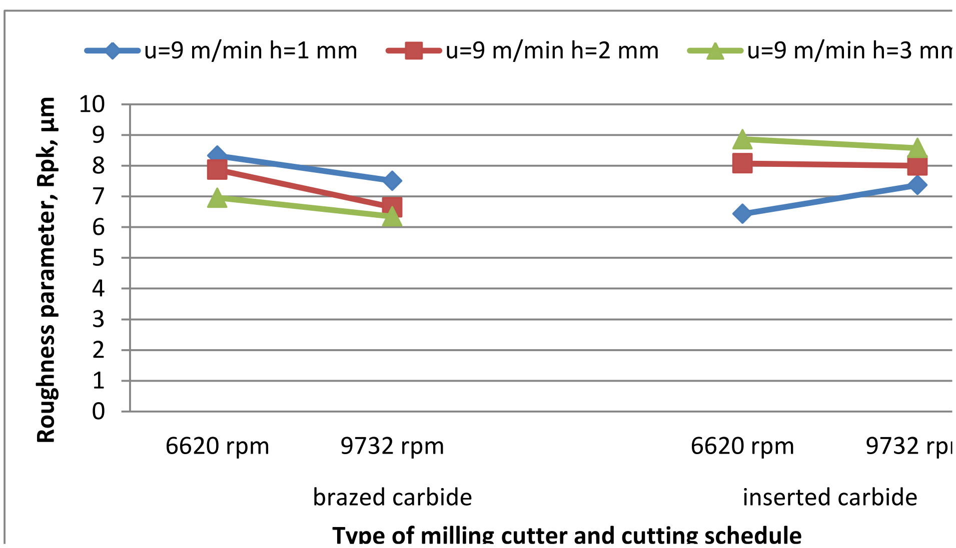


Figure 4: Variation of roughness (R_{pk}) as a function of different cutting schedules for two milling cutters

4 CONCLUSION

The results of this study showed that the two milling cutters generated smooth surfaces with no or low fuzzy grain and such quality of the processed surfaces can be obtained when using low feed speeds and light cutting depths. Findings of this work could help to use more efficiently the wood of black alder in the furniture sector.

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Alkaline Sulfite Anthraquinone (As-Aq) and Monoethanolamine (Mea) Processes; A Progress in Non-Woody Plants Pulping

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ALKALINE SULFITE ANTHRAQUINONE (AS-AQ) AND MONOETHANOLAMINE (MEA) PROCESSES; A PROGRESS IN NON-WOODY PLANTS PULPING

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ABSTRACT

Non-woody plant pulping is gaining more and more importance, particularly in countries with deficient wood resources. For non-woody plant pulping mostly soda and soda/AQ pulping have been employed. The alkaline sulfite anthraquinone (AS-AQ) and monoethanolamine (MEA) processes may be realistic alternatives to soda pulping. In particular the higher yields and delignification selectivity especially in the case of monoethanilamine process and superior unbleached brightness of AS-AQ pulps along with significantly higher pulp strengths of AS-AQ pulps are main benefits of these processes compared to soda pulping. These advantages could be open an optimistic window in non-woody plants pulping technology. Furthermore, according to the efforts which were done in order to implementation of gasification technology in kraft mills in contexts of realization of biorefinery concepts, the main drawback for using of the AS-AQ process in industry scale namely chemical recovery has been overcome. Monoethanolamine process with simple recovery of monoethanolamine as an organic solvent by distillation is a good solution for a lack of chemical recovery in non-woody plant based pulp mills due to high silica content of these raw materials. In this paper, the different aspects of AS-AQ and MEA processes and their pulps properties as an alternative for soda pulping will be discussed.

KEYWORDS: Non-woody plants, pulping, Soda process, Alkaline-Sulfite Anthraquinone, Monoethanolamine

1 INTRODUCTION

Non-woody pulping is gaining more and more importance, particularly in countries with deficient wood resources. From1970 to present time, the non-wood plant fibre pulping capacity has increased on a global basis two to three times as fast as the wood pulping capacity. But unfortunately, non- woody based mills have some serious drawbacks as compared with wood. These pulp mills are fairly small and many mills have pollution problems because they do not have a recovery system or even a closed mill operation. The high-silica content of the black liquor causes recovery problems and in addition pulp bleaching is mostly performed with chlorine compounds. Successful development of non-woody pulping requires a technology which is able to exploit the full potential of these raw materials. Specifically this means that selectivity in pulping and bleaching has to be on a high level resulting in pulps with high yield and good strength properties. Bleaching of non-woody pulps should be performed in a totally chlorine free (TCF) sequence, facilitating not only the closure of the bleach plant but also of the total mill. This includes efficient energy generation, chemical recovery and conversion of cooking chemicals as well as the alkali used in bleaching.

For non-woody pulping mostly soda and soda/AQ pulping have been employed and nearly all bleaching sequences have considered CEH, HH or similar sequences based on these bleaching agents. Soda pulping is a well-understood process which is able to process a large variety of non-woody lignocellulosic sources but this process has particular disadvantages as well. Strongly alkaline cooking liquors decompose carbohydrates by peeling-off reactions and alkaline hydrolysis. Sodium hydroxide easily dissolves phenolic lignin structures. In non-phenolic lignin moieties only beta-ethers are cleaved. Under strongly alkaline conditions lignins undergo condensation reactions which reduce the reactivity of residual lignin. This has also an impact on bleaching. It particularly holds true for most chlorine free bleaching agents. Non-woody plants have fairly high-silica content and strongly alkaline cooking liquors dissolve them to a high extent. The dissolved silica creates mainly precipitation problems in evaporators, recovery boilers and in the causticizing plant. Some of the mentioned deficiencies of soda pulping can be overcome by addition of anthraquinone. Anthraquinone protects the reducing aldehyde groups of carbohydrates against alkaline peeling and improves lignin solubility. Compared to soda pulps those soda/AQ pulps have slightly better bleachability, higher yield and sometimes better strength.

There are only limited studies on the usage of sulfite compounds in pulping of non-woody plants. In a former study pulping of different hardwoods and agricultural residues including wheat straw, elephant grass, bagasse and sorghum were investigated applying Alkaline Sulfite- Anthraquinone- Methanol (ASAM) pulping and TCF bleaching (Kordsachia and Patt, 1991). The results indicate that compared to the conventional soda process, ASAM pulping of agricultural residues showed better delignification, improved yield and higher brightness of the unbleached pulp. The ash content, especially silica content of the ASAM pulp is higher due to less alkaline pulping conditions, which reduces the silica content in black liquor and thereby reduces recovery problems caused by silicate precipitation. Hedjazi et al. (2008, 2009a, b) investigated on AS-AQ pulping of some non-woody plants and reported the same trends in results as above mentioned in the case of ASAM pulping but without methanol which due the high pressure in the digester causes some problems in realization of the process in industrial scale.

Theoretically, organic solvents alone or in mixture with water can overcome recovery problems associated with conventional annual plant pulping. In particular, alcohols or organic acids with low boiling points can be easily recovered and recycled by distillation. Dissolved organic material can either be burnt for energy generation or used for different purposes, such as production of alcohol or yeast or as chemical feedstock. But so far, no commercial pulp line works with organic solvents. For a long time, monoethanolamine (MEA) is known as highly selective delignifying agent, well appropriate for isolation and determination of holocellulose in wood(Harlow and Wise 1938; Wise and Person 1939). This discovery prompted several studies of pulping with MEA. Mostly, these investigations focused on alkaline pulping of wood with MEA as additive to support the delignification process. Extensive studies on MEA application as the only delignifying agent in cooking of hardwood (Eucalyptus grandis) and softwood (Pinus elliottii) were carried out by Wallis (1976, 1978a, b, 1980).

The most prominent feature of MEA pulping is the exceptionally good preservation of hemicelluloses result in unusually high pulp yield. On the other hand, the maximum degree of delignification attainable with MEA as the sole delignifying agent is limited, especially in the case of softwoods. Severe cooking conditions, especially high temperatures, have to be applied to achieve sufficient delignification for the production of bleachable pulp grades. In this regard, it must be considered that MEA may decompose at its boiling point of approximately171 °C (Wallis 1980). Therefore, the maximum temperature should be kept well below this temperature to avoid too severe MEA losses. Another point, which has to be considered, is that MEA is also consumed in reactions with lignin and, consequently, the MEA losses are high when the raw material has high lignin content and the lignin is difficult to degrade due to its structure. Thus, it can be concluded that MEA is not suited at all for pulping of softwoods (high content of condensed G lignins).However, MEA could be better applied for pulping of hardwoods (low content of less condensed GS lignins),at least in principle, but the viability of this way is also doubtful. Even rather small MEA losses will render this process not competitive to conventional kraft pulping with a highly efficient recovery system for the inorganic cooking chemicals. The situation is completely different when non-woody plants are considered for pulping. Non-woody can be easily cooked under mild alkaline conditions and only a lows chemical charge is needed for lignin dissolution. The most important advantage of MEA pulping of non-woody plants is the direct MEA recovery by distillation. After distillation of MEA, the residual organic matter could be used either as chemical feedstock or as nitrogen containing organic fertiliser, which, contrary to nitrogenin minerals, has slow-release long-term effects because gradually released by microbial degradation of the carrier material.

The pulp and paper industry is on a permanent search for environmentally and economically sound pulping of non-woody plants. Thus, in the present paper some of these efforts will be presented.

2 MATERIALS AND METHODS

Materials

Wheat straw, rice straw and barley straw were collected from the fields in Iran. The raw materials were dried at room temperature, debris was separated and then the straw stalks were chopped in a crop chopper into 3–5 cm long pieces. Bagasse was received from Pars Pulp and Paper mill in southwest of Iran.

Pulping

All AS-AQ and MEA cooks were performed in a 15-L rotating digester with 300 gr of straw (o.d.). The experimental conditions applied in AS/AQ, MEA-AQ, Soda-AQ and Soda pulping were presented in Table 1.

Table 1: The variables in different pulping processes.

Raw Material	Pulp No.	Process	Alkali (%)	MEA/Water ratio	Na2SO3/NaOH ratio	Cooking Temp.(°C)
	1				40/60	
	2	AS-AQ	16	_	50/50	160
Wheat straw	3			75/25		
	4	MEA-AQ	_	50/50	_	150
	5	Soda-AQ				160
	6	Soda	16	_		
	7	AS-AQ	16	_	40/60	
	8	MEA-AQ		75/25		160
Rice straw	9	MEA-AQ	_	50/50	_	150
	10	Soda-AQ				160
	11	Soda	14	_		
	12	AS-AQ	16		40/60	160
	13	AS-AQ		_	30/70	
	14	MEA-AQ	_	50/50	_	160
Bagasse	15	Soda-AQ	18		_	155
	16	Soda				160
	17	MEA-AQ		75/25		160
Barley straw	18		_	50/50	_	
	19	Soda	20	_		150

Heating and cooking times kept constant for all experiments 60 min., except for MEA-AQ processes with 75% MEA charge, in which the cooking time of 90 min. was selected. AQ charge was 0.1% of oven dry raw material in all corresponded processes. After cooking, the pulp was discharged in a washing screen, washed thoroughly with tap water, defibered in a laboratory pulper and then screened on a 0.15 mm laboratory slot screen to determine the yield of accepted pulp and rejects. The screened pulp was dewatered and stored in polyethylene bags at 4 °C till further processing.

Pulp characterization

All pulp properties were determined according to corresponded TAPPI standards.. Pulp beating was done in a Jokro mill.

3 RESULTS AND DISCUSSION

Pulp properties

Several pulping experiments were performed for each pulping processes and the conditions presented in table 1 are the optimum conditions resulted in pulps with acceptable properties. Figure 1 shows the AS-AQ pulp characteristics of trail numbers 1, 7 and 12 in table 1 which produced under same conditions. Among the raw materials, bagasse AS-AQ pulp has the highest total and screened yields. Wheat straw AS-AQ pulp introduces the lowest yields. In the case of shives the reverse situation is seen but the amount of rejects is acceptable. The rice straw AS-AQ pulp has the significantly lowest kappa number(5.4) which traced back to lower amount of lignin in this raw material than that of others. Interestingly, AS-AQ pulping resulted in the pulps with same kappa numbers (12) for wheat straw and bagasse. The rice straw AS-AQ pulp has also the considerably higher brightness than wheat straw and bagasse AS-AQ pulps. As a kappa number, the brightness of wheat straw and bagasse AS-AQ pulps are in the same level.

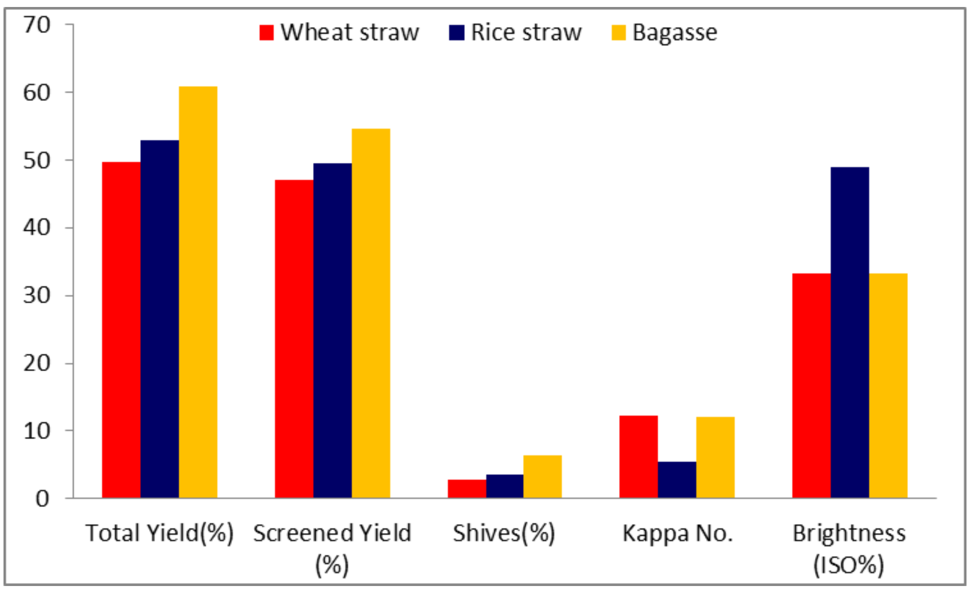

Figure 1: AS-AQ pulp properties of different non-woody species.

Figure 2 shows the properties of MEA-AQ pulps of trail numbers 3, 8, 14 and 17 in the table 1 from wheat, rice and barley straws. In the case of MEA-AQ pulping, the rice straw has the highest total and screened yields. The total yield of wheat straw MEA-AQ pulp is higher than that of barley straw which is due to higher shive amounts and the screened yields of these raw materials lie in the same level. Again rice straw pulping resulted in pulp with lowest kappa number follows with barley straw. The same trend could be seen in the case of the brightness of these pulps.

Figure 3 shows the pulp properties of wheat straw produced with different processes namely trail numbers 2, 4, 5 and 6 in table 1. As it could be seen the MEA-AQ process resulted in pulp with highest total and screened yields among other processes. This is due to better preservation of carbohydrates specially hemicelluloses in MEA pulping (Hedjazi et al. 2009c). Also, Figure 3 presents that the pulp produced with AS-AQ process has higher total and screened yields in comparison of conventional soda-AQ and soda processes.

Furthermore, the AS-AQ process resulted in pulp with lowest kappa number. The MEA-AQ pulp kappa number is higher than that of soda-AQ but much lower than soda pulp. AS-AQ process produces the pulp with

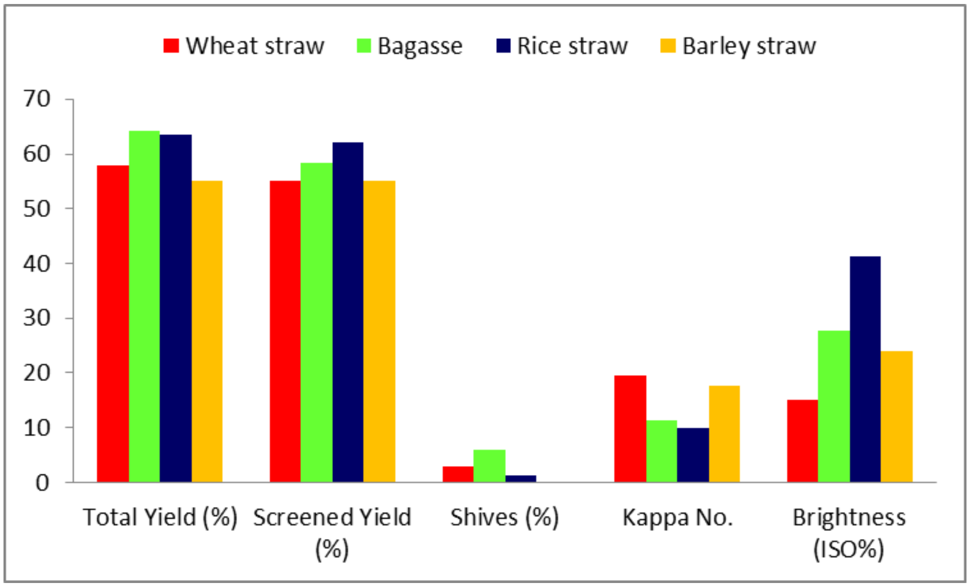

Figure 2: MEA-AQ pulp properties of different non-woody species.

significantly higher brightness among other processes. MEA-AQ pulp has the lowest brightness which is due to the formation of azo compounds in the pulp.

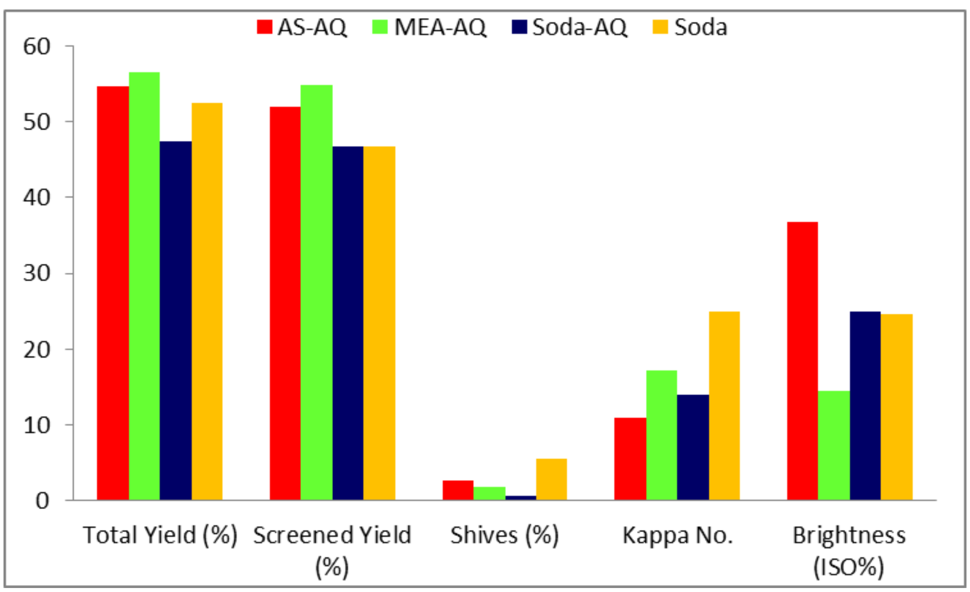

Figure 3: Wheat straw pulp properties produced with different processes.

Figure 4 shows the pulp properties of rice straw produced with different processes namely trail numbers 7, 9, 10 and 11 in table 1. Again MEA-AQ process produces pulp with the highest total and screened yields follows with AS-AQ process. The similar trend in the case of the pulp kappa numbers are seen as figure 3 and AS-AQ pulp has the lowest one. Also, AS-AQ pulp has the highest brightness and in the case of rice straw, MEA-AQ process produces pulp which has the higher brightness than that of soda-AQ and soda processes.

Figure 5 shows the pulp properties of bagasse produced with different processes, trail numbers 13, 14, 15 and 16 in table 1. It can be seen that the AS-AQ process produces pulp with the highest total and screened yields and lowest kappa number in comparison of conventional soda-AQ and soda processes. But the brightness of AS-AQ pulp is slightly lower than that of soda-AQ and soda pulps.

Figure 6 shows the pulp properties of barley produced with MEA-AQ and soda processes, trails 18 and 19in the table 1. The MEA-AQ pulp has obviously higher total and screened yield. The kappa number of soda pulp is somewhat lower than MEA-AQ pulp but its brightness is clearly higher than that of MEA-AQ pulp.

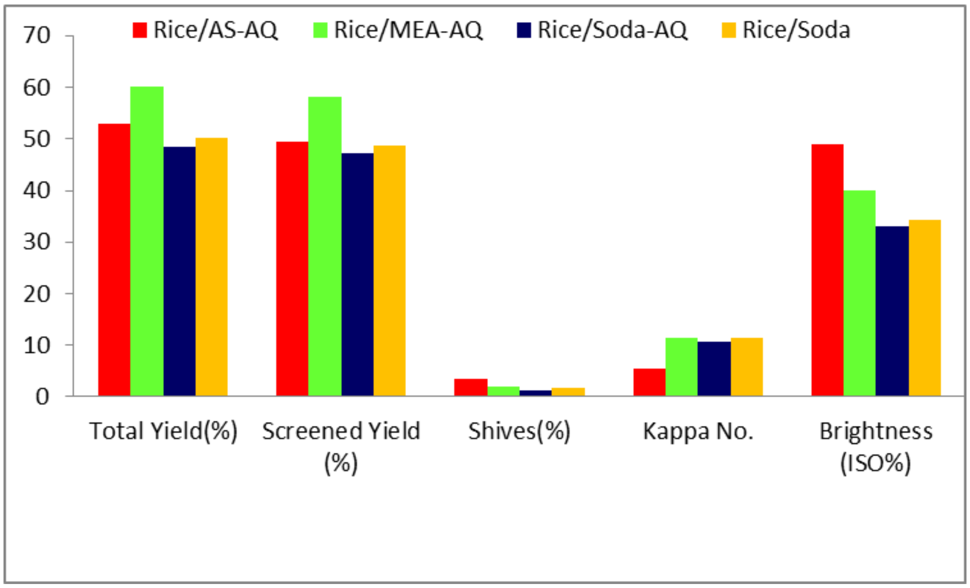

Figure 4: Rice straw pulp properties produced with different processes.

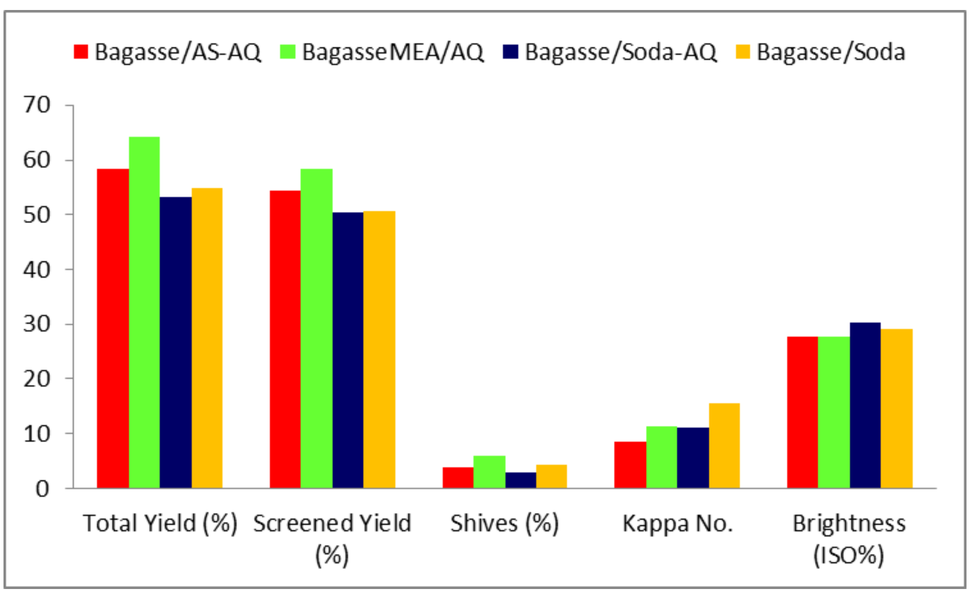

Figure 5: Bagasse pulp properties produced with different processes.

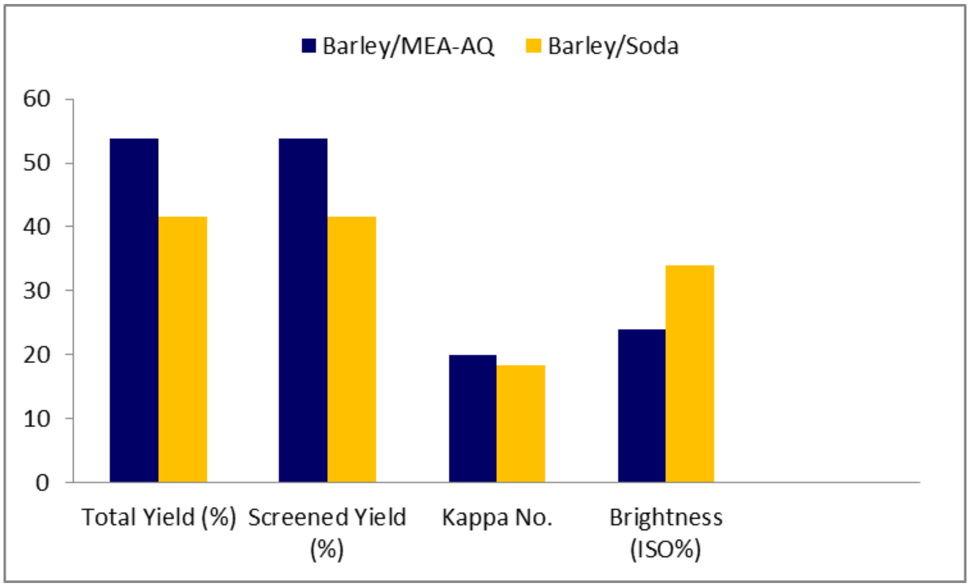

Figure 6: Barley pulp properties produced with MEA-AQ and soda processes.

Mechanical properties

Figures 7 and 8 show the tensile, burst and tear indices of different pulps. It can be seen that AS-AQ pulps except rice straw AS-AQ pulp have the highest tensile indices. The tensile indices of MEA-AQ pulps are lower than that of soda-AQ and soda pulps. Interestingly, the pulps produced with soda process show slightly higher tensile indices than the pulps made with soda-AQ process.

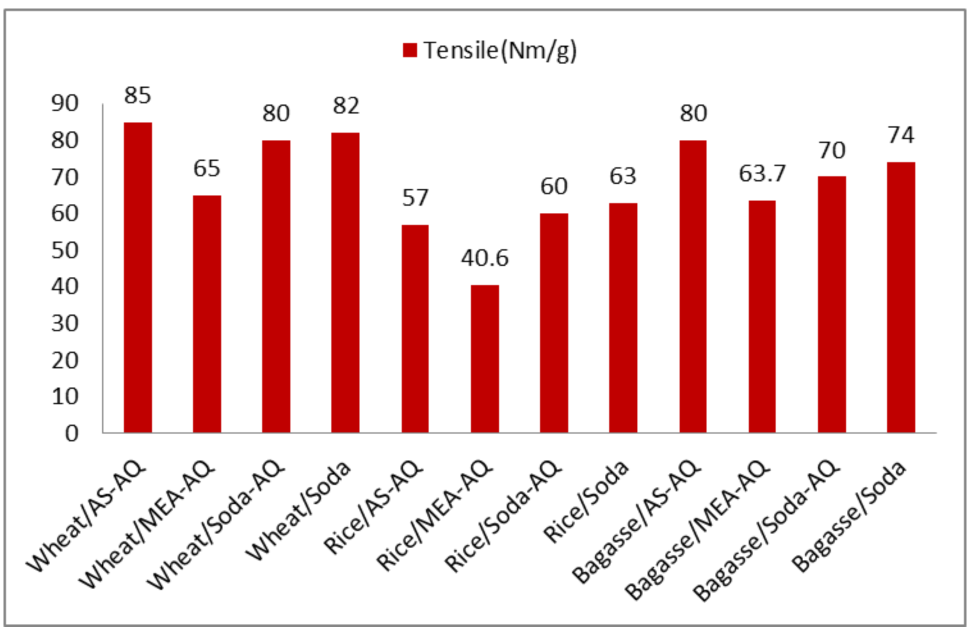

Figure 7: Tensile index of different pulps.

As figure 8 shows the trend in burst indices of different pulps are similar to that of tensile indices. In respect of tear index, it can be seen that AS-AQ pulps show the highest tear indices among the pulps.

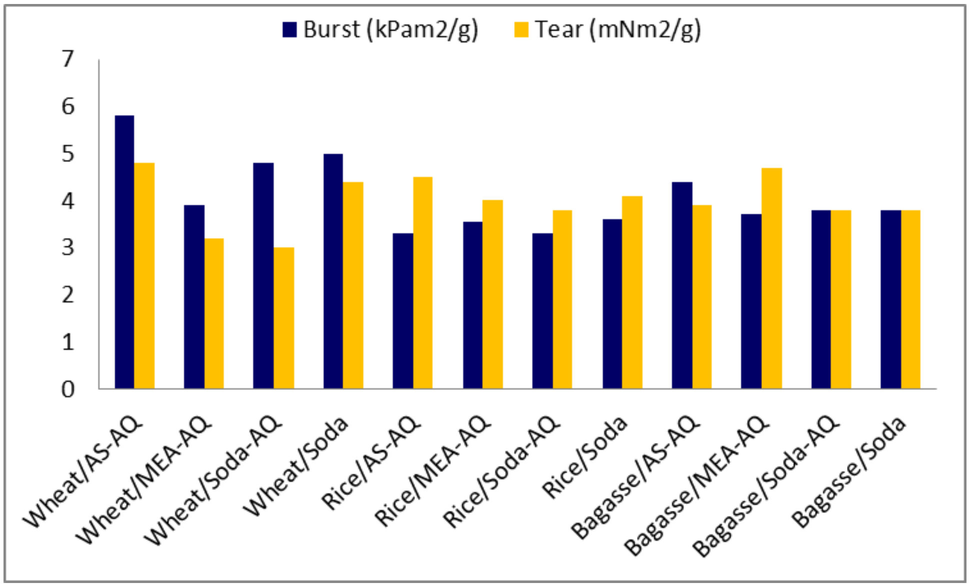

Figure 8: Burst and tear indices of different pulps.

4 CONCLUSION

Non-woody plant pulping is of high importance in areas where the availability of wood resources is limited. Pulping technology of non-woody plant has to be improved in order to produce better pulp qualities and reduce pollution associated with existing pulping processes. Many countries using non-woody plants as a pulping raw material suffer from water shortage. This means for the pulp industry that they have to reduce the specific water consumption. Among the existing pulping processes, alkaline sulfite pulping seems to be a good approach to overcome these problems, at least partially. This process is able to delignify a large variety of different non-woody plant species to low kappa numbers. Delignification proceeds very selectively producing high pulp yield, brightness and pulp strength. AS-AQ pulps are easily bleachable, bleaching can be performed in TCF or chlorine reduced short sequences. The process is odor free and most of the silica present in the raw material is left in the pulp which facilitates chemical recovery. The application of AS/AQ pulping on non-woody plants provides an approach for a better utilization of these valuable fiber sources, and could be considered as an economic and environmental solution for the medium-sized non-woody plant pulp production.

MEA-AQ pulping of non-woody plant is promising too. It is remarkable that the extremely high pulp yields are due to the uniquely high selectivity of MEA in lignin dissolution. In principle, MEA applied in cooking can be recovered by distillation. MEA-AQ pulping provides the possibility of separation of solvent and dissolved lignocellulosic matter. The latter can be used as a source of energy, chemical feedstock, or as a slow-release organic fertilizer. From this point of view, the MEA/water/AQ process is also a producer of useful by-products.

AS-AQ and MEA-AQ pulping processes are promising and environmentally sound alternative to soda or soda-AQ pulping. These processes open new perspectives for non-woody plant pulping.

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The Potential of Different Pulping Processes in Production of Pulp-Plastic Composites (PPC) From Bagasse and Rice Straw

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THE POTENTIAL OF DIFFERENT PULPING PROCESSES IN PRODUCTION OF PULP-PLASTIC COMPOSITES (PPC) FROM BAGASSE AND RICE STRAW

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ABSTRACT

Natural fibres are renewable, biodegradable, low-cost, low-density raw materials with high stiffness and strength compared to the other conventional products such as glass, aramid and carbon. There are a large variety of natural fibers such as rice straw, rice husk, wheat straw, corn stalks, palm, bagasse, hemp, flax and other agricultural residues. Natural fibers contain various organic materials (mainly celluloses as well as hemicelluloses and lignin) and there are several chemical treatments such as bleaching, esterification, silane treatment, use of compatibilizer, acetylation, alkali treatment and treatment with other chemicals in order to enhance the fiber matrix adhesion, which improve the physical and mechanical properties of composites.

This study investigates different pulping processes as a novel chemical treatment on bagasse and rice straw fibers and consequently, properties of biocomposites. By pulping processes, the treated natural fibers as a biofiller could be used to produce the new classes of bio composites defined as pulp- plastic composites (PPCs). Different pulping processes which are categorized in mechanical, semi-chemical and chemical methods led to natural fibers with different anatomical and chemical properties such as surface modification and delignification in comparison with untreated fibers. Furthermore, the comparison of natural fibers treated by chemical and mechanical pulping processes and effects of these treatments on physical and mechanical properties of natural fibers are worth considering.

Therefore in this paper, High-density polyethylene (HDPE), bagasse and rice straw fibers treated by four pulping processes (AS-AQ (alkaline sulfite anthraquinone), SODA-AQ (soda anthraquinone), MEA (monoethanolamine) and chemical mechanical pulping (CMP)) and maleic anhydride polyethylene as coupling agent were used to produce pulp plastic composites (PPCs) by injection molding. The physical and mechanical properties of corresponding composites were evaluated according to ASTM standards. The results showed that compared to untreated bagasse and rice straw/HDPE composite, the addition of bagasse and rice straw pulp fibers increased significantly the mechanical properties such as tensile strength and modulus, flexural strength and modulus, and hardness. The chemical pulps-reinforced composites showed better mechanical strengths than that of CMP-reinforced composites, but in some properties, CMP pulp composites have comparable results to the chemical pulp-reinforced composites. Natural fibers (untreated and treated) increased water absorption and thickness swelling of composites compared to pure HDPE. The comparison of PPCs from bagasse and rice straw untreated and treated fibers will be also presented and discussed.

Keywords: Biocomposite, pulp, Natural fibre, Bagasse, Rice straw

INTRODUCTION

Wood plastic composites (WPCs) are a relatively new class of materials and one of the fastest growing sectors in the wood composites industry. WPCs have experienced significant market expansion in recent years as a replacement for solid wood, mainly in outdoor applications such as railings, decking, landscaping timbers, fencing, playground equipment, windows and door frames, etc. (Hosseini 2013). With increased wood costs and competition of wood resources from traditional wood sectors, developing alternative, cheap, and environmentally friendly natural fiber sources for plastic composite is highly needed (Hosseini et al. 2014). The utilization of lignocellulosic material, such as wood or nonwood as a reinforcing component in polymer composites (thermoplastic or thermoset), has received considerable attention particularly for price-driven/high-volume application (Felix and Gatenholm 1991, Joseph et al. 1996, Bledzki et al. 1996, Gassan and Bledzki 1997, Rozman et al. 1999, Rozman et al. 2001). This development has been brought about by several advantages offered by lignocellulosic materials, such as: (1) low density, (2) low cost, (3) non-abrasive nature, (4) safe fiber handling, (5) high possible filling levels, (6) low energy consumption, (7) high specific properties, (8) biodegradability, (9) a wide variety of fiber types, (10) recyclability, and (11) generation of a rural/agricultural based economy (Mapleston 1997, Scheller 1996). As can be seen by the recent trends, lignocellulosic materials have been the subject of intensive studies in producing fiber-reinforced plastic (Felix and Gatenholm 1991, Joseph et al. 1996, Bledzki et al. 1996, Gassan and Bledzki 1997, Rozman et al. 1999, Rozman et al. 2001, Rozman et al. 1998, Valadez-Gonzalez 1999, Marcovich et al. 1998, Gassan 2002, Marcovich 2001a,b)

Blending of different polymers to achieve superior properties is a widely used process (Park 2008). Solution blending is one of the processes that are used for blending varieties of polymers and making polymer composite (Deka and Maji 2010, Deka et al. 2011). But the major problems to make composite are the immiscibility among different polymers and decrease in interfacial adhesion between polymers and wood. This results in the formation of inferior composites. In order to improve the miscibility among the polymers as well as with wood, a third component called compatibilizer is used (Ashori 2008). Compatibilizer is such a compound which can interact with the hydrophobic polymer through their non polar group and with the hydrophilic wood flour (WF) through their polar group. This leads to an improvement in interfacial adhesion that enhances the properties (Chiu et al. 2010). Different types of compatibilizer like glycidyl methacrylate (GMA), polyethylene grafted glycidyl methacrylate (PE-g-GMA), maleic anhydride grafted polypropylene (MAPP), maleic anhydride grafted polyethylene (MAPE), etc. are widely used to enhance the compatibility among different polymers and WF (Devi and Maji 2007, Dikobe and Luyt 2007, Kim et al. 2007).

In general, the low compatibility of natural fibers with the hydrophobic polymeric matrices persists as their major disadvantage. In spite of a small cost increase, fiber surface treatments may be able to partially overcome these limitations. Simple treatments such as mercerization (Vazquez et al. 1999), heat treatment (Sapieha et al. 1989), sizing (Mutjé et al. 2006) or refining (Nakagaito and Yano 2004) have been attempted with discreet positive effects. More recently, newer treatments have been reported to improve the fiber/matrix compatibility in natural fiber composites. Corona discharges (Belgacem et al. 1994), treatment with high-frequency ultrasounds (Gadhe et al. 2006), vacuumultraviolet- induced surface oxidation (Hollander et al. 1994, Kato et al. 1999), graft copolymerization (Mondal et al. 2002), treatment with silanes (Gironès et al. 2007) and other chemicals have been positively applied. One of the most popular treatments is alkaline treatment (Rozman et al. 1998, Valadez-Gonzalez et al. 1999, Marcovich et al. 1998, Gassan 2002, Marcovich 2001a,b, Gassan and Bledzki 1999). According to Bledzki and Gassan (Bledzki and, Gassan 1999), alkaline treatment of natural fiber would make the fibrils more capable to rearrange themselves along the tensile deformation.

Soda anthraquinone (SODA-AQ), alkaline sulfite anthraquinone (AS-AQ) and Monoethanolamine (MEA) are the most important chemical pulping methods to treat lignocellulosic non-wood natural fibers. SODA-AQ pulping is a promising and environmentally friendly method compared to sulphur based processes: Kraft and Sulphate (Khristova et al. 2002). SODA-AQ pulping is categorized as alkaline pulping processes with using mainly NaOH and partial anthraquinone (AQ) in cooking liquor. Alkaline sulfite anthraquinone (ASAQ) pulping is another alkaline pulping process with cooking liquor consisting of a mixture of Na_2SO_3 and NaOH which is able to delignify lignocellulosic materials, particularly in present of anthraquinone (AQ). The extent of delignification depends on the lignin structure as well as on the adjusted Na_2SO_3 to NaOH ratio. Monoethanolamine (MEA) pulping process is an organosolv pulping process which has appropriate performance on lignocellulosic non-wood natural fibers (Hedjazi et al. 2009). The most important advantage of MEA pulping of annual plants is the direct MEA recovery by distillation. After distillation of MEA, the residual organic matter could be used either as chemical feedstock or as nitrogen containing organic fertilizer, which, contrary to nitrogen in minerals, has slow-release long-term effects because nitrogen is gradually released by microbial degradation of the carrier material. The most prominent feature of MEA pulping is the exceptionally good preservation of hemicelluloses resulting in unusually high pulp yield. Green and Sanyer (1982) presumed that carbohydrates in the presence of MEA are stabilized against peeling reactions by reduction of reducing end groups. Compared to the SODA pulping, MEA pulping gives 12% higher yield (Hedjazi et al. 2009). The chemical-mechanical pulping (CMP) process has the advantages of a mild chemical treatment with cooking liquor consisting of a mixture of Na_2SO_3 and NaOH and of high pulping yield compared with the chemical pulping process. Additionally, a lower refining energy is required in the CMP process than in mechanical pulping and this is because of chemical treatment in chemical-mechanical pulping (CMP) process.

The objective of present study is to investigate the influence of different pulping processes as treatments of bagasse and rice straw fibers on the physical and mechanical properties of pulp plastic composites (PPCs) and presentation a comparative study on performance of bagasse against rice straw as natural fiber reinforcement factor in biocomposites.

MATERIALS AND METHODS

Materials

Injection molding grade high-density polyethylene (HDPE) was supplied by Jam Petrochemical Co. (Iran), with melt flow index of 18 g/10min and density of 952 kg/m^3. Maleic anhydride polyethylene (MAPE), as a coupling agent was obtained from Kimiajavid chemical products (Iran), with trade name PE-G 101, melt flow index of 50-80 g/10min, and maleic anhydride content of 0.8-1.2 %. The bagasse fibers were provided by Pars Paper Co., Khuzestan province, south west of Iran. Bagasse fibers were ground into flour with particle size of 40 mesh by screening. Rice straw was obtained from rice farms of north of Iran. The rice straw was cut into shorter length of 5-7 cm to incorporate in pulping processes. Bagasse and Rice straw pulp fibers which are treated by pulping processes (AS-AQ, SODA-AQ, MEA, and CMP) were investigated in this study and both of them were ground into flour subsequently.

Sample preparation

Bagasse and Rice straw fibers turned to pulps by four pulping processes under different pulping conditions including various cooking time and chemical ratio. However, the optimum pulping conditions which used to produce pulp plastic composites are given in tables 1 and 2. Pulps were dried in an oven at 103±2 ºC for 24 hours. Polymer to fibers ratio for all reinforced composites were 60:40 wt.%. MAPE amount was reduced from polymer amount. Formulation of the composites and abbreviations used for the corresponding composites are given in Table 3.

Table 1: Pulping conditions and the properties of produced bagasse pulps

Process	Abbreviation	Features			
		Time (Min)	Yield (%)	Kappa	Details
Alkaline sulfite anthraquinone	AS-AQ	90	62.16	12.3	16% alkalinity, NaOH to Na_2S ratio 50:50, AQ:0.1%, 160°C
Sodium hydroxide anthraquinone	SODA-AQ	90	61.44	11.45	20 % alkalinity, AQ:0.1 %, 160°C
Monoethanolamine	MEA	90	76.8	12.5	MEA to H_2O ratio 75:25, 160°C
Chemi- mechanical pulping	CMP	30	86.4	-	NaOH to Na_2SO_3 ratio 4:10 on the basis of OD bagasse and NaOH, 160°C

Table 2: Pulping conditions and the properties of produced rice straw pulps

Process	Abbreviation	Features			
		Time (Min)	Yield (%)	Kappa	Details
Alkaline sulfite anthraquinone	AS-AQ	90	50	20	16% alkalinity, NaOH to Na_2S ratio 20:80, AQ:0.1%, 160°C
Sodium hydroxide anthraquinone	SODA-AQ	45	49.8	19	16 % alkalinity, AQ:0.1 %, 160°C
Monoethanolamine	MEA	30	55.25	18	MEA to H_2O ratio 50:50, 160°C
Chemi- mechanical pulping	CMP	30	85	-	NaOH to Na_2SO_3 ratio 8:18 on the basis of OD bagasse and NaOH, 160°C

Table 3: Composition of the studied formulation

Composites *	Bagasse (wt.%)	Bagasse pulp (wt.%)	Rice straw (wt.%)	Rice straw pulp (wt.%)	MAPE (wt.%)	HDPE (wt.%)
PE	-	-	-	-	-	100
PE/B	40	-	-	-	5	55
PE/AS-AQ	-	40	-	-	5	55
PE/SODA-AQ	-	40	-	-	5	55
PE/MEA	-	40	-	-	5	55
PE/CMP	-	40	-	-	5	55
PE/R	-	-	40	-	5	55
PE/AS-AQ	-	-	-	40	5	55
PE/SODA-AQ	-	-	-	40	5	55
PE/MEA	-	-	-	40	5	55
PE/CMP	-	-	-	40	5	55

* PE:HDPE, B:Bagasse, AS-AQ:Alkaline sulfite anthraquinone, SODA-AQ:Soda anthraquinone, MEA:Monoethanolamine, CMP:Chemical mechanical pulping, R:Rice straw

Composites were prepared by following processes:

The compositions were extruded by Collin twin screw extruder (screw speed of 60 rpm, L/D 16, Germany, 1990), then they were grounded to prepare the granules using a pilot scale grinder (WIESER, WGLS 200/200 model). Experimental specimens were prepared by injection molding (Injection pressure 100 kg/m^2, temperature 180 C°, Imen Machine, Iran) according to ASTM standard. Dimension of specimens for tensile and flexural properties were 165×19×3.2 and 100×12×5 mm, respectively.

Mechanical testing

Injection-molded specimens were tested following ASTM standards, D 638 for tensile properties, D 790 for flexural properties, and D 256 for notched Izod impact strength. The flexural properties were measured in three-point bending tests. Flexural and tensile tests were conducted using an Instron Universal Testing Machine (model 4486) at crosshead speed of 8 mm/min at room temperature. Impact test was performed by a digital impact test machine (SANTAM, SIT-20 D model) using conventional V notched specimens. Three replicates were tested for each property and each formulation.

Physical testing

Physical properties, namely, water absorption (WA) and thickness swelling (TS) were tested in according to ASTM D 570. Before testing, the weight and thickness of each specimen were measured. Conditioned specimens of each type of composite were soaked in distilled water at room temperature for 24 hours. For each measurement, specimens were removed from water, patted dry and then measured again. Each value obtained represented the average of three specimens. WA and TS were calculated according to Eqs. (1) and (2).

$$WA\ (\%) = \frac{W_f - W_i}{W_i} \times 100 \qquad \textbf{(1)}$$

$$TS\ (\%) = \frac{T_f - T_i}{T_i} \times 100 \qquad \textbf{(2)}$$

Where W_f (gr) and T_f (mm) are the weight and thickness at given time, respectively and W_i (gr) and T_i (mm) are the initial weight and thickness, respectively.

One-way variance of analysis was conducted using SAS statistical software (9.1 version). The Duncan test, at the 99% confidence level, was used for comparing and grouping of the mean values.

RESULTS AND DISCUSSION

Tensile properties

The effect of bagasse and rice straw pulps content on the tensile strength and modulus of composites are presented in Fig. 1. Natural fibers have higher modulus compared to the HDPE and it is expected to have higher modulus values when the amounts of them are increased in the matrix (Dönmez Çavdar et al. 2015). Bagasse and rice straw fibers (in both form of treated and untreated) led to significant increase of tensile strength and modulus of natural composites compared to pure HDPE sample (Fig. 1). The addition of natural fibers resulted in a reinforcement of the HDPE matrix in terms of stiffness and strength (Migneault et al. 2015).

Alkali treatment leads to an increase in tensile strength and modulus of composites. These changes in mechanical properties are affected by modifying the fiber structure, basically via the crystallinity ratio, degree of polymerization, and orientation (Gassan and Bledzki 1999). It is also noteworthy that the AS-AQ, SODA-AQ, MEA, and CMP bagasse fibers showed similar performance in both tensile strength & modulus and there is no clear difference concerning tensile strength and modulus between chemical and mechanical pulps. Untreated rice straw and CMP rice straw composites showed similar results of tensile modulus and also minimum value among rice straw reinforced composites. By contrast, AS-AQ and SODA-AQ rice straw composites reached to maximum performance.

According to Fig. 1a, the maximum values of tensile modulus (4076.2 MPa) belong to PE/CMP bagasse composite. As it was expected, the minimum value of tensile modulus (1235.4 MPa) belongs to pure HDPE. Addition of AS-AQ rice straw pulp to composites demonstrated the maximum values of tensile modulus (3648.6 MPa). Generally, composites which are reinforced by both treated bagasse and rice straw fibers with AS-AQ and SODA-AQ pulping processes shown effective results between others. This is due to role of anthraquinone (AQ) in pulping processes by improving pulping factors.

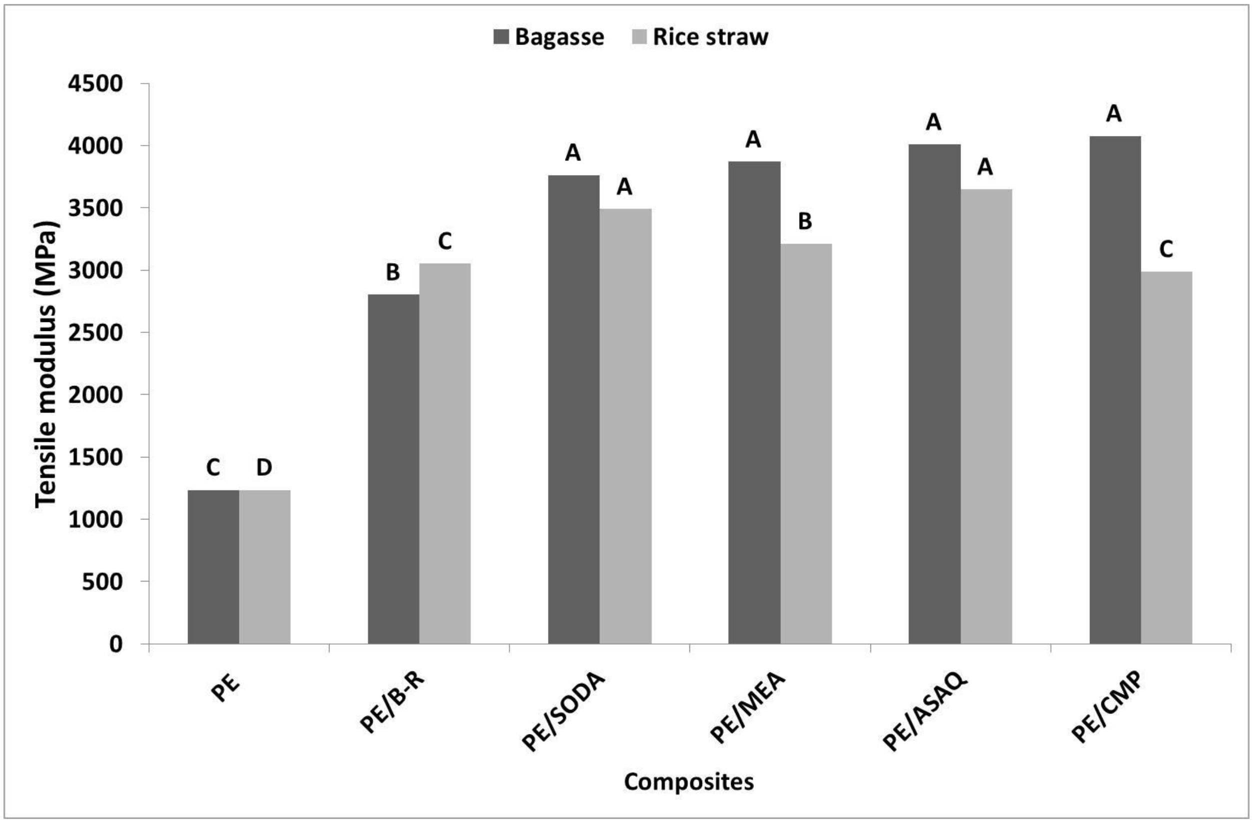

Figure 1a: Tensile modulus as function of bagasse and rice straw pulps

According to Fig. 1b, addition of natural fibers led to significant and positive effect on tensile strength of pulp plastic composites compared to pure HDPE with minimum value of tensile strength (22.71 MPa). From Fig. 1b, MEA fibers filled composite containing bagasse fibers reached to maximum tensile strength (44.87 MPa) among all biocomposites (both bagasse and rice straw reinforced composites). Fig. 1b also shows that AS-AQ fiber filled composite containing treated rice straw exhibited the highest tensile strength (32.74 MPa) compared to other rice straw reinforced composites. The tensile strength of oil palm empty fruit bunch (EFB) pulp polypropylene composites showed improvement as the NaOH content in the treatment was increased (Tay et al. 2010). However, the results of tensile strength demonstrated higher performance of bagasse filled composites compared to rice straw reinforced composites. Compared to that of chemical pulp reinforced HDPE composites, the better strength of CMP reinforced HDPE composites are rather surprising, because it is well known that chemical pulps are preferred reinforcing fiber source for paper products prepared from CMP in paper industry. By contrast, mechanical pulping processes such as chemical-mechanical pulping (CMP) and thermal-mechanical pulp (TMP) show higher reinforcement in polymer composite; this improvement is result of more remained lignin is mechanical pulping processes in comparison to chemical pulping processes. Other researchers reported similar results that TMP-reinforced PP composites have the highest tensile strength compared to bleached Kraft pulp (BKP) PP composites (Li and Sain 2003).

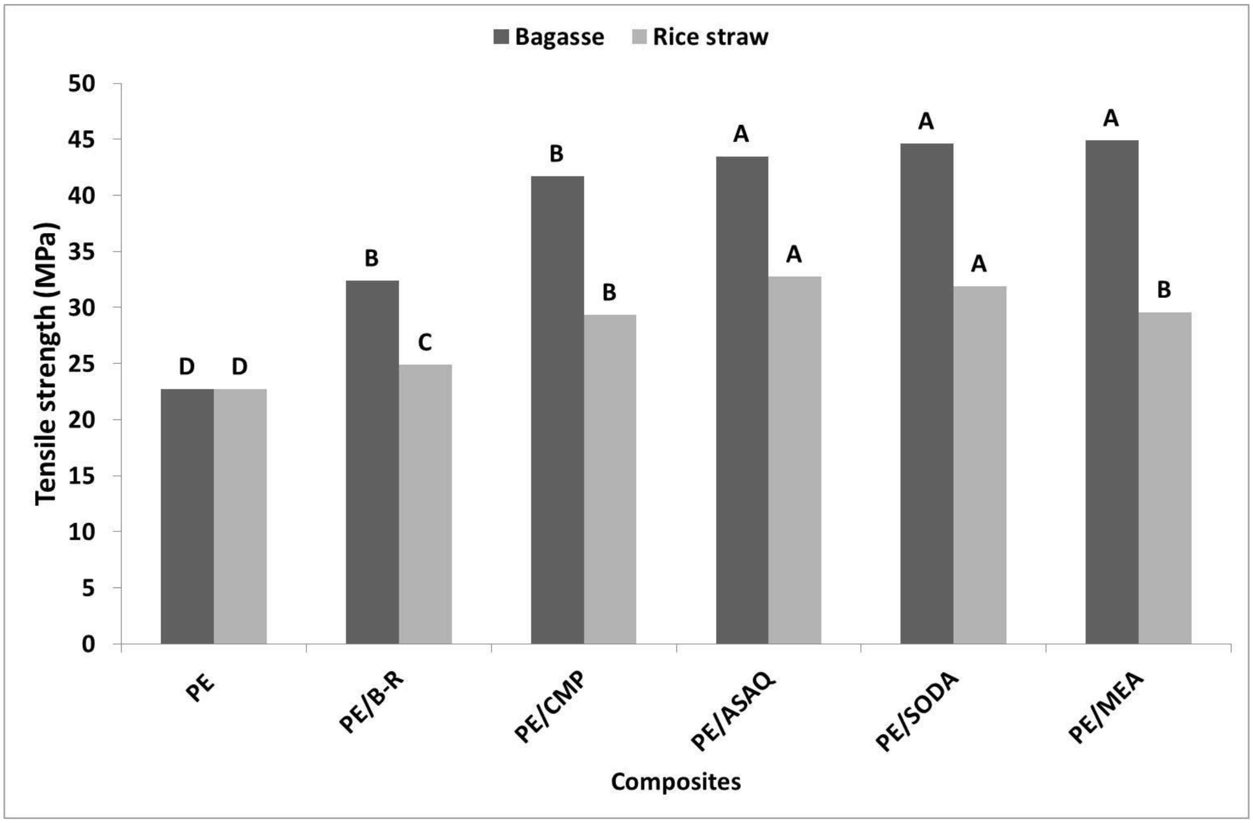

Figure 1b: Tensile strength as function of bagasse and rice straw pulps

Flexural properties

Flexural strength and modulus of pulp plastic composites compared to untreated fiber composites which could be considered as common wood-plastic composites and pure HDPE are shown in Fig. 2. The addition of untreated fibers and both bagasse and rice straw fibers which were treated by different pulping processes led to noticeable increase in flexural strength and modulus results. This is due to the fact that the natural fibers have higher modulus than polymer matrix (Mengeloğlu and Karakus 2008, Bouafif et al. 2009, Dönmez Çavdar et al. 2011). The results of flexural modulus showed two different trends for bagasse and rice straw reinforced composites (Fig. 2a). On the one hand, the minimum flexural modulus of pulp plastic composites containing bagasse fibers belongs to untreated bagasse-HDPE composite (2158.11 MPa) and the addition of treated bagasse fibers by pulping processes led to significant increase in flexural modulus of composites with maximum value of 2803.89 MPa for CMP bagasse composite (Fig. 2a). On the other hand, untreated rice straw composite with maximum flexural modulus of 2953 MPa showed the best performance of flexural modulus among all bio-composites. As it is obvious from figure 2a, all of pulping processes as rice straw treatments demonstrated noticeable decrease and negative effect on flexural modulus of rice straw composites. In term of rice straw treated composites, chemical pulping processes including SODA-AQ, AS-AQ, and MEA pulping processes showed higher flexural modulus compared to CMP-rice straw composite. Chemical pulping processes led to more delignification and solubilization of lignin and subsequently, higher fiber strength. Cellulose was reported to be positively related with stress transfer and benefit the mechanical strength of the polymer composites (Shebani et al. 2009, Liu et al. 2014, Migneault et al. 2014).

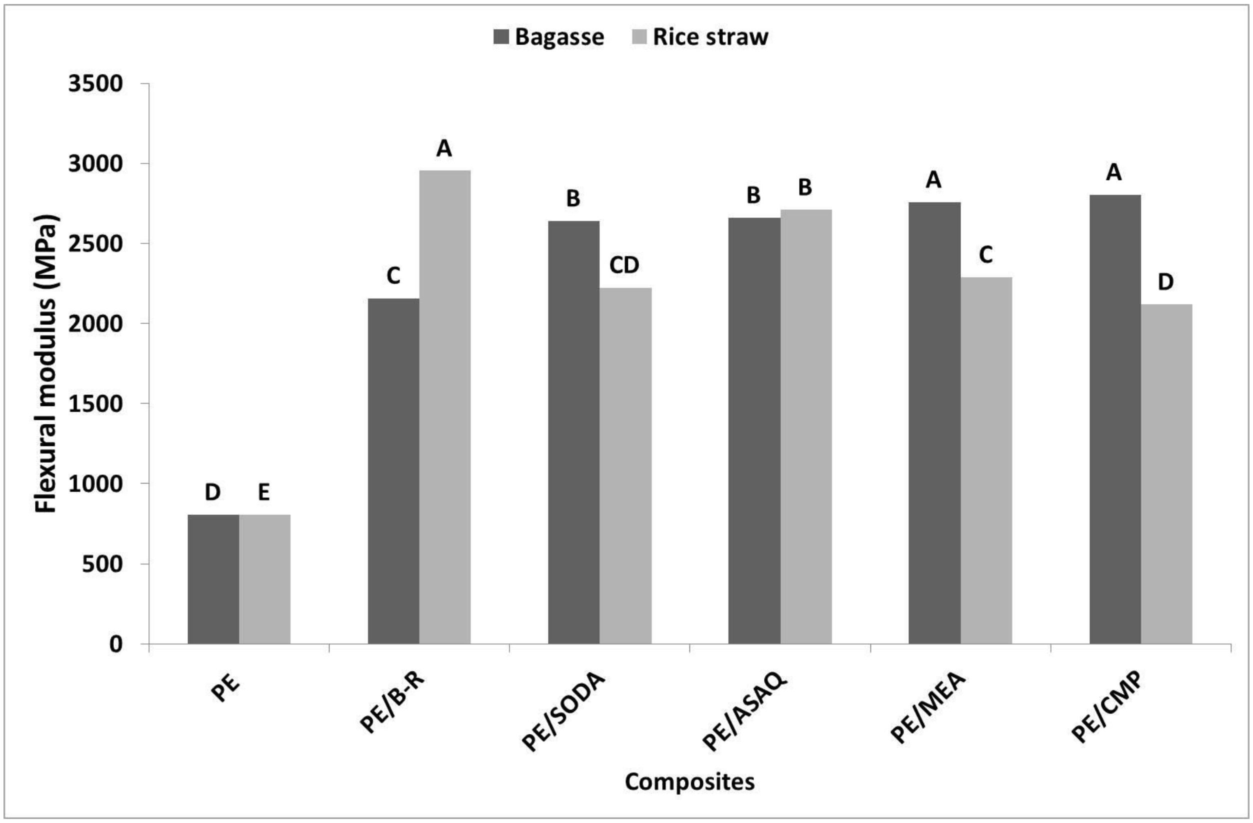

Figure 2a: Flexural modulus as function of bagasse and rice straw pulps

As shown in Fig. 2b, the minimum values of flexural strength belong to pure HDPE (26.55 MPa) and untreated bagasse and rice straw composites which are 45.79 and 40.49 MPa, respectively. Flexural strength results of composites demonstrated that bio-composites with treated fibers by pulping processes shown better performance compared to untreated natural fiber composite and pure HDPE in both cases of bagasse and rice straw filled composites (Fig 2b). The chemical treatment of fiber improved the adhesion between fiber surface and polymer matrix by modifying fiber surface and also increasing fiber strength and their mechanical properties (Li et al. 2007). MEA and AS-AQ bagasse composites depicted maximum (61.6 MPa) and minimum (57.88 MPa) flexural strength values among other pulping processes. By contrast, AS-AQ rice straw composite showed the highest flexural strength (44.87 MPa) and other treatment methods had not significant difference in flexural strength (Fig 2b). An alkali treatment applied on different tropical wood polymer composites improved the strength of up to 16% and the modulus of 13% maximum (Islam et al. 2012). The alkaline impregnation may cause fiber fibrillation and increase adhesion between fiber and polymer matrix (Bisanda and Ansell 1991, Mohanty et al. 2000, Habibi et al. 2008). This is also supported by some researchers who studied on the effects of alkaline treatment on properties of reinforced low density polyethylene composites (Ikhlef et al. 2012).

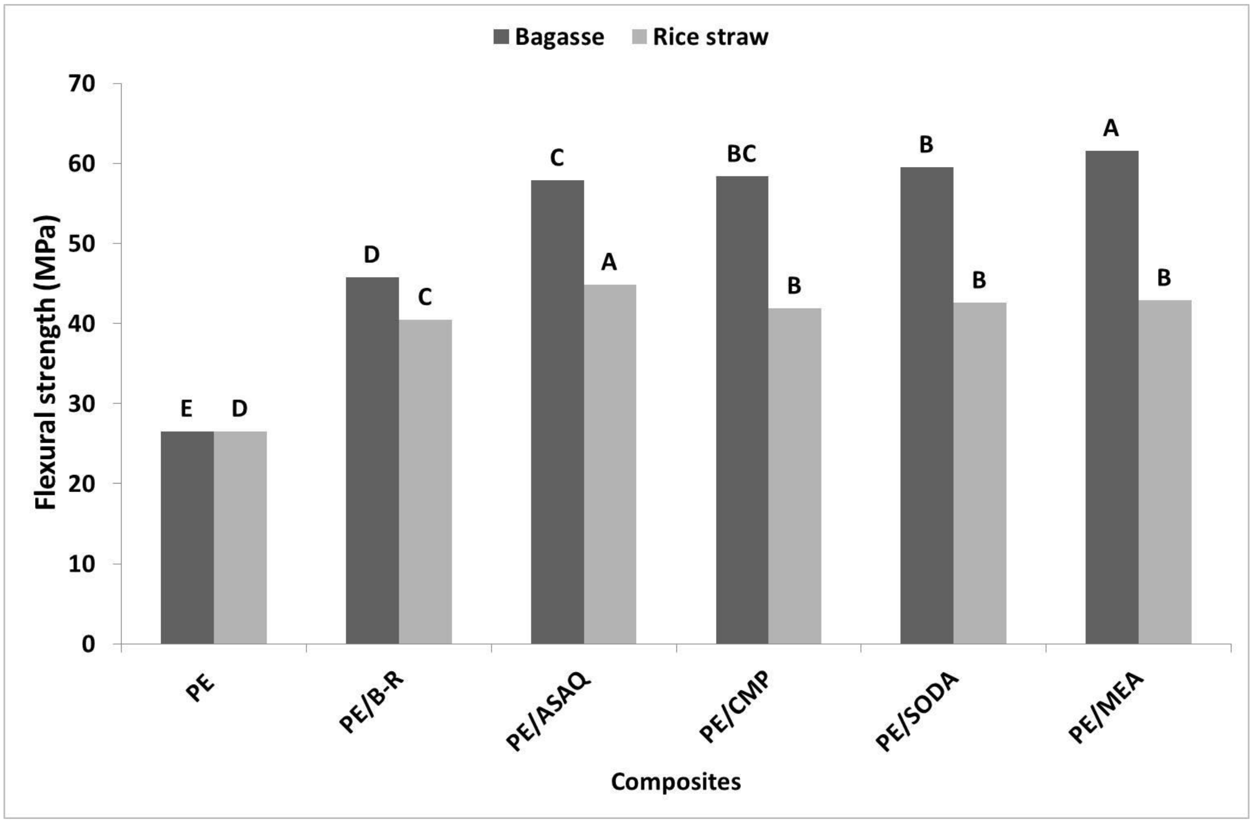

Figure 2b: Flexural strength as function of bagasse and rice straw pulps

Impact strength

Impact strength values of the four types of HDPE/pulps fibers composites for both bagasse and rice straw/HDPE composite are shown in Fig. 3. As it can be seen in Fig. 3, the addition of all types of fibers (treated and untreated) decreased the impact strength of HDPE matrix, but untreated bagasse composite (B/PE) showed so close impact strength value (60 J) to pure HDPE (60.88 J). This negative effect may be ascribed to the reduction of polymer matrix content and poor compatibility between the fibers and polymer matrix. Decreasing of impact strength values by addition of natural fibers are observed in many studies (Klyosov 2007, Mengeloğlu and Karakus 2008, Basiji et al. 2010, Hosseini et al. 2014). Different types of pulps showed no significant influence on impact strength of rice straw composites compared to untreated rice straw reinforced composite(Fig 3). However, all types of bio-composites counting treated and untreated rice straw fibers showed significant and higher values of impact strength compared to pure HDPE and also other bagasse filled composites. The maximum impact strength value was related to SO-AQ, AS-AQ, MEA, and untreated rice straw with 74 J. the Izod impact strength of CMP rice straw composite and pure HDPE were 73 and 60.88 J, respectively.

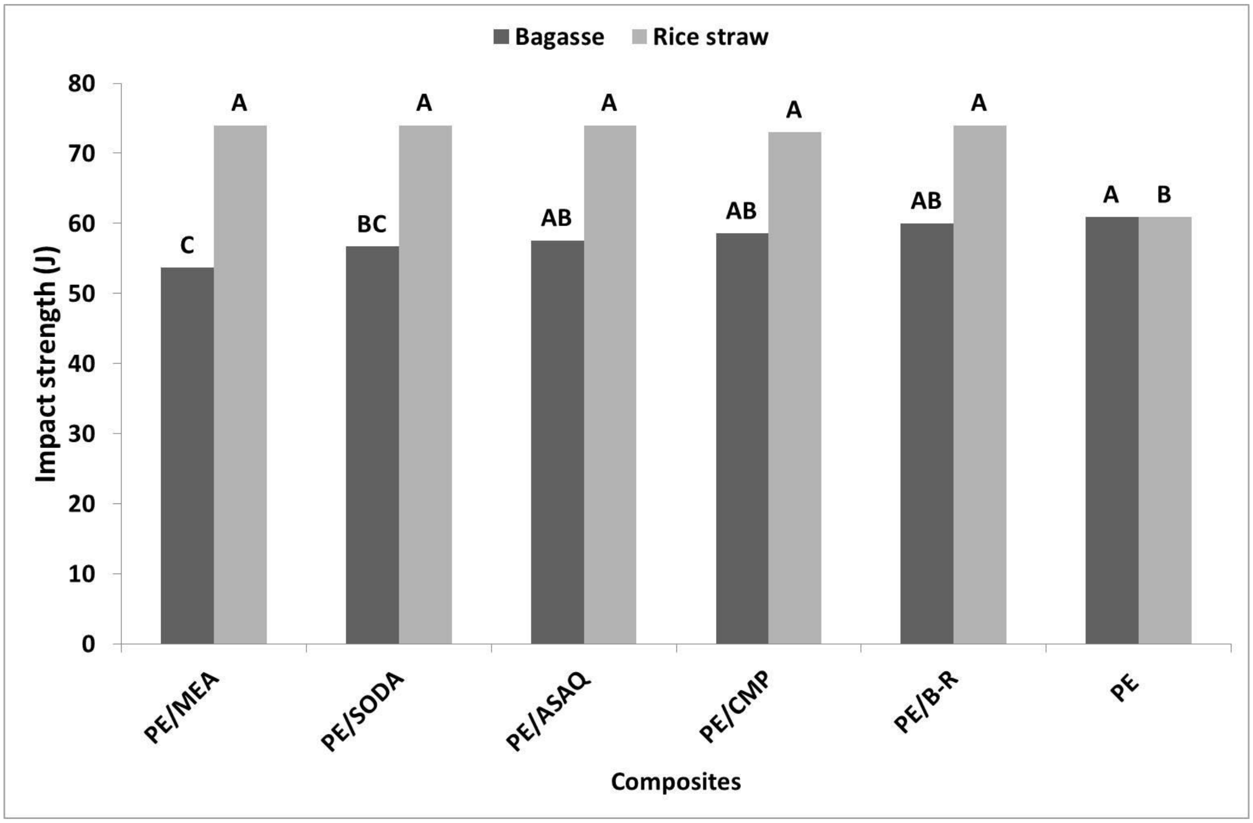

Figure 3: Comparison of impact strength of the composites as function of bagasse and rice straw pulps

Water absorption

The water absorption results of pure HDPE and fiber reinforced composites containing bagasse and rice straw are shown in Fig 4. Mechanical properties of composites are known to be greatly affected by the presence and distribution of water, and this distribution should be taken into consideration during testing (Gnatowski et al. 2015). The value of water absorption capacity of pure HDPE (0.12 %) was significantly increased after the addition of pulps and untreated fibers into the pure HDPE for both bagasse and rice straw composites. The hydrophilic nature of natural fibers (free hydroxyl groups) caused an increased in the water absorption. These hydroxyl groups strongly interact with water molecules by hydrogen bonding and then favor water absorption by fibers (Pouzet et al. 2015). AS-AQ, SODA, and CMP bagasse composites exhibited almost same values of water absorption, whereas MEA bagasse composite showed the highest WA (0.46 %) compared to other pulp plastic composites due to high hemicelluloses content of this type of pulp. The addition of treated and untreated rice straw fibers into HDPE matrix led to no significant change of WA among all types of natural fiber reinforced composites. However, untreated rice straw composite showed maximum WA (1.5 %), whereas AS-AQ rice straw composite demonstrated the minimum value of water absorption (1.19 %), (Fig 4). The different trend in mentioned composites is due to fiber properties, agglomeration of their fibers and consequently, formation of composites. It is noteworthy from Figure 4 that all water absorption values of bagasse composites were less than 0.5 %, whereas WA values of rice straw reinforced composites were in range of 1.19-1.5 %.

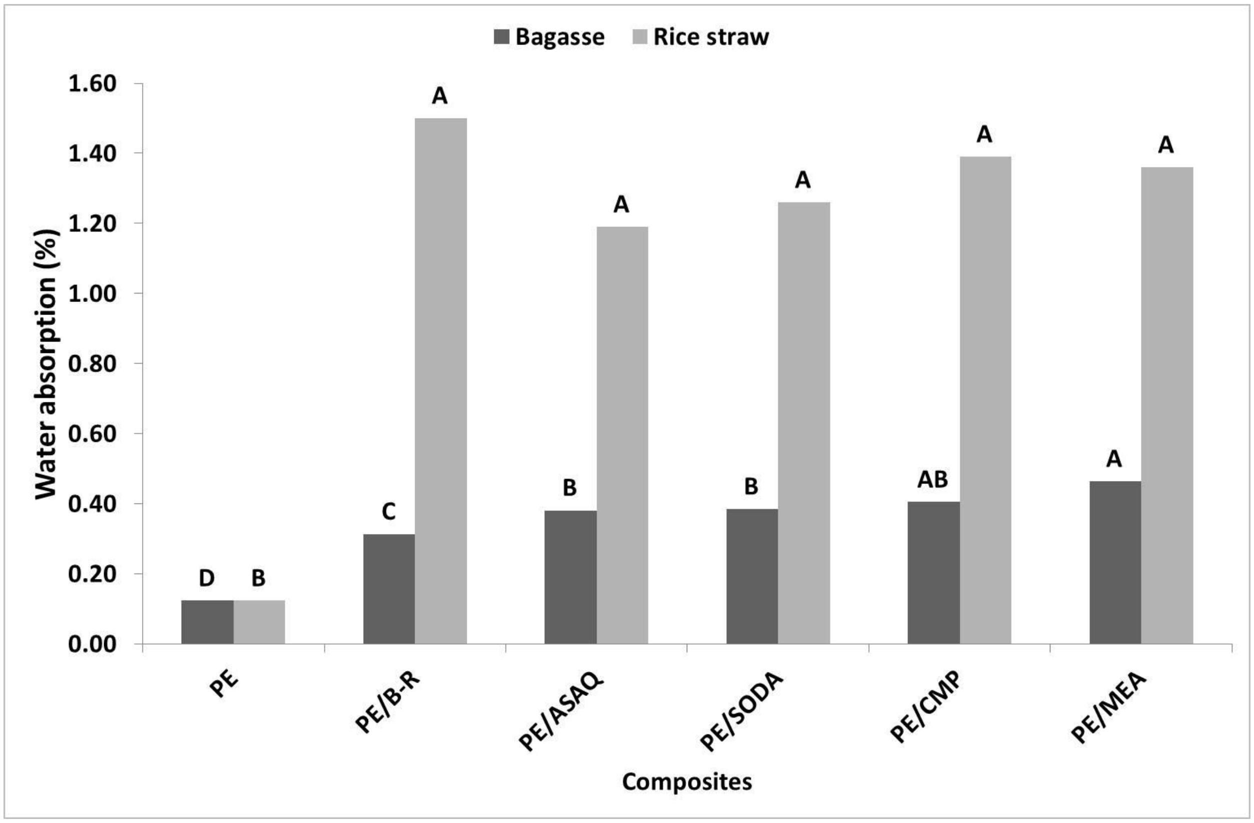

Figure 4: Comparison of water absorption (WA) of the composites as function of bagasse and rice straw pulps

Thickness swelling

Fig. 5 depicted the thickness swelling (TS) values of natural fibers/HDPE composite and pure HDPE. As shown in Fig. 5, by addition of both bagasse and rice straw fibers and pulps into HDPE; the thickness swelling values are increased. The increasing of thickness swelling could be expected due to the inherent features of lignocellulosic materials (the water uptake capacity). Once again, reinforced composites by bagasse pulp fibers (specially, SODA-AQ pulp composite) shown better performance (lower TS of 0.46 %) in comparison with untreated bagasse composite (0.1 %). All pulping processes as rice straw treatments showed significant and positive effect on thickness swelling by decreasing maximum TS of untreated rice straw composite (1.95 %) to minimum TS (0.71 %) for AS-AQ rice straw filled composite. It is obvious from Fig. 5 that chemical pulping treatments on both fibers led to lower TS in comparison with CMP-pulp and untreated natural composites.

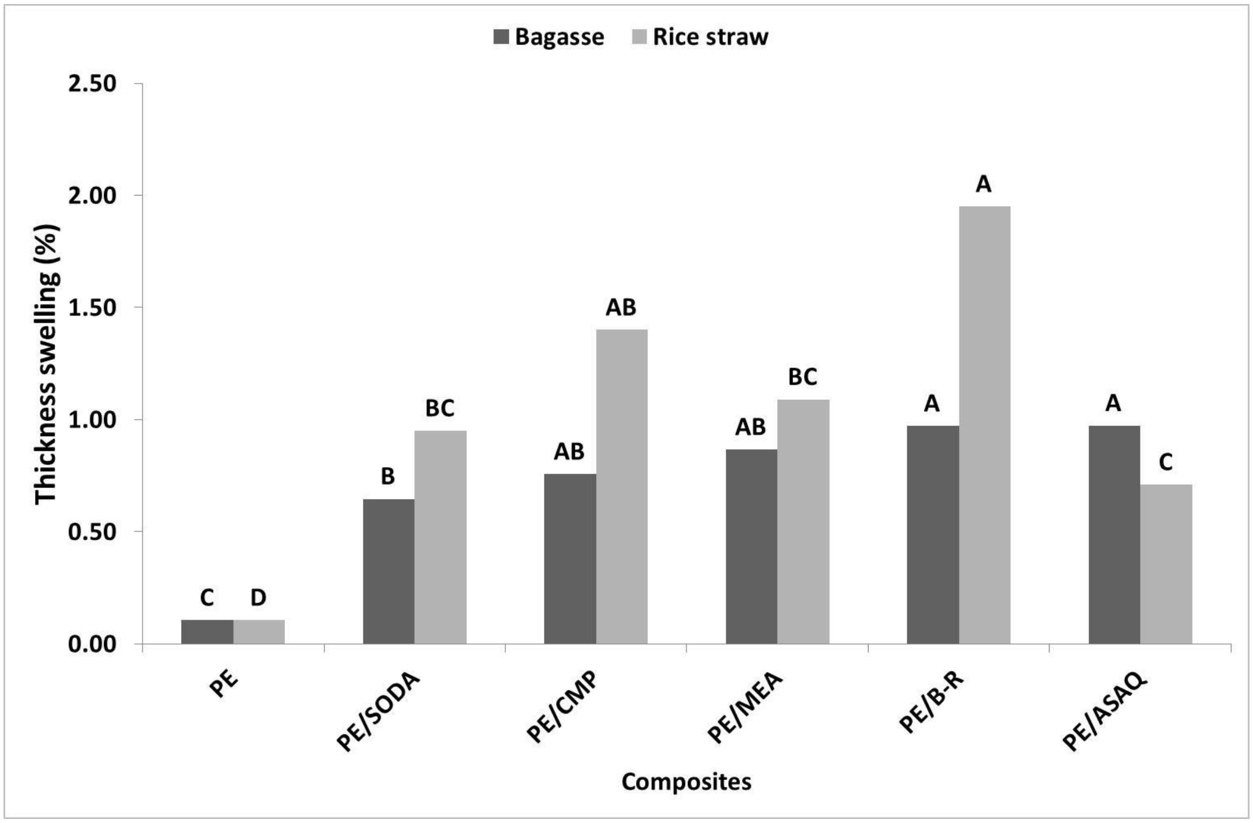

Figure 5: Comparison of thickness swelling (TS) of the composites as function of bagasse and rice straw pulps

CONCLUSIONS

The present study investigated effect of four pulping processes (ASAQ, SODA, MEA, and CMP) as chemical treatment of bagasse and rice straw fibers on physical and mechanical properties of pulp plastic composites (PPCs). Treated bagasse fibers by pulping processes increased tensile, flexural, and water absorption properties of composites. By contrast, treated bagasse fibers decreased impact strength and thickness swelling of pulp plastic composites. The addition of rice straw treated fibers by chemical and mechanical pulping processes led to increase of tensile strength and modulus and flexural strength properties of composites. The addition of treated rice straw also caused negative effects on some properties by decreasing flexural modulus and thickness swelling of rice straw treated composites. In term of Izod impact strength and water absorption, treated rice straw fibers led to no significant change compared to untreated rice straw composite. This study demonstrated that chemical treatments are more effective on bagasse fibers compared to rice straw, but untreated rice straw in comparison to untreated bagasse fibers showed better performance in many properties. The addition of rice straw and bagasse fibers (both treated and untreated) illustrated positive and negative effect on Izod impact strength of biocomposites compared to Pure HDPE, respectively. According to results of water absorption, the minimum WA among all types of fiber reinforced composites belongs to untreated bagasse composite, whereas rice straw filled composites (both treated and untreated) showed noticeable increase in water absorption. Thickness swelling of untreated bagasse and rice straw composites remarkably decreased by addition of treated fibers via four pulping processes. TS results also demonstrated better performance of chemical pulping processes for decreasing TS of composites compared to chemical mechanical pulping (CMP) process. According to this research, the pulp-plastic composites (PPCs) are superior to untreated fiber reinforced composites (both bagasse and rice straw composites) and PPCs could be introduced as serious alternatives of natural fiber reinforced composites.

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The Impact of Wood Veneer Species on Its Adhesion Strength on Surface of Medium Density Fibreboard

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ABSTRACT

This paper presents results of analysis of the adhesion strength of veneers of selected hardwood species: beech (*Fagus sylvatica*), oak (*Querqus robur*) and walnut (*Juglans nigra*) glued on the surface of medium density fibreboard (MDF). In addition, the impact of MDF preparation by surface sanding before veneering on the adhesion strength of veneer applied on MDF was evaluated. The statistical analysis (two-way ANOVA) revealed that the veneer species had significant impact on the veneer`s adhesion strength on the surface of the MDF. On the other hand, the sanding of the surface of MDF prior to veneering had no effect on the adhesion strength of none of the selected veneer species. The highest adhesion strength was obtained for beech veneered samples (2.40 MPa), followed by walnut veneered samples (2.32 MPa), while the lowest value was observed for oak veneered samples (2.21 MPa). However, the difference in the veneer adhesion strength on the surface of the MDF was statistically significant only for beech veneered samples compared to oak veneered samples.

KEYWORDS: Wood veneer species, MDF, Adhesion strength, Sanding

1 INTRODUCTION

The veneered panels are often used in the manufacture of furniture and interior furnishing. One of the main advantages of this engineered product are economical savings, since thin sheets of wood are glued to the surface of the panel giving a visual impression of the solid wood.

Most of the wood-based panels can be used as a substrate under the veneer. When using medium density fibreboard (MDF) as a substrate, very fine fibers create the smooth surface and the good basis for veneer overlaying. There are a number of factors that affect the adhesion strength between veneer and MDF: surface roughness of MDF (Kiliç et al. 2009; Ayrilmis et al. 2010); wood veneer species and adhesive type (Kureli and Doganay 2015); adhesive properties and pressing regimes (Martins et al. 2012); thermal treatment of fibres (Jarusombuti et al. 2010); fineness (size) of fibers (Ozdemir et al. 2009); post-heat treatment of veneered panels (Ayrilmis and Winandy 2009) etc. In the research of the effect of the wood veneer species on it`s adhesion strength on the surface of MDF, using polyvinyl acetate (PVAc) adhesive in cold pressing, it was concluded that different wood veneer species caused significant distiction in the adhesion strength (Kureli and Doganay 2015). In order to enhance the productivity of the veneering process, hot pressing cycles are often used. In this research, we analyzed if the wood veneer species has an effect on the it`s adhesion strength on the surface of MDF, in the case of hot pressing of veneers using PVAc adhesive. The use of different hardwood species of veneers could reveal whether differences in anatomical structure of wood had an effect on the adhesion strength between veneer and MDF surface.

The flatness and surface roughness of MDF is crucial for the quality of the veneering process, since all the unevenness in the surface layer of the substrate can be telegraphed to the veneer, especially if the case of veneer of low thickness. In order to reduce the costs of production process, manufacturers of furniture often opt for cutting the costs of input materials. In the case of MDF, it can result in lower quality of the raw panels, with variations in thickness across the surface. If these variations are not eliminated prior to veneering, there is a risk that during the sanding of veneered surface the telegraphed deviations can lead to over-sanding and exposure of the substrate or to insufficient sanding of the surface layer, which could lead to potential problems in adhesion between the veneered panels and subsequent materials (etc. coatings).

Another argument for sanding of MDF prior to veneering is to ensure the adequate adhesion strength between the veneer and the surface of the panel via mechanical anchoring. Also, it is known that a chemical weak boundary layer[1] caused by inactivation (deactivation) of wood surface can led to problems in adhesion. Due to the lower surface free energy of aged (inactivated) wood surface in comparison to the freshly cut surface (Gindl et al. 2004) the wetting of an aged wood surface is more challenging, especially in case of water-based adhesives with high surface free energy. The similar can be expected in the case of MDF. The removal of surface layer of MDF by sanding can improve the adhesion between inactivated surfaces (Ayrilmis and Winandy 2009). In the study of the effects of sanding on the surface properties of the MDF panels made from rhododendron (*Rhododendron ponticum* L.) wood it was concluded that sanding has a significant effect on the wettability, surface roughness, and surface absorption of the MDF panels, which could have impact on bonding and finishing of the MDF panels (Ayrilmis et al. 2010). On the other hand, the sanding of MDF implies the additional technological operation, which increases the total working time, and thus cost of production. Besides, the sanding of MDF can "open" the porous structure of the panel which absorbs more adhesive, leading to increase of the adhesive consumption.

In addition to the evaluation of the impact of wood veneer species on its adhesion, the effect of sanding of MDF surface (expressed through surface roughness parameters) on the adhesive strength between veneer and MDF was analysed.

2 MATERIALS AND METHODS

For this research 12 samples of the commercially manufactured MDF for interior application dimensions: 500 x 400 x 19 mm were use. One half of samples (6 samples) was sanded on crossed sanding machine (manufacturer Viet, model Rita Act 4CT EL) with 4 sanding units: one narrow-belt, followed by three wide-belt. During preparation of samples only the second sanding unit with P120-grit wide abrasive belt was activated. Sanding speed was set to 20 m/s, conveyor speed was 7 m/min and the sanding pressure was 0.5 bar.

The surface roughness of both groups of the samples (sanded and non-sanded) was determined by measuring the roughness parameters: R_a, R_z and R_t, in accordance with standard ISO 4287:1997. The measurement of surface roughness was carried out by stylus contact tester (model TimeSurf TR200, manufacturer Beijing TIME High Technology Ltd.), Figure 1. The diameter of the diamond stylus tip was 2 μm, and the stylus was pressed on the surface by the force of 4 mN. Reference length was 2.5 mm, which is in accordance with the recommendation of the standard ISO 4288: 1996. For sanded and non-sanded samples measurements were carried out at ten positions. On the sanded samples, roughness measurements were made perpendicular to the direction of sanding.

Figure 1: Measurement of surafece roughness parameters by stylius contact tester

[1] Chemical weak boundary layer is a layer on a molecular level with such low cohesion that the layer constitutes a weak boundary layer (acoording to Stehr and Johansson 2000)

After sanding of one half of samples, all of the samples were subdivided into 3 subgroups, according to the wood veneer species: beech (*Fagus sylvatica*), oak (*Querqur robus*) and walnut (*Juglans nigra*). The veneer sheets were made by joining veneers with paper tape on the one side and zigzag stitching with hot melt adhesive on the other side. The dimensions of the veneer sheets were: 520x420x0.6 mm. PVAc glue (type KL 730, manufacturer Henkel) was applied on both side of each MDF sample in approximately amount of 130 g/m^2 by roller coater, Figure 2. PVAc coated samples of MDF were overlaid with prepared veneer sheets (Figure 3) and hot pressed in one-stage hydraulic press with 8 pistons (model T150, manufacturer Sormec 2000 System Press) at temperature of 90^0 C and pressure of 150 bar, for 5 minutes.

Figure 2: Application of PVAc adhesive on both sides od MDF samples

Figure 3: The samples of MDF overlaid with veneer sheets on both sides at begining of hot pressing cycle

After veneering, samples were conditioned for 7 days in the controlled working conditions (temperature 20 ± 2 C, and relative humidity 50 ± 5%). The measurement of the adhesion strength between veneer and MDF surface was performed by the pull-off test (Figure 4a), in accordance with the standard EN ISO 4624:2005. 20 mm-diameter dollies were glued to the surface of the veneered samples using 2K epoxy adhesive (model Epoxy universal, manufacturer Bison). After 24 hours, area under the dollies was separated from the rest of the surface by cutting through the veneer around the edges of the dolly, removing any excess glue (Figure 4b). The force required to pull dollies, glued to veneers, away from substrate using hydraulic pressure was recorded and expressed as tensile strength (the ratio of breaking force and surface underneath the dolly). Only the results of adhesive fracture[2] between veneer and MDF were taken into account. Fifteen

[2] Adhesive fracture - fracture occurs at the interface between layers

measurements of pull-off strength were recorded from each subgroup of samples, which make total of 90 measurements.

a) 

b) 

Figure 4: Pull-off test of adhesion strenght of veneer on surface of MDF: a) pull-off device; b) dollies glued to the veneered MDF and separate from the rest of the surface by cutting tool

Statistical analysis of the results was performed in the software IBM SPSS statistics 21, using descriptive statistics, t-independent tests and analysis of variance (ANOVA). To determine if there was an interaction effect between preparation of the samples by sanding and wood veneer species on the adhesion strength between veneer and MDF surface two-way ANOVA was used. For statistically significant difference between sample groups, a Tukey HSD post-hoc test was used.

3 RESULTS

Table 1 shows the results of surface roughness of sanded and non-sanded samples of MDF prior to veneering.

Table 7: Surface roughness of sanded and non-sanded samples of MDF

	***Surface roughness parameters* (µm)**		
Preparation of samples	R_a	R_z	R_t
Sanded	2.27 (0.38)	18.85 (2.53)	26.12 (4.05)
Non-sanded	2.57 (0.18)	19.24 (1.44)	24.47 (2.73)

Values of standard deviation are written in parentheses

The results of independent t-test shows that there is no statistically significant differences between sanded and non-sanded samples of MDF, for all three surface roughness parameters R_a, R_z and R_t (t(9.800)=1.981 for R_a; t(11.113)=0.375 for R_z; t(12.254)=-0.951 for R_t)). The higher values of standard deviations of all measured surface roughness parameters of sanded samples, in comparison to non-sanded samples, could be related to variations in thickness of raw MDF samples. Without calibration of the panel, uneven penetration depth of sanding grit across the surface of MDF can be expected, that could lead to higher variations of vertical distances between peaks and valleys of roughness profile.

The values of the R_a of sanded MDF samples with 120-grit sanding paper, in direction to the conveyor movement, was lower than the value obtained in the previous research, using the same grit of the sanding belt (Ra = 3.32 µm in Kureli and Doganay 2015). These deviations can be attributed to unknown characteristics of MDF and differences in sanding process parameters (sanding speed, conveyor speed etc.).

The values of surface roughness parameters of commercially manufactured MDF found in literature are various (R_a = 2.72µm, R_z=14.78 µm and R_{max}[3] =20.94 µm (Büyüksari 2013); R_a = 3.31 µm (Kiliç et al. 2009); R_a = 2.85 µm (Kureli and Doganay 2015); R_a = 2.04 µm, R_z=19.57 µm and R_{max}=23.72 µm for samples exposed to 65% of relative humidity (Ozdemir et al. 2009)). These results confirm that the surface roughness of MDF is governed by characteristics of the raw materials used in production, production conditions and machining characteristics (Kiliç et al. 2009). On the other hand, the use of additional parameters (besides R_a) for the characterisation of surface roughness becomes necessary and justified.

Table 2 shows the results of adhesion strength of veneer sheets of three wood species glued to the surface of sanded and non-sanded samples of MDF.

Table 2: Adhesion strength of veneer glued to sanded and non-sanded samples of MDF

***Adhesion strenght* (MPa)**	**Wood veneer species**		
Preparation of samples	***Beech***	***Oak***	***Walnut***
Sanded	2.348 (0.23)	2.211 (0.25)	2.263 (0.19)
Non-sanded	2.455 (0.13)	2.208 (0.35)	2.377 (0.25)

Values of standard deviation are written in parentheses

Results of two-way ANOVA for adhesion strength between veneer and MDF are presented in Table 3.

Table 3: Results of two-way ANOVA for adhesion strength between veneer and MDF

Factor	**Degree of freedom (df)**	**Mean Squares (MS)**	**F statistic**	**Sig. (*p* value)**
Wood veneer species	2	0.232	4.632	0.012
Sanding	1	0.117	2.344	0.130
Wood veneer species * Sanding	2	0.011	0.220	0.803
Error	84	0.050		
Total	90			

If $p < 0.05$, the critical value of F statistics for the respected degrees of freedom is lower than the computed F statistic meaning that effect of observed factor is statistically significant.

The results of two-way ANOVA showed that there is no statistical significance interaction of effects of the wood veneer species and the preparation of the MDF on the adhesion strength between veneer and MDF, Table 2. In addition, the results of the adhesion strength of veneer (of all three wood species) on the surface of sanded and non-sanded samples, showed no statistically significant difference. These findings could be explained by non-significant variations in surface roughness of sanded and non-sanded samples. From the other side, the higher speed of solidification of PVAc adhesive during hot pressing, reduced the time of contact of raised grains of surface layer of MDF with water from PVAc dispersion. In addition, due to the action of the high temperature and pressure during hot pressing, the surface roughness differences of sanded and non-sanded samples could be "annulled".

In research by Kureli and Doganay (2015), statistically significant decrease of the adhesive strength of sanded samples of MDF veneered with beech, oak and pine veneers (for 12.5, 29.9 and 14.5%, respectively) in comparison to non-sanded samples, could be explained by the higher surface roughness of MDF achieved by sanding.

Since the interaction effect between sanding and wood veneer species on adhesion strength was not significant, one-way ANOVA was conducted to determine if there is significant impact of wood veneer species on the adhesion strength. Sanded and non-sanded samples were observed as one group. The results of one-way ANOVA are shown in Table 4.

[3] R_{max} corresponds to R_t

Table 4: Adhesion strength of veneer glued to samples of MDF

***Adhesion strenght* (MPa)**	**Veneer species**		
	Beech	***Oak***	***Walnut***
	2.40 A	2.21B	2.32AB

Groups with same letters in column indicate that there was no statistical difference ($p<0.05$) between the samples according Tukey HDS Post Hoc test.

The highest value of the adhesion strength was determined for beech veneer (2.40 MPa) which has the highest density among observed species. The density of wood has the highest impact on the swelling rate of wood in contact with water (Šoškić and Popović 2002). The higher sensitivity of beech veneer sheets towards water during the gluing, in comparison to other two lower density wood species, could cause more swelling and roughening of the surface layer of the beech veneer by water from the PVAc adhesive. That could led to the highest contact area between beech veneer and MDF among observed wood veneers species, and thus the highest adhesion strength of beech veneer.

Since the oak is coarse-grained species it is possible that, under the pressure during veneering, the uneven penetration of the adhesive in the surface of the oak had occurred, resulting in the lowest adhesion strength (2.21 MPa). A similar consideration was made when adhesion strength of polyurethane coating was analyzed, in relation to the changes in surface roughness of MDF, caused by relative humidity of surrounding air (Ozdemir et al. 2009). Weak adhesion strength properties of polyurethane coating on MDF surface at higher relative humidity was explained by the non-uniform contact area between the panel surface and coating, due to significantly higher surface roughness of the MDF.

The difference in the density of walnut and oak veneers did not caused significant difference in adhesion strength between veneer and MDF, among these species. This could be due to differences in the anatomical structure, which needs additional testing for conformation. In research of the mechanical behaviour of veneer subjected to bending and tensile loads (Buchelt and Wagenführ, 2008), inferior performance of the oak veneer in comparison to beech veneer, especially when the load was in perpendicular direction to the fibre, was explained with a less homogenous structure of the oak. The reduction of the mechanical strength of ring-porous veneers with very large vessels, was related to possibility of presence of only 2 or 3 vessels are in one layer of veneers. The further research should explore the differences in penetration depth of PVAc adhesive into the surface of different wood veneer species, to get more information about the adhesion mechanism between veneer and MDF.

The use of PVAc adhesive in hot pressing in our study, led to an increase of the adhesive strength of beech veneer (for 14.7%) and oak veneer (13.6%) in comparison to the cold pressing (20 ° C) during 60 minutes of the same wood veneer species, using PVAc in previous research (Kureli and Doganay 2015). From these results, it could be concluded that the application of the hot pressing regime during veneering, can result in a higher adhesion strength of veneer to MDF surface.

4 CONCLUSION

Based on the results of this research, the following can be concluded:

- Wood veneer species had an impact on the adhesion strength of veneer glued to the surface of MDF with PVAc adhesive in hot press cycle.
- The highest adhesion strength between veneer and MDF was obtained in the case of beech veneer (2.40 MPa), followed by walnut veneer (2.32 MPa) and the lowest value was obtained in case of oak veneer (2.21 MPa). Statistically significant difference among adhesion strength between different wood veneer species and MDF was recorded only between the beech and oak veneer.
- Surface sanding of MDF with 120-grit sanding paper did not affect the adhesion strength of veneer on the surface of MDF, for all three wood species of veneer. From the point of adhesion strength between veneer and MDF, it can be concluded that sanding with 120-grit is not necessary step in veneering process. But from the technological point of view, when dealing with surface unevenness of MDF and necessity to ensure no-telegraphing of surface defects to the veneer sheets, 120-grit sanding can be recommended, since it has no impact on the adhesion strength of veneer to MDF surface.

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Chemical Composition of Wood and Bark of Taxus baccata L.

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ABSTRACT

In addition to industrial and fuel wood production from forests, non-wood forest products are also produced. This is getting more and more important day by day. Our country has rich resources in terms of non-wood forest products. These resources, which are so valuable, will be benefited enought ocontribute to the economy of the country. It is known that some extracts obtained from Taxus baccata L. (Turkish Yew) which is naturally distributed in our country especially in the Black Sea Region have antitumor properties for some types of cancer. In this regard, Taxus baccata L. has a great proposition to illuminate the chemical structure of the heartwood, sapwood and bark and to determine the extractive amount. It is thought that the findings obtained will form a basis for the work to be done in this regard.

In this study, the chemical composition of hearth wood, sap wood and bark of Taxus baccata L. taken from the Amasra Series of Arıt, Espiye Series of Ekindere and Pazar Series of Pazar was determined by standard methods. According to the results obtained, average values of chemical compositions are calculated as follow: Holocellulose content; 57.88% in hearth wood, 67.40% in sap wood, 52.19% in bark, lignin content; 27.67% in hearth wood, 30.45% in sap wood, 25.97% in bark, cellulose content; 45.38% in hearth wood, 52.78% in sap wood, 28.50% in bark, α-cellulose content; 36.89% in hearth wood, 43.31% in sap wood. Besides these chemical contents obtained, some solubility characteristics were investigated. According to the results obtained, the solubility characteristics are as follows: Solubility in hot water content; 12.69% in hearth wood, 2.86% in sap wood, 27.41% in bark, solubility in cold water content; 8.34% in hearth wood, 1.83% in sap wood, 23.43% in bark, solubility in 1% NaOH content; 22.21% in hearth wood, 11.02% in sap wood, 49.24% in bark, solubility in alcohol- benzene content; 15.30% in hearth wood, 2.59% in sap wood, 22.38% in bark.

KEYWORDS: Taxus baccata L., Wood Constituents, Bark Constituents, Extractives

1 INTRODUCTION

Taxus baccata L. has a wide distribution area(Europe, West of North Africa, West Asia and Turkey). It is a slow growing species. It naturally grows in our country. They are in small groups in the Rize, Ayancık, Yenice, Karabük, Düzce, Bolu, Demirkoy forests, Sultan Mountains, Kaz Mountains, Mediterranean coastal forests, the mountains of Amanos (Yaltırık and Efe, 1994). Taxus baccata is among the harmful wood species due to toxic substances. For this reason, in 1973, a standard on dust control was developed in Germany to protect the health of people working in sewing workshops (Scheiber,1975). These toxic substances are used for various diseases by obtaining valuable extracts. Taxol extract in taxus species has antitumor properties for cancer disease. Potentially limited resources have made it necessary to investigate precursors that can be converted to taxol and taxol by various chemical routes in various morphological parts of this tree. For this purpose, six taxus strains (Taxus baccata cv.Rapandes, Taxus brevifolia, Taxus canadensis, Taxus cuspidata cv.Capitata, Taxus X media cv.Hicksii) and needles in taxol and semisynthetic pathway in needles in the NCI-Frederick Cancer Research Facility quantities of 10-deacetylbaccatin III convertible to taxol were investigated (Witherup at al.,1990). In 1990, a study in the USA yielded a diterpene called taxol with anticancer potency which was as low as 0.00003-0.069% by weight in different parts of various taxus species. This material was found on the barks of Taxus brevifolian growing in the largest area. Subsequently, the plant was found in high quantities, moderate in shoots and leaves, and low in taxol (Vidensek at al.,1990). As a result of the leaf analysis, the leaves were found to contain alkaloids, reducing sugars, resins and tannins, but no saponifying substances, volatile oils and steroids(Vohara and Kumar,1971). In a study on the leaves of one year old of Taxus baccata, it was found that the gums of the leaves were very high in early spring and late winter. The glue is in the vacuoles of mesophyll cells. According to the examinations made, glue; polysaccharide compounds containing xylose, arabinose, glucose, rhamnose and galactose, less than 5% uranoic acid and 6-15% peptide. The amount of gum in the vacuoles of Taxus baccata was found to be around 5-6% (Distelbarth and Kull, 1985). On the leaves, an extract called as ferredoxin was obtained from algae, bacteria and some angiosperms (Zanobini et al., 1967). 2-0- (4-coumaryl) -myo-inositol was synthesized in the protein preparations prepared from the leaves (Heilemann et al., 1990). The waxes found in the leaves of Taxus baccata L.; were found to contain 21% very long chain fatty acids, 19% alkanediols, 15% phenyl esters, 9% secondary alcohols, minor aldehydes, primary alcohols, alkanes, alkyl esters and tocopherols(Wen et al., 2006). Taxus baccata has found a hormone called as ecdysteron in woods and leaves that prevents the growth and development of insects. This hormone is active in Taxus baccata, inactive in Pinus sylvestris, Cupressus spp, Picea abies, Thuja occidentalis (Hoffmeister et al.,1967). A study has been made on the changes in the chemical structure of the injured tissues of Taxus baccata caused by the injury of the woodpecker. As a result, wounded tissues were found to contain less polysaccharides and more lignin and extractive substances (Kucera,1973).

The amount of taxan in the bark of Taxus baccata L varies seasonally. The highest amounts are found in October, the lowest in January, February (Veselá et al., 1999). The maximum content of paclitaxel in the bark of Taxus baccata was found to be 0.37% in october, with a minimum of 0.002% in February (Sénilh et al., 1984). Also, The amount of neutral and basic alcohololide in Taxus baccata barks varies seasonally. However, the optimal time for harvest has not been determined. This varies depending on the type of tree, the taxus baccata variety, location and taxoid type (Hook et al., 1999).

In a research, taxan as an anticancer agent, notes that many cancers are used in combination with other chemotherapeutic agents in treatment (Rowinsky, 1997). Taxus baccata L. sapwood from Çamlıhemşin-Rize, 1400 meters altitude were isolated 4 taxoids (taxusin, baccatin VI, baccatin III and 1-β-hydroxybaccatin I) and 4 lignans (lariciresinol, taxiresinol, 3'-dimethylisolaricire-cinnol-9'-hydroxyisopropylether, isolariciresinol and 3-demethylisolariciresinol) by column chromatography. Antiinflammatory and antinociceptive effects of these components were investigated (Küpeli et al., 2003). Three taxanesinol, 3'-dimethylisolaricire-cinnol-9'-hydroxyisopropylether, isolariciresinol and 3-demethylisolariciresinol were obtained from the hearth wood of Taxus baccata L.. Cytotoxicity, antimicrobial, antifungal and antibacterial effects of isolated lignans cells were investigated against breast, colon, ovarian, prostate and lung cancer (Erdemoğlu et al., 2004). Paclitaxel was found to be effective on ovarian and breast. And also Palitaxel in combination with cisplatin has been evaluated in randomised trials as first line treatment of non small cell lung cancer (Eisenhauer and Vermorken, 1998). Clinical studies on paclitaxel and docetaxel continue intensively. Other anticancer drugs are being tested with different types of tumors. The results are compared with standard treatments and effective results are tried to be taken (Erdemoğlu and Şener,2000). Taxus baccata L. has valuable extracts used in the treatment of various diseases.

İn this study; it is aimed to illuminate the chemical structure of the wood and bark of this tree which has very valuable extracts and to determine the extractive amount. It is thought that the findings obtained will be the source of the work to be done in this respect.

2. MATERIAL AND METHOD

2.1. Material

Taxus baccata L. shows most of the spread in our country in the Black Sea Region. Therefore, the trees needed for the research were obtained from Amasra, Pazar and Espiye in this region. Trees to be used in the research; diameter, age and the place of receipt are given in Table 1.

Table 1: Research samples and information on where they are from

REGİON	Tree no	Annual Ring	Diameter (cm.)	Altitude (m.)	Trees planted on stand(*)	Soil properties (*)	Length (m.)	Location	Symbol
AMASRA Arıt Series	1	78	16	650	Kayın Şimşir Gürgen	Rocky Stony Humus	7	N.west	A1
	2	53	17.5	600			8	N.west	A2
	3	79	14	700			6	N.west	A3
ESPİYE Ekindere Series	1	239	25.5	1400	Akçaağaç Kayın Ladin	Sandy Clayey	7	N.west	E1
	2	243	27	1400			8	N.west	E2
	3	195	28	1400			7	N.west	E3
PAZAR Pazar Series	1	95	20	1300	Ladin Kayın Kestane	Clayey Acidic	6	N.east	P1
	2	86	15.5	1400			5	N.east	P2
	3	155	34	1200			8	N.east	P3

(*)For each region, the same conditions apply for trees 1,2,3.

A total of 9 trees were sampled, 3 in each area. Taking into consideration that the wood shows differences from bottom to top and from the bark to the hearth in terms of density, fiber length and chemical composition, 3 sectioning methods in the Tappi standards are used on the body. According to the method, three circular sections are taken from the bottom, middle and end parts of each tree so that the height is not less than 5 cm. Tree samples taken from three regions, three from each region, were separated into bark, hearth and sapwood pieces and then shredded to the size of a matchstick with a cutting tool. It was then milled in a laboratory Willey mill according to TAPPI T 11 os-75 standards. In order to bring the material to homogeneous size, sieving process was carried out using a shaky sieve. For use as material; the mixture was passed through a 40 mesh screen and placed on a 60 mesh (250 µ) screen and placed in closed glass jars.

2.2. Method

2.2.1. Determination of Moisture Content

Approximately 2 g of sample was weighed on a precision scale and dried at 105 ± 3 ° C to determine full dry weight. Then the amount of moisture was calculated using the following formula (Bozkurt and Göker, 1987).

% r= (Mr-Mo)*100
r: Moisture content (%)
Mr: moist weight
Mo: full dry weight

2.2.2. Holocellulose Analysis

The amount of holocellulose in wood and bark was determined by chlorite method, which is a standard method.

2.2.3. Cellulose Analysis

The 'Nitric Acid' method developed by Kurschner and Hoffner was used for the determination of cellulose.

2.2.4. α- Cellulose Analysis

The α-cellulose is the portion of the wood and the bark remaining after the lignin is removed and then treated with 17.5% NaOH. Samples having previously been subjected to holocellulose determination were used in determining the ratio of α-cellulose. The standard TAPPI T 203 os-71 standard has been applied.

2.2.5. Lignin Analysis

The lignin content was determined by Klason method using 72% sulfuric acid.

2.2.6. Ash Analysis

TAPPI T 211 om-85 standard was applied at the determined ash ratio. Holocellulose, cellulose, α-cellulose, lignin and ash determinations were made according to TAPPI standards (Anonymous, 1992).

2.2.7. Solubilities

Alcohol-benzene, 1% NaOH, cold water and hot water solubility were made according to TAPPI 207 T om-88 standards.

2.2.8. Staisny Number

It was made to determine the amount of condensed tannins found in the bark. firstly about 2g. bark sample was taken and the hot water was dissolved. The filtrate was poured into a 250 mL erlenmeyer flask. Distilled water was added until 200 ml. This solution is 50 ml. was taken and put in a beaker. then the solution was evaporated. ıt was dried and weighed, add 50 ml respectively distilled water, 5 ml. concentrated HCl and 10 mL. 37% formaldehyde was added. The erlenmeyers were kept in a water bath at 100 °C by shaking for half an hour. Then, filtration and washing were carried out and weighed by drying at 105 ± 2 ° C. The amount of insoluble matter in the solution was calculated as a percentage of the dry weight (Tisler et al., 1986).

2.2.9. Methods Used in Statistical Evaluations

Statistical differences between the obtained data were determined by simple variance analysis. The Duncan test was used to determine which factors were among the differences obtained.

3. RESULTS

Three different samples taken from each region were studied on native and sapwood and samples obtained by uniformly mixing shells taken for three trees. Sap wood and hearth wood of three different samples taken from each region and samples obtained by mixing barks taken for three trees at equal rate was used. Holocellulose, cellulose, lignin, alpha cellulose, ash content and hot water, cold water, alcohol-benzene and 1% NaOH solubilities was made. In addition, the Stiasny experiment was used to determine the amount of tannin in the bark. Experiments were performed in triplicate and mean values were given in the corresponding tables.

3.1. Chemical Composition of Wood of Taxus baccata L.

According to the region, the results of the analysis of the cell wall components of the hearth wood and sapwood are given in Table 2 and Table 3.

Table 2: Cell wall components of the hearth wood of the Taxus baccata L.

REGION	Lignin(%)	Holocellulose(%)	Cellulose (%)	∝- Cellulose (%)	Ash(%)
AMASYA	28.16	63.38	48.55	40.35	0.49
ESPİYE	26.05	54.49	41.66	34.47	0.56
PAZAR	28.79	55.76	45.94	35.84	0.36

Table 3: Cell wall components of the sapwood of Taxus baccata L.

REGION	Lignin(%)	Holocellulose(%)	Cellulose (%)	∝- Cellulose (%)	Ash (%)
AMASYA	29.86	69.07	52.16	45.29	0.32
ESPİYE	31.12	66.65	53.20	42.94	0.40
PAZAR	30.37	66.49	52.98	41.69	0.29

The results of the analysis of the the solubility characteristics of the hearth wood and sapwood are given in Table 4 and Table 5.

Table 4: The solubility characteristics of the hearth wood of Taxus baccata L.

REGION	Solubility in cold water(%)	Solubility in hot water(%)	Solubility in alcohol-benzene (%)	Solubility in 1% NaOH (%)
AMASYA	6.37	9.33	10.23	18.77
ESPİYE	9.69	16.20	20.58	26.58
PAZAR	8.96	12.55	15.10	21.27

Table 5: The solubility characteristics of the sapwood of Taxus baccata L.

REGION	Solubility in cold water(%)	Solubility in hot water(%)	Solubility in alcohol-benzene (%)	Solubility in 1% NaOH (%)
AMASYA	1.89	2.83	2.73	10.27
ESPİYE	1.47	2.66	2.34	10.50
PAZAR	2.12	3.10	2.69	12.30

3.2. Chemical Composition of Bark of Taxus baccata L.

The cell wall components and the solubility characteristics of the Taxus baccata L. in different regions shell are given in Tables 6 and 7

Table 6: Cell wall components of bark of the Taxus baccata L.

REGION	Lignin(%)	Holocellulose(%)	Cellulose (%)	Ash(%)
AMASRA	27.60	54.02	27.37	3.87
ESPİYE	25.57	52.13	27.21	5.62
PAZAR	24.73	50.41	30.92	4.10

Table 7: The solubility characteristics of bark of the Taxus baccata L.

REGION	Solubility in cold water(%)	Solubility in hot water(%)	Solubility in alcohol-benzene (%)	Solubility in 1% NaOH (%)	Stiasny number(%)
AMASRA	19.26	22.82	18.28	47.39	8.61
ESPİYE	23.39	28.35	22.63	49.83	11.04
PAZAR	27.65	31.07	26.23	50.50	15.45

4. DISCUSSION AND CONCLUSION

Lignin, holocellulose, cellulose, alpha cellulose, ash and solubility characteristics are given in the respective tables. Variance analysis and Duncan test were performed within 1% probability of error in order to determine whether there were significant differences between these values.

4.1. Evaluation of findings related to the cell wall components and the solubility characteristics

4.1.1. Lignin

As a result of the variance analysis applied to the lignin values of the hearth wood and sapwood of Taxus baccata L., it was found that there is no difference between the regions. The amount of lignin is 26-32% in coniferous trees, 24-28% in broadleaved and 30% in tropical trees (Sjöström,1981). The highest amount of lignin was found in the Pazar region with 28.79% and in the Espiye region with the lowest rate of 26.05%. In literature, the amount of lignin Taxus baccata L. is given as 29.4%(Nikitin, 1966).

4.1.2. Holocellulose

Analysis of variance applied to the holocellulose values of hearth wood of the Taxus baccata L. showed that there were differences between the regions. As a result of the Duncan test, it was determined that the difference between the Pazar region and the Amasra region and the difference between the Espiye region and the Amasra region are significant, although there is no significant difference between the Espiye region and the Pazar region. Variance analysis of the holocellulose values determined on the sapwood revealed differences between the regions. Although there is no significant difference between the Pazar and the Espiye region, the differences between Amasra and Espiye and Amasra and the Pazar region are clear. As a result of the obtained data; the lowest holocellulose content of the hearth wood of Taxus baccata L. was found in the Espiye Region with 54.49% and the highest amount of holocellulose was found in the Amasra region with 63.38%. The sapwood of Taxus baccata L., the lowest amount of holocellulose was obtained in the Pazar region with 66.49% and the highest amount of holocellulose was obtained in the Amasra region with 69.07%.

4.1.3. Cellulose

It has been determined that there are significant differences between the results of variance analysis applied to hearth wood of the Turkish Yew cellulose values. As a result of Duncan test; It has been determined that there is no significant difference between Amasra and Pazar region. But there is differences between Amasra and Espiye Region and Espiye and Pazar region. İn this study; the lowest amount of cellulose in the hearth wood was found in the Espiye region with 41.66% and the highest amount of cellulose was found in the Amasra region with 48.55%. In literature the amount of cellulose in wood of Taxus baccata L. is given as 42.6%(Nikitin,1966). The values determined are fairly close to the values given in the literature. The differences between the regions are thought to be due to the age of the specimens and the geological and ecological characteristics of the regions from which they are taken. As a result of analysis of variance applied to sapwood values, there was no difference between the regions. The highest percentage of cellulose was detected in Espiye region with 53.20% and the lowest percentage of cellulose was found in Amasra region with 52.16%.

4.1.4. α- cellulose

It has been determined that variance analysis applied to the a-cellulose values in the hearth wood of the Taxus baccata L. shows differences across regions. The results of the Duncan test show that there is no significant difference between Amasra and Pazar region and Espiye and the Pazar region, but there is a significant difference between Amasra and Espiye. In the hearth wood, the lowest amount of α-cellulose was found in the Espiye region with 34.47% and the highest amount of α-cellulose was found in the Amasra region with 40.35%.

4.1.5. Ash

The variance analysis and the Duncan test applied to the ash values of the hearth wood, sapwood revealed that the differences between the region were significant. The lowest value of ash content was found in the Pazar region with 0.36%, and the highest value was found in the Espiye region with 0.56%. The lowest value was found in the Pazar region with 0.29% and the highest value was 0.40% in the Espiye region. In the literature, the amount of ash in the wood of Taxus baccata L. is given as 0.39%(Nikitin,1966). The values are very close to the values given in the literature. The reason why the highest ash content is found in the Espiye region is that the samples taken from this region are composed of older individuals than the samples from other regions. This is because the content of inorganic matter is high in the ages of the youth in the age of youth, this rate decreases in the individuals reaching maturity age and increases again in later ages.

4.1.6. Solubility in Cold Water

As a result of the variance analysis applied to the cold water solubility values of the hearth wood and sapwood, it was determined that there is no significant difference between the zones. The lowest value of the cold water solubility in the hearth wood was found in the Amasra region with 6.37% and the highest value was found in the Espiye region with 9.69%. The lowest value of cold water solubility in the sapwood was determined in Espiye with 1.47% and the highest value in the Pazar regions with 2.12%. Cold water solubility values close to each other in all regions indicate that the cold water soluble materials (some extractives and simple sugars) are almost identical in the samples taken from these regions.

4.1.7. Solubility in Hot Water

The variance analysis applied to the cold water solubility values of the hearth wood and the Duncan tests revealed significant differences between all regions. As a result of applied variance analysis applied to sapwood cold water values, there was no difference between the regions. The lowest value of the hot water solubility in hearth wood was found in the Espiye region with 9.33% in Amasra and the highest value was 16.20%. The sapwood is; the lowest value of hot water solubility was found in the Espiye region with 2.66% and the highest value was found in the Pazar region with 3.10%.

4.1.8. Solubility in 1% NaOH

Variance analysis and Duncan tests showed that there were differences between some regions. It is determined that there is no significant difference between Amasra and Pazar regions, there are differences between Pazar and Espiye region and Amasra and Espiye region. There are no differences among the regions in the sapwood. The lowest value was found in the Amasra region with the lowest value of 18.77% and the highest value was found in the Espiye region with 26.58% in the hearth wood. The lowest value was found in the Amasra region with the lowest value of 10.27% and the highest value was found in Pazar regions with 12.30% in the sap wood.

4.1.9 Solubility in Alcohol- Benzene

Differences were found as a result of analysis of variance applied to the values of alcohol-benzene solubility in hearth wood of Taxus baccata L.. As a result of the Duncan test to determine the differences between the regions; It is seen that there is no significant difference between Amasra and the Pazar region, whereas there is a distinct difference between Pazar and Espiye and Amasra and Espiye region. In the sapwood, it was found that there is no difference between the regions. The lowest value of alcohol-benzene solubility in the wood was found in the Amasra region with 10.23% and the highest value was found in the Espiye region with 20.58% in the hearth wood. The lowest value was found in the Espiye region with 2.34% and the highest value was found in the Amasra region with 2.73% in the sapwood. In the solubility characteristics of Taxus baccata L., there are significant differences between the core and sapwood. Especially in the sapwood, the samples of the Pazar region show the highest rates in terms of the solubility values, while the samples in the Espiye region give the lowest rates. The reason for this may be the fact that the specimens of the Espiye region are older than the samples taken from other regions. İn the heartwood; especially in all the resolution experiments, Espiye region samples gave the highest value whereas Amasra region samples showed the lowest values.

4.2. Evaluation of Findings of Chemical Analyzes of Bark of Turkısh Yew

Bark samples of three trees taken from each region were mixed in equal proportions and reduced to one specimen for each region. Since variance analysis and Duncan test were not performed on individual values, no statistical analysis was done for bark samples. The highest amount of lignin was found in the Amasra region with 27.60% and the lowest in the Pazar region with 24.73%. The highest amount of holocellulose was found in the Amasra region with 54.02% and the lowest in the Pazar region with 50.41%. The highest amount of cellulose was found in the Pazar region with 30.92% and the lowest in the Espiye region with 27.21%. The amount of cellulose was considerably lower than that of the bark. This can be attributed to the fact that the bark is in a less fibrous structure. Low levels of cellulose, holocellulose and lignin can be attributed to the presence of high extractive matter content of about 18% to 27% and high ash content of about 3% to 6% in the bark. The highest ash content was detected in the Espiye region with 5.62% and the lowest ash content was determined in Amasra region samples with 3.87%. The cold water, hot water, alcohol-benzene and 1% NaOH solubilities were 27.65%, 31.07%, 26.23%, 50.50%, respectively, in the highest Pazar region. The lowest values were ascertained in the Amasra region; were 19.26%, 22.82%, 18.28% and 47.39%, respectively.

The differences between the heartwood, sapwood and bark solubility characteristics of Taxus baccata L. in different regıon are shown in graphs 1, 2 and 3.

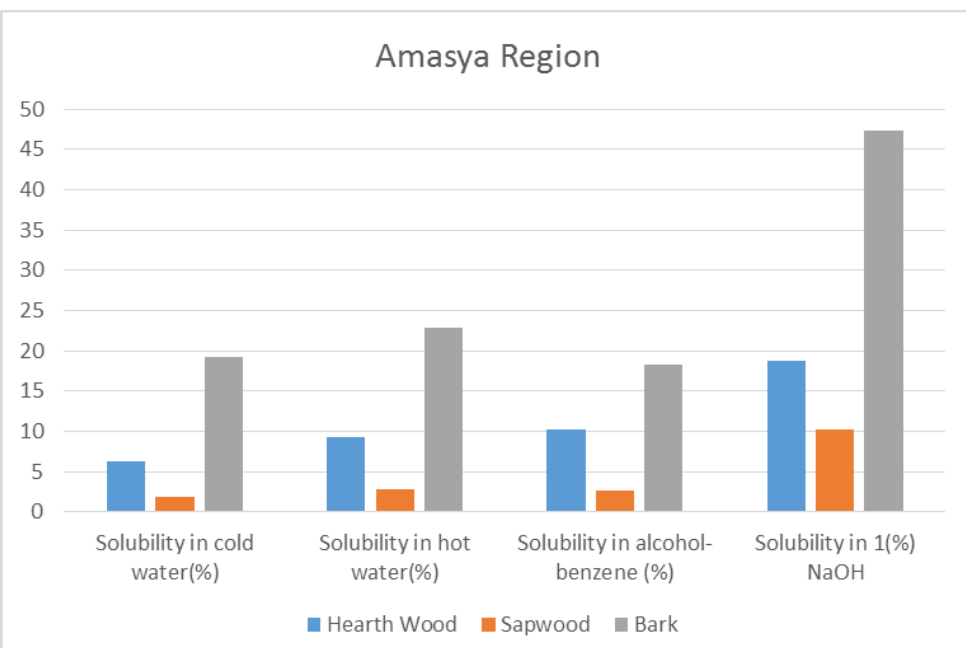

Figure 1: Difference in the solubility characteristics of Taxus baccata L. in the Amasya region

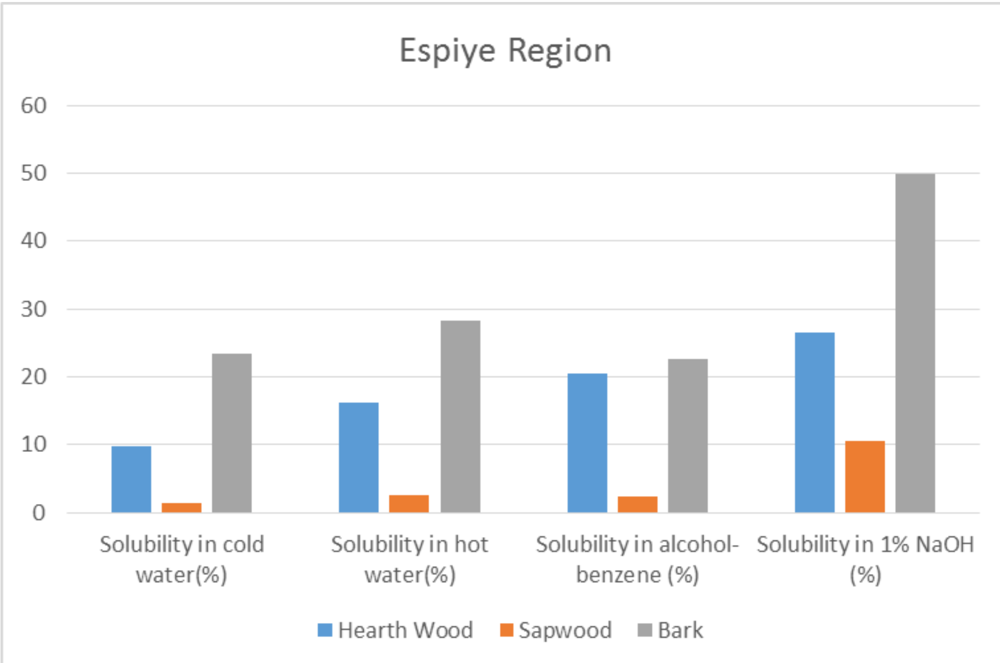

Figure 2: Difference in the solubility characteristics of Taxus baccata L. in the Espiye region

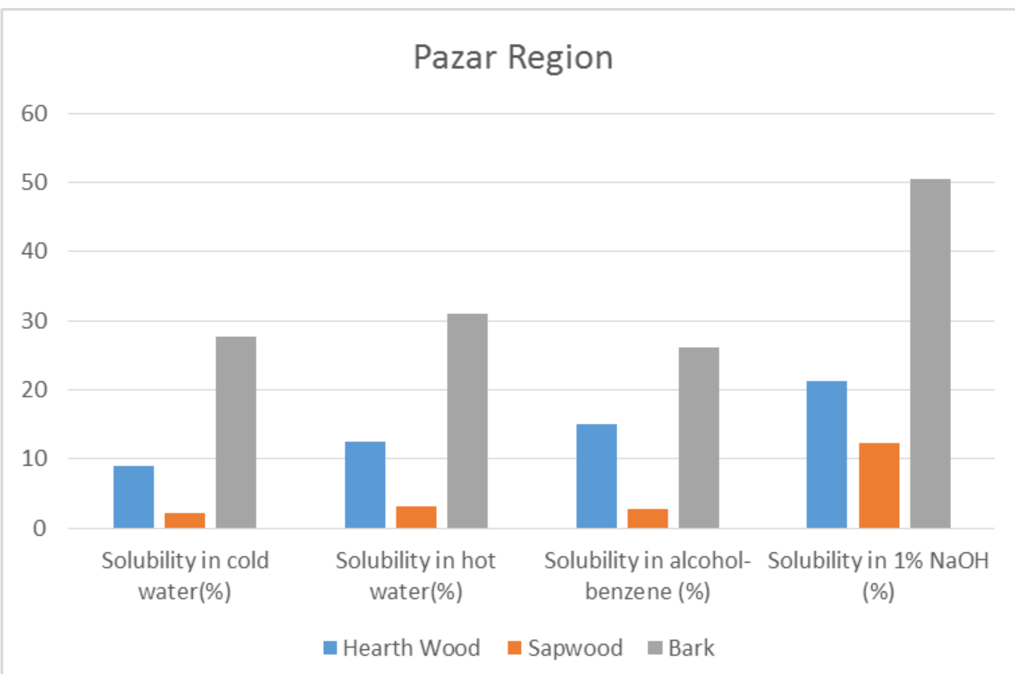

Figure 3: Difference in the solubility characteristics of Taxus baccata L. in the Pazar region

Stiasny number was highest in the Pazar region with 15.45% and lowest in Amasra region with 8.61%. Since the amount of extractive matter directly affects the Stiasny number and the highest extractive amount is found in the samples taken from the Pazar region, the highest Stiasny number is naturally found in this region. Extract material is also present in very high quantities such as 10-21% in the hearth wood. This rate is between 2.34% and 2.73% in the sapwood.

5. RESULT

This study was carried out to determine the amount of extractive substance estimated to be abundant in bark and hearth wood besides the chemical composition of wood and bark of Turkısh Yew obtained from the Black Sea Region and the desired amount of extractive substance was found. The most striking aspect of this study on the chemical composition of wood and bark of Taxus baccata L. is that the extractive material of this tree is rich. Especially the bark contains 18-26% extractive substance. Extract material is also present in very high quantities such as 10-21% in the hearth wood. This rate is between 2.34% and 2.73% in the sapwood.

It is normal that there is a difference between the results obtained when considering that the amounts of extractive substances differ even between different individuals of the same tree species and different parts of the same individual (branch, log, bark). The most important differences between the other coniferous trees are that the amount of extractive matter is considerably higher than that of resinous trees although natural and pathologically it does not come to the sensation of resin. The cellulosic rate is normally higher in the sapwood than in the hearth wood, while in the bark there is less of both the hearth wood and sapwood. In this study, the differences among the regions in the cell wall components are primarily due to the age characteristics of the tree. In addition to this, the factors such as soil, climate, elevation, and altitude also influence the differences. When the cell wall components are taken into consideration, the values obtained are found to match the typical cell wall characteristics of coniferous trees. However, this tree is rarely found in our country and it shows little spread in places where it is located, making it necessary to benefit from this tree in the most efficient and economical way. Taxol has been obtained in very small quantities as a percentage of the extractive substance in studies carried out abroad. Subsequent studies should focus on finding the maximum taxol from the potentially limited tree source by the most efficient and economical methods and finding the precursors that can be converted to taxol by various chemical routes. It is also thought that it would be beneficial to carry out the necessary studies for the preservation and youth of this species, which is a rare and very valuable byproduct of this species.

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ABSTRACT

In this study, the internal forces distributed to the frame members were analyzed by loading the working load on a supporting side frame of a bench in accordance with TS EN 1728 standard. Elements and joints of the required dimensions to accommodate the maximum forces distributed to the elements of the carrier frame have been determined. In the dimensions suitable for this analytical calculation, 10 experimental specimens (total 20) were produced from yellow pine (Pinus silvestris L.) and eastern beech (Fagus orientalis L.) wood. The performance of the chair specimens from both materials was determined by applying diagonal force to the test specimens representing the static load of seat and backrest according to TS EN 1729-2 standard.

As a result, it was determined that the highest performance was achieved on the side of the prototype chair designed and developed from the eastern beech wood, and the yellow pine chair was in the second place. Performance in the eastern beech chair; An average of 2380 N, and a yellow pine chair, 2140 N, respectively. These forces correspond to 4760 N and 4280 N in a full seat and it is determined that the average load of the boat is 800 N and 5.75 and 5.35 times, respectively

KEYWORDS: Wooden chair, design, performance, stress analysis, prototype.

1 INTRODUCTION

Seating furniture is a chair, moving and multipurpose furniture. For this reason, researcher designers need to work on chairs the most.

Yilmaz and Güntekin (2012) found that stresses and deformations occurred mostly in the intermediate indifferent models by finding the extreme forces and moments acting on the chair elements when the intermittent registration positions of the chairs were replaced with the critical seating positions.

Tankut and Sözen (2015) produced chair skeletons and determined fatigue performances. As a result of the fatigue tests, the metal joining elements in the intermediate-register assemblies indicated that they completed the acceptance levels in the backrests of the seat while not reaching the desired level.

Kasal et al. (2015) investigated the effect of the corner support element on the tree strength and strength of the tree type and size. It has been stated that the corner support elements are effective in strength and the joints must be supported by corner support elements.

Efe et al. (2015) studied 21 different model seats and found performance values between 845 and 2802 N in front-to-back loads in chairs.

Kasal et al. (2015) examined the effects of chair mortar measurements on joint strength. The results of the study showed that 40 x 50 mm trenches were the best results in T-type joints.

Altınok, M., (1995), in his study of the doctorate, found that the strength of the chairs was as good as the strength of the tongue joint, the junction point of the elements.

Gustafsson (1997) mentioned that the majority of chairs are made up of so-called complex frameworks, making analysis of the resulting internal forces difficult. For this reason, this disadvantage is reduced by using the finite element method. At the end of the study, it has been shown how a chair can be analyzed and designed by methods in other disciplines rather than furniture production.

Gustafsson (1996) stated that, in the design of chairs and other furnitures, the works mostly consisted of hands-on experience, and engineering calculations in these products were hardly ever used to find suitable solutions.

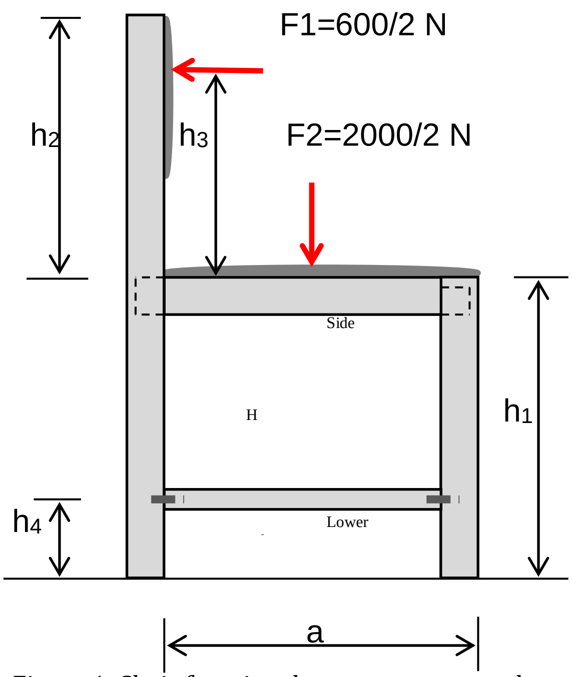
Likos (2013), the effect of different tenon section forms applied to chair corner joints on the chair strength was examined experimentally and the results obtained were compared with the structural analysis program. The torque values calculated in the structural analysis program and the values obtained in the experiments were determined to be similar in 92.3%.

Küreli (1988) compares the strength of mitered, doweled and doweled-jointed joints used in the carrier frame assemblies of the chairs. According to this, it has been determined that the joining in front and back of the seats is better than the joining in the side records.

In this study, it was aimed to perform the aesthetic shaping of the bearing elements during chair design according to the stresses to be determined by mechanical analysis.

2 STATICAL AND MECHANICAL ANALYSIS

Sitting furniture chair; Functional dimensions and ergonomic form, mechanical properties such as performance, durability and safety requirements are standardized. The reason for the standardization of the dimensions and form, the mechanical properties of the chair, despite the fact that many furniture standards are not available; (Ergonomic overlap) with the human body, is known to be very dynamic (dynamic) and intensive use. This mode of use emphasizes the necessity of designing and producing the chair in accordance with an ergonomic form, size and engineering account, not random. In this context, a bench in accordance with TS EN 1729-1 standard has been designed on the basis of an analytical procedure (engineering account) of prototype chairs to be produced from two different types of timber (eastern beech and yellow pine). For this purpose, the static analysis forces of the seat (seat) and the backrest (backrest), which represent a sitting user load and standard prescribed by the standard, are applied to a wooden chair assumed to be of the following size and shape.



Functional measurements of the chair:

a) Seating depth: 420 mm,
h_1) Seat height: 460 mm,
h_2) Height of backrest: 400 mm,
h_3) Test force height: 300 mm,
h_4) Lower element height: 150 mm,

Since the chair is a symmetrical system, one side of the supporting frame of the chair is based on (redundant), and this half-frame is used in the calculation of the internal forces (T: shear force, N: normal force and M: moment) in static analysis and experimental application. In static analysis, full chair forces were actuated by ½ rate.

Figure 1. Chair functional measurements and static analysis forces

The back, sides, and front elements of the chair carrier frame are joined and glued together with the tongue joint. For this reason, it is assumed that the junctions are rigid and bear momentum. The lower element is joined and glued together with a single dowel joint. For this reason, it is accepted that the junctions are not rigid and momentary. The lower element serves only to transmit the axial force and hold the two legs together.

Statical analysis:
Static test forces (representing the usage load) were applied to this support frame at a rate of ½, and the frame trimming method was applied. The internal forces (T: shear force, N: normal force and M: moment) distributed in the elements of the carrier frame (hind leg, side element, front leg) of the test method using the cutting method or its simulation are calculated by applying the static analysis and cutting method Figure 2). The calculated internal force values are given in Table 1.

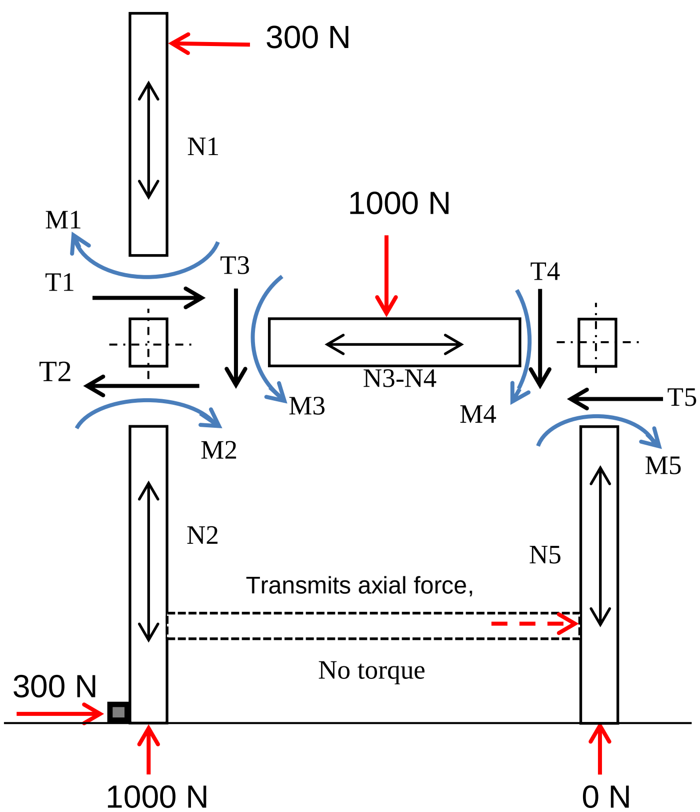


Figure 2. Distribution of internal forces to elements

Mechanical analysis
Based on the maximum values of the internal forces calculated by the cutting method on the members of the chair carrier system, the required cross-sections and the sufficient tenon sizes M/W and F/A are calculated at the joining points of the members according to the safety stresses of both wooden members (M: Moment, W: Strength moment, F: Shear force, A: Area). The required cross-section and mortise dimensions of the calculated element are given in Table 2.

Table 2: Dimensions of element and tongue (dimensions in mm).

Wood type	Front leg	Hind leg	Side element	Lower element	Front tenon	Hind tenon
Pine	60 x 25	65 x 25	69 x 25 mm	34 x 25	50 x 55	65 x 55
Beech	58 x 25	63 x 25	67 x 25 mm	32 x 25	48 x 55	58 x 55
The thickness of the chair elements was taken as 25 mm with the construction application and the visual admission requirement.						

In mechanical analysis, it was determined that there is no disadvantage that the upper end of the chair's hind leg is 25 mm and the lower end of the front and hind legs is conically tapered to 30 mm.

3 Material and method

3.1 Materials

In the experiments, Scotch pine (Pinus sylvestris L.) and beech (Fagus orientalis L.) wood types were used. Wood materials were obtained by the method of random selection in the site of Woodworking - Ankara. Wood materials' being natural in color, clean, smooth parallel to grain and part of the sapwood, free of decay, growth defects, insect and fungi damages were ensured.

3.2 Adhesive

Desmodur-Vinyl Trie Ketonol Acetate (D-VTKA) adhesive was used in this study and it was obtained from the Polisan Company in Izmit, Turkey. D-VTKA adhesive has usually been found to be preferable for the assembly process in the woodworking and furniture industry. The bonding surface should be clean, dry, dust and oil free. Adhesive is directly applied to one of the surfaces and the bonding process is conducted at 20 ± 2 0C and 65 ± 5% relative humidity. The specific gravity of D-VTKA: 1,1–1,14 g/cm3, it has a pH of about 7 and a viscosity of 3500-5500 cps at 25 0C (Keskin et al. 2009).

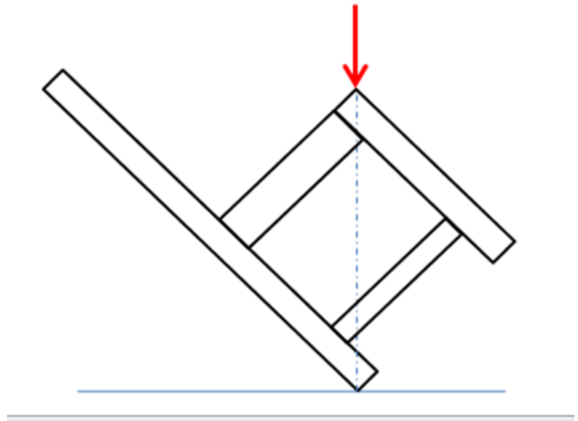
3.3 Preparing of Test Samples

The chair frame elements were cut from the wooden material of the pine and beech in accordance with Figures 1 and 2. 10 mm diameter and 20 mm deep holes were drilled on the lower element edges, and also the front and rear standing tenon holes were opened. D-VTK was grafted to the grooves and holes of the chair frame members according to the calculation of 150 g / m2, the elements were joined with each other and pressure was applied. Thus, 10 chairs of each type of chairs were prepared. The frames of the assembled test specimen were stored in a cabinet with a temperature of 20 ± 2 ° C and 65 ± 5% relative humidity until reaching 12% equilibrium humidity.

3.4 Test method

The test specimen was placed on a universal test device in the form of a chair seat critical sitting and diagonal pressure was applied at a rate of 400 kg/cm2 per minute (Figure 4). During the test, the force that initiates the opening of the tenon was determined and maintained until the break of the test elements. The amount of opening in the grooves was measured and recorded with a precision of 0,1 mm.

Diagonal compression test



4 Findings

Diagonal pressure test results applied to pine and beech chair frame examples; The force they were carrying was determined as the amount of opening in the front and hind tenon, and these values are given in Table 3.

Table 3: The strength of the chair frames, the amount of opening in the front and hind tenon.

	Pine Chair Frame			Beech Chair Frame		
	Force (N)	Opening front tenon (mm)	Opening hind tenon (mm)	Force (N)	Opening front tenon (mm)	Opening hind tenon (mm)
N	10	10	10	10	10	10
Min.	2050	4,2	4,4	2112	3,8	4,0
Max.	2188	6,6	8,4	2420	5,6	6,4
Average	**2140**	**5,5**	**6,8**	**2380**	**5,2**	**6,0**

In terms of the strength of the frames; Mean 2380 N in the largest beech samples, and 2140 N in the smallest pine samples. In the tests where force application continues, some experimental specimens have fractured in their tongue and some have been subjected to tearing deformations in the forelock of the front leg. However, there was no increase in strength after the opening of the test specimens.

In terms of opening on the frame tongues; In the largest pine specimens; the amount of opening in the average front tenon was 5.5 mm in the hind tenon 6,8 mm in the smallest beech specimen; in the front tenon 5,2 mm and hind tenon 6 mm. During the opening of the tenons, some glue layer breaks, and in some cases deformations in the form of wooden breaks.

5 Evaluation of the Results and Recommendations

Based on the safety stresses of both wood types, a resistance balance is achieved by means of the constant moment distributed in the static analysis, the determined cross-sections and the size of the grooving surfaces. However, some more force bearings of beech specimens may be welded because the beech is more rigid and transmits the test force as it is, while the pine is less rigid, since it absorbs and partially transfers some of the test force.

In addition, beech chairs have the largest average carrying force in the frame; can be said to be due to the fact that the density of beech material (0.68 g / cm^3) is higher than that of pine material (0.49 g / cm^3), resistant, dense texture and hence better adhesion resistance. The number of grooves opening in the grooved joints of the frame elements (hind leg, side element and front leg) also differed according to the material type. This difference is due to the fact that the beech material is more rigid and transmits the test force as it is; since it is less rigid, it absorbs some of the strength of the test and is partially known to transmit. In addition, the amount of opening of tenon in the front leg is less than that of the hind leg in the frame of the same type of wood. This is because the moment acting on the front tenon (93 930 N * mm) is less than the hind tenon (139380 N * mm).

According to the results obtained with this study;

1) In this study carried out with a side of the board (doubled); The forces are 2380 N in beech frame and 2140 N in pine frame which means that they can carry 4760 N (about 476 kg) in a real size beech chair and 4280 N (about 428 kg) in a real size pine chair. Assuming a user's average weight of 80 kg (approx. 800 N), it can be said that the beech chair is about 5,9 (476/80) and the pine chair is 5,3 times more secure.

2) Generally, a static and mechanical analysis is required before designing in a wooden system (wood chair).

3) In the production of very active furniture such as chairs, the rigidity and density are more and more frequent and the textured beech materials and so on. It is preferable to use wood species.

4) In order to provide visual aesthetics and ease of use in chair design; The chair can be tapered up to 25 mm or the backrest element can be curved (Fig. 3), so that the chair can have a backlash angle (approx. 15 degrees) in the right-axis hind-legged chairs. Again, for visual aesthetics, it was determined that there was no drawback that the lower end of the hind leg was conical up to 30 mm (Fig. 3).

5) Three alternative chair designs that are shaped according to these criteria are given in Figure 3

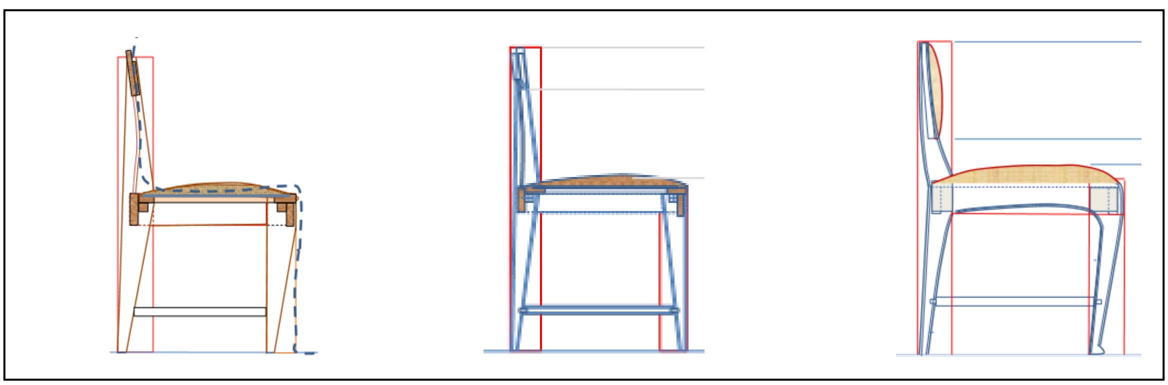


Figure 3: Alternative chair designs

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Determination of the Effect on the Color Homogeneity of the Use of Natural Dye Stuff in Paper Obtained from Recycled Paper by Accelerated Wheathering

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ABSTRACT

In the event of reusing the waste paper, which was exposed various contaminants according to its place of use, the stain on it breaks the colour homogeneity. In this study, it was aimed to obtain the colour homogeneity of waste paper with the dyestuff obtained from the wild cranberry (Cornus australis L.). In the study, waste paper groups were formed as mixtures (MP) in the same proportions from offset printed magazine (OPM), newsprint (NP), copy paper (CP), unbleached paper (UP), corrugated cardboard (CB) and paper. In order to investigate the effect of dyestuff, the waste paper groups were produced under groups including the control paper without any additives (I), paper mixed with dyestuff (II) and paper with dyestuff and alum (III). The same conditions were repeated with the imported bleached paper (BP) with the purpose of controlling the hiding power of the dyestuff. The paper produced was subjected to accelerated weathering test for 5-10-25-50 and 100 hours. Wave intensity of 0.65 W/m2 was chosen as the test condition. At each weathering period, the changes in colour, gloss and opacity values of samples were investigated. According to the results obtained, the highest colour change value was obtained in the sample group I, and the lowest total colour change value was obtained in the sample group III. In Group II, the total colour change was the highest in imported bleached paper. The increase in weathering period did not affect the opacity. During the first 5 hours of weathering, the lowest opacity value was obtained in imported bleached paper. Through weathering method, the maximum decrease in opacity was observed in group II-BP

KEYWORDS: Waste paper, dyestuff, mordant, accelerated weathering

1 INTRODUCTION

In the general sense, paper is obtained from fibrous substances by means of water, without using any additives. The waste paper can be converted into pulp in order to use in paper production by turning into fibre with the use of water and a mixer. With the increase in demand for raw materials, the production costs are tried to be reduced in the paper industry as well as in every area by recycling. Considering the recycling processes in other industries, it is quite easy to recycle paper. This case significantly reduces the cost of pulp which is the most important input in the paper industry. For instance, it was stated that when the first-hand chemical pulp is used in paper production, the proportion of pulp cost is 95% of the total cost and that with the use of waste paper, the cost of raw materials is reduced by 35-55% which is 65-85% of the total cost (Siewert 1989).

Some disadvantages are encountered in the use of recycled fibres in addition to their economical advantages. Foremost among them is the fact that recycled paper varies depending on the user and the place of use and also contains stain or foreign matter in different qualities and proportions. Not all used paper can be used as raw material in recycling. For instance, paper used for cleaning purposes are not recycled for hygiene reasons. In addition, there may be paper, which is too dirty to be used, among the collected paper. For this reason, the usable amount of paper obtained from recycling is important. The usability ratio of recycled paper depends largely on the awareness of the users. Regardless of the condition of recycled paper, they should go through cleaning and washing operations so that they can be reused. According to the results, which Hubbe (2007) and Sahin (2013) obtained from the comprehensive compiled articles, they reached the conclusion that recycling would be more efficient, decrease would be prevented in resistance and quality paper would be obtained, if recycled paper was to be reused by having knowledge on the pulp of the recycled paper and the method, by which they were produced, and by re-classifying them accordingly.

The most important factor for being successful in recycling paper is the user. In a statistical study conducted by Berger (1997) on 43000 people living in houses in Canada, he stated that the recycling ratio increased depending on their socioeconomic status, education and income. With increasing environmental awareness, not only economic value is considered in recycling, but also the desire of people for protecting nature increases awareness in paper recycling. In the research conducted by Jung et al. (2012), they noted that office workers with environmental consciousness did not pay attention to the negative appearance of the colours on the paper produced from recycled fibres. Tilikidou and Delistavrou (2005) reported that mainly young and educated students and professionals did not find recycled paper poor quality and that they stated that using the paper produced from recycled fibres was a social responsibility in order to protect the trees. They also recommend paper factories to increase the use of recycled fibre and to raise awareness in the social media for this purpose.

The chemical content of the paper is quite different because of the additives added to the special purpose paper. Pivnenko et al. (2015) stated that in addition to hazardous substances such as clay, calcium, carbonate and starch used during paper production, the number of hazardous substances caused by dye and ink used in printing and writing was 133. In the examination conducted on the waste water of recycled paper processing mills, Rigol et al. (2002) determined that these facilities had as much toxic material in their wastewater as mills producing paper and pulp. They reported that most of these substances transmitted to paper produced during recycling and because of this reason they were harmful especially in food and hygiene papers.

One of the most significant problems encountered in the paper obtained from the recycled fibres is the colour heterogeneity caused by stain and ink. In order to obtain homogeneous colour in paper, processes such as ink removal, bleaching, dyeing etc. are applied. Darlington (1989) noted that no satisfactory cleaning could be achieved due to the deep penetration of the ink on the toner-printed paper. However, it was reported that when three times-recycling process was performed in bleached Kraft pulp, 5% of sodium hydroxide used to increase whiteness and gloss ratios increased the whiteness by 5.1% and the gloss by 9.1%, compared to control samples (Sutcu and Sahin 2017). However, the fibres suffer some damages during the ink removal and bleaching process of the recycled paper. Wastewater pollution caused by the use of chemical substances also arises in these processes. There are also some inconveniences in producing general-purpose paper without any processing the fibres obtained by recycling. One of these inconveniences is the colour differences that vary depending on the writing and printing properties of the waste paper used. Another way of obtaining homogeneous colour is to re-dye the recycled fibres. Although different synthetic dyestuff is used for this purpose, pollution load increases in wastewater of paper mill due to the property of dyestuff. Springer (1993) stated that the dyestuff used conforming with the fibres facilitates the reduction of the dyestuff transmitting to the waste water of paper mill and the recycling of the water.

Beyond its traditional use, paper is used by being dyed in order to gain visual appeal. In addition, the writing and printing process is made by means of dyestuff. The dying of the paper dates back to the Middle Ages. Synthetic dyes began to be used in 1856 after the invention of inorganic pigments such as Prussian Blue and Ultramarine Blue. Since some dyes adhere weakly, their wastewater becomes coloured so their treatment is difficult. The mordant should be used to increase adherence (Murray 19XX). Different mordant is used for this purpose and Bechhtold (2009) stated that alum had been an important mordant used for many years. Gencer and Can (2016) stated that permanence was poor when the paper was dyed with organic dyestuff obtained from the seeds of the elderberry (*Sambucus nigra* L.) plant. Gencer et al. (2017) stated that the permanence was poor when it was dyed with cherry wood bark but they also stated that the permanence was increased by the use of alum.

In this study, the dyestuff obtained from the bark of wild cornel (*Cornus australis* L.) wood was used for colouring waste paper. The reason for preferring the cornel bark is to make use of idle bark of cornel wood that have been debarked to be used in making traditional handicrafts ‘Devrek Walking Sticks’ from cornel wood in Devrek. In order to sustain this handcraft, which contributes to tourism and economics of the region, Devrek Forest Management Directorate of Zonguldak Regional Directorate of Forestry grants permission to local handcraft artisans for logging in certain areas. Since a stool becomes suitable for making a walking stick in 5 to 6 years, logging is made in accordance with the Inventory and Planning of Non-Wood Forest Products and Principles of Sales prepared by General Directorate of Forestry numbered 297 and dated 04.05.2013 for sustainable production. According to this plan, a total of 91.400 stools shall be available to be cut from an area of 22 ha between 2014 and 2019. Devrek Forest Management Directorate carries out this plan successfully.

2 MATERIALS AND METHODS

In the study, recycled paper, offset printed magazine (OPM), non-reference bleached pulp (BP), newsprint (NP), copy paper with a pencil-written text on it (CP), corrugated cardboard (CB), unbleached writing paper with a pencil-written text on it (UP) and a mixture of these paper types (MP). The images of unprocessed recycled paper and reference bleached pulp are as shown in Figure 1.

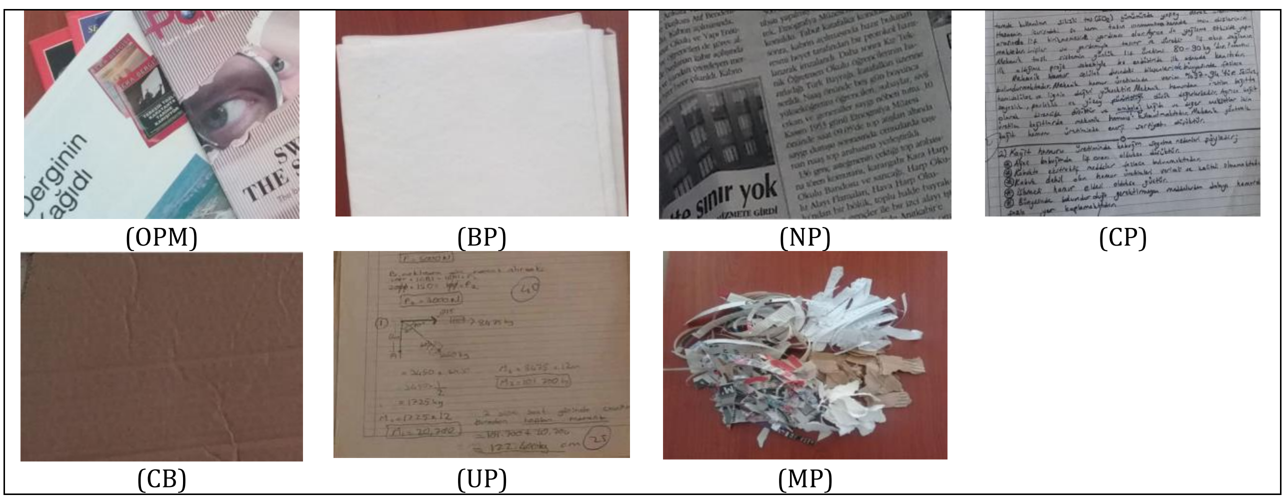

Figure 1: Recycled paper samples and example of reference bleached pulp.

Reference bleached pulp, used paper and corrugated cardboard samples were individually torn by hand in the size of a palm and they were kept in the beakers for 25 hours by adding water. These samples were pulped by being mixed with a mixer for 10 minutes, provided that they were not exposed to any mechanical effect. The same procedure was repeated for mixed pulps and for white control pulp. The paper obtained from this pulp wasclassified as paper group ‘I’. To obtain dyestuff, 100 g of complete dry barks were boiled in 500 ml of water for 2 hours. Test paper was obtained by adding the dyestuff to the fibre suspension in the fibre mixer. This group paper was classified as paper group 'II'. Also, paper was produced by adding 1%

alum suspension to the full dry fibre weight as mordant in order to increase colour permanence. This group paper was classified as paper group 'III'.

Accelerated weathering test was carried out in the device of Q-Panel Lab Products, in the laboratory of the Industrial Forest Engineering department of Bartin University. Test parameters in the device are as follows; UV (340 nm, wavelength) at 0,65 W/m2 for 8 h and conditioning at 50 ºC for 4 h. Overall, this cycle was operated for 500 h totally (ASTM-G53, 1998).

Test paper was tested for opacity according to TAPPI T 519 om-02.

Colour measurement of the test samples before and after the accelerated weathering were carried out in accordance with ISO 7724 standards by Konica Minolta CD-600 colour meter. On the wood samples, the color measurements from 3 different points were measured and their mean value was calculated for three replicates in each variation (ISO-7724, 1984).

The CIELab (Commission Interational de i'Eclairage) system consists of three variants (ISO 7724). L* refers to Light stability, a* and b* chromotographic coordinates (+a* indicates red, -a* green, +b* yellow, -b* blue). The values of L*, a* and b* were measured on the samples and the color changes were determined according to the following formulas

$$\Delta L^* = L_f^* - L_i^* \quad (3)$$

$$\Delta a^* = a_f^* - a_i^* \quad (4)$$

$$\Delta b^* = b_f^* - b_i^* \quad (5)$$

$$\Delta E^* = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1/2} \quad (6)$$

One of the first signs of ageing is the gradual loss of gloss of the coating film. Gloss measurements were taken in a KONICA Minolta Multi gloss 268 plus. The angle of incidence of the radiation was 60±0.1°, as defined in ISO 2813. Six measurements were made in each test panel, three parallel to the application direction and three perpendicularly.

3 RESULTS

The colour change values occurred in the samples exposed to 100-hour of weathering are given in Figure 1 as compared with the control samples. In addition, ΔL, Δa, Δb and ΔE values occurring on the sample surfaces are listed in Tables 1-4, respectively.

Images of recycled paper, paper produced from bleached pulp without using dyestuff and alum (paper group I), paper with added dyestuff (paper group II), paper with dyestuff and alum (paper group III) before weathering and after 100 hours of weathering are given in Figure 2.

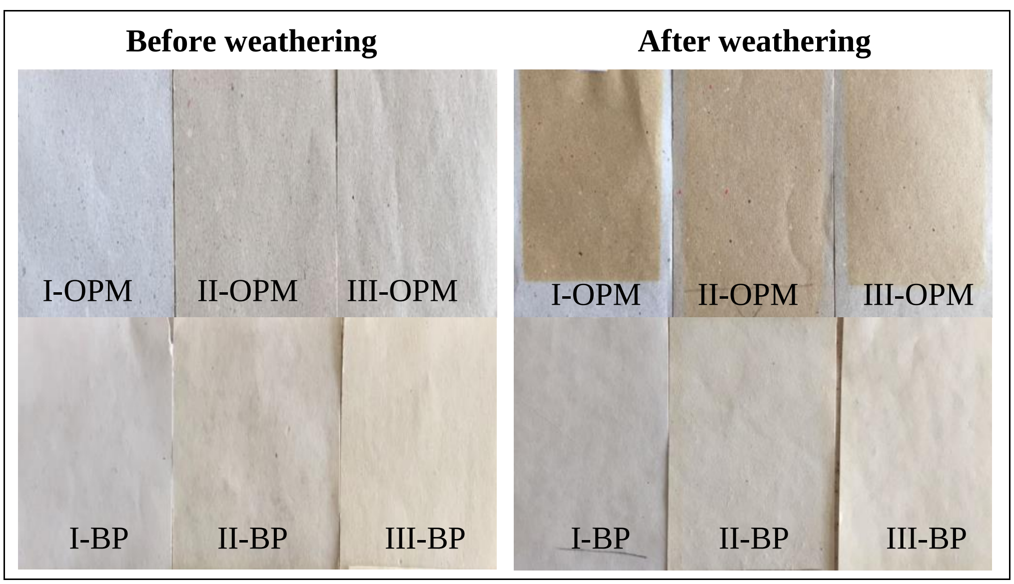

Figure 2: Colour change occurring on the sample surface after 100 hours of weathering; OPM:offset printed magazine, BP: bleached pulp, NP: newspaper, CP: copy paper, CB: corrugated board, UP; unbleached printing paper, MP: mixed paper

When the Figure 2 is examined, obvious stains appear in some of the paper (group I) obtained from the recycled fibres. While the number and size of stains were observed to be decreased in paper produced with dyestuff (group II), it is seen that stains disappear completely in some of the paper produced with alum and dyestuff (group III). The stains and spots covered with dye and alum addition did not become visible after 100 hours UV application. This shows that the permanence of the dyestuff used for long-term in the paper production is effective. Pictures were chosen one for each in order to represent groups in tens. Since human eye is relative in colour measurement, actual results shall be determined via the measurements made with optical devices. Opacity, gloss and Lab values of the paper produced was given below with the UV times applied.

Table 1: ΔL values of test and control samples

	ΔL				
	5 hours	10 hours	25 hours	50 hours	100 hours
I-OPM	-1,97 (1,46)	-2,84 (1,38)	-4,20 (0,04)	-4,91 (0,14)	-5,34 (1,20)
I-BP	-0,34 (0,21)	-0,41 (0,18)	-0,47 (0,20)	-0,32 (0,30)	-0,31 (0,15)
I-NP	-1,12 (0,19)	-1,50 (0,13)	-2,17 (0,21)	-2,47 (0,17)	-2,89 (0,12)
I-CP	-0,15 (0,40)	-0,22 (0,21)	-0,29 (0,17)	-0,34 (0,17)	-0,42 (0,28)
I-CB	0,09 (0,44)	0,54 (0,83)	1,15 (0,45)	2,03 (0,57)	2,68 (0,78)
I-UP	-1,00 (0,13)	-1,59 (0,04)	-2,01 (0,13)	-2,34 (0,18)	-2,80 (0,13)
I-MP	-0,56 (0,21)	-0,71 (0,10)	-1,15 (0,23)	-1,02 (0,23)	-1,06 (0,11)
II-OPM	-1,59 (0,37)	-1,77 (0,27)	-1,69 (0,30)	-1,46 (0,26)	-1,27 (0,19)
II-BP	-0,52 (0,10)	-0,36 (0,05)	0,74 (0,14)	2,15 (0,11)	3,32 (0,11)
II-NP	-0,34 (0,14)	-0,41 (0,25)	0,13 (0,18)	0,52 (0,30)	1,03 (0,06)
II-CP	-0,56 (0,10)	-0,31 (0,42)	0,33 (0,18)	1,28 (0,12)	2,48 (0,19)
II-CB	-0,85 (0,11)	-0,35 (0,29)	0,67 (0,29)	1,47 (0,14)	2,50 (0,03)
II-UP	-0,66 (1,36)	-0,59 (1,07)	-0,76 (0,77)	-0,63 (0,92)	-0,99 (1,16)
II-MP	-0,93 (2,47)	-0,75 (2,45)	-0,24 (2,32)	0,39 (0,45)	1,01 (1,79)
III-OPM	-0,57 (0,29)	-0,61 (0,40)	0,12 (0,36)	1,18 (2,37)	1,80 (0,82)
III-BP	0,11 (0,32)	0,75 (0,51)	1,52 (0,95)	3,10 (0,96)	4,55 (0,49)
III-NP	-0,59 (0,20)	-1,08 (0,27)	-0,68 (0,64)	-0,30 (0,50)	-0,19 (0,35)
III-CP	-0,19 (0,95)	0,20 (0,13)	1,32 (1,20)	3,04 (0,77)	6,17 (0,55)
III-CB	-0,39 (0,56)	0,39 (0,29)	1,14 (0,70)	2,57 (0,43)	3,93 (0,47)
III-UP	-1,63 (0,35)	-1,53 (0,18)	-0,88 (0,29)	-0,35 (0,29)	0,31 (0,31)
III-MP	-0,76 (0,41)	-1,24 (1,23)	-1,23 (1,35)	-0,68 (0,88)	-0,03 (0,29)

The colour change values in the test and control samples were calculated using the L* (light intensity), a* and b* chromatographic coordinates (+a red, -a green, +b yellow, -b blue) determined according to the CIELab system. According to the results obtained, with the increase in ΔL, group I increased negatively except I-CB, and groups II and III increased positively. Darkening is expected on the sample surfaces in-group I, which represents the group without dyestuff and alum. The lowest ΔL values were obtained in OPM in-group I and in NP in groups II and III. In addition, the highest ΔL values were observed in the I-CB, II-BP and III-CP sample groups. When the groups II, III, and I were compared with each other, the highest change was obtained in the III-CP samples with the value of 6.17. The ΔL values tended to be positive with the use of dyestuff and alum.

When Δa values (Table 2), which represents the red-green colour coordinates of the samples, were examined, it was negative (green) in groups I-II-III CP and CB positive (red) in the other variations. In the variations generated, while UP had the highest Δa value, I-CB, II-III BP had the lowest Δa value. Among all variations, the highest Δa was obtained in I-UP with the value of +3.97. This is due to the structure of UP. It is because of the high content of lignin in unbleached pulps (UP) and the fact that the lignin changes colour by oxidation.

Table 2. Δa values of test and control samples

	Δa				
	5 hours	**10 hours**	**25 hours**	**50 hours**	**100 hours**
I-OPM	-0,05 (0,19)	0,29 (0,16)	1,04 (0,03)	1,62 (0,13)	2,31 (0,19)
I-BP	-0,22 (0,15)	-0,16 (0,12)	-0,12 (0,14)	-0,03 (0,11)	0,02 (0,11)
I-NP	0,05 (0,06)	0,40 (0,05)	1,28 (0,06)	1,97 (0,04)	2,72 (0,09)
I-CP	-0,55 (0,02)	-0,71 (0,04)	-0,98 (0,03)	-1,07 (0,05)	-1,09 (0,02)
I-CB	-0,75 (0,13)	-0,97 (0,13)	-1,13 (0,26)	-1,30 (0,28)	-1,21 (0,24)
I-UP	0,40 (0,04)	0,86 (0,04)	1,95 (0,06)	2,86 (0,11)	3,97 (0,09)
I-MP	-0,22 (0,07)	-0,23 (0,03)	0,25 (0,16)	0,55 (0,10)	0,89 (0,04)
II-OPM	0,75 (0,11)	1,09 (0,49)	1,11 (0,05)	1,37 (0,08)	1,50 (0,04)
II-BP	0,54 (0,12)	0,56 (0,10)	0,07 (0,09)	-0,57 (0,01)	-1,05 (0,10)
II-NP	0,54 (0,09)	0,84 (0,10)	1,25 (0,11)	1,46 (0,07)	1,80 (0,05)
II-CP	0,45 (0,03)	0,32 (0,07)	-0,09 (0,10)	-0,36 (0,11)	-0,73 (0,09)
II-CB	0,09 (0,13)	-0,11 (0,18)	-0,30 (0,07)	-0,54 (0,18)	-0,71 (0,13)
II-UP	0,42 (0,63)	0,89 (0,54)	1,72 (0,34)	2,41 (0,51)	3,37 (0,68)
II-MP	0,62 (0,54)	0,68 (0,55)	0,95 (0,40)	1,02 (0,18)	1,11 (0,22)
III-OPM	0,73 (0,14)	0,96 (0,04)	0,96 (0,27)	1,10 (0,48)	1,18 (0,18)
III-BP	0,34 (0,13)	0,18 (0,18)	0,01 (0,32)	-0,50 (0,39)	-0,95 (0,17)
III-NP	0,77 (0,10)	1,15 (0,15)	1,22 (0,26)	1,76 (0,19)	2,19 (0,29)
III-CP	0,47 (0,07)	0,56 (0,03)	0,51 (0,09)	0,19 (0,17)	-0,61 (0,17)
III-CB	0,08 (0,09)	0,19 (0,18)	0,23 (0,07)	0,03 (0,18)	-0,36 (0,21)
III-UP	1,34 (0,11)	1,84 (0,09)	2,25 (0,42)	3,03 (0,23)	3,74 (0,09)
III-MP	0,08 (0,10)	0,26 (0,23)	0,55 (0,34)	0,77 (0,21)	1,03 (0,05)

When Δb value (Table 3), which represents the yellow-blue colour coordinates of the samples, were examined (Table 3), the lowest value was obtained in BP while the highest value was obtained in UP among all groups of I, II and III. Among all variations, the highest Δb value was obtained in I-UP with 17,30 and the lowest in III-BP with -4,41. That is to say, the tendency was observed towards yellow colour in I-UP and towards blue colour in III-BP. Since the lignin content in the unbleached pulp is high, the yellow colour tendency is increased due to the weathering effect and the oxidation occurred in the lignin. There is a minute amount of lignin in bleached pulp, because of this there is no tendency to become yellow. As the bleaching substances are actually blue in colour, tendency towards blue is increased by oxidation.

When all variations were examined, the lowest total colour change (ΔE) was observed in CB samples. The highest colour change was obtained in I-NP, II-III UP samples. Adding dyestuff and alum into the CB did not have a significant effect on total colour change. Total colour change was 3.30 in I-CB, 3.14 in II-CB and 4.37 in III-CB. This may be caused by the inadequate hiding power of the dyestuff due to the production of CBs from non-bleached pulp. This situation is supported by the fact that the colour change in II-CB and III-CB group paper is higher than the paper with non-additives (I-CB).

When the groups I, II and III were evaluated in themselves, the highest total colour change (ΔE) after 100 hours weathering process was obtained in samples numbered I, and the lowest total colour change was obtained in samples numbered II. The fact that sample group I did not have dyestuff and alum caused ΔE value to be high. While the lowest ΔE value for the first 25 hours was obtained by the use of alum, which enables the dyestuff adherence on the paper, the effect of alum disappeared with the increase of the weathering period and ΔE values in samples numbered III became higher than those in group II.

Table 3. Δb values of test and control samples

	Δb				
	5 hours	**10 hours**	**25 hours**	**50 hours**	**100 hours**
I-OPM	6,97 (0,5)	9,84 (0,28)	12,99 (0,45)	14,35 (0,10)	15,26 (0,38)
I-BP	2,10 (0,43)	2,06 (0,47)	1,92 (0,35)	1,42 (0,43)	0,95 (0,24)
I-NP	8,44 (0,16)	11,10 (0,08)	14,68 (0,07)	16,09 (0,22)	16,92 (0,15)
I-CP	3,50 (0,44)	4,73 (0,21)	6,90 (0,29)	8,16 (0,42)	9,16 (0,10)
I-CB	0,89 (0,43)	1,14 (0,19)	2,04 (0,50)	1,98 (0,28)	1,88 (0,41)
I-UP	7,63 (0,18)	10,56 (0,09)	14,10 (0,23)	16,09 (0,39)	17,30 (0,23)
I-MP	4,36 (0,84)	6,29 (0,69)	8,56 (0,78)	9,68 (0,79)	9,57 (0,69)
II-OPM	4,16 (0,10)	5,49 (0,08)	7,18 (0,09)	7,87 (0,14)	7,68 (0,16)
II-BP	0,86 (0,40)	0,84 (0,14)	0,00 (0,24)	-1,64 (0,18)	-3,81 (0,40)
II-NP	4,67 (0,15)	6,34 (0,35)	8,44 (0,18)	8,96 (0,49)	9,60 (0,17)
II-CP	2,10 (0,10)	2,81 (0,36)	3,12 (0,42)	2,83 (0,36)	1,74 (0,56)
II-CB	0,76 (0,17)	1,22 (0,16)	2,04 (0,06)	1,97 (0,28)	1,76 (0,17)
II-UP	6,17 (1,35)	8,43 (0,95)	11,46 (0,47)	12,63 (1,65)	13,66 (1,85)
II-MP	2,65 (1,02)	3,62 (0,99)	5,00 (0,73)	5,17 (0,65)	5,06 (0,38)
III-OPM	3,79 (0,17)	5,31 (0,08)	6,44 (0,49)	6,69 (0,65)	6,33 (0,34)
III-BP	0,78 (0,49)	0,30 (0,70)	-0,13 (0,82)	-1,99 (1,11)	-4,41 (0,63)
III-NP	4,52 (0,37)	6,23 (0,36)	7,87 (0,64)	9,25 (0,81)	9,95 (0,94)
III-CP	1,25 (1,08)	1,84 (0,19)	2,40 (1,26)	2,00 (0,47)	-0,19 (0,77)
III-CB	0,50 (0,31)	1,31 (0,18)	2,00 (0,31)	2,15 (0,42)	1,83 (0,39)
III-UP	4,21 (0,49)	6,21 (0,28)	7,94 (0,70)	9,87 (0,48)	11,29 (0,16)
III-MP	3,56 (0,22)	4,92 (0,35)	6,86 (0,48)	7,88 (0,23)	8,50 (0,23)

Table 4. Total colour change (ΔE) values of the test samples

	ΔE				
	5 hours	**10 hours**	**25 hours**	**50 hours**	**100 hours**
I-OPM	7,33 (0,69)	10,30 (0,63)	13,69 (0,44)	15,25 (0,12)	16,35 (0,74)
I-BP	2,14 (0,47)	2,11 (0,50)	1,99 (0,38)	1,49 (0,42)	1,02 (0,18)
I-NP	8,51 (0,15)	11,21 (0,09)	14,89 (0,07)	16,39 (0,19)	17,38 (0,15)
I-CP	3,56 (0,45)	4,79 (0,22)	6,98 (0,29)	8,23 (0,43)	9,24 (0,11)
I-CB	1,16 (0,35)	1,58 (0,24)	2,68 (0,46)	3,25 (0,41)	3,30 (0,54)
I-UP	7,71 (0,17)	10,72 (0,10)	14,37 (0,24)	16,51 (0,43)	17,97 (0,24)
I-MP	4,41 (0,78)	6,33 (0,17)	8,65 (0,22)	9,75 (0,37)	9,67 (0,42)
II-OPM	4,52 (0,20)	5,88 (0,16)	7,46 (0,04)	8,12 (0,11)	7,93 (0,15)
II-BP	1,15 (0,39)	1,07 (0,14)	0,78 (0,13)	2,76 (0,14)	5,16 (0,35)
II-NP	4,71 (0,14)	6,41 (0,35)	8,53 (0,19)	9,10 (0,49)	9,82 (0,16)
II-CP	2,22 (0,11)	2,87 (0,40)	3,14 (0,42)	3,13 (0,35)	3,15 (0,31)
II-CB	1,16 (0,13)	1,30 (0,17)	2,18 (0,09)	2,53 (0,21)	3,14 (0,11)
II-UP	6,33 (1,50)	8,53 (1,05)	11,63 (0,56)	12,89 (1,75)	14,14 (2,02)
II-MP	3,48 (1,52)	4,27 (1,31)	5,47 (0,84)	5,30 (0,63)	5,51 (0,16)
III-OPM	3,91 (0,21)	5,44 (0,06)	6,52 (0,52)	7,18 (0,39)	6,73 (0,27)
III-BP	0,98 (0,24)	1,12 (0,17)	1,76 (0,81)	3,75 (1,38)	6,41 (0,79)
III-NP	4,63 (0,37)	6,43 (0,39)	8,02 (0,66)	9,44 (0,80)	10,20 (0,97)
III-CP	1,74 (0,65)	1,94 (0,19)	2,87 (1,56)	3,71 (0,45)	6,23 (0,59)
III-CB	0,84 (0,14)	1,41 (0,19)	2,36 (0,56)	3,36 (0,55)	4,37 (0,41)
III-UP	4,73 (0,42)	6,65 (0,30)	8,30 (0,80)	10,34 (0,52)	11,90 (0,15)
III-MP	3,66 (0,27)	5,20 (0,17)	7,10 (0,15)	7,98 (0,24)	8,57 (0,22)

Table 5. Opacity values of paper samples before and after weathering test

	0 hour	5 hours	10 hours	25 hours	50 hours	100 hours
I-OPM	99,02	99,03	98,87	98,86	99,21	99,14
I-BP	88,72	89,05	89,29	89,42	89,12	89,02
I-NP	99,86	99,86	99,85	99,96	99,76	99,84
I-CP	96,26	96,69	97,02	96,79	96,81	96,78
I-CB	99,31	98,71	99,05	99,97	99,72	98,91
I-UP	99,73	99,88	99,62	99,14	99,63	99,55
I-MP	99,30	99,63	99,66	99,61	99,54	99,51
II-OPM	99,42	99,66	99,87	99,96	99,88	99,76
II-BP	91,74	90,05	90,30	89,76	89,29	88,90
II-NP	99,51	100,00	99,99	99,99	99,98	99,87
II-CP	99,06	98,25	98,32	98,26	98,15	97,88
II-CB	98,48	99,66	99,82	99,69	99,51	99,41
II-UP	99,10	99,71	99,51	99,69	99,56	99,51
II-MP	99,74	99,78	99,79	99,79	99,77	99,68
III-OPM	99,72	99,51	99,42	99,78	99,56	99,88
III-BP	89,65	92,18	92,08	95,64	91,24	90,53
III-NP	99,85	99,75	99,56	99,10	99,51	99,63
III-CP	98,63	99,13	99,01	98,59	98,61	97,04
III-CB	98,59	97,90	99,54	99,39	98,61	98,78
III-UP	99,68	99,49	99,36	96,13	99,35	99,91
III-MP	99,72	99,89	99,74	99,73	99,83	99,78

The increase in weathering period did not change the opacity value. Iosip (2010) stated that if the ratio of recycled non-bleached wrapping paper and cardboard was high in the paper to be newly produced, despite the fact that its ink had been removed, it reduced the gloss and increased the number and sizes of stains. However, in the study conducted by Gulsoy and Erenturk (2017), they noted that the value of gloss increased with the addition of waste paper to virgin pulps obtained by Kraft method from pine wood. This may be due to the low ink content in recycled paper or the higher gloss value than the pulp obtained by the Kraft method. Generally, the high colour change with UV in the paper obtained from non-bleached pulps is not related to the dyestuff used but it is directly proportional to the ratio of lignin remaining in the pulp.

4 CONCLUSION

The paper, which is obtained from the colorant obtained from wild cranberry stains and dirt, were significantly reduced compared to the control samples. It was also found that some of the aluminum used samples were completely lost. After 100 hours of UV treatment the stains and spots did not become clear again. it can be said that the covering of the stain obtained in this case is sufficient.

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The Impact of Sanding System on the Surface Roughness of Medium Density Fibreboard

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The Impact of Sanding System on the Surface Roughness of Medium Density Fibreboard

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ABSTRACT

This paper examines the impact of the sanding system on automatic sanding machine in real production conditions on the surface roughness of medium density fibreboard (MDF). The surface of samples was egalized by sanding on wide–belt sanding machine using P80 grit sanding belt. Afterwards, the samples were sanded on the 4 aggregate automatic sanding machine at sanding speed of 14 m/s in a two-step process with the following sanding belt grits: P120+P150 and P120+P180, using two conveyor speeds: 8 and 12 m/min. In the first stage of sanding, the samples were sanded by narrow belt aggregate, with sanding direction perpendicular towards the processing direction of sample in sanding machine. The second stage of sanding was conducted on the wide-belt aggregate, with sanding direction parallel towards the processing direction of sample in sanding machine. The surface roughness was measured by the contact-mechanical gauge and expressed by parameters R_a, R_z and R_t. As expected, results confirmed that sanding belt grit in the last stage of sanding had significant effect on the surface roughness of MDF. On the other hand, variation of speed of conveyor did not affect the surface roughness of MDF, for both combinations of sanding belt grits.

KEYWORDS: MDF, Sanding, Surface roughness, Sanding belt grit, Speed of conveyor

1 INTRODUCTION

Most often sanding is the first operation in the technological process of surface finishing of wood and wood-based products. Nowadays, the sanding of flat panels is usually done on the automatic sanding machines in several following steps (stages), ensuring gradual removal of the irregularities on the surface and thus achieving the minimum required roughness and uniform quality of the surface on the entire panel. The uniform roughness of the surface layer of the substrate is a prerequisite for the quality surface finishing of the wood and wood-based products. Most of the defects in the surface layer of the substrate become apparent after the application of the surface treatment material (coatings, etc.). In those cases, the correction of the transferred defects from the substrate, often involves total removal of the material surface layer to the raw substrate. Any additional step in technological process of wood surface finishing means additional costs, in regards to processing time and cost of materials. Those costs are enlarged by the costs of the re-processing of the substrate after total removal of the film coating with defects. Therefore, it is necessary to pay special attention to the selection of the optimal sanding program, according to the type of substrate and type of finishing material, but also in regards to the further purpose of the finished product.

The surface roughness of wood products is depending on many factors related both to wood properties and wood working operational parameters (Gurau et al. 2007; Magoss E. 2008). It is known that during sanding the processing roughness of the wood surface is affected by number of factors: grit-size of sanding belts (Ratnasingam et al. 2002; Saloni et al. 2005; Hendarto et al. 2006; Kilic et al. 2006; de Moura and Hernández 2006; Salcă and Hiziroglu 2012; Varasquim et al. 2012; de Sampaio Alves et al. 2015; Laina et al. 2017), sanding speed (de Moura and Hernández 2006; Varasquim et al. 2012), speed of the conveyor (Ratnasingam et al. 2002; de Moura and Hernández 2006; Škaljić et al. 2009; Salcă and Hiziroglu 2012), type of abrasive material (Ratnasingam et al. 2002; Saloni et al. 2005; de Moura and Hernández 2006), direction of sanding, sanding pressure (Saloni et al. 2005; Varasquim et al. 2012), operating time of the sanding belt (Ratnasingam et al. 2002; Palija et al. 2014), hardness of the rubber contact roller (Ratnasingam et al. 2002) etc.

Medium density fiberfboard (MDF) is an engineering product obtained by hot-pressing of fine glued wood fibers at certain regimes (temperature, pressure and time). Due to lower impact of irregularities that are result of anatomical structure of pressed fibers, initial surface roughness of MDF is generally lower in comparison to surface roughness of wood. It is assumed that the factors that affect the roughness of the wood during sanding will affect the roughness of the MDF as well. Previous research confirmed that surface roughness of sanded MDF is affected by: grit-size of sanding belts (Kiliç et al. 2009; Ayrilmis et al. 2010); sanding speed and feed speed (WILKOWSKI et al. 2015), fibers wood species (Gurau et al. 2017), fineness of wood fibers and relative humidity of exposure (Ozdemir et al. 2009).

This research examines the technological process of the surface preparation of MDF in real production conditions. The aim of this paper was to determine the optimal sanding program of MDF in terms of the grit of the sanding belts in the two-stage process and the speed of conveyor belt, expressed by the lowest surface roughness of MDF.

2 MATERIALS AND METHODS

For this research 12 samples of the commercially manufactured MDF dimensions: 750x300x4 mm, were used. To ensure a safe passage through the sanding machine, MDF samples were glued to calibrated 34 mm-thick blind frame. Surface preparation of MDF carried out in real production conditions on automatic sanding machines. Calibration of the glued MDF samples was done on the wide–belt sanding machine with contact rubber roller (model LMF 1300 RRRR, manufacturer Egurko-Ortza), using 80-grit sanding paper. After calibration, fine sanding of samples was carried out on the 4 aggregate wide-belt sanding machine (model Rita 4CT EL, manufacturer Viet): first aggregate with narrow sanding belt and following aggregates with wide sanding belt. All sanding aggregates were equipped with flat sanding platen. The calibrated samples were divided into 4 group, according to program of fine sanding of MDF surface (Table 1). Each group consisted of 3 samples. During sanding the sanding speed was set constant: 14 m/s, while conveyor speed was varied. One half of all samples was sanded at 8 m/min conveyor speed, while the other half was sanded at conveyor speed of 12 m/min. The indicated speed of sanding and speeds of conveyor were in accordance with the recommendations of the sanding belt manufacturer for sanding of MDF and other wood-based panels (Web-1). Sanding was conducted in two-step process by activation of the first and second aggregate. In first step sanding was conducted perpendicular to the processing direction of sample in sanding machine, while in second step sanding was parallel to the processing direction of sample. This combination of sanding directions enables the raising of the wood fibers from the surface in first step and its removal in the following step. Sanding was carried out using two combinations of grits of the sanding belts: P120+P150 and P120+P180. The sanding pressure was 0.5 bar.

Table 8: Groups of samples

Group of samples	**I**	**II**	**III**	**IV**
Gritof sanding belt	P120+P150		P120+P180	
Speed of conveyor (m/min)	8	12	8	12

After sanding, surface roughness of the sample was determined by measuring the roughness parameters: R_a, R_z and R_t, in accordance with standard ISO 4287:1997. The measurement of surface roughness was carried out by stylus contact tester (model TimeSurf TR200, manufacturer Beijing TIME High Technology Ltd.), Figure 1. The diameter of the diamond stylus tip was 2 μm, and the stylus was pressed on the surface by the force of 4 mN. Reference length was 2.5 mm, which is in accordance with the recommendation of the standard ISO 4288: 1996. Measurements were made perpendicular to the direction of of the movement of the samples in the machine (perpendicular to the final sanding step). 6 measurements of surface roughness parameters were measured for each sample, which make total of 72 measurements (6x3x4).

Figure 1: Measurement of surafece roughness parameters of MDF by stylius contact tester

3 RESULTS

Table 2 shows the results of surface roughness of sanded MDF according to the groups of samples.

Table 2: Surface roughness of sanded MDF for different conveyor speed and combination of sanding belt grits

	Group of samples			
Surface roughness parameter (µm)	***I***	***II***	***III***	***IV***
R_a	7.091 (1.03)	7.787 (1.79)	5.327 (0.54)	5.719 (0.71)
R_z	48.50 (6.36)	51.45 (8.92)	37.86 (4.02)	40.13 (5.14)
R_t	65.30 (12.13)	65.57 (22.04)	49.02 (7.67)	52.22 (9.29)

Values of standard deviation are written in parentheses

The use of lower conveyor speed (u = 8 m/min) resulted in lower surface roughness of MDF samples in comparison to the use of higher conveyor speed (u = 12 m/min), for both combinations of sanding bet grits: P120+P150 and P120+P180. In addition to lower values of surface roughness parameters, values of the standard deviation were lower for the samples that were sanded at lower feed, in comparison to samples sanded at higher feed speed and with same grits of sanding papers. These results can be explained by the longer contact of the abrasive grains and the surface layer of the panel at lower conveyor speed, which contributed to more uniformity and lower roughness of the surface substrate. These results are in line with finding of paper on quality of sanded surfaces of sugar maple wood, where increasing feed speed led to rougher surfaces due to higher fibrillation of cell walls in surface layer of wood (de Moura and Hernández 2006). Increasing the feed speed (from 6 to 18 m/min) during sanding of black alder led to general increase of the processing roughness expressed by the R_k (Salcă and Hiziroglu 2012).

Along with sanding, the increase of the conveyor speed in other working processes leads to higher surface roughness of wood and wood-based substrate. Thus the increase of feed rate (from 6 to 24 m/min) during planning of beech, oak and fir wood resulted in the increase of R_a (Škaljić et al. 2009). In the research of surface roughness aspects in milling of MDF, it was found that as the speed of the conveyor increased (from 0.5 to 5 m/min), the roughness parameters: R_a, R_z and R_t increased (Davim et al. 2009). Sanding of MDF at constant rotational spindle speed (n = 8000 rpm) showed tendency to increase of surface roughness with increase of feed per revolution (WILKOWSKI et al. 2015).

On the other hand, the results of the independent t-test (for P120+P150: t = (27.157) = - 1.427, p = 0.163 for R_a; t = (34) = - 1.144, p = 0.261 for R_z; t = (26.426) = - 0.045, p = 0.964 for R_t and for P120+P180: t = (34) = - 1.873, p = 0.07 for R_a; t = (34) = - 1.478, p = 0.149 for R_z; t = (34) = - 1.129, p = 0.267 for R_t) showed that there is no statistically significant difference between the surface roughness parameter: R_a, R_z, and R_t for different speed of the conveyor belt, for both combinations of the sanding belt grits .

Due to the absence of the statistically significant differences in surface roughness of MDF samples sanded at different conveyor speeds, the results of surface roughness parameters were further analyzed independently of the conveyor speed, Table 3. When comparing the surface roughness of sanded MDF samples using two combinations of the sanding belt grits, it is clear that the use of smaller abrasive grains in the final step of sanding resulted in the lower surface roughness expressed by all three roughness parameters (R_a, R_z, R_t). The results of independent t-test confirmed that the difference in values of all three observed roughness parameters for two combinations of the sanding belt grits was statistically significant ($t(43.650)=-6.717$, $p \le 0.05$ for R_a, $t(50.418)=-6.804$, $p \le 0.05$ for R_z and $t(48.257)=-4.728$, $p \le 0.05$ for R_t), This results were expected since sandpaper with higher grit size contains finer abrasive thus produces finer sanded surface (Tan et al. 2010).

Table 3: Surface roughness of sanded MDF for different combination of the sanding belt grits

Surface roughness parameter (μm)	***Grit of sanding paper***		Decrease of roughness (%)
	120+150	120+180	
R_a	7.439 (1.48)	5.523 (0.65)	25.76
R_z	49.97 (7.78)	38.99 (4.69)	21.97
R_t	65.44 (17.54)	50.62 (8.55)	22.65

Values of standard deviation are written in parentheses

In the research of the impact of sanding of MDF panels made from R. ponticum wood using P60 + P80 + P120 sanding bets (Ayrilmis et al., 2010), values of surface roughness parameters (R_a = 4.15μm, R_z = 30.76μm and R_t = 38.60 μm) were lower in comparison to values of surface roughness parameters that were obtained in our research, when using higher grits of sanding paper in final stage (P150 or P180). This disagreement confirms that the surface roughness of MDF is affected by characteristics of the raw materials used in production, production conditions and machining characteristics (Kiliç et al. 2009). Thus in support of that, after sanding of MDF made of thermally treated rubberwood fibers, with P120 and P150 grit sanding belts, values of surface roughness parameters (R_a = 6.93 μm, R_z = 41.15μm and R_t = 52.08 μm) were slightly lower than the values obtained in this study, which can be explained by type of fibers, thermal treatment of fibers and pressing regimes (Jarusombuti et al., 2010).

The values of surface roughness parameters of MDF sanded with P100 and P150 grit sanding paper in previous research (Ozdemir, Hiziroglu and Malkocoglu 2009) were lower in comparison with results that we obtained (R_a = 2.04 μm, R_z = 19.57μm and R_t = 23.73 μm, for samples made from unrefined fibers and exposed to 65% of relative humidity). This deviation can be related to the direction of sanding, since in mentioned research sanding was performed parallel to direction of the movement of the samples on the conveyor through the machine. In our research, the sanding was done perpendicular to the feed direction in the first step, and then parallel to the feed direction in second step. The combination of the perpendicular and parallel sanding in relation to the movement of the samples is recommendation for effective removal of wood fibers from the surface of the panel. In addition, prior to fine sanding, an equalization using 80grit sanding paper was carried out. According to the data of the sanding belt manufacturers, the size of grains of 80 grit sanding paper average about 200 μm. Knowing that the surface layer of MDF is compact, the use of 80 grit sanding paper in calibration of MDF had created scratches that was too depth for removal by subsequent higher grit sanding belts, resulting in higher values of surface roughness.

According to the data obtained from the practice, the value of parameter R_a of sanded wood samples is approximately 5 times lower than the parameter R_z, and the value parameter R_z is approximately 1.6 times lower than the parameter R_{max} (Janković, 1975). The ratio of parameters R_z to R_a of MDF samples sanded at different systems (P60; P60 + P80 and P60 + P80 + P120) ranged from 6.56 to 7.41(Ayrilmis et al. 2010), while the ratio of R_t and R_z varied from 1.24 to 1.25. The ratio R_z: R_a for sanded MDF samples in this research was 6.72 and 7.02 for sanding grits P120+P150 and P120+P180, respectively. The higher ratio of R_z to R_a in samples of MDF can be associated with a more compact structure of MDF, where the proportion of valleys of is smaller compared to the valleys in surface layer of sanded wood that are the result not only of sanding process, but also of structural roughness of wood surface. The ratio of R_t: R_z for sanded MDF in this research was 1.30 for P120+P150 and 1.31 for P120+P180. Similar values of R_z and R_t (lower ratio) indicate constant surface irregularities, while significant difference between them indicates a surface defect in an otherwise constant surface (Web-2). Thus, the lower ratio of R_t to R_z in MDF in relation to wood can be explained by the compact initial MDF structure prior to the sanding. The use of smaller abrasive grains in final stage of sanding created higher deviation between the average surface roughness and the maximum height of peak to valley (8.80 for sanding grits P120+P150 and 9.17 for sanding grits P120+P180).

Although all of measured parameters of surface roughness decreased when using P180 grit sanding paper, instead of P150 grit sanding paper in final stage of sanding, the largest change was in value of R_a parameter (25.8 %). Based on these results, the surface roughness parameter R_a can be recommended to be used for basic evaluation of surface roughness of MDF. For further research, it is necessary to include additional combinations of sanding papers grits to determine the most sensitive parameter for characterization of surface roughness of MDF after sanding.

4 CONCLUSION

Based on the results of this research, the following can be conclu to ded:

- The increase of conveyor speed during sanding (from 8 to 12 m/min) did not led to statistically significant increase of surface roughness parameters, R_a, R_z and R_t.
- The lower surface roughness of MDF, expressed by R_a, R_z and R_t was achieved when using P120+P180 sanding grit sequence in comparison to P120+P150. In respect to these findings, the use of the higher speed of the conveyer and higher sanding grit in final sanding step is recommended. This proposed system ensures higher productivity of the sanding process without reducing the quality of the sanding process in term of the surface roughness. This recommendation should be related to the final use of the MDF and the properties of the material that would be applied on its surface in the following step.

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Chemical Composition of *Pinus brutia* Ten. Turpentine

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ABSTRACT

In this study, volatile composition of *Pinus brutia* Ten. oleoresin collected from Kahramanmaraş (Turkey) was analysed. Oleoresin tapping was done according to borehole method in 2014 between July - November. Average diameters of trees were between 30-31 cm. In each tree two holes were drilled on the south aspect of stem. Diameter and depth of holes were 35 mm and 10 cm, respectively. Hydro-distillation was applied to obtained turpentine and colophony from oleoresin. Chemical composition of turpentine was elucidated with Shimadzu GCMS-QP2010 GC-MS coupled with TR5-MS column and quantified with Shimadzu GC 2010 FID-GC.

Thirty compounds were found in the turpentine of *P. brutia* Ten. The major compounds were α-pinene (60.5%), Δ-3-carene (17.2%) and β-pinene (12.4%). Slyvestrene (2.49%), caryophlene (1.89%), p-cymenene (1.46%) and β-myrcene (1.34%) were the other important compounds.

KEYWORDS: *Pinus brutia*, turpentine, pinene, oleoresin

1 INTRODUCTION

Turkish pine (*Pinus brutia* Ten.) has 5.610.215 hectare spread area in Turkey. It's the second important species concerning with 25% of total forest asset (Anonymous, 2015). Because of its high extractive and oleoresin content it's an important species.

Turpentine (volatile compounds) is an important non-wood product used in solvents and pharmacy, agrochemical and food industry (Füller et al., 2016). Depending on tree species, the composition of the turpentine contains α-pinene, β-pinene, borneol, camphene, carene, carvacrol, caeveol, p-cymene, limonene, linalool, myrcene, phellandrene, terpineol, isopimaric acid, bisabolene and longifolene (Rodrigues-Corrêa et al., 2013).

Chemical components, its ratio and physical specifications of turpentine and colophony effect the quality and prize in the market. Alpha-pinene and β-pinene which are the most important compounds in turpentine used frequently in chemical industry. However, Δ-3-carene has a negative effect to the quality of turpentine in the markets (Rodrigues-Corrêa et al., 2013).

In this study, it was aimed to analyse the chemical composition of Turkish pine turpentine oil obtained from Kahramanmaraş-Turkey by borehole method with GC-FID and GC-MS.

2 MATERIALS AND METHODS

2.1 Plant Material

The oleroresin of Turkish pine (*Pinus brutia* Ten.) was obtained from x 324430 and y 4149941 Kapıcam-Elmalar province of Kahramanmaraş-Turkey. The altitude was 679 m, Bonitet II and area's slope was 15-20°. The diameters of trees were 30-31 cm. Oleoresin tapping was done according to borehole method in 2014 between July -November. In each tree two holes, 20 cm high from the soil level, were drilled on the south aspect of stem. Diameter and depth of holes were 35 mm and 10 cm, respectively. Oleoresin samples were homogeneously mixed and stored in glass jam at cool and dark place.

2.2 Preparation of Extracts

The turpentine was extracted from the oleoresin by hydrodistillation method using a Clevenger apparatus for 4 h. The obtained oils were dried over anhydrous sodium sulphate and stored in the dark at 4 °C until used. Turpentine was diluted with diethyl ether (1:50) before quantitative and qualitative analysis.

2.3 FID-GC and GC-MS analysis

FID-GC analysis was performed by Shimadzu GC-2010 system coupled with TRB-5 capillary column (30 m x 0.25 mm internal diameter, 0.25 µm film thickness). The temperature program was 60°C (5 min.) raised at 2°C/min. to final 260°C (10 min.). Hydrogen was carrier gas. 1 µl sample was injected with an auto injector for equivalent retention time (split ratio 1:50). C7-C30 n alkane mixture of Supelco was used to calculate the retention indices (RI) for the identification of compounds. Triplicate injection was done and mean values were used in the table.

2.4 GC-MS analysis

GC-MS analysis was performed by Shimadzu GCMS-QP2010 system coupled with TRB-5M capillary column. The temperature program was as above. Helium was used as carrier gas (0.8 mL/min), injection temperature was 250°C and ion source was 200°C. Ionization energy was 70 eV. For the identification of compounds FFNSC (Flavour and Fragrance Natural and Synthetic Compounds Library), NIST27, NIST147 and WILEY 7 libraries were used.

3 RESULTS

The chemical composition of *P.brutia* turpentine was identified by GC-MS and the results of GC-FID are given in Table 1. 30 compounds were identified and this represents 99.94% of total oil. As seen in Table 1 α-pinene (60.5%) was the main compound which is used in fragrances, repellents, plasticizers, solvents, perfumery and insecticides (Rodrigues-Corrêa et al., 2013). The second important compound determined in *P.brutia* turpentine was Δ-3-carene (17.2%). Industrial applications of this compound are repellents, manufacture of menthol and pesticides (Rodrigues-Corrêa et al., 2013).

The rate of β-pinene was found as 12.4%. Slyvestrene (2.49%), caryophylene (1.89%), p-cymenene (1.46%), β-myrcene (1.34%), camphene (0.71%), longifolene (0.41%), sabinene (0.40%), α-humulene (0.33%) are the other compounds found in turpentine oil.

Myrcene which has an antioxidant and antimicrobial effects in pharmaceutical industry was found to be 1.34%.in *P.brutia* turpentine. Sabinene, another monoterpene hydrocarbon was found 0.40%. This compound has a potential usage as fuel in the aircraft (Zhang et al., 2014).

Table 1: The chemical composition of *P.brutia* turpentine (%)

	Compounds	RI		ID
1	tricylene	922	0.06±0.001	MS, RI
2	α-thujene	926	0.16±0.001	MS, RI
3	α-pinene	935	60.5±0.06	MS, RI
4	camphene	947	0.71±0.002	MS, RI
5	thuja-2,4(10)-diene	953	tr	MS, RI
6	sabinene	973	0.40±0.00	MS, RI
7	β-pinene	977	12.4±0.001	MS, RI
8	β-myrcene	991	1.34±0.002	MS, RI
9	α-phellandrene	1005	0.05±0.001	MS, RI
10	Δ-3-carene	1011	17.2±0.024	MS, RI
11	α-terpinene	1016	0.08±0.001	MS, RI
12	p-cymene	1021	tr	MS, RI
13	o-cymene	1024	0.06±0.001	MS, RI
14	slyvestrene	1028	2.49±0.004	MS, RI
15	(Z)-β-Ocimene	1037	0.01±0.001	MS, RI
16	(E)-β-Ocimene	1047	tr	MS, RI
17	δ-terpinene	1058	0.17±0.001	MS, RI
18	α-terpinolen	1086	0.07±0.002	MS, RI
19	p-cymenene	1089	1.46±0.005	MS, RI
20	trans-pinocarveol	1139	0.01±0.001	MS, RI
21	p-cymen-8-ol	1186	0.01±0.001	MS, RI
22	β-fencyl alcohol	1191	0.04±0.002	MS, RI
23	trans-3-caren-2-ol	1198	0.01±0.001	MS, RI
24	α-longipinene	1353	0.08±0.003	MS, RI
25	α-copaene	1378	0.01±0.001	MS, RI
26	sativen	1393	0.01±0.002	MS, RI
27	longifolene	1409	0.41±0.004	MS, RI
28	caryophylene	1423	1.89±0.016	MS, RI
29	α-humulene	1457	0.33±0.002	MS, RI
30	caryophele oxide	1588	0.04±0.005	MS, RI
Σ n.i			0.06	

Data expressed as means ± standard deviation, n=3
MS = Mass Spectra; RI = Retention Index

Caryophylene, a sesquiterpene hydrocarbon used in perfume, cosmetic and food industry, was found 1.89%. p-cymenene which was found 1.46% is used as solvent, disinfectant and flavoring (Rodrigues-Corrêa et al., 2013).

As can been seen from Table 2 the main type of compounds in *P.brutia* turpentine were monoterpene hydrocarbons-MT (97.1%) and sesquiterpene hydrocarbons-ST (2.73%). Also monoterpene oxides (0.07%) and sesquiterpene oxides (0.04%) were detected. In another study made in Greece with *P.brutia* turpentine, the amount of MT and MT-oxides were found 97.8-92.9 % and 0-0.1 % respectively (Roussis et al., 2014). According to our results α-pinene was found to be higher whereas β-pinene and 3-carene were lower compared to Greece *P.brutia* turpentine.

Table 2: Main composition types of terpenes in the *P.brutia* turpentine

Compounds	**% in turpentine**
Monoterpene	97.1
Sesquiterpene	2.73
Hydrocarbons	99.83
Oxygenated monoterpenes	0.07
Oxygenated sesquiterpenes	0.04
Oxygenated compounds	0.11
Total	**99.94**

4 CONCLUSION

Oleoresin, produced from *Pinus brutia* Ten. according to the borehole method, was separated into turpentine and colophony by hydrodistillation method. According to GC-FID and GC-MS analyses results it was determined that turpentine of *P. brutia*, contains 30 compounds (corresponding to 99.94% of the total weight). The main compounds were in the order of α-pinene (60.5%), Δ-3-carene (17.2%), β-pinene (12.4%), slyvestrene (2.49%), caryophylene (1.89%), p-cymenene (1.46%) and β-myrcene (1.34%).

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Capacity Calculation Approach for Furniture Companies and Application of a Process Efficiency Analysis

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ABSTRACT

One of the most important decisions affecting the establishment process for a company is production capacity. Basic information such as the size of the enterprise, the establishment area, the qualifications of the machines, the number of the auxiliary facilities, the connections between the worker cells, the flexibility and the automation structure, the supply need, stock, energy and personnel need to be clarified in the process of establishment decision. However, such policies can not be careful enough capacity in the process of organization in fast-growing countries such as Turkey after the new machines are also added as needed to the production line and the line re-balance is composed in a different way. From this point of view, furniture enterprises have a characteristic feature. Flexibility and automation in the furniture factories are two important critical concepts and directly affect production capacity in practice.. This study examined the capacity calculation in Turkey approaches and methods applied in the furniture industry, the process on the basis of existing practices, resources and capacity from the level of injury were analyzed. For this purpose, 55 furniture enterprises operating in Istanbul and the existing capacity reports are discussed. The machinery and installation structures, closed areas, number and quality of employees, product structures, installed power and production and consumption capacities of the companies were investigated and it was investigated whether there is a significant relation between these parameters. As a result of the research, it can be seen that there is not enough meaningful relations between the enterprises in terms of field use, installed power and production capacities. In the Turkish furniture companies, process efficiency are 61% for sizing process, % 64 for edge banding process and % 64 for sheathing process.

KEYWORDS: Furniture Companies, Production Capacity, Capacity Calculation, Proses Efficiency

1 INTRODUCTION

Capacity planning can be considered as a basic management technique based on its own managerial understanding of businesses in the narrow sense. Of course, the enterprises make capacity planning according to their demand and production conditions. However, this is not enough for firms to adequately explain themselves in the market environment. Particularly in the case of working in the public, the official capacity documents of the companies that the company defines according to its functioning are taken as basis for any product request. If the firm enters into a tender, the product range and production quantities of the officially identified capacity certificate become important, not their own calculations and statements. In addition, the production and consumption information of firms can be seen as reference information in organizations such as finance, tax office, environment, energy and municipality in quantity and quality. For this reason, capacity information can sometimes be seen as a major problem for the firm or as a saving tool.

There are concepts such as theoretical capacity, normal capacity and actual capacity for the factory. Capacity reports usually focus on the capacity that the firm can do, not directly on the actual capacity. Actual capacity can only be used as an important indicator for a better understanding of the production and consumption relationship of the firm's product range.

The furniture industry in Turkey is among the five fastest-growing sector. Furniture foreign trade has been steadily positive in recent years (Koç et al., 2016 and 2017). However, in spite of the positive indicators that the furniture sector possesses, how effectively it can use its resources and how much added value it creates is also an important area of discussion (Öztürk, Tunçel 2017). Because the rapidly developing sector is changing the structure very rapidly and adding machines or work cells with advanced technology to the production line in order to get more out of the opportunities caught in the market. In particular, such as computer-controlled machines, flexible work cells that may be of such a high capacity can be used as effective enough, in countries such as Turkey remains committed to running purely coincidental. For example, taking a product or part order that requires intensive work on that work cell can completely change the process efficiency.

The capacity report on The Union of Chambers and Commodity and Exchanges of Turkey (TOBB) Capacity Principles is defined as a document showing the production power of all public and private sector establishments manufacturing and valid for 2 years from the date of approval. Capacity reports must be registered in the trade register of the companies for which the capacity report is to be issued, and must be a member of the place where the workplace is located. Capacity reports; as well as company's contact information, annual production capacities, machine park, raw materials used, capacity calculations, capital and employment information. Capacity reports have a legal basis, such as Trade Law No. 6984, TOBB Law No. 5174. Capacity Report; Investment Incentive Certificate, Inward Processing Permit Certificate, Industry Register Certificate, various import and export transactions, Tenders, Credit supply, Preparation of Industry Data Base. In the Capacity Report Automation System, the products included in the Capacity Reports are coded by the PRODCOM 2010 coding system derived from the NACE coding system, main machines and main consumption items. Capacity Reports are the source of the industry database, which is the only database in which our country can be informed about the industry (TOBB, 2018)

Criteria for the forest industry in the TOBB system are under the heading "3311 Tree and Mushroom Products". Here, there are five criteria for Timber, Particleboard, Fiberboard, Plywood, Wood Covering and Furniture.

In the Furniture Industry Capacity Calculation Criteria, the machine capacity and the labor capacity that can create a bottleneck depending on the product structure are evaluated together. The following main structures are considered in this framework.

a) Panel sizing, edge banding, panel coating (pressing) and assembly capacities are primarily considered for wood-based products (such as chipboard, chopping board, MDF board, MDF laminate board).

b) For solid wood (timber) products: Timber processing, profile drawing, installation capacities are taken into consideration.

c) Wooden processing capacities for framed - upholstered products (such as chairs, armchairs, sofas), installation and upholstery capacities are considered together.

d) Metal Goods Industry criteria shall be used for fully or partially metal based furniture (metal cabinets, tables, bunk beds, seats and chairs, etc.).

The processing capacity of the metalworking raw material is calculated, if necessary, the labor capacity for wood processing capacity, installation and flooring is evaluated. According to the capacity calculation criteria for furniture companies, processing capacities for machinery and labor are defined according to development level. For example, the capacity values that can be taken for panel sizing machines are given in table 2 and the work capacity in table 1 are given in table 2.

For example, the sizing capacity is calculated taking into account the following formula.

$Kc = H \times 8 \times 300$

H: Sizing speed (m^2/hour)(it can be used if the date available)

Table 1. sizing capacity values used in Capacity Calculation of Furniture Firms

Type of Machinery and installation	With manuel loading and unloading sytem (m^2/h)	With otomated loading and unloading system ($m2/h$)
CNC wooden panel sizing machines	150	200
Horizontal wooden panel sizing machines	50	75
Vertical wooden panel sizing machines	30	50
Circular sawing machine with drawing	10	10
CNC wooden panel machining center(if the table size can be us for sizing)	30	50
Other machines	Determined by the chronometer in the examination process.	

Table 2. Panel processing capacity values used in Capacity Calculation of Furniture Firms

Type of Machinery and installation	B(min, m^2 / person x hour)	B(max, m^2 / person x hour)
The firm has only traditional machines	1	2
The firm has either traditional and developed machines(NC, CNC)	3	5
The firm generally has developed machines(CNC,NC)	5	10
The firm has developed machines and works as fason (only sizing, edging, etc)	10	20
The		
The firm has different machines	Determined by the chronometer in the examination process	

$\mathbf{K_{ig}}$ = Capacity of panel machining per year (m^2/year)
$\mathbf{K_{ig}}$ = B x N x 8 x 300
B: the quantity of panel machining per a person X hour
N: Numbers of workers

The capacity for edge banding application is calculated according to the following formula.
$\mathbf{K_b}$ = H_b x 60 x 8 x 300 x D
$\mathbf{K_b}$: Capacity of edge banding per year
$\mathbf{H_b}$: Speed of edge banding (m/minute)
CNC edge banding machines: 15-20 meter/minute
Traditional edge bending machines : 8-12 meter/minute
D: Loading percentage (% 60-80)

In the capacity calculation for products such as chair seats, labor time to be needed for each product is taken in bar 3 and calculated according to the following formula.
$\mathbf{K_{ü(n)}}$: Production capacity of the product
$\mathbf{K_{ü(n)}}$: K_{ig} x p_n / B
$\mathbf{K_{ig}}$: Labour capacity per year
$\mathbf{p_n}$: Percantage of labour used for the product
B: Required labour for per product (person x hour / number of piece)

Table 3. Values of occupancy in seating group products such as chair seats

Type of Product	B(min) Person xhour/number of piece)	B(max) personxhour/number of piece)
Wooden chair	1	3
Wooden armchair (for a person)	2,5	6
Wooden armchair set (for a products grup)	12	32
Soffa (triple)	4	10
Wooden lounge suite	15	30
Other products	Determined by the chronometer in the examination process	

The transaction capacities determined by identifying the bottleneck points are distributed to the products taking into account the structure of the production schedule of the operator. In particular, how much of each of the products defined in the database will be generated is determined, and the consumption capacities are calculated taking into account the codes in the code system, taking production capacity and input structure into account.

2 MATERIALS AND METHOD

This study examined the capacity calculation in Turkey approaches and methods applied in the furniture industry, the injury levels were analyzed from the current process for existing applications based on furniture firms. For this purpose, existing capacity reports of 55 furniture operations operating in Istanbul and renewed capacity reports in the last 1 year have been handled. The machinery and installation structures, closed areas, number and quality of employees, product structures, installed power and production and consumption capacities of the companies were examined and it was researched whether there is a significant relation between these parameters. MS Excel and Minitab software are used for this purpose.

As the data collection area, the TOBB data base covers the activity area code 31.09.12. The purpose of this limitation is to increase the efficiency of the evaluation based on companies with similar production structure. In the TOBB database, the presence of a total of 307 firms with capacity reports in the Istanbul region was identified in the 31.09.12 field. These companies are generally companies that produce wooden or board products (bedrooms, dining rooms, young room sets, decoration products) or semi-finished products. A total of 150 of these companies have been renewed in the last year. The evaluations were carried out by transferring the information defined in the report of 55 companies to the excel environment.

The information on the approved capacity reports of Firms was transferred to the excel environment and evaluated.

3 FINDINGS

3.1 General Information on Furniture Firms

The general overview of companies operating in the area of 31.09.12 in the Istanbul region is summarized in table 4. The average number of employees of 55 firms with a total of 2,724 employees is 50 in average. The average engineer employment of the firms is 1.5 per firm, while the closed area is 4.195 m2. There are significant differences between firms in terms of number of employees. As Figure 12 shows, the number of employees can range from 10 to 250. This difference can be seen in almost every area from the number of engineers to the number of CNC machines. B in Figure 2 shows the number of engineers working and the situation regarding the existence of CNC machines.

Table 4. General Information on Furniture Companies Covered by Research

Total number of employees	**2.724 number**
Average number of employees	49,5 person/company
Number of Average Engineers	1,5 number/company
Average Forest Industry Eng. Woodworking End. Eng	0,6 number/company
Average Closed Area	4.195 m²/company
Average machine equipment value (year 2018)	1.121.184 TL/company
Average number of CNC machines	3 number/company
Most common CNC; CNC machining center	1,1 number/company
Most common 2nd place CNC: CNC wood panel sizing	1,0 number/year
Most common 3rd place CNC: CNC edge banding machine	0,7 number/company
The average installed power of the companies	233,9 kW/company
Average panel processing capacity	122.018 m2/company
Process efficiency in panel sizing	61,1 %
Process efficiency in edge banding	64,64 %
Process activity in panel cover	58,74 %

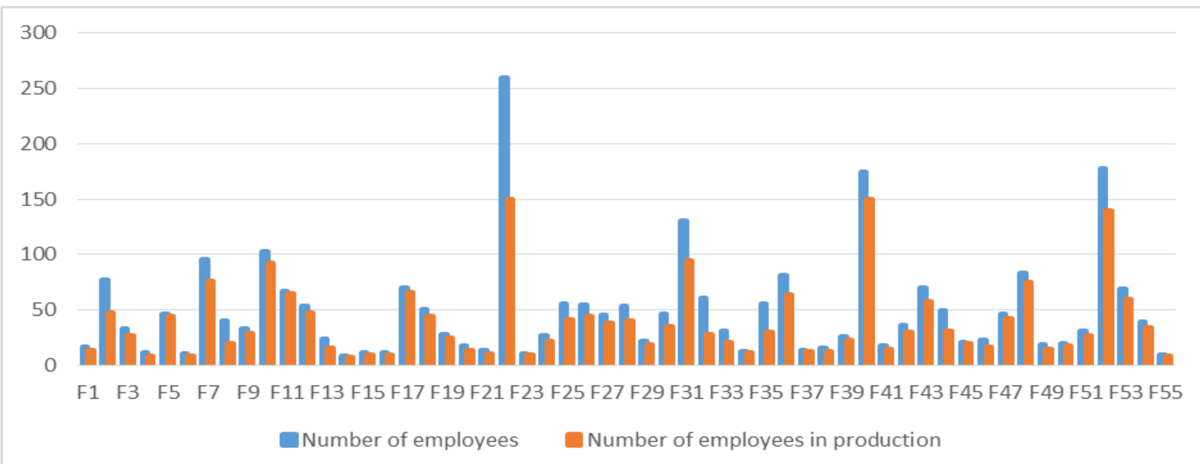

Figure 1. Numbers of Workers in the Turkish Furniture Companies

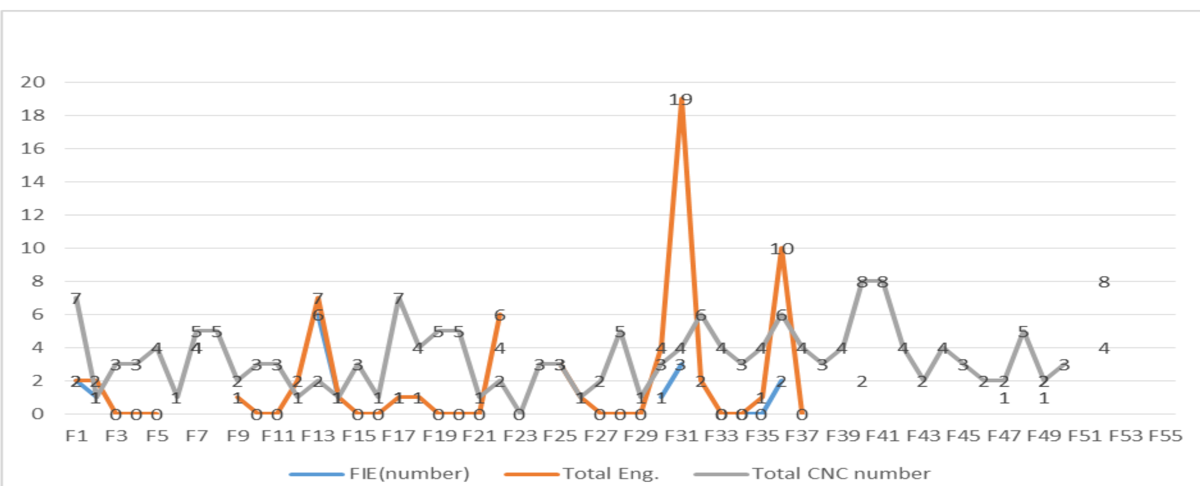

Figure 2. Numbers of Engineers and CNC in the Turkish Furniture Industry

3.2 Process Efficiency in Furniture Firms

Process efficiency has been examined for three sub-processes in furniture production. If we define furniture production as the main process, its sub-processes are panel sizing, edge banding and panel coating processes. These sub-basic process steps are often seen as a bottleneck in capacity calculations. Panel sizing usually indicates the first basic process step. All generic entrances pass through the sizing process at least once. The sizing process has been a highly planned, controllable and manageable process with technological advances. Especially CNC machines are a process in which machine capabilities are fully known, process, waste time, and operational pressure can be managed to a great extent. However, the average efficiency value for the sizing process in the current conditions was 61%. That means 40% of the capacity remains idle.

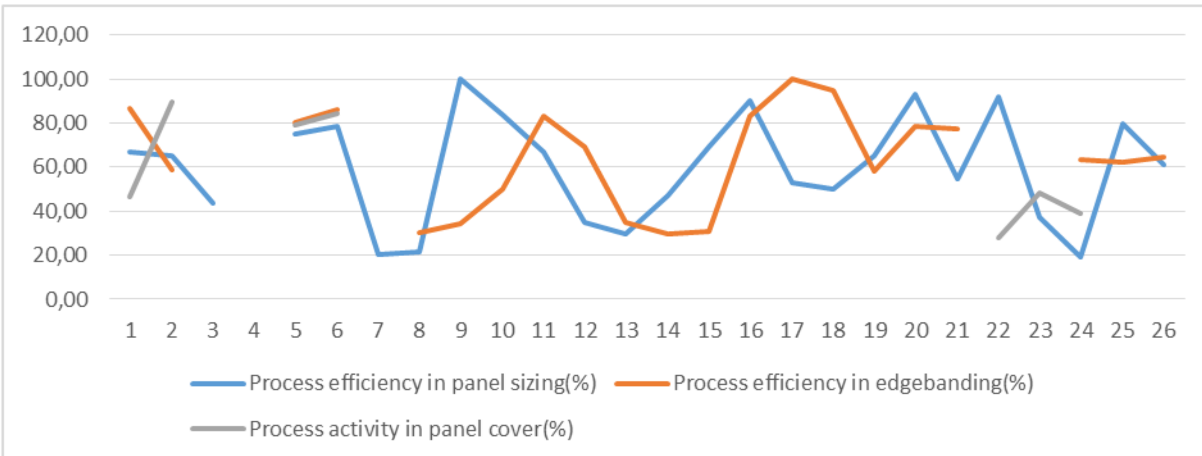

Figure 3. Process Effectiveness in the Turkish Furniture Industry

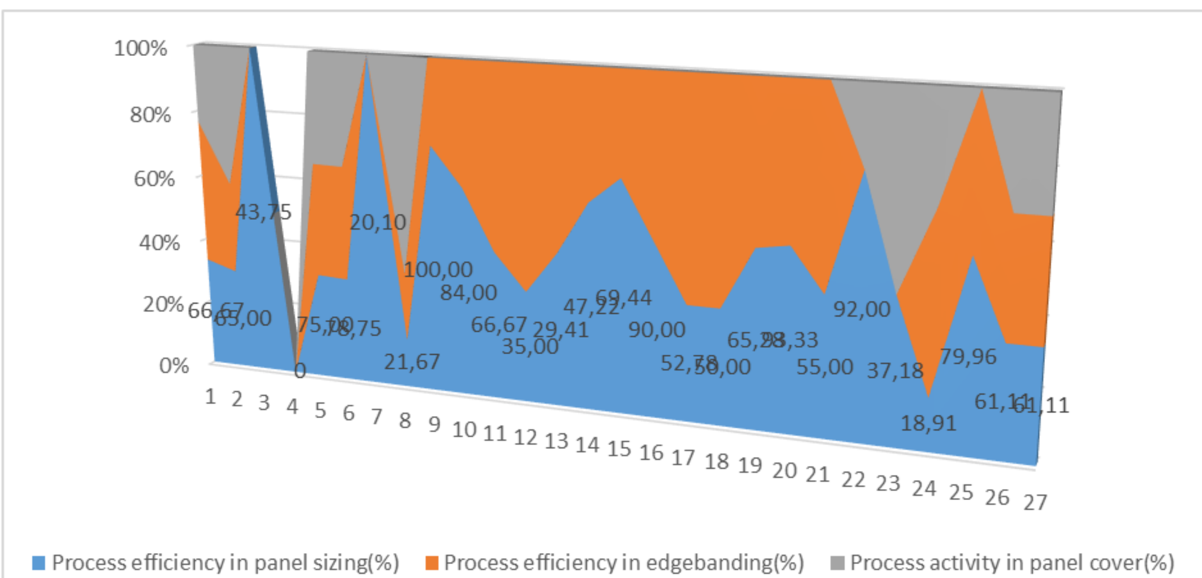

Figure 4. Process Effectiveness in the Turkish Furniture Industry

3.3 Relations Analysis Between Parameters of Furniture Companies

The relationship between the parameters is given in Table 1. These values were obtained by using Pearson correlation analysis. According to results, the relationship between machine value and number of person, number of CNC and number of person, number of CNC and machine value, power and machine value, processing capacity and machine value, power and number of CNC, processing capacity and number of CNC, processing capacity and power were found significant factors. Because Table 5 displayed the P -value is less than 0.05 showing the model is significant at 95% confidence level. Moreover, the matrix plot (relations matrix) is shown figure 5. In this figure, the directions and structure of relations can be evaluated.

Table 5. Relationship between the parameters.

Parameters	Number of person	Area	Machine Value	Number of CNC	Power
Area	0.180				
Machine Value	0.001	0.638			
Number of CNC	0.042	0.150	0.000		
Power	0.129	0.778	0.008	0.018	
Processing Capacitiy	0.154	0.346	0.000	0.000	0.002

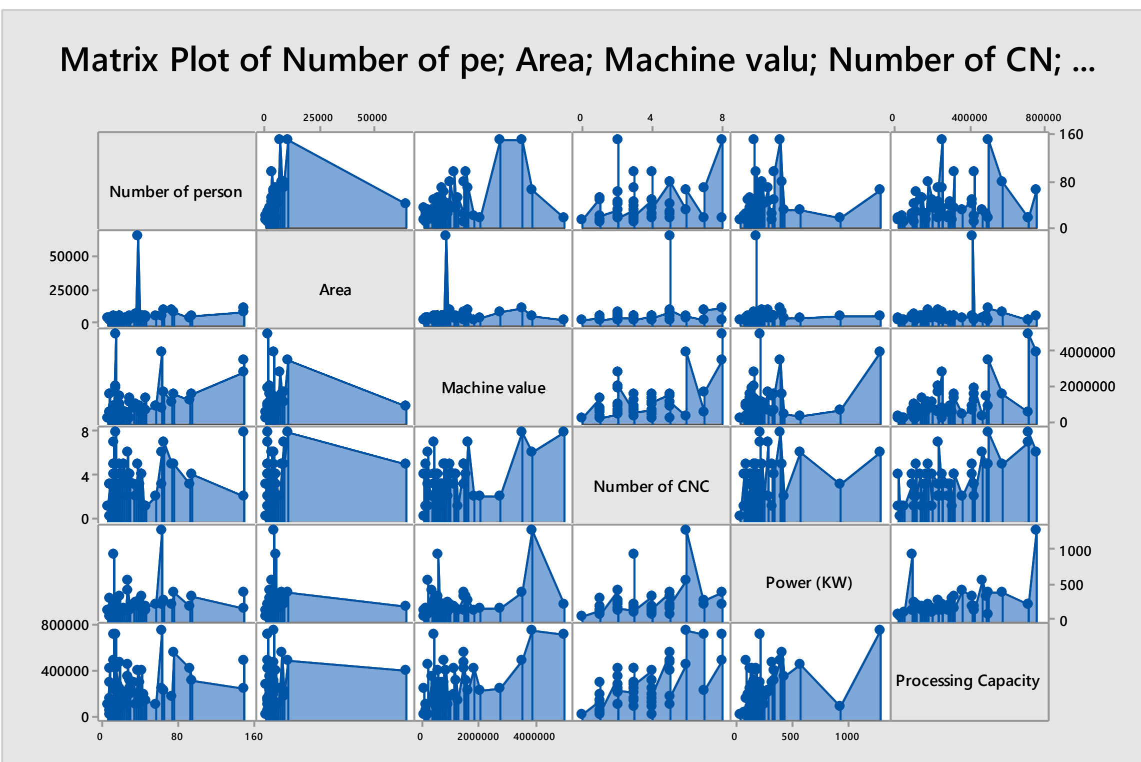

Figure 5. Matrix Plot of the capacity parameters.

4 CONCLUSION AND DISCUSSION

The furniture industry in Turkey is rapidly developing key sectors. The production value of the sector is increasing rapidly; export and import are continuously developing. From time to time, the wave of domestic demand for furniture shows a dynamic structure, and firms are turning to new demand areas and deepening in foreign markets. Despite these positive developments, research shows that the furniture sector also carries significant structural problems and those significant inefficiencies in resource utilization, productivity and profitability continue to develop together.

By understanding the causes of failure of one of Turkey's most important tools to guarantee the development of the furniture industry is rapidly starting to improve application. One of the important areas to be focused on in this respect is process competence studies. Turkey Furniture Company in process efficiency ranges between 58-64%. If companies want to reduce their costs in the long run and work with higher profits, they have to master every detail of their processes and increase their level of process competence. In the short term, sales-driven high profits are not enough to secure long-term firm future. It is also seen that furniture companies frequently increase production capacity and skills with advanced machines (such as CNC machining, CNC sizing, CNC edge banding) at critical production stages depending on the students they particularly catch. Having an average of 3 CNC machines in furniture firms is an important indicator of this change.

However, the value of the process efficiency at the level of 40% is a serious consideration. As firms develop in terms of machine installation, personnel, and all physical conditions, it is expected that the relationship between the parameters affecting each other is higher. Monitoring this relationship will not improve capacity, it will be an important tool to guide the factory planning. In this sense, capacity reports should be seen as important issues for companies. Capacity reports also provide an important contribution in terms of market balances in the market, even if they represent the actual theoretical capacity. It can also be seen as a guiding tool in balancing companies' lines.

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Development of Foreign Trade and Production in Furniture Hardware Sector in Turkey

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ABSTRACT

Nowadays, the birth and spread of modern electro-furniture equipped with technology as a necessity of modern trends and global trends have increased the importance of furniture accessories. In this study, accessories that give functionality and prestige to the furniture and contribute to the quality, aesthetics and beauty at the same time, industrial production and foreign trade as the development of the structural situation in Turkey in this field have been investigated. In this context, the development of the sector present results of the study conducted on furnishing accessories manufacturer in Turkey last 10 years foreign trade (exports-imports) was evaluated in the framework of the data. Material and technological development level of world standards, some product groups have shown that an equivalent structure of Turkey accessory industry; (45.4%) in terms of catching up and implementing the development trends in the world furniture sector and being in a market environment open to unfair competition conditions (35.6%).

As a result, the general problems of the sector study essentially both product groups, identified as undefined as well as industry groups stems from a sector effect in achieving the strategic objectives of Turkey's furniture sector, was also making suggestions for the improvement of international competitiveness of taking accessories industry into consideration.

KEYWORDS: Furniture hardware, Hardware production, Hardware import, Hardware export.

1 INTRODUCTION

In this study, accessories that give functionality and prestige to the furniture and contribute to the quality, aesthetics and beauty at the same time, The development of production and trade in Turkey were examined.

According to literature research; furniture and building elements accessories which have been tried to be explained with various names such as hardware items, hardware items, architectural tools, building materials or woodworking aids; furniture and door-window fixing, joining, ease of movement, protection from all external influences, aesthetics and comfort. It is clear from this definition that furniture is; The importance of hardware that contribute to quality, usability, prestige appearance and reliability is steadily increasing. Because, today, with the decreasing market conditions, in the increasing competitive environment, the furniture can gain the new demand dimension and the sales advantage can be obtained (Dilik 1992, Kurtoglu and Dilik 2018).

It is seen that the production quantities of the accessories with various models and types are determined by classifying them as 7 product groups based on the usage place and functions in the researches. There are no definitions for customs tariff statistical position numbers, which are based on furniture accessories, neither manufacturing industry classification nor foreign trade statistics, and it is seen that they are scattered among manufacturing industry and groups belonging to foreign trade statistics classes by TUIK. This includes product groups; Hinges are classified as furniture and door-window, sliding mechanisms (systems), handles and knobs, shutting equipments (locks and latches), assembly fittings and connecting elements, underfoot equipments (castors and glides, under frames), other hardware fittings (Kurtoglu and Dilik 2017).

On the other hand, it is important for international competitiveness to know the level of development of main industry and subsidiary industry integration or complementary sectors, in the sense that the countries with the world accessory market are also important countries in world furniture trade. For this purpose, it is determined the structural condition of this sector in Turkey in 1992 and by two separate research results made in 2003 for the last 10 years, Turkey Statistical Institute of foreign trade (export-import) the development of the production and foreign trade accessories industry utilizing data was tried to determine (Dilik 1992, Dilik and Erdinler 2003, Uçar 2016, TUIK 2004, TUIK 2018).

2 MATERIAL AND METHOD

In this research which covers the development of production and foreign trade in the furniture and buildings element hardware sector, A method based on literature research has been chosen. The firms to be taken in consideration in this research were chosen with referance to:

- The results of a previous research,
- The records of chamber of industry in the cities where the furniture and building elements producers are mainly located,
- Records of Turkey Statistics Institute,
- Records of foundations and organizations related with this profession,
- Hardware sellers and brokerage companies have benefited.

However, it has been difficult to reach all of the manufacturing enterprises that make up the sector, largely because the majority of enterprises are not registered in the various environments mentioned above, or because they have been closed or have changed the field of activity in parallel with developments in world trade and economic problems. For this reason, the development of production; were evaluated in the form of regional surveys in the regions where the enterprises were concentrated and on the data covering 1996-2000 years. Thus, the number of 137 known enterprises has been updated to 128 (Dilik and Erdinler 2003). The development of foreign trade in this area has been tried to be determined by evaluating TUIK data covering the years 2007-2017 (Kalıpsız 1988).

3 RESULT AND DISCUSSION

3.1 General Characteristics of Turkey Furniture Hardware Manufacturing Sector

The production sector of furniture and building elements hardware is not defined as a separate industrial area and is distributed in the sub-sectors of the metal goods industry in the manufacturing industry as product groups (35590125-Furniture wheels, 38110201-Locks and keys, 38110301-Hardware materials, 38190301- nails and pin, 38190901- bolts, screws, etc.) are visible.

In this production sector, it was determined that 128 businesses operate in Turkey. Of these, 17 (13%) are active in other areas besides hardware production. In this survey where 52% participation is provided, 25% of the sector enterprises are small scale, 36% are medium scale and 39% are large scale, 21% of them are private or common partnership, 42% of them are in joint stock companies. Considering that the majority of enterprises not participating in the operation are small-scale enterprises, it has been found that the enterprises have not yet completed the process of incorporation (Table 1). However, it has been found out that most of the sector enterprises are in the tendency to turn into capital companies and as a capital enterprise. (Dilik and Erdinler, 2003).

Table 1: Structural view and distribution of sector enterprises.

Ownership		S.S.B.*	M.S.B.*	L.S.B.*	Total	
					Number	Percent (%)
Incorporated company		-	10	15	25	37
Limited company		6	11	11	28	42
Private company or simple partnership		11	3	-	14	21
Total	Number	17	24	26	67	100
	Percent (%)	25	36	39	100	

*) As the criteria of the scale, the definition of the size of the enterprise made by TUIK was taken as basis and the evaluations were made according to this approach.
S.S.B.: Small-scale business (Less than 10 employees)
M.S.B.: Medium-scale business (10-25 employees)
L.S.B.: Large-scale business (25 or more employees)

The capacity utilization rates of sector enterprises are based on 2000 data; 40% is above the establishment capacity, and 30% is under the establishment capacity. When this situation is examined on the basis of business scale; L.S.B.'s predominantly above the establishment capacities, S.S.B.

3.2 Turkey Furniture and Building Elements Hardware Production

Furniture and building accessories Turkey production quantities in Table 2 are determined by classifying the form as shown 7 product groups. The last 5 years production quantities of this production sector determined in this frame have been given separately as product groups. Except for some product groups (such as hinges, locks, etc.), the production amounts of furniture and structural elements, which are inadequate both in terms of quality and quantitatively, have tended to increase rapidly in 1999-2000 according to the demand level of the country in 1999 and after 1999 , with the economic crisis in the globalizing world, it is seen that the earthquake disasters that lived in our country, economic instability and constricted investment studies and unfair competition environment are seen to be caused by such reasons. (Dilik and Erdinler, 2003).

Despite the fact that the statistics of recent years have not been reached, it can be said that this development in production sector continues parallel to the development in the world furniture sector. This is evident from the fact that the sectoral reports prepared by professional organizations, as well as the information obtained from accessory sellers and brokerage houses, and positive developments from foreign trade (export and import) data. (TBSB 2013, TOBB 2015, Uçar et al. 2016, TUIK 2018)

If these production quantities, which are determined as one of the indicators related to the level of development of the sector, will be examined individually by product groups; Turkey hinges and furniture production in 1996 with a total production of 105 million units in 2000 as door and window hinge is observed to be around 151 million units.

The total production of furniture and door-window sliding mechanisms was determined to be around 92 million sets in 2000, while it was 18 million in 1996. It is seen that the sector has been making a rapid leap after the 1990s, especially in this product group, where domestic production is inadequate both in terms of quantity and quality against the demand level of the country.

According to this survey is evaluated as a separate product group of drawer systems of total production in Turkey, from 47 million in 1996, the team was determined to be around 81 million sets in 2000.

The production of door and window handles in Turkey; while it was 185 million in 1996, it was determined as 188 million in 2000. If furniture handles and handles are to look at production quantities; It was determined that 265 million pieces were produced in 2000 while it was 202 million pieces in 1996. Off the supplies provided under the product groups and key manufacturing data related to Turkey, shutting equipments all kinds of locks; it was determined to be around 85 million units in 2000 while it was 76 million units in 1996.

Regarding wood screw production, the figure was 3.2 tonnes in 1996 and 7 tonnes in 2000. In relation to the production of assembly fittings and connecting elements, a total of 81 million number were produced in 1996, and about 126 million number were produced in 2000.

The production of underfoot equipments including all types of underfoot castors and elements except wooden foot was estimated to be 91.6 million number in 2000 while it was about 63 million number in 1996.

Table 2: Production amount of hardware for Turkish furniture and building elements by years.

Product Group	**1996**	**1997**	**1998**	**1999**	**2000**
1. Hinges					
- Furniture hinges (x bin adet)	70.658	94.490	137.187	110.080	114.150
- Door and window hinges (x bin adet)	35.000	41.300	50.100	48.750	36.700
2. Furniture and door-window sliding mechanisms (x bin takım)	18.700	55.500	38.090	62.750	92.000
3. Drawer systems (x bin takım)	47.550	89.450	92.100	85.320	81.850
4. Handles and Knobs					
- Door-window handles (x bin takım)	185.000	190.500	205.100	192.000	188.500
- Furniture knobs and handles (x bin adet)	202.000	278.000	303.750	250.100	265.000
5. Shutting equipments (Locks and Latches) - Locks (x bin adet)	76.100	78.500	85.600	80.200	85.000
6. Assembly fittings and connecting elements					
- Wood screws (x ton)	3.250	6.600	7.235	7.050	7.000
- Plastic connecting elements and knock-down fittings (x bin adet)	81.000	105.100	125.800	120.000	125.900
7. Underfoot equipments (furniture castors, glides etc.) (x bin adet)	63.000	71.300	78.550	85.250	91.600

3.3 Foreign Trade of Turkey Furniture Hardware

It can be said that the production quantities determined in the study are the amount of hardware which are subject to commercialization at the same time. On the other hand, if the hardware will look at Turkey's import and export value in order to demonstrate the development of foreign trade (Figure 1), which is an increase of imports and exports. However, with the economic crisis of 1998, the stagnation after the earthquake disaster in 1999 has been seen in all industrial branches as well as in the accessory sector and the import and export values have decreased. This decline continued after 2000. However, it is worth noting that the import coverage ratio of exports over the years. For example, this ratio increased from 43% in 2000 to 50% in 2003 (Figure 2).

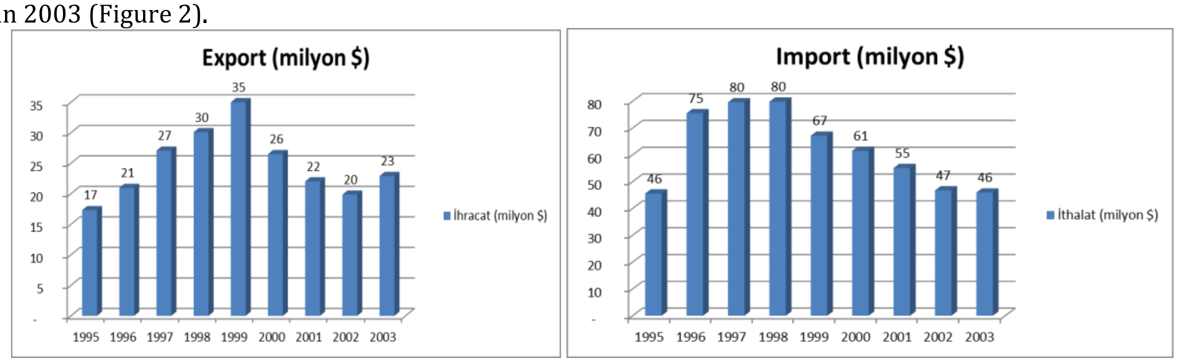

Figure 1: The foreign trade data from the period 1995-2003 furniture hardware sector in Turkey (TUIK 2004)

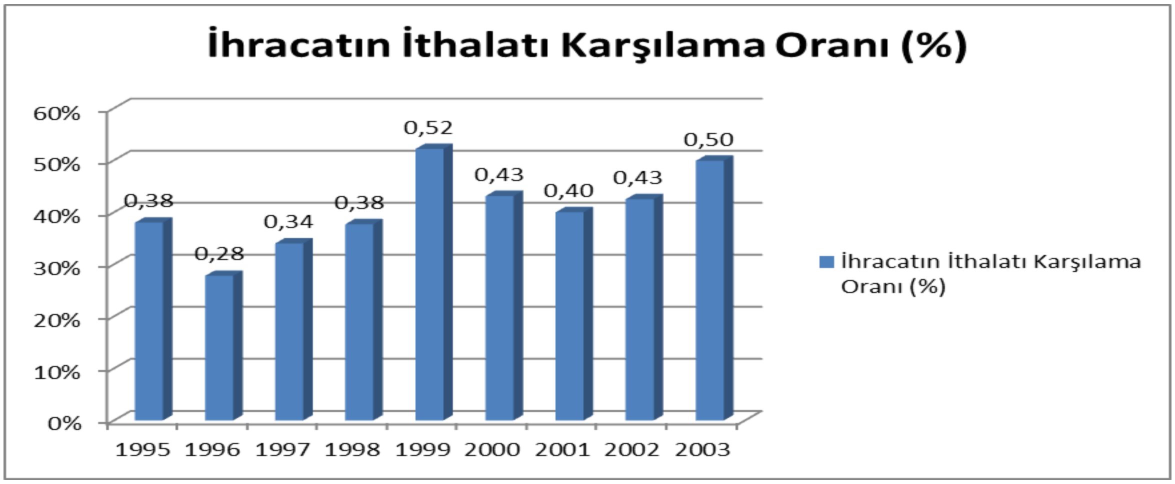

Figure 2: The export-import ratio between the period 1995-2003 furniture hardware sector in Turkey.

This development in the foreign trade of the sector is obviously seen in the foreign trade values covering the years 2007-2017, which is shown in Figure 3, which has increased exponentially in favor of export especially after 2000. If we look at the export coverage of imports of this period, it is possible to say that the sector continues to develop in the positive direction by giving more foreign trade (Figure 4).

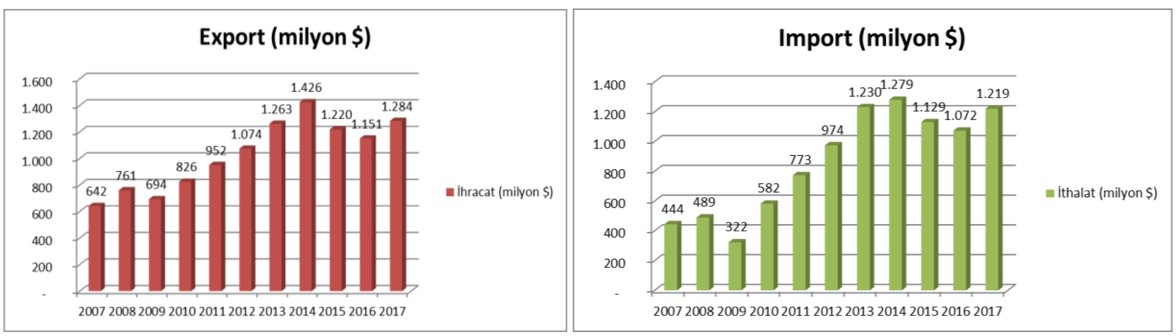

Figure 3: The foreign trade data between the years of 2007-2017 furniture hardware sector in Turkey (TUIK 2018).

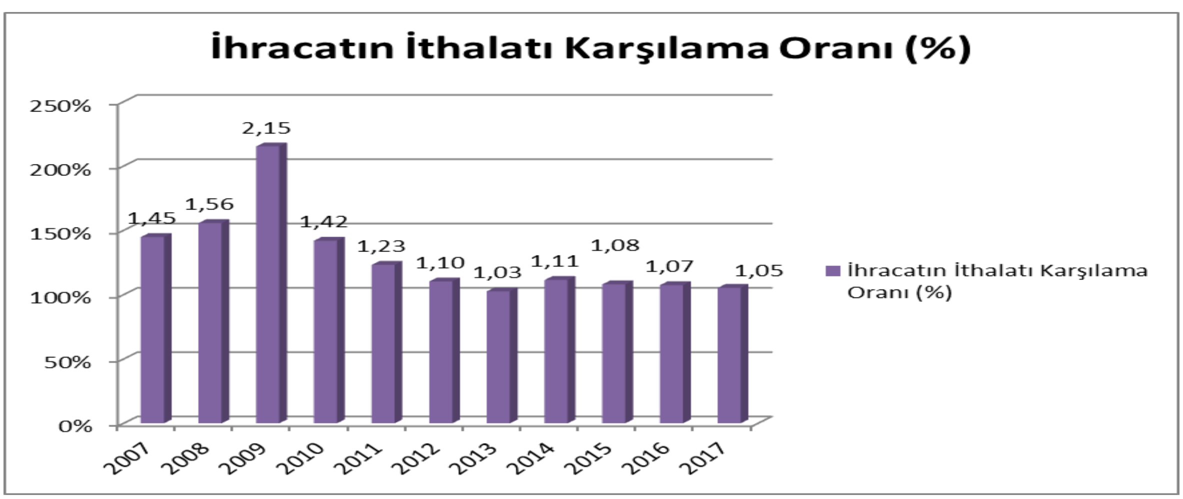

Figure 4: The export-import ratio between the period 2007-2017 furniture hardware sector in Turkey.

In this research, if the import and export values in the accessory sector are to be considered as their product groups in their shares, while imports take the first order hinges while second order take furniture and door-window sliding mechanisms and drawer systems. Then comes door and window handles and knobs, plastic connecting elements and knock-down fittings, locks, underfoot equipments and wood screws, respectively. In the case of exports, it appears that the hinges and locks are in the first place. The distribution of the other product groups comes from door-window handles and knobs, wood screws, underfoot equipments, drawer systems, plastic connecting elements and knock-down fittings.

This value is determined in relation to Turkey's foreign trade hardware, compared with developed countries in the foreign trade of hardware is quite low production values are evident (Table 3). On the other hand, while export values higher than the value of imports in these countries, the export value in Turkey until 2007, said to be lower than the import value (Dilik and Erdinler 2002). For example, Germany imported $ 0.99 billion in 1998, compared to $ 2.81 billion in exports. Italy's imports of $ 0.95 billion compared to $ 2.35 billion of exports in 1998. In contrast, if we will see the foreign trade of Turkey the same year, 1998, $ 30 million health response to export $ 80 million worth of imports convenience. We see that these values are decreasing both in exports and imports after 2000 due to the reasons we mentioned earlier, but after 2003 we are in an increasing tendency (Figure 1, Figure 3).

Table 3: Exports and imports of furniture and building elements hardware of some European countries (Assofermet 2000, TUIK 2004) (* Values are rounded.)

Country	Export (billion $)*						Import (billion $)*					
	1995	1996	1997	1998	1999	2000	1995	1996	1997	1998	1999	2000
Germany	2.10	2.30	2.75	2.81	2.89	2.97	0.82	0.91	0.94	0.99	1.01	1.04
Italy	1.75	1.96	2.20	2.35	2.43	2.51	0.71	0.83	0.88	0.95	0.98	0.99
Holland	0.39	0.43	0.45	0.48	0.53	0.58	0.29	0.34	0.36	0.41	0.44	0.49
Turkey	0.02	0.02	0.03	0.03	0.03	0.02	0.05	0.08	0.08	0.09	0.06	0.06

In the question regarding the export situation of enterprises participating in the survey, 48 enterprises did not export at all (72%), 10 enterprises exported between 1-5% (15%), 3 enterprises stated that they export between 5-10% (4% Exported over 50%. As can be seen, the share of exports of exporting enterprises in total production is very small except for a few enterprises. It has been determined that the first order is locks and the second order is hinges in the hardware exports of the sector. Again, from the results of the survey, it seems that exports to almost all the countries of the world for this manufacturing sector, but only 28% of enterprises are interested in foreign trade. It has also emerged that the Middle East, Turk and Balkan countries are important markets. However, exports have also been made to European Union countries.

4 CONCLUSION

As a result;

- Furniture and building elements hardware have been identified as the general problems of the manufacturing sector originating mainly from product groups, not necessarily defined as industrial groups. The main problem seems that the sector is undtermined.
- It is found that the Turkish furniture hardware industry lacks vision and mission. It has been found that the vast majority of sector enterprises are in the tendency to turn into capital companies and as a capital enterprise.
- Material and technological development level of world standards, some product groups have shown that an equivalent structure of Turkey furniture hardware industry; (45.4%) in terms of catching up and implementing development trends in the world furniture sector, and being in an open market environment for unfair competition conditions (35.6%).
- Both furniture manufacturers, the industry as from interviews with both accessory marketing companies, Turkey furniture hardware required opposite the hinges and the level of demand in the country except for groups of locks production quality, has emerged as both the quantity as inadequate.

- It is clear from the findings of the development of foreign trade that the developed countries in this area remained far behind the data on foreign trade. However, like the countries that developed together with the furniture sector, our country also started to have higher export values than the import values in 2007.

Within the framework of these results, the following proposals have been developed in order to enable the sector to continue its development and to increase international competitiveness;

- As soon as possible the sector should be defined as a separate sector group,
- Increasing the level of technology and product quality for capturing and implementing development trends in the world furniture sector,
- Main-supply industry integration must be provided,
- Establishment and dissemination of joint marketing organizations, increasing cooperation between businesses and preventing open market environment for unfair competition conditions,
- Creation of an image (brand awareness) with original design and products.

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ABSTRACT

In this study, *Trapa natans* nut collected from the costs of Inkumu-Bartin was analyzed according to its lignin content. In the last two years, *T. natans* nut husks were seen in the north-west Anatolia costs. The husks were 3-5 cm wide and sclerosis. Husks were miled in a Wiley-mill. Acid-insoluble lignin content was determined according to TAPPI T222om-02 as 28.31%. TGA and FTIR analysis were done.

FTIR analysis indicated that *Trapa natans* contained cellulose, hemicelluloses and lignin. The peaks at 1506-1510 cm^{-1} in both samples are characteristic peaks for the lignin components due to C = O and COO- non-symmetric stretching vibrations in the aromatic rings of the lignin structure. 1510 cm^{-s} peak is found in the literature as lignin's fingerprint peak . The peaks at 1230-1270 cm^{-1} band show the vibrations of guayasil ring with CO tension in lignin and hemicelluloses. Around the 900, 1025, 1030 and 1050 cm^{-1} peaks cellulose's O-H, C-H and C-O-C type bonds are seen. When TGA analyzes are examined, approximately 4.5% of the sample is lost from 30 °C to 200 °C. At these intervals, samples generally lose volatile constituents and moisture. From 200 to 271 °C 4.6% of the weight is lost. The decrease in this range may be due to the decomposition of cellulose and hemicelluloses. The DTG curve shows maxima weight-loss occurring at 349 °C. The weight-loss in the range from 271-352 °C is about 50%. Pure lignin sample's TGA and DTG curve results show 10%, 50%, and 70% weight-losses at 233 °C, 489 °C, and 1167 °C respectively. According to these results, dominantly lignin and small quantities of cellulose and hemicelluloses are present in trapa samples. After consumed as food, husks can be utilized in various areas according to its lignin content.

KEYWORDS: *Trapa natans*, lignin, water-chestnut.

1 INTRODUCTION

Trapa natans L. (TN); known as water chestnut or water-nut is an annual, floating–leaved plant that naturally grows in rivers, lakes, fresh-water wetlands and firths in Asia and Europe (Yasuda et al., 2014). In Turkey, it is found in thrace (Istanbul, Edirne and Kırklareli) (Web-1). In the last years, it was seen in the cost of North Black Sea region (TÜBİVES, 2018). It is a warm season crop and can harvest in June-September (Liu et al., 2010; Parker and Waldron, 1995).

It has 5 cm wide leaves with sharp serrate and stiffy hairs. It also has 15 cm long submersed leaves. In spring time, it has white flowers. Having an economic value, the fruit grows under water and has horned nut-like structure (Web-2).

It has an economical worth as food and raw material in different areas especially for China and India. Dried and grounded nuts can be added into flour for baking (Sturtevant and Hedrick, 1972; Web-3).Because of high water content, it is used for thirst and also used as traditional medicine. In an experimental study was showed that herbal mixture extracts which include TN decreased the pain of shingles (Hijikata et al., 2005). The outer part of nuts is utilized in pulp-paper, fish food, compost and biofuel (Hummel and Kiviat, 2004).

TN resembles a water lily at first view with its green leaves floating on the water. Floating leaves have rosette form, and leaflet is solid and triangular (5.2x6.4 cm) (Nedhuka and Kardyum, 2016). The leaves are dark green, and their bottom surface is reddish purple (Adkar et al., 2014; Zhu, 2016). The submerged stems cling to the soil by extending to 1-5 m along the roots (Adkar et al., 2014; Hummel and Kivrat, 2004).

TN, which has been used for food and therapeuthic purposes in China and India since ancient times (Zhu, 2016), is a major ingredient in many food products such as jams, beverages and biscuits in China (Sheng et al., 2006). Due to its characteristic taste and high nutritional value, it has commercial importance in the food industry (Parker ve Waldron, 1995; Liu et al., 2010). The nuts has 15% protein, 7.5% fat, 52% starch, 3% sugar and 22.5% water (Zhu, 2016). TN is also an important source in terms of nutrients, protein, minerals and vitamins for fishs (Kalita et al., 2007; Kalita et al., 2008; Mukherjee, et al., 2010). It is also stated in the ancient medicine books in China that TN husks can help fight against various diseases such as diarrhea and alcohol poisoning (Sheng et al., 2006).

Its fruits and husks have a rich content consisting of starch, dietary fibre, essential amino acids and some types of phenols and minerals. Previous studies have shown that TN leaves, fruits, husks, flowers and roots have 19.5% amylose (Lertphanich et al., 2013), 1.9 mg/g phosphorus (Akao et al., 2013; Zhu, 2016), fatty acids such asnervonicacid (63.5%), α-linolenic acid (6.4%), palmitolenic acid (6.4%), linoleic acid (6.3%) (Mukherjee et al. Zhu, 2016), phenols such as caffeic acid, chlorogenic acid, ferrulic acid and 3-O-methylgallic acid (Stoicescu et al., 2012; Zhu, 2016), flavonoids such as quercetin and kaempferol (Niranjan et al., 2013; Zhu, 2016). The majority of fatty acids (69.3%) in the TN content form unsaturated fatty acids (Mukherjee et al., 2010). The fruit in the husk contains a higher amount of starch, while the husk contains higher amounts of phenolic material.

TN husks contain higher amount of C (43.4%), O (50.4%) ve H (5.7%) (Liu et al., 2010). Its husk have higher bioactivity properties (anti-cancer, anti-atherogenic, antimicrobial, antioxidant, hepatoprotective, immune enhancing, anti-imflammatory, anti-hyperglycemic, anti-skin photoaging) than fruits (Zhu, 2016). After harvesting period, pink colored TN husks change its color to dark brown in time (Huang et al., 2016). These husks contain dietary fibres and polyphenols (such as hydrolysable tannins) (Yasuda et al., 2014; Kim et al., 2014; Huang et al., 2016). The total phenolic, flavonoid and tannin amounts in TN husk extract were: 63.81% mg/g gallic acid equivalents, 21.34% mg/g of rutin equivalents and 17.11% mg/g of total tannin equivalents respectively (Malviya et al., 2010; Zhu, 2016).

Despite all of the good qualities, TN, which was exposed over large areas in North America in the 1800's, was considered as a tribulation. This is why it prevents the light permeability below the surface in the water it is spreading. With the reducing amount of light permeability, the amount of dissolved oxygen in the water reduces and that is adversely affects fish communities. It also displaces other submerged plants, making it difficult to navigate the boats, catch fish and swim (Hummel veKiviat, 2004; Zhu, 2016).

The TN fruits must be peeled from the dark brown husks before they are cooked or canned. The peeled husks are burned or disposed of as waste. Husks thrown in this way cause water and air pollutions (Liu et al., 2010).

Lignin is the most abundant natural polymer after cellulose. It generates 10-25% of the lignocellulosic biomass. It has a complex structure composed of different types of phenol (sinapyl, p-coumaryl, and coniferyl alcohols). There are many usage areas such as emulsifiers, dyes, thermosets, dispersant agents, synthetic flooring, and paints (Watkins et al, 2015).

TN husks include 72.3 g/100 g (dry basis) of crude fiber. When this amount compared to dietary fiber contents (ranged from 10.2 to 87.9 g/100 g) of other fruits and greens (apples, citrus fruits, oat, wheat, corn), it can be said that it is a rich natural source of dietary fiber (Chau and Huang, 2004; Grigelmo-Miguel and Martin Belloso, 1999a, 1999b; Jaime et al., 2002). The previous studies have reported that the TN husks contain 6-14.6 g/100 g hemicellulose, 9-10.2 g/100 g cellulose and 35.4-48.3 g/100 g lignin (Chiang and Ciou, 2010).

In the last few years, a lot of TN shells have been seen in the Bartin coasts. The reason why these husks were not utilized is that the local people were unaware of TN. In this study, the use of TN, causing coastal pollution, as a source of valuable chemicals was investigated by determining the amount of lignin.

2 MATERIALS AND METHODS

2.1 Materials

TN nuts were collected from the costs of Inkumu-Bartin in 2017. Identification of the plant material was performed by Prof. Dr. Z. Kaya at the Faculty of Forestry of Bartin University. Husks were dark brown, 3-5 cm wide and sclerosis and had no fruits inside. For analysis, TN husks were washed with tap water and then freezedried. Dried husks were cut with knife and grinded with Wiley Mill. Pure lignin sample was purchased from LignoWorks.

2.2 Methods

Acid-insoluble Lignin Determination

Firstly extractive substances were removed from the TN sample for determining the amount of lignin. 5 g at a time of 3 samples were put in the extraction tubes then the tubes were placed in the soxhlet apparatus and extracted for 6 hours. The tubes were left overnight in the oven for reaching dry weight then the percentage of extractive material was calculated with using dry weights.

15 ml of 72% H_2SO_4 was added to 1 g at a time of 3 TN samples which had been purified from the extractives, followed by stirring for 2 hours. Then the mixture were placed in 1 l erlenmayer with adding 560 ml of distilled water and boiled on a multi-heater for 4 hours by attaching a cooler. At the end of 4 hours, the samples were filtered on glass crucibles and washed with hot distilled water. Afterwards, the samples were weighed as they became fully dry and acid-insoluble lignin content was determined according to TAPPI T222om-02.

Fourier Transform Infrared Spectroscopy (FTIR)

FTIR analysis was carried out with Shimadzu IRAAffinity-1 spectrometer with single reflection Attenuated Total Reflectance (ATR) pike MIRacle sampling accessory (Fourier transform infrared spectra were obtained using a PerkinElmer Spectrum 100 with a universal ATR sampling accessory). Four accumulated spectra were collected in the wave number region of 700–4000 cm^{-1}, with a spectral resolution of 4 cm^{-1}.

Thermal gravimetric analysis (TGA) and differential thermal gravimetric (DTG) analysis

TGA/DTG analyzes were carried out with Hitachi STA7300 Thermal Analysis System. 3 mg of dried and ground sample was heated from 30 °C up to 1200 °C. Analysis was carried out at the heating rate of 10 C min^{-1} in nitrogen atmosphere.

3 RESULTS AND DISCUSSION

Acid-insoluble Lignin Determination

The acid-insoluble lignin content was found to be 28.31% as a result of the analysis of the samples purified from the extractives (8.61%). It can be said that TN is a good source of lignin when the amount of lignin obtained from lignocellulosic materials is compared with the amount of TN lignin (Table 1).

Table 1: Lignin values of some lignocellulosic materials.

Sample	**Lignin (%)**	**Literature**
Trapanatans	28.31	Detection
Pinussylvestris	27.2	Dönmez, 2010
Larix decidua Mill.	13.42-29.54	Muhcuet al., 2015
*Pinusbrutia*Ten.	25.9	Taş, 2017
Tectonagrandis	23.7-25	Dwumaa, 2016
*Quercusrobur*L.	22.6-23	Krutul et al., 2010
Betula pendula Roth.	18.8-19.8	Krutulet al., 2014
Pseudocydoniasinensis	21	Qin et al., 2018
Hybrid Pennisetum	20.8	Wang et al., 2018

Fourier Transform Infrared Spectroscopy (FTIR)

FTIR analysis indicated that TN contained cellulose, hemicelluloses and lignin as expected. 3400-3330 cm^{-1} OH stretching of alcohols, phenols, and acids (Tjeerdsma and Militz, 2005; Müller et al., 2009;

Esteves et al., 2013; Mattos et al., 2015; Missio et al., 2015; Gonultas and Candan, 2018). 2970-2820 cm^{-1} C-H stretching in methyl and methylene groups (Müller et al., 2009; Esteves et al., 2013; Mattos et al., 2015; Gonultas and Candan, 2018). It can be said that 1650-1652 cm^{-1} bands are absorbed water molecules of C=O stretching of the aromatic structures (Kotilainen et al., 2000; Nuopponen, 2005; Ozgenc et al., 2017). In the TN samples, it is seen that the range of 1750-1650 cm^{-1} bands it appears to have a variety of pixels unlike the pure lignin (Figure 1). These peaks are derived from water and extractive substances (Zhou et al., 2015). The peaks at 1506-1510 cm^{-1} in both samples are characteristic peaks for the lignin components due to C = O and COO-non-symmetric stretching vibrations in the aromatic rings of the lignin structure (Can ve Sivrikaya, 2017, Can ve Sivrikaya, 2016; Özgenç, 2014).

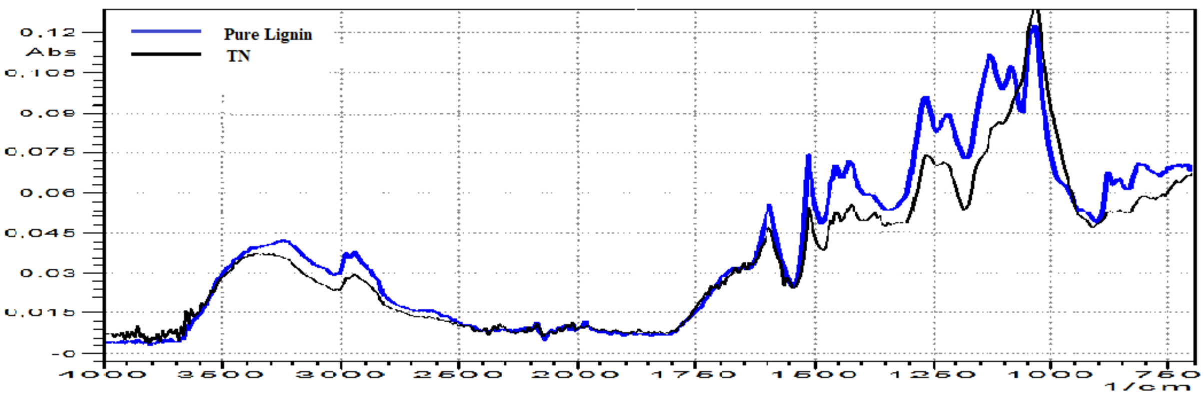

Figure 8: TN and Pure lignin ATR-FTIR spectrums.

The bands at 1452-1459 cm^{-1} belong to C=C and C=H bond, O-H in plane deformation, and asymmetric bending in lignin (Ishimaru et al., 2007; Nuopponen, 2005; Ozgenc et al., 2017). 1420-1422 cm^{-1} bands belong to aromatic skeletal vibration combined with CH inplane deformation for lignin (Muller et al., 2009; Chen et al., 2010; Herrera et al., 2014; Traore et al., 2016). 1263 cm^{-1} band belongs to guaiacyl ring breathing, C–O stretch in lignin and C–O linkage in guaiacyl aromatic methoxyl groups (Popescu et al., 2007; Muller et al., 2009; Traore et al., 2016). 1233 cm^{-1} and 1155 cm^{-1} bands show the alkyl-aryl-ether bonds, lactones and cellulose C-O-C symmetric stretching respectively (Nuopponen et al., 2003; Nuopponen, 2005; Ozgenc et al., 2017). 1110 cm^{-1} band belongs to OH association of cellulose and this peak is seen just in the TN spectrum. At the 1033 cm^{-1} band aromatic C-H deformation, C-O deformation, and C=O stretching in lignin are seen in both spectrum (Zhou et al., 2015).

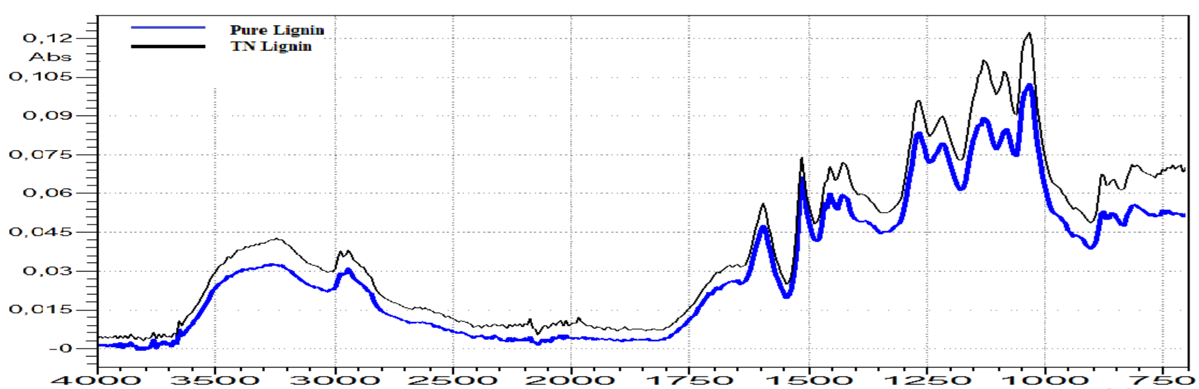

Figure 2: TN lignin and Pure lignin ATR-FTIR spectrums.

As can be seen in the Figure 2; TN lignin and pure lignin samples have very similar FTIR spectrums. As far as we know, the pure lignin was obtained from pine species which shows that TN lignins chemicalstructure looks like pine lignin's.

Thermal gravimetric analysis (TGA) and differential thermal gravimetric (DTG) analysis

TN and pure lignin samples's TGA/DTG curves shown in Figure 2, are sharing similarity at some temperatures.WhenTN TGA curves were examined, approximately 4,5% of the sample is lost from 30 to 200 °C. At these intervals, samples generally lose volatile constituents and moisture (El-Sayed and Mostafa, 2014). From 200 °C to 271 °C 4,6% of the weight is lost. The decrease in this range may be due to the decomposition of cellulose and hemicelluloses. The DTG curve shows maxima weight-loss occurring at 349 °C. The weight-loss in the range from 352 °C is about 50%. According to these results, dominantly lignin and small quantities of cellulose and hemicelluloses are present in TN samples.

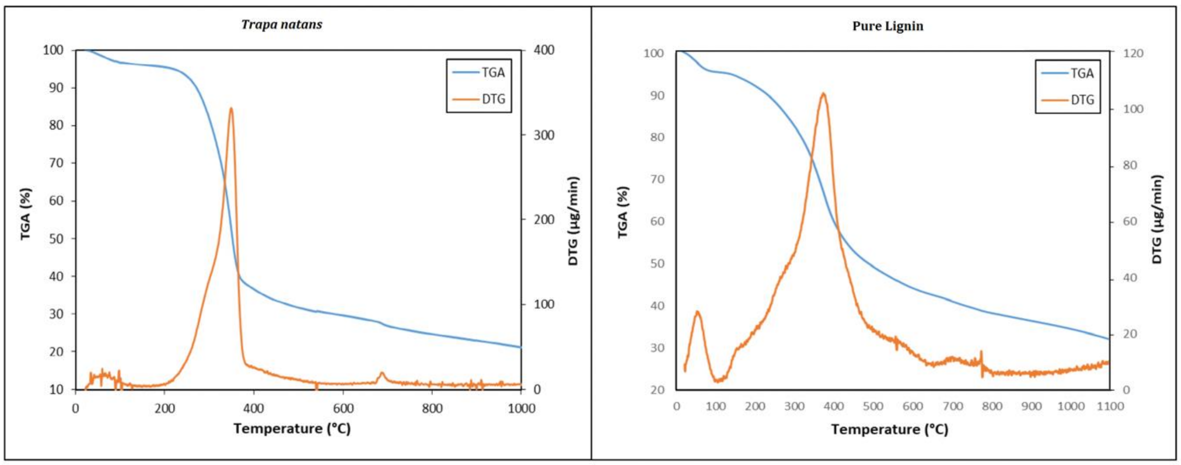

Figure 3: TGA and DTG diagrams of TN and pure lignin samples.

Lignin's complex structure includes mostly, various branching aromatic rings. These chemical bands have a wide degradation temperature range from 100 °C to 800 °C (Yang et al., 2007). From 30 °C to 200 °C, volatile constituents and moisture removes from lignin sample. At the range of 180 °C-350 °C, carbohydrates are converted to volatile gasses (CO, CO_2, and CH_4). Following 350 °C phenolics, alcohols, and aldehyde acids are removed from lignin (Watkins et al., 2015). Pure lignin sample's TGA and DTG curve results show 10%, 50%, and 70% weight-losses at 233 °C, 489 °C, and 1167 °C respectively (Table 2). Differently from TN sample, pure lignin's 10% of degradation temperature 37,9 °C lower. It may be due to pure lignin samples contamination cause of storage conditions. 50% degradation temperature of TN has difference owing to it's cellulose and hemicelluloses content.

Table 2: Termal degredation tempratures of TN and pure lignin samples.

	T10%	T50%	T70%	Residue (%)	DTGmax
Trapa	271,5°C	352,1°C	576,7°C	82,8	349,6°C
lignin	233,6°C	489,2°C	1167°C	100	373,1°C

4 CONCLUSION

In many coastal strips of Bartin such as Inkumu and Guzelcehisar, TN can not only cause an environmental pollution, but also can reach the wetlands and it may be the possibility of spreading in those areas. When considering the richness of the lignin in TN husks, the evaluation of these materials will be able to be used as a new source of valuable chemicals to produce lignin and besides can help to eliminate the environmental pollution.

There are about 750-1000 tons of such husks produced per year just in the Nansi lake area (China) (Wang et al 2009). While the fruit partis consumable as food,the outer part (husk) can be utilizable as a new lignin resource. Thus, it may be possible to obtain precious chemicals from tons of husks that go to waste every year.

In case of seeing that TN spread over Bartın coasts as expected, chemical composition and utilization areas of TN fruits can be analyzed in further studies. Also, damage to submerged life will be avoided by controlling the spread.

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Some Natural and Exotic Plant Taxa, which is used Non-Wood Forest Products, in Parks of Trabzon

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ABSTRACT

Trabzon contains many exotic and natural plant taxa in its green nature. These plant taxa have been used in the parks and gardens in order to ensure for local people benefit from this green nature in daily life. In order to benefit non-wood forest products, priority natural species have been brought to these areas. And also exotic plant taxa have been exploited for aiming direction. 100th Year Park, Trabzon Fatih Park, Trabzon Square Park, Atapark, Ekopark, Olympic Park, Zağnos Valley park were studied and determined the floristic situation of these areas. Generally in these areas have; *Aesculus hippocastanetum, Berberis thunbergii, Betula pendula, Citrus* sp., *Coryllus avellana, Cotoneaster salicifolius, Cotoneaster nummullaria, Crataegus spp., Erica arborea, Eriobotrya japonica, Eucalyptus camaldulensis, Eucalyptus globulus, Fraxinus excelsior, Junglas regia, Juniperus communis, Juniperus virginiana, Lauroceracus officinalis, Laurus nobilis, Liriodendron tulipifera, Magnolia grandiflora, Malus floribunda, Morus alba, Nerium oleander, Olea europea, Pinus pinea, Platanus orientalis, Populus tremula, Prunus avium, Prunus cerasifera* "Atropurpurea", *Prunus persica, Pyrus communis, Rosa* spp., *Rosmarinus officinalis, Rhododendron ponticum, Rhus coriaria, Robinia pseudoacacia, Salix babylonica, Taxus baccata, Tilia platyphyllos, Tilia tomentosa* taxa. As a result of the study, it has been recommended that some different naturel and egzotic plant taxa will be used in these park and gardens.

KEYWORDS: Trabzon, non-wood, natural, exotic, park.

1. INTRODUCTION

Parks are natural areas that are designed within the boundaries of the city. They are largely composed of soft surfaces such as soil, grass, bushes, trees and shrubs. The parks in the city are important not only for human health and quality but also life of urban ecology. The plants are the most important elements of these areas. The appearance of the plant material in the parks, such as measurements, forms, textures, colors, etc., are carried a value for people in the city (Tercan, 1994; Eren, 2012).

People have started to move away from nature in recent years and they have started to live in the artificial environment that they were created. And they began to protect nature because of their miss for nature. Environmental problems such as rapid urbanization, industrialization and population growth, have been led people to prefer places where they can be intertwined with nature. Urban green areas, which are contributed to the city's open green space system and allowed for recreational activities, are very important areas for the city (Konaklı and Önder, 2005).

One of the most important objects of landscape design is plant materials. In addition to the colour, shape, form, texture of the plant that will be used for planning and design, choosing the suitable plant for planning and design will be made thanks to the knowledge of the growing environment of the plant, besides of the color, shape, form and texture of the plant. In addition, the possibility of supplying the plant species to be used also needs to be demonstrated (Ertekin et.al.., 2010).

When plant design is carried out, some issues have great importance such as, ecological characteristics of plants, their significance in terms of landscape, and the right choice of destination and purpose of use in landscaping (Altınçekiç and Kart, 2007). People can get rid of the pressure on daily life and meet nature thanks to the planting design (Karaşah and Var, 2012). In addition, the first objective of the planting design is to contribute functionally to the park site and thus respond to the requests of the users in these areas (Robinson, 1992).

Plants, which are used in parks, should be evaluated in ethnobotany terms. Therefore, the concept of ethnobotanic has been researched and described by many people. The ethnobotanic term was described by John W. Harshberger, who is a biology professor, as "the use of plants by the local people" (Heinrich, 2004). Yıldırımlı (2004) is defined the ethnobotanic term in shortly as "the use of plants to meet the various needs of people".

Laurocerasus officinalis Roem, *Rosa canina* L., *Sorbus torminalis* L. Crantz, *Sorbus aucuparia* L., *Crateagus monogyna* Roem., *Arbutus unedo* L., *Vaccinium arcthostophyllos* L., *Corylus avellana* L., *Pyrus communis* L., which are grown naturally in Trabzon and its region, are preferred because of their features such as flower beauty, fruit beauty and autumn coloring rather than wood value in landscape architecture. These plants are widely preferred in landscapes of Europe and America, with their advantages such as general form features, medicinal fruity, ability to grow in different altitude steps (Atay, 1987; Kayacık, 1982).

In this research, the parks in the city center were considered as the study area. During the first step of the study, plant species in the study areas were identified. In the next step, the importance of the species in terms of non-wood products in parks and gardens was researched.

2. MATERIALS AND METHODS

The floristic structure of the parks and gardens in Trabzon was investigated in the year of 2018. Within the scope of the study, plants from the study area were collected and identified. The plant taxa which particularly have non-wood significance were determined. It has also been investigated that for which purposes these plant taxa are used. As a result of detailed literature study (Güner et al., 2000; Bonnier, 1912-34; Lanzara and Pizzetti, 1997; Kreutz, 2009; Simpson, 2012; Yaltırık and Efe, 1996; Baytop, 1998; Mamıkoğlu, 2007), the listed taxa and some properties of these plant taxa were found out. In addition, these properties particularly have been determined from the "Flora of Turkey" (Davis, 1965-1985; 1988) and " Türkiye Bitkileri Listesi (Damarlı Bitkiler) (Güner et. al., 2012)".

3. RESULTS AND DISCUSSION

As a result of the study, plant species which are used the parks and the gardens in Trabzon, were determined. Among these species, the species with non-wood importance have been determined by literature research. Conclusion of the study, some properties of plant species (type of plant, family, botanical name, common name, flowering season, flower colour etc.) were determined and showed in Table 1.

Table 1. Some characteristics of plant species, which were determined in the parks and the gardens in Trabzon, were demonstrated in the Table below.

Type of Plant	**Family**	**Botanical name**	**Common name**	**Flowering season**	**Flower colour**	**Deciduous state**	**Natural/ Exotic**
Climbing	Araliaceae	*Hedera helix*	Duvar sarmaşığı	August-September	Greenish	Evergreen	Natural
Shrub	Adoxaceae	*[11] Viburnum opulus*	Gilaburu	May-June	White	Deciduous	Natural
Shrub	Adoxaceae	*Viburnum tinus*	Filburnu	February-March-April-November-December	White	Evergreen	Natural
Shrub	Anacardiaceae	*Rhus coriaria*	Sumak	June- July	Greenish white	Deciduous	Natural
Shrub	Anacardiaceae	*Cotinus coggygria*	Boyacı sumağı	April-June	Whitish green	Deciduous	Natural
Shrub	Apocynaceae	*Nerium oleander*	Zakkum	April-September	Pink -Red	Evergreen	Natural
Shrub	Aristolochiaceae	*[12] Yucca* sp.	Avize ağacı	Spring and Summer start Summer mid end	Whitish yellow	Evergreen	Exotic
Shrub	Berberidaceae	*Berberis thunbergii*	Japon kadın tuzluğu	May	Yellow	Deciduous	Exotic
Shrub	Betulaceae	*Coryllus avellana*	Fındık	February- March	Red	Deciduous	Natural
Shrub	Cistaceae	*Cistus creticus*	Laden	May –June	Pink	Deciduous	Natural
Shrub	Ericaceae	*Vaccinium arcthostophyll os*	Likarpa	May - July	Whitish	Deciduous	Natural
Shrub	Ericaceae	*Rhododendron ponticum*	Kumar	March-May June-August	Purplish pink	Evergreen	Natural
Shrub	Ericaceae	*Erica arborea*	Funda	March-July	Pale pink-White	Evergreen	Natural
Shrub	Hydrangeaceae	*Hydrangea macrophylla*	Ortanca	Beginning of summer	White-blue-pink	Deciduous	Exotic

Continuation of Table 1

Shrub	Lamiaceae	*Rosmarinus officinalis*	Biberiye	February to May	Pale blue	Evergreen	Natural
Shrub	Malvaceae	*[13] Hibiscus syriacus*	[14] Kerkede	Winter beginning Summer Mid-summer End Autumn beginning Autumn middle Autumn end	BeyazEflatunMenekşeMorPembe	Deciduous	Exotic
Shrub	Oleaceae	*[15] Jasminum fruticans*	Boruk	May	Yellow	Evergreen or semi-deciduous	Natural
Shrub	Poaceae	*Phyllostachys bambusoides*	Gölge bambusu			Evergreen	Exotic
Shrub	Rosaceae	*Cotoneaster nummularia*	Dağ muşmulası	April- June	White	Deciduous	Natural
Shrub	Rosaceae	*Rosa canina*	Kuşburnu	April-September	White to pale pink - Rarely dark pink	Deciduous	Natural
Shrub	Rosaceae	*Cotoneaster salicifolius*	Söğüt yapraklı dağ muşmulası	June	White	Evergreen	Exotic
Shrub	Rosaceae	*Photinia x fraseri*	Alev çalısı	Beginning of spring-Mid-spring	Whitish	Evergreen	Exotic
Shrub	Rosaceae	*Pyracantha coccinea*	Ateşdikeni	April-June	Whitish	Evergreen	Natural
Shrub - Small tree	Buxaceae	*Buxus sempervirens*	Şimşir	April	Yellowish green- whitish	Evergreen	Natural
Shrub - Small tree	Ericaceae	*Arbutus unedo*	Kocayemiş	October November	Greenish white	Evergreen	Natural
Shrub - Small tree	Oleaceae	*Ligustrum japonicum*	Lügüstrüm	Mid-summer End of summer Autumn beginning	White	Evergreen	Exotic
Shrub - Small tree	Rosaceae	*Crataegus* spp.	Alıç	April-May, June-July	White - Pink	Deciduous	Natural

Continuation of Table 1

Shrub - Small tree	Rosaceae	*Persica vulgaris*	Şeftali	March-April	Pink-red- - rarely white	Deciduous	Natural
Shrub - Small tree	Rosaceae	*Laurocerasus officinalis*	Karayemi ş	April-June	White	Evergreen	Natural
Shrub- Tree	Cupressaceae	*Chamaecyparis lawsoniana*	Lawson Yalancı servisi	-	-	Evergreen	Exotic
Shrub- Tree	Cupressaceae	*Juniperus communis*	Ardıç	-	-	Evergreen	Natural
Shrub- Tree	Fabaceae	*[16] Acacia dealbata [17] [18]*	Gümüşi Akasya	Spring Mid Spring Summer Mid-Summer End Autumn Beginning	Yellow	Deciduous	Exotic
Shrub- Tree	Lauraceace	*Laurus nobilis*	Defne	March-May	Yellow	Evergreen	Natural
Shrub- Tree	Moraceae	*[19] Ficus carica*	İncir	March - April / May - June / August September	Whitish	Deciduous	Natural
Shrub- Tree	Oleaceae	*Olea europaea*	Zeytin	May	White	Evergreen	Natural
Shrub- Small tree	Rosaceae	*Eriobotrya japonica*	Yenidüny a	April-May	White	Evergreen	Exotic
Small tree	Cupressaceae	*Juniperus virginiana*	Kurşun kalem ardıcı	-	-	Evergreen	Exotic
Small tree	Rosaceae	*Prunus cerasifera "Atropurpurea"*	Kırmızı yapraklı erik	April- May	Dark pink - white	Deciduous	Natural
Tree	Arecaceae	*Phoenix* spp.	Hurma	Mid-spring and end	Whitish	Evergreen	Exotic
Tree	Betulaceae	*Betula pendula*	Huş ağacı	April- May	Green	Deciduous	Natural
Tree	Betulaceae	*Alnus glutinosa*	Kızılağaç	April		Deciduous	Natural

Continuation of Table 1

Tree	Bignoniaceae	*[20] Catalpa bignonioides*	[21] Katalpa	Spring and Summer beginning Summer	Whitish	Deciduous	Exotic
Tree	Cupressaceae	*Biota orientalis*	Doğu Mazısı	-	-	Evergreen	Exotic
Tree	Fabaceae	*Robinia pseudoacacia*	Yalancı akasya	April-June	White - Yellow	Deciduous	Natural
Tree	Fabaceae	*Cercis siliquastrum*	Erguvan	April-May	Bright pinkish-purple	Deciduous	Natural
Tree	Fabaceae	*[22] Robinia pseudoacacia*	Yalancı akasya	April- May	Yellowish white	Deciduous	Natural
Tree	Fagaceae	*Fagus orientalis*	Kayın	May		Deciduous	Natural
Tree	Ginkgoaceae	*Ginkgo biloba*	Mabet ağacı	-	-	Deciduous	Exotic
Tree	Juglandaceae	*Juglans regia*	Ceviz	May	Green	Deciduous	Natural
Tree	Magnoliaceae	*Liriodendron tulipifera*	Lale ağacı	May-July	Yellow-Orange	Deciduous	Exotic
Tree	Magnoliaceae	*Magnolia grandiflora*	Manolya		White	Evergreen	Exotic
Tree	Malvaceae	*Tilia platyphyllos*	Yaz ıhlamuru	The beginning and the middle of summer	Yellowish white	Deciduous	Natural
Tree	Malvaceae	*Tilia tomentosa*	Gümüşi ıhlamur	The beginning summer	White	Deciduous	Natural
Tree	Moraceae	*Morus alba*	Akdut	May	Pale green	Deciduous	Exotic
Tree	Myrtaceae	*Eucalyptus camaldulensis*	Sıtma ağacı	November-May	White	Evergreen	Exotic
Tree	Myrtaceae	*Eucalyptus globulus*	Mavi ökaliptus		White-red	Evergreen	Exotic
Tree	Oleaceae	*Fraxinus excelsior*	Dişbudak	March April	White	Deciduous	Natural

Continuation of Table 1

Tree	Pinaceae	*Pinus pinea*	Kızılçam	-	-	Evergreen	Natural
Tree	Pinaceae	*Cedrus spp.*	Sedir	-	-	Evergreen	Natural
Tree	Platanaceae	*[23] Platanus orientalis*	Çınar	March-May	Green	Deciduous	Natural
Tree	Plataneceae	*Platanus occidentalis*	Batı Çınarı	March -May	Brown-Green	Deciduous	Exotic
Tree	Rosaceae	*Malus floribunda*	Süs elması	April-May	White to pink	Deciduous	Exotic
Tree	Rosaceae	*Cerasus avium*	Kiraz	March -May	White	Deciduous	Natural
Tree	Rosaceae	*Pyrus communis*	Armut	April May	White	Deciduous	Natural
Tree	Rosaceae	*Sorbus aucuparia*	Kuş üvezi	May-June	White	Deciduous	Natural
Tree	Salicaceae	*Populus tremula*	Titrek kavak	March -May	White	Deciduous	Natural
Tree	Salicaceae	*Salix babylonica*	Salkım söğüt	April	White -Green	Deciduous	Natural
Tree	Salicaceae	*[24] Populus nigra*	Karakavak	March - April	Yellowish green- orange-pink	Deciduous	Natural
Tree	Sapindaceae	*Aesculus hippocastane tum*	Atkestanesi	May	White	Deciduous	Natural
Tree	Taxaceae	*Taxus baccata*	Porsuk	-	-	Evergreen	Natural

Our research was to aim the interactions between plants and human to live where parks and gardens are. In this present study, the plant species distribution and diversity pattern have been determined and their significance of parks potential characteristics were put forward. The whole plant materials are greatly important for parks and gardens in Trabzon. The distribution of ornamental plant species in parks are significantly related to rehabilitation purposes. Considering the determined plant taxa in parks and gardens, it was appeared that these species was to be much aimed to benefit as well as ornamental purposes. But, we need much scientific information and researching about knowing the socio-cultural effects on this distribution of plant species.

4. CONCLUSION

This study has been carried out within the city of Trabzon, in Black Sea Region of Turkey. A rapid urbanization as a consequence of a population increase of the city. Thus, numerous new parks were constructed in the city center. These areas are included mostly ornamental plant materials while the green areas of the city have been decreased at present.

As the result of the study, 70 plants taxa are used in ethnobotanical terms under 32 families were determined. The most common species are found from the families of Rosaceae (14) and Cupressaceae, Ericaceae, Fabaceae and Oleaceae (4). Most of these species (67,14%) are natural and (32,86%) exotic taxa. On the other hand, 40 (57,14%) taxa are deciduous and 30 (42,86%) taxa evergreen. In this study also, 1 climbing, 22 shrubs, 32 tree and 15 shrub-tree plant taxa were determined.

As a result, this study showed that these plant taxa were used especially for landscaping and rehabilitation purposes.

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ABSTRACT

In Turkish culture, handicrafts are treated as one of the most important cultural elements. Wood materials which is used on handicrafts by local people, not only supply additional income but also used for to meet their own needs in Trabzon. In this study, plants which are used by people dealing with handicrafts in Trabzon region were investigated. Plants that benefit from handicrafts of local people such as woodworking, basket, saddle, door ornament, broom, dyestuffs and so on were identified and usages of these plants have been revealed. As a result of the study, some plants used in handicrafts are *Phyllostachys bissetii, Marsdenia officinalis, Cornus* sp., *Corylus* sp., *Cannabaris sativa, Phragmites australis, Musa cavandishii, Zea mays, Juglans regia, Buxus sempervirens, Erica arborea, Sambucus nigra, Allium cepa*, moss and cones. The plants, which are used making handicrafts, have been listed that their family, botanical and local names, usage parts and usage purpose. As a result of the study has been seen that using plants are mostly exotic species, for that reason suggestions have been made that the natural species will be used more extensively.

KEYWORDS: Trabzon, handicraft, exotic.

1. INTRODUCTION

The human has established mutual relationship with the living and non-living beings around him since the day he has been existed and has used these products for a variety of purposes, such as food, clothing, construction, and fuel. People benefited from plants firstly to meet their nutritional needs and solve their health problems, according to the archaeological finding from the early ages. This information, which were obtained by trial and error at first, have been carried on to the actual date, according to the changes and developments of the different usage areas for these materials. For those reasons, ethnobotanical studies are very important. Knowing the methods of how people benefit from nature in the past, we can transfer sustainable information to future generations without destroying the nature (Koçyiğit, 2005; Faydaoğlu and Sürücüoğlu, 2011; Kendir and Güvenç, 2010).

The ethnobotanic term can be described as the human-plant relationship in its simplest form. Although this term is defined by many people, Ertuğ shortly made its definition as; "Ethnobotany defines the mutual interaction, use, production and consumption that arise as the result of the relationship between man and plant" (Ertuğ, 2004). In terms of ethnobotany, this definition hosts and meets many ethnobotanical aims.

There is wealth of valuable information about the ethnobotany in our country. However, parallel to migrations to cities from the countryside, new generations do not know the value of this treasure. For this reason, this information needs to be written up as soon as possible. Determination of which plants can be used in which regions is only possible with ethnobotanical studies. (Başaran, 2003; Sadıkoğlu, 1998). By doing such studies, it can be possible to contribute to the economy of local people by producing these plants in regions, which has similar ecological characteristics. And also sustainable plant use can be realized in its natural environment, within the protection-utilization balance. The use of plant species especially in handicrafts loses its significance from day to day, for that reason updated information about the use of natural products in handicrafts should be obtained. This situation can be explained about the ethnobotanical researches are mostly focused on plants used as medical and food in recent years in our country.

In the first times, handicrafts had been met the basic needs of people, such as nutrition, dressing (Arlı, 1992; Akpınarlı et. al., 2008). Nowadays, it is used for mostly ornamentally. Handicrafts, which are developed in accordance with the living characteristics and nature conditions in our region, have the economical importance. Handicrafts are an important cultural element because of having historical and touristic value, traditional features and also reflection of one's pleasure, feeling and thought (Özdemir, 2004). Handicrafts have great importance in terms of reflecting the social structure of the people. Handicrafts have great importance in terms of reflecting the social structure of the people. (Hünerel and Er, 2012).

Handicrafts also provide to evaluate leisure time and leisure work, as well as many other features, such as making income, providing solutions to unemployment, being able to do with simple tools and equipments. These arts must be taught to young people by opening various courses, because the arts and masters disappear from day to day In addition, handicrafts can provide that income for elderly, disabled and detained individuals and they can evaluate their free time by means of handicrafts. Some institutions and organizations have also reported that they are interested in handicrafts. In addition, stands are opened to introduce handicrafts at many fairs and events held in provinces, regions and even country-wide (Yanar et. al., 2011; Çavuş, 2014).

2. MATERIALS AND METHODS

In the light of this general information, some plant taxa used in handicrafts were researched in Alacahan Kigem (Trabzon Governorship Women Employment Development Center), which was established in 2014. In this study, it is also aimed to transfer the handicraft activities to the next generations. Because these important knowledge about the handicraft have begun to disappear from a recent past, due to the developing technology. As a result of this goal, the places, where manufacturing were made, are visited in Trabzon and which plants these handicrafts were made and how they were used were determined. It was recorded that other materials of the plants, which were used in handicrafts, are procured from consumer companies. In addition, some handicrafts were visually promoted with original photographs.

"Flora of Turkey and The East Aegean Islands" were used for the identification of plant materials (Davis 1965-85; Davis et. al., 1988; Güner and ark., 2000). In addition, from illustrated atlases of the plants (Bonnier, 1912-34; Lanzara and Pizzetti, 1997; Fitter et.al., 2000; Sheasby, 2007; Ekim, 2009; Kreutz, 2009; Simpson, 2012), from various plant guides (Yaltırık and Efe, 1996; Baytop, 1998; Foulis and Meynert, 1999; Mamıkoğlu, 2007) have been widely utilized. When suspected the diagnosis of plant samples, the plant samples were compared with the samples of KATO Herbarium.

3. RESULTS

Within the scope of this study, plants used in local handicrafts have been identified in Trabzon. Some properties of these plants, which are used for making handicrafts, such as family names, local names, used parts, usage purposes are illustrated in Table 1.

Table 1. Some properties of plants, which is used in local handicrafts, in Trabzon

Family	Plant taxa	Local Name	Used Parts	Traditional Usage
-	Algae	Su yosunu	Whole plant part	It is used for knitting chairs and baskets.
-	moss and cones			It is used for decoration purposes.
Apocynaceae	*Marsdenia officinalis*	Rattan	Above ground	It is used for making of baskets.
Betulaceae	*Corylus* sp.	Fındık	Above ground	Branches of plant are used in decorative purposes, such as home furnishings.
Buxaceae	*Buxus sempervirens*	Şimşir	Above ground	It is used for decoration purposes.
Cannabaceae	*Cannabis sativa*	Kendir	Above ground	It is used for making of baskets.
Cornaceae	*Cornus* sp.	Kızılcık	Above ground	Branches of plant are used in decorative purposes of home furnishings, such as door ornamental.
Ericaceae	*Erica arborea*	Ağaç fundası	Above ground	It is used in broom construction.
Juglandaceae	*Juglans regia*	Adi ceviz	Mezokarp and Shell	Green colored mesocarp and barks are boiled to obtain dye.
Liliaceae	*Allium cepa*	Soğan	Shell	Barks are boiled to obtain dye.
Musaceae	*Musa cavendishii*	Muz	Shell	Barks are dryed for weaving the basket.
Poaceae	*Bambuseae* altfamilyasına dahil olan türler	Bambu	Above ground	It is used for making of baskets.
Poaceae	*Phragmites australis*	Kamış	Above ground	It is used for making of baskets.
Poaceae	*Zea mays*	Mısır	Cob	Corn cobs are used to weave baskets and chairs.

Marshlandia officinalis, Cannabis sativa, Phragmites australis, Musa cavendishii, Zea mays are plants (These plant species included in the subfamily *Bambuseae*) that they were identified in the study area and they do not grow naturally in our country and they are transported from abroad.

Allium cepa and *Juglans regia* are used for dyeing materials of decorative products such as baskets, chairs, door decorations. However, when these products are used in damp environments, the dye can be flow.

Phyllostachys bissetii, Marsdenia officinalis, Cornus sp. and *Corylus* sp. must be immersed in hot water or soaked in cold water to soften their branches before knitting.

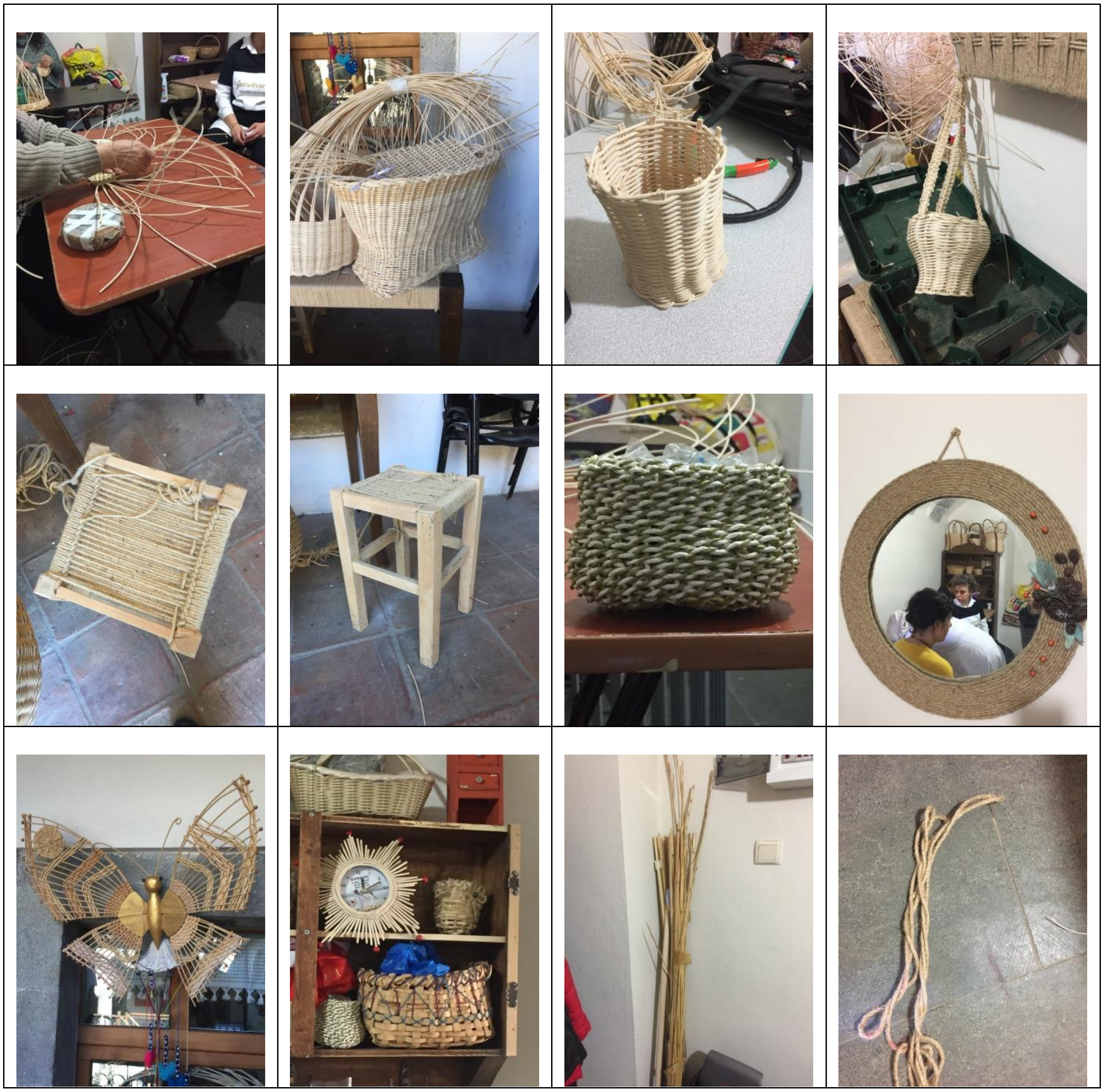

Figure 1. Demostration of some Handicrafts samples

4. DISCUSSION

In the result of the study, researchers are conducted in the Trabzon Regional Women's Employment Development Center in Trabzon Governor's Office and they were determined that natural and exotic plants are used in the construction of various handicrafts and these plants are also used in the production of dye. In this region, it is also recorded that cones and mosses are used for making decorative products.

As a result of the study, It was found out that local people sold their own hand made handicrafts in local markets to earn small commercial income, in the research area.

It is great of importance that this traditional herbage heritage transferred from generations to generations. For this reason, this study is important in terms of providing resources and giving ideas to new ethnobotanical studies which will be made in our country, in the future.

In this study, the plants which are used by local people in handicrafts were determined. So this study will probably prevent the disappearance of the use of information about these plants. Because any change will take place in the social and cultural structure will be decisive in how to continue the existence of handicrafts (Etikan and Çukur, 2011).

With the aim of converting the handicrafts produced into marketing for income by the local people, should be contacted to the relevant ministries, public institutions and organizations to support large and small businesses. Thus, it will be ensured that these regional products of handicrafts will take place especially in the global market. Among the rural development plans, it is absolutely necessary to place and encourage the handicrafts.

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ABSTRACT

In this study, physical disorders caused by ergonomic problems arising by increased computer use were examined. For this purpose, this study was carried out in two different computer laboratories in the same school as the students of Information Technology Technologies in Çay Vocational and Technical Anatolian. With the measurement tools, the physical conditions of the laboratories, relative humidity and temperature, noise, desk and chair, monitor, keyboard etc. dimensions have been determined. A healthy computer usage simulation was shown to the students and a questionnaire applied to the students was tried to determine problems arising from the laboratory environment and equipment. As a result, much more complaints emerged than in the literature, and students were found to be uncomfortable with the physical conditions of the laboratories. According to the results obtained, it has been discussed which improvements should be made.

KEYWORDS: Ergonomics, Information Technology, Computer Laboratory, Classrooms Conditions

1 INTRODUCTION

Computers, which are at the center of our lives and which are an important necessity product, poses many positives and threatens the user's health as a countermeasure for long hours usage during the day. These negative consequences of computers and their health-threatening aspects have been revealed in various studies. Technological developments have also affected education and teaching, and computers have become indispensable for schools as well. Problems such as eye disturbances, hand and wrist aches, waist, back and neck disturbances, headaches are encountered for a long time in front of the screen. These disturbances are caused by the fact that working environments are not designed according to ergonomic criteria. (Keser, 2005). For this purpose, it is aimed to determine what health problems that occur or are likely to occur on the students as a computer source are examined and how healthy the students use the computers.

Ergonomics; which provides the optimum design for the performance of the individual and the whole system, with practical and theoretical principles, data and methods, within the framework of human, machine and environment interaction (Kahraman, 2013). In other words, ergonomics is the whole of applications aiming to optimize design, working and living conditions for human use (Uluuysal and Kurt, 2001). The rapid increase in computer usage in the working population over the last 20 years brought with it the problem of occupational musculoskeletal diseases due to computer use (Özcan et al, 2007). In the United States, business statistics show that the highest rate of computer use (64%) is related to work-related health problems, and an annual spending of $ 20 billion has been made on this issue (İnandı and Akyol, 2008). In addition, in the study conducted by Sommerich, Ward and Sikdar (2007) in USA on 11th and 12th grade students, the use of computers accounts for as much as 69%, causing the most eye-related problems.

In the last 20 years, the Ministry of Education has accelerated the establishment of Computer Laboratories in schools and nowadays almost every school has a computer laboratory established. In this framework, especially the vocational high school computer department is the area where computer laboratories are the most used areas. 9, 10, 11 hours of object lesson per day are taught in the Information Technologies workshops of the vocational high school. In these lessons, the students are sitting at the computers and applying by the general course structure. Students are interacting with the mouse, keyboard and monitor when they stay on the stool / chair for 130 minutes (valid for Çay technical and vocational high school sample, but many workshops have used stools) when the lessons are processed as a block.

Individuals who use computers can reduce health problems the most if they comply with some criteria. In this context, the table height is 58.4 - 73.6 cm, the gaze distance is 40.6 - 73.1 cm, the working space width is at least 71.3 cm, the viewing angle is 15 - 30 degrees, the chair seat width is at least 51 cm, knee-table distance must be at least 38.1 cm (Orhun, 2016). At the same time, the chair used must have adjustable back and arm supports, a five-legged and wheeled, height-adjustable and self-pivoting seat, as well as a footrest platform (Orhun, 2016).The front part of the sitting surface of the chair should be spaced between the knees and the front edge should be designed to reduce the pressure behind the thighs and be slightly downward sloping. In the sitting position, the body angle should be 90 degrees or more, the feet should be on the floor or foot support, and the waist and shoulders should be seated on the back support of the chair (Yücel et al, 2016). At the same time, the working center should be large enough so that the individual can change the sitting position and move freely in the sitting position (Ministry of Labor and Social Security, 2013). Computer operating ergonomics and seating position according to the mentioned criteria are shown in Fig.1

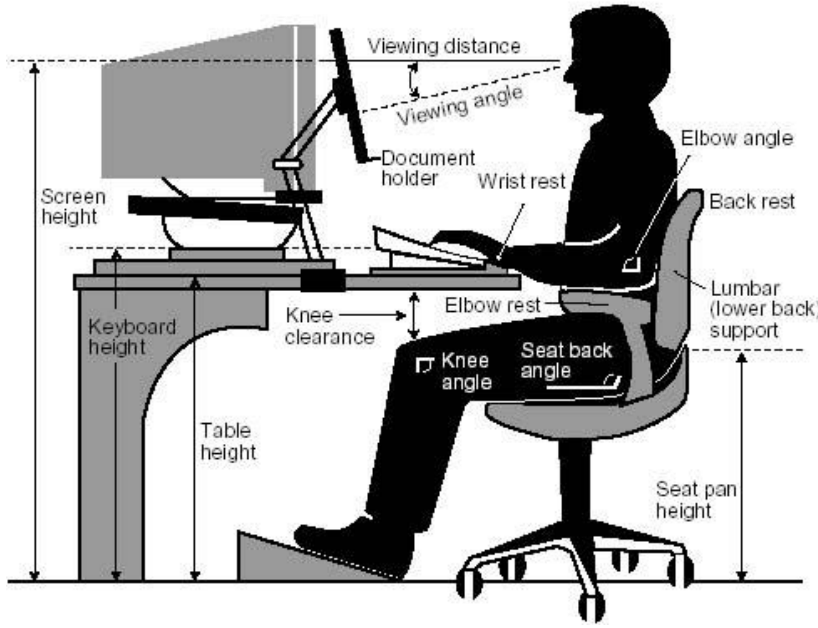

Figure 1. Proper Seating Position at the Computer (Web-6)

In addition to tables and chairs, as well as the Ministry of Labor and Social Security's (2013) Regulation on Health and Safety Precautions in Working with Displayed Vehicles, the screen display must be stationary the display should not vibrate and must be adjustable However, it is necessary to prevent reflection and glare which may disturb the user on the monitor. At the same time, the monitor should be in full contact so that the position is not tilted, the distance to the user should be at least 50-60 cm and the top edge of the monitor should be in the eye of the appropriate sitting person. According to the ergonomics principles of the keyboard, the surface should be up to 8-12 cm from 70-72 cm which is the standard height of the table, the surface should be at a height to allow the shoulders to relax. When using the keyboard, there should be no lengthening movement, the forearms should be parallel to floor and the angle of the elbow should be at least 90 degrees (Yücel et al, 2016).

2 METHOD

This research was carried out by applying 58 student questionnaires to determine the suitability of two computer laboratories for ergonomic principles of Çay Vocational and Technical Anatolian High School Information Technology Fields located in Afyonkarahisar Çay Town center. These 2 computer laboratories have a total of 30 computers, 15 stools, 15 chairs, 30 F keyboards, 30 computer desks and 2 interactive boards. The laboratory is located on the east side of the sun for the first half of the day, while the laboratory 2 is located on the northern front for some sun only in the morning and evening. The work was done on the last week of May and the heaters were not burning. The laboratory1 is located on the east side and take the sun at the first half of the day, while the laboratory 2 is located on the northern and only take the sun only in the morning and evening. The work was done on the last week of May and the heaters were not burning.

In determining the physical properties of the laboratories, a tape meter for measuring the length, a hygrometer for measuring relative humidity, a thermometer for temperature, a noise meter for determining the amount of noise in the environment, and a water balance for keyboard tilts.

2.1 Data collecting

The internationally accepted computer-based seating rules have been taken into account as a means of data collection in the survey, and it has been researched how well the students and the computer laboratory fit into the ergonomic rules. The data collection phase was carried out on the questionnaire form.

2.2 Analysis of Data

Data obtained by systematic data collection method and evaluated by systematic data analysis method. The data collected through observation are summarized and interpreted under the thematic topics of the research. In the first step, the data are categorized under the following categories: physical characteristics of laboratories, humidity and temperature, noise level, working desk and chair, monitor properties, keyboard properties. In the second step, the data observed for the features in each theme and the standards and criteria proposed in the literature are collected in the same table and visualized. Finally, the data were interpreted in comparison with the criteria.

Before being answered by the students the questionnaire involving observations and ergonomics issues were watched sitting position simulation on the computer and they were provided with ready availability before the questionnaire.

Students are asked to fill in the expressions at the end of the questionnaire "type the problems you want to add here". The final questionnaire includes complaint areas of the body related to the literature review and the most complained computer-based work.

3 FINDINGS

Physical properties of laboratories

Kahraman (2013), Gök and Gürol (2002) stated that the per capita area for the physical characteristics of laboratories is 2m2, Dan (2000) and Neufert (2016) stated that it should be 1.5-2m2. For the per capita volume per student; Akgül and Yıldırım (1995) 4 m3, Gök and Gürol (2002) 6 m3, Akal (1997) 10 m3, and Neufert (2016) 12 m3 had expressed.

Some researchers have stated that for ceiling elevation, it should be at least 3 m (Polat, 2007; Akal, 1997) and some are 3-360 m (Kahraman, 2013). The ratio of the total window surface area of the laboratory to the floor area should be 1/5 (Akgül and Yıldırım, 1995), at least 17% (Akal, 1997), 6% (Polat, 2007). Many researchers both agree on the preference of fluorescence as a means of lighting tool (Cengizhan, 2004; Polat, 2007; Yücel et al., 2016). The daylight, the main determinant of natural lightness, is uncontrolled in quantity and quality. Thus, controlling the class light with multiple buttons allows the environment to be adapted to the changes of the sunlight (Polat, 2007).

The physical properties of the laboratories obtained as a result of the measurements and the recommended values (reference value) are given in Table 1.

Table 1: Physical Properties of Laboratories

Physical Properties of Laboratories	Recommended Value	Lab 1	Lab 2
Area per student (m2)	En az 1.5–2	1.65	2.05
Volume of air per student (m3)	En az 4	5,61	6.97
Ceiling height (m)	En az 3	3.40	3.40
Window surface / floor area	0.2 (1/5)	0.12	0.11
Lighting tool	Fluorescent	Fluorescent	Fluorescent
Protective (curtain, blind, etc.)	Must Have	Yes	Yes
light control on buttons	should be	not	not
Status of electrical wiring and cables	hidden	open	open
Accessibility of students to electrical insurances	There shouldn't be	Being there	Being there

In table 1, it is seen that the results per measure are above the lowest recommended value per student. When the researches pertaining to the volume per student are examined, it is seen that Akgül and Yıldırım (1995) have a volume above the determined value (4 m3). The suggested value for ceiling height is at least 3 m and both laboratories are suitable for criterion with ceiling height.The ideal ratio of the total window surface in the laboratory to the floor area is 1/5 and the data obtained from both laboratories is smaller than the recommended value.

This suggests that laboratories are inadequate in terms of daylight savings. To alleviate this negative situation, artificial lighting is required, where the light intensity will be between 300-500 lux (????). Fluorescence, which is recommended as a lighting tool, has also been preferred in two laboratories. A positive situation in the laboratories has also been reduced by means of light, curtains, blinds and similar tools coming from the window, preventing direct entry into the room. The screen reflections resulting from the violent light that may come from the window on this screen and the inconveniences that may occur in the detection of the screen have been removed.

Regarding safety in laboratories, electrical wiring and cables must be confidential, which can cause security problems in both laboratories where cables are exposed. However, electrical fuses should not be accessible to students. But in both laboratories the insurances are in a closed and sheltered box, although they are easily accessible.

Noise Levels of Laboratories

According to Osha (2016), the sound level up to 30 dB is very quiet, the maximum range we can call quiet is 50 dB, the range from this value to 60 dB will disturb the environment. In addition, it was stated that the noise level should be maximum 35 dB when there is no activity for "Environmental Hazard Assessment and Management Regulations" in the areas of education facilities (school buildings, laboratories etc.) (Ministry of Environment and Forestry, 2008). The data obtained for the noise levels in the laboratory are given in Table 2.

Table 2. Results of Noise

Noise	Recommended Value	Lab1	Lab2
When no vehicle is running	< 35 dB	36.2	36.5
When all vehicles are in operation	< 50 dB	51.3	51.4

According to the obtained data on the noise levels in the laboratories (Table 2), it is seen that in both laboratories when no vehicle is operated, the "Environmental Hazard Assessment and Management Regulation" according to this situation, it can be said that the laboratories do not have adequate sound insulation. According to the measurements made by Branch and Beland (1970) in the measurements made when all the vehicles (computers, projection equipment, etc.) are in operation in the laboratories, the reference value in both laboratories is somewhat exceeding and uncomfortable.

Relative Humidity and Temperature of Laboratories

There are different suggestions for relative humidity for ideal working environments. Neufert (2016) stated that it should be between 40 and 60%, ASHRAE (2013) %30–60, Edi (1995) %50–60, Orhun (2016) %30–70, Akal (1997) %40–65 says it should be at this interval. The recommends on the ideal temperature of working environment Yücel et al. (2016) 20-24 º C in winter and 22-26 º C in summer, Akgül and Yıldırım (1995) 19.4-22.8 º C, Edi (1993) for summer season 18-24 º C, 17-20 º C for winter season, ASHRAE (2013) 18-23 ° C.

Table 3 Relative Humidity and Temperature (measurements were made on the last week of May, the heater did not burn)

	Recommended Value	**Lab1 Devices off**	**Lab1 Devices on**	**Lab2 Devices off**	**Lab2 Devices on**
Relative Humidity	%30–60	51.8	46.7	53.3	48.9
Ambient temperature	18–23°C	23.1	24.2	22.6	23.5

The recommended relative humidity value in the laboratory environment was accepted as 30-60%, as specified by ASHRAE (2013) (Table 2). In laboratory 1 when all devices in the environment were closed, the humidity of the environment was 51.8%, when all devices were turned on the humidity of the environment decreased to 46.7%. Relative humidity has been identified when closed devices 53.3%, and when open 48.9% in laboratory 2. If the relative humidity of laboratory 2 is higher than Lab 1, measurements may have been made at different times, and Lab 1 may have been affected by more sunlight. However, it has the ideal humidity ratio in both laboratories.

The ambient temperature was taken as 18-23 ° C recommended by ASHRAE (2013) for computer laboratories (Table 2). According to this, the laboratory 1 when measured with all devices turned off temperature was 23.1 ° C, when measured with open devices the temperature exceeded the ideal temperature with 24.2 ° C.

In laboratory 2 measurements, when all devices were closed was at ideal values with 22.6 ° C, when measured with open devices the temperature exceeded the ideal temperature with 23.5 ° C. It can be said that Laboratory 1 is getting more sunlight, which causes higher values.

Table 4. Evaluation of the questions directed to the students about the physical conditions of the laboratories

Questions for Students	Yes	%	No	%
The keyboard should be 8-12 cm below the standard height of the table, 70-72 cm, at the height of the surface to keep the shoulders relaxed?	58	100	0	0
Is classroom lighting appropriate?	31	53,45	27	46,55
Is the seating width at least 51 cm?	29	50	29	50
Is the top edge of the monitor in the eye of the right person?	29	50	29	50
Does the used chair have adjustable back and arm supports?	0	0	58	100
Does the feet push the foot or foot support?	58	100	0	0
Does the waist and shoulders sit on the back support of the chair?	29	50	29	50
Is the screen image stationary?	58	100	0	0
Can the screen be rotated in any direction according to the need?	58	100	0	0
Is there reflection and glare on the monitor that could disturb the user?	0	0	58	100

The students were asked about the physical conditions of the computer laboratories in question 1, and the results in Table 4 were obtained. According to the answers given by the students, the most significant result was that the students were uncomfortable with the use of chairs and stools. Most notably, all students are complainants in the same situation. Below the form given to the students is the same situation and there are a lot of statements that "our efficiency will increase even more with a chair with a soft seating area and where we can stand."

The answers given to the 3 questions in the above questionnaire were common and a rate of 50% was obtained. This is the reason why research has been done in two different computer laboratories. In general, the physical condition of laboratory 1, established by the Ministry of Transport, is favorable.

In answers to classroom lighting, students expressed distress to the screen when they were associated with a drop in brightness. There are also problems with the brightness of the morning sun class.

Students also expressed their complaints on the F keyboard. F can not be fast on the keyboard, they can not raise the applications in time. They have indicated that they are forced to use Q keyboards at home and in internet cafes when talking to one another.

The data emerged in the second part of the questionnaire are given in Table 5.

Table 5. How well students are able to work ergonomics in a computer lab

Questions for Students		**Evet**	**%**	**Hayır**	**%**
Are you looking at the computer from 15 to 30 degrees?		44	75,86	14	24,14
Have you set the knee-table distance at least 38.1 cm?		58	100	0	0
When using the keyboard, no stretching should be done, the forearms should be parallel to the sides and the angle of the elbow should be at least 90 degrees. Do you follow this rule?		51	87,93	7	2,07
Is your computer view distance between 40.6 and 73.1 cm?		58	100	0	0
Is the body angle 90 degrees or more in the sitting position?		58	100	0	0
Which part of your body aches the most at the computer?	Neck	29	50	28	50
	Back	42	72,4	16	27,6
	Waist	58	100	0	0
	Other	50	86.2	8	13,8

In the second part of the questionnaire, students were asked about the extent to which their bodies could fit their ergonomic rules in computer laboratories. The students showed that they had better adjusted themselves to the answers given in part 1 of the questionnaire. The line of vision is that students have the most problems. This is due to the feature of the monitors in laboratory 1.

4 DISCUSSION

As a result of the study, it was determined that the physical characteristics of the laboratories per capita area, the ceiling height and the volume are above the recommended lower values. When the related researches in the literature were examined, it was seen that Akgül and Yıldırım (1995) had a volume above the determined value (4 m3) per capita area, the ceiling height and the volume. The ratio of the total window surface in the laboratory to the floor area is less than the recommended value in both laboratories and these findings are better values than Tamer and Koç (2010) findings. This suggests that laboratories are inadequate in terms of daylight savings. It has been found that this adverse situation is resolved with the preferred fluorescence as a lighting medium and with a light intensity between 300-500 lux.

A favorable situation in the laboratories is that the preference of the screen is prevented from entering the sunlight directly from the window. so that the screen reflections due to violent light and the inconveniences that may occur in the detection of the screen have been removed.

Electrical wiring and cables in laboratories need to be hidden, which can cause security problems in both laboratories where cables are exposed. But in both laboratories the fuses are in a closed and sheltered box.

According to the obtained data on the noise levels in the laboratories, the reference value is somewhat exceeded in both laboratories when the vehicle is not working and when it is in operation, which is uncomfortable. These values are closer to the findings of Tamer and Koç (2010). According to this situation, it can be said that the laboratories do not have adequate sound insulation.

In laboratory 1, when all devices in the environment were closed, the humidity of the environment was 51.8%, when all devices were turned on the humidity of the environment decreased to 46.7%. Relative humidity in laboratory 2 were 53.3% when devices closed and 48.9% when open. There are different suggestions for relative humidity for ideal working environments. Akgül vs Yıldırım (1995) and Orhun (2016) 30-70%, Akal (1997) % 40-65 respectively, while Neufert (2016) stated that it should be between 40-60%. If the relative humidity of laboratory 2 is higher than Lab 1, measurements may have been made at different times, and Lab 1 may have been affected by more sunlight. However, it has the ideal humidity ratio in both laboratories.

The ambient temperature is slightly above the ideal temperature when both devices are turned on, while both instruments are in the ideal range while all devices are off. It can be said that laboratory 1 is getting more sunlight, resulting in higher temperature values.

One of the issues that students complain about is the use of F keyboard. The regulations on the use of the F keyboard have been read to the students and the students have been informed about why the F keyboard should be used. It has been emphasized that the use of F keyboards in students should not be seen as a difficulty forcing them in the laboratory.

While the students are not disturbed by the light especially in the north-facing computer lab; they complained about the cold due to the fact that the computer lab did not get sunshine. This affects the motivation of the students especially in the first hours of the morning. It was stated that the students would be dressed more tightly in the first lessons and that they would be able to overcome this situation with more comfortable clothes and aprons over the following hours. Students are disturbed by light from the east faced computer lab until noon. This means that the curtains of relevant laboratories must be replaced by light-shielded curtains.

It has been observed that the height of the monitor complained by the students is not caused by the table, the computer and the monitors in the standard scale, but the stress is caused by the height of the stools. Different standard and non-standard stools affect the eye-to-eye distance of students with the monitor. In addition, the answers given by the students' questionnaire "Do you have adjustable backrest and armrests?" And "Is the chair seat width at least 51 cm?" are among the topics most frequently complained by the students. In the article reviews, the back and the back pain of the people working on the computer are the main factors. Our work is consistent with the researches of Akbaba and friends (2009). However, the answers given by all the students in Çay Vocational and Technical Anatolian Studies to the question "Which organ is the most painful at the computer desk?" Is much more than the complaints of Akbaba and his colleagues (2009). This indicates that the stool and chair equipment of the laboratories of Çay Vocational and Technical Anatolian High School Information Technologies Area should be renewed. The findings of Uluuysal and Kurt (2011) are less complaints of students. In this study, it is seen that students generally complain about computer laboratories; the result is that they adjust their body movements according to the position and condition of the computers.

5 CONCLUSION

The result is that only good technological equipment does not increase the efficiency of the students in the classroom, but the ergonomic rules can only provide efficient training with suitable furniture. Even though the computers in the computer laboratories of Tea Vocational and Technical Anatolian High Schools are technologically good, it is seen that other equipments should have contemporary requirements and ergonomic elements. the results and suggestions obtained are shared with the school management.

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Impact of Impregnation and Varnishing on Combustion Properties of Spruce (*Picea Orientalis* L.) Wood

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ABSTRACT

Wood and wood based materials have been used as construction and building material in woodworking industry for years. The ignition or combustion properties of wood are the most important disadvantages for woodworking industry. Many fire retardants solutions were used for to protect wood materials from fire and its destructive effects in recent years. The objective of this paper is to evaluate the effects of varnishing after impregnation process on combustion temperature of spruce (*Picea orientalis* L.) wood. Firstly test samples were impregnated with Imersol aqua (Ia) Timbercare aqua (Ta) Boric acid (Ba), and Borax (Bx) solutions according to ASTM-D 1413-99 and then surfaces were varnished with water-based (Wb), cellulosic (Cv) and polyurethane (Pu) varnishes according to ASTM-D 3023 standard. Combustion temperature of samples was determined according to ASTM-E 160–50 standard. The results showed that the impregnated spruce wood had a lower value than untreated wood. In addition, cellulosic and water-based varnishes showed an increasing effect, while polyurethane varnish has a little decreasing effect on combustion temperatures.

KEYWORDS: combustion, impregnation, varnish, wood material

1 INTRODUCTION

Wood and wood based materials have many alternative advantages to conventional materials. Wood products require less manufacturing energy than other construction materials and it has an aesthetic appearance that is not found in other structure materials. Many buildings, products and some of their parts were produced from wood and wood based material in the world. Wood material has these positive features, however wood is highly flammable and its burning is very easy (Lowden and Hull, 2013; Atar and Keskin, 2007). Many methods have been used to eliminate or minimize this property of wood by scientists and users. Many fire retardant chemicals are widely used for last years in order to prevent buring properties of wood material. Boron compounds are the most used substances for this aim (Çolak et al., 2002; LeVan and Winandy, 1990).

Uysal and Kurt, (2005), studied combustion characteristics of beech and scots pine woods impregnated with some fire retardant. They reported that combination of borax and boric acid was showed positive effect in scots pine wood. Atar, (2008) reported that used varnish systems indicated an increasing effect, however boric acid and borax solutions showed a decreasing effect on combustion characteristics of oak (*Quercus petreae* Liebl.) wood. Baysal et al. (2003), investigated the fire characteristics of calabrian pine (*Pinus brutia* Ten.) impregnated with some plant tannins and boron compounds. They declared that impregnated samples with tannins showed negative effect, but boron compounds had significantly better fire retardant feature on combustion properties of wood samples. Keskin, (2009) investigated the effects of timbercare-aqua, borax, boric acid and imersol-aqua on combustion properties of laminated veneer lumber. He reported that the impregnation chemicals have a greater influence than the wood type on combustion properties of test specimens.

The aim of this study was to investigate the combustion temperature of varnished spruce (*Picea orientalis* L.) samples with polyurethane, water-based and cellulosic systems previously impregnated with imersol-aqua, timbercare-aqua and borax and boric acid solutions.

2 MATERIALS AND METHODS

2.1 Materials

For using in the experiments, all test specimens were prepared from air-dried spruce (*Picea orientalis* L.) wood. Firstly the wood samples were cut parallel to grain directions in a sawmill according to the TS 2470, which without knots, reaction wood and free of decay or insect damage. Spruce wood is commonly used in woodworking and furniture industry. The spruce woods for the preparation test samples are obtained from timber sellers in Simav-Kütahya.

For the varnishing of the samples, polyurethane (Pu), water-based (Wb) and cellulosic (Cv) varnish systems were used. The varnish applications were made according to the Budakçı, (2003) and manufacturer's recommendations of firm and the principles in ASTM D3023-98 (2003), (DYO-Dewilux, 1996).

For the impregnation materials, commercially available borax (Bx), boric acid (Ba), timbercare-aqua (Ta) and imersol-aqua (Ia) were used in the study. Boron compounds were purchased from Emet Boric Acid Plant, Kütahya, Turkey, while timbercare-aqua and imersol-aqua were obtained from Hemel-Hickson Timber Products Ldt., in Istanbul. Borax and boric acid were dissolved in distilled water to concentrations of 4%. The pH value was 9.43 for borax and 6.87 for boric acid. Imersol aqua and timbercare aqua are nonflammable, odorless, water based impregnated chemicals. The pH values are 7 for both the imersol and the timbercare aqua and ready for use (Keskin, 2007).

2.2 Method

Preparation of Test Samples and Impregnation Process

Wood specimens measuring 13 (tangential) x 13 (radial) x 76 (longitudinal) mm were prepared for combustion tests from air-dried sapwood of spruce wood and conditioned at a temperature of 20±2°C and 65±3% relative humidity until reaching equilibrium moisture content. The oven-dry density of specimens was 0.446 g/cm^3 before treatments. The prepared test samples were impregnated according to ASTM D1413-99. For this aim, Ba, Bx and Ia were applied by dipping method for 6 h to the specimens and Ta was by brushing method. Brushing process was applied twice at 5 hour intervals. The retention values were calculated by using following formula.

$$R = \frac{G.C}{V} x10^3 (kg/m^3), \; G = (G_2 - G_1) \quad (1)$$

Where, G is the amount of impregnation material absorbed by the specimens, T2 is the specimen weight after the impregnation, T1 is the specimen weight before the impregnation, C is the concentration (%) of the impregnation material, and V is the volume of the samples.

After impregnation process, the test samples were dried at room temperature and specimens were stored under 20 °C±2 temperature and 65%±3% relative humidity until reaching an equilibrium moisture content. Then the surfaces of the samples were sanded with no 220 sanding papers. The surfaces of samples were varnished according to ASTM D-3023. In varnishing process, a spray device was used. The varnishes were applied at 20 °C±2. The samples were first varnished with the filler varnish then dried samples were sanded with a no 220 sanding papers and after the topcoat varnish was applied. Varnish application was applied to the samples surface as one layer of filler and one layer of topcoat.

2.3 Combustion Test

Combustion temperatures of impregnated and varnished samples were determined using the combustion apparatus as detailed in the ASTM-E 160–50 standard. For this aim, test samples were conditioned under at 27°C and 30% relative humidity for three weeks before the combustion tests. The weights of samples were determined before the tests. In the combustion test, when the gas burned temperature was set at 315±8°C in the funnel and flame distance from maker type outlet below was fixed to 25±1.3 cm. Flame source combustion (FSC) stage was continued for three minutes. After extinguishing of flame source without flame source (WFSC) combustion stage was carried out. The temperatures were metered during tests with a thermometer located on the samples at 15 and 30 s, respectively.

2.4 Statistical evaluation of the data

The MSTAT-C package software was used for the statistical evaluation of the data. Analysis of variance (ANOVA) tests were performed to determine the effect of combustion type, impregnation material and varnish type on combustion temperature of at the 0.05 significance level. When there was a significant difference between the groups was compared with least significant differences (LSD) test.

3 RESULTS AND DISCUSSION

Table 1 shows retention values according to the impregnation materials. Retention is the highest in Ia and the lowest in Ba. As can be seen from Table 1, type of impregnation solution is effective on the amount of retention value. The reason for the higher amount of retention with Ia it can be explained by the difference in the concentration of solution. Average temperature values according to combustion type, impregnation material, varnish type and homogenous groups (HG) are given in Table 2.

Table 1. Retention quantities of impregnation materials

Impregnation chemicals	**Retention amount (kg/m^3)**
Bx	7.23
Ba	6.06
Ia	39.21
Ta	32.38

According to this result, it was found that the highest combustion temperatures belonged to WFSC, control samples and water-based varnish, while the lowest values belonged to the boric acid and polyurethane varnish. In terms of combustion type, it can be seen from these results temperature of FSC lower than temperature of WFSC. In addition, from the Table 2, it can be said that impregnation materials decreased combustion temperature, however varnishes showed an increasing impact for combustion temperature. The fire retardant impregnation chemicals have increased the combustion resistance. Flame retardant chemicals changes the burning features of wood material to reduce surface flame spread. Namely these solutions cause acid catalyzed dehydration reactions in wood material to facilitate the formation of char and decrease the effective heat of burning, resulting in lower heat release and flame spread value (LeVan and Tran, 1990). Combustion temperature values of specimens showed differences in varnishes. For varnish type, the varnished samples with polyurethane system yielded lower values than others varnish systems. Fidan et al. (2016) studied that combustion properties of impregnated and varnished Chestnut (*Castanea sativa* Mill.) wood. As a varnish system water based and synthetic varnishes were used. They reported that combustion temperature of synthetic varnished specimens was lower than water-based varnished specimens.

Table 2. Average temperature values of different combustion processes and materials

Type of material and treatment		Statistical Values	
		X(°C)	HG
Types of combustion*	FSC	455.9	B
	WFSC	482.3	A
Impregnation materials**	Control (Co)	517.5	A
	Boric acid (Ba)	420.3	D
	Borax (Bx)	428.0	D
	Imersol aqua (Ia)	481.6	C
	Timbercare aqua	497.9	B
Varnishes***	Unvarnished (Uv)	460.4	C
	Polyurethane (Pu)	456.5	C
	Cellulosic (Cv)	471.2	B
	Water-based (Wb)	488.1	A

*LSD: 5.883; **LSD: 9.302; ***LSD: 8.320

Average temperature values depending on combustion type and impregnation material; impregnation material and varnish type; and also combustion type and varnish type are given in Table 3.

Table 3. Average temperature value in interaction of combustion and process type

Combustion type +impregnation material*	**X(°C)**	**HG**
FSC	495.5	C
FSC+Ia	455.8	E
FSC+Ta	479.3	D
FSC+Bx	429.3	F
FSC+Ba	419.5	F
WFSC	539.5	A
WFSC+Ia	507.5	BC
WFSC+Ta	516.5	B
WFSC+Bx	426.8	F
WFSC+Ba	421.0	F
Combustion type +varnishes**	**X(°C)**	**HG**
FSC	450.4	DE
FSC+Wb	471.8	BC
FSC+Pu	439.2	E
FSC+Cv	462.0	CD
WFSC	470.4	BC
WFSC+Wb	504.4	A
WFSC+Pu	473.8	B
WFSC+Cv	480.4	B
Impregnation material +varnishes***	**X(°C)**	**HG**
Co	518.5	B
Wb	554.0	A
Pu	476.5	D
Cv	521.0	B
Ia	484.5	CD
Ia+Wb	499.5	C
Ia+Pu	470.0	D
Ia+Cv	472.5	D

Ta	482.5	CD
Ta+Wb	522.5	B
Ta+Pu	488.5	CD
Ta+Cv	498.0	C
Bx	409.0	G
Bx+Wb	434.0	EF
Bx+Pu	421.5	FG
Bx+Cv	447.5	E
Ba	407.5	G
Ba+Wb	430.5	EF
Ba+Pu	426.0	FG
Ba+Cv	417.0	FG

*LSD: 13.16;**LSD: 11.77;***LSD: 18.60

According to the obtained test results in the Table 3, for the interaction of combustion type and impregnation material, the highest value was obtained in WFSC+Ta, the lowest was obtained in FSC+Ba. In general, the values of impregnated WFSC temperatures were almost higher than the results of impregnated FSC temperatures. It is evident from Table 3 that when considering the interaction of combustion type and varnishes, the highest value was obtained in WFSC+Wb, the lowest was obtained in FSC+Pu. In relation to impregnation material and varnishes, the highest value was obtained in Ta+Wb, however the lowest was obtained in Ba+Cv. In general, varnishes showed increasing impact for combustion temperature with impregnation material. The test results obtained by Atar et al. (2015) show similarities with the findings in the present study. Table 4 shows the result of the ANOVA for effect of combustion type, impregnation material and varnish type on combustion temperature of spruce wood.

Table 4. Analysis of variance (ANOVA) results for temperature values

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Signature (P<0.05)
Factor A	1	20908.800	20908.800	78.9458	0.0000
Factor B	4	177670.950	44417.737	167.7090	0.0000
AB	4	15151.950	3787.737	14.3024	0.0000
Factor C	3	17995.500	5998.500	22.6487	0.0000
AC	3	1579.800	526.600	1.9883	0.1224
BC	12	15809.250	1317.438	4.9743	0.0000
ABC	12	8721.450	726.788	2.7441	0.0036
Error	80	21188.000	264.850		
Total	119	279025.700			

Factor A: Combustion type (FSC, WFSC)
Factor B: Impregnation material (Ia, Ta, Ba, Bx)
Factor C: Varnish type (Pu, Wb, Cv)

As shown in Table 4, it was found that the results of the analysis of variance indicated that the effects of the combustion type, impregnation chemicals, varnish type and their interactions were found to be statistically significant (a≤0.05), except for interaction of combustion type and varnish type. Duncan test was used to determine the differences between the treatment groups and test results were shown in Table 5.

Table 5. Duncan test results for the temperatures

Combustion type + impregnation material + varnish type	X (°C)	HG	Combustion type + impregnation material + varnish type	X (°C)	HG
FSC	501	EFGH	WFSC	536	ABCD
FSC+Wb	548	A	WFSC+Wb	560	A
FSC+Pu	436	NOPQRST	WFSC+Pu	517	CDEF
FSC+Cv	497	EFGHI	WFSC+Cv	545	AB
FSC+Ia	456	KLMNO	WFSC+Ia	513	DEF
FSC+Ia+Wb	462	JKLMN	WFSC+Ia+Wb	537	ABCD
FSC+Ia+Pu	446	MNOPQR	WFSC+Ia+Pu	494	EFGHI
FSC+Ia+Cv	459	KLMNO	WFSC+Ia+Cv	486	GHIJ
FSC+Ta	473	IJKL	WFSC+Ta	492	FGHI
FSC+Ta+Wb	502	EFGH	WFSC+Ta+Wb	543	ABC
FSC+Ta+Pu	465	JKLM	WFSC+Ta+Pu	512	DEFG
FSC+Ta+Cv	477	HIJK	WFSC+Ta+Cv	519	BCDE
FSC+Bx	417	STU	WFSC+Bx	401	U
FSC+Bx+Wb	434	OPQRST	WFSC+Bx+Wb	434	OPQRST
FSC+Bx+Pu	423	QRSTU	WFSC+Bx+Pu	420	RSTU
FSC+Bx+Cv	443	MNOPQRS	WFSC+Bx+Cv	452	KLMNOP
FSC+Ba	405	U	WFSC+Ba	410	TU
FSC+Ba+Wb	413	TU	WFSC+Ba+Wb	448	LMNOPQ
FSC+Ba+Pu	426	PQRSTU	WFSC+Ba+Pu	426	PQRSTU
FSC+Ba+Cv	434	OPQRST	WFSC+Ba+Cv	400	U

LSD: 26.31

It is evident from Table 5, generally the WFSC temperature values of impregnated and varnished specimens were higher than FSC temperature values. The highest combustion temperature was recorded in WFSC+Wb. In addition, it is evident from the results that impregnation materials have a decreasing effect on temperature for FSC and WFSC, while varnishes have an increasing effect on temperature. These results can be explained by fire retardant properties of impregnation chemicals. A similar study was conducted by Yasar et al. (2017) with impregnated and warnished spruce (*Picea orientalis* L.) wood. They reported that Wolmanit-CB and synthetic varnish showed the better result. Similarly in another study was conducted by (Budakçı, et al. 2016) showed that for scots pine (*Pinus sylvestris* L.) and beech (*Fagus orientalis* L.)woods. They declared that combustion characteristics favorably affected when increase the boric acid value in the water-based varnish.

4 CONCLUSIONS

At the end of combustion test, it was found that type of impregnation solution is effective on the amount of retention of wood material. In terms of combustion type, WFSC temperature was higher than FSC temperature. Impregnation chemicals have decreasing effect on temperature during combustion process. In terms of varnish type, cellulosic and water-based varnishes have increasing effect, while polyurethane varnish has a little decreasing effect on combustion temperature. For impregnation material boric acid yielded the lowest value compared to the control and others impregnation materials. Consequently, should be careful varnishing process to the wood material after the impregnation process in places where the high fire risk. In case of the use of wood materials for places which has fire risk, usage of spruce (*Picea orientalis* L.) wood impregnated with boric acid and varnished with polyurethane varnish would be advantageous.

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ABSTRACT

In this study, it was investigated the effect of pine bark powder (*Pinus brutia*), valonia (*the extract of Quercus ithaburensis*) and gallnut (*Quercus infectoria* Olivier) extracts on weight loss during combustion properties of Scotch pine (*Pinus sylvestris* L.), European oak (*Quercus Petraea* L.) and Oriental beech (*Fagus orientalis* L.) woods. For this purpose, the solution has been prepared by dissolving tannin 3%, 5% and 7% in distilled water based on the amount of weight. The test samples prepared from woods were impregnated with these natural solutions according to ASTM D 1413-76. After impregnation process, combustion test was performed according to the ASTM E 160-50 standard. The results showed that test samples treated with aqueous solutions of tannin extract had a negative effect on combustion properties. Generally, the weight loss of impregnated specimens increased. Moreover, weight losses were increased with concentration level and the oak samples were gave better results than beech and scotch pine.

KEYWORDS: Impregnation, tannin, combustion, wood

1 INTRODUCTION

Wood is one of the most important building material that versatile, sustainable, completely renewable and natural source, so it has been used extensively in the woodworking industry for a long time. Also, the wood has many excellent features as compared with other material (Triantafillou, 1998). Because of its structural properties, there is an increasing demand for wood and wood based material for both interior and exterior building construction applications. On the other hand, as a building material, wood has some disadvantages. Wood materail is affected negatively and more easily degraded by fire and biotic and abiotic factors approptiate conditions because of its organic nature (Peker et al. 1999; Yaşar et al. 2016; Demirkir et al. 2013).

Many wood preservatives are widely used in the woodworking industry for wood protect in accordance with the field of use, sush as Copper Chromium Arsenate (CCA), creosete, pentachlorophenol and other copper-based wood preservatives such as alkaline copper quaternary (ACQ) and amine copper azole (CA) for a long time. Some of these chemical substances are harmful for human and environmental health and expensive (Venmalar and Nagaveni 2005; Temiz et al. 2014; Ozdemir et al. 2015). As the awareness of environment and health increases and due to the new regulations, for protection of wood there is an urgent need to develop new wood preservative chemical formulations which will not cause any harmful effects on the environment and human health (Adanur, 2015; Yildiz et al. 2004).

In recent years, several new environment friendly chemical formulations have been developed for wood protect. Boron compound is one of the widely used chemicals for this purpose (Hafızoglu et al. 1994; Yalinkilic et al. 1999). Besides, in literature there are several evaluations of the effects of tannins and plant extracts on phyical and mechanical properties of wood and wood-based material (Elbadawi et al. 2015; Schnabel et al. 2014; Tondi et al. 2013). Tannins are a group of natural polyphenolic compouns that may act as important defenses against some micro organisms, insects, fungi and bacteria. (Barbehenn and Constabel, 2011; Hagerman et al. 1998). Condensed tannins are natural preservatives and antifungal agents (Zucker, 1983). Tannins holds an important place among the phenolic materials that constitute 20-30% of wood material (Şen and Hafızoğlu, 2008).

Baysal et al. 2003 studied combustion properties of Calabrian pine (*Pinus Brutia* Ten.) wood impregnated with vegetable tanning extracts and boron compounds. For this purpose, wood were treated with borate-supplemented aqueous solutions of Calabrian pine bark powder, acorn powder, sumach leaf powder and gall-nut powder. Then combustion test applied according to ASTM E 160-50 standard. The test results showed that the lowest temperature (323 °C) for the flame source stage was recorded for specimens treated with mixtures of boric acid and borax (BA and Bx). In the without flame stage, the lowest temperature (404 °C) was recorded for specimens treated with acorn powder and (BA and Bx) mixture. In the glowing stage, the lowest temperature (107 °C) was obtained for specimens treated with sumach leaf powder and (BA and Bx) mixture. Digrak et al. (1999) studied that the antimicrobial activities of valex (the extract of valonia), the extracts of mimosa bark, gallnut powders, *Salvia aucheri* Bentham var. *aucheri* and *Phlomis bourgei* Boiss. by the disk diffusion method. The test results showed that mimosa bark extracts had the greatest antibacterial activity, and they were followed by the valex, gallnut powders, *Salvia aucheri* var. *aucheri* and *Phlomis bourgei*. extracts, respectively.

Based on the previous researches, used extract for wood treatment may be effect the phsical, mechanical, chemical properties of treated wood. Knowledge about the combustion properties of extracts is limited. Therefore, the objective of the present work was to determine the combustion properties of Scotch Pine (*Pinus sylvestris* Lipsky) European oak (*Quercus Petraea* L.) and Oriental beech (*Fagus orientalis* L.) woods treated with pine bark powder (*Pinus brutia*), valonia (the extract of *Quercus ithaburensis*) and gallnut (*Quercus infectoria* Olivier) extracts.

2 MATERIALS AND METHODS

2.1 Wood Materials

Scotch pine (*Pinus sylvestris* L.), European oak (*Quercus Petraea* L.) and Oriental beech (*Fagus orientalis* L.) woods were used as experimental material and they were obtained from Ankara province timber management completely randomly, that commonly used in furniture, decoration and woodworking industries in Turkey. The samples were prepared from first-class wooden materials, which are smooth fiber, knotless, crack-free, without color and density difference, with annual rings perpendicular to the surfaces, and from parts of sapwood, in accordance with TS 2470 (1976) standard.

2.2 Impregnation Materials

In this study, pine bark powder (*Pinus brutia* Ten.), valonia (the extract of *Quercus ithaburensis*), and gallnut powder (*Quercus infectoria* Oliver) were used as impregnation material which is easy to supply to and also a cheap extractive material. The vegetable extrac materials were optained from the Balaban Palamut Company in Salihli-Manisa. The tannin materials were dissolved in distilled in water at 60 °C to a concentration of 3%, 5% and 7% which is the suggested ratio to protect wood from a number of biotic and abiotic factors (Sen, 2001; Baysal, 2003).

2.3 Preparation of Test Samples and Impregnation Process

The wood sticks cut into 17 x 17 x 550 mm from sapwoods. Then these sticks were cut to a net size. The dimensions of the test samples were 13 mm × 13 mm in cross section and 76 mm longitudinally. A total of 2592 test samples were prepared by using scotch pine, European oak and Oriental beech woods, also 3 different impregnating materials and control group, 3 concentration level and 3 groups in each test with 24 samples (3x4x3x3x24). Before impregnation process, the test specimens were conditioned at a temperature of 20°C±2°C and 65% ± 3% relative humidity till they reached 12% humidity distribution. The test specimens were impregnated by a vacuum-pressure method in accordance with ASTM D 1413-76 (1976). For this reason, the samples were subjected to 760 mm/Hg^{-1} prevacuum for 30 min and then test specimens were held in impregnation materials under normal atmospheric pressure for 30 min.

2.4 Combustion Experiments

Combustion tests were carried out according to the ASTM E 160-50 (1975) in combustion test device. Before the tests, the samples were conditioned at 27°C and 30% relative humidity. Each sample group was weighed before the combustion test and the 24 specimens were placed on the wire stand. After this process, combustion tests were performed with a flame source, without a flame source and at the glowing stage according to ASTM E 160-50. After the settings specified in the standard were made, flame source combustion (FSC) was continued for 3 minutes and the flame source was extinguished. After FSC stage, without flame source combustion (WFSC) and glowing combustion stage (GC) were carried out. The weight loss of the specimens was determined after combustion process.

2.5 Data Analysis

In this study, evaluation of data MSTAT-C statistical software program was used. The effect of impregnation material, concentration level and wood type on combustion properties were analyzed by ANOVA (Analysis of Variance). When the differences between groups were found to be significant, Duncan test was used to determine the differences between means at prescribed level of α=0.05.

3 RESULTS AND DISCUSSION

Average weight loss during combustion test according to wood type, impregnation material, and concentration level are given in Table 1.

Table 1: The average values for the weight loss

Wood type*	**Weight loss (%)**	**HG**
Scotch pine	89.86	a
Oak	85.38	c
Oriental beech	89.21	b
Impregnation material**	**Weight loss (%)**	**HG**
Control	86.36	c
Valonia	88.77	ab
Pine	88.23	b
Gallnut	89.24	a
Concentration ***	**Weight loss (%)**	**HG**
3%	87.99	a
5%	88.45	a
7%	88.02	a

Different letters in the columns refer to significant changes in the weight loss at 0.05 confidence level, *LSD: 0.4739; **LSD: 0.7789; ***LSD: 0.6745; HG: Degree of Homogeny

According to Table 1, in terms of wood type the highest weight loss value was found in scotch pine and the lowest in oak wood. Scotch pine is a relatively a resinous tree species and this situation may be an effect of increasing the compustion properties. In the impregnation material the highest result was obtained in the gallnut tannin, the lowest was in control samples. According to the these results, the impregnation materials have increased the weight loss rate by %2-4 in the during combustion. In the concentration value, highest weight loss was found in 5% and the lowest in 3%. It is evident from Table 1, the weight loss values test specimens increased as the concentration level increases. Results of ANOVA, for effect of wood material, concentration level and impregnation material on the weight loss of samples are given in Table 2.

Table 2. Results of variance analysis on the weight loss rate of samples

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Signature (P<0.05)
Factor A	2	422.074	211.037	101.2642	0.0000
Factor B	3	129.047	43.016	20.6406	0.0000
AB	6	123.187	20.531	9.8517	0.0000
Factor C	2	4.772	2.386	1.1449	0.3240
AC	4	51.770	12.943	6.2104	0.0002
BC	6	30.366	5.061	2.4285	0.0341
ABC	12	65.080	5.423	2.6023	0.0062
Error	72	150.050	2.084		
Total	107	976.345			

Factor A = Wood material (Scotch pine, Oak, Beech)
Factor B = Impregnation material (valonia, pine, gallnut)
Factor C = Concentration level (3%, 5%, 7%)

According to the Table 2, except from the concentration level of the impregnation material, all factors and interactions on weight loss rate were found to be significant (α = 0.05). Average weight loss value according to wood material + impregnation material, wood material + concentration level, and impregnation material + concentration level combinations are given in Table 3. Also, Duncan Test results are given in Table 4 to indicate the importance of differences between the groups.

Table 3. Average weight loss for the combination of type of material and treatment

Wood material + impregnation material*	**X(%)**	**HG**
Beech+pine	91.42	a
Scotch pine+gallnut	91.27	ab
Beech+valonia	90.34	abc
Scotch pine+valonia	89.94	bcd
Scotch pine+pine	89.54	cd
Beech+gallnut	88.92	d
Scotch pine+control	88.70	de
Oak+gallnut	87.53	e
Beech+control	86.17	f
Oak+valonia	86.04	f
Oak+control	84.21	g
Oak+pine	83.74	g
Wood material+Concentration**	**X(%)**	**HG**
Beech+5%	90.56	a
Scotch pine+5%	90.37	ab
Scotch pine+7%	89.87	ab
Scotch pine+3%	89.34	bc
Beech+3%	88.63	c
Beech+7%	88.44	c

Oak+3%	85.99	d
Oak+7%	85.74	d
Oak+5%	84.41	e
Impregnation material + Concentration ***	**X(%)**	**HG**
Gallnut+5%	90.28	a
Valonia+5%	89.41	ab
Pine+7%	89.16	ab
Gallnut+3%	89.10	abc
Valonia+3%	88.70	bcd
Gallnut+7%	88.34	bcd
Valonia+7%	88.21	bcd
Pine+3+	87.79	cd
Pine+5%	87.75	d
Control	86.36	e

*LSD: 1.349; **LSD: 1.168; ***LSD: 1.349

According to wood material + impregnation material, the highest weight loss rate was measured in impregnated beech wood with pine tannin, but the lowest in impregnated oak samples with pine tannin. Weight loss value was measured as the highest in impregnated beech with 5%, the lowest in impregnated oak with 5% according to wood material and concentration level. Average weight loss values according to the impregnation material + concentration level, the highest was determined in 5% gallnut, and lowest in control samples. Accordingly, impregnation materials showed increasing impact on weight loss rate during combustion. Atar and Keskin (2007), studied impacts of coating with various varnishes after impregnation with boron compounds on the combustion properties of Uludag fir(*Abies Bornmülleriana* Mattf.) wood. They reported that the tested varnishes showed an increasing impact on combustion properties of Uludag fir wood.

Table 4. Duncan Test Results for weight loss of test specimens

Wood material+ concentration level + impregnation material	**X**	**HG**	**Wood material+ concentration level+ impregnation material**	**X**	**HG**
Beech+5%+gallnut	92.38	a	Scotch pine+control	88.70	efghıj
Scotch pine+5% +gallnut	92.12	ab	Oak+3%+gallnut	88.23	fghıjk
Beech+5%+pine	92.07	abc	Oak+7%+gallnut	88.02	ghıjkl
Scotch pine+3%+gallnut	91.92	abc	Scotch pine+3%+pine	87.44	hıjkl
Beech+5%+valonia	91.63	abcd	Beech+7%+gallnut	87.23	ıjklm
Beech+ 3%+pine	91.21	abcd	Beech+3%+gallnut	87.14	ıjklm
Beech+7%+pine	90.98	abcde	Oak+3%+valonia	86.77	jklmn
Scotch pine+7%+pine	90.67	abcde	Oak+5%+valonia	86.43	jklmno
Scotch pine+5%+pine	90.49	abcdef	Oak+5%+gallnut	86.33	klmno
Scotch pine+7%+valonia	90.35	abcdefg	Beech+control	86.17	klmno
Scotch pine+5%+valonia	90.16	abcdefg	Oak+7%+pine	85.81	lmno
Beech+3%+valonia	90.01	bcdefg	Oak+7%+valonia	84.92	mno
Scotch pine+7% +gallnut	89.77	cdefgh	Oak+3%+pine	84.73	no
Beech+7%+valonia	89.37	defghı	Oak+control	84.21	o
Scotch pine+3%+valonia	89.31	defghı	Oak+5%+pine	80.68	p

LSD: 2.337

According to the Table 4, in the interaction of wood material, concentration value and impregnation material, the weight loss during combustion were found highest in beech samples impregnated with 5% gallnut tannin (92.38%), the lowest in oak samples impregnated with 5% pine tannin (80.68%). According to the test results, it can be concluded that plant extracts have no fire retardant an important effect on weight loss during combustion test. This situation may be caused from the characteristic properties of tannin extracts. In the literature Baysal (2003), studied fire properties of Scots pine (*Pinus sylvestris* L.) which treated aqueous solutions of boric acid and borax mixture and aqueous solutions of some natural extractives (the concentration 4% of bark powder, sumach leaf powder, gall-nut powder and acorn powder). He reported that natural extractives showed unfavourable effects on fire parametres and they showed same or more badly burning properties compare to control specimen. In another study by Baysal et al. (2003), Calabrian pine (*Pinus brutia* Ten.) wood samples were impregnated with borate-supplemented solutions of pine bark powder, acorn powder, sumach leaf powder and gall-nut powder extracts and then impregnated and control samples have been subjected to combustion tests. Test results showed that wood specimens treated with aqueous solutions of extract solutions provided higher weight losses compared to the control specimens. In this study, generally impregnated specimens with extracts showed more burning properties.

4 CONCLUSIONS

In this study examined weight loss during combustion properties of Scotch pine (*Pinus sylvestris* L.), European oak (*Quercus Petraea* L.) and Oriental beech (*Fagus orientalis* L.) wood specimens treated with pine bark powder, gallnut and valonia extracts. In conclusion, it was determined that after combustion test, tannin extracts showed more badly burning properties compared to the control specimen. The weight loss of impregnated samples increased after combustion process. This situation should be considered in places where there is a risk of fire and some fire retardant chemicals may be recommended to be used with the tannin extracts. In addition, the studies on combustion properties of tannin impregnated wood materials are limited and in this study only comparisons were made to compare samples weight loss after impregnation in during combustion. So, more detailed investigations may be require in the impregnated woods with tannin solutions on combustion properties.

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The Effects of Nanoboron Nitride on the Physical Properties of PLA and PHB Nanocomposites

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ABSTRACT

The goal of this study is to investigate the effect of nano boron nitride (hBN) on the physical properties of polylactic acid (PLA) and polyhydroxybutyrate (PHB) nanocomposites. PLA and PHB nanocomposites reinforced with cellulose nanofibrils (CNFs) and nanoclays (NC). hBN added to composites with optimum properties and all composites were used to prepare in twin screw extruder. According to results, the highest water absorption values were found pure PLA (1,57) and 1% hBN-NC (1,31) in PLA composites, 2% NFC (2,33) and 10% hBN-NFC (2,26) in PHB composites. The highest thickness swelling values were found 0,5% NFC (5,74) and 10% hBN-NFC (8,94) in PLA composites, 4% NFC (7,81) and 5% hBN-NFC (16,02) in PHB composites. Both PLA and PHB composites reinforced with hBN increased thickness swelling.

KEYWORDS: Polylactic acid, Polyhydroxybutyrate, Nano boron nitride (hBN), Nanocomposites, Water absorption, Thickness swelling.

1 INTRODUCTION

The environmental aspects of the production and disposal of petroleum-based plastics are a major concern of the worldwide. Many research have been carried out on the recycling of plastics to reduce the damage and consumption of plastics by the environment. One of them is to increase the use of recycled plastics. The other is to replace these materials with bioplastics (Butylina et al., 2010). In recent days, natural materials have attracted substantial interest due to the decrease of environmental loads and the increase of sustainability. (Siakeng et al., 2017, Nam et al., 2011). Biocomposites from renewable sources and natural fibers with a wide range of applications are being explored and developed due to their advantages like eco-friendliness, lightweight, carbon dioxide reduction, and biodegradable properties (Nam et al., 2011).

PLA (Polylactic acid) is a widely researched and used polymer with the potential to replace petroleum-derived polymers (Rasal et al., 2010). PLA biodegradable from lactic acid is a renewable thermoplastic polyester, and having similar properties to polyethylene terephthalate, but has a lower maximum continuous use temperature (Rasal et al., 2010, Pang et al., 2010). Polyhydroxybutyrate (PHB) is a conventional thermoplastic material obtained by fermentation of renewable resources (Al et al., 2018, Kuciel and Liber-Kneć, 2011). PHB produced by many bacteria and present in all living organisms (Kuciel and Liber-Kneć, 2011).

Natural fibers are renewable and sustainable materials. Also, these fibers are economic, non-toxic, low-density, easily accessible materials, and therefore, attracting to researchers as a biodegradable replacement of synthetic fibers (Faruk et al., 2012, Asim et al., 2017). Reinforced with natural fiber composites are used in many different areas such as furniture, automobile, construction, and packaging industry. (Asim et al., 2017). Lignocellulosic natural fibers are highly hydrophilic and water permeable. For this reason, lignocellulosic fiber reinforced composites generally have a higher water absorption rate (Sreekala et al., 2002). Biocomposites which reinforced with natural fibers are sensitive to moisture. Also, water absorption affects the mechanical strength and fiber-matrix interface bonds that lead to poor stress transfer efficiency to the matrixed fibers (Siakeng et al., 2017). Many factors affect the water absorption of natural fiber reinforced composites such as temperature, fiber loading, and orientation, fiber properties, exposed surfaces, diffusivity and surface protection (Devi et al., 2011). Water absorption in fiber-reinforced composites mainly depends on three ways. The first method is diffusion processes; water molecules flow into the micro fractures of the polymer chains. In the second method capillary flow; if the interface between the fiber and the matrix is weak, the flow of water along with the interface will occur. The third is the storage of water in micro-cracks, both in polymer and in natural fiber (Devi et al., 2011, Siakeng et al., 2017). In a variety of applications, such as outdoor component, packaging and building industries, water absorption in natural fiber composites needs to be investigated (Siakeng et al., 2017).

In this study, water absorption, and thickness swelling tests were performed to determine the dimensional stability of neat PLA and PHB, NC/PLA, NC/PHB, NFC/PLA, NFC/PHB and NBN added PHB and PLA composites.

2 MATERIALS AND METHODS

Materials

In this present work, Polyhydroxybutyrate (PHB) and polylactic acid (PLA) were purchased from Good Fellow, England. Nanoclay (NC) and nanofibril cellulose (NFC), which are reinforcement materials, were supplied from NC Nanocor (Canada) and NFC JRS (Germany). Hexagonal nano boron nitride (BN), which improve the thermal properties, was supplied by Boron Product Tech. San. Tic. A.Ş (BORTEK) (Eskisehir, Turkey).

Biocomposites Preparation

Polymers matrix (PHB and PLA) and fillers (CNF, NC, and NBN) were dried for 3 hours at 80 ^{0}C before production. After this step, the reinforcement materials and pellets were mixed in the speed mixer. And then biocomposites were compounded using a twin screw extruder in which eight stage temperature (170 ^{0}C -175 ^{0}C -180 ^{0}C -180 ^{0}C -185 ^{0}C -190 ^{0}C -195 ^{0}C -200 ^{0}C) (Aysa Instruments, Turkey). Twin screw extruders rotor speed at 5 r/min during the extrusion. The obtained samples were dried for 24 hours at 80 C and passed through a lab-grinder. Then the pellets dried to 2-3% humidity before compression molding. The compression molding temperature was 180 °C and compression pressure 25 bar. Biocomposites samples were prepared by compression molding, press temperature 175 °C with a pressing time of 7 min at 25 atm. The formulations of the composites are summarized in Tab.1 and Tab. 2.

Table 1. Formulations used in the study.

Samples	**PHB (%)**	**PLA (%)**	**NC (%)**	**NFC (%)**
Neat PHB	100			
PHB+ 0.5% NC	99.5		0.5	
PHB+ 2% NC	98		2	
PHB+ 4% NC	96		4	
PHB+ 0.5% NFC	99.5			0.5

PHB+ 2% NFC	98			2
PHB+ 4% NFC	96			4
Neat PLA		100		
PLA+0.5% NC		99.5	0.5	
PLA+ 2% NC		98	2	
PLA+ 4% NC		96	4	
PLA+ 0.5% NFC		99.5		0.5
PLA+ 2% NFC		98		2
PLA+ 4% NFC		96		4

Table 2. Formulations used in the study.

Samples			NBN(%)
4% NC and NFC	PHB PLA	Biocomposites	1, 5 ve 10

Water Absorption and Thickness Swelling Tests

ASTM D 1037 and EN 317 standards comply with when determining the properties of the composites in water absorption and thickness swelling tests. Five samples which representing each composite were dried at 103 ± 2 ° C for 24 hours. Dry samples taken from the oven were weighed with a precision balance of 0,001 g. These weighed samples were placed in the water tank of Memmert (Germany) filled with pure water and kept at room temperature for 24 hours to 1 month. To measure the water absorption of samples, Eq. 1 was used.

$$Increase\ in\ weight\ (\%) = \frac{wet\ weight - conditioned\ weight}{conditioned\ weight}\ x\ 100 \quad (1)$$

The thicknesses of these samples were measured with the vernier caliper to the nearest 0,001 mm. To measure the thickness swelling of samples, Eq. 2 was used.

$$\text{Thickness swelling } (\%) = \frac{final\ \text{thickness} - initial\ \text{thickness}}{initial\ \text{thickness}}\ x\ 100 \quad (2)$$

3 RESULT AND DISCUSSION

Water absorption and thickness swelling tests on biocomposites lasted 1 month. The water absorption percentages of composites increased with time. The increase in water absorption percentages of the composites towards to 20th day is the maximum. The rate of increase in water absorption after 20th day has slowed down. Lower water absorption rates have been found in the last 10 days. PHB/PHB composites have received more water than PLA/PLA composites. It was also observed that NFC additive composites received more water than PHB and PLA controls. The swelling rate of PHB/PHB composites is higher than PLA and composites. Besides after 20 days of thickness swelling in PHB composites, swelling formed and fractional dispersion occurred.

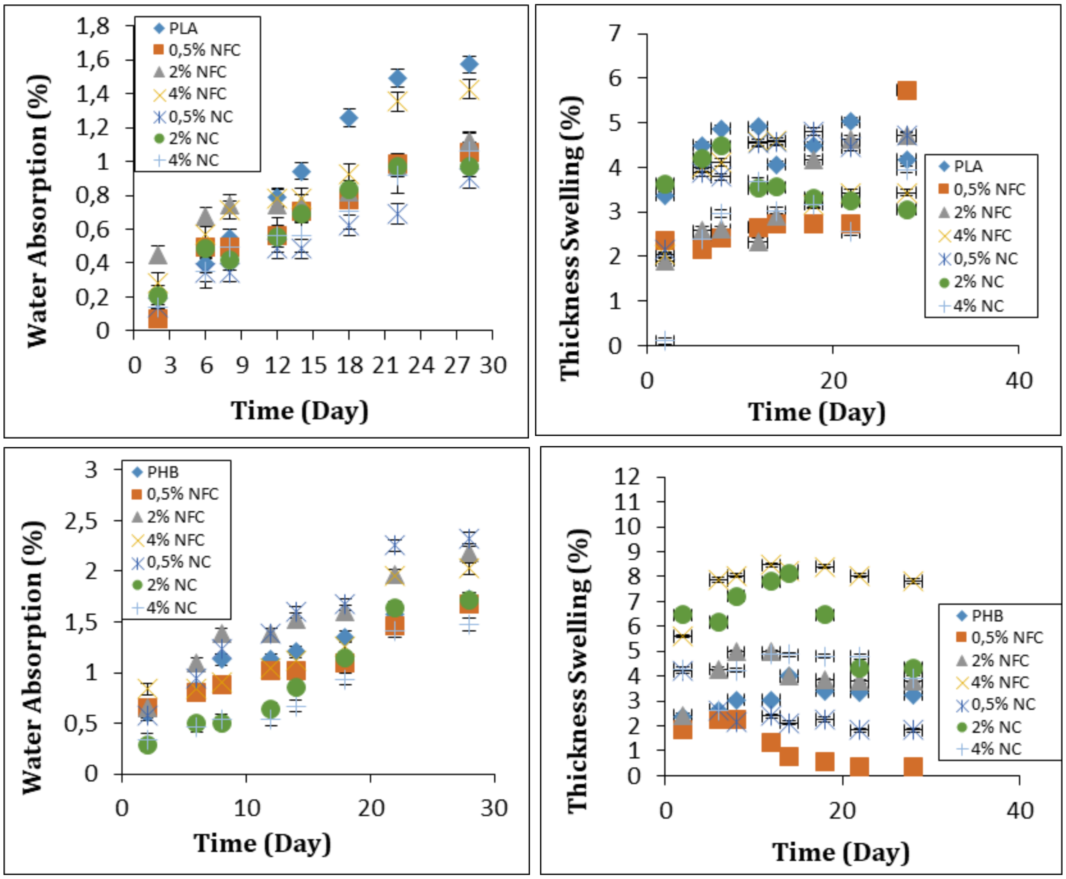

Figure 9: PLA and PHB biocomposite water absorption and thickness swelling values.

Yew et al. conducted water absorption tests in PLA and PLA / rice starch (PLA/RS) composites for 30 days. The moisture absorption rate in composites initially showed a linear trend, followed by saturation was reached. Rapid water uptake was observed in all samples in the first few days of immersion. Water absorption is related to the diffusion rate of the composites. The maximum moisture content (M_m) value of PLA/RS composites is higher than pure PLA composites. Wang et al. higher M_m and D (diffusivity) values in composites say that RS may be attributed to the hydrophilic nature due to the presence of a hydroxyl group moiety that may interact with water molecules. Also Preechawong et al. have suggested that starch is prone to moisture and water absorption due to its hygroscopic nature (Yew et al., 2005).

Chow et al. were used organo-montmorillonite clay (OMMT), stearic acid coated nano-precipitated calcium carbonate (NPCC) and PLA. When OMMT and NPCC were added to PLA, water uptake increased. Zaikov and Jimenez said that the increase in Mm value; OMMT's surface and the octadecylamine intercalant can be attached to the hydrophilic nature (Chow et al., 2014).

Yu et al. conducted water absorption tests in PLA and PLA /ramie fiber (PLA/ramie) composites. It was observed that the water absorption of neat PLA increased as the immersion time until achieved the equilibrium. Yu et al., performed water absorption tests on short ramie fiber reinforced PLA composites. The water absorption of neat PLA was found to increase during the dipping time until reaching the equilibrium. Tham et al.; Neat PLA mechanism of the diffusion water molecule can be explained as either infiltration into microvoid or other morphological defects or specific molecular interaction being controlled by the hydrogen bond present in the hydrophilic regions. The ramie/PLA composites show a different trend than the pure PLA composites. Gil-Castell et al.; this behavior is attributed to the development of surface microfractures that water can swell fibers and result in the phenomenon of capillarity (Yu et al., 2018).

Kalagar et al. conducted water absorption tests and thickness swelling tests in PLA and wheat straw fibers reinforced PLA composites. The values of water absorption and thickness swelling of all composites increased with the extension of immersion time. According to the analysis results, pure PLA has the lowest water absorption and thickness swelling value due to its hydrophobic structure. When wheat straw fiber added to PLA, the values of water absorption and thickness swelling increased. Formation of hydrogen bonds between fibers (cell walls of the fibers) and water molecules, hydrophilic nature of the wheat straw fibers and voids between the two phases may be effective the increase of water absorption in composites (Kalagar et al., 2015).

Siakeng et al. conducted water absorption tests and thickness swelling tests in Coir fibers (CF) /Pineapple leaf fibers (PALF) /Polylactic acid (PLA) composites. Neat PLA sample showed the lowest water absorption value. The surfaces of the CF/PLA and PALF/PLA composites have a void content and porous structure. Due to this reason, the weight of the composites increases by trapping the water into the voids. The lowest thickness swelling showed in the pure PLA sample. High thickness swelling values indicated the presence of composites with high porosity or voids on the surface.

Kuciel and Liber-Kneć conducted water absorption tests on wood flour and kenaf fiber reinforced PHB composites for 90 days. Water absorption increased that reinforced wood flour and kenaf PHB composites. Biocomposites when remaining in humid environments expansion by absorbs moisture.
Especially thermoplastic composites, are more sensitive to heat and moisture when operating in a changing environment and changing usage conditions (Kuciel and Liber-Kneć, 2011).

NBN Reinforced Composites

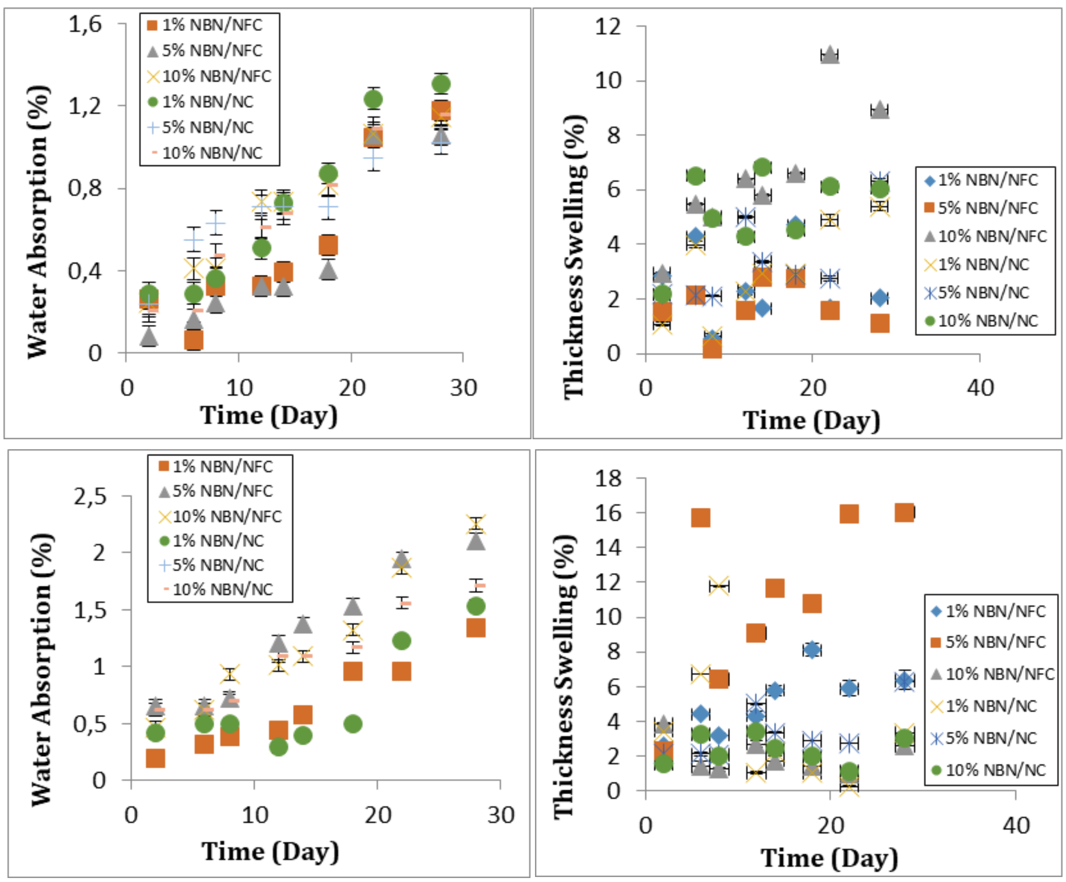

Figure 10: NBN reinforced PLA and PHB biocomposite water absorption and thickness swelling values.

PLA and PHB biocomposites have increased water absorption dependent by time. In other words, there is a direct correlation between time and water absorption rates. On the other hand, there is a polynomial relationship between the swelling ratios of the biopolymers. At the end of the water absorption test, no fragmentation occurred in the PLA composites. After one month PHB composites were disintegrated, and wide swellings observed. Thickness swelling values increased when NBN added to the composites. The highest thickness swelling values were found 10% NBN/NFC in PLA and 5% NBN/NFC in PHB composites.

4 CONCLUSION

The effects of nanoboron nitride on the physical properties of PLA and PHB nanocomposites were investigated. The water absorption ratio of PLA and PHB composites increased parallel to the soaking time. The largest increase ratio for water absorption of the composites was found to find to 20 days. PHB and PHB composites have also absorbed more water than PLA and PLA composites. It was observed that the addition of NFC to both PLA and PHB polymers was determined to raise the water absorption of both PHB and PLA polymers as a comparison with the addition of NC. With the addition of NBN, there was no significant change in the water absorption values, while the thickness swelling values of the composites increased greatly. As a result, it can be said that the addition of NBN hasn't a significant effect on the water absorption of the biocomposites, but increased the thickness swelling of the all composites.

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Application of ABC Analysis in A Large-Scale Furniture Factory

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ABSTRACT

Nowadays, inventory management and control play an important role in the success of the organizations in the business environment. It is not clearly possible for a large-scale furniture factory that store thousands of inventory items to economically design an inventory management policy for each inventory item separately. Hence, the managers need to classify these items in order to control each inventory category properly based on its importance rating.

The importance of inventory items should be determined in a large-scale furniture factory. Quantities of inventories must be met according to order cost and need, value classification for thousands of inventories must be done. In this study, ABC analysis will be made to classify inventories in a large-scale furniture factory. In a large-scale furniture factory, inventory will be allocated primarily to raw materials, semi-finished products and accessories. Approximately ten thousand inventories will be allocated according to currencies and units of measure. ABC analysis will be applied when there are no currencies and units of measure differences between the inventories.

In materials management, the ABC analysis is an inventory categorization technique. ABC analysis divides an inventory into three categories- "A items" with very tight control and accurate records, "B items" with less tightly controlled and good records, and "C items" with the simplest controls possible and minimal records. After applying the ABC analysis, A, B and C group inventories will show up. It is aimed to use ABC analysis data in system analysis program for Material Requirement Planning (MRP).

KEYWORDS: ABC Analysis, Inventory Control, Furniture, SAP

1 INTRODUCTION

Inventory control is based on the foundation of the 1920's. Little progress has been made in the studies of stock control until the Second World War, and it has been seen since 1950 that it has grown greatly (Ertuğrul, 2013).

Inventory is a stock of physical goods held at a specific location at a specific time. each distinct item in the inventory at aa location is termed a stock keeping unit (SKU), and each SKU has a number of units in stock (Narasımhan, 1995)

The purpose of inventory control is the materials and spare parts that need to be supplied for production. It is the task of finding answers to two seemingly simple questions about "when" and "how much" to procure. These questions form the basis of the inventory control function. The purpose of inventory control is to ensure that the material requirement is met at the desired time, in the desired quantity, at the desired location, at the desired quality (Tanyaş, 2013).

The desire of businesses to use materials requested by them and to make them ready for use necessitates stockpiling. Because of this need, businesses face a number of problems related to the control and management of stocks, whatever their size. Having too little stock in the business opens up the risk of not meeting customer expectations and expectations due to possible production / service interruptions. Having too much inventory in the business affects the liquidity and financial structure of the enterprises in the negative direction due to the capital attached to the stocks (Karagöz, 2015).

Inventory control attempts to determine the optimum stock amount for the operation by balancing the information that can be provided by transferring the information about stocks to the management and holding stocks and holding stocks. Stock control; stock quantities and types are determined economically according to supply, production, sales and financial possibilities of the operator. Determination of the material requirements of the operator, selection of the material to be stocked, determination of the quantity to be kept for the production failure and continuation, determination of the ordering time, regulation of the inventory registration transactions, connection to the stocks held in hand such as the calculation of the minimum capital required (Ertuğrul, 2013).

An organization's Inventory may include raw materials, supplies used in operations, finished goods and spare parts. Every SKU needs some time to be manageable by logisticans and time is one of the most important players in nowadays economical situations. One of the most widely used methods to solve this conflict is the ABC classification method. By classifying the SKUs in inventory, a manager can spend much more time to the SKUs that is more important relatively (Kıyak, 2015).

As computerized inventory management systems are implemented, accurate and timely records can be obtained more economically on all items. In situations where computerized inventory control systems are installed for all items, the ABC classification system takes a back seat (Narasımhan, 1995).

Many enterprises apply stocking methods for raw materials and semi-finished products according to their needs or according to the production management they apply. The most commonly used ones are as follows (Çevik, 2012):

1- Visual Control Method

In the visual inspection method, stocks are followed by a warehouse officer responsible for stocks. The dispatcher identifies the shortcomings and contacts the relevant department of the business for ordering.

2- Single Box Method

In this method, the boxes or shelves are filled with stock as much as they are received periodically, so no records are recorded for stock entry and exit. This method, which has a very high risk of falling into stomatitis, is a simple and inexpensive method that is easy to apply, such as the visual control method.

3- Double Box Method

Double box stock control method; unit value is a method used for controlling low and volume small inventory items. Stock items are stored in a box with two compartments. When the first box is completely finished, a new order is placed. The goods in the second box must meet the need until the order is received.

4- Maximum – Minimum Stock Control Method

In this method, the desired maximum stock level and minimum stock level are determined from the beginning. Stocks are ordered at fixed time intervals, for example every two weeks, when the stock amount is below the predetermined minimum level.

5- Inventory Control Cards Method

Quantity and value movements are monitored by Stock Control Cards. The cards held in the Ambard only contain the amount movements and the remainder. On the cards held in the accounting department, value movements are shown.

6- Optimal Safety Stock Method

In this method, it is important to determine the amount of safety zone. There are many factors affecting the quantity of safety factor, the most important being the degree of uncertainty in the amount of sales or production, the level of uncertainty in the supply, the loss of operation in the absence of stagnation, and the costs of carrying additional stock. Optimal safety stock arises at the point where the cost of the stockless stock and the cost of maintaining additional stock are minimal. At this point, the additional stochastic marginal utility (yield) equals this stochastic marginal cost

7- Computerized Inventory Control Method

The material entering the facility is loaded into the system via barcode. When information about material exits is processed on the computer, the material falling below the minimum stock level is automatically determined. Inventory status is also monitored in the computer environment and information on the missing items is reported to the purchasing unit. Thus, the barcode system stands out with its advantages such as fast, reliable and continuous stock information storage.

8- ABC Analysis

ABC analysis was discovered by Pareto, an Italian economist, approximately 100 years ago. He discovered that a small percentage of a population always has the greatest effect. Because of its easy-to implement nature and remarkable effectiveness in many inventory systems, this approach is widely used in practice (Chen et.al., 2006). Pareto's law was further expanded to the ABC classification and is summarized below. Viale (1996) has explained ABC analysis like this: "When considering how to apply this tool to establish inventor y levels, consider the following: From a practical standpoint, ask yourself: "Which products (and which customers) generate 80 percent of the revenue?" Answer: Approximately 20 percent of the products and customers generate 80 percent of the revenue (Jumabaeva, 2011).

In this work, which is carried out under the title of Master's Degree Program in "Material Requirements Planning and Implementation in A Great Scale Furniture Factory", ABC analysis inventory grouping was carried out using real stock flow data of a large-scale furniture factory. The obtained group information will be used for the planned control of inventory of materials.

2 METHOD

The research was carried out in a large-scale furniture operation in Ankara. All the procurement products used in the panel section of the operator within one year have been examined in terms of gender, annual consumption amount, unit price and total procurement cost. The proportion of each procurement product in total cost was found proportionally and each procurement product was grouped into A, B and C according to Table 1. The resulting results were evaluated in terms of the stock control method to be applied and the control frequency.

Here are the ABC analysis steps applied at the panel workshop of a large-scale furniture factory:

Step 1. The raw materials used in the panel workshop are defined. A list is made that describes the quantities and unit prices used from the identified raw materials,

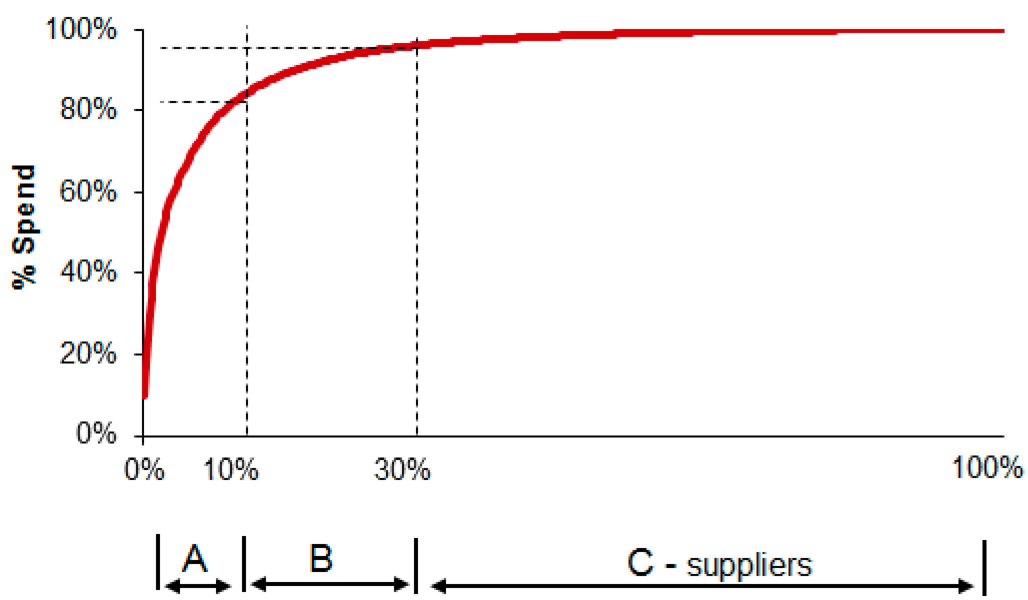
Step 2. The annual consumption cost for each product is calculated by multiplying the annual consumption quantity by the unit price,

Step 3. The monthly average of the annual cost is calculated,

Step 4. As a result of the averages, the products are ordered from the largest to the smallest.

Step 5. The cumulative cost percentage is calculated according to the ratio of the total costs of the products to the overall total.

Step 6. According to ABC analysis rules, products are divided into groups A, B and C.



Graphic 1: ABC Analysis Graph

"A" items have the highest value. These are relatively few items (15– 20 percent) whose value accounts for 75– 80 percent of the total value of the inventory. As a general rule, 20 percent of the items constitute 80 percent of the annual requirements. All "A" items are counted monthly.

"B" items have medium value. These are a larger number in the middle of the list, usually about 30– 40 percent of the items, accounting for about 15 percent of the value. All "B" items are counted quarterly.

"C" items have low value. These are the bulk of the inventory, usually about 40– 50 percent of the items, whose total inventory value is almost negligible, accounting for only 5–10 percent of the value. All "C" items are counted annually. Many times, these physical counts are based on estimates (Jumabaeva, 2011).

In this study, firstly the panel group materials used in the continuous manufacturing stage were evaluated. Annual consumption quantities of these materials are calculated, unit prices of materials and annual consumption values are calculated. The annual values of the materials are calculated as the monthly average value.

3 FINDINGS AND DATA ANALYSIS

In the case of the ABC analysis of a large-scale firm, panel / plate group materials were determined for production orders for the furniture produced by the firm and monthly consumption averages were calculated within one year.

The cumulative value of the cost of purchasing the most used materials for the firm has been determined. This value is listed in the smallest value from the largest value. In ABC analysis, these values were determined in necessary groups and letter assignment was made.

PRODUCT	ANNUAL CONSUMPTION QUANTITY (M2)	UNIT PRICE (TL)	PURCHASING COST (TL)	MONTHLY AVERAGE COST (TL)	CUMULATIVE VALUE	CUMULATIVE TOTAL	ABC
MDF 18 MM	381185,99	20,92	7974410,911	1329068,485	0,487943657	0,48794366	A
MDF 06 MM	158312,307	12,19	1929827,022	321637,8371	0,118083563	0,60602722	A
MDFLAM 18 MM A402 NATUREL	64555,472	23,33	1506079,162	251013,1936	0,092154992	0,69818221	A
S.LAM 18 MM D152 OPAK BYZ BUTE	30917,434	18,6	575064,2724	95844,0454	0,035187422	0,73336963	A
S.LAM 18 MM 4208 B.MEŞE	28125,652	17,64	496136,5013	82689,41688	0,030357936	0,76372757	A
MDFLAM 18 MM D161 DAFNE-NTR	12690,902	38,29	485934,6376	80989,10626	0,029733698	0,79346127	A
MDFLAM 18 MM OPAK BYZ T.YÜZ BUTE	13675,683	26,96	368696,4137	61449,40228	0,022560046	0,81602131	B
MDFLAM 18 MM D122 VİZON	12453,317	20,31	252926,8683	42154,47805	0,015476261	0,83149757	B
MDFLAM 18 MM F236 KOTON VİZON	8098,373	22,15	179378,962	29896,49366	0,010975961	0,84247354	B
MDFLAM 18 MM D152 OPAK BYZ	6171,103	27,56	170075,5987	28345,93311	0,010406701	0,85288024	B
MDF 30 MM	4439,497	35,56	157868,5133	26311,41889	0,009659766	0,86254	B
YONGA LEVHA 18 MM	12811,305	11,93	152838,8686	25473,14477	0,009352008	0,87189201	B
YONGA LEVHA 38 MM	4362,837	34,89	152219,3829	25369,89716	0,009314103	0,88120611	B
MDF 12 MM	7648,31	15,72	120231,4332	20038,5722	0,007356802	0,88856292	B

PRODUCT	ANNUAL CONSUMPTION QUANTITY (M2)	UNIT PRICE (TL)	PURCHASING COST (TL)	MONTHLY AVERAGE COST (TL)	CUMULATIVE VALUE	CUMULATIVE TOTAL	ABC
S.LAM 30 MM D107 SİYAH	3682,353	31,65	116546,4725	19424,41208	0,007131325	0,89569424	B
MDFLAM 08 MM D122 VİZON	8751,512	13,14	114994,8677	19165,81128	0,007036384	0,90273062	B
S.LAM 18 MM D107 SİYAH	5364,796	19,23	103165,0271	17194,17118	0,006312532	0,90904316	B
MDFLAM 08 MM D161 DAFNE-NTR	5476,394	18,25	99944,1905	16657,36508	0,006115453	0,91515861	B
YONGA LEVHA 38 MM YEŞİL	1157,211	62,62	72464,55282	12077,42547	0,00443401	0,91959262	B
S.LAM 18 MM ANTRASİT 075 KALIN BUTE	2884,831	21,86	63062,40566	10510,40094	0,003858705	0,92345132	B
MDF 18 MM LAKELİK	2538,368	22,44	56960,97792	9493,49632	0,003485367	0,92693669	B
S.LAM 30 MM 4208 B.MEŞE	2043,679	27,17	55526,75843	9254,459738	0,003397609	0,9303343	B
MDF 40 MM	842,857	63,58	53588,84806	8931,474677	0,003279031	0,93361333	B
MDF 08 MM	4286,56	10,45	44794,552	7465,758667	0,002740919	0,93635425	B
S.LAM 16 MM D152 OPAK BYZ BUTE	2413,824	18	43448,832	7241,472	0,002658577	0,93901283	B
S.LAM 18 MM D104 FİLDİŞİ	2745,547	15,17	41649,94799	6941,657998	0,002548505	0,94156133	B
S.LAM 30 MM D152 OPAK BYZ BUTE	1188,019	34,54	41034,17626	6839,029377	0,002510827	0,94407216	B
S.LAM 08 MM D107 SİYAH	2525,614	14,97	37808,44158	6301,40693	0,002313449	0,94638561	B
MDF 16 MM	2191,113	16,51	36175,27563	6029,212605	0,002213517	0,94859912	B
MDFLAM 08 MM V137 LATİN CEVİZ	23,52	1513,78	35604,1056	5934,0176	0,002178568	0,95077769	C
MDFLAM LEVHA 18 MM 4273 CEVİZ	1774,224	19,84	35200,60416	5866,76736	0,002153878	0,95293157	C
S.LAM 08 MM 4208 B.MEŞE	3958,01	8,86	35067,9686	5844,661433	0,002145763	0,95507733	C
KONTRAPLAK 04 MM ESNEK SOKRASINA KAYIN	995,234	34,06	33897,67004	5649,611673	0,002074154	0,95715149	C
MDF 25 MM	1004,59	32,42	32568,8078	5428,134633	0,001992842	0,95914433	C
MDFLAM 08 MM A402 NATUREL MEŞE	2879,106	11,06	31842,91236	5307,15206	0,001948426	0,96109275	C

PRODUCT	ANNUAL CONSUMPTION QUANTITY (M2)	UNIT PRICE (TL)	PURCHASING COST (TL)	MONTHLY AVERAGE COST (TL)	CUMULATIVE VALUE	CUMULATIVE TOTAL	ABC
MDFLAM 2,7 MM D104-101 F.DİŞİ-BYZ	7521,457	3,98	29935,39886	4989,233143	0,001831707	0,96292446	C
S.LAM 30 MM ANTRASİT 075 KALIN BUTE	1072,558	27,73	29742,03334	4957,005557	0,001819876	0,96474434	C
S.LAM 18 MM 3101 BEYAZ	1556,978	18,85	29349,0353	4891,505883	0,001795829	0,96654017	C
YONGA LEVHA 30 MM	1526,396	18,34	27994,10264	4665,683773	0,001712922	0,96825309	C
MDF 10 MM	2085,782	13,36	27866,04752	4644,341253	0,001705087	0,96995818	C
YONGA LEVHA 44 MM	393,505	70,59	27777,51795	4629,586325	0,00169967	0,97165785	C
MDFLAM 08 MM F236 KOTON VİZON	2364,653	11,29	26696,93237	4449,488728	0,00163355	0,97329139	C
S.LAM 08 MM D152 OPAK BYZ BUTE	1709,507	12,48	21334,64736	3555,77456	0,001305439	0,97459683	C
MDF 14 MM	1191,182	17,1	20369,2122	3394,8687	0,001246365	0,9758432	C
YONGA LEVHA 08 MM	2615,124	7,45	19482,6738	3247,1123	0,001192119	0,97703532	C
S.LAM 18 MM 3766 EGGER	476,48	38,35	18273,008	3045,501333	0,001118101	0,97815342	C
S.LAM 08 MM ANTRASİT 075 KALIN BUTE	905,528	18,88	17096,36864	2849,394773	0,001046104	0,97919952	C
MDFLAM 30 MM D161 DAFNE-NTR	393,552	41,91	16493,76432	2748,96072	0,001009232	0,98020876	C
MDFLAM 18 MM VT-068 BEYAZ	910,999	17,96	16361,54204	2726,923673	0,001001141	0,9812099	C
S.LAM 30 MM 3096 T.YÜZ BEYAZ	547,438	28,35	15519,8673	2586,64455	0,00094964	0,98215954	C
S.LAM 18 MM 3153 GRİ	944,823	16,4	15495,0972	2582,5162	0,000948125	0,98310766	C
MDFLAM 18 MM PARLAK BEYAZ AGT	471,791	31,81	15007,67171	2501,278618	0,0009183	0,98402596	C
S.LAM 30 MM A402 NATUREL MEŞE	384,044	33,03	12684,97332	2114,16222	0,000776177	0,98480214	C
KONTRAPLAK 6 MM	498,292	24,37	12143,37604	2023,896007	0,000743037	0,98554517	C
MDF 22 MM	435,036	27,3	11876,4828	1979,4138	0,000726706	0,98627188	C
S.LAM 16 MM D143 ANTRASİT	760,818	15,47	11769,85446	1961,64241	0,000720182	0,98699206	C
MDFLAM 18 MM D104 T.YÜZ F.DİŞİ	518,664	22,38	11607,70032	1934,61672	0,00071026	0,98770232	C

PRODUCT	ANNUAL CONSUMPTION QUANTITY (M2)	UNIT PRICE (TL)	PURCHASING COST (TL)	MONTHLY AVERAGE COST (TL)	CUMULATIVE VALUE	CUMULATIVE TOTAL	ABC
MDFLAM 18 MM D109 MAVİ BUTE	383,507	29,52	11321,12664	1886,85444	0,000692725	0,98839505	C
S.LAM 18 MM A402 NTRL MEŞE	606,107	17,59	10661,42213	1776,903688	0,000652358	0,98904741	C
S.LAM 18 MM D122 VİZON	467,738	21,73	10163,94674	1693,991123	0,000621918	0,98966932	C
S.LAM 18 MM 4484 AMERİKAN CEVİZ	461,132	21,5	9914,338	1652,389667	0,000606645	0,99027597	C
MDF 18 MM NEME DAYANIMLI	308	27,31	8411,48	1401,913333	0,000514687	0,99079066	C
S.LAM 18 MM 133 TOLEDO	580,969	13,87	8058,04003	1343,006672	0,000493061	0,99128372	C
MDFLAM 18 MM 3099 KİRLİ BYZ	392,442	20,37	7994,04354	1332,34059	0,000489145	0,99177286	C
YONGA LEVHA 25 MM	358,78	19,65	7050,027	1175,0045	0,000431382	0,99220424	C
YONGA LEVHA 28 MM YEŞİL	804,572	7,76	6243,47872	1040,579787	0,00038203	0,99258627	C
MDFLAM 18 MM 4642 SANTHIA	183,186	33,67	6167,87262	1027,97877	0,000377404	0,99296368	C
MDFLAM 18 MM D160 AYTAŞI	254,767	23,49	5984,47683	997,412805	0,000366182	0,99332986	C
MDFLAM 18 MM D129 LAKE BEYAZ	237,407	23,43	5562,44601	927,074335	0,000340359	0,99367022	C
S.LAM 18 MM D164 GRİ LUNA-NTR	235,534	20,5	4828,447	804,7411667	0,000295446	0,99396567	C
S.LAM 18 MM H3700 N.P.CEVİZ ST10 EGGER	207,442	22,84	4737,97528	789,6625467	0,00028991	0,99425558	C
S.LAM 18 MM 4598 BEYAZ A.MEŞE	440,891	10,57	4660,21787	776,7029783	0,000285153	0,99454073	C
MDFLAM 18 MM F237 KOTON LATTE	185,731	24,58	4565,26798	760,8779967	0,000279343	0,99482007	C
KONTRAPLAK 03 MM ESNEK SUYUNA	125,444	33,33	4181,04852	696,84142	0,000255833	0,9950759	C
MDF 04 MM	775,541	5,13	3978,52533	663,087555	0,000243441	0,99531934	C
MDFLAM 30 MM OPAK BYZ T.YÜZ	65,64	55,66	3653,5224	608,9204	0,000223554	0,9955429	C
MDF 03 MM	1248,876	2,92	3646,71792	607,78632	0,000223138	0,99576604	C

PRODUCT	ANNUAL CONSUMPTION QUANTITY (M2)	UNIT PRICE (TL)	PURCHASING COST (TL)	MONTHLY AVERAGE COST (TL)	CUMULATIVE VALUE	CUMULATIVE TOTAL	ABC
S.LAM 18 MM A847 ALASKA	284,544	12,64	3596,63616	599,43936	0,000220073	0,99598611	C
S.LAM 18 MM 4207 MONTREAL	257,962	13,83	3567,61446	594,60241	0,000218298	0,99620441	C
S.LAM 08 MM 3153 GRİ	291,288	11,1	3233,2968	538,8828	0,000197841	0,99640225	C
MDFLAM 18 MM 4481 WALNUT	114	27,33	3115,62	519,27	0,000190641	0,99659289	C
S.LAM 18 MM H1181 DOKULU MEŞE EGGER	45,499	62,74	2854,60726	475,7678767	0,00017467	0,99676756	C
S.LAM 18 MM D160 AY TAŞI	128,916	21,51	2772,98316	462,16386	0,000169675	0,99693723	C
S.LAM 08 MM 133 TOLEDO	231,654	11,09	2569,04286	428,17381	0,000157196	0,99709443	C
S.LAM 18 MM H1180 DOKULU A.MEŞE EGGER	49,687	51,49	2558,38363	426,3972717	0,000156544	0,99725097	C
S.LAM 18 MM A353 TEAK	190,684	12,7	2421,6868	403,6144667	0,00014818	0,99739915	C
S.LAM 08 MM 4598 BEYAZ A.MEŞE	176,782	13,49	2384,78918	397,4648633	0,000145922	0,99754508	C
S.LAM 08 MM D122 VİZON	155,584	15,14	2355,54176	392,5902933	0,000144132	0,99768921	C
S.LAM 08 MM 3101 BEYAZ	217,397	9,73	2115,27281	352,5454683	0,000129431	0,99781864	C
MDF 18 MM DĞL KAPLAMA LİGNUM HASIR DESEN	15,516	122,48	1900,39968	316,73328	0,000116283	0,99793492	C
S.LAM 30 MM 3101 BEYAZ	95,14	19,96	1898,9944	316,4990667	0,000116197	0,99805112	C
S.LAM 08 MM A356 ZEBRANO	91,2	17,97	1638,864	273,144	0,00010028	0,9981514	C
S.LAM 30 MM A356 ZEBRANO	45,6	32,38	1476,528	246,088	9,03468E-05	0,99824175	C
MDF 02 MM	320,045	4,54	1453,0043	242,1673833	8,89074E-05	0,99833065	C
YONGA LEVHA 18 MM KAPAKLIK	140,423	10,11	1419,67653	236,612755	8,68681E-05	0,99841752	C
S.LAM 30 MM 075 TEK YÜZ ANTRASİT	134	10,43	1397,62	232,9366667	8,55185E-05	0,99850304	C
S.LAM 25 MM A423 SANREMO STR	159,945	8,33	1332,34185	222,056975	8,15242E-05	0,99858456	C

PRODUCT	ANNUAL CONSUMPTION QUANTITY (M2)	UNIT PRICE (TL)	PURCHASING COST (TL)	MONTHLY AVERAGE COST (TL)	CUMULATIVE VALUE	CUMULATIVE TOTAL	ABC
MDF 18 MM DĞL KAPLAMA LİGNUM DALGA DESEN	7,715	168,58	1300,5947	216,7657833	7,95817E-05	0,99866415	C
S.LAM 18 MM 5709 ABSOLUTE PEARL	52,992	24,26	1285,58592	214,26432	7,86633E-05	0,99874281	C
S.LAM 30 MM 4598 BEYAZ A.MEŞE	68,934	17,1	1178,7714	196,4619	7,21275E-05	0,99881494	C
KONTRAPLAK 07 MM ESNEK SOKRASINA KAYIN	29,768	35,27	1049,91736	174,9862267	6,42431E-05	0,99887918	C
MDFLAM 30 MM D152 OPAK BYZ	30,996	32,78	1016,04888	169,34148	6,21707E-05	0,99894135	C
S.LAM 08 MM 4484 AMERİKAN CEVİZ	73,036	13,21	964,80556	160,8009267	5,90352E-05	0,99900039	C
KONTRAPLAK 06 MM ESNEK SOKRASINA KAYIN	28,913	32,91	951,52683	158,587805	5,82227E-05	0,99905861	C
MDFLAM 18 MM D152 T.YÜZ BYZ DÜZ	27,44	31,81	872,8664	145,4777333	5,34095E-05	0,99911202	C
MDFLAM 08 MM D160 AYTAŞI	38,826	21,62	839,41812	139,90302	5,13629E-05	0,99916338	C
MDFLAM 08 MM 4642 SANTHIA	29,205	27,81	812,19105	135,365175	4,96969E-05	0,99921308	C
S.LAM 08 MM 4207 MONTREAL	70,99	10,73	761,7227	126,9537833	4,66088E-05	0,99925969	C
S.LAM 08 MM A353 TEAK	44,557	16,86	751,23102	125,20517	4,59668E-05	0,99930565	C
S.LAM 08 MM A402 NATUREL MEŞE	63,386	10,74	680,76564	113,46094	4,16551E-05	0,99934731	C
S.LAM 16 MM FİLDİŞİ D104	44,275	14,84	657,041	109,5068333	4,02035E-05	0,99938751	C
S.LAM 18 MM 035 ISPARTA CEVİZ	34,684	18,13	628,82092	104,8034867	3,84767E-05	0,99942599	C
MDFLAM 08 MM 3101 BEYAZ	56	10,94	612,64	102,1066667	3,74866E-05	0,99946348	C
S.LAM 30 MM 3153 GRİ	25,644	23,37	599,30028	99,88338	3,66704E-05	0,99950015	C

PRODUCT	ANNUAL CONSUMPTION QUANTITY (M2)	UNIT PRICE (TL)	PURCHASING COST (TL)	MONTHLY AVERAGE COST (TL)	CUMULATIVE VALUE	CUMULATIVE TOTAL	ABC
S.LAM 18 MM H1215 BROWN C.ASH ST22 EGGER	38,054	15,32	582,98728	97,16454667	3,56722E-05	0,99953582	C
S.LAM 25 MM 3101 BEYAZ	20	24,59	491,8	81,96666667	3,00926E-05	0,99956591	C
S.LAM 30 MM 4484 AMERİKAN CEVİZ	28,093	17,12	480,95216	80,15869333	2,94288E-05	0,99959534	C
S.LAM 18 MM 4206 AKÇAAĞAÇ	35,19	12,53	440,9307	73,48845	2,698E-05	0,99962232	C
S.LAM 30 MM 133 TOLEDO	19,802	22,06	436,83212	72,80535333	2,67292E-05	0,99964905	C
S.LAM 30 MM D122 VİZON	19,741	20,92	412,98172	68,83028667	2,52698E-05	0,99967432	C
S.LAM 18 MM D118 ELVİRA	28,64	14,32	410,1248	68,35413333	2,5095E-05	0,99969941	C
S.LAM 18 MM D143 ANTRASİT	33,041	12,36	408,38676	68,06446	2,49886E-05	0,9997244	C
S.LAM 08 MM A847 ALASKA	30,516	12,13	370,15908	61,69318	2,26495E-05	0,99974705	C
S.LAM 18 MM 4208 B.MEŞE KRAFT	34,95	10,52	367,674	61,279	2,24975E-05	0,99976955	C
MDFLAM 18 MM D143 ANTRASİT	17,038	20,92	356,43496	59,40582667	2,18098E-05	0,99979136	C
S.LAM 18 MM 049 KB BEYAZ	31,24	9,78	305,5272	50,9212	1,86948E-05	0,99981005	C
MDFLAM 03 MM D160-101 AYTAŞI-BYZ	27,74	7,84	217,4816	36,24693333	1,33074E-05	0,99982336	C
S.LAM 08 MM 035 ISPARTA CEVİZ	22,64	9,48	214,6272	35,7712	1,31328E-05	0,99983649	C
S.LAM 18 MM H3452 F.WD GRAPHT ST22 EGGER	11,782	16,02	188,74764	31,45794	1,15492E-05	0,99984804	C
S.LAM 18 MM MESSİNA KEPİ	9	19,9	179,1	29,85	1,09589E-05	0,999859	C
S.LAM 25 MM 4598 BEYAZ A.MEŞE	16,276	10,44	169,92144	28,32024	1,03973E-05	0,9998694	C
S.LAM 18 MM V102 VARIO BYZ KRAFT	6,024	27,8	167,4672	27,9112	1,02471E-05	0,99987965	C
MDFLAM 18 MM D160 T.YÜZ AYTAŞI	8,812	18,98	167,25176	27,87529333	1,02339E-05	0,99988988	C

PRODUCT	ANNUAL CONSUMPTION QUANTITY (M2)	UNIT PRICE (TL)	PURCHASING COST (TL)	MONTHLY AVERAGE COST (TL)	CUMULATIVE VALUE	CUMULATIVE TOTAL	ABC
MDFLAM 08 MM F237 KOTON LATTE	27,856	5,99	166,85744	27,80957333	1,02098E-05	0,99990009	C
S.LAM 18 MM H3451 F.WD CHMPNR ST22 EGGER	7,934	17,81	141,30454	23,55075667	8,64624E-06	0,99990874	C
MDFLAM 03 MM D152 OPAK BYZ	42,175	2,92	123,151	20,52516667	7,53545E-06	0,99991627	C
S.LAM 30 MM ORMA AVOLA ÇAM ASD 3079	28	4,23	118,44	19,74	7,24719E-06	0,99992352	C
S.LAM 30 MM 4207 A.AĞAÇ KRAFT	10,75	10,52	113,09	18,84833333	6,91983E-06	0,99993044	C
S.LAM 30 MM 035 ISPARTA CEVİZ	5,954	18,82	112,05428	18,67571333	6,85645E-06	0,9999373	C
KONTRAPLAK 05 MM ESNEK SUYUNA	3,768	24,16	91,03488	15,17248	5,5703E-06	0,99994287	C
KONTRAPLAK 18 MM SU KONTRASI	1,632	53,83	87,85056	14,64176	5,37546E-06	0,99994824	C
S.LAM 18 MM 3168 ASD KIZIL CEVİZ	75,906	1,09	82,73754	13,78959	5,0626E-06	0,9999533	C
S.LAM 18 MM 4279 TEAK	4,904	16,57	81,25928	13,54321333	4,97215E-06	0,99995828	C
S.LAM 08 MM 4279 TEAK	6,17	12,48	77,0016	12,8336	4,71163E-06	0,99996299	C
MDFLAM 08 MM D109 MAVİ BUTE	6,972	10,44	72,78768	12,13128	4,45378E-06	0,99996744	C
S.LAM 08 MM 4208 B.MEŞE KRAFT YILDIZ ENT	13,952	4,83	67,38816	11,23136	4,12339E-06	0,99997156	C
MDFLAM 18 MM D129 T.YÜZ LAKE BYZ	3,07	19,57	60,0799	10,01331667	3,67621E-06	0,99997524	C
S.LAM 08 MM D104 FİLDİŞİ	4,609	8,99	41,43491	6,905818333	2,53535E-06	0,99997778	C
S.LAM 18 MM H3782 NTRL YUKON ST22 EGGER	2,901	14,04	40,73004	6,78834	2,49222E-06	0,99998027	C
S.LAM 08 MM D118 ELVİRA	3,2	11,26	36,032	6,005333333	2,20475E-06	0,99998247	C
KONTRAPLAK 15MM SU KONTRASI	1,148	29,66	34,04968	5,674946667	2,08345E-06	0,99998456	C

PRODUCT	ANNUAL CONSUMPTION QUANTITY (M2)	UNIT PRICE (TL)	PURCHASING COST (TL)	MONTHLY AVERAGE COST (TL)	CUMULATIVE VALUE	CUMULATIVE TOTAL	ABC
S.LAM 18 MM 4212 TRUVA	2,638	12,06	31,81428	5,30238	1,94667E-06	0,9999865	C
S.LAM 18 MM 1017 GRİ	3,336	9,4	31,3584	5,2264	1,91878E-06	0,99998842	C
S.LAM 18 MM 056 VANİLYA	1,7	16,89	28,713	4,7855	1,75691E-06	0,99999018	C
MDF 05 MM	9,534	3,01	28,69734	4,78289	1,75595E-06	0,99999194	C
KONTRAPLAK 07 MM ESNEK SUYUNA KAYIN	14,544	1,77	25,74288	4,29048	1,57517E-06	0,99999351	C
S.LAM 18 MM H3070 N.URBANO ST22 EGGER	1,389	15,28	21,22392	3,53732	1,29866E-06	0,99999481	C
S.LAM 08 MM 5709 ABSOLUTE PEARL	1,092	18,87	20,60604	3,43434	1,26086E-06	0,99999607	C
S.LAM 18 MM A427 BAROK	1,214	11,91	14,45874	2,40979	8,84711E-07	0,99999695	C
S.LAM 18 MM D123 AÇIK GRİ	1	12,59	12,59	2,098333333	7,70365E-07	0,99999772	C
S.LAM 08 MM 4212 TRUVA	1,056	9,68	10,22208	1,70368	6,25476E-07	0,99999835	C
YONGA LEVHA 12 MM	1	8,36	8,36	1,393333333	5,11537E-07	0,99999886	C
S.LAM 08 MM D143 ANTRASİT	0,67	10,01	6,7067	1,117783333	4,10374E-07	0,99999927	C
S.LAM 08 MM 1017 GRİ	0,59	9,41	5,5519	0,925316667	3,39713E-07	0,99999961	C
YONGA LEVHA 16 MM	0,48	8,09	3,8832	0,6472	2,37608E-07	0,99999985	C
S.LAM 18 MM D126 CAPPİCUNO	0,11	11,9	1,309	0,218166667	8,0096E-08	0,99999993	C
S.LAM 18 MM D140 KUMTAŞI	0,11	10,55	1,1605	0,193416667	7,10095E-08	1	C

Table 1: ABC Classification on A Large-Scale Furniture Company

4 CONCLUSION

In this study, most used panel / plate group materials were selected for the products produced by a large-scale furniture company. It is necessary to provide stock controls for the company implementing the SAP system and to process these stocks into the system. By ABC analysis, the most valuable materials were identified in the panel / panel group and assigned as Group A. The materials in this group are used very frequently and are of great importance for the company. These materials should be checked as often as every week, and suggestions should be made accordingly in the system. Materials in group B are used regularly, and stocks should be checked in 2-3 weeks in general. The SAP system should determine the needs accordingly and provide suggestions and suggestions. If group C materials are to be applied in the SAP system with a check once a month. It is an assignment made for occasional supplies that are of little importance.

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The Effect of Vermiculite Usage on Surface Properties of Medium Density Fibreboard

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ABSTRACT

In this study, the effects of vermiculite of volcanic minerals usage on the surface properties were investigated in medium density fiberboard (MDF) production. The test boards were produced using the dry method with 12% urea formaldehyde resin. Additions of 10%, 15%, 20% and 30% vermiculite were used based on the full dry fiber weight. Surface roughness, color and gloss values of both surfaces of the obtained boards were determined. Based on the results, the ratio of vermiculite increased, roughness values on the surfaces increased. The roughness values in the bottom surface of the produced boards were determined to be higher than the top surface. With the use of 30% vermiculite, the average minimum surface roughness (Ra) was found to be 8.65 μm on the upper surfaces and 15.44 μm on the lower surfaces. It has been found that total color change and brightness are improved by the increase of vermiculite usage and the color change on the bottom surface is found higher. In short, the use of vermiculite in the production of MDF negatively affects the surface roughness and discoloration of the boards, but it has been found to positively affect the gloss.

KEYWORDS: Color, Gloss, MDF, Surface roughness, Vermiculite

1 INTRODUCTION

Nowadays, board products are widely used as building materials in many areas such as construction, decoration, interior and exterior architecture, furniture production (Kim. Et al. 2002; Seo et al. 2016). Medium density fibreboard (MDF) is one of wood-based panels produced by bonding wood fibers with resin under temperature and pressure and produced in high quantities (Ustaömer, et al. 2008; Saligna, et al. 2001; Koch, 1972; Maloney, 1993). In recent years, MDF production has increased significantly and has a large market share in the wood composite sector (İstek., et al. 2017a). As with other wood-based boards, the disadvantages of MDF boards are poor resistance to moisture and low resistance to burning (Ustaömer, et al. 2008; İstek., et al. 2017b). Some measures must be taken against these disadvantages in order to make better use of wood based boards products and to use these products efficiently. This is because the objective of board production is to improve the economic, aesthetic and technological properties of the material, as well as to increase the resistance against biotic and abiotic factors (Hall, et al. 1982; Dix, 1997). It is reported that vermiculite can be used to increase the fire resistance of cellulose based composites in different studies (Kozlowski et al., 1999, Rider, 2015, Rider, 2016, Wang et al., 2016, Aksogan et al., 2018).

Many methods and materials are used to improve the burning properties of wood materials. Important chemicals used as preservatives for this purpose are combustion retardants such as ammonium sulphate, ammonium chloride, dicyandiamide, borax and boric acid, and various phosphorus compounds (phosphoric acid, monoammonium phosphate and diammonium phosphates) (Ustaömer, 2008; Peker and Atılgan, 2015; İstek et al. 2012, 2013; İstek and Özlüsoylu, 2016; Özdemir and Tutuş, 2013). It is reported that vermiculite can be used to increase the fire resistance of cellulose based composites in different studies (Kozlowski et al. 1999; Binici, 2015; Binici, 2016; Wang et al. 2016; Aksoğan et al. 2018).

Vermiculite is a magnesium aluminosilicate clay mineral formed by natural wear of mikan. It is a mineral obtained from volcanic magma rocks and it is expanded at high temperatures to increase volume and permeability. The bulk density value changes significantly by falling shape (Toksoy, 1997). Vermiculite has good sound and heat insulation properties and also has the ability to stick to different surfaces. When used as a fire retardant, the smoke and gases released are not toxic and do not pose a threat to the environment (Crawford et al. 1990). The expanded vermiculite has a density of between 80 kg / m3 and 120 kg / m3 with a heat transfer coefficient of 0.04 W / (m · K) to 0.12 W / (m · K) and a high melting point of 1240 ° C - 1430 ° C. It is also a chemically inert, stable and environmentally safe material (Suvorov and Skurikhin 2003; Nguyen et al. 2013; Wang et al. 2016).

Surface properties are important in terms of wood-based boards, mainly medium density fiberboard (MDF) and chipboard, and board products are coated with liquid or solid coating materials to enhance their aesthetic, resistance properties and economic values (İstek et al. 2010; İstek et al. 2015; Atar, 2006; Nemli, 2003). Since the board products form the lower layer of the coating materials, surface properties such as surface roughness, bonding and quality of the final product are important. It is known that many factors are effective on the surface roughness depending on raw material and production conditions (Kılıç et al. 2009; İstek, et al. 2012; Nemli, et al. 2007; Dündar, et al. 2008; Özdemir, 2016;)

Various studies have indicated that fire-retardant materials have different effects on the physical, mechanical and surface properties of wood materials and wood-based composite (İstek and Özlüsoylu, 2016; Ustaömer, 2008; Winandy et al. 2002; Taghiyari et al. 2013; Winandy 1998; Ayrilmis et al. 2007; Ayrilmis et al. 2005; Ayrilmis, 2007; Simsek ,et al. 2013; İstek, et al. 2017c; İstek, et al. 2017d).

The needle screening method used in the metal and plastics industries with board surface roughness is more widely used in the measurement of wood composite boards and the roughness of solid wood product surfaces (Hızıroğlu, 1996; Burdurlu et al., 2005; Peters and Mergen 1971). The use of combustion retardants affects the surface properties of the boards. In this study, the effects of vermiculite used as fire retardant on the surface properties of the boards were investigated. For this purpose, some surface properties such as roughness, colour and gloss of MDF boards produced by adding vermiculite at different ratios have been determined.

2 MATERIAL AND METHOD

In this study oriental beech (*Fagus orientalis*) and black pine (*Pinus nigra*) wood fibers were used as raw materials. Fibres was supplied from Kastamonu Integrated Company MDF Plant and consists of 80% beech and 20% larch wood fibre blends. Urea formaldehyde binder (57% solid content) was used with respect to 12%
total dry fibre weight. Vermiculite is commercially available and is used in MDF production at rates of 10%, 15%, 20% and 30% relative to the total dry fibre weight. The vermiculite used was milled in 0.5 mm mesh.

2.1 MDF Production

In the study, the total of 15 boards were produced including vermiculite in 4 different ratios (10%, 15% 20% and 30%) and control boards without vermiculite as three boards of each group. The target density of the produced boards was 800 kg/m^3 and the form sizes were 400X400X12 mm. The fibres used in the production are supplied in a ready-made form and are brought to the laboratory in plastic bags in such a way that they do not get in contact with air. After the moisture control has been carried out, it is mixed with vermiculite at the specified ratios using a rotary drum gluing machine. The prepared fibres were hand-laid out in a wooden shaping mold with dimensions of 400x400x300mm and a board mat was formed. The board mat was exposed to 180 bar pressure and the temperature of 170^{0}C and 5 minutes hot press (SSP180 Cemil Usta, Turkey). The MDF boards were produced using a 12 mm thick metal thickness control sticks. The color change, gloss values and the surface roughness values of the produced boards were determined and they were compared with the control group. The colour, gloss and surface roughness measurements made to determine the surface properties of the vermiculite-added boards were made from two different surfaces, top and bottom, depending on the position of the boards in the formation.

2.2 Colour measurements

Colour measurement of the test samples were carried out in accordance with ISO 7724 standards by Konica Minolta CD- 600 colour meter. On the board samples, the colour measurements from 3 different points were measured and their mean value were calculated for three replicates in each variation (ISO-7724, 1984). The CIELab (Commission Internationale de l'Eclairage) system consists of three variants (ISO 7724). L* refers to Light stability, a* and b* chromatographic coordinates (+a* indicates red, -a* green, +b* yellow, -b* blue). The values of L*, a* and b* were measured on the samples and the color changes were determined according to the following Formula 1.

$$\Delta E^* = (\Delta L^*2 + \Delta a^*2 + \Delta b^*2) ½ \quad (1)$$

2.3 Gloss measurements

Gloss measurements were taken in a KONICA Minolta Multi gloss 268 plus. The angle of incidence of the radiation was 60±0.1°, as defined in ISO 2813.1994. Six measurements were made in each test panel.

2.4 Surface roughness

Mitutoyo Surftest SJ-301 was used for surface roughness measurements. The mean surface roughness (Ra), maximum height (Rz) and ten-point average roughness (Rq) values of the test samples were evaluated. Both of side measurements were made on the surfaces of the control and test samples according to the ISO 4287 standard. The measurements were used as a boundary wave length of 8 mm, a velocity of 0.5 mm/s and a scanning length of 12 mm. Ten measurements were made to evaluate the surface roughness of each group.

3 RESULT AND DISCUSSION

The results of the board groups with vermiculite added at different ratios and the results of the control group boards produced without vermiculite with respect to colour, gloss and surface roughness were discussed below.

3.1 Colour change

The colour change values in the test and control samples were calculated using the L (light intensity), a and b chromatographic coordinates (+ a * red, -a green, + b yellow and -b blue) determined according to the CIELab system. Table 1 shows the bottom surface, top surface and average values and standard deviations of L *, a *, b * values for the board groups.

Table 9: L*, a*, b* values of test boards

Type of boards		**Control**	**10% vermiculite**	**15% vermiculite**	**20% vermiculite**	**30% vermiculite**
Bottom surface	**L***	-	56.28±0.87	58.49±1.27	57.40±2.67	60.90±1.30
	a*	-	8.60±0.29	7.56±0.71	8.10±1.32	6.11±0.42
	b*	-	22.25±0.38	20.99±0.93	21.97±1.81	19.40±0.46
Top surface	**L***	-	56.09±0.98	53.99±1.56	53.47±2.25	54.92±1.58
	a*	-	9.29±0.24	9.47±0.44	9.50±0.37	8.85±0.27
	b*	-	24.08±0.53	23.46±0.64	23.25±0.73	22.18±0.56
Average values	**L***	52,01±2,14	56.18±0.88	56.24±0.92	55.44±0.82	57.91±1.02
	a*	9,69±0,47	8.95±0.19	8.51±0.39	8.80±0.56	7.48±0.25
	b*	23,45±0,87	23.16±0.22	22.23±0.50	22.61±1.11	20.79±0.37

According to the results obtained, the average L * value increased as the chemical substance added increased except for the addition of 20% vermiculite. An increase in L * is an indication that the surfaces of the boards have colouring. Also, the L * values obtained at the bottom surface are higher than the values measured from the top surface. This is due to the fact that some of the vermiculite used as a dust in the forming mold collapses on the bottom surface of the mat and is found to be higher than the surface of the mat. Figure 1 shows the mean change values of L *, a and b.

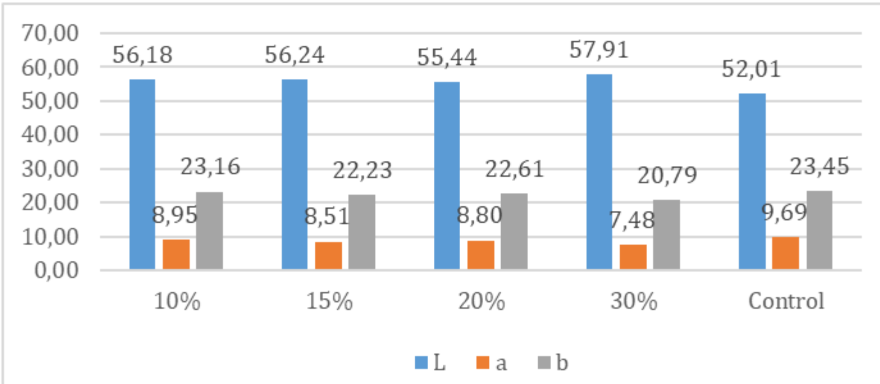

Figure 1: Average L*, a, b values change of board types

The a * value decreased as the ratio of additional chemicals increased, except for the addition of 20% vermiculite for the average a * values. Reduced a * value is a sign of red colour on the board surfaces. Similarly, as the rate of added material increased, the b * value decreased. The decrease in b * indicates the increase in blue colour on the board surfaces. Figure 2 shows the total colour change values (ΔE *).

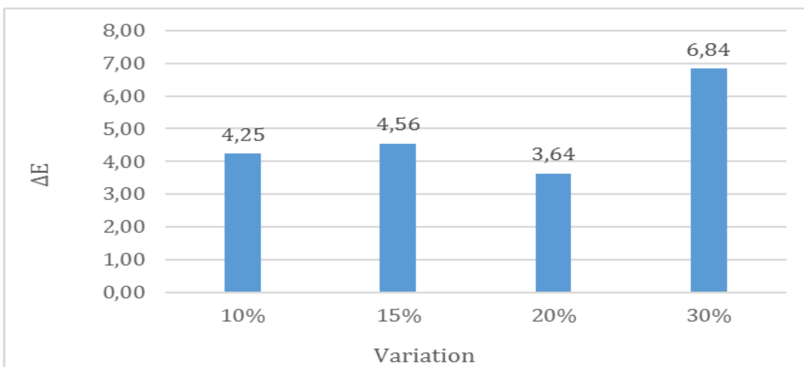

Figure 2: Total colour change of board types

The total colour change value indicates the colour change on the surface of the board compared to the control sample. As the utilization rate of vermiculite increased in board production, total colour change values increased except for the use of 20% vermiculite. The maximum total colour change was 6.84 in the addition of 30% vermiculite while the minimum total colour change value was 3.64 in 20% vermiculite use. Ustaömer et al. (2006) found that treatment with boric acid, borax and sodium perborate tetrahydrate at 1% and 3% concentrations increased the discoloration (ΔE) value of the fibre board due to the increase in chemical concentration and that the highest 3% was sodium perborate tetrahydrate stated. In another study, it was reported that ΔE values increased in direct proportion with increasing chemical concentration (Ustaömer, 2008).

3.2 Glossiness

Glossiness values of control group and groups of vermiculite added boards at different ratios are given in Table 2. It has been understood that the use of vermiculite as compared to the control sample increases the gloss value of the boards but this increase is not linear. The highest gloss value was achieved as 2.33 with 15% vermiculite use, while the lowest gloss was achieved with control as 2.09.

Table 2: gloss value of test boards

Type of boards	Bottom surface	Top surface	Average values
Control	-	-	2.09±0.03
10% vermiculite	2.18±0.13	2.38±0.05	2.28±0.06
15% vermiculite	2.38±0.17	2.28±0.05	2.33±0.06
20% vermiculite	2.25±0.17	2.20±0.12	2.23±0.06
30% vermiculite	2.15±0.10	2.08±0.05	2.11±0.05

3.3 Surface roughness

The surface roughness test results of the boards produced in the study are given in Table 3.

Table 3: Surface roughness of test boards

Type of boards		Control	10% vermiculite	15% vermiculite	20% vermiculite	30% vermiculite
Bottom surface	Ra	-	8.69±1.42	9.39±1.08	11.76±1.63	15.44±3.92
	Rq	-	9.97±1.72	12.03±1.30	15.12±2.19	20.51±4.97
	Rz	-	72.42±6.31	77.63±10.71	95.83±15.35	124.92±14
Top surface	Ra	-	8.63±1.06	8.71±1.37	8.84±1.04	8.65±1.40
	Rq	-	11.25±1.26	11.14±1.78	11.35±1.42	11.14±1.87
	Rz	-	65.15±8.28	69.25±12.47	70.80±10.91	73.29±12.20
Average values	Ra	8.06±1.58	8.66±1.24	8.94±0.80	10.09±0.86	10.97±1.34
	Rq	10.27±2.05	10.61±1.49	11.40±0.88	12.97±1.39	14.48±1.81
	Rz	60.43±6.01	68.78±7.30	72.83±6.98	75.33±7.08	89.30±6.13

It was determined that vermiculite addition increases the surface roughness (Ra, Rz and Rq) properties and reduces the smoothness of the surfaces when compared to the control group of surface roughness properties. Moreover, the higher roughness values on the bottom surfaces were caused by the accumulation of more vermiculite on the bottom surface of the board compared to the pavement pattern during the formation of the board. Figure 3 shows the change of Ra, Rq and Rz values of the board groups.

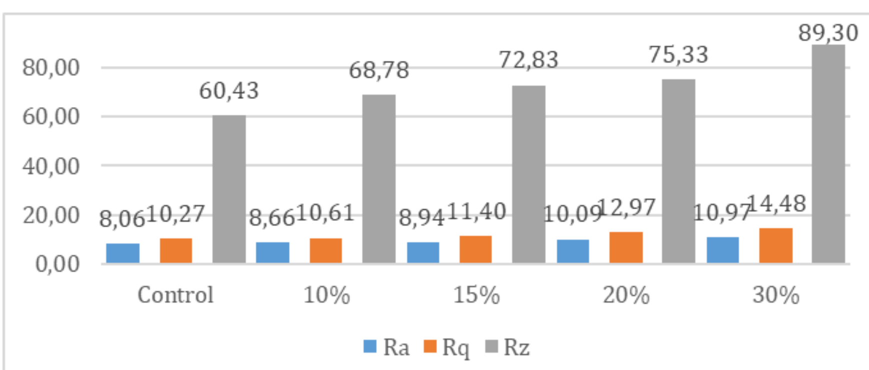

Figure 3: Change of Ra, Rq and Rz values of the board groups

As shown in Fig. 3, the lowest Ra value was 8.06 μm in control and the highest Ra was 10.97 μm in 30% vermiculite added boards. It has been concluded that vermiculite used in powder form does not disperse homogeneously in the board and adversely affects bonding between fibres and glue, preventing smooth surface formation during hot pressing. This has led to an increase in surface roughness values with increasing vermiculite use. This appears to be more pronounced on the bottom surfaces where vermiculite is distributed unevenly. It is thought that the grain size of the vermiculite used additionally may be effective on the surface roughness. Ustaömer et al. (2008) reported that surface roughness values of MDF boards produced were increased due to chemical types and concentration increase of 3%, 5% boric acid, borax, sodium perborate tetrahydrate, zinc borate and boric acid+borax mixtures of fire retardant treatment. In addition, different studies have reported that the morphological properties of the used fiber raw materials and the production parameters effect surface roughness (Nemli, et al., 2007; Dündar, et al., 2008, Özdemir, 2016).

4 CONCLUSION

In this study, colour, glossiness and surface roughness values of MDFs produced by vermiculite addition at different ratios were determined. As a result of the study, L * value increased with increasing vermiculite use rate, but a * and b * values decreased. This is an indication of the increase in white colour and blue colour and decrease in red colour on the boards. Total colour change was increased with increasing vermiculite usage rate except 20% vermiculite usage. When the glossiness values were examined, it was determined that vermiculite usage increased the glossiness compared to the control sample. The surface roughness values (Ra, Rg and Rz) increased as vermiculite usage increased and the surfaces became rougher.

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ABSTRACT

Main advantage of the technology for production of fibreboards (FB) are the reduced requirements to the wood and the possibility for inclusion of other non-woody lignocellulosic raw materials in the composition of boards. This is of main significance in view of the world shortage of wood raw material. Such lignocellulosic raw materials are residues (waste) from the agriculture, e.g. maize stalks.

In this paper, an investigation about the effect of participation of mass of maize stalks on some physicomechanical indicators of MDF is presented.

Under laboratory conditions, test boards with participation of mass of maize stalks to the amount of 0% to 100% were produced. The defibration was performed in a laboratory disk crusher defibrator. The main fraction of maize fibres has a length of 1 to 2 mm. The boards were produced with 10% participation of urea-formaldehyde resin (UFR), at a temperature of hot pressing of 185 °C. The set density of the boards is 850 kg/m^3.

The qualitative yield during defibration of maize stalks was determined. Regression models for the effect of content of mass of maize stalks on some physicomechanical indicators of MDF were derived. The permissible share of mass of maize stalks in the MDF composition and at what share of mass of maize stalks most significant deterioration of these indicators is observed were analyzed. On the basis of the results, a recommendation with respect to the maximum content of mass of maize stalks in the MDF composition was derived.

Key words: MDF, non-woody lignocellulosic raw material, maize stalks.

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1 INTRODUCTION

In Bulgaria, and also on a world-wide scale, there are considerable number of successful investigations about at least partial substitution of the wood raw material in the composition of wood-based panels by lignocellulosic raw materials, such as hemp and flax hurds, straw, vine twigs, etc. (Eroğlu H, et al., 2010; Gencer A et al., 2001; Mihailova, J. et al., 2006; Mihailova, J. et al., 2007; Mihailova, J. ,2008; Mihailova, J. et al., 2009; Mihajlova, J., 2012; Mihajlova, J. et al., 2015; Thoemen, H. et al., 2010).

Almost in all of these raw materials, some main disadvantages are observed. They may be reduced to the following: considerably lower amount of cellulose at the expense of increase of the share of hemicelluloses in their composition and presence of wax in part of this type of raw materials (Tsolov, V. et al., Kalaycıoğlu H., 1992).

Due to the low cellulose content, decrease of the number of cohesive bonds in the boards is observed, and the presence of wax strongly hinders the formation of cohesive bonds in the boards. A problem in the utilization of this type of raw material is silicon content. This problem may be, at least partially, solved with suitable treatment (Tutuş A, 2003).

Maize is an agricultural crop with wide distribution in Bulgaria. Maize stalks also have the above-mentioned disadvantages in their capacity of raw material for wood-based panels. Nevertheless, a number of successful investigations about the production of particleboards (PB) (Wang, D., et al., 2002), of hard FB (Tsolov, V. et al., 1987, Chow P, 1974) and of high-density FB (Savov, V. et al., 2016) with participation of maize stalks were performed.

There also exist successful attempts at obtaining MDF with the participation of coniferous wood and maize stalks (Akgül et al., 2010). The effect of the content of mass of maize stalks in the composition of MDF made of broad-leaved wood raw material was investigated to a smaller extent.

The above presented outlines the topicality of one investigation about the effect of participation of mass of maize stalks in the composition of medium-density fibreboards (MDF). Investigations of this type have not been performed in Bulgaria, and as an addition to their topicality, the increasingly higher share of MDF in the production of wood-based panels on a world-wide scale should be also emphasized (Thoemen, H. et al., 2010).

2 MATERIALS AND METHODS

For the purposes of the investigation, MDF with set thickness of 6 mm and density of 850 kg/m^3 were produced under laboratory conditions. Mass of maize stalks of 0% to 70% was included in the composition of the boards, with a control board made entirely of mass of maize stalks, whose indicators were compared to that made of 100% wood raw material, being also produced. The participation of mass of maize stalks was increased with a step of 10%.

Urea-formaldehyde resin at 10% content relative to oven-dry mass was used as binding agent.

The mass of maize stalks was obtained with a laboratory disk crusher defibrator, whereupon it was dried in a drying cabinet at a temperature of 103 °C. The water content in the mass is 8.93%. Its fractional composition that is presented in Table 1 was determined.

Table 1: Fractional composition of mass of maize stalks

1st fraction	2 / 1 mm	76%
2nd fraction	1 mm / 800 µm	0.20%
3rd fraction	800 / 500 µm	3.24%
4th fraction	500 / 315 µm	6.81%
5th fraction	315 / 200 µm	5.34%
6th fraction	200 / 100 µm	4.80%
dust	< 100 µm	3.61%

The wood-fibre mass was produced under factory conditions in VELDE Bulgaria AD – the town of Troyan. It is composed of wood of hard broad-leaved tree species: beech and Turkey oak – 60%, poplar – 20%, and Scots pine – 20%. It was dried in a laboratory drier to water content of 10%.

Urea-formaldehyde resin produced by KASTAMONU Bulgaria AD was used as binding agent. The resin is with initial concentration of 58% and working concentration of 50%.

The maize stalks were cut to a length of 30 mm and submerged in water for a period of 72 hours, whereupon they were defibred in a disk crusher defibrator, Fig. 1. During the defibration, they were continuously washed with water, and the defibration duration was 2 min.

Figure 1: Laboratory disk crusher

The ready mass was subjected to water sorting by means of washing, Fig. 2.

It should be emphasized that the quantitative yield under the applied technology is very low – below 30%.

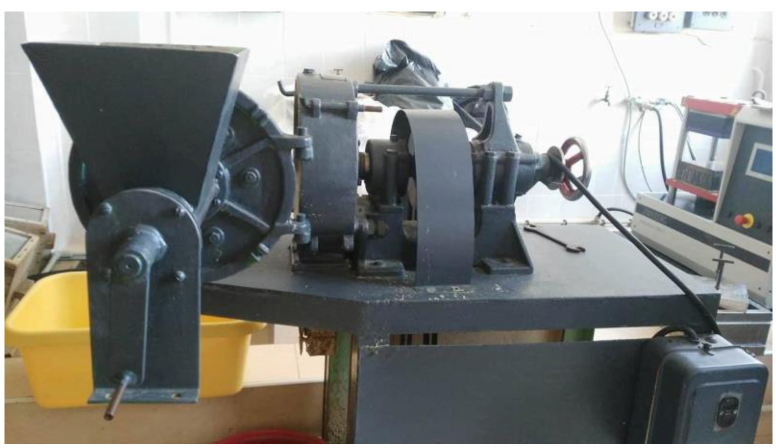

Figure 2: Mass defibration and sorting

Pressing was performed at a platen temperature of 185 ± 5 °C and duration of 1 min/mm, in three stages, at specific pressure as follows: 1st stage – 2.5 MPa; 2nd stage – 1.3 MPa; 3rd stage – 0.6 MPa. The duration of the individual stages is the following: 1st stage – 20% of the complete cycle; 2nd stage – 30% of the cycle; 3rd stage – 50% of the pressing cycle.

Determination of the performance indicators of the boards was performed in conformity with the valid

European norms EN 310; EN 316; EN 317; EN 323.

The results for the performance indicators of MDF, depending on the content of mass of maize stalks, were processed after the methods of variation statistics and regression analysis, with approximation functions being derived for the examined relationships. The coefficient of determination was used as a measure for definiteness (Giampiero, M. et al. 2017).

3 RESULTS AND DISCUSSION

The summarized results for the performance indicators of MDF, depending on the content of mass of maize stalks, are presented in Table 2.

Table 2: Performance indicators of MDF, depending on the content of mass of maize stalks

No.	Content of mass of maize stalks *Px*, %	Density *ρ*, kg/m³	Water absorption *A*, %	Swelling in thickness *Gt*, %	Bending strength *fm*, N/mm²
1	0	858	61.20	16.72	42.01
2	10	852	68.61	16.86	37.76
3	20	861	69.32	18.32	35.89
4	30	848	73.52	23.77	34.49
5	40	841	75.76	23.09	30.16
6	50	853	76.43	25.26	29.58
7	60	861	77.29	25.24	26.82
8	70	847	81.39	25.57	26.99
9	100	857	86.24	29.39	23.27

The variation of water absorption of MDF, depending on the content of mass of maize stalks, is presented in Fig. 3.

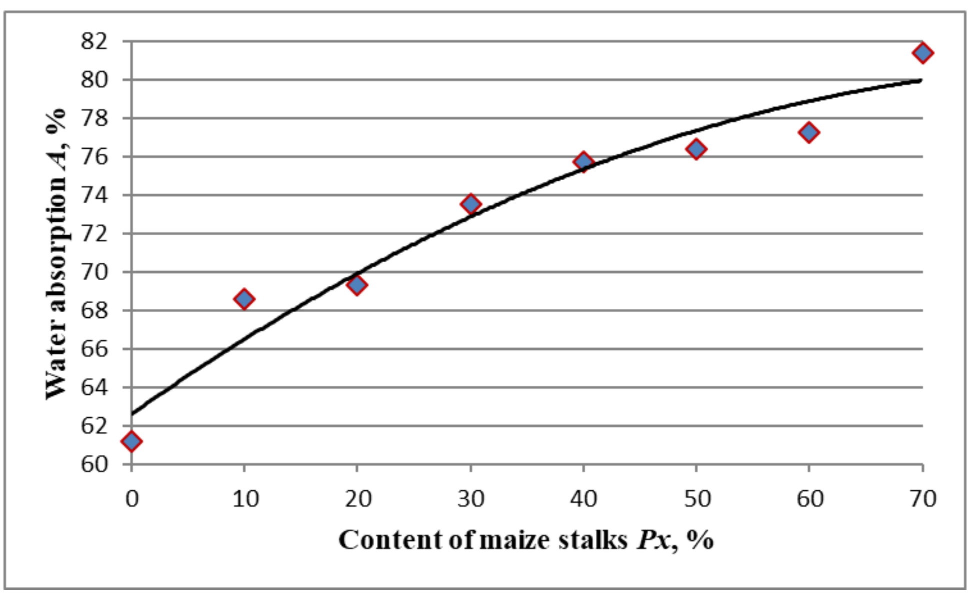

Figure 3: Variation of water absorption, depending on the content of mass of maize stalks

The relationship between the water absorption and the content of mass of maize stalks is described with regression equation of the type:

$$\widehat{A} = 62.61 + 0.413.P_x + 0.002.P_x^2, \qquad (1)$$

where $\widehat{A}$ is the predicted value for water absorption of the boards, %;

Px – the content of mass of maize stalks, %.

Equation (1) is characterized with coefficient of determination, R^2, of 0.89.

Under the conditions of the experiment, the water absorption varies from 61.20% to 86.24% in case of increase of the content of mass of maize stalks from 0 to 100%, with the deterioration of the indicator being by 25.04%. Most significant deterioration of the water absorption is observed already with the addition of the first 10% of mass of maize stalks – by 7.41%. Increase of water absorption is also recorded in case of further increase of the content of mass of maize stalks, with the deterioration being more significant in case of increase of its content from 20 to 30% (by 4.2%), from 60 to 70% (by 4.1%) and from 70 to 100% (by 4.85%).

In graphic form, the variation of the swelling in thickness of MDF, depending on the content of mass of maize stalks, is presented in Fig. 4.

The relationship between the content of mass of maize stalks and the swelling in thickness of MDF is of the type:

$$\widehat{Gt} = 17.09 + 0.133.P_x, \qquad (2)$$

where $\widehat{Gt}$ is the predicted value for the swelling in thickness of boards, %;

Px – the content of mass of maize stalks, %.

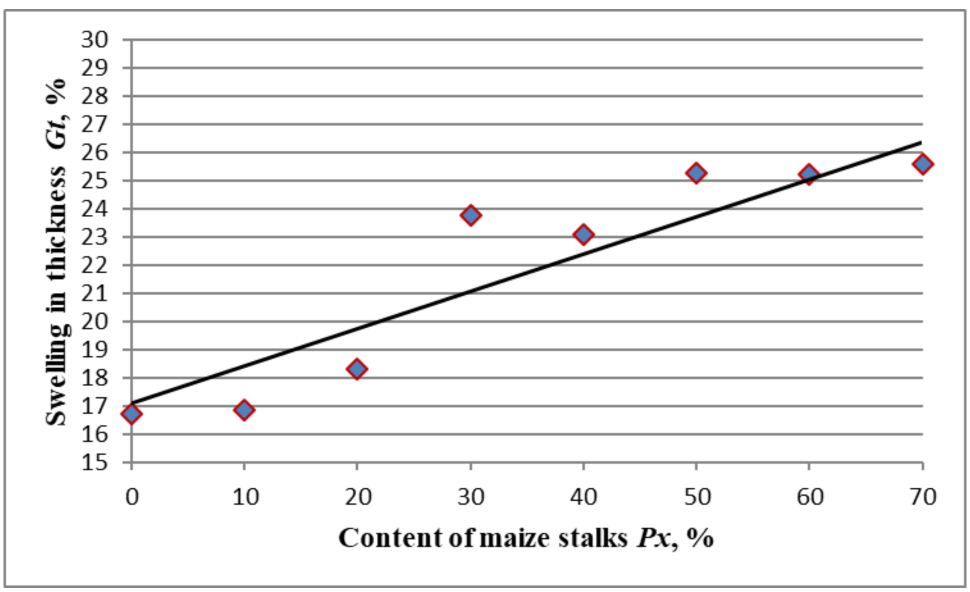

Figure 4: Variation of the swelling in thickness, depending on the content of mass of maize stalks

Equation (2) is characterized with coefficient of determination, R^2, of 0.90.

Also in the case of this indicator, the tendency for deterioration in case of increase of the content of mass of maize stalks is clearly observed.

In case of change of the content of mass of maize stalks from 0 to 100%, the swelling in thickness of MDF increases from 16.8 to 29.39%, or deterioration of the indicator by 12.67% is observed. Most significant deterioration is observed in case of increase of the content of mass of maize stalks from 20 to 30% (by 5.45%), from 40 to 50% (by 2.17%) and from 70 to 100% (by 3.82%).

All manufactured boards meet the requirements for use in dry environment with respect to the swelling in thickness indicator. Only the board with content of mass of maize stalks of 10% meets the requirements for use in humid environment (the required value of the swelling in thickness is below 18% pursuant to BDS EN 622-5). It should be emphasized that the exceedence of the requirements to the indicator in the case of the boards with 20% mass of maize stalks is insignificant and is within the statistical error.

As a whole, FB with content of mass of maize stalks show satisfactory values of swelling in thickness. In case that they are intended for use in humid environment, the requirements to the indicator may be easily met with insignificant modification in the composition of boards – increase of the content of hydrophobic substances.

The variation of the bending strength of MDF, depending on the content of mass of maize stalks in the composition of the board, is presented in graphic form in Fig. 5.

The relationship between the content of mass of maize stalks and the bending strength of MDF is of the type:

$$\widehat{fm} = 49.72 - 0.186.P_x, \qquad (3)$$

where $\widehat{fm}$ is the predicted value for the bending strength of boards, N/mm^2;
Px – the content of mass of maize stalks, %.

Equation (3) is characterized with coefficient of determination, R^2, of 0.90.

As a whole, with the increase of the content of mass of maize stalks, the bending strength of the obtained MDF deteriorates.

In case of increase of the content of mass of maize stalks from 0 to 100%, the bending strength decreases from 42.01 to 23.27 N/mm^2, i.e. the deterioration of the indicator is by 18.74 N/mm^2. Most significant deterioration is observed in case of increase of the content of mass of maize stalks from 0 to 10% (by 4.25 N/mm^2), from 30 to 40% (by 4.33 N/mm^2) and from 70 to 100% (by 3.72 N/mm^2).

With respect to the bending strength indicator, all boards meet the requirements to those of general purpose and for use in dry environment. For this type of MDF, the bending strength should be at least 23 N/mm^2 (BDS EN 622-5).

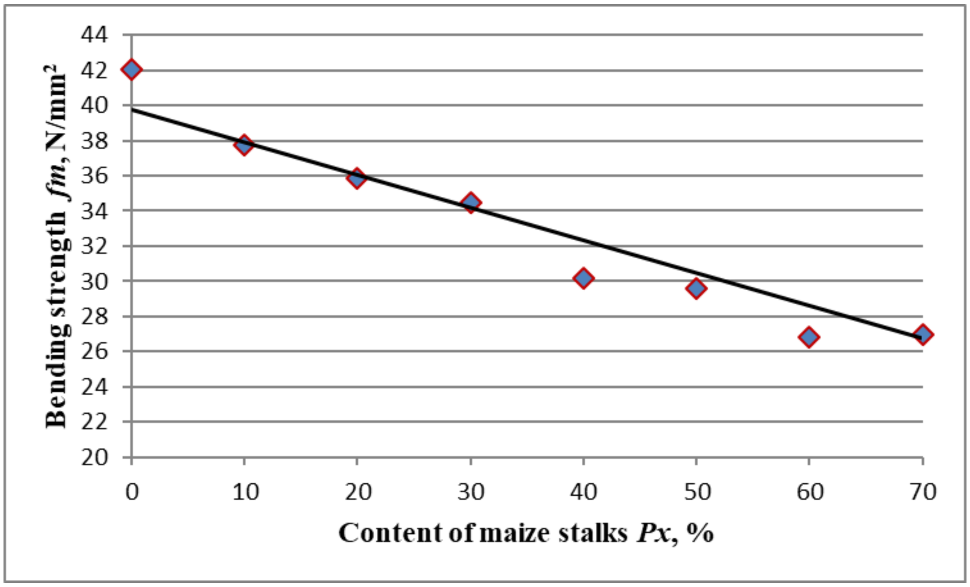

Figure 5: Variation of the bending strength, depending on the content of mass of maize stalks

The boards with 50% content of mass of maize stalks meet the requirements to the bending strength indicator for MDF, viz. for bearing structures and use in dry environment. Here, the reference value is 29 N/mm^2.

The boards with 10%, 20% and 30% content of mass of maize stalks meet the most rigorous requirements to the bending strength indicator for MDF, viz. for bearing structures and use in humid environment. Here, the reference value is 34 N/mm^2.

This shows that maize stalks may be successfully used as a substitute for the wood raw material in MDF in case of content of up to 50%, with the boards meeting the requirements to the bending strength indicator. Nevertheless, in view of the results obtained, putting in mass of maize stalks to an amount greater than 30% is not justified as this would lead to a significant decrease of the bending strength of the boards.

4 CONCLUSIONS

As a result of the investigation performed about the effect of participation of mass of maize stalks on the performance indicators of MDF, the following conclusions may be drawn and the following recommendations may be made:

- The maize stalks may be successfully used as a substitute for the wood raw material in the MDF composition;
- As a disadvantage, the low qualitative yield during defibration of this raw material should be shown here;
- In view of the low qualitative yield during defibration, as well as due to the deterioration of the MDF indicators in case of increase of the content of mass of maize stalks, it may be shown as a main recommendation that the content of such mass in the composition of the boards should not exceed 20%.

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EN 323:1993 Wood-based panels - Determination of density
EN 622-5:2010 Fibreboards - Specifications - Part 5: Requirements for dry process boards (MDF)

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Utilization of Mass of Industrial Hemp in the Production of Medium-density Fibreboards (MDF)

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ABSTRACT

In the near past, industrial hemp (Cannabis sativa L. subsp. sativa) found main application in the production of ropes and fabrics. At the present moment, this crop finds increasingly big application for pharmaceutical purposes and in the cosmetics industry. As a result of which not only hurds, but whole stalks remain as waste from this production. On the other hand, MDF, which on a world scale are the second production of wood-based boards in terms of volume after that of veneer plywood, allow at least partial inclusion of non-woody lignocellulosic raw materials in their composition. That is why, in this paper, an investigation about the possibility for inclusion of mass of hemp stalks in the MDF composition is presented.

Under laboratory conditions, previously washed hemp stalks were defibred. The defibration was performed in a laboratory crusher defibrator for 2 min. Under laboratory conditions, MDF with participation of mass of hemp stalks form 0% to 100% in the MDF composition were produced. The content of mass of hemp stalks was increased by a step of 10%. The boards were produced at a temperature of hot pressing of 185 °C, with 10% participation of urea-formaldehyde resin (UFR) and have a density of 850 kg/m^3.

The effect of the content of mass of hemp stalks on the physicomechanical indicators of MDF was established. Regression equations for this effect on the individual physicomechanical indicators were also derived. It has been established in case of increase of what share in the composition of boards, most significant deterioration of the MDF indicators is observed. On this basis, a recommendation for the maximum justified content of mass of hemp stalks in the MDF composition was derived.

Key words: MDF, non-woody lignocellulosic raw material, stalks of industrial hemp.

***The investigations are part of the investigations under project No. 153/08.03.2017, financed by the Research Sector at the University of Forestry**.

1 INTRODUCTION

Industrial hemp (*Cannabis sativa* L.) has many different applications, mainly in the production of paper, fabrics, biodegradable plastics, building materials, healthy food, fuels and another approximately 50,000 types of applications besides industry, in medicine and potentially in almost any other sphere.

Hemp is an annual plant that reaches 5 m in height and 6 to 60 mm stalk thickness for a period of growth of about 3 months depending on the plantation density (Mohanty A.K. et al, 2000).

This is one of the fastest growing biomasses known to man and one of the plant crops most early known and home-grown by man. Hemp does not require pesticides for its cultivation, does not lead to erosion of soil, just the contrary, it aerates it by producing oxygen (https://www.konop.bg).

Hemp stalk consists of lignified heartwood with wide pith, covered by a cambial layer, bast, bark and epidermis (Fig. 1).

Bast represents about 1/4 of the stalk and plays a main role for the tensile strength and, respectively, bending strength of the stalk. Bast is covered by epidermis covered with great number of cuticles that protect the plant from parasites by means of the strong resins they secrete. Xylem (so called lignified part) of the stalk represents about 3/4 of the volume and plays a main role for the plant firmness.

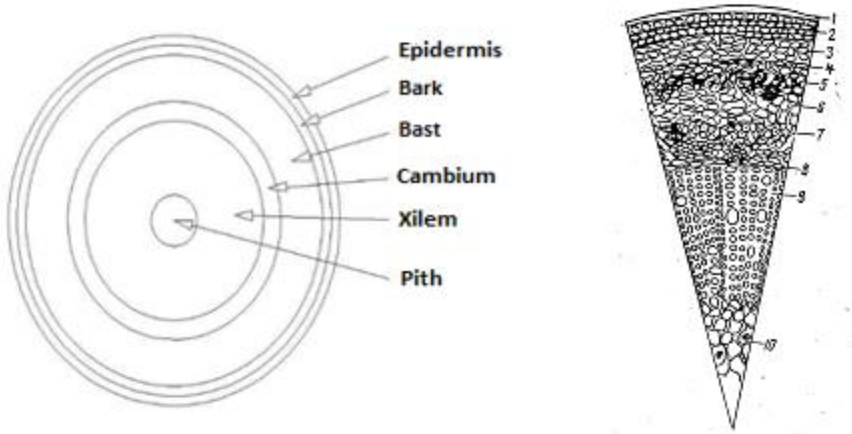

Figure 1: Structure of hemp stalk

1 - epidermis; 2 - collenchyma; 3 – cortical parenchyma; 4 – endodermis; 5 – primary bast fibres; 6 – bast parenchyma; 7 – vascular tissue; 8 – cambium; 9 – wood; 10 - pith

There are considerable differences between the chemical composition of the xylem and the bast of the hemp stalk. The bast fibres have cellulose content of about 60-70%, hemicelluloses – 15-20%, lignin – 2-4%, pectins – 2-4%, fats and waxes – 1-2%. Xylem has rather content analogous to broad-leaved tree species: cellulose about 40%, hemicelluloses about 25%, lignin about 20% and extractives – 4% (Garcia-Jaldon, C. et al., 1998). This difference determines also the serious difference in the strength of bast fibres and those of xylem, that is why whole stalks comprising both types of fibres were used for the investigation.

In the past, hemp was mainly grown to use the bark fibres for ropes, paper and textile, but nowadays these productions are supplemented by the extraction of high-quality seed oil and resins irreplaceable for medicine, the plant value being increased many times in this way and its cultivation becoming low-risk and promising business. In most of those productions, waste are exactly hemp stalks that, in the countries developing this branch, are abundant and acquire industrial significance. In older references, directions are given for the use of hemp as additive to wood raw material at most up to 30% of the total mass, but in recent investigations results meeting some basic standards at hemp content of 60% of the raw material's total mass were achieved (Radosavljevic et al., 2008). Characteristic of hemp, as well as of wheat lignocellulosic waste is the need for treatment with weak solution of alkali (NaOH 5-8%) and 1 to 3% of oligomeric siloxane in alcohol solution because they separate hemicelluloses, lignin and waxes from the fibres and thus assist the adhesion at a later stage, and, hence, increase the strength and performance characteristics (Kabir et al., 2012).

It should be emphasized that there is a considerable amount of investigations about utilization of hemp stalks in particleboards (PB) composition (Mahieu, A. et. al., 2015; Shöpper, et. al., 2008; Selinger J. et al. 2015), while investigations about their utilization in MDF composition are considerably fewer (Fajrin, J. et. al. 2018).

2 MATERIALS AND METHODS

For the purposes of the investigation, MDF with set thickness of 8 mm and density of 850 kg/m^3 were produced under laboratory conditions. Urea-formaldehyde resin at content of 10% relative to the oven-dry mass was used as binding agent.

The wood-fibre mass that was used to produce the boards was produced in the fibreboards (FB) factory of VELDE Bulgaria AD – the town of Troyan. It is composed of wood of Turkey oak and beech to the ratio of approximately 2:1 and has water content of 10%.

The hemp mass was produced in the Pressing Laboratory of the Chair of Mechanical Wood Technology at the University of Forestry. The hemp stalks with diameter of 6 to 32 mm were previously cut to a length of 200 mm and were immersed in water for 5 days at room temperature. Defibration was performed with laboratory defibrator in amounts of 100 to 150 g with addition of additional 200 ml of water and cycle duration of 150 s, whereupon they were dried at a temperature of 100 °C to water content of 6%. The fibres obtained in this way were sifted through a sieve with mesh of 2x2 mm and are up to 5 mm long.

Urea-formaldehyde resin produced by KASTAMONU Bulgaria AD was used as binding agent. The resin is with initial concentration of 68% and working concentration of 55%.

For the purpose of the investigation, 11 boards with various share of hemp mass within the range of 0 to 100%, at a step of 10%, were produced.

Pressing was performed at a platen temperature of 185 ± 5 °C and duration of 1 min/mm, in three stages, at specific pressure as follows: 1st stage – 2.6 MPa; 2nd stage – 1.3 MPa; 3rd stage – 0.6 MPa. The duration of the individual stages is the following: 1st stage – 12.5% of the complete cycle; 2nd stage – 37.5% of the cycle; 3rd stage – 50% of the pressing cycle.

Determination of the performance indicators of the boards was performed in conformity with the valid European norms EN 310; EN 316; EN 317; EN 323.

The results for the performance indicators of MDF, depending on the content of mass of hemp stalks, were processed after the methods of variation statistics and regression analysis, with approximation functions being derived for the examined relationships. The coefficient of determination was used as a measure for definiteness.

3 RESULTS AND DISCUSSION

The summarized results for the performance indicators of MDF, depending on the content of mass of hemp stalks, are presented in Table 1.

Table 1: Performance indicators of MDF, depending on the content of mass of hemp stalks

No.	Content of mass of hemp stalks *Px*, %	Density ρ, kg/m³	Water absorption *A*, %	Swelling in thickness *Gt*, %	Bending strength *fm*, N/mm²
1	0	848	81.44	28.53	44.02
2	10	854	85.78	29.53	43.99
3	20	845	86.54	31.50	43.52
4	30	858	89.13	32.96	42.96
5	40	846	89.40	36.03	39.49
6	50	850	95.61	40.41	34.19
7	60	844	94.54	40.44	34.03
8	70	860	96.70	41.18	34.97
9	80	859	100.2	41.47	31.21
10	90	850	102.2	41.04	22.32
11	100	846	119.2	50.43	23.30

In graphic form, the variation of the water absorption of MDF, depending on the content of mass of hemp stalks, is presented in Fig. 2.

The relationship between the water absorption and the content of mass of hemp stalks is described with regression equation of the type:

$$\widehat{A} = 84.18 + 0.026.P_x + 0.003.P_x^2, \qquad (1)$$

where $\widehat{A}$ is the predicted value for water absorption of the boards, %;

Px – the content of mass of hemp stalks, %.

Equation (1) is characterized with coefficient of determination, R^2, of 0.95.

From the data presented is seen that with addition of mass of hemp stalks in the MDF composition, the water absorption of the boards increases, i.e. deteriorates. Under the conditions of the experiment, the water absorption varies from 81.44 to 119.2%. Lowest is the water absorption of the board obtained from 100% wood raw material, and highest – in that obtained from 100% hemp stalks. Deterioration of the indicator is by 37.76%. Significant deterioration of the water absorption is observed already with the addition of the first 10% of mass of hemp stalks – by 4.34%. Increase of water absorption is also recorded in case of further increase of the content of mass of hemp stalks, with the deterioration being more significant in case of increase of its content from 20 to 30% (by 2.59%), from 40 to 50% (by 6.21%), from 70 to 80% (by 3.50%). Most significant deterioration of this indicator is observed in case of increase of the content of mass of hemp stalks from 90 to 100%.

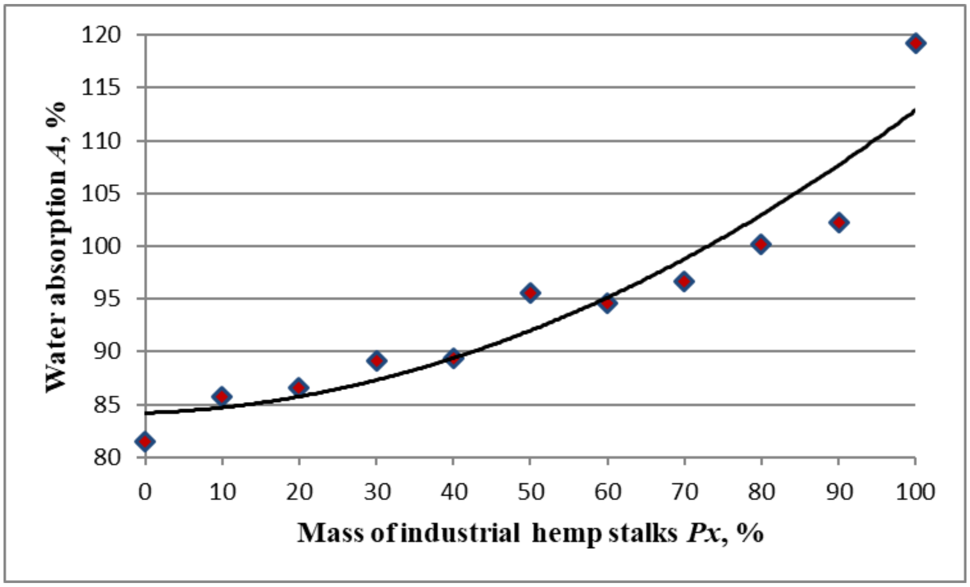

Figure 2: Variation of the water absorption of FB, depending on the content of mass of hemp stalks

The dependence of the swelling in thickness of MDF on the content of mass of hemp stalks in their composition is presented in Fig. 3.

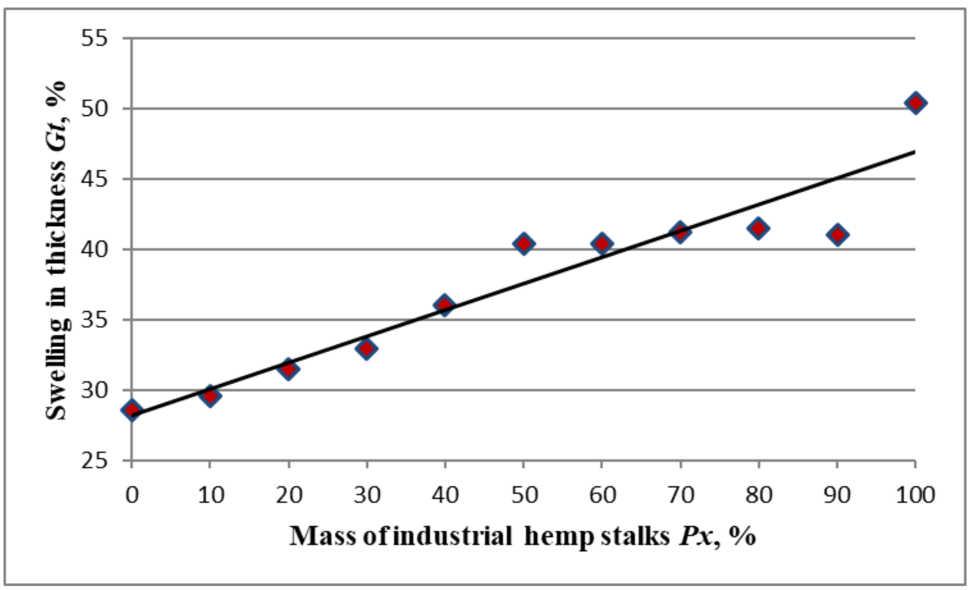

Figure 3: Variation of the swelling in thickness of FB, depending on the content of mass of hemp stalks

The relationship between the content of mass of hemp stalks and the swelling in thickness of MDF is of the type:

$$\widehat{Gt} = 28.22 + 0.19.P_x\,, \qquad (2)$$

where $\widehat{Gt}$ is the predicted value for the swelling in thickness of boards, %;

Px – the content of mass of hemp stalks, %.

The equation is characterized with coefficient of determination R^2 = 0.86.

Under the conditions of the experiment, the swelling in thickness of MDF varies from 28.53 to 50.43%, i.e. here also we observe deterioration of the indicator with increase of the content of mass of hemp stalks in the composition of boards, with this deterioration being by whole 21.9%. Lowest is the swelling in thickness of FB entirely composed of wood raw material, and highest in those composed entirely of mass of hemp stalks. Most significant deterioration of the indicator is observed in case of increase of the content of mass of hemp stalks from 90 to 100%, where the increase is by 9.39%. More significant deterioration of the indicator is also observed in case of increase of the content of mass of hemp stalks from 30 to 40%, as well as in case of increase of the content of mass of hemp stalks from 40 to 50% (by 4.38%).

In graphic form, the variation of the bending strength of MDF, depending on the content of mass of hemp stalks in their composition, is presented in Fig. 4.

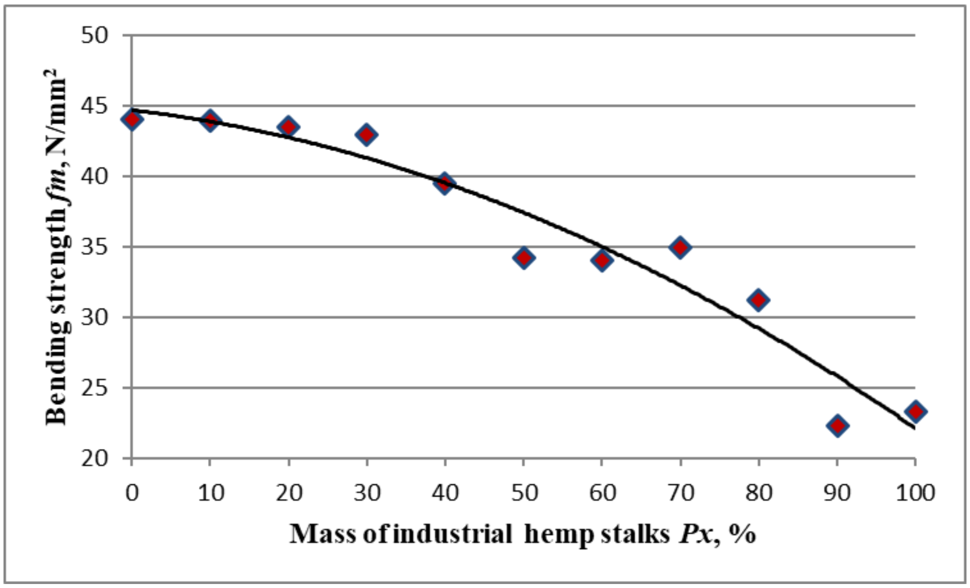

Figure 4: Variation of the bending strength of FB, depending on the content of mass of hemp stalks

The regression equation in the case of this indicator is:

$$\widehat{fm} = 44.70 - 0.065.P_x - 0.002.P_x^2, \tag{3}$$

where $\widehat{fm}$ is the predicted value for the bending strength of boards, N/mm²;

Px – the content of mass of hemp stalks, %.

The equation is characterized with coefficient of determination $R^2 = 0.96$.

As a whole, with increase of the content of mass of hemp stalks, the bending strength of the obtained MDF deteriorates.

Under the conditions of the investigation, the bending strength of the boards varies from 44.02 to 23.30 N/mm². The total deterioration is by 20.72 N/mm². Most significant deterioration of the indicator is recorded in case of increase of the content of mass of hemp stalks from 80 to 90% (by 8.89 N/mm²), from 70 to 80% (by 3.76 N/mm²) and from 30 to 40% (by 3.47 N/mm²).

In spite of the deterioration of the indicator as a whole, the boards with content of up to 80% mass of hemp stalks meet the requirements for bending strength for boards of general purpose, for use in dry environment (23 N/mm²) and for use in humid environment (27 N/mm² for type MDF.LA). The boards with content of up to 80% mass of hemp stalks also meet the requirements for bending strength to boards for bearing structures, used in humid environment (34 N/mm² for type MDF.HLS).

4 CONCLUSIONS

As a result of the investigation performed about the effect of participation of mass of hemp stalks on the performance indicators of MDF, the following conclusions may be drawn and the following recommendations may be made:

- The industrial hemp stalks may be successfully used as a substitute for the wood raw material in the MDF composition;

• It is recommended that the investigations about the utilization of hemp stalks as part of the MDF composition are continued by looking for possibilities for improvement of the hydrophobic properties of the boards.

5 ACKNOWLEDGEMENTS

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An Application on The Assignment of The Most Proper Worker with The Hungarian Algorithm in The Furniture Manufacturing Processes

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AN APPLICATION ON THE ASSIGNMENT OF THE MOST PROPER WORKER WITH THE HUNGARIAN ALGORITHM IN THE FURNITURE MANUFACTURING PROCESSES

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ABSTRACT

In the problems of worker's assignment to machines, inadequacy of worker skills in making of the work and/or changing of operation time of the work from employee to employee are very important problems to consider. In the production activities such as furniture production in which many operations are performed simultaneously and in parallel, assignment of the most proper worker in terms of quality and making time of work has a significant effect on productivity, delivery time and costs.

In this study, in the course of production activities carried out at the Application Workshop of Wood Products Industrial Engineering Department in the Faculty of Technology of Gazi University; operation times of 4 workers (students) in the machines of jointer, spindle moulder, router and horizontal drilling machines were measured in accordance with work measurement techniques. The obtained data were analysed and adapted to solve the 0-1 integer assignment problem. The derived data from analyses were used to solve the problem of "which person will be assigned to which machine by considering the smallest total time" using "Hungarian Method" of Kuhn (1955).

KEYWORDS: Assignment Problem, Hungarian Method, 0-1 Integer Programming, Furniture Production, Employee Selection

1 INTRODUCTION

In today's environment, where competition is cruel and production resources are scarcely considered in the resource class, businesses have to increase the amount of products they produce in the most efficient and efficient way using their resources. Businesses are forced to make rapid production and to have a standardized and meaningful production process in order to survive in the market conditions of continuously variable structure and to maintain the production-consumption balance under the influence of numerous variables.

In the production systems, which are physical products, it is aimed to bring the processed raw material to the point of consumption by removing it from the cycle as soon as possible as final product after the production process in which benefit is gained. The productivity level of any production factor used during this process has direct and indirect influence on the production period of the product to be produced. It is not possible to use a production technique that would completely abandon inefficient periods resulting from scheduled or unplanned downtimes such as machine vacancies, deadlines for handling and loading, breakdown, updating or renewal, maintenance. However, investigating the production techniques that will keep these periods at the lowest level is the main topic that is discussed at the point of production management.

Assignment problems are investigations to solve the problem of assigning employees to work or machine in the most appropriate way. It is aimed that the assignment problems are primarily in the search for solutions, while the total duration or cost during the task is smallest; the performance to be obtained from the work is at the highest level (Odior, Charles, & Oyawale, 2010). The assignment problem is a method of dealing with the matching of two or more data sets to the most appropriate value. In other words, the problem is related to how m workers are to be assigned to n relays or machines with minimum cost (Burkard, Dell'Amico, & Martello, 2009).

Classical assignment problems are the process of mapping n worker to m tasks. In order to find a solution to the general assignment problems, the n = m balance is searched because the assumption is that the problem is balanced. General assignment problems have many application areas such as placement problems, vehicle routing, scheduling and group technology (Tapkan, Özbakır, & Baykasoğlu, 2008).

In assignment problems, the goal is to determine a solution vector that simultaneously fills contradictory sets of conflicting objectives in a multi-purpose programming model based on the idea of achieving optimum while the worker is matched to the appropriate task. In the target-programming model, the deviations from the target values are minimized, and a solution that the decision-maker finds satisfying is tried to be determined. While this work is being done; if they have weights and priorities, they are also taken into consideration. One of the important benefits of target programming is that it allows different evaluation bases and work with different units (Taha, 1997).

Knutson et al. (1980) solved the problem of assigning students with goal programming to provide racial equilibrium in public schools. Freed & Glover (1981) proposed an assignment method using a simple but effective target programming method for discriminant problems. Zanakis (1983) used priority target programming in assigning jobs to the workforce with an integer number of 0-1. Badri (1996) used a two-step multiobjective method of 0-1 in the faculty course scheduling problem. In the two-stage model, the first of the faculty members' requests to the courses was maximized. In the second stage, the maximum size of the requests is realized when the courses are placed in the designated time blocks. Azaiez & Al-Sharif (2005) have addressed the nurse scheduling problem in their study. Here, they have developed a model with 0-1 target programming approach instead of manual scheduling. Slomp & Suresh (2004) solved the problem of assigning teams to the multi-shift manufacturing system through interactive target programming. The model, consisting of integer variables, has two steps. The first step is to determine the size of the shift teams and the appropriate machines for these teams. The second stage is to assign the operators to the teams and determine the necessary trainings as a result of this assignment. Yücesan (2017) proposed two different integrated production plans with the primary target programming approach for the integrated production planning activities of an operator producing a sofa in the furniture industry. In these schemes, integrated production plans with two and three priority targets are proposed, considering the targeted amount of profit, targeted production amount and line straightening priorities.

In this study, it is aimed to gain an example of work assignments according to work by observing the performances of different employees for the same job in order to be an example of the work to be done in order to minimize the loss of human work losses depending on the employee performance in the furniture producing systems. For this purpose, during the production activities realized at Gazi University Faculty of Technology Wood Products Industrial Engineering Department Practice Workshop, work performance of each of five (5) students in jointer, spindle moulder, router and horizontal drilling machines was measured in accordance with work measurement techniques. The obtained data were analyzed and adapted to solve the assignment problem of 0-1 integer. Analysis-derived data were analyzed by "Hungarian Method" developed by Kuhn (1955), and it was determined which machine was assigned to which machine according to the smallest total time basis.

2 MATERIALS AND METHOD

2.1 Materials

Data used in the study; Gazi University Faculty of Technology was obtained by using machine (jointer, spindle moulder, router and horizontal drilling machine) and hardware at the workshops of the Wood Products Industrial Engineering Department and observing the performances of the students in the same machine for the same job.

- **Jointer:** It has a working range of 1450-2850 rpm with 550-750 W and 380 V motor power.
- **Spindle Moulder:** The S. Söhne & Co. Zürih brand machine has a working value of 20-500 V and 25-99 A and has a working capacity of 1500-3000 rpm.
- **Router:** "NETMAK FR 2000 S CE" brand and router machine has working range of 4000-10000 rpm.
- **Horizontal Drilling Machine:** The S. Söhne & Co. Zürih brand machine, 230-400 V and 3.1-5.4A working value of the machine can work at 2900 rpm.

- **Workers:** Five (5) students randomly selected from the group of students who had undergraduate education at the departmental second-year level and who had never experienced or had a relatively low background for such operations were followed up as an observation group.
- **Time Study Observation Form:** The observation form in Table 1 was used when the working performance monitoring time values were recorded and evaluated together.

Table 10: Time study observation form

<table>
<tr><th colspan="13">TIME STUDY OBSERVATION FORM</th></tr>
<tr><th colspan="2">Machine:</th><td colspan="11"></td></tr>
<tr><th colspan="2">Measurement Date / Time:</th><td colspan="11"></td></tr>
<tr><th colspan="2">Measurement Information</th><th colspan="10">Observation</th><th rowspan="2">Average Time</th></tr>
<tr><th>Job description</th><th>Worker</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th></tr>
<tr><td></td><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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</table>

2.2 Method

In the study, the performance of five (5) students in the jointer, spindle moulder, router and horizontal drilling machines during the industrial application based production at the Gazi University Faculty of Technology; Wood Products Industrial Engineering Department was measured by returnable work measurement technique. The measured times were recorded in 10 replicates on the observation forms, from which the average observation times were derived. The average observation times are also converted to worker-dependent worker / time matrices.

The Hungarian algorithm developed by Kuhn (1955, 1956) was used to determine which worker should work with which machine, and the solution of the problem was carried out with the following steps:

If the source and target (row and column) numbers are not equal, the matrix is balanced by adding imaginary resources or targets.

In order to solve the problem of balanced assignment with the Hungarian algorithm, firstly the time matrix of the problem (assignment matrix) is created. Each line of the cost matrix corresponds to one of the sources (worker) and each column corresponds to one of the targets (machine). In the matrix (i, j) cell, the value of cij, which is the folded time, is assigned when the worker i is assigned to the machine j. The steps of the Hungarian algorithm applied to the worker / time matrix prepared in this way are as follows (Winston, 1994):

Step 1. The smallest element in each row of nxn dimension is found. A new matrix is created by subtracting this value from each cell value in the corresponding rows. This time the new matrix is subtracted from the cell values in the corresponding columns of the smallest value of each column. Thus, a reduced performance time matrix is obtained.

Step 2. At least a number of horizontal and vertical lines are drawn, passing through all zero-valued cells in the reduced matrix. If n number of lines are drawn so that all zero values are covered, then the best solution is to cover the zeros. Otherwise, proceed to Step 3, the next step.

Step 3. The smallest element not covered by the line is found. This value is subtracted from the uncovered elements in the reduced matrix and added to the elements covered by the two lines and returns to Step 2.

If the worker i is assigned to the machine j, then the performance time cij (model parameter) is defined and the binary decision variable xij is set to one (1) if, resource i is assigned to machine j and zero (0) otherwise. In this case, the mathematical model of assignment problem consisting of n workers and n machines will be as follows (Hillier & Lieberman, 2001):

$$Z_{min} = \sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}x_{ij} \qquad (1)$$

Constraints

$$\sum_{j=1}^{n} x_{ij} = 1; i \in \{1,2,\ldots,n\} \qquad (2)$$

$$\sum_{i=1}^{n} x_{ij} = 1; j \in \{1,2,\ldots,n\} \qquad (3)$$

$$x_{ij} \in \{0,1\};\ i \in \{1,2,\ldots,n\}, j \in \{1,2,\ldots,n\} \qquad (4)$$

Equation (1) represents the objective function that minimizes the total cost of assignment. Equation (2) expresses that each source should be assigned to only one target, while Equation (3) allows each target to be assigned to only one source. Equation (4) shows that all decision variables are binary types (0 and 1).

3 FINDINGS AND DATA ANALYSIS

Ten (10) repetitive observation times and average observation times of each worker demonstrating their performance in a machine are given in Table 2, Table 3, Table 4 and Table 5.

Table 2: Time study observation form for jointer

TIME STUDY OBSERVATION FORM												
Machine:		Jointer (J)										
Measurement Date / Time:		21.03.2018										
Measurement Information		**Observation**										**Average Time**
Job description	**Worker**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
Planing	1	25.77	28.30	38.10	32.44	35.02	31.68	34.80	35.50	37.20	33.48	33.229
	2	27.05	35.46	39.55	45.48	41.23	38.62	37.26	36.85	39.36	38.74	37.96
	3	32.37	34.76	36.63	35.20	35.85	41.20	36.13	35.01	35.64	38.79	36.158
	4	42.72	43.09	38.56	38.02	34.36	34.78	30.37	29.86	31.68	30.86	35.43
	5	30.69	32.38	35.31	34.26	33.89	35.01	34.56	30.89	31.41	30.58	32.898

Table 3: Time study observation form for spindle moulder

TIME STUDY OBSERVATION FORM												
Machine:		Spindle Moulder Machine (Smm)										
Measurement Date / Time:		21.03.2018										
Measurement Information		**Observation**										**Average Time**
Job description	**Worker**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
Shaping	**1**	24.11	26.86	21.19	21.96	22.04	21.68	20.95	21.74	22.32	21.01	22.386
	2	19.68	21.00	21.98	23.25	22.64	20.89	22.41	22.63	21.30	21.09	21.687
	3	20.65	27.30	27.94	29.10	28.85	29.08	27.85	27.40	26.65	28.03	27.285
	4	19.64	22.36	21.71	21.14	21.63	22.43	19.95	21.28	21.12	22.30	21.356
	5	26.12	34.13	34.58	26.63	27.12	33.63	28.01	26.76	26.45	27.48	29.091

Table 4: Time study observation form for router

TIME STUDY OBSERVATION FORM												
Machine:		Router (R)										
Measurement Date / Time:		21.03.2018										
Measurement Information		**Observation**										**Average Time**
Job description	**Worker**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
Shaping	**1**	26.86	23.02	23.69	23.56	24.40	23.78	25.86	28.12	28.43	23.64	25,136
	2	22.42	22.75	28.46	22.18	23.30	23.08	22.78	22.89	24.13	23.63	23,562
	3	34.90	35.42	35.30	34.92	36.75	35.23	35.46	36.21	34.92	34.88	35,399
	4	26.50	23.56	25.63	25.42	24.13	26.20	26.42	23.85	23.68	24.69	25,008
	5	43.34	39.71	43.22	41.69	41.75	42.10	42.86	39.89	39.76	41.56	41,588

Table 5: Time study observation form for horizontal drilling machine

TIME STUDY OBSERVATION FORM												
Machine:		Horizontal Drilling Machine (Hdm)										
Measurement Date / Time:		21.03.2018										
Measurement Information		**Observation**										**Average Time**
Job description	**Worker**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
Cutting mortise	**1**	274,2	305,4	312	275,4	307,2	303	301,8	305,4	274,8	303,6	296,28
	2	267	268,8	267,6	273	274,2	301,2	275,4	300,6	268,2	268,8	276,48
	3	454,2	453	433,8	429	388,2	390	391,2	421,8	393	389,4	414,36
	4	490,8	492	495	496,8	482,4	485,4	487,2	487,8	485,4	492	489,48
	5	432	438,6	395,4	421,2	422,4	391,2	394,8	392,4	420,6	395,4	410,4

This data, presented in Tables 2, 3, 4 and 5, has been transformed into the assignment / cost matrix as shown in Table 6 in accordance with the solution of the assignment problem by the "Hungarian Method". The "Hungarian Method Algorithm" has been solved on the obtained matrix. Numbers are rounded to the nearest integer number for ease of calculation.

Table 6: Worker / Machine time matrix

Worker / Machine	J	Smm	R	Hdm
1	33	22	25	296
2	38	22	24	276
3	36	27	35	414
4	35	21	25	489
5	33	29	42	410

3.1 Operation of the Hungarian Algorithm

Equilibration

For the algorithm's working principle to be nxn square matrix, the 5x5-assignment matrix is arranged in Table 7 by adding all artificial work points with all zero values (0).

Table 7: Balanced worker / machine time matrix

Worker / Machine	J	Smm	R	Hdm	Artificial Variable
1	33	22	25	296	0
2	38	22	24	276	0
3	36	27	35	414	0
4	35	21	25	489	0
5	33	29	42	410	0

Step 1: Create Reduced Cost Matrix

Step 1.1: The minimum Worker / machine time value for each line of the assignment matrix is determined. A new matrix was created from each element of the matrix by subtracting the minimum worker / machine time value for its line (Table 8).

Table 8: Worker / Machine time matrix

Worker / Machine	J	Smm	R	Hdm	Artificial Variable	Z_{min}
1	33	22	25	296	0	0
2	38	22	24	276	0	0
3	36	27	35	414	0	0
4	35	21	25	489	0	0
5	33	29	42	410	0	0

Step 1.2: With the new matrix in mind, the same procedure as in Step 1.1 was applied for columns (Table 9). The matrix obtained in this way is called the reduced worker / machine time matrix.

Table 9: Worker / Machine time matrix

Worker / Machine	J	Smm	R	Hdm	Artificial Variable
1	33	22	25	296	0
2	38	22	24	276	0
3	36	27	35	414	0
4	35	21	25	489	0
5	33	29	42	410	0
Z_{min}	33	21	24	276	0

Table 10: Reduced worker /machine time matrix

Worker / Machine	J	Smm	R	Hdm	Artificial Variable
1	0	1	1	20	0
2	5	1	0	0	0
3	3	6	11	138	0
4	2	0	1	213	0
5	0	8	18	134	0

Step 2: Performing the Assignment

Step 2.1: All zero values in the rows and columns of the reduced matrix are closed with at least a few lines (Table 11).

Table 11: Reduced worker / machine time matrix

Worker / Machine	J	Smm	R	Hdm	Artificial Variable
1	0	1	1	20	0
2	5	1	0	0	0
3	3	6	11	138	0
4	2	0	1	213	0
5	0	8	18	134	0

Step 2.2: If the line number matrix is equal to the number of rows (or columns), the most appropriate assignment is made by using the zero values in the reduced cost matrix and the solution is terminated.

Step 2.3: Go to Step 3 if the number of lines is less than the number of lines.

Step 3: Arrangement of the Matrix

The matrix elements that are not covered by the lines drawn in Step 2 are found to be the smallest (Table 12). This value is subtracted from all elements that are not covered by the lines and added to the elements enclosed by two lines. Go back to Step 2 (Table 13).

Table 11: Reduced worker / machine time matrix

Worker / Machine	J	Smm	R	Hdm	Artificial Variable
1	0	$\boxed{1}$	$\boxed{1}$	**20**	0
2	5	1	0	0	0
3	3	**6**	**11**	**138**	0
4	2	0	1	213	0
5	0	**8**	**18**	**134**	0

Table 12: Reduced worker / machine time matrix

Worker / Machine	J	Smm	R	Hdm	Artificial Variable
1	0	**0**	**0**	**19**	0
2	**6**	1	0	0	**1**
3	3	**5**	**10**	**137**	0
4	**3**	0	1	213	**1**
5	0	**7**	**17**	**133**	0

Table 13: Reduced worker / machine time matrix

Worker / Machine	J	Smm	R	Hdm	Artificial Variable
1	0	0	0	19	0
2	6	1	0	0	1
3	3	5	10	137	0
4	3	0	1	213	1
5	0	7	17	133	0

As shown in Table 12, the most appropriate assignments are determined by using the zero values on the reduced worker / time matrix by stopping the algorithm with the reason that the number of lines used to close zero values is the same as the matrix size (5x5 matrix 5 lines). The assignments thus obtained are:

- Worker 1 = R (Router)
- Worker 2 = Hdm (Horizontal Drilling Machine)
- Worker 3 = Artificial Variable
- Worker 4 = Smm (Spindle Moulder Machine)
- Worker 5 = Jointer (J)

When the calculation of the assignment problem is based on the mathematical model, the objective function for the cost / duration of work expected to be obtained according to the final assignment decision is obtained as in equation (5) and (6):

$$Z_{min} = \sum_{i=1}^{n} \sum_{j=1}^{n} c_{ij} x_{ij} \tag{5}$$

$$Z_{min} = 33x_{11} + 22x_{12} + 25x_{13} + 296x_{14} + 38x_{21} + 22x_{22} + 24x_{23} + 276x_{24} + 36x_{31} + 27x_{32} + 35x_{33} + 414x_{34} + 35x_{41} + 21x_{42} + 25x_{43} + 489x_{44} + 33x_{51} + 29x_{52} + 42x_{53} + 410x_{54} \tag{6}$$

The result obtained when assignment is made according to the equality (6) and 0-1 decision variables obtained by rearranging according to the assignment preferences on the obtained objective function; the sum of the processing times of one unit of each machine is determined as 355 seconds (equation (7)).

$$Z_{min} = 33(0) + 22(0) + 25(1) + 296(0) + 38(0) + 22(0) + 24(0) + 276(1) + 36(0) + 27(0) + 35(0) + 414(0) + 35(0) + 21(1) + 25(0) + 489(0) + 33(1) + 29(0) + 42(0) + 410(0)$$

$$Z_{min} = 355\ sn \tag{7}$$

4 CONCLUSION

In this study, an example of an effective and useful solution to the problem of machine assignment according to work and workmanship in furniture manufacturing works has been shown. Five different operators are presenting the same job in four different stations; significant labor and timesaving will be achieved by assigning appropriate work and machinery according to the performance achieved by measuring the total completion time for the unit product. This gain will have an impact on increasing the capacity utilization efficiency and will make a significant contribution to increasing total efficiency.

The use of more intensive quantitative decision methods in this type of assignment problems and even the spread of cross-diversified applications can solve the multivariate and multi-objective decision problems more easily, quickly and efficiently.

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Pheromone Types Usable Against Wood Destroying Insect Species

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ABSTRACT

Wood destroying insect species are one the most important biotic factors and decrease the economic value of wood as well as technological properties. For this reason, the struggle methods have to applied against wood destroying insects. Various methods have been developed and used in fighting with wood destroying insects. One of these is pheromone traps. Pheromones are based on the principle of catching insects by bringing them towards the trap system by affecting the opposite sex. It is possible that different pheromones can be used against each insect as well as the same pheromone against more than one insect. In this study, pheromones used against insect species which have caused considerable damage to wood materials was stated and some instructions about principle these pheromone types were given.

KEYWORDS: Pheromone, Wood, Insect, Fighting methods with insect

1 INTRODUCTION

Pheromones are secretions secreted by insects and used by insects as communication tools. It is important to know which pheromone to use against which beetle in order to be able to effectively carry out the struggle with harmful insects. It is clear that there is a lack of literature on the variety of pheromones that can be used against insect species fighting wood destroying insects. In this study, a general evaluation has been made about pheromone species and pheromones which can be used against harmful insect families.

The main pheromone varieties used in struggle with wood damaging insects are classified under five headings: sex pheromones (sexually attractive pheromones), alarm pheromones, gathering pheromones, host marker pheromones and trap pheromones.

1.1. Sex pheromones (sexually attractive pheromones)

The male insect tries to reach by following the trace of feeling the smell that a ready-to-mate female insect has secreted. The odor that provides this mating is sexual pheromone. This communication can be quite long distance. For example, female moths release a chemical material into the air as a sign of their presence and so they attract male insects in long distances. The females of the emperor's moths can manage to pull males at a distance of more than 11 km.

Male insects usually perceive of the female sex secretions with through antennas. Removing from the place or covering antenna with something can destroy all sexual perceptions (Butenandt, 1963).

1.2 Alarm pheromones

Some species emit volatile chemicals that can lead to the accumulation or flight of members of their species (ants, termites, and bees) when they are attacked by predators. This chemical is called as an alarm pheromone (Landoldt, 1999). For example; Vespula squamosa uses the alarm pheromone to pass alerts to others in during of a threat. Pheromones are also found in the plants. For example, some plants produce tannins. When these plants are feed, tannins make the plant less appetizing for herbivores (WEB 1).

1.3 Gathering pheromones

Gathering pheromones are used in the choice of partner, such as defense against predator and collective response to mass attacks. Most pheromones are produced by the female insects, only a small part of the sex pheromone is produced by male insects. But, male insect secretes gathering pheromone, and it resulted both species reach to gathering place. Gathering pheromones are found in the members of Coleoptera, Diptera, Hemiptera, Dictyoptera and Orthoptera. Collection pheromones are among the most ecologically selective insect suppression methods. Very low concentrations are also effective and non-toxic (Schneider, 1999).

1.4 Host marker pheromones

The host mark pheromones are known as a number of insect orders and reduce competition among individuals. Rhagoletispomonella (Tephritidae) is one of the best studies seen when laying eggs on the fruit surface and giving up other females. This behaviour has also been observed in studies on cherry fly (*R. cerasi*).

1.5 Trap pheromones

This pheromone commonly found in social insect species such as ants and bees are used to protect food exploration routes. Because pheromones are volatile, the pheromones used for this purpose must be sustained by the individuals.

2. MATERIAL AND METHODS

In this study, some literature investigations have been done about pheromones which can be used against most damaging insects to wood. Insect families and species was evaluated according to their pheromones

3. RESULTS AND DISCUSSION

3.1 Pheromones of Some Wood Damaging Insect Species

Pheromones belonging to some important wood Damaging species Anobiidae, Buprestidae, Cerambycidae and Curculionidae family are shown in Table 1 (Mayer and McLaughlin, 1990; White and Birch, 1987, Birch and White, 1988; Costello et al., 2008; McIntosh et al., 2001; Miller, 2006; Evans and Higgs, 1975; Doppelreiter, 1979; Serez and Schönherr, 1985; Benz and Bovey, 1986; Harring and Vite 1975; Vite, 1980; Vasechko, 1978; Tommeras et al., 1984; Allison et al., 2013). Stegobinone (2,3-dihydro-2,3,5-trimethyl-6-(1-methyl-2-oxobutyl)-4H-pyran-4-one) is used against the wood damaging furniture beetle, which causes damage to hardwoods and soft woods. Ipsenol, Ethylalcohol, Alpha-pinene, 3-carene and 1S-alpha-pinene pheromones are used to protect wood against *Chalcophora maiana* from Buprestidae family which damages on fir (Kaygın, 2007). It is well known that Cerambycidae family is one of the most dangerous insect families known as harmful in wood and wooden material. For example, old house borer (*Hylotrupes bajulus*) in this family can destroy coniferous and broad-leaved trees in the construction (Çankçıoğlu and Mol, 1998). P-Cymene-8-ol, cis-Verbenone, Myrtenol, α-Terpineol, Trans-Pinocarveol, 3,6,6-Trimethylcyclohepta-2,4-dienone, Terpinen-4-ol, Chrysanthenone pheromones can be used for *H. bajulus*. Curculionidae and Curculionidae/Scolytinae families damage on planted trees and can dry and kill them (Emin, 2012). For this families, pheromones usable were given in the table 1. It is made with pheromones fighting with *I. typographus*. The pheromone traps are placed in insecticidal areas a week before the time of the fly. Insects collected in trappings are destroyed. In cases where it is not possible to fight with pheromone, infested trees are cut off and the existing insects are destroyed mechanically. Generally, Ipsenol, Ipsdienol, cis verbenol and Alpha-pinene pheromones are used against most of damaging beetle in table. In a most recent study, Ipsenol, Ipsdienol, cis verbenol and Alpha-pinene pheromones were successfully used against damaging insects in Turkey (Yalçın et al. 2016).

Table 1. Pheromones used against some important wood damaging insects

Family	Species	Pheromones
Anobiidae	*Anobium punctatum*	1) 2, 3-dihydro-2,3,5-trimethyl-6-(1-methyl-2-oxobutyl)-4H-pyran-4-one (stegobinone)
Buprestidae	*Chalcophora mariana*	1) Ipsenol, 2) Ethylalcohol, 3) Alpha-pinene, 4) 3-carene, 5) 1S-alpha-pinene
Cerambycidae	*Acanthocinus aedilis*	1) Ipsenol, 2) Ipsdienol, 3) cis-verbenol, 4) 1S-alpha-pinene, 5) Ethylalcohol
	Hylotrupes bajulus	1) p-Cymene-8-ol, 2) cis-Verbenone, 3) Myrtenol, 4) α-Terpineol, 5) Trans-Pinocarveol, 6) 3,6,6-Trimethylcyclohepta-2,4-dienone, 7) Terpinen-4-ol
		8) Chrysanthenone
	Rhagium bifasciatum	1) 2-Methyl-3-Buten-2-ol, 2) (s)-cis-verbenol, 3) 2-methyl-6-methylene-2,7-octadien-4-ol(Ipsenol)
	Rhagium inquisitor	1) 2-methyl-3-buten-2-ol, 2) (S)-cis-verbenol, 3) 2-Methyl-6-methylene-2,7-octadien-4-ol(ipsenol)
Curculionidae	*Hylobius abietis*	1) Pentadecanal, 2) Hexadecanal, 3) Octadecanal, 4) Myrtenol, 5) Hexadecan-1-ol acetate, 6) Octadecan-1-ol acetate, 7) (z)-9-Octadecen-1-ol acetate, 8) (E)-9-Octadecen-1-ol acetate, 9) Eicosan-1-ol acetate
	Hylobius dermestoides	1) 2,5-Dimethyl-2-Izopropyl-2,3-dihydrofuran, 2) 2-methyl-3-buten-2-ol 3) (S)-cis-verbenol, 4)2-methyl-6-methylene-2,7-octadien-4-ol(Ipsdienol)
Curcolonidae/Scolytinae	*Cryphalus piceace*	1) Verbenol, 2) 2-methyl-3-buten-2-ol, 3) 2-methyl-6-methylene-2,7-octadien-4-ol (Ipsenol)
	Ips sexdentatus	1) 2-methyl-6-methylene-2,7-octadien-4-ol (Ipsdienol), 2) 2-methyl-6-methylene-7-octen-4-ol(Ipsenol), 3) Amitinol, 4) Ipsdienone
	Pityokteines curvidens	1) (S)- 2-methyl-6-methylene-7-octen-4-ol(Ipsenol)
	Pityokteines vorontzovi	1) (S)-(-)-2-methyl-6-methylene-7-octen-4-ol., 2) 2-methyl-6-methylene-2,7-octen-4-ol (Ipsenol)
	Dendroctonus micans	Exo-7-Ethyl-5-methyl-6,8-dioxabicyclo[3.2.1]octane (exo-Brevicomin)
	Ips acuminatus	1) α-Phellandren-8-ol, 2) p-Cymen-8-ol, 3) cis-Verbenol, 4) trans-Verbenol, 5) Myrtenol, 6) Verbenone
	Ips typographus	1) 2-methyl-3-buten-2-ol, 2) (R)-(trans)-Verbenol, 3) (-)-(4S)-(cis)-Verbenol 4) Myrtenol, 5) trans-myrtanol
	Phloeosinus armatus	1) terpinine-4-ol, 2) α-terpineol, 3) Ethanol
	Pityogenes bidentatus	1) 2-methyl-3-buten-2-ol, 2) (S)-cis-Verbenol, 3) 2-methyl-6-methylene-2,7-octadien-4-ol(Ipsdienol)
	Pityokteines spinidens	1) 2-methyl-6-methylene-7-octen-4-ol(Ipsenol), 2) 2-methyl-6-methylene-4,7-octadien-4-ol(Ipsdienol), 3) cis-Verbenol, 4) trans-Verbenol
	Scolytus multistriatus	1) (3S,4S)-(-)-4-methylheptan-3-ol, 2) (1S,2R,4S,5R)-(-)-α-2,4-dimethyl-5-ethyl-6,8-dioxabicyclo [3.2.1] octane(mutistiriatin), 3) (-)-α-cubebene, 4) 4-methyl-3-heptanone
	Scolytus scolytus	1) (±)-(erythro)-4-methylheptan-3-ol

4. CONCLUSION

Pheromone traps are especially developed and are an integral part of many pest control programs to detect and monitor the number of insects that are potentially harmful to plants today (Birişik et al., 2013). In this study, pheromone traps were explained and pheromone types were reported for most common and imported damaging insects. Pheromone types against common wood pests can be struggled with the output obtained from this study.

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The Evaluation of Wood Destroying Insects Detected in Some Provinces of Turkey According to Shannon Species Diversity and Margalef Species Richness

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ABSTRACT

The purpose of the study was to determine insect species diversity and abundance according to Shannon species diversity and Margalef species richness in log depots covering Düzce, Bolu, Zonguldak, Bartın, Karabük, Kastamonu and Sinop provinces in Western Black Sea region of Turkey. For this purpose, two indexes were calculated based on log depots, provinces and sub regions. The highest species diversity was calculated in Düzce Yığılca Aksu log depot while the lowest species diversity was calculated in Zonguldak Alaplı Mollabey log depot based on the log depots. For provinces, the highest species diversity and richness was calculated in Düzce while the lowest was calculated in Zonguldak provinces. When evaluated according to regional directorates, the highest species diversity and richness were found in Bolu Forest Regional Directorate and the lowest was found in Zonguldak Forest Regional Directorate. It was found that the temperature, relative humidity, altitude and wood species in log depots effected on species diversity and richness differences in the working area.

KEYWORDS: Shannon species diversity, Margalef species richness, Insect, Log depots

1 INTRODUCTION

Insects in Arthropoda class provides 70% of all living species on earth therefore considered very important ecologically (Kansu, 2000; Erwin, 2000; Grimaldi & Engel, 2005) Turkey has very rich resources in terms of genes, species and ecosystem (Kışlalıoğlu & Berkes, 1992, Aydın, 2011)

As it is known a variety insect species utilize wood as food source on use as shelter. While some insect species cause harm in living trees, the others live in processed wood material. Therefore, trees and processed wood contribute significantly to diversity of insect species on earth.

This study deals with the identification of most common insect species in log depots in Western Black Sea Region in Turkey. The species diversity and richness of the region were calculated according to Shannon and Margalef indexes.

2 MATERIAL AND METHOD

2.1 Placement of Pheromone Traps and Collection of Insects

Table 1 shows locations of pheromone traps used in western Black sea Region.

Table 1. Study areas

Forest depots	Depot locations	Altitude (m)	Direction
Düzce – Merkez-Büyükaçma	40°47'2.99"K 31°11'49.89"D	199	F
Düzce - Gölyaka-Merkez	40°46'33.91"K 30°59'43.61"D	129	NE
Düzce -Yığılca-Aksu	40°56'23.16"K 31°22'56.78"D	289	NW
Bolu - Merkez-Çelegölcük	40°49'40.39"K 31°40'55.23"D	1166	S
Bolu – Merkez-Sultanköy	40°40'16.48"K 31°34'22.24"D	794	NE
Bolu-Mengen-Pazarköy	40°55'29.14"K 32°10'18.67"D	690	NW
Bolu-Gerede - Merkez	40°47'18.77"K 32°12'16.88"D	1270	S
Zonguldak - Ereğli- Soğanlıyörük	41°26'20.31"K, 31°52'0258" D	39	SW
Zonguldak - Alaplı- Mollabey	41°8'57.27"K 31°24'57.20"D	19	S
Karabük - Merkez -1	41°13'17.23"K 32°36'52.16"D	506	SW
Karabük - Merkez -2	41°13'23.26"K 32°36'45.35"D	538	SW
Karabük - Safranbolu- Merkez	41°16'59.55"K 32°40'2.22"D	785	NE
Bartın - Helkeme	41°26'51.30"K 32°33'11.43"D	308	N
Bartın - Kozcağız	41°28'35.68"K 32°20'39.52"D	71	SW
Bartın - Merkez- Epçiler Kadıköy	41°36'25.48"K 32°25'35.63"D	35	SW
Kastamonu – Hanönü-Gökçeağaç	41°37'31.68"K 34°29'51.98"D	431	W
Kastamonu - Taşköprü - Ardıçlık	41°30'14.72"K 34°14'16.81"D	657	W
Kartamonu - Araç - Sarpun	41°13'48.46"K 33°16'32.72"D	603	F
Kastamonu - Samatlar- İğdir	41°13'9.59"K 33° 9'16.30"D	604	NE
Sinop - Boyabat- Büyükmeydan	41°48°37.73"K 34°73°42.94"D	342	F
Sinop-Durağan-Akkır	41°25'53.99"K 35° '20.28"D	277	F

F: Flat, N: North, S: South, W: West, E: East

Pheromone traps were used to attract insects into the cages installed on log depots. Trans –verbenole (100 mg) + alpha pinene (20 mg), lpsdienol (attracting the opposite sex),2-methyl 3-butenol and cis-verbenole chemicals were used as preperats. The manufactures of pheromone chemicals indicated that, they can be used up to 40 days. In this study, pheromone chemicals were replaced over 30 days instead due to higher weather temperatures. These chemicals were stored at + 4°C to keep them effective and fresh

2.2 Identification of insect species

Identification of larvae and pupa

Larvae, pupa and adult insects were collected from trap wood installed at various locations on log depots. An identification key was used for larvae and pupa identifications. The other species, especially Dorcus parallelipipedus, Rhagium inquisitor, Hylotrupes bajulus, Valgus hemipterus ve A. punctatum were difficult to identify from larvae on pupas, therefore they transferred to a condition chamber at 75% RH and 26-28°C mean temperature until they became adults for identification (Cherepanov , 1991)

Identification of adult insects

The adult insects captured with pheromone traps in log depots within the region were identified using identification keys obtained from books on research papers (Acatay, 1961; Freude, et al., 1981; Freude, 1983; Bevan, 1987; Borror et al., 1989; Bense, 1995; Creffield, 1996; Çanakçıoğlu and Mol, 1998). A stereo microscope (Olympus SZ51, Olympus Corporation, Tokyo, Japan) was used for species naming.

2.3 Calculation of Species variation indexes

Shannon Weaver species diversity index

The following formula (1) was used to calculate Shannon Weaver index of log depots in western Black sea region (Shannon and Weaver 1949). In this formula p indicates proportional ratio species distribution. Logarithmic value of p and number of species and multiplied. Logarithmic negative value of all species within the region is multiplied by number of species gives Shannon-Weaver (H).

$$H=-\sum\{pi \log(pi)\} \quad (1)$$

Margalef species richness index

The following Formula has used to calculate Margalef species richness index in log depots (Margalef 1958) within the region.

$$D=(S-1)/\ln N \quad (2)$$

Where, D represents Margalef index, S; number of species, N;number of species within the group.

3 RESULTS AND DISCUSSION

3.1. Insect Species Diversity and Evaluation of Frequency Based on Biodiversity Indexes.

Shannon index: When number of species and frequency of species distribution are concerned, the highest Shannon index value was calculated for Duzce province, Yıgılca Aksu depot. The lowest index values, on the other hand, found for Zonguldak Alaplı and Bartın Helkeme depots. This can be explained with a more uniform distribution of species variation in Yıgılca Aksu depot.

Margalef index: Margalef index counts on number of species and total population number. Thus, uniform distribution of insect numbers on species is not important. Duzce Yıgılca Aksu depot gave 7, 84 (lmg) index value, while Zonguldak, Mollabey depot resulted in only 1,26 (lmg) (Figure1).

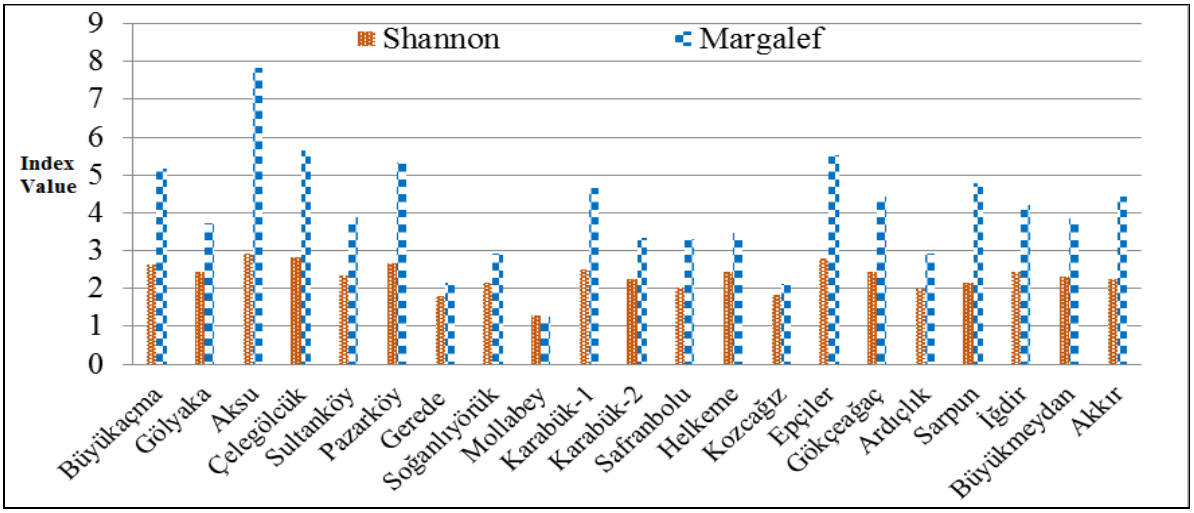

Figure 1. Species diversity and richness of insects in log depots according to Shannon and Margalef indexes

Species variation on different locations depends on biology and egg lying habits of insect species. The reasons of high species richness in Yığılca Aksu depot can be explained with closeness to the forested area and low altitude which provides an appropriate habitat for insect to thrive.

When all 7 provinces were compared, Düzce had the highest species variation and richness while Zonguldak region was the lowest (Figure 2).

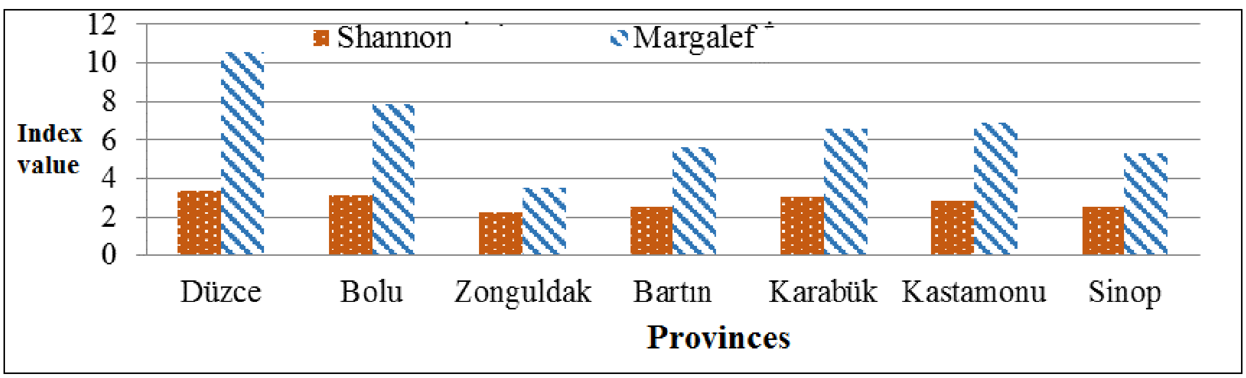

Figure 2. Species diversity and richness of insects based on provinces according to Shannon and Margalef indexes

When regions were related, Bolu region showed highest species variation and richness. Zonguldak region was the lowest (Figure 3).

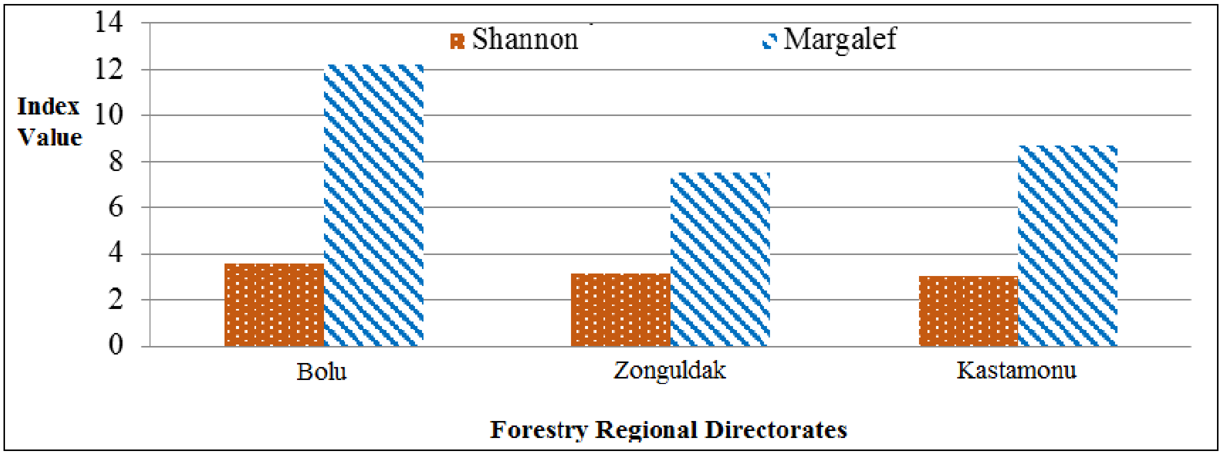

Figure 3. Species diversity and richness of insects based on sub regions according to Shannon and Margalef indexes

4 CONCLUSION

Based on findings, the highest species variation and richness were found in Bolu region. When the provinces are compared, Duzce log depots showed highest values. Based on log depot locations, Yığılca Aksu depot resulted in highest values for Margalef index (7,84) and Shannon index (2,92), respectively. Relative humidity and temperature recordings of the locations believed to play important role in species variation and richness values. In addition, wood species and storage time also significantly contributed to the index values.

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D15 – Type Flooring Structures Designed for Gymnasiums and Tested for The Ball Repelling Requirement

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ABSTRACT

In this paper the results of the experiments carried out on three wooden flooring structures are presented. The structures are made from beech wood and they are designed for the indoor basketball courts. These structures are characterized by simple design, ease of manufacture and low price. The proposed flooring structures have to have good elastic properties in order to ensure a proper bounce height of the ball and the high efficiency of the athletes when playing the basketball game.

The basic and reference structure is composed of flooring board strips of 15 mm thick and arranged as the English parquet model. The flooring board supports on half-lap jointed joists and noggins that form a wooden grid frame with 16 square openings on a tested surface of 1000 mm x 1000 mm. The flooring board strips had the dimensions of 500 mm x 50 mm x 15 mm and 250 mm x 50 mm x 15 mm respectively. Joists and noggins had the dimensions of 1040 mm x 40 mm x 20 mm, spaced 250 mm between the crosscut sections midpoints. The two improved variants proposed in the research had additional wooden shock pads positioned differently: for the first variant they were positioned at equal distances between the half-lap joints, whilst for the second variant they were positioned under the half-lap joints. The shock pads with dimensions of 60 mm x 40 mm x 10 mm were made of beech wood, as the whole flooring structure was made.

The tests were carried out on a floor test stand S-TPS-3, designed and executed for this purpose at the Transylvania University of Brasov according to SR EN 12235:2014. During the test, the basketball ball dropped on the tested floors from the height of 1.80 m set to the stand, and the bounce ball height was afterward measured and compared to the height measured on a standard concrete floor. The purpose of the research is to assess whether floor structures designed and built for sports courts, following the tests carried out, meet the requirements of indoor sports flooring courts.

KEYWORDS: wooden floorings, sport floorings, rebound, ball, testing stand

1 INTRODUCTION

Over time, due to the fact that the wood flooring industry has been constantly changing, researchers' concerns have generally been related to improving and optimizing the properties of wood used in wood flooring (Gasparik and Gaff 2013, Dömény et al. 2014, Dömény, et al., 2018). Wood has remained one of the materials successfully used in sports field (Cismaru 2006, Cismaru et al., 2015). due to its qualities. Floors for sports facilities are considered special due to their "behaviour" in response to the sporting activity they support (Cismaru et al., 2015).

The concern of sports floor specialists is to optimize floor structures in terms of their flexibility and rigidity and to reduce the unevenness of the substrate to obtain flat surfaces. Also, in an optimal balance between their rigidity and flexibility, the aim is in fact to have minimum effort on the side of the user and at the same time to avoid athletes' injuries during sports activities (Pardoseli Magazin 17). This is why specialists have focused on developing a wide variety of structures for sports floorings, ranging from the traditional systems to the most innovative systems, taking into account the performance levels required by sports activities.

Even though in recent years a lot of innovative materials have appeared, wooden floors for sports halls such as basketball, squash or dancing are preferred because in these sports the elasticity has to be spread and not punctual as it is for rubber surfaces, for example (www.kineticsport.ro). As Kolitzus (2012) noted, testing in the world of sports and recreational games is a scientific process requiring highly specialized expertise. For this reason, a number of research centres have emerged and developed in the last decade. Del Tec in the Netherlands (www.deltecequipment.com), is one of the leading developers and manufacturers of special (mobile) testing equipment for sports floors. Demker (2009) conducted a study of 51 different materials for floorings, and developed a global standard for measuring the mechanical comfort for all types of floorings, both in-situ and in the laboratory conditions. Their test methods are presented in EN 14808 and EN 14809 standards.

At international academic level, there are few studies and published research results in the field of the present research. For this reason, all the work done for testing the wood flooring proposed in this paper will only refer to the studies presented above and to the regulations imposed by the European Standards and Sports Federations (European & International Standards. Surfaces for sports areas. A short guide. 2014).

2 OBJECTIVE

The main objective of this study is to develop wood flooring structures that have a high level of performance and are competitive with similar ones. The basketball ball bounce heights on two improved variants of sports wooden floors are compared to the basic one and to standard one (tested on the concrete floor). The testing method carried on the designed flooring structures shows if they meet the requirements imposed by the Sports Federations and National and International Standards for sports courts.

3 MATERIALS, METHOD, EQUIPMENT

The dimensions of the flooring board strips were 500 mm x 50 mm x 15 mm, and 250 mm x 50 mm x 15 mm, respectively. They were made from steamed beech wood. Arrangement of the strips into the floorboards was done according to the English model. The tested flooring structures were executed in the Polyfunctional Woodworking Workshop of the Faculty of Wood Engineering at the Transilvania University of Brasov.

The minimum tested flooring area according to SR EN 12235: 2014 requirement has to be at least 1.00 m x 1.00 m. Following the standard, the designed structures had a tested area of 1.00 m x 1.00 m. The JOWACOLL® 103.05 adhesive was used to glue the strips and forms the floorboards.

The basic structure was composed of flooring board 15 mm thick, which supports on half-lap jointed joists and noggins in a shape of the wooden grid frame with 16 equal square openings. The improved variants of sports floorings tested in the research had additional wooden shock pads positioned at equal distances between the half-lap joints for the first variant, and under the half-lap joints for the second variant. The wooden shock pads had dimensions of 60 mm x 40 mm x 10 mm and they were made from beech wood.

The basic structure is presented in Table 1 and Figure 1.

Table 11: Characteristics of basic flooring structure

D2-a structure (1,00 m x 1,00 m)							
Wood flooring boards				**Joists**			
Thickness	Width	Length	Amount	Thickness	Width	Length	Amount
mm	mm	mm	pcs.	mm	mm	mm	pcs.
15	50	500	30	20	40	1040	5
15	50	250	20	Noggins			
				20	40	1040	5

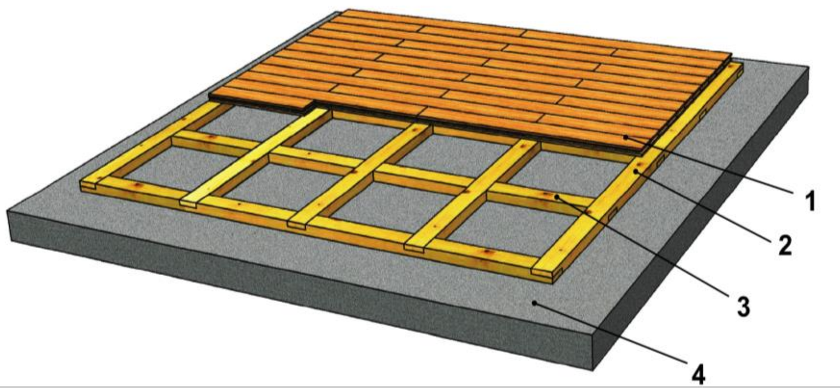


Figure 1: Basic flooring structure (D2-a); 1 – parquet strips; 2 – joists; 3 – noggins; 4 – concrete foundation

The components of the wooden floors were mounted using screws with dimensions: ϕ 3,5 x 30 mm and ϕ 6 x 75 mm, respectively.

Table 2: Characteristics of D2-b1 flooring structure

D2-b1 structure (1,00 m x 1,00 m)							
Wood flooring boards				**Joists**			
Thickness	Width	Length	Amount	Thickness	Width	Length	Amount
mm	mm	mm	pcs.	mm	mm	mm	pcs.
15	50	500	30	20	40	1040	5
15	50	250	20	Noggins			
Wooden shock pads				20	40	1040	5
10	40	60	40				

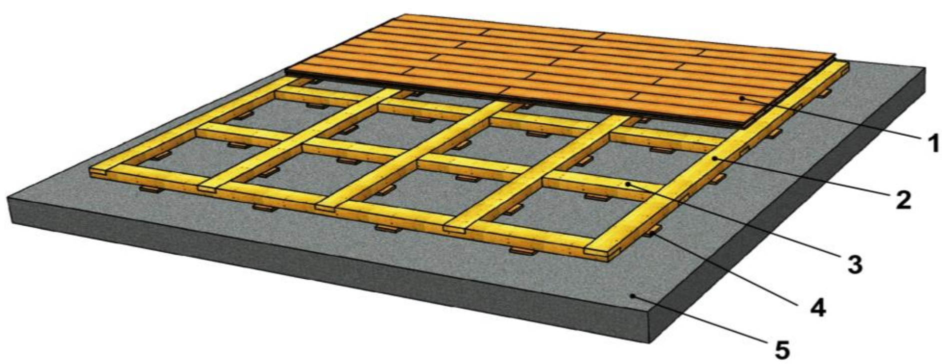


Figure 2: Structure of wooden flooring D2-b1 type – parquet strips; 2 – joists; 3 – noggins; 4 – pads; 5 – concrete foundation

Table 3: Characteristics of D2-c1 flooring structure

D2-c1 structure (1,00 m x 1,00 m)							
Wood flooring boards				**Joists**			
Thickness	Width	Length	Amount	Thickness	Width	Length	Amount
mm	mm	mm	pcs.	mm	mm	mm	pcs.

15	50	500	30	20	40	1040	5
15	50	250	20	Noggins			
Wooden shock pads				20	40	1040	5
10	40	60	25				

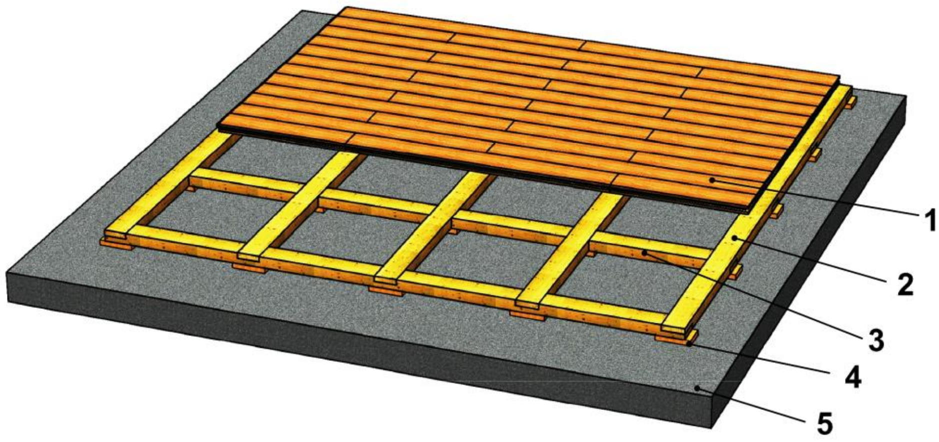


Figure 3: Structure of wooden flooring D2-c1 type; 1 – parquet strips; 2 – joists; 3 – noggins; 4 – pads; 5 – concrete foundation

The two improved variants of wooden floorings differ through the number and position of wooden shock pads, as seen in Tables 2 and 3, and Figures 2 and 3.

As a support layer for the tested structures, a reinforced concrete floor was applied over which a special quick primer for non-absorbent substrates (Super Grund from BAUMIT) was applied and a layer of 2-3 mm self-levelling screed was used to ensure the flatness of the substrate (Nivello Duo from BAUMIT).

Figure 4: Testing stand S-TPS-3 and official Molten basketball ball used for experiment

The test method was a procedure developed in accordance with SR EN 12235: 2014 which provides that the bounce height of the ball on the sporting surface is calculated with equation (1):

$$R\% = \frac{R_s}{R_c} \times 100 \qquad (4)$$

in which:

R% - repulsion of the ball on the floor surface;

Rs - bounce height on the tested floor surface, in m;

Rc - bounce height on the concrete floor surface (standard floor), in m.

In order to comply with the provisions of standard SR EN 12235: 2014 and of the General Rules for Organizing Basketball Competitions 2016-2017 (RGOCB) with regard to the testing of wooden floors, a test stand was designed and executed within of the Faculty of Wood Engineering laboratories at Transilvania University of Brașov (figure 4).

The operating principle of the stand consists in fixing the ball inside a ring. Three elements, namely two fixed ones and one with mechanical retraction ensured the initial position of the ball at the height of 1.80 + 0.01 m (according to the standard SR EN 12235: 2014). Using an Einstein distance sensor - Sensor DT020-1, the height to which the ball rises after falling on the floor surface is measured. Using the MiLAB software, the ball bounce height is calculated. The software is installed on a dedicated digital tablet, which allows the collection, display and analysis of data, transforming the ball's movements into relevant graphical representations.

MOLTEN 7 official basketball ball was used for the test (Figure 4). This type of ball is used in the competitions organized under the aegis of Basketball Federation. The ball was inflated at a pressure of 0.7 bar

4 RESULTS AND DISCUSSION

Five measurements of the ball bounce heights were made in nine different points of the tested surfaces (Figure 5). The initial height of the ball set on the testing stand was 1.80 + 0.01 m, according to the standard SR EN 12235: 2014.

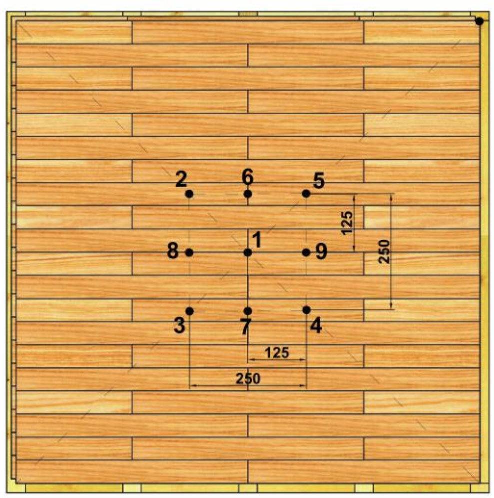


Figure 5: The nine measurement points

The standard value of the ball bounce height was obtained when testing the ball on the concrete floor surface. The bounce height measured in this case was of 1.204 m. When testing the wooden floor surfaces, the ball bounce height has to reach at least 90% of this standard value.

The results of the measurements of the ball bounce heights made in the nine points of the basic flooring structure (D2-a) are presented in Figure 6.

The floor type D2-a was able to obtain 91.366% of the standard value (1.204 m), which is a better result than 90%, the minimum value according to SR EN 12235: 2014 standard. The result shows that this type of flooring is recommended for basketball indoor courts.

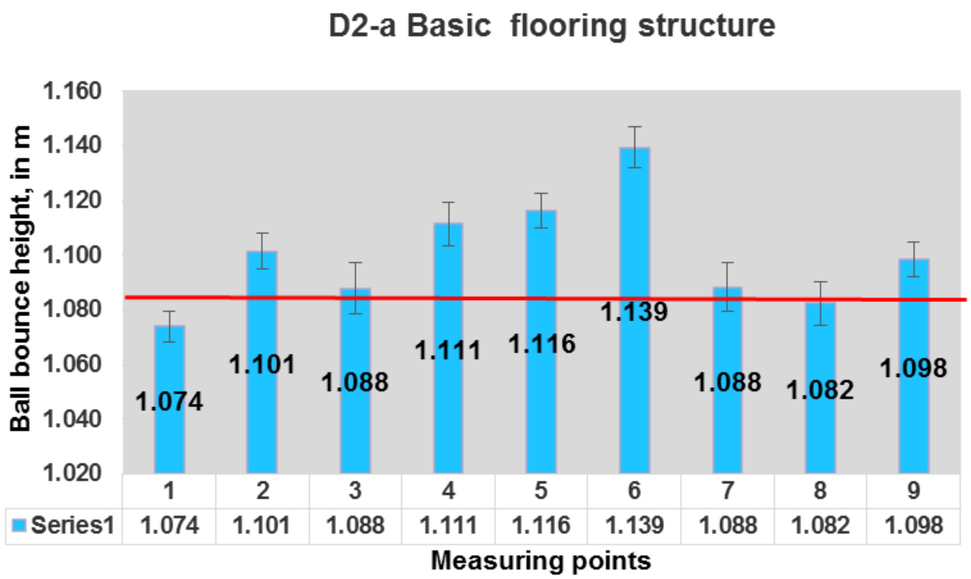


Figure 6: Ball bounce height measured in the nine points for basic D2-a structure

The diagram in Figure 7 shows the results obtained from the 9-point testing of the D2-b1 flooring structure.

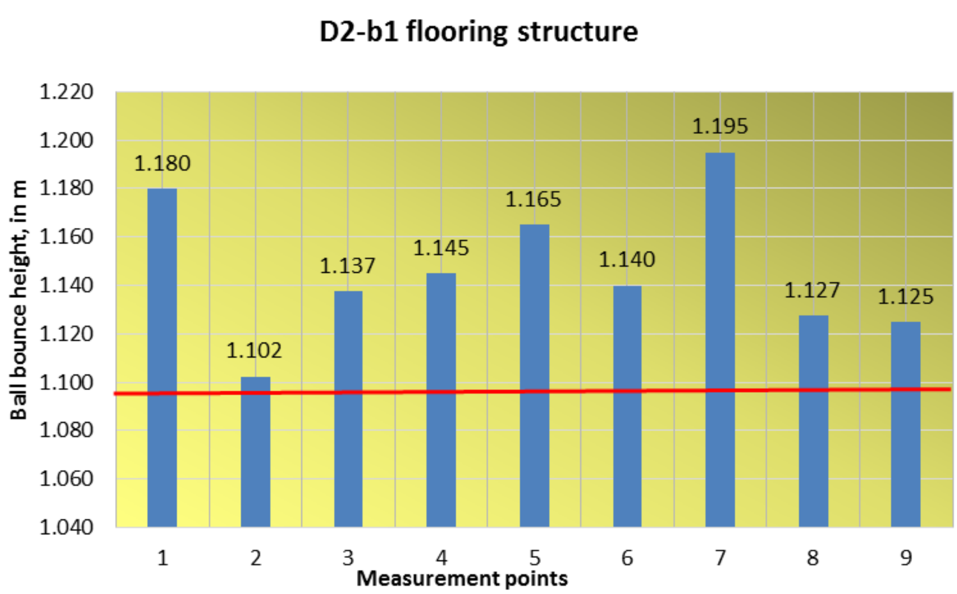


Figure 7: Ball bounce height measured in the nine points for D2-b1 structure

The floor type D2-b1 managed to obtain 93.659%, exceeding by 3.659% the reference value (1.204 m). This demonstrates that this type of flooring is recommended for basketball courts, and the shock pads added to the basic flooring structure improved its elastic properties.

In the diagram of Figure 8, the results obtained from the 9-point testing of the D2-c1 wood flooring are presented.

The floor type D2-c1 responded by only 88.44% of the standard height, missing 1.56% to reach the required minimum of 90% for use in sports basketball facilities, as required according to SR EN 12235: 2014 standard.

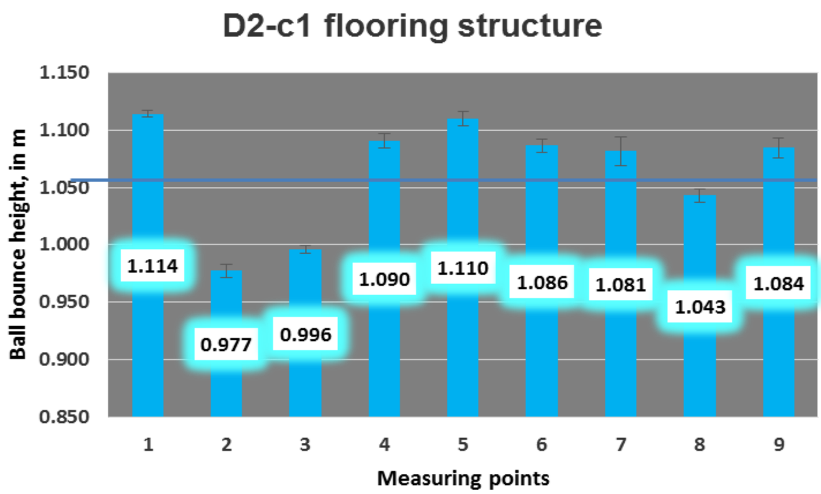


Figure 8: Ball bounce height measured in the nine points for D2-c1 structure

Repulsions of the ball on the tested floors surfaces calculated with Eq. 1 are presented in the diagram in Figure 9. Table 4 presents the comparison between the results of the tested flooring structures

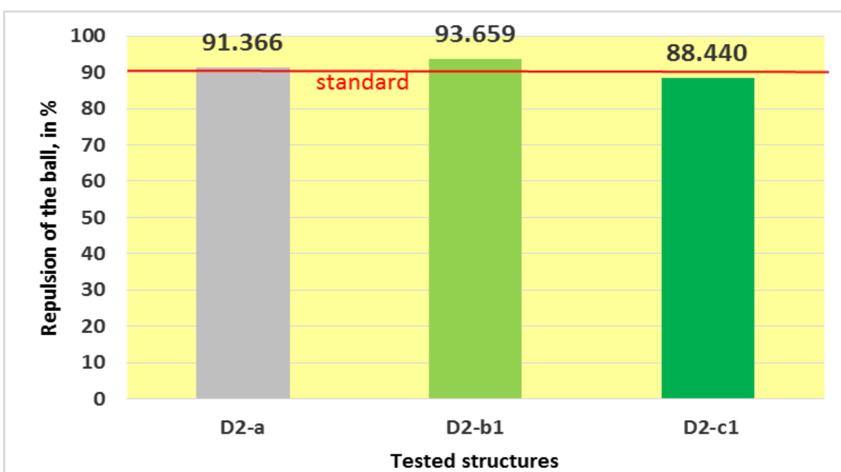
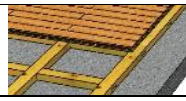
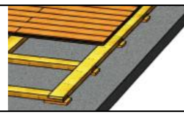


Figure 9: Repulsion of the ball on tested flooring surfaces

Table 4: Comparison between performances of the tested flooring surfaces

Structure	Detail	Ball bounce height, in m/ Repulsion, in %		Increase/ decrease	
Basic D2-a		1.100 m	91.366 %	D2-b1 compared to D2-a	
				0.028 m	2.294%
D2-b1		1.128 m	93.659 %	D2-b1 compared to D2-c1	
				0.063 m	5.219%
D2-c1		1.065 m	88.440 %	D2-c1 compared to D2-a	
				- 0.035 m	-2.926%

5 CONCLUSIONS

All the structures tested with MOLTEN 7 basketball ball, inflated at a pressure of 0.7 bar were compared to the concrete floor, for which the standard ball bounce height was of 1.204 m.

The basic structure without shock pads (D2-a) recorded a good value of the ball bounce height and a better repulsion of the ball compared to that obtained on standard concrete floor (91.366% compared to 90%). By adding the wooden shock pads, an improvement of the results was expected. Unfortunately, only one of the improved structures responded better than the basic one to the requirements imposed by SR EN 12235: 2014 standard (D2-b1). In this case the flooring joists and noggins supported on 40 wooden shock pads positioned at the half distance between the half-lap joints. The other structure (D2-c1) having only 25 wooden shock pads situated under the half-lap joints didn't met the requirements imposed for these types of floorings.

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Industry 4.0 Awareness in Furniture Enterprises: Case Study of Ordu and Giresun

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ABSTRACT

The Industry 4.0 approach has added a new and different window to the viewpoints of the revolutions that took place during the industrialization process throughout human history. In the nineteenth century, the power and importance of water and steam was understood and this power was made part of the production. In the 20th Century, electricity and mechanical energy production technologies were fed and this has provided the production to enter in all areas. After this process, digital technologies were developed quickly. The constant and rapid change of technology has been brought the necessity of the industry to take a new step. This situation is influential to make changes of production of the enterprises. That is it is the Industry 4.0 approach which will be totally effect of the world and humanity and as a new vision for the industry.

This approach will cause enterprises to make a breakthrough for change in production, and to move towards new and ever-evolving technologies such as digital planning, artificial intelligence, and robotics in production facilities to increase production and productivity. Industry 4.0 is to introduce new concepts such as the internet of objects (Internet of things – IOT), virtual three dimensions, artificial intelligence, robots, continuous innovation in to face of enterprises. This is forced to enterprises to set up new teams who know the software well, follows the new technologies, plans and programs them, open to change and development, entrepreneurial spirit. Turkish furniture industry which has a suitable structure of development is confronted us as one of the important sector. Nevertheless, the fact that the sector is consisted of small and micro scale enterprises and the structural and economic problems caused by being small to emerge as a big obstacle to the use of digital technologies.

Within this study, it was tried to show the awareness of the furniture industry about the Industry 4.0 approach, the present possibilities, future plans and where they saw themselves in these developments. As a target group of the study, furniture enterprises of Ordu and Giresun were selected. Data were collected through questionnaire from the 45 enterprises in these provinces. The obtained data were analysed in computer environment. The possible effects of the Industry 4.0 on the furniture industry were highlighted, what should be done in this transition and transformation process, and suggestions were developed and discussed.

KEYWORDS: Industry 4.0, Furniture Industry, SME, Industry 4.0 Awareness.

1 INTRODUCTION

With the start of the industrial age towards the last quarter of the eighteenth century, a great change and development has occurred in the industry. These changes and developments have been described as a revolution, and there have been 4 industrial revolutions to date. The first industrial revolution marked the nineteenth century, and in addition to human power in industry, machinery, water and steam power was also used. After the first quarter of the 1900's, the concept of mass production was introduced to the use of integrated machines together with electricity and this change was called the second industrial revolution. With the emergence of computers, from the third quarter of the twentieth century, electrical and computerized machines have begun to be used in the production line. This change is also described as the third revolution in industry. Countries and societies still have been continuing to experience the changes brought about by the Third Industrial Revolution. While this change has not yet been completed and especially as SMEs continue to resist this change the industry has faced a new revolution. With the emergence of faster and widespread mobile internet, powerful sensors and artificial intelligence, learning, communicating and managing processes, also known as the digital revolution since the middle of the first quarter of the 21st century, has begun the transition to The Fourth Industrial Revolution, or another known name Industry 4.0.

Industry 4.0 brings a whole new way of life. Such as the internet of objects (IoT), the internet of systems, intelligent and powerful sensors, three-dimensional printers, robotics, intelligent manufacturing systems, large data, cloud computing, artificial intelligence, many technological concepts have occurred with this new concept (Web-1, cited by Öztürk and Koç, 2017). Keeping up with the rapid development of these newly emerging concepts is very important for the countries. Evaluating our country especially in terms of SMEs, it is seen that they are between the 2nd and 3rd Industrial Revolution, and far away from a deal with these new concepts. While machine investments, mass production technologies and production capacities in the 20th century, it seems to be a competitive advantage for companies, but nowadays knowledge is providing a competitive advantage (Web-2; cited by Öztürk and Koç, 2017).

According to one of the World Economic Forum reports published in 2015, the 21-turning point that will shape our future digital and hyperlinked world is mentioned. All of these turning points are expected to take place until 2025. These transformations that will occur in such a short period of time will significantly affect the competitiveness of our country's industrial sector. These mentioned turning points and expectation percentages are shown in the table below (Schwab, 2017):

"Table 12: Turning Points Expected to Occur by 2025

Turning Points	**Expected (%)**
10% of people wearing clothes connected to the internet	91.2
90% of people having unlimited and free (advertising-supported) storage	91.0
1 trillion sensors connected to the internet	89.2
The first robotic pharmacist in the US	86.5
10% of reading glasses connected to the internet	85.5
80% of people with a digital presence on the internet	84.4
The first 3D-printed car in production	84.1
The first government to replace its census with big-data sources	82.9
The first implantable mobile phone available commercially	81.7
5% of consumer products printed in 3D	81.1
90% of the population using smartphones	80.7
90% of the population with regular access to the internet	78.8
Driverless cars equalling 10% of all cars on US roads	78.2
The first transplant of a 3D-printed liver	76.4
30% of corporate audits performed by AI	75.4
Tax collected for the first time by a government via a block chain	73.1
Over 50% of internet traffic to homes for appliances and devices	69.9
Globally more trips/journeys via car sharing than in private cars	67.2
The first city with more than 50,000 people and no traffic lights	63.7
10% of global gross domestic product stored on block chain technology	57.9
The first AI machine on a corporate board of directors	45.2

Source: Deep Shift - Technology Tipping Points and Societal Impact, Global Agenda Council on the Future of Software & Society, World Economic Forum, Survey Report, September 2015, pp. 7."

It is almost impossible to predict the extent and breadth of this digital revolution, which will cause the economic, social and cultural change in large dimensions. One of the biggest impacts in all of these areas is the strengthening of the governments, citizens, businesses' employees, shareholders and customers, and superpower relationships in smaller countries. Due to the disruptive impact of Industry 4.0 on the existing political, economic and social models, these actors need to be aware that they have become part of a dispersed power system that demands more collaborative forms of interaction in order for them to succeed (Schwab, 2017).

It is not enough for businesses to make only the production lines and technology compatible for the transition to Industry 4.0. Complete planning of production, marketing, delivery, after-sales services, customer relations and feedback processes is required for a complete transition and success. Standing against us as a complex structure, industry 4.0 is a long process that begins when the product is still in the process of thinking, ordering, development and production, delivering it to the end user, then recycling all services and adding them to the process. This means that businesses need to completely renew themselves and integrate all systems. The positive effects of this revolution, which integrates people, objects and systems into one another and transform the world into a great information system in this process, can be summarized as follows (Web-3, cited by Öztürk and Koç, 2017):

- More automation in manufacturing with industry 4.0, mass production more connected to customer preferences, maximum manufacturing quality, localized manufacturing processes, rapid innovation process and less resource use,
- Identification of the possibilities of production processes more flexible and free of system and applications,
- The minimum cost of producing highly personalized products for customers,
- Increase in data transmission speed and simplification of logistics operations by enabling products to be produced at closer centres by means of 3D printers,
- The efficient use of energy resources.

A qualified workforce is one of the essential elements of Industry 4.0. Most of today's professions will disappear in the near future and some will change. The ability to survive today's operating systems and align themselves with Industry 4.0 depends on the ability to innovate from scratch, to perform digital transformations, and to be a new player on the market. In order to comply with Industry 4.0, changes in the qualifications of existing employees, work patterns, and job descriptions need to be redefined. In the near future, employees will be asked to have higher qualifications than today's "employees". For these high qualities required, it will be necessary to restructure the education system and introduce radical change and transformation from beginning to end (Öztürk and Koç, 2017).

Industry 4.0 has entered into business life in the industry as internet technologies started to offer business solutions in production. "In this way, digitization and mutual relations have increased in business models. Companies in the manufacturing and engineering, automotive, process industries, electronics, information and communication industries believe that digitalization will lead to transformation. This digitalization requires an investment of 40 Billion Euros in Germany and 140 Billion Euros in the EU each year until 2020. "(Koch et al., 2015; cited by Şenkayas et al., 2016). The biggest problem at this point is that there are ambiguities in the way that countries cannot afford these huge investments, how soon SMEs can benefit from this system, and the industrial internet can be fully understood. Particularly SMEs need to establish partnerships with technology and infrastructure companies, even competitors, in order to carry on their vital activities. In this context, the EU plans to support SMEs for high value-added and technologically advanced manufacturing (Davies, 2015; cited by Şenkayas et al., 2016).

Looking at Industry 4.0 as our country, we are at a point far away from the subject. Looking at the technological infrastructures of the enterprises in our country, they cannot complete the Industry 3.0 revolution yet and they are in a position between Industry 2.0 and Industry 3.0. When TSI 2016 statistics are examined, it is seen that the total number of enterprises is 2.689.910 and the number of SMEs in this number is 2.684.838. Proportionately, 99.81% of the total number of enterprises is operated as SME. It is known that large-scale enterprises aren't already experiencing a major difficulty in capturing Industry 4.0, and are already beginning to realize these transformations. However, the fact that the enterprise structure is SME-dominated, and especially the majority of SMEs, is also micro-scale, Industry 4.0 will be a sign that we are quite far from the truth and we are still discussing conceptual dimensions.

When we look at the operating structure of the furniture sector, it is seen that the total number of enterprises is 34.477 and the number of SMEs in these enterprises is 34.417 according to TSI 2016 data. When the enterprise numbers in the sector are evaluated proportionally, it is determined that 99.83% of the total number of enterprises is SME. The sector stands as a sector with producing in 61 provinces at the country scale, interacting with 19 different sectors, receiving input or giving input and having a high sector connection and having a market share of 10 billion dollars (Öztürk and Koç, 2017).

"One of the factors that the furniture industry should consider in its forward-looking strategies is the growth of digital consumer mass. The result of the study is shown that 65% of consumers in Turkey is digitalized and the digital consumers use every channel. It has been determined that digital consumers prefer products and services that make life easier for them, with competitive pricing and campaigns as a priority, and it has been determined that 60% use of them both digital and traditional channels." (Web-4; cited by Öztürk and Koç, 2017).

"Today's furniture is now seen as a high-tech design object. Large-scale enterprises in the sector have acquainted with the concepts of "Smart Factory" and Industry 4.0, and have started production processes with a new generation of project-based lines consisting of full automation and robotic processing. Branded furniture companies representing 75% of the sector are turning their production facilities to the AR-GE base. The use of full-automatic production lines with CNC-controlled and ERP systems has become a necessity, not the luxury, for brands anymore." (Web-5; cited by Öztürk and Koç, 2017). On the contrary, It is stood as a question mark that SMEs understand this new concept or don't understand, and they know what is waiting for SMEs in the future or don't know. "It is stated that in the first 6 months of 2018, the economic situation in the country and the increase in the prices of raw materials are not reflected in the final product sales prices. It seems that enterprises are trying to reduce the number of workers in order to resist for surviving the adverse effects of this downsizing" (Web-6).

The aim of this study is to look at the current situation of our country -especially in terms of SMEs- while putting great digital changes in the world until the year 2025. While the changes and transformations started at Industry 4.0 in terms of large-scale enterprises, it is aimed to create a conceptual, business-based and country-based awareness for SMEs, especially small-scale enterprises. At this point, the furniture sector, which we consider to be one of the locomotive sectors of our country's economy, has been chosen as the subject of the study.

2 MATERIAL AND METHOD

The main aim of the study is to measure awareness and to compose awareness about Industry 4.0 in SME furniture enterprises. The main mass of the survey is limited to Ordu and Giresun provinces located in the Black Sea Region. The absence of large and medium-sized furniture enterprises in these provinces is an important influence in the election. Social Security Institution (SSI), Turkey Employment Agency (TEA) and Small and Medium Enterprises Development Organization's (SMEDO) records have been taken into consideration in determining business numbers. It is determined that there are 43 enterprises in Ordu and 22 enterprises in Giresun. It was tried to reach all the furniture enterprises active operating and producing in Ordu and Giresun.

The survey method was used to collect data in the study. In the research, firstly literature survey about awareness concept, awareness scales and Industry 4.0 was done. As a result of the literature search, a previously prepared scale related to the topic was not found. For this reason, a form with 80 questions was organized with the help of information obtained from a literature review. This form consists of four parts: demographic information, conceptual awareness, business-based awareness and country-based awareness. The prepared questionnaire was applied to a sample enterprise and clarity of the questions on the questionnaire was tested. Factor analysis was conducted to measure the consistency of these four sections on the questionnaire. With the information gathered, necessary regulations were made in the questionnaire form and the questionnaire form was put into practice. This prepared form was sent to the enterprises determined via the internet environment. 45 enterprises responded the questionnaire forms. 30 of these enterprises are located in Ordu and 15 of them are located in Giresun.

The survey was implemented in June, July, and August of 2018. 5 Likert Scale (Strongly Agree, Agree, Undecided, Disagree, Strongly Disagree) were used to evaluate the awareness of the businesses.

3 FINDINGS

3.1 Demographic Information

A total of 45 businesses responded to the survey. 66.7% of these enterprises are in Ordu (30 enterprises) and 33.3% are in Giresun (15 enterprises). 62.2% of the enterprises are named as Private Company, 33.3% as Limited Company and 4,4% as Joint Stock Company. 48.9% of the enterprises were established after 2000.

55.6% of the respondents were business owners, 22.2% were professional managers, 11.1% were engineers/architects/technicians, and 11.1% were the employee. When the respondents' gender distribution is examined, it is seen that 84.4% is male and 15.6% is female. When we look at age distribution, approximately 80% of respondents are 33 years of age or older. 45% of the respondents are university graduates and 42% are vocational or high school graduates. Only 13% were graduated from primary and secondary schools.

31.1% of the enterprises are in the organized industrial zone, 31.1% are in the urban neighbourhood and 37.8% are in the small industrial zone. 64.4% of enterprises responding to the survey are micro-scale enterprises and 33.3% are small-scale enterprises. Only 1 of the enterprises is medium-sized enterprises. Engineers at 9 enterprises, architects at 12 enterprises, technicians at 28 enterprises, and industrial designers at 11 enterprises are employed. It is stated that 77.8% of the enterprises have a medium level technology, 20% have a high-level technology and 2.2% have the low-level technology. Approximately 75% of the participating enterprises say that they do not use CNC or NC looms in production. Up to now, 65% of the enterprises have not benefited from any support such as incentive, credit or KOSGEB support.

3.2 Industry 4.0 Awareness in Furniture Enterprises

3.2.1 Conceptual Awareness

Table 2. Conceptual Awereness in the enterprises.

Questions	Percentage (%)
I know the 1st Industrial Revolution.	44
I know the 2nd Industrial Revolution.	44
I know the 3rd Industrial Revolution.	53
I know the 4th Industrial Revolution.	58
I know mechanization in production.	78
I know what serial production is.	87
I know about electronicization and computerization in production.	80
I know the concept of internet of objects.	47
I know intelligent production technologies.	64
I know 3D printers.	78
I know smart factories.	80
I know artificial intelligence.	71
I know the concept of wearable internet.	31
I know the concept of Industry 4.0.	36
When production is mentioned, the mind first comes to work with factories and physical power.	73
I understand the production of information from the concept of production and the work done with brain power.	51
When I say Industry 4.0, I understand that machine power manages the production processes instead of human power.	38
3D printers are used only for 3-D books and similar prints.	33
Machines can connect and communicate with each other in the virtual environment and manage the process.	60
Industry 4.0 is a process that creates intelligent factories that can be developed and transformed by production technology, cyber physical systems, Internet of objects and cloud computing.	36

The ratios of strongly agree and agree responses among the 20 questions prepared at 5 point Likert scale (Strongly Agree, Agree, Undecided, Disagree, Strongly Disagree) are as follows.

The average of the responses to the questions was calculated as 3.436 standard deviation score of 0.985 and standard error score of 0.033.

It was not determined the significant difference between the distribution of the respondents' enterprises and the level of awareness. It has been found that the awareness levels of the enterprises are around 50%. According to the enterprises' places of production, there is a significant relationship between the level of awareness and the places of production. It has been determined that as the technical infrastructure of the production sites improved, awareness levels increased. While the awareness level of the enterprises which producing between neighbourhoods in the inner-city is around 38%, the awareness of those which producing in the organized industrial zones is 74%.

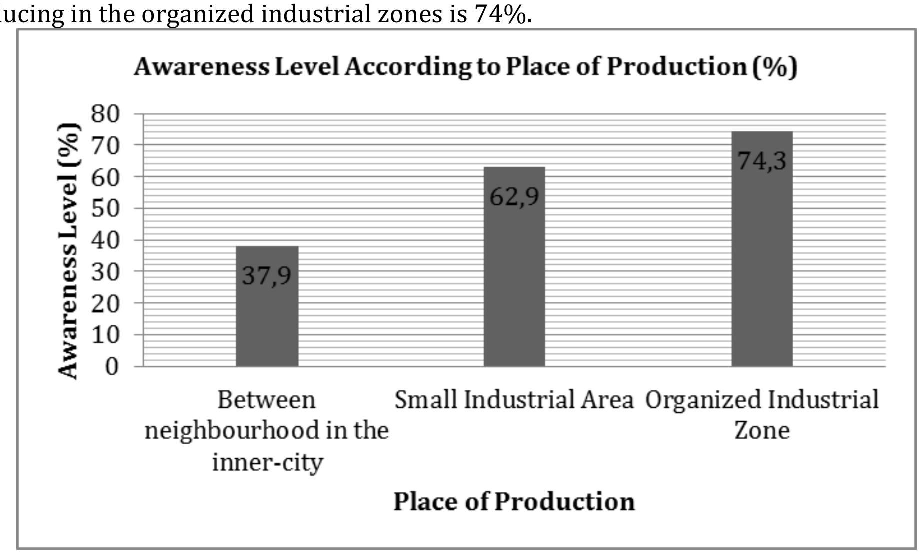

Figure 1: Awareness levels according to the place of production.

There was a meaningful relationship between the respondents in the enterprises and the level of awareness. It has been determined that the level of awareness of employer or employee is well below the level of awareness of professional managers or engineers/ architects/technicians in the enterprises. The level of awareness of employee is 37%, that of employers is 49%, that of engineers/ architects/technicians is 72%, and also that of professional managers is 80%.

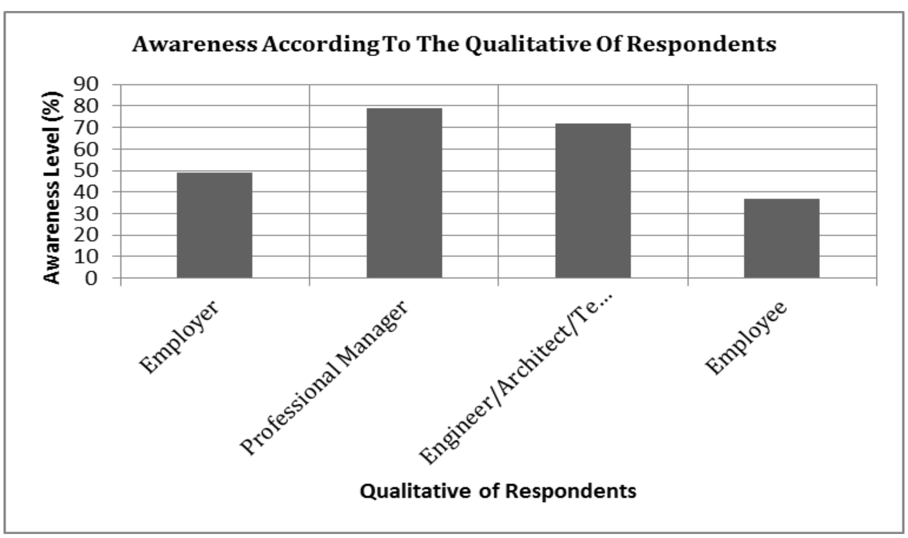

Figure 2: Awareness levels according to the qualitative of respondents.

When the level of awareness of the respondents to the questionnaire was examined according to the age criterion, it was seen that there was a significant difference between the age of 26-32 and the other age groups. The level of awareness among people aged 26-32 was determined to be 84%.

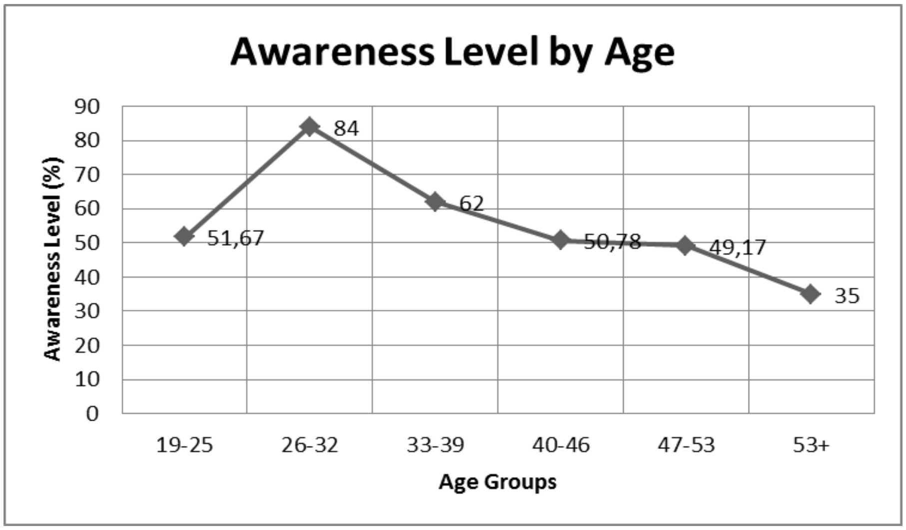

Figure 3: Survey respondents' awareness levels by age.

There is also a significant relationship between the levels of education and awareness of respondents in the enterprises. As education levels of people increased, awareness levels increased too. It is seen that the level of awareness of primary graduates is 35%, that of secondary graduates is 27.5%, that of high school graduates is 37%, that of vocational high school graduates is 45%, that of university graduates is 77.6%, and that of graduate graduates is 95%.

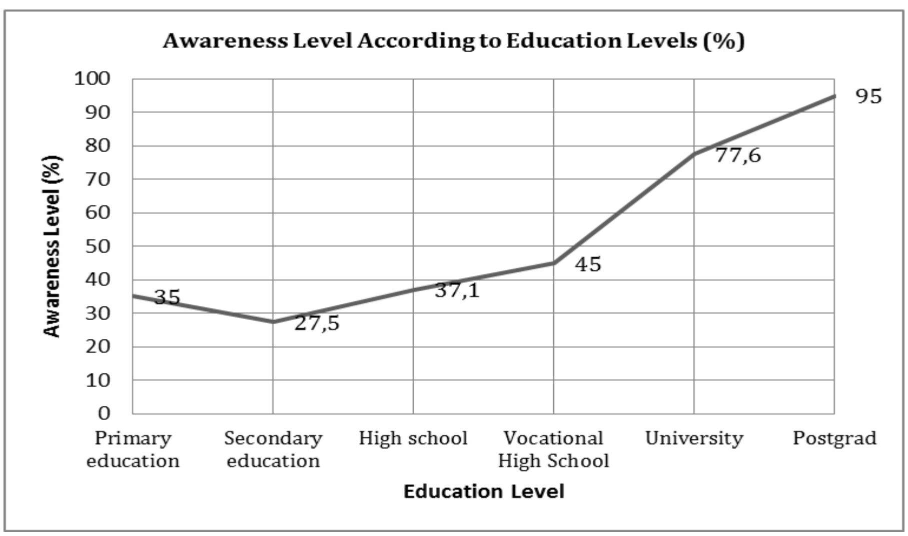

Figure 4: Awareness levels of survey respondents according to their education level.

3.2.2 Awareness on The Basis of Enterprise

The answers given in 20 questions, which are prepared for awareness on the basis of enterprise, are shown in the table below. It has been calculated that the mean score of the responses to the questions is 3.11, the standard deviation is 1.086 and the standard error is 0.036.

Table 3. Awareness on the basis of enterprise in the enterprises.

Questions	Percentage (%)
I use computer effectively in my enterprise.	49
I make use of the internet in production.	60
I follow technological developments closely.	78
I use computerized tools and machines in production.	40
I use CNC machines effectively on my production line.	31
Workers in the production line usually work using physical force.	80
The effective use of computers and the internet in my enterprise provides me with administrative convenience.	47
The usage of computerized tools and machines in production reduces the effectiveness of my employees.	18
Usage of many computers or more internet leads to security weaknesses in my enterprise.	18
It is unnecessary to use 3D printer in my enterprise.	11
As the number of computerized tools and machines in production increases, the need for employees decreases.	42
Technological developments make it difficult to train and find qualified workers.	58
Industry 4.0 is a threat to the future of my enterprise.	13
It is not affected my enterprise that big enterprises have adopted Industry 4.0.	16
I have to combine and grow with my opponents for Industry 4.0.	13
Smartphone usage at my enterprise is sufficient for the transition to Industry 4.0.	13
Industry 4.0 is a great advantage for the growth of my enterprise and competition with my opponents.	36
The roadmaps that governments will set for Industry 4.0 do not adversely affect my enterprise.	31
The transition to Industry 4.0 will increase production capacity in my enterprise.	44
I do not have any difficulty in finding a qualified employee to work in my enterprise.	22

There was no relationship between the distribution according to provinces of enterprises responding to the survey and the level of awareness of the enterprises. Although awareness levels of enterprises in Ordu are higher than those of Giresun, the awareness level of the enterprises is very low. The level of awareness of enterprises in Ordu was 40% while the level of awareness of enterprises in Giresun was 25%.

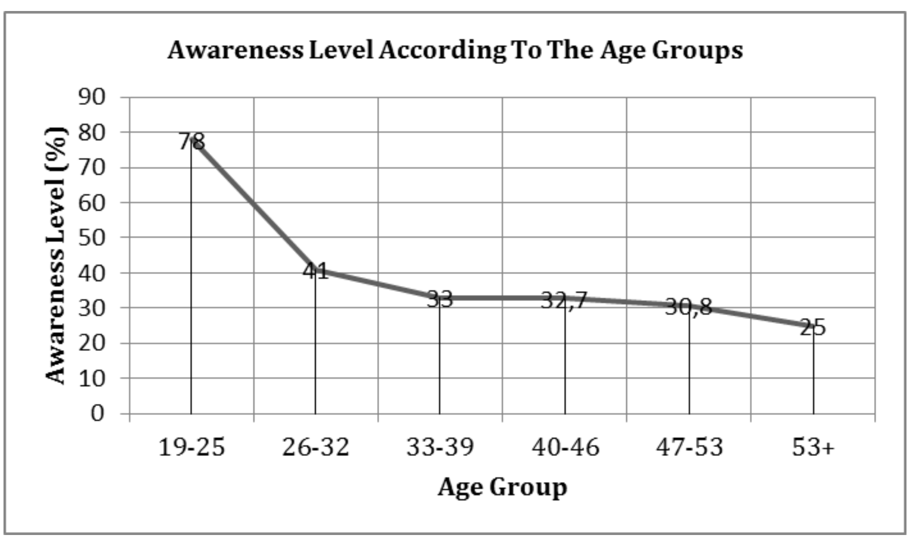

Figure 5: Survey respondents' awareness levels by age.

There was also no significant relationship between the foundation year of the enterprises and awareness levels. However, it has been seen that the enterprises established between 1991 and 2000 have a higher awareness than the enterprises established in the other years.

It is founded that there was a meaningful relationship between respondents and awareness levels in the enterprises. It has been determined that awareness levels of the enterprises' employers or employees are lower than awareness levels of professional managers or engineers / architects / technicians in the enterprises. The level of awareness is 18% in employees, 28% in employers, 55% in professional managers, 58% in engineering / architect / technicians.

When the level of awareness of respondents to the questionnaire was examined according to the age criterion, it was seen that there was a significant difference between the age group of 19-25 and the other age groups. As the person's age grows older, the awareness level has been reduced. Awareness levels of people aged between 19 and 25 were determined as 78%.

There is no significant relationship between the respondents' levels of education in enterprises and awareness level. As the education levels of people increase, the awareness level increases. But this increase remains at a pretty low level. Even the people having the postgraduate degree's whose conceptual awareness level about Industry 4.0 is 95%, their enterprise-based awareness level remained at about 45%.

It is not seen that there is no significant relationship between awareness levels and production sites when enterprises were analysed according to their production places. It has been found that as the technical infrastructure of the production sites improves, awareness levels increase slightly. While that awareness producing in organized industrial zones are 55%, the awareness of those who produce in neighbourhoods in the inner-city or small industrial sites is around 30%.

3.2.3 Awareness On The Basis Of Country

The answers given for 20 questions, which are prepared for country-based awareness, are shown in the table below. It is calculated that the mean score of the responses to the questions was 3.17, the standard deviation was 0.76, and the standard error was 0.025.

Table 4. Awareness on the basis of country in the enterprises.

Questions	Percentage (%)
With the 1st Industrial Revolution, people working in agricultural areas have been fronted to the factories.	44
With the 4th Industrial Revolution, there will be lived comeback from agricultural areas to factories.	40
With Industry 4.0, there will be entrepreneurship in the country and sectoral growth in SMEs.	40
Integrating new systems with Industry 4.0 increases data security issues.	18
Industry 4.0 is reduced human efficiency in protecting the integrity of the production process.	16
The inclusion of robots and robotic systems in the production process will lead to the mobility of the workforce.	42
Due to technical problems that may be experienced in new technological systems, there may be big losses.	29
For Industry 4.0, our country has sufficient R&D infrastructure and accumulation of knowledge.	22
For Industry 4.0, the qualification of the University and Public Research Institute are insufficient.	16
Current legislation is appropriate and sufficient for the transition to Industry 4.0.	24
The R&D experience and infrastructure of the enterprises across the country are sufficient.	24
It is sufficient for enterprises across the country to integrate Intelligent Automation Systems and related technologies into production lines.	33
The digital maturity level in our country's industry is between Industry 2.0 and Industry 3.0.	38
The transition to Industry 4.0 leads to an increase in unemployment across the country.	20
In our country, new work fields have been developed for the manpower that will be made redundant with Industry 4.0.	11
Information and communication technologies are used intensively in our country to reduce production costs.	33

Our country is prepared for the cyber-security problems that may arise after the Industrial 4.0 transformation.	11
Public financing resources and incentives directed at SMEs for Industry 4.0 technology investments are adequate.	9
There are training and qualification programs in schools and universities in our country to educate people with sufficient qualifications for Industry 4.0.	22
SMEs should be supported separately as they can deal with financial, technological and personnel problems less than large enterprises.	71

It is not founded that there was no relationship between the distribution of businesses responding to the survey and the level of awareness of the enterprise. The awareness levels of the enterprises in Giresun are pretty low level. While the awareness level of enterprises in Ordu was 33%, the awareness level of enterprises in Giresun was determined as 19%.

It isn't founded that there are no links between the establishment years of the enterprises and the levels of awareness. The level of awareness of enterprises established between 1991 and 2000 is higher than that of other enterprises. Still, this level is around 38%. It has been found that as well as there is no significant relationship between the type of enterprises and awareness levels, and that the proprietorships' awareness is a pretty low level. This level is approximately 18%.

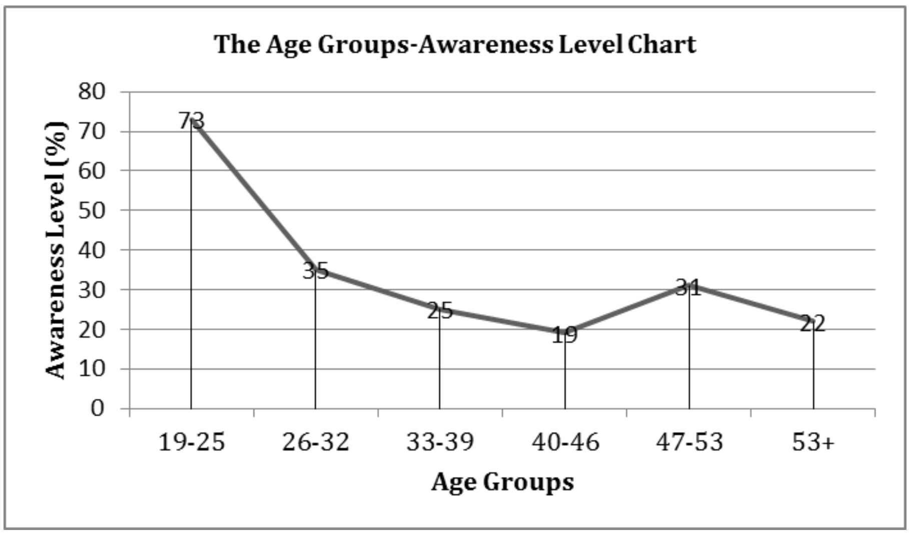

Figure 6: Awareness levels of respondents in the survey by age.

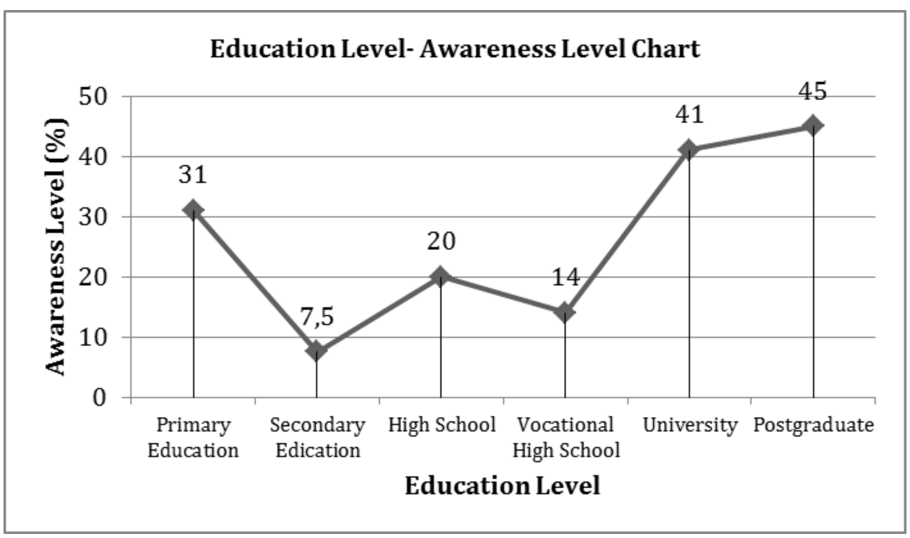

Figure 7: Level of awareness of respondents according to the education level in the enterprises.

There is a relationship between the respondents' qualifications in the enterprises and the level of awareness. If the respondents are employers or employees, the level of awareness is low, whereas if they are professional managers or engineers/architects/technicians, awareness levels are relatively higher. However, awareness levels are even low. While the awareness of employers is 20%, the awareness level of engineers / architects / technicians is 48%.

There is an inverse relationship between the age of the respondents and their level of awareness. Awareness levels are diminishing as people age. For example, those aged between 19 and 25 have a level of awareness of 73%, while those aged between 40 and 46 have a level of awareness of 19%. There was no significant relationship between the education level of the respondents and the level of awareness. On the other hand, awareness levels were also lowered as the education levels of the persons decreased. For example, the awareness of graduate alumni is 45% while the level of awareness of secondary graduates is 7.5%.

4 CONCLUSIONS

A total of 45 enterprises participated in the survey. 30 of these are in Ordu and 15 are in Giresun. 25 of the respondents were business owners, 10 were professional managers, 5 were engineers / architects / technicians, and 5 were employees. When the data obtained as a result of the questionnaire survey is analysed, it is seen that the answers given to the questions related to the enterprise, which are included in the 3 sections of the questionnaire, raise the awareness levels. It is also been that the answers given to the questions related to the concept of Industry 4.0 and the general situation questions, decrease the awareness levels. In the question of the conceptual and general situation, it was determined that the respondents generally gave moderate answers "Undecided". It has been determined that the levels of awareness of employers or employees who responded to the survey are lower than those of the professional manager or engineer / architect / technician and that there is an inverse correlation between the level of education and awareness of the persons.

The conclusion of the research shows that the SME-type furniture enterprises hear the Industry 4.0 concept and the new technological concepts emerging with this concept, but do not know what these concepts mean. Moreover, when the responses to the demographic questions are examined, it is seen that the enterprises still use old technologies in production and can not go to technology renewal due to financial insufficiencies. At the same time, this situation also has been reflected in our country's reality. That is to say that technological maturity in our country is between Industry 2.0 and Industry 3.0.

5 DISCUSSION

In summary, it can be said that they have adopted the concept of Industry 4.0, depending on the size of the enterprises themselves. It is known that large businesses are either using new technologies in production lines or adapting quickly to new technologies. However, for SMEs, -especially small enterprises- the same mobility is out of the question. It is quite difficult to capture Industry 4.0 for those businesses that have not even reached the digital maturity.

The SMEs' resistance to the transition to the Industry 4.0 concept is entirely based on material insufficiencies and unawareness. For this reason, it is first necessary to raise the awareness for employees, especially employers, about the issue. For Industry 4.0 and concomitant the new concepts, At the point of educating qualified personnel and qualified people, training and proficiency programs should be organized by the Ministry of National Education's school and by the universities.

New technological investments should be made in order to increase the level of technological maturity in our country, especially SMEs should be encouraged with public finance resources. It is necessary to catch the great technological transformations expected to take place by 2025 and not to miss the train. For this reason, SMEs, that are more difficult than bigger enterprises to cope with economic and technological and personnel qualifications, should also be supported. Since SMEs are suppliers of large-scale enterprises, the gap between large businesses and SMEs should not be increased while moving towards Industry 4.0.

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ABSTRACT

This research includes housing suggestion and furniture arrangement for a family of 4 (four) living with grandparents (grandmother and grandfather). There is a separate bed, living room and bathroom for grandparents in the project which has been developed considering the importance of the privacy necessity of grandparents in common life and providing more comfortable living conditions. Therefore, a child will not have to stay in other child's room, children's room will not be separated and sofas that are available every day in the living room will not be opened and closed for the grandparents. Grandparents will be able to spend time with other members of the family in daily life easily and will be able to use the spaces reserved for them in the evening or when they need to be alone. In addition, there is a living room, kitchen, two children's rooms, parents' bedroom, bathroom and a water closet in the housing. It is possible to go to the spaces belonging to grandparents with a door opening from the kitchen. Space measures have been kept at the minimum limits taking the costs in the housing design into consideration.

KEYWORDS: Furniture, interior space, housing

1 INTRODUCTION

Nuclear family is defined as the family that includes only spouses or spouses and children or single parents and at least one child. The extended family is defined as a family consisting of at least one nuclear family and other individuals (Web-1). Family or housing where individuals stay is defined as a living or settling form which has sheltering-protection function developed by families or individuals that are living together and sharing the same parts of the space and doing all the living activities such as sleeping, resting, eating etc. together (Arcan and Evci, 1999). The cultural elements that need to be taken into account in the housing design process are examined in two groups as physical factors and socio-psychological factors. While climate and settlement are among the physical factors; traditions, manners and customs, norms, religious beliefs, ethnicity, family structure, social relations, lifestyle, social structure, behavioural rules, privacy behaviours, personal space, dominance limit and behaviours, economic structure, language, education, law and technology are among the socio-psychological factors (Demirarslan, 2005). The developmental stages of the family are as follows (Atasoy, 1973):

The establishment stage of the family: It is the first and second years of the marriage. The family is small and mobile.

The expanding family stage: After the birth of the first child, the family becomes the expanding family. In the expanding family stage, all or most of the children are under the age of 18. In this stage, the needs of the family are constantly changing and increasing. It can be assumed that it is less mobile than the first stage.

The shrinking family stage: When children start to leave their parents' house, the family enters into this stage and it continues until the old age stage.

The old age stage: In this stage, the children have left their parents' house and the family is small as in the establishment stage of the family.

Duvall (1957) divides the stages that the family goes through in parallel with the lifecycle of the family associating them with the age of the children. These are:

(1) New families (married couples without children)
(2) Childbearing families (child<30 months)
(3) Families with pre-school children (2.5 years old> child <6 years old)
(4) Families with school-age children (6 years old> child <13 years old)
(5) Families with adolescent children (13 years old>child <20 years old)
(6) Launching families (the child leaves the house)
(7) Middle-age families (empty nest and retirement)
(8) Aging families (death of one or both spouses)

After the last stage, the following questions come to mind:
How often will children who have left home and married visit their parents' home?
Who will take care of the new-born babies of the children who got married?
How often will parents visit their children?

When trying to give the following answers to the questions which were stated above:

According to the 2016 results of the family structure research conducted by Turkstat (Turkish Statistical Institute) it was seen that 92.3% of individuals in general think that children should take care of their parents when they get old. The height of the rate is attention-grabbing.

According to the results of the Address-based Population Registration System between 2014-2017 of Turkstat, the rate of household types in total households is given in Table 1 (Web-1).

Table 1: Rate of household types in total households (Web-1)

Household Types	**Rate in Total Households (%)**			
	2014	**2015**	**2016**	**2017**
Single-person households	13,9	14,4	14,9	15,4
Household consisting of one nuclear family	67,4	66,9	66,4	66,1
Nuclear family consisting of only spouses	14,1	14,3	14,2	14,2
Nuclear family consisting of spouses and children	45,7	44,8	44	43,5
Nuclear family consisting of single-parent and children	7,6	7,8	8,2	8,5
Nuclear family consisting of father and children	1,5	1,6	1,7	1,8
Nuclear family consisting of mother and children	6,1	6,2	6,5	6,7
Households consisting of at least one nuclear family and the other individuals	***16,7***	***16,5***	***16,3***	***16***
Households consisting of more than one individual without a nuclear family	2,1	2,2	2,4	2,5

Accordingly to the table, the ratio of extended family which is defined as a family consisting of at least one nuclear family and other individuals is 16% of the total population by 2017 (Web-1).

Again according to the data of Turkstat, information related to who delivers out the day care of the children aged between 0-5 years is given has been given Table 2 (Web-3).

Table 2: Who delivers the day care of children who are aged between 0-5 years in the house (Web-3)

Who delivers the day care	%
Mother	86
Grandmother	7,4
Day nursery or kindergarten	2,8
Care taker	1,5
Other close relative or neighbour	1,3
Children receiving more than one day care	1
Total	100

According to this table; it is seen that mothers are the ones who deliver the day care of 86% of the houses. The day care service is delivered by grandmothers with 7.4% after the mother. The rate of caring in day nursery or kindergarten is 2.8% while the rate of day care delivered by care takers is 1.5% (Web-3).

According to a typology encountered in the literature which was conducted related to the family composition and place of the family members in the life cycle, housings are classified as homes for young single individuals, young couples without children, couples with young children, couples with middle aged children, couples without middle aged children, old couples; single family house with outbuilding behind multi-family residences, house for two families, a twin house, a group house, a row house, a contiguous multi-family residence, a medium residence and a large residence (Dülgeroğlu Yüksel, 1995).

When all of the above data are placed one under the other:
Children want to look after their parents in their old age,
Children are looked after by their grandmothers at a certain rate,
16% of the families already live as a large family.
The following problem of the study and its purpose are revealed.

Problem: Housing is not adequate for a nuclear family of 4 (four) living with grandparents.
Purpose: The importance of privacy needs of grandparents in common life and the necessity of providing more comfortable living conditions.

2 METHOD

In this study, housing suggestion and furniture arrangement were given for a family of 4 (four) living with grandparents. Literature review was carried out and similar studies (Kızıl, 1978, Alga, 2005, Demirarslan, 2005, Dülgeroğlu Yüksel, 1995) were used in the study. Meeting the needs of the people who live in the house in the most comfortable way was one of the most significant issues that was taken into consideration while designing the project. Grandparents in the housing were not neglected or abstained; on the contrary, their space was privatized because of the need for their privacy and comfort. In the housing, grandparents live with other family members and become a part of the life; however, they spend their time in their private rooms when they need privacy. In order not to increase the construction costs, the residential areas have been tried to be kept at minimum level.

3 FINDINGS

The floor plan of the proposed house for a nuclear family of 4 (four) living with grandparents has been given in Figure 1.

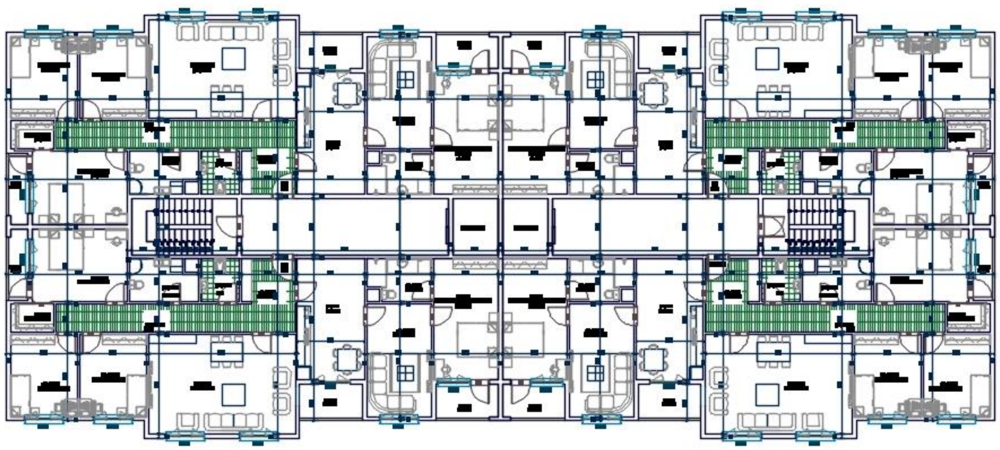

Figure 1: The floor plan of the proposed house for a nuclear family of 4 (four) living with grandparents

The apartment plan proposed for a nuclear family of 4 (four) living with grandparents has been given in Figure 2.

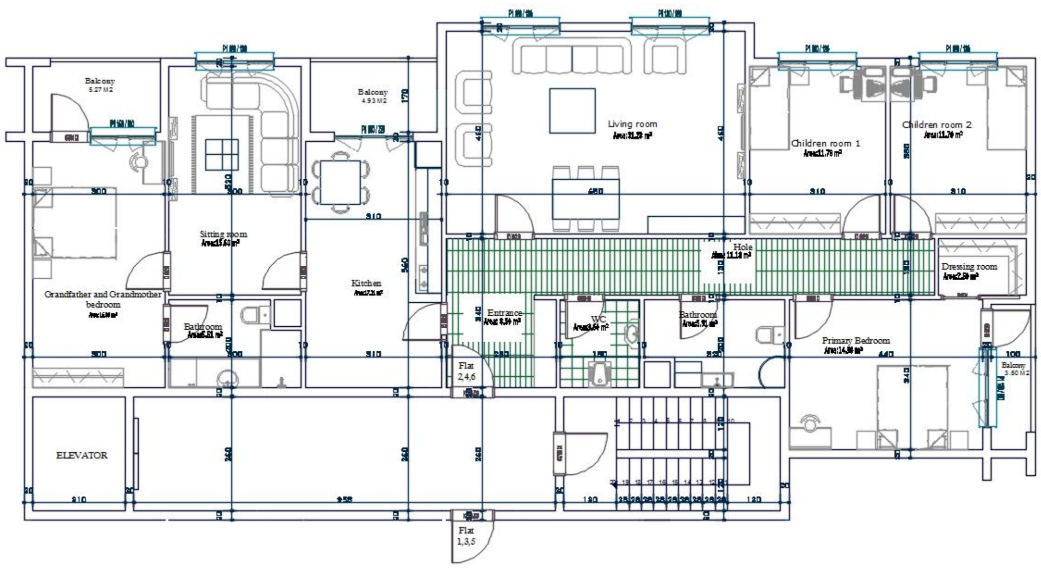

Figure 2: The apartment plan proposed for a nuclear family of 4 (four) living with grandparents

According to these plans, there is a kitchen on the left side of the house entrance door and a living room opposite. The right side of the entrance is considered for mother, father and their children while the left side of the entrance is considered for grandmother and grandfather in the plan where the kitchen and living room are assumed as the shared spaces. The living room designed for the grandparents can be entered through a door opening from the kitchen and then the bedroom can be entered. There is a balcony and bathroom for the use of grandmother and grandfather in the plan. There are 2 children's rooms on the right side of the living room and there the parent's bedroom opposite the children's rooms. In addition, there is also a bathroom and a water closet for the use of all family members in the plan. The purpose of the living room designed for grandparents is providing a private space to them for using in situations where it is necessary to be alone or in situations where a few intimate guests need to be accommodated.

The cabinets designed for the entranceway of the house are given in Figure 3.

Figure 3: Cabinets designed for the entranceway of the house

There are two different types of hall stand recommendations in the entranceway. The first type has a sliding door while the second type is with open shelves.

Cabinets designed for kitchen of the houses are given in Figure 4.

Figure 4: Cabinets designed for kitchen of the houses

There is a kitchen table, sink, refrigerator, dishwasher, cooker, lower and upper cupboards in the kitchen.

Cabinets designed for the bathroom of the nuclear family section of the house are given in Figure 5.

Figure 5: Cabinets designed for the bathroom of the nuclear family section of the house

There is a toilet seat, washbasin, shower cabin, washing machine and cabinets in the bathroom.

Living room arrangement of the housing is given in Figure 6.

Figure 6: Living room arrangement of the housing

There is a seating group, the TV unit, dining table and a console in the living room.

The arrangement of the parents' bedroom of the housing is given in Figure 7.

Figure 7: The arrangement of the parents' bedroom of the housing

The parents' bed and night stands can be seen in the visual but there is also a dressing table and a dressing room in the project.

Two different arrangements for the teen room of the housing are given in Figure 8.

Figure 8: Two different arrangements for the teen room of the housing

Figure 8: Two different arrangements for the teen room of the housing.

The arrangement belonging to the grandparents’ bedroom is given in Figure 9.

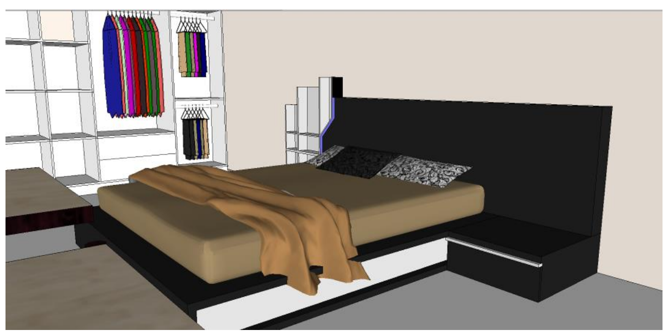

Figure 9: The arrangement belonging to the grandparents’ bedroom

There is a bed and a wardrobe in the arrangement.

The arrangement belonging to the grandparents’ sitting room is given in Figure 10.

Figure 10: The arrangement belonging to the grandparents’ sitting room

There is a seating group and a TV in the arrangement.

4 CONCLUSIONS

In this study which includes housing suggestion and furniture arrangement for a nuclear family of 4 (four) living with grandparents, the relationship between the married child and the family is strengthened. The project will serve not to loosen the family ties hence the community will remain standing through both daily, weekly visits and monthly visits when staying together or taking care of the grandchildren. In addition, individuals can look after their aging parents with the project. There are many housing types in the market; 5+1, 6+1, duplex, triplex etc. Of course, large families may prefer these houses. The unique aspect of this project is that it aims to keep family relations to a maximum level while residential areas are kept at the minimum level.

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Radial Stick Sawing Optimization

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RADIAL STICK SAWING OPTIMIZATION

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ABSTRACT

Stability in wood is related to moisture content and annual ring direction. Many manufacturers choose radial material for less shrinkage and swelling ratios and uniform shape change avoiding deformations especially for layered and joined materials. Sawmill operators usually prefer quarter sawing diagram to obtain radial boards from logs for this purpose. However, quarter and another diagrams give solutions for only boards that have larger dimensions than sticks, which are commonly used layered materials.

In this study, radial stick sawing optimization from logs was aimed. For this purpose, commercially preferred logs with 200mm, 300mm, 400mm and 500mm diameter, and cylindrical shape, were drawn in CAD program. Commonly used sawing diagrams (live, quarter, around) were tried empirically basing on cross sections. However, studies showed that when tangential boards were sawn to obtain radial sticks, all sticks could not be radial due to annual ring direction, especially at the end of boards. Therefore, some diagrams were modified to obtain maximum radial stick yield.

Results showed that the radial stick yield can reach 57,8% and the yield increment reached max. 28,9% (12,97% in average) when the all diagrams for all logs were considered. Especially around sawing method gave maximum radial stick yield. It is originated from the diagram, which normally gives radial sticks from tangential boards. Furthermore, modified sawing diagrams gave better yields from commercially preferred diagrams. However, sawing process is becoming extended and complicated with them.

Otherwise, it is suggested that log sawing optimization programs should calculate lower dimensions than boards with considering secondary sawing process and annual rings can be drawn in program or scanned for evaluating board is radial or tangential.

KEYWORDS: Log Sawing, Sawing Optimization, Around Sawing, Radial Stick

1 INTRODUCTION

Solid wood material changes dimensions according to moisture exchange with atmospheric environment within certain limits. Dimensional changes and shape deformation are serious problem especially in laminated and bonded wood products. They may not be considered in structural wood products e.g. Glulam. Otherwise they are more considered at multi-layered parquets, wooden door and window laminated profiles which are more sensitive changes at milimetric level. For example, stability of sticks is important at multi-layered parquets due to cupped sticks generates ondulation problem on finished flooring (Fig. 1). Ondulation isn't defined as a deformation in standards (TS 5204 EN 13756 (2004), TS EN 13647 (2015), TS EN 14342 (2008), TS EN 13489 (2017) etc.). Especially, convex and concave cup deformations are defined, however they were evaluated for all parquet width or length. Although it isn't considered in standards, end-users don't want to see it due to aesthetic problems.

Figure 1: Above: Ondulation at finished multi-layered (laminated) parquet surfaces
Below: Tangential stick array in parquet

Dimensional change ratio is mainly related to wood specie, anatomic characteristics, defects and annual ring angle. For example, many angles at cross-section preserve cross section shape after drying. However cupping can occur at tangential lumbers having less annual ring angle than 45°, while diamonding can occur at square lumbers having annual ring angle is 45°. Most of factors affecting dimensional stability can be eliminated while choosing right raw material (log or lumber) or choosing right production proces.

Optimization studies for log sawing are focused primarily quantity yield or quality yield with evaluating defects as fissure, knots. However quarter sawing and around sawing were developed with evaluating sawing methods due to annual ring angle and solid wood material anisotropy. Then radial or tangential lumber began to take part in quality yield. On the other hand, in conventional log sawing methods, operators aim manufacturing lumbers with larger dimensions (e.g. 25mm x 50mm). However many factories which are integrated with value-added wood products having narrower cross-section sizes as sticks. Because the aim change can production process. For example, it is known that narrowing cross-sectional dimensions decreases quantity yield (Kantay, 2005).

In this study, radial stick sawing optimization from logs was aimed. Otherwise quantity and quality (tangential or radial) yield change were evaluated with different sawing pattern.

2 MATERIAL AND METHODS

Commercially preferred Fir logs with 200mm, 300mm, 400mm and 500mm diameter were drawn in drawing software (Autocad). Only cross sections of logs and sticks were considered determining effect of pattern while sawing sticks. Conventional live and around sawing diagrams were used. These diagrams normally give best solutions for produce boards, which have larger dimensions than sticks. In addition to all these, radial sawn were modified to determine alternative tangential lumber sawing method at the 400mm diameter log drawings (Fig. 2).

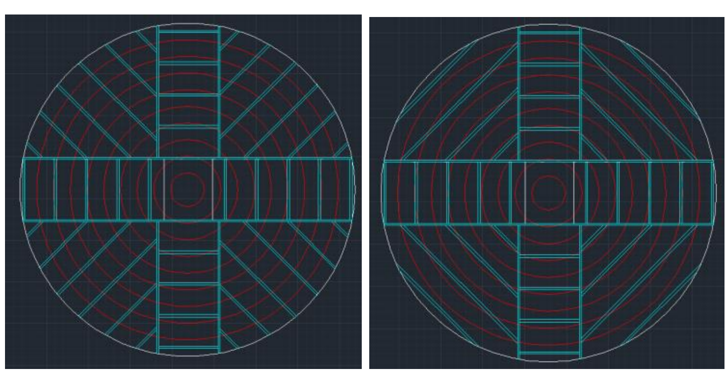

Figure 2: Left: Standard Radial Sawing Diagram, Right: Modified Diagram
(Red: Annual Rings, Blue: Saw kerf line)

The diagrams were determined empirically with aiming maximum stick number. 2,5mm saw kerf for board sawing and 3,15mm saw kerf dimensions for stick sawing were considered. Centre board with 77,5mm x 90mm dimensions was excluded to avoid stability and strength problems due to annual ring shapes and pith for each logs. Sticks having dimensions with 35mm x 9mm and without wane were aimed.

Surface exit angles (α) of annual rings (20 mm width for each log) were considered to determine sticks were radial (α>45°) or tangential (α <45°). The angles were measured with drawing temporary lines in software as shown in Fig. 3.

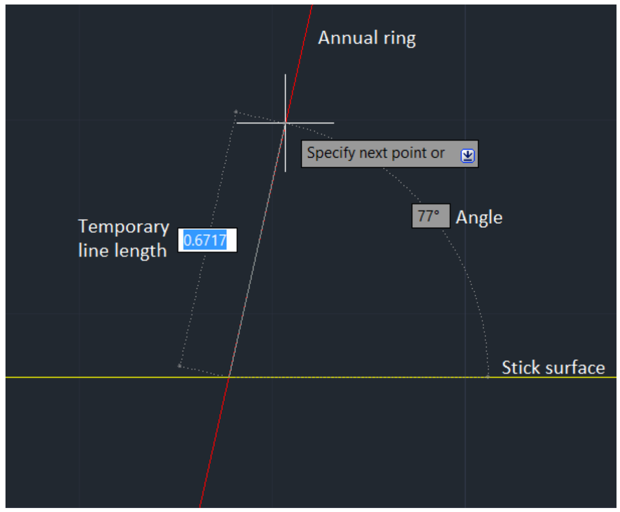

Figure 3: Surface exit angle measurement

Total sticks area was divided to log cross-section area for quantity yield , while total radial stick area were divided log cross-section area for quality yield (as shown in Eqs.1, Eqs.2, Eqs.3, Eqs.4 and Eqs.5).

$$\text{Total Stick Area (mm}^2\text{)} = \text{Number of sticks x Stick cross section area} \quad (5)$$

$$\text{Radial Stick Area (mm}^2\text{)} = \text{Number of radial sticks x Stick cross section area} \quad (6)$$

$$\text{Cross Section Area (mm}^2\text{)} = \pi \times [\text{Log radius}]^2 \quad (7)$$

$$\text{Quantity Yield (\%)} = [(\text{Total stick area} / \text{Cross section area of log})] \times 100 \quad (8)$$

$$\text{Quality Yield (\%)} = [(\text{Radial stick area} / \text{Cross section area of log})] \times 100 \quad (9)$$

Furthermore, radial sticks ratio in all sticks was determined (Eqs.6) due to laminated parquet companies reported that tangential sticks can't be utilized except burning to heat drying kilns.

$$\text{Radial Stick Ratio (\%)} = [(\text{Radial stick area} / \text{Total stick area})] \times 100 \quad (10)$$

Moreover, economic gain were calculated with yield to compare sawing diagrams. For this, 2nd grade Fir log price (561 TL at 25th November 2017) was considered (Web-1) and sawmill capacity was based on 1250m^3/month log sawing capacity.

3 RESULTS

The drawing tests were performed for each diameter of logs and they were shown at Fig. 4, Fig. 5, Fig. 6, and Fig. 7. After the figures, all results were shown in Table 1.

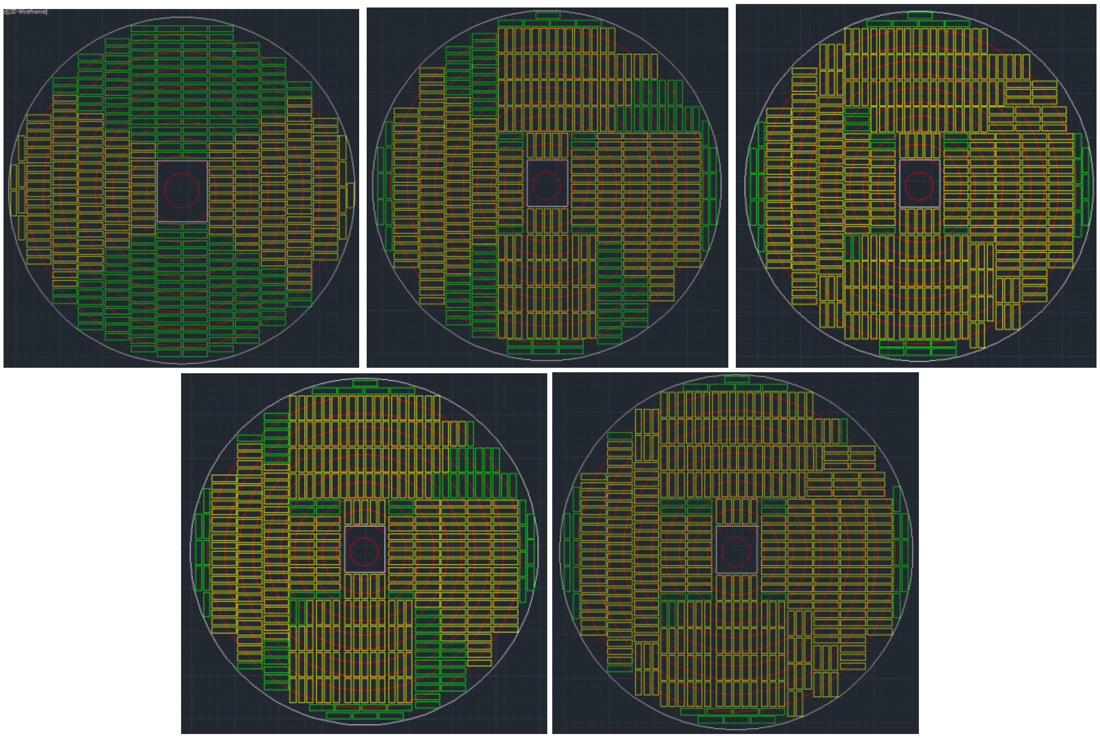

Figure 4: Sawing Diagram Possibilities for 500mm Diameter Log
(Live, Tangential-1, and Modified tangential-1, Tangential-2, and Modified tangential-2 sawing methods, respectively.)

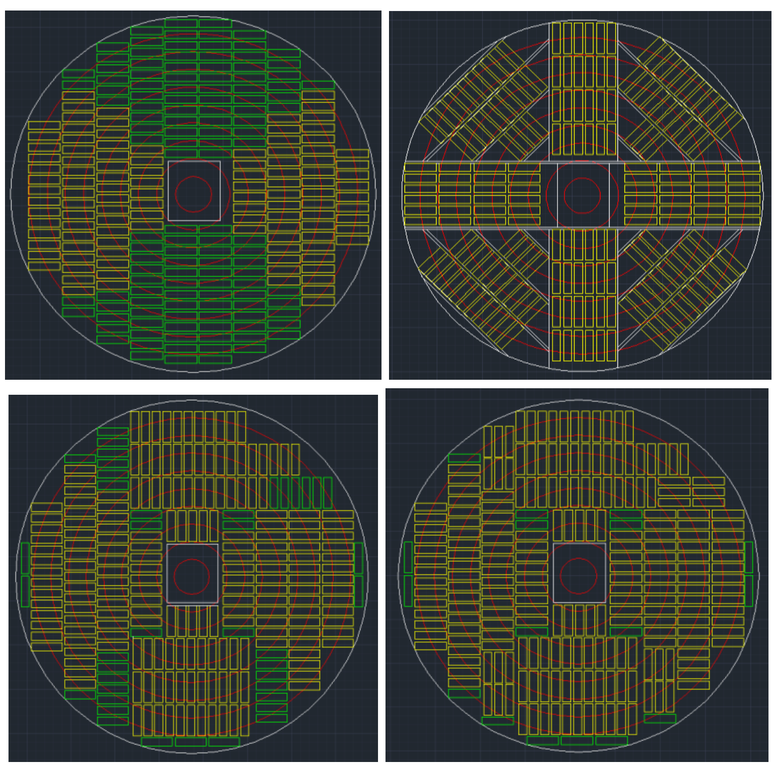

Figure 5: Sawing Diagram Possibilities for 400mm Diameter Log
(Live, Modified radial, Tangential and Modified tangential sawing methods, respectively.)

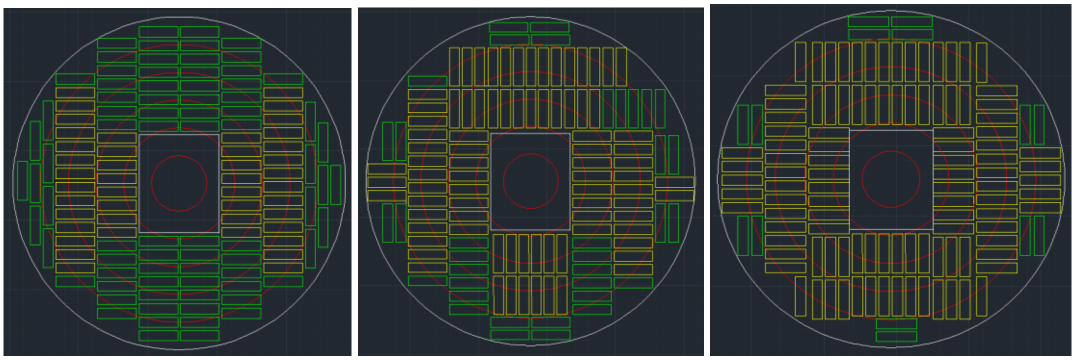

Figure 6: Sawing Diagram Possibilities for 300mm Diameter Log
(Live, Around sawing, Modified around sawing methods, respectively)

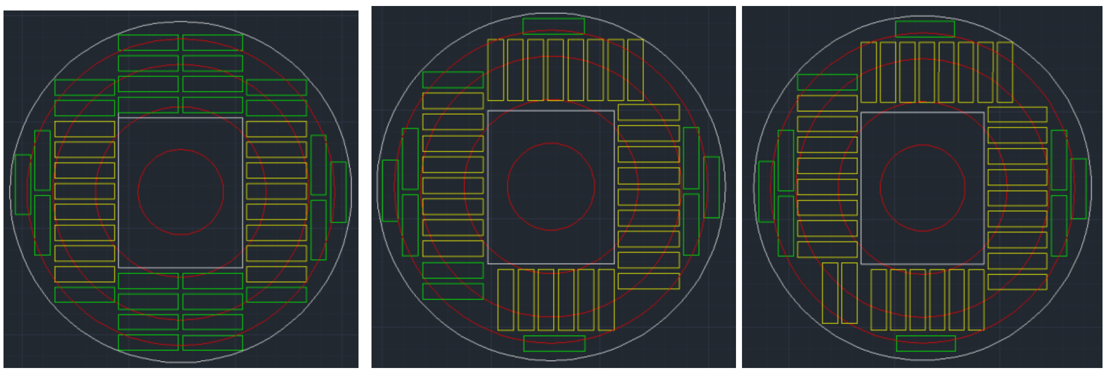

Figure 7: Sawing Diagram Possibilities for 200mm Diameter Log
(Live, Around, Modified around sawing methods, respectively)

Table 1: All results for each log diameter and each diagram

Log Diameter	Sawing Diagram	Total Radial Stick	Total Tangential Stick	Total Stick	Radial Stick Ratio (%)	Quantity Yield (%)	Qualtity (Radial Stick) Yield (%)
500 mm	Live	180	200	380	47,4	61,0	28,9
	Around 1-1	283	101	384	73,7	61,6	45,4
	Around 1-2	344	37	381	90,3*	61,2	55,2
	Around 2-1	328	87	415**	79,0	66,6**	52,7
	Around 2-2	360**	53	413	87,2	66,3	57,8**
400 mm	Live	116	128**	244*	47,5	61,2*	29,1
	Modified Quarter	196	0	196	100**	49,2	49,2
	Around 1	194	41	235	82,6	58,9	48,7
	Around 2	218*	17	235	92,8	58,9	54,7*
300 mm	Live	44	80*	124*	35,5	55,3*	19,6
	Modified Live	106*	14	120	88,3*	53,5	47,3*
	Around	84	36	120	70,0	53,5	37,5
200 mm	Live	18	26*	44*	40,9	44,1*	18,1
	Around	31	11	42	73,8	42,1	31,1
	Modified Around	33*	9	42	78,6*	42,1	33,1*

Starred (*) values are the highest value of each diameter. Double starred (**) values are the highest value of each column for all diameters.

According to results, profit per month of sawmill with between choosing the best sawing pattern instead of the worst sawing pattern for radial stick production were calculated (Table 2).

Table 2: Radial stick yields and change with different sawing pattern for each log diameter

Log Diamaeter	Min. Radial Stick Yield (%)	Max. Radial Stick Yield (%)	Difference (%)	Profit* (TL)
500 mm	28,90	57,80	28,90	202661
400 mm	29,10	54,70	25,60	179520
300 mm	19,60	47,30	27,70	194246
200 mm	18,10	33,10	15,00	105188

*The profit were calculated with using monthly production values

4 CONCLUSION

Wood is an engineering material. Anisotropy, dimensional change, variety of tree species or wooden product etc. affecting factors should be considered and each production process of wood should be considered with detail. As seen in this study, changing sawing pattern with changing quality understanding can cause yield increase up to 28,9% with up to 202661 TL profit per month. When the ecological factors come into the forefront, the production can be performed with less log usage. In terms of economy, laminated parquet industry has many companies and even if 1TL difference for end-product price is important for getting ahead of rivalry.

In this study, the radial stick yield and profit change were compared to min. radial stick yield that can be determined with live sawing. The change can decrease when compared another sawing methods. Moreover the waste utilization of the sawmills weren't considered. Many sawmills can use wastes for heat source for drying kilns and waste usage is calculated for reducing the heat costs.

Otherwise the production process is getting complicated with increasing radial stick yield. Because log-turning time increases in sawing patterns having better yield. It causes more production time and it needs more operator attention.

Conventional sawing diagrams give solutions to produce boards which have larger dimensions than sticks. Because these diagrams generally were prepared for headrig in primary breakdown process. However, diagrams can include end-products as radial sticks which can be produced in secondary breakdown process. Otherwise, it can be thought that diagram gives max. tangential boards can be used, cause of radial sticks can be produced with sawing tangential boards. But, this study showed that all tangential boards can't be fully sawn radial sticks due to annual ring shape. Furthermore, it is found that when the log diameter increased, radial stick yield increased. Because annual ring angle changes is getting more at the centre area of logs having smaller diameter.

In addition, sawing optimization programs developed in recent years started to consider annual ring to determine radial – tangential lumber. Today, determining annual ring shape of each log is difficult and it is calculated empirically. However, developed non-destructive evaluating devices as computed tomography can help to transmit the information of each log to the programs and healthier results can be obtained.

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Comparison of Mechanical and Thermal Properties of Waste and Neat Polypropylene

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Comparison of Mechanical and Thermal Properties of Waste and Neat Polypropylene

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ABSTRACT

Polypropylene (PP) have used in many areas for different purposes. In addition to neat polypropylene (NPP), waste polypropylene (WPP) has also found its place of use for different purposes. Climate change and international agreements have forced many countries to reorganize waste management, especially plastic waste. Due to its petroleum-derived nature, the use of polypropylene and the recycling process are becoming more important. In this study, waste and neat of polypropylene which is high potential in the production of wood plastic composites was examined. The bending resistance and tensile strength properties of NPP were found the higher than WPP 54.2% and 20.8%, respectively. On the other hand, impact resistance of WPP is 46.5% higher than NPP. As a result of XRD (X Ray Diffraction) tests, NPP has been found to have a higher degree of crystallinity. According to TGA (Thermo-Gravimetric Analysis) curves T10% values of neat and WPP are the same (433.5 °C). Amounts of weigh loss of neat and WPP are 99% and 86%, respectively. The DTA (Differential Thermal Analysis) results showed that the Tm and Td values of neat and WPP were 166.6-462.9 and 159.1-459.4, respectively.

KEYWORDS: Mechanical properties, Thermal characterization, Waste polypropylene, Neat polypropylene

1 INTRODUCTION

Plastic plays an important role in different areas of our daily life. Wood has increased the popularity of plastics, which are light and low in production costs compared to conventional materials such as concrete and metal. Plastics are now key material in construction, medicine, engineering, automotive, aerospace, entertainment, electronics, packaging, food and many others. In addition, due to economic growth and population growth, there is an increase in plastics and chemicals used in their production. The plastics industry, which has grown rapidly over the last 20 years, reached 299 million tons in 2013. This figure rose to 311 tons in 2014 with a 4% increase [WI, 2015].

Many plastic wastes are perceived as one of the major environmental problems because they cannot be biodegraded. Worldwide, plastics production reached 311 million tons / year (ul Hassan et al., 2017). Waste plastics mainly consist of polyethylene (PE), polypropylene (PP) and polystyrene (PS). In particular, the polystyrene used with different types of polymers has a share of more than 70% in the waste plastics sector (Ciliz et al., 2004). Polypropylene (PP) is one of the most widely used plastics and has versatile use in the polymer industry. Polypropylene was developed in the early 1950s using Ziegler-type catalysts and has received considerable attention since its physical properties, versatility and ease of production (Schwarz 1995; Valenza and La Mantia 1988). The PP, which is a polymer thermoplastic, can be heated to a melting point within a few minutes, molded into a wide variety of shapes and sizes. The material is also resistant to oxidation or environmental degradation and has the ability to be applied to a variety of abrasive surfaces. The biggest disadvantage of polypropylene is its adverse effect on the environment, and this is done by burning (Valenza and La Mantia, 1987). The chemical reactions that occur during combustion and the effect of emitted gases carry this situation to a different dimension.

Most PP products are produced without the filler material, and therefore PP is a suitable material for recycling. Recycled PP products also degrade faster and contribute to the degradation of plastics. It has been tried by researchers to convert waste PP into composites or laminates, to disassemble it into monomers, and to turn into granulates (Bhat et al., 1999, Williams and Williams 1998, Gong et al., 2014).

As the recycling methods of plastics; Glycolysis, hydrolysis, pyrolysis, aminolysis and hydrogenation methods are used. However, the pyrolysis method called advanced thermo-chemical treatment (TCT) is the most preferred method due to its environmental and operational advantages. This process, especially at high temperatures (500 ° C - 650 ° C), is the process of converting waste PP into liquid (Mastral et al., 2002). The products obtained by the pyrolysis method are easily marketable and can be turned into electricity and heat source by burning in gas fuel boilers (Demirbaş, 2001). Since pyrolysis uses an oxygen-free inert atmosphere, products do not form dioxin by reacting with oxygen. It also contributes to lowering carbon footprint rates of products and processes by reducing emissions of carbon monoxide and carbon dioxide (Chen et al., 2014; Stanmore, 2004). Recycling of plastics due to economic and environmental reasons has gained importance because of differences in production methods and usage areas. Ingredients as additives are added for initial use cause differences in the structure of the plastics. Recycling of recycled plastics will contribute to the production process by knowing the properties of the material. The aim of this study is to determine the physical, mechanical and thermal properties of waste polypropylene and compare it with neat polypropylene.

2 MATERIAL AND METHODS

Waste polypropylenes used in this work obtained from BGS Ltd. Beypazari, Turkey in granular form. BUPLEN® homopolymer 6131 from Lukoil was used as neat polypropylene. The general appearance of granular neat (a) and waste (b) polypropylene is given in Fig. 1.

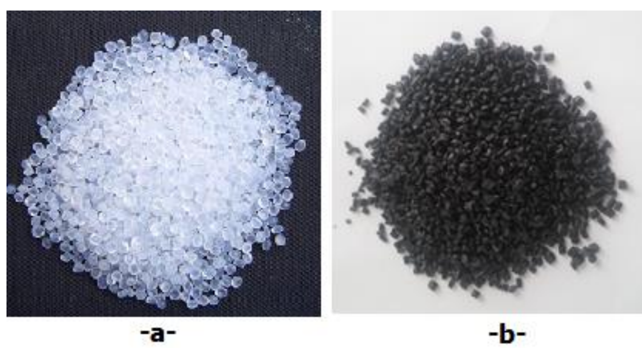

Figure 1. An overview of pure (a) and waste (b) polypropylene

Injection molding machine (BOY22A) located in Bartın University, Central Laboratory was used to form the test samples. Experimental samples to be used for physical, mechanical and thermal tests after injection molding are shown in Fig 2.

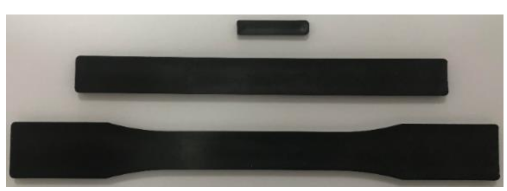

Figure 2. The samples used in the study

Bending and tensile tests were carried out at Kahramanmaraş Sütçü İmam University, Faculty of Forestry according to ASTM D790 and ASTM D 638 respectively. Independent T-test was used to compare the physical and mechanical properties of pure and waste polypropylene. The thermal stability of all the composites was investigated using a TGA/DTA and DSC (Perkin Elmer, TA Instruments, USA). In TGA/DTA, the samples were heated from 25 °C to 600 °C with a heating rate of 10 °C/min and a nitrogen flow of 100 mL/min. The samples weighing about 10 mg were used for the tests. Degradation temperatures at 10% weight loss (T%10) and 50 % weight loss (T%50), maximum degradation temperature in the derivative thermogravimetric peaks (DTGmax), and mass loss of the samples in the TGA cures were measured and compared with the results obtained.

3 RESULTS AND DISCUSSION

The tests conducted within the scope of the study are grouped under three main headings. These are physical and mechanical properties (density, izod impact, bending, tension, MOE in the bending and tension), thermal properties (TG, DTA) and finally XRD analysis.

3.1. Physical and mechanical properties

The bending and tensile strength values of neat and waste polypropylene are shown in Fig 3. When the values of bending and pulling resistance are examined, the superiority of neat polypropylene is multiplied. Neat polypropylene showed 54% higher tensile strength and 20% higher bending strength compared to waste polypropylene. This is because the APP contains different components. There is a significantly difference between NPP and WPP duration (Sig.=0.000 < 0.05) according to independent T-test.

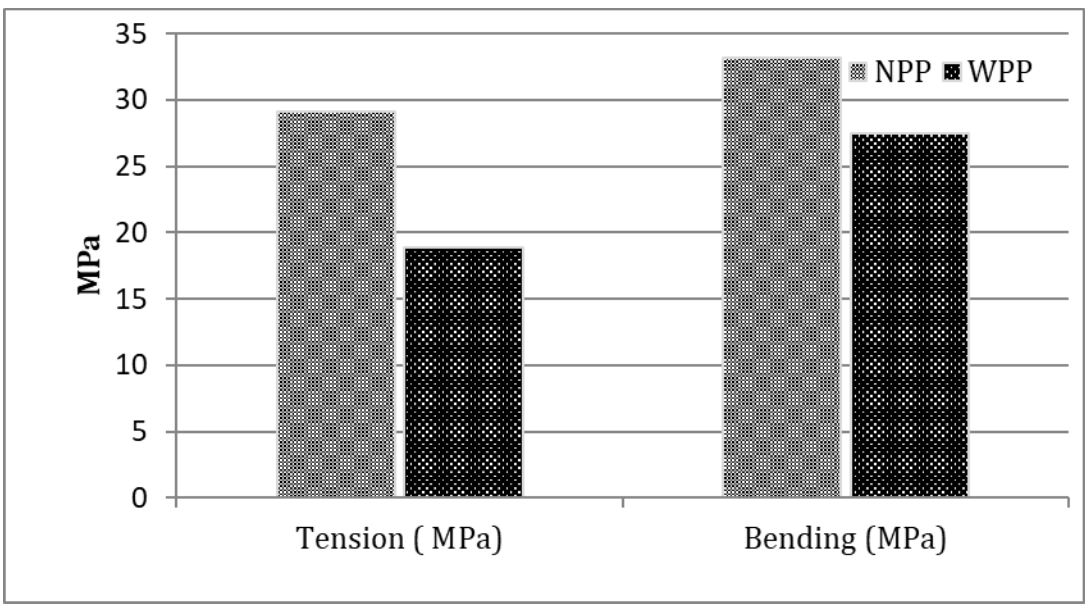

Figure 3. Bending and tension values of NPP and WPP

Mechanically declining tests can also be seen at the degree of crystallinity determined by XRD. Neat PP with high crystallinity grade showed higher performance. Relevant results are given under the heading of XRD analysis results. The difference between the modulus of elasticity of waste and neat PP is lower than the flexural and tensile strength values. The modulus of elasticity in tension and bending of the neat PP was 10% and 9.4% higher than that of Waste PP respectively. In Figure 4, modulus of elasticity in tension and bending of neat PP and waste PP is given.

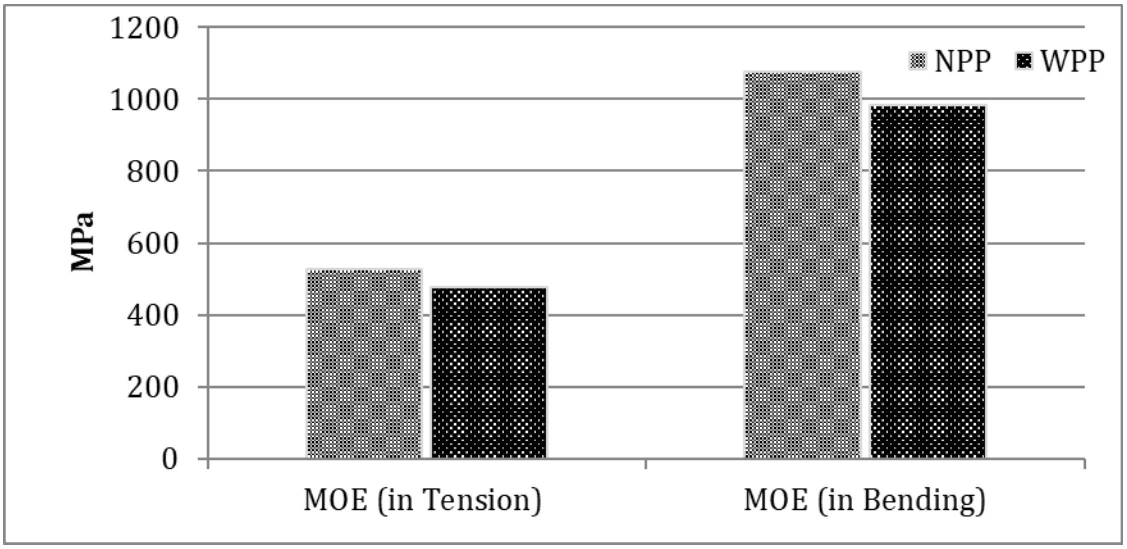

Figure 4. Modulus of elasticity of NPP and WPP in the bending and tension tests

When the samples are evaluated in terms of physical properties, the density value of WPP is higher than that of neat PP. In terms of mechanical resistance properties, impact resistance is the only resistance value of waste PP. Waste PP has 46.7% higher impact resistance than neat PP. Also density is 10% higher. It is likely that the effect of additives added for initial use in WPP increased the density. Figure 5 shows the values of izod impact resistance (A) and density (B) for neat and waste PP.

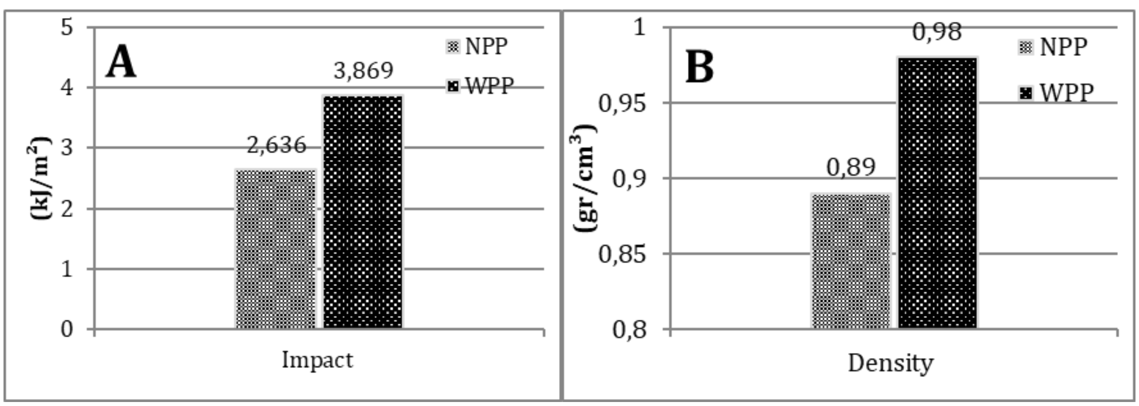

Figure 5. Izod impact resistance (A) and density values of neat and waste polypropylene

3.2. Thermal Properties

The thermal stability of waste and neat polypropylene was determined by Thermogravimetric analysis (TGA) method. The TG curves obtained from the analysis made are shown in Fig. 6 and Fig. 7 shows the maximum mass losses (DTGmax) in the unit time and the melting points (Tm) and the tangential points (Td) determined during the thermal deterioration period are also shown in Fig 8. referring to Fig. 6, it was determined that the TG curves of neat PP showed a change in both waste and neat PP. While the Tonset temperature of neat PP was around 411 °C, and the waste PP gave the Tonset temperature at 430 ° C. When the mass loss values were examined, it was found that neat PP showed mass loss values of 99.9% and waste PP lost 86% of its mass. Based on this, it can be said that waste PP contains various inorganic substances. For this reason, the mass loss values are also lower. In Figure 7, when DTGmax values are examined, neat PP gives maximum mass loss at 467 °C, while waste PP gives maximum mass losses at 457 °C.

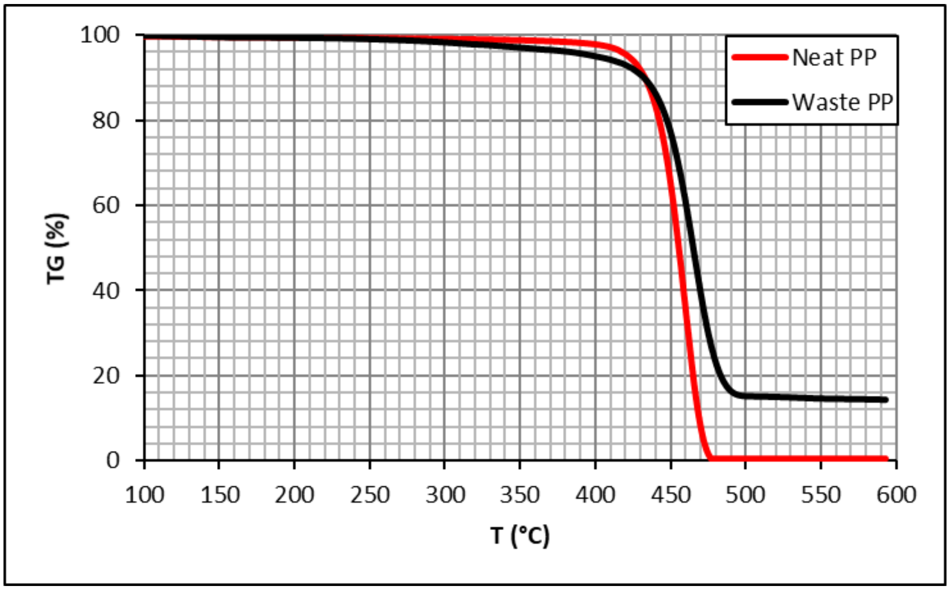

Figure 6. TG curves of NPP and WPP.

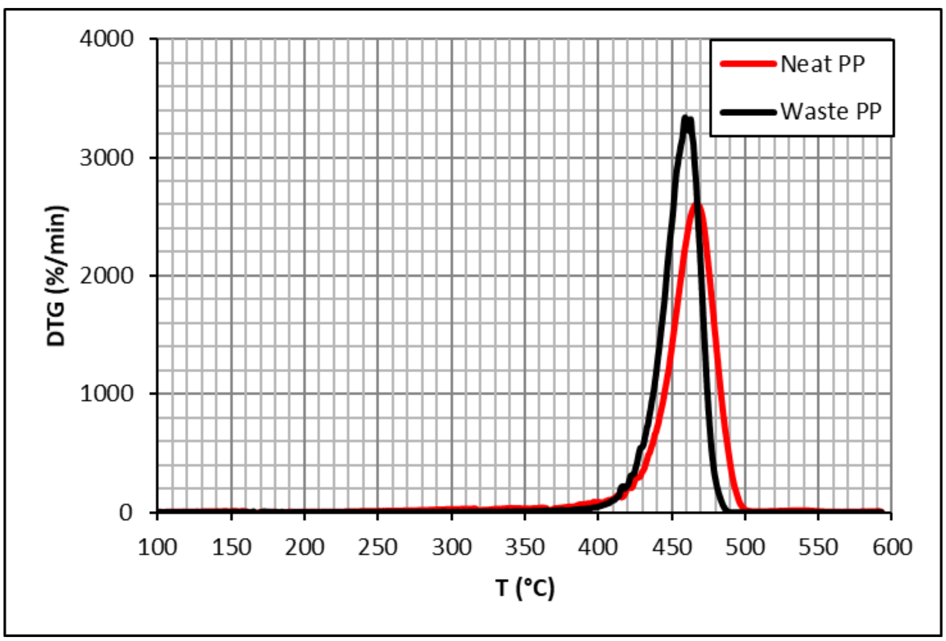

Figure 7. DTG curves of NPP and WPP.

Figure 8 also shows the Tm and Td values of waste PP and neat PP. When the figure is examined, both waste and neat PP clearly show 2 isotherm curves. One of these curves (the first one) is Tm, while the second isotherm curve is the Td (second) degredation temperature. When the Tm values were examined, it was determined that the neat and the reference PP gave melting peaks at 165.4 ° C and 172.6 °C and gave Td values at 458.8 °C and 462.8 °C respectively.

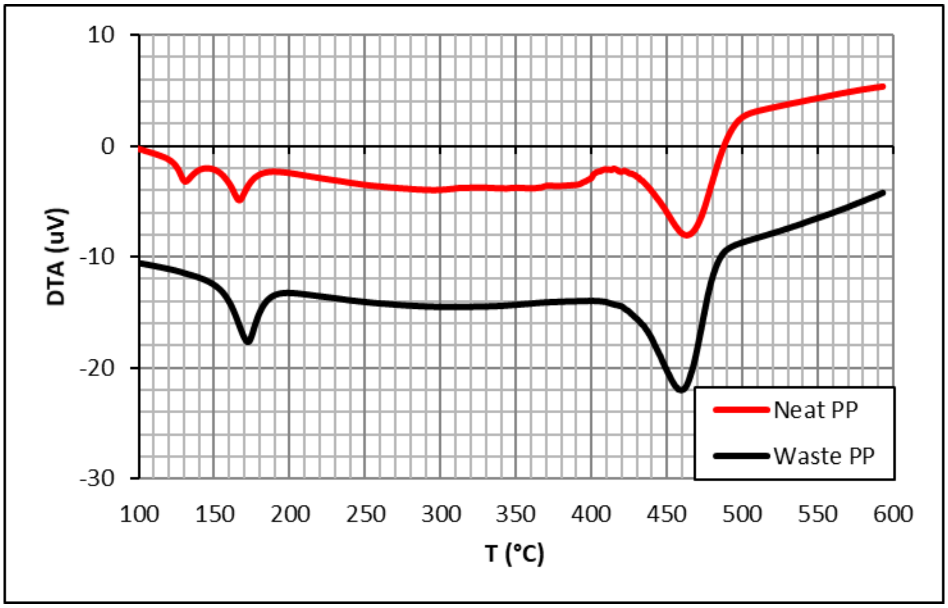

Figure 8. DTA curves of NPP and WPP.

The XRD curves of waste and neat PP are given in Fig 9. When the figure is examined, it is seen that there are different crystalline peaks which neat PP does not contain. It can also be said from here that waste PP contains various inorganic substances. It was found that neat PP contained crystal peaks at 10-25 °, while waste PP contained neat PP values, especially large peaks at 27-30 °. This is the reason of the peak changes in thermal properties occurred. When the crystallinity grades of neat and waste PP were examined by XRD, it was determined that crystal layer ratio was found as 44% in neat PP and 30% in waste PP.

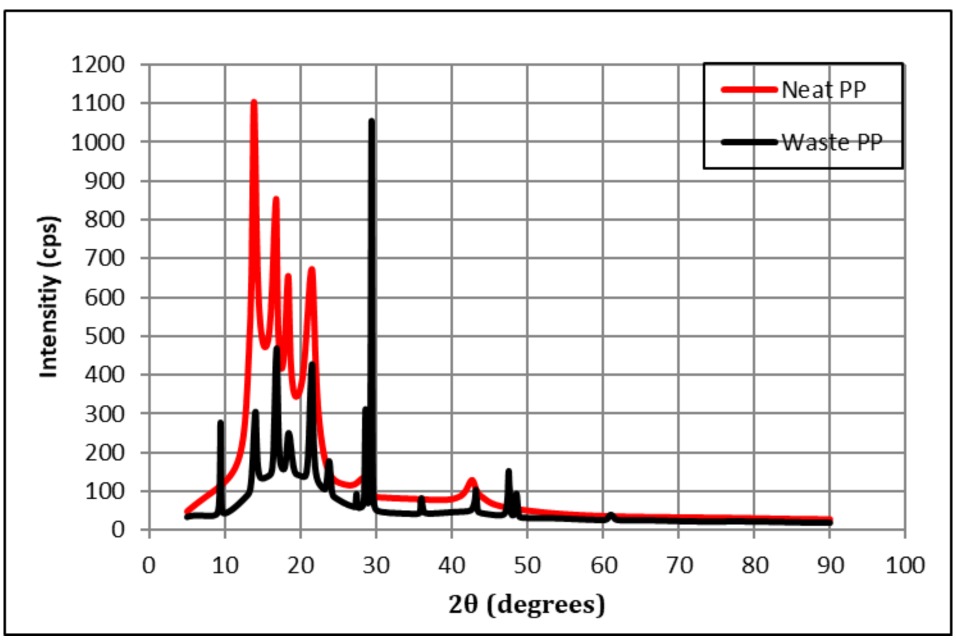

Figure 9. XRD curves of NPP and WPP.

4 CONCLUSION

In this study, the physical, mechanical and thermal properties of neat and waste polypropylene in granules were examined, and the densities of neat and waste polypropylene were determined to be 0.89 gr/ cm^3 and 0.98 gr/cm^3, respectively. This is thought to be due to the possibility of different substances or elements in WPP. The likelihood of a different substance was also observed in the TG analyzes performed within the scope of the study. The fact that the remaining mass amounts in the TG analysis do not disappear even at 600 °C explains this situation. Mechanical tests showed that the neat PP tested showed higher performance in other tests (MOR, MOE in bending and tension) except impact resistance. Waste PP showed 46% higher performance in impact resistance. It is believed that the different substances likely to be found in waste PPs increase the impact resistance as filler. It can be concluded that waste PP is reusable according to the results, especially where it is exposed to high impact resistance. It is believed that, the evaluation of polypropylene waste will contribute to waste plastics management and applications.

5 ACKNOWLEDGEMENTS

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THE INTERNATIONAL FOREST PRODUCTS CONGRESS

Construction of Framework for Determination of Wood Biomass in Turkey Forests

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ABSTRACT

The rapid increase in the population of the world and, in parallel with this, the pressures on the use of natural resources with industrialization are increasing. Therefore, the need for forest resources increases and the use of these resources in a planned manner gains importance over time. The only natural raw material that can be recycled from these sources is the wood raw material, the forest industry at the top of the demand. In parallel with the developments in other industries in the world in recent years, the forest products industry has also shown a rapid change and development, which has led to a considerable increase in the use of wood materials. Along with this increase, forest assets are also rapidly consumed. Because of this, the raw materials of the wood should be used consciously and have a lot of knowledge about the characteristics of the wood. At the same time, the physical properties of the wood must be known so that it can be evaluated appropriately for its purpose and purpose. Therefore, the anatomical structure, physical and mechanical properties and chemical composition of the wood raw materials enable the use of wood materials in various fields. Physical properties of wood; wood-water relations, weight-volume relations, and in this context the determination of wood biomass is of great importance. Many studies have been carried out to determine wood biomass in the world. As a result of these studies, direct methods applied by the development of the allometric equations belonging to each country in line with the guidelines of Land Use, Land Use Change and Forestry (LULUCF), Agriculture, Forestry and Other Land Use (AFOLU) and Global Forest Resources Assessments (FRA) are used. In this study, through the methods being used until today, has created conceptual framework for the calculation of wood biomass in Turkey's forests.

KEYWORDS: Wood Biomass, Guides, Volume Weight, Regression Analysis

1 INTRODUCTION

The wood material, which has been used up to the early ages, is entering into people's living spaces more intensively with the ever-improving processing technologies and the demand for wood materials is continuously increasing. Taking into account that the world population is increasing and the rate of increase is 12.4 % in our country, it should be adopted as an inevitable method to prevent unnecessary and irregular consumption without delay. The importance of wood in human life comes from meeting many requirements. This situation brings about the rapid depletion of forests.

Forest products and forest products are processed and new products are processed by various industrial enterprises of various wood raw materials of forest products which constitute the narrow sense forests such as maintenance and repair of forests, presentation of these products to buyers and utilization of other services and products of forests, including the whole of the forest and outside the forest (Eryılmaz, 1985). The forestry sector nurtures many industries and thus plays an active role in the creation of value added and employment growth (Anonim, 1995).

Although wood material has been produced in various forms for centuries, it is rarely designed considering its structural characteristics (Eckelman, 1966). Engineering design in wood materials is important in terms of designing products that will provide reliable service to the users. In addition to being able to be structurally designed and analyzed in accordance with the rules of a wood material, it is necessary to have extensive knowledge of the characteristic features of wood in order to consciously use the depleted wood raw materials. When the functions of the wood material and the loads to be carried are considered, knowing the properties of the materials to be used will also positively affect the value and economic life of the obtained products. Therefore, there are many studies about the anatomical structure, physical and mechanical properties and chemical composition of wood raw materials today.

Physical properties of wood; cell wall material and air void volume, specific gravity, volume-density values, and the dry weight of the wood is of great importance in determining these properties. Many studies have been carried out in the world to determine dry weight, or biomass, in other words. The Intergovernmental Panel on Climate Change (IPCC) first targeted the Land Use, Land Use Change and Forestry (LULUCF) guidelines in 2003 to determine the effects of human intervention changes over time on greenhouse gas emissions and reductions. Later on in 2006, the IPCC introduced the use of Agriculture, Forestry and Other Land Use (AFOLU) guidelines for the same purpose. When AKAKDO and AFOLU guidelines are examined, the basic approach is to transform the tree fortune and increment values determined as volume in the forest inventory into vegetative mass using various coefficients. At the same time, the Food and Agriculture Organization (FAO) regularly monitors the world's forests on the request of Member States and presents their management and use through the Global Forest Resources Assessment (FRA) guidance. The FRA guide assumes the most comprehensive assessment of forests and forestry to date and new coefficients have been calculated according to FRA-2010 guidelines by Asan, 2011. As in the guidelines of AKAKDO and AFOLU, the plant mass is determined with the help of the coefficients calculated by Asan, 2011. In this study, which was formed through the conceptual framework for the calculation of the methods being used until today, Turkey forest wood biomass.

2 MATERIAL AND METHOD

In the study, different methods of determining the amount of biomass of our country's forests, and especially the biomass of wood, which has the largest share in biomass, have been examined. Various methods are used for the calculation of biomass.

In the unit area method; it is beneficial to estimate the biomass for a forest area using certain large sample areas. The total weight (in wet and dry) of each component is measured by cutting all the trees in the sample areas and dividing them into components (root, stem, branch, leaf and bark). Then the value obtained is converted into hectares and the biomass amounts for stands are obtained separately according to the tree components. The biomass values for the components are summed and the total biomass for the area is estimated. Decisions on the number, size and distribution of sample areas during the application of this method are very important. The sample areas should be representative of the stand and represent the stand with the features they possess. Saraçoğlu (1990) stated that this method is suitable for use in young stands, in multi-layered tropical forests and in low vegetation forests.

In the mean tree method; by taking the sample areas, the biomass is determined by cutting the mean tree of these sample areas. The sample tree which is decided as the mean tree is cut and the biomass of this sample tree is determined. The value obtained is multiplied by the number of trees in the sample, and the biomass for the sample area is found. This value is converted to the hectare and the biomass of the stand is determined. As in the case of the Unit Area Method, this method can also determine the total biomass quantity for the tree components separately or for the entire sample tree. One of the major deficiencies of this method is that the amount of biomass is obtained as a total value and detailed information on the diameter classes can not be provided. Another immortality is that if it is desired to estimate the components (root, stem, branch, leaf and bark) of different diameter classes are separately estimated, these components will show various differences depending on the size of the sample trees and again a single general value will be obtained in this method.

The purpose of regression method; regulating the regression equations according to measurements taken from many sample trees and estimating the biomass with the aid of these equations. In the development of these equations, various parameters which can be easily measured such as diameter at breast height and total height are taken as independent variables. Biomass values, which are more difficult and complicated to measure, are estimated as dependent variables, as a function of the mentioned independent variables. These equations can be developed separately for the tree components as well as for the total tree. The regression method is the most preferred and applied method in the world because it can determine the quantities of biomass of single tree components and whole tree as well as giving more reliable results compared to other methods (Saraçoğlu, 1990).

On the other hand, the effects of forest ecosystems on global warming are being investigated with regard to the amount of carbon storage. Biomass studies constitute the basic data when carbon storage quantities of forests are determined. In this context, a lot of work has been done up to daylight and firstly, the Intergovernmental Panel on Climate Change (IPCC) issued guidelines on Land Use, Land Use Change and Forestry (LULUCF) in 2003. Later in 2006, the IPCC introduced the use of Agriculture, Forestry and Other Land Use (AFOLU) guidelines. The most common method of calculation of carbon is to calculate from the amount of carbon accumulated in the biomass. With the help of the coefficients in the guidelines, the amount of biomass is determined primarily (Table 1).

Table 1. Coefficients used in the calculation of biomass and carbon stocks in biomass in LULUCF and AFOLU

Coefficients used in LULUCF		**Coefficients used in AFOLU**	
Symbol	**Statement**	**Symbol**	**Statement**
WD	Wood Density (t / m^3)	$BCEF_1$	The factor for conversion and expansion of stem volume to above ground biomass (t / m^3)
BEF_1	The increase in stem biomass resulting from the annual net volume increase (including bark) is calculated as the above ground biomass expansion factor (dimensionless)	$BCEF_S$	Conversion and expansion factor to convert the merchantable stem value to above ground biomass (t / m^3)
BEF_2	Available mass of stem biomass above ground biomass expansion factor (dimensionless)	$BCEF_R$	The biomass conversion and expansion factor for conversion of removals in merchantable stem (including bark) volume to above ground biomass (t / m^3)
R	Root to shoot ratio (dimensionless)	R	Root to shoot ratio (dimensionless)
fBL	The part of the biomass decomposing in the forest (dimensionless)	CF	Carbon factor (0.51 for the peasants, 0.48 for the leaves)
CF	Carbon factor (0.50)		

In these studies, the distribution of the biomass on the forest areas according to tree species and the calculations are made on the basis of their dried amount in the oven by taking the national forest inventory as a basis. The amount of biomass above ground and below ground is very general calculated by the coefficients determined for coniferous and deciduous. In these studies, the coefficients obtained according to the degree of latitude in which the forests of our country are located are used and the total amount of carbon stored in the forests is calculated for the wide and different study areas of the country (Asan, 1995; 1999; 2011; Asan et al., 2002, Güner et al., 2010; Polat et al., 2011; Tolunay, 2011;).

The approach adopted by the IPCC, 2006 in accordance with the guidelines for Agriculture, Forestry and Other Land Use (AFOLU) requires dynamic models calibrated to national conditions, allowing direct calculation of biomass increase or detailed national forest inventory data supported by allometric equations.. Due to differences in inventory methods and forest conditions, this practice may vary from country to country. In the LULUCF guideline, the BEF_1 coefficient is calculated by proportioning the above ground biomass (ton) to the stem (including bark) biomass (ton), while the BEF_2 coefficient is calculated by proportioning the above ground biomass (ton) to the merchantable stem biomass; the $BCEF_1$ and BCEFs coefficients in the AFOLU guide are equal to the stem (including bark) value multiplied with the BEF_1 and BEF_2 coefficients. The $BCEF_R$ coefficient is found by dividing the $BCEF_S$ coefficient to 0.92 in the coniferous and 0.9 in the deciduous, as described in the AFOLU guide.

The final report of the Global Forest Resources Assessment (FRA 2010) that the most comprehensive assessment of the world forests of the United Nations Food and Agriculture Organization (FAO) is one of the key findings that reveals the decline in forest areas such as the world's forest biodiversity, high forests deforestation and forest destruction. FRA 2010 is the document of the current state of the world's forest resources and the main changes that have occurred in the last 25 years and is data quality. Similar to the approach in other guides, new coefficients are calculated by Asan, 2011, as the degraded areas are included in the account as a separate item. With the help of these coefficients, the amount of biomass and carbon stocks of country forests are determined.

3 RESULTS

Today, many studies have been carried out for different tree species to determine the amount of biomass by regression method and biomass equations have been developed for these species. In these studies, the amount of biomass in different components such as stem, branch, needle, leaf and bark were determined for each type of tree. The largest part of the total tree biomass is the stem wood. In some studies carried out in Turkey's forests, the stem biomass equations of important tree species are given in Table 2. This situation, the sample trees which taken to obtain the equations can be caused by not paying attention to the distribution of each diameter class. At the same time, the site class of the stands can be attributed to factors such as age.

Table 2. Stem biomass equations from some studies

The studies	**Stem biomass equations**
Pinus sylvestries (Atmaca, 2008)	$Y = 6.8334237 + 0.6652d^2$
Pinus sylvestries (Çömez, 2010)	$Y = 0.445 \times V^{1.011}$
Pinus sylvestries (Aydın, 2010)	$Y = -6.358 + 0.139d^2$
Pinus sylvestries (Ülker, 2010)	$Y = 31.071 - 4.202d + 0.57d^2$
Pinus sylvestries (Tolunay, 2012)	$Y = 0.0347 \times (d^2h)^{0.8974}$
Fagus orientalis (Bulut, 2012)	$Y = 0.212 \times d^{2.277}$
Fagus orientalis (Erkut, 2013)	$Y = 0.51592 \times d^{2.677403}$
Fagus orientalis (Mısır ve diğ., 2013)	$Y = 41.483 \times (1.073)^d$
Abies (Karabürk, 2011)	$Y = 0.042861 + 0.04161d^2$
Abies (Mısır ve diğ., 2012)	$Y = 107.197 - 13.702d + 0.665d^2$
Picea orientalis (Mısır ve diğ., 2012)	$Y = 15.0845 - 3.3166d + 0.3358d^2$
Cedrus libani (Ülküdür, 2010)	$Y = -31.0516 + (0.303619d^2)$
Alnus glutinosa (Saraçoğlu, 1991)	$Y = -30.817 + 0.225d^2 + 3.034h$
Quercus sp. (Durkaya, 1998)	$logY = a + bxlog(d)$
Pinus brutia (Ünsal, 2007)	$InY = 6.564528 + 1.50280256Ind$ (f=1.13)
Pinus nigra (Çakıl, 2008)	$Y = 0.10335d^2 + 9.773876d - 103.221$

Coefficients were determined by the Intergovernmental Panel on Climate Change (IPCC) in 2003 by Asan (1995; 1999) to determine the biomass quantities of Turkey's forests according to the guidelines on Land Use, Land Use Change and Forestry (LULUCF) (Tablo 3). According to LULUCF, the wood density is used to transform the stem volume to the biomass (IPCC, 2003). Wood Density (t / m^3) is determined by the ratio of the stem (including bark) biomass (t) to the stem (including bark) volume (m3). The biomass conversion and expansion coefficients used to convert the stem (including bark) volume to biomass of the tree components (stem, bark, total branch, needle, leaf) are determined by adding the biomass (t) to the tree components.

Table 3. Coefficients according to Land Use, Land Use Change and Forestry (LULUCF) (Asan, 1995; 1999).

Carbon Pools	Group of Species	Productive
Above Ground Biomass (AGB)	Coniferous	Volume x 0.473 x 1.20
	Decidious	Volume x 0.640 x 1.25
Below Ground Biomass (BGB)	Coniferous	AGB x 0.20
	Decidious	AGB x 0.15
Litter and Shrub Biomass (LSB)		(AGB + BGB) x 0.40
Total Biomass		(AGB + BGB + LSB)

According to the AFOLU guidelines, studies were carried out to determine the biomass and carbon stocks of Turkey's forests and the coefficients were determined by Mısır et al. (2017) and Tolunay (2011) (Table 4). Total above ground biomass was calculated as 1.3 Gt and below ground biomass was calculated as 0.3 Gt according to data from the national forest inventory in 2015 with the AFOLU coefficients that updated by Mısır et al. (2017). There was no much difference with the amount of biomass obtained as a result of work done according to AFOLU coefficients by taking the national forest inventory completed in 2004 as a basis by Tolunay (2011). It seems that the difference is due to the fact that the national forest inventory data and the determined coefficients change slightly.

Table 4. $BCEF_1$, $BCEF_S$, $BCEF_R$, $BCEF_{leaf}$ and $BCEF_{branch}$ coefficients according to the AFOLU guidelines.

	Group of species	$BCEF_1$ (t/m³)	$BCEF_S$ (t/m³)	$BCEF_R$ (t/m³)	$BCEF_{leaf}$ (t/m³)	$BCEF_{branch}$ (t/m³)
Mısır et al., 2017	Coniferous	0.548	0.570	0.620	0.031	0.070
	Decidious	0.712	0.729	0.810	0.043	0.128
Tolunay, 2013	Coniferous	0.541	0.563	0.612	0.028	0.067
	Decidious	0.709	0.717	0.797	0.039	0.128

According to FRA 2010 guidelines for determining the carbon storage capacity of Turkey forest first calculating above ground and below ground biomass then is to be converted to carbon of the biomass. In this context, stand types are divided into coniferous - decidious and productive - degraded categories, and the values of volume of stand types are multiplied by oven-dried weight and biomass expansion factor according to these categories and biomass values are calculated. According to the FRA 2010 guidelines, Asan (2011) has calculated new coefficients for the determination of biomass and carbon storage quantities, as the degraded areas are included as a separate item. (Tablo 5). The total amount of above ground biomass is calculated as 1.1 Gt and the total amount of below ground biomass is calculated as 0.3 Gt in our country with coefficients determined by Asan (2011) according to data from the national forest inventory in 2015.

Table 5. Coefficients and calculation method used when determining the amount of carbon stock (Asan, 2011)

Carbon pools	Group of species	Coefficients and calculation method	
		Productive	Degraded
Above Ground Biomass (AGB)	Coniferous	volume x 0.496 x 1.22	volume x 0.496 x 1.22
	Decidious	volume x 0.638 x 1.24	volume x 0.638 x 1.24
Below Ground Biomass (BGB)	Coniferous	AGB x 0.29	AGB x 0.40
	Decidious	AGB x 0.24	AGB x 0.46
Total Biomass		AGB + BGB	AGB + BGB

4 DISCUSSION

Until today, many studies on biomass have been made in Turkey. In some studies, mean tree method was used for taking sample trees. In this method, measurements were made on the tree by determining the mean tree in the sample areas. The biomass of the mean tree was found and the value obtained was multiplied by the number of trees to obtain the biomass of the stand. The mean tree gives unreliable results when the volume is equal to the mean tree but the branch wood, needle or bark quantities are determined, for this reason, it may not be possible to obtain sufficient accurate results according to the characteristics of the stand type or stand. Moreover, while this method yields the total biomass yield only as an estimate, it does not give information on the biomass or biomass yield of the trees at the diameter classes of the stand. In regression models method, regression equations can be regulated according to the measurements taken from many test trees and the biomass of other tree components can be determined with easily measurable parameters such as diameter at breast height and height. This method is the most preferred and applied method in the world because it can determine the total raw and dry weights of single tree items and single tree and gives more reliable results than other methods. Saraçoğlu used this method for the first time in Turkey's country. The use of regression modeling methods is recommended to provide more reliable results in biomass studies. However, the regression models show differences when compared within themselves. Much work must be done in order to remove these differences, and a regression model should be developed that we can use for the same species of trees on a country basis.

On the other hand, many studies have been carried out to determine the biomass in the world and these studies are still being developed. As a result of these studies, direct methods applied by the development of the allometric equations belonging to each country in the direction of Land Use, Land Use Change and Forestry (LULUCF), Agriculture, Forestry and Other Land Use (AFOLU) and Global Forest Resources Assessments (FRA) guidelines are used. When calculations are made with the coefficients determined in the direction of guides, it is seen that different results are obtained. The main reasons for this difference are the use of different coefficients in different methods, and the coefficients in many general classifications such as coniferous - decidious and productive - degraded categories. Mixing conditions in the forests are not taken into account and no specific coefficients are determined for mixed stands. In some methods, the amount of biomass in the dead wood was not taken into account, but it was taken into consideration in some methods. In addition, national forest inventories used for making calculations according to the guidelines have mainly focused on determining wood density. Therefore, the volume values revealed by forest inventories must be converted to biomass values. In this transformation, wood density is generally used. With this calculation, only the wood biomass of the trees in the forest ecosystem can be determined. On the other hand, in the trees, besides the stem, branches, leaves and roots also produce biomass. After the wood volume data are transformed into wood biomass, the branch and leaf biomasses must be added. For this process, coefficients called biomass expansion coefficients are used. For these reasons, national forest inventory studies should be broadly organized to determine biomass. When determining the amount of biomass of forests, biomass expansion coefficients should be determined for each species first. In addition, new coefficients based on mixing ratios should be developed, taking into account the mixing state in the forests.

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ABSTRACT

This study was aimed to determine surface roughness and gloss changes of heated and varnished Scots pine (*Pinus sylvestris* L.) and Oriental beech (*Fagus orientalis* L.) woods after 3 months of weathering for in Mugla Region. Heat treatment of Oriental beech and Scots pine woods were carried out by hot air in an oven for 1, 2, and 3 h at 205, 215, and 225°C. After heat treatment, Scots pine and Oriental beech wood specimens were varnished using a polyurethane varnish (PV) and cellulosic varnish (CV).

According to the test results, the weathering process caused an increase in the surface roughness of the test specimens. In general, heated and varnished Oriental beech and Scots pine woods gave better surface roughness and gloss properties than only varnished Oriental beech and Scots pine after weathering. Generally, higher duration and temperature for Scots pine and Oriental beech resulted in better surface characteristics of Oriental beech and Scots pine woods after weathering. Our results showed that while heat treated and PV coated both wood specimens gave better results in terms of surface roughness, heat treated and CV coated both wood specimens gave better results in terms of gloss values after weathering.

KEYWORDS: Heat treatment, Scots pine (*Pinus sylvestris* L.), Oriental beech (*Fagus orientalis* L), weathering, surface roughness, gloss.

1 INTRODUCTION

The most important external elements that affect the wood appearance are weathering process. Weathering, as the term is used to descript the degradation of materials exposed to the weather (Williams, 2005). The weathering process mostly ends up with discoloration, a physical deterioration of the wood surface primarily due to the effects of sunlight (ultraviolet light) and water (Yalinkilic et al., 1999; Miklečić and Irouš-Rajković, 2011, Turkoglu et al., 2015). It causes change in the chemical, physical, and mechanical properties of the wood (Pandey, 2005; Rasouli et al., 2016). Weathering of wood is mainly a surface event that results in the gradual erosion of wood fibers on the surface (Williams et al., 2001). The weathering initially causes the discoloration and gloss loss, followed by the occurrence of surface checking and increased roughness of the wood (Denes and Young, 1999, Ozgenc et al., 2012). Wood has been protected from damage caused by various weather factors using some modification methods (thermal, chemical, and impregnation) and finishes. Environmental concerns associated with the use of conventional wood preservatives, however, have increased interest in thermal modification approaches (Hill, 2006). When thermal processing is considered as a thermal modification method, the wood is maintained at a temperature of 100-250 °C in a normal atmosphere, nitrogen gas or any inert gas atmosphere for a certain period of time. The heat treatment of wood products is carried out for three purposes. The first is to increase the biological resistance of wood materials to destructive organisms; the other is to reduce the moisture exchange of the wood material, that is to give dimensional stability to the wood. In addition to this, it is also possible to increase the performance of the surface treatment, to reduce the amount of moisture balance, and to increase the permeability by heat treatment (Yildiz, 2002; 2005). Heat treated wood possesses new physical properties such as reduced hygroscopy, improved dimensional stability, better resistance to degradation by insects and micro-organisms, and most importantly, attractive darker color. These new versatile and attractive properties help heat treated wood to become popular for outdoor applications (Huang et al., 2012). Heat treated wood has a large application for outdoor use in cladding, decks, garden furniture, and window frames as well as indoor use for kitchen furniture, parquet, decorative panels, and mainly for the interior of saunas (Esteves and Pereira, 2009).

Baysal et al. (2014a) Oriental beech wood samples were subjected to heat treatment at 140, 170 and 200 ° C for 2, 4 and 8 hours to investigate the change in roughness value. As a result of the experiment, they stated that the roughness values of the heat treatment, R_a, R_z and R_q, cause a decrease depending on the time and temperature. Karagöz et al. (2011) reported that heat treatment for 2 hours at 200 °C in Scots pine reduced the surface roughness and did not significantly affect the beech and the fir. Korkut et al. (2013) reported that R_z values of surface roughness parameters in annealed Wild cherry wood decreased by 1.5% at 212 ° C and 12% and 22%, respectively, in 2 hour heat treated samples. Turkoglu et al. (2015) investigated the changes in gloos value by applying heat treatment at 140, 170 and 200 °C for 2, 4, and 8 hours to the Oriental beech samples. As a result of the experiment, it was observed that the amount of gloss decreases with temperature and time. Esteves et al. (2008) reported a 52.9% reduction in the L^* gloss of wood after 12 hours of heat treatment at 200 °C. Temiz et al. (2006), Nuopponen et al. (2004), Ayadi et al. (2003) reported that heat treated wood is more resistant to weathering. Baysal et al. (2014b) reported that surface roughness of the heat treated Scots pine wood after accelerated-weathering was lower than that of non-heat treated control samples. Yildiz et al. (2013) reported that heat treatment caused a decrease in surface roughness of wood after weathering in softwoods. Turkoglu et al. (2017) investigated surface roughness of heated and varnished Oriental beech wood after accelerated weathering. Heat treatment of Oriental beech wood was carried out by hot air in an oven for 0.5, 1, and 1.5 h at 210, 220, and 230°C. After heat treatment, Oriental beech wood specimens were varnished using a polyurethane varnish. The results showed that accelerated weathering generally caused increase of surface hardness of Oriental beech. Surface roughness and total color changes of heated and varnished Oriental beech were lower than only varnished (control) Oriental beech after accelerated weathering.

In this study; it was aimed to investigate surface roughness and gloss changes of heat treated and PV and CV coated Scots pine and Oriental beech after 3 months of weathering in Mugla region.

2 MATERIAL AND METHOD

2.1 Preparation of test specimens

Specimens 10x100x150 mm (radial by tangential by longitudinal) were machined from air-dried sapwood of Scots pine (*Pinus sylvestris* L.) and Oriental beech (*Fagus orientalis* L.) lumbers. All specimens were conditioned at 20°C and 65 % relative humidity for two weeks before tests.

2.2 Heat Treatment

Heat treatment was performed using a temperature-controlled laboratory oven. Three different temperatures (205, 215, and 225°C) and three treatment durations (1, 2, and 3 h) were applied to wood specimens under atmospheric pressure and in the presence of air.

2.3 Varnish application

Cellulosic and polyurethane varnishes were used. PV and CV varnishes were applied over heat treated Oriental beech and Scots pine wood. The varnishes were applied to all surfaces and sides of the treated and untreated pine specimens with a spray gun according to the ASTM D3023-98 (2003) standard. Filler was used as the first coating applied to the wood surface was for filling the voids, and the second and third coatings were applied for top coating. Sufficient time for layer settling was allowed between successive applications until the target retention of 100 g/m^2 for the primer and 100 g/m^2 for the top coating were reached, controlled by consecutive weighting. Specimens were left in ambient conditions for 24 h according to the manufacturer's recommendations after the first coating, and then surfaces were gently sanded using a fine-grit sandpaper (220 grit) to obtain a smooth surface before the top coating. After the top coating of varnishes to the surfaces, specimens were conditioned for 3 weeks.

2.4 Weathering method

Each groups consisted of 5 individual wood specimens. In total, 20 groups of wood specimens for each species were exposed to weathering conditions during April- May-Jun in 2015. Wood panels were prepared for weathering exposure according to ASTM D 358–55 (1970). A test site was established close to the Regional Meteorological Observation Station of Mugla which is in Southern Aegean Region to enable practical assessments. The details of the climate condition of Mugla city in this period are given in Tab. 1 (Turkish State Meteorological Service Database 2015).

Table 1: Details of the climate condition of Mugla city during April-May-June in 2015

Mugla	April	May	June
The highest temperature per month (°C)	24.7	31.8	32.0
The lowest temperature per month (°C)	1.3	6.4	10.6
Average temperature per month (°C)	11.4	18.2	20.8
Humidity per month (%)	60.5	61.9	61.7
Sunbathing time per month (hour)	233.6	227.6	254.8
The number of the rainy days per month	6	6	7
Total rainfall per month (mm=kg/m^2)	25.2	89.1	59.0

2.5 Surface roughness test

Surface roughness of specimens was measured by the Mitutoyo Surftest SJ-301 (Mitutoyo Corporation, Tokyo, Japan) according to DIN 4768 (1990). The surface roughness measurement instrument includes a pick-up unit which includes a 5 μm tip radius containing diamond stylus and tip detector of conical taper angle of 90°and a main unit. The stylus scans the surface with the constant speed of 0.5 mm.s-1 over 8 mm sampling length (Zhong et al., 2013). Three roughness parameters which are typically used in previous studies for evaluation of wood and wood based materials surface characteristics: mean arithmetic deviation of profile (*Ra*), mean peak-to-valley height (*Rz*), and root mean square (*Rq*) (Hiziroglu, 1996; Hiziroglu and Graham, 1998). Surface roughness test device is given in Figure 1.

Figure 1: Surface roughness test device

2.6 Surface gloss test

Gloss of wood specimens was measured with a ASTM D523-08 (2008) based gloss meter (MicroTRI-Gloss, BYK Gardner, MD, USA). 60 º incidence angles is chosen as the preferred geometry. Surface gloss test device is given in Figure 2.

Figure 2: Surface gloss test device

3 RESULTS

3.1 Surface Roughness Changes

3.1.1. Surface Roughness Changes of Scots Pine

The surface roughness changes of heat treated and varnish coated Scots pine before and after 3 months of weathering are given in Table 2.

Table 2: Surface roughness changes of heat treated and varnish coated Scots pine before and after weathering

Hour	Temperature (^{0}C)	Varnish Type	Before natural weathering			After 3 months of weathering			Differences		
			R_a	R_z	R_q	R_a	R_z	R_q	ΔR_a	ΔR_z	ΔR_q
PV (Control)			0.13 (0.03)	1.29 (0.16)	0.19 (0.04)	0.36 (0.03)	3.54 (0.88)	0.53 (0.11)	0.23	2.25	0.34
1	205	PV	0.14 (0.06)	1.17 (0.69)	0.22 (0.13)	0.35 (0.05)	2.51 (0.49)	0.53 (0.07)	0.21	1.34	0.31
2			0.28 (0.34)	1.27 (0.74)	0.19 (0.10)	0.45 (0.09)	2.43 (1.55)	0.47 (0.21)	0.17	1.16	0.28
3			0.12 (0.03)	1.01 (0.80)	0.18 (0.09)	0.25 (0.04)	2.26 (1.36)	0.37 (0.07)	0.13	1.25	0.19
1	215		0.25 (0.21)	2.24 (1.30)	0.41 (0.30)	0.41 (0.12)	3.54 (0.99)	0.71 (0.21)	0.16	1.30	0.30
2			0.31 (0.08)	2.07 (0.83)	0.42 (0.11)	0.41 (0.15)	2.98 (1.45)	0.57 (0.26)	0.10	0.91	0.15
3			0.09 (0.03)	1.12 (0.67)	0.13 (0.05)	0.18 (0.04)	2.21 (1.41)	0.30 (0.10)	0.09	1.09	0.17
1	225		0.17 (0.14)	1.93 (1.15)	0.26 (0.23)	0.27 (0.02)	3.15 (1.26)	0.48 (0.06)	0.10	1.22	0.22
2			0.08 (0.02)	1.11 (0.74)	0.12 (0.05)	0.14 (0.21)	2.04 (0.78)	0.22 (0.29)	0.06	0.93	0.10
3			0.11 (0.03)	1.38 (0.92)	0.17 (0.06)	0.15 (0.02)	1.72 (0.70)	0.29 (0.04)	0.04	0.34	0.12
CV (Kontrol)			0.24 (0.03)	1.98 (0.21)	0.42 (0.03)	0.49 (0.03)	4.60 (0.61)	0.78 (0.07)	0.25	2.62	0.36
1	205	CV	0.47 (0.17)	1.59 (2.02)	0.32 (0.34)	0.64 (0.28)	3.77 (2.49)	0,63 (0.51)	0.17	2.18	0.31
2			0.25 (0.07)	2.52 (0.91)	0.35 (0.12)	0.37 (0.15)	4,10 (1.40)	0.57 (0.26)	0.12	1.58	0.22
3			0.16 (0.02)	1.13 (0.09)	0.21 (0.02)	0.26 (0.06)	2.75 (0.62)	0.36 (0.08)	0.10	1.62	0.15
1	215		0.22 (0.08)	1.71 (0.98)	0.30 (0.16)	0.37 (0.16)	3,06 (1.56)	0.55 (0.25)	0.15	1.35	0.25
2			0.20 (0.07)	1.96 (0.92)	0.30 (0.12)	0.29 (0.26)	3.26 (1.56)	0.48 (0.39)	0.09	1.30	0.18
3			0.23 (0.06)	1.48 (0.31)	0.30 (0,06)	0.31 (0.41)	2.50 (2.27)	0.42 (0.54)	0.08	1.02	0.12
1	225		0.27 (0.17)	2.40 (1.12)	0.42 (0.29	0.38 (0.20)	4.00 (1.40)	0,64 (4.05)	0.11	1.60	0.22
2			0.18 (0.03)	2.19 (0.65)	0.27 (0.02)	0.22 (0.07)	3.95 (0.61)	0.39 (0.13)	0.04	0.76	0.12
3			0.24 (0.08)	1.90 (0.63)	0.33 (0.11)	0.29 (0.06)	2.28 (0.69)	0.42 (0.12)	0.05	0.38	0.09

Note: The results reflect the average of 5 samples, values in parenthesis show standard deviations.
PV: Polyurethane varnish, **CV:** Cellulosic varnish.

Examining Table 2, the following results were obtained:

1. R_a, R_z, and R_q values of heat treated and varnish coated Scots pine were increased after 3 months of weathering exposure.
2. R_a, R_z, and R_q values of heat treated and varnish coated Scots pine were lower than only varnish coated Scots pine.
3. R_a values of heat treated and varnish coated Scots pine were increased with increasing temperature and duration.

4. R_a, R_z, and R_q values of heat treated and CV coated Scots pine were higher than heat treated and PV coated Scots pine after weathering.

3.1.2. Surface Roughness Changes of Oriental Beech

The surface roughness values of heat treated and varnish coated Oriental beech before and after 3 months of weathering are given in Table 3.

Table 3: Surface roughness changes of heat treated and varnish coated Oriental beech before and after weathering

Hour	Temperature (^{0}C)	Varnish Type	Before natural weathering			After 3-months natural weathering			Differences		
			R_a	***R_z***	***R_q***	***R_a***	***R_z***	***R_q***	***ΔR_a***	***ΔR_z***	***ΔR_q***
PV (Kontrol)			0.16 (0.02)	1.50 (0.44)	0.24 (0.03)	0.48 (0.06)	4.02 (1.61)	0.59 (0.11)	0.22	2.52	0.35
1	205	PV	0.10 (0.02)	1.04 (0.43)	0.15 (0.04)	0.26 (0.27)	2.92 (1.27)	0.40 (0.34)	0.16	1.88	0.25
2			0.14 (0.03)	1.54 (1.31)	0.20 (0.05)	0.28 (0.02)	2.72 (1.14)	0.38 (0.10)	0.14	1.18	0.18
3			0.14 (0.02)	1.31 (0.63)	0.20 (0.06)	0.23 (0.04)	2.21 (0.54)	0.33 (0.08)	0.09	0.90	0.13
1	215		0.27 (0.19)	1.89 (0.58)	0.37 (0.24)	0.45 (0.07)	3.58 (0.91)	0.58 (0.08)	0.18	1.69	0.21
2			0.11 (0.03)	1.23 (0.56)	0.14 (0.04)	0.21 (0.16)	2.52 (3.98)	0.28 (0.29)	0.10	1.29	0.14
3			0.23 (0.07)	2.24 (0.61)	0.36 (0.10)	0.30 (0.09)	2.92 (1.93)	0.46 (0.13)	0.07	0.68	0.10
1	225		0.14 (0.04)	1.12 (0.49)	0.20 (0.09)	0.23 (0.07)	2.69 (1.39)	0.38 (0.17)	0.09	1.57	0.18
2			0.11 (0.03)	1.18 (0.72)	0.17 (0.08)	0.25 (0.08)	2.08 (1.82)	0.29 (0.20)	0.08	0.90	0.12
3			0.09 (0.03)	1.08 (0.73)	0.14 (0.08)	0.20 (0.05)	1.45 (0.55)	0.18 (0.08)	0.06	0.37	0.04
CV (Kontrol)			0.23 (0.03)	1.84 (0.30)	0.33 (0.06)	0.56 (0.09)	4.73 (0.98)	0.71 (0.19)	0.23	2.89	0.38
1	205	CV	0.19 (0.07)	1.50 (0.46)	0.26 (0.09)	0.47 (0.04)	3.53 (0.52)	0.59 (0.10)	0.21	2.03	0.33
2			0.28 (0.06)	2.31 (1.04)	0.40 (0.10)	0.50 (0.08)	3.71 (0.56)	0.56 (0.10)	0.10	1.40	0.16
3			0.18 (0.02)	2.79 (2.40)	0.29 (0.11)	0.38 (0.14)	3.82 (1.58)	0.43 (0.28)	0.09	1.03	0.14
1	215		0.23 (0.10)	1.53 (0.43)	0.29 (0.12)	0.42 (0.16)	3.57 (2.38)	0.55 (0.37)	0.13	2.04	0.26
2			0.16 (0.05)	1.54 (0.43)	0.22 (0.07)	0.37 (0.06)	2.78 (0.37)	0.42 (0.09)	0.15	1.24	0.20
3			0.33 (0.14)	3.10 (0.73)	0.51 (0.28)	0.59 (0.20)	3.84 (1.82)	0.62 (0.22)	0.08	0.74	0.11
1	225		0.26 (0.04)	2.92 (1.02)	0.39 (0.12)	0.51 (0.15)	4.45 (0.45)	0.50 (0.16)	0.12	1.53	0.21
2			0.25 (0.10)	1.88 (0.73)	0.34 (0.16)	0.44 (0.12)	2.86 (1.11)	0.58 (0.21)	0.10	0.98	0.14
3			0.25 (0.03)	2.74 (0.87)	0.37 (0.03)	0.44 (0.24)	3.22 (0.66)	0.45 (0.27)	0.07	0.48	0.08

Note: The results reflect the average of 5 samples, values in parenthesis show standard deviations. **PV:** Polyurethane varnish, **CV:** Cellulosic varnish.

Examining Tab. 3, the following results were obtained:

1. Surface roughness values of heat treated and CV coated Oriental beech were higher than heat treated and PV coated Oriental beech before weathering.
2. R_a, R_z, and R_q values of the heat treated and varnish coated Oriental beech were lower than only varnish coated Oriental beech after 3 months of weathering.
3. Generally, surface roughness of heat treated and PV coated Oriental beech were lower than heat treated and CV coated Oriental beech after 3 months of weathering.
4. In general, surface roughness of heat treated and varnish coated Oriental beech were decreased with increasing temperature and duration.

3.2 Gloss Changes

3.2.1 Gloss changes of Scots pine

The gloss changes of heat treated and varnish coated Scots pine before and after 3 months of weathering exposure are given in Table 4.

Table 4: The gloss changes of heat treated and varnish coated Scots pine before and after weathering

Varnish Type	Temperature (^{0}C)	Before natural weathering			3 months after natural weathering			% Change		
PV (Control)		96.58 (7.13)			55.70 (5.73)			-42.32		
Time (Hour)		1	2	3	1	2	3	1	2	3
PV	205	94.98 (6.63)	97.28 (8.78)	94.78 (6.93)	70.53 (3.80)	75.66 (6.46)	75.78 (6.52)	-25.74	-22.22	-20.04
	215	83.90 (6.98)	96.58 (8.92)	88.84 (4.54)	63.76 (5.95)	74.52 (5.81)	72.14 (6.49)	-24.00	-22.84	-18.79
	225	95.08 (7.23)	93.32 (6.84)	96.30 (7.41)	73.66 (4.83)	78.54 (4.02)	81.58 (6.26)	-22.52	-20.08	-15.28
CV (Control)		89.90 (7.97)			58.52 (5.51)			-34.90		
CV	205	88.12 (6.52)	77.22 (11.83)	81.88 (4.89)	63.68 (6.52)	60.26 (8.47)	68.82 (10.45)	-27.73	-21.96	-15.95
	215	90.58 (8.67)	74.76 (6.12)	82.08 (9.25)	68.22 (3.34)	60.36 (6.37)	70.60 (2.80)	-24.68	-19.26	-13.98
	225	85.78 (6.54)	86.24 (7.13)	83.16 (8.91)	66.72 (8.32)	70.84 (5.51)	72.90 (5.28)	-22.21	-17.85	-12.33

Note: The results reflect the average of 5 samples, values in parenthesis show standard deviations.
PV: Polyurethane varnish, **CV:** Cellulosic varnish.

Examining Table 4, the following results were obtained:

1. Generally, heat treatment before varnish coating caused to decrease gloss values of Scots pine before weathering.
2. Gloss losses of heat treated and varnish coated Scots pine were lower than only varnish coated Scots pine after 3 months of weathering
3. Gloss losses of heat tread and varnish coated Scots pine were decreased with increasing temperature and duration.
4. For heat treated and PV coated Scots pine; while gloss loss of only PV coated Scots pine was 42.32% after 3 months of weathering, the lowest gloss loss was 15.28% with heat treated at 225 °C for 3h and PV coated Scots pine after weathering.
5. For heat treated and CV coated Scots pine; while gloss loss of only CV coated Scots pine was 34.90% after 3 months of weathering, the lowest gloss loss was 12.33% with heat treated at 225 °C for 3 h and CV coated Scots pine.

3.2.2 Gloss changes of oriental beech

The gloss values of heat treated and varnish coated Oriental beech before and after 3 months of weathering exposure are given in Table 5.

Table 5: The gloss changes of heat treated and varnish coated Oriental beech before and after weathering

Varnish Type	**Temperature (^{0}C)**	**Before natural weathering**			**After 3 months natural weathering**			**%Change**		
PV (Control)		92.84 (4.18)			65.52 (6.31)			-29.42		
Time (Hour)		1	2	3	1	2	3	1	2	3
PV	205	94.74 (2.64)	93.02 (2.84)	91.16 (2.94)	71.90 (4.30)	72.28 (6.19)	74.54 (7.78)	-24.10	-22.29	-18.23
	215	87.80 (7.73)	95.40 (3.94)	88.24 (7.05)	66.43 (3.13)	74.81 (7.74)	72.34 (6.78)	-24.33	-21.58	-18.09
	225	92.20 (4.90)	92.72 (7.62)	92.84 (1.29)	72.76 (2.20)	73.46 (4.60)	76.84 (3.46)	-21.08	-20.77	-17.23
CV (Kontrol)		86.56 (2.49)			62.58 (8.36)			-27.70		
CV	205	88.72 (4.47)	79.78 (10.50)	83.44 (6.61)	67.02 (5.56)	60.10 (5.79)	66.96 (5.93)	-24.45	-24.66	-19.75
	215	84.28 (5.71)	85.44 (5.17)	81.12 (7.52)	62.84 (7.76)	69.60 (6.44)	66.82 (5.78)	-25.43	-18.53	-17.62
	225	80.96 (4.93)	86.28 (2.14)	76.20 (9.01)	67.46 (3.16)	71.56 (3.66)	67.06 (6.71)	-16.67	-17.06	-11.99

Note: The results reflect the average of 5 samples, values in parenthesis show standard deviations.
PV: Polyurethane varnish, CV**:** Cellulosic varnish.

Examining Table 5, the following results were obtained:

1. Gloss values of heat treated and PV coated Oriental beech were higher than heat treated and CV coated Oriental beech before natural weathering.
2. Gloss losses were observed for all heated varnished Oriental beech after weathering.
3. Gloss losses were decreased with increasing temperature and duration for heat treated and PV coated Oriental beech.
4. While for heat treated and PV coated Scots pine gloss loss (29.42%) was the highest for only PV coated Oriental beech, it was 27.70% for heat treated and CV coated Oriental beech after 3 months of weathering.

4 CONCLUSIONS

This study was carried out in order to determine gloss and surface roughness changes of heat treated and PV and CV varnishes coated Scots pine and Oriental beech after 3 months of weathering.

Heat treatment caused to gloss loss before weathering. It was observed that the gloss values of heat treated and PV coated Scots pine gave higher gloss values than heat treated and CV before weathering. Generally, gloss values of heat treated and varnish coated both wood specimens were higher than only varnish coated both wood specimens after 3 months of weathering. Surface roughness values of heat treated and CV coated both wood specimens were higher than heat treated and PV coated both wood specimens. Heat treatment before varnish coating caused to decrease surface roughness of both wood specimens.

In conclusion, weathering caused to gloss loss and increase of surface roughness of Scots pine. Heat treatment before varnish coating decreased gloss loss and surface roughness Scots pine after weathering. Generally, Scots pine gave better gloss changes and surface roughness with increasing temperature and duration after weathering.

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The Reaction to Fire of Some Chemicals Treated Pine Wood Product Surface

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ABSTRACT

Wooden materials have been extensively used for furniture, outdoor and indoor cladding, buildings, terrace, fence, garden furniture and interior decoration and to decorate the roofline of houses. However, wood which is used outdoors or in areas exposed to moisture needs to be protected against wood-destroying organisms and to be shielded from water, marine pests, fungi, fire and weather conditions. Untreated wood materials have no resistance to the spread of fire and many buildings which constructed from wood based materials needs to fire resistance. It is possible that the wooden material ensures very durable and resistant against physical effects by surface applications such as wood preservative paint and acrylic resin-based varnish. The application of fire retardant chemicals can also provide to satisfy regulatory requirements for wood products.

In this study, titanium dioxide and antimony trioxide were applied on pine (Pinus sylvestris L.) solid wood material to determine durability of reaction to fire using by oxygen index test technique (ASTM D 2863-6) and real fire test. These chemicals were added to the wood preservative paint which is a commercial product as concentrations of 2%, 5% and 10% for titanium dioxide and 2% and 5% for antimony trioxide. The effects on colour change of their surfaces, brightness and surface roughness measurements, water absorption and thickness swelling of this wood material were also carried out. The results obtained were analysed statistically and compared with the related standards. Addition of these chemicals to used wood preservative paint had a positive impact on the fire properties of the pine wooden surface.

KEYWORDS: Titanium dioxide, Antimony trioxide, Fire retardant, Wood preservative paint

1 INTRODUCTION

Wood is renewable material, easily workable, coupled with its outstanding physical and mechanical properties. Since it is used flats, window and door, furniture, ceilings and floors, stairs, benches, its preservation is important significantly. But the use of wood can be restricted by safety regulations concerned with its ignitability and flame spreading characteristics. The application of a suitable fire retardant system can prevent these problems, thus can be used in many areas of use (Russell et al., 2004; Web-1).

The resistance of wood to burning and flame spread have been researched for many years. A wood consists of carbon and hydrogen which make it highly combustible. A fuel, an oxidizer and a source of heat are three main elements in a combustion reaction. The combustion of wood occurs by the pyrolysis of the cellulose and its reaction to oxygen. When temperature is increased, the pyrolysis starts. The combustion stops if any of the elements is removed (Pabelina et al., 2012) Many fire retardant techniques are named surface treatment with fire retardant chemicals such as fire resisting coatings and pressure impregnations of chemical solutions into wood (Eickner, 1975; White, 1999).

Fire retardants are mainly based on organic phosphorus, halogens and metallic oxides. A fireretardant such as phosphorus, aluminium, antimony, chlorides, bromides, and boron-containing compounds can act in physically or chemically. It can cause a charred layer of carbon to form on the surface (Demir, et al., 2005). The fire retardant chemicals work in several ways such as by conversion of volatile gases to on flammable gases, promotion of char formation, forming an intumescent foam barrier at the surface, free radical termination in the gaseous phase, and occurring a glaze barrier at the surface (Ötsman and Tsantaridis, 2016). Fire retardants can affect the reaction to fire properties, however this effect is lower for the fully developed fire. When intumescent paints are used the time for start of charring can be delay and the fire resistance can be increased. The fact is that fire retardants cannot make wood non-combustible. Fire performance of fire retardant treated the virgin wood products may degrade depending on time in outdoor applications. Fire retardant chemicals can be removed in the wood surface when the wood surface is exposed to high humidity (Nussbaum, 1988; Östman et al., 2001;Ötsman and Tsantaridis, 2016). Mineral fillers such as titanium dioxide for intumescent fire retardant coating have attracted much attention in recent years. Titanium dioxide (TiO_2) can be also used in coating industry as pigments. Some researchers were found that the presence of rutile type TiO_2 could improve the fire resistance of the coating by enhancing char formation (Li et al.,2015, ;Lam et al., 2011). Antimony trioxide is usually used as a synergistic energy to improve fire retardancy (Giúdice and Benítez, 2001).

Pine wood which is a type of softwood grown in many varieties in world has a uniform texture, finishes well, and east to work. It is usually light yellow in colour and also some resistance against shrinkage, sharping and swelling (Zhong et al., 2013). It is considered that these properties will be improved by the use of some chemicals treated wood preservative paint. Wood preservatives contain pentachlorophenol or creosote in oil, water-borne salt treatments, copper, zinc, chromium, arsenic and other compounds can protect wood against attack by fungi, bacteria and insects (Thamasson et al., 2006).

There is a need to search new fire retardant treated wood products with improved long term durability of the reaction to fire performance in many usage areas. The main aim of the study is to obtain an improved fire performance of pine wood surface. In this study, the effects on the flammability (the limiting oxygen index (LOI) and real fire test) of pine wood surface with applied of titanium dioxide and antimony trioxide were investigated owing to the synergy effect of wood preservative paint and these chemicals. The surface roughness, colour change, brightness and physical properties of the pine wood surfaces were also measured in according to the relative standards.

2 EXPERIMENTAL

2.1 Materials

Pinus sylvestris L. solid wood surface was used for improving its flammability properties in this study. Wood preservative paint was obtained from Polisan, Turkey. Titanium dioxide and antimony trioxide were purchased from Sigma-Aldrich in this study. The purity grades of these chemicals are above 99,99%. Table 1 and 2 show average size of chemicals and sample codes, respectively.

Table 13: Average size of chemicals

Chemical type	Average size (nm)
Titanium dioxide	30≥
Antimony trioxide	30≥

Table 2: Composition of fire retardant coatings, % by volume on wood preservative paint

Sample Code	2%	5%	10%
Control	-	-	-
WPP	-	-	-
A1	x	-	-
A2	-	x	-
A10	-	-	x
T1	x	-	-
T2	-	x	-

WPP: Wood preservative paint; A: Antimony trioxide; T:Titanium dioxide

2.2 Preparation of Wood Surfaces

Firstly, the wood preservative paint is applied onto the pine wood surface. Amounts of fire retardant chemicals were changed in proportion to amounts of titanium dioxide (2% and 5%) and which of antimony trioxide (2%, 5% and 10%). Secondly, they were mixed for 5 minutes with wood preservative paint, and then applied by a brush onto solid pine surface. Once again was painted by the wood preservative paint after the wood surfaces were dried for 12 hours.

2.3 Fire Properties

The limiting oxygen index (LOI) test method was determined using a Dynisco Limiting Oxygen Index Chamber according to ASTM D 2863 to measure the minimum oxygen concentration. Four samples with the dimensions of 10 mmx15mmx5 mm were used for each group. All wood samples were placed in vertical glass column and then adjusted oxygen and nitrogen flow. The LOI test determines minimum concentration of oxygen to support combustion of materials in a mixture of oxygen and nitrogen flowing upward in a test column. The five samples for each group were tested.

The real fire test was also performed. The sample dimensions were the same as the dimensions of the previous LOI sample. All samples were burned to the mark in mm/min. The blowtorch was kept at a distance of 10 cm from the kraft paper. The flame was applied for 5 seconds. The flame extinguishing time was recorded after the flame source cut off. Four samples for each group were tested.

2.4 Colour Measurements

All surfaces were removed from dust and dirt to minimize the risk of variation of colour values by differences in surface structure. The colour measurement was carried out according to CIE L*a*b* method by parameters L*a*b* and ΔE* with a PCE-TCD 100 (CM10P Color Meter). Measurements were realized on both sides of wood samples. The arithmetic mean of these measurements was calculated for each samples. The coordinates L* (lightness or black-white relation), a* (coordinate red-green), b* (coordinate yellow-blue), measured on unpainted and painted solid pine wood were used to determine overall color change ΔE* by using the CIE L*a*b* color measuring system.

2.5 Surface Roughness

The residual particles remaining after painting were removed by cleaning the surface. Surface roughness of painted or unpainted samples was measured with a profilometer (Mitutoyo SJ-210). Equipment has stylus with 0.5µ radius and 90° contact angle running at speed of 0.5 mm/s. A total of 25 random measurements with a span of 15 mm were taken from the surface. Mean peak to valley height (R_z) which is well accepted roughness parameter was used an indicator of the surface quality of wood samples. Measurements were performed in different areas, along two different perpendicular directions (longitudinal and tangential).

2.6 Surface Brightness

The brightness measurements were measured by PCE-GM 100. Measurements were done with a gloss meter which measured at 20°, 60°, and 80° as parallel and perpendicular to the fibers for each wood surface before and after painting.

2.7 Physical Testing

The thickness swelling (TS) and water absorption (WA) were determined after 2h, 24h, 48h, 72h, 96h and 120h soaking in water in accordance with EN 317.

2.8 Statistical Analysis

Statistical analysis was carried out with using SPSS 21.0 statistical package software. The results were statistically tested with the one-way analysis of variance. The significance ($P<0.05$) between the samples was compared with Duncan homogeneity groups. Each value is an average of 6 specimens and the values in the parentheses are standard deviations.

3 DISCUSSION

3.1 Reaction to Fire Properties

The results of LOI and real fire test are shown in Table 3. LOI levels of the samples were in the range of 26,5-27 for pine wood and wood preservative paint. The LOI levels of antimony trioxide and titanium dioxide with samples were ranging from 28,5 to 30. A maximum LOI level was obtained with A10 sample including antimony trioxide of 10%. Antimony trioxide is a well-known pigment for the interference on flame spreading velocity. It shows an adequate fire-retardant behaviour during the fire spreading reaction. But it is not effective it by itself. It should be used in combination with halogenated organic compounds. The antimony trioxide increases smoke production since the char analysis shows that about 80-95% of antimony volatilizes. It also decreases concern for the toxicity of antimony oxide (Giúdice, and Benítez, 2001). According to ISO 4589, control and WPP samples were located in “Limited fire retardant material” class while A1, A10, T1 and T2 were classified in “Fire retardant material” class, as seen in Table 4. For real fire test, the effect of A10 and T2 was important to decrease the flame spreading. The fire retardant chemicals can act combining one or more mechanisms. Titanium dioxide shows a significant physical activity generated by reducing the concentration of the organic part which divides the material in isolated pieces by occupation of pores and amorphous polymer regions. As a result of which a higher amount of heat is required to attain the pyrolysis temperature (Giúdice and Benítez, 2001). Hashim et al. (2009) reported that lignocellulosic material reduced heat release rate and increased charring rate. When compared with char weight of all samples, a minimum value was obtained with T2 sample, followed by A10 sample.

Table 3: LOI and real fire test results of samples

Sample	LOI	Real Fire Test					Smoking
		First weight (g)	Weight after burning (g)	After flame time (sec.)	After glow time (sec.)	Char weight (g)	
Control	26,5	9,480	7,791	60	60	1,689	+
WPP	~27	11,431	10,632	60	29	0,799	
A1	28,5	10,319	9,560	60	17	0,759	
A2	-	10,881	10,131	60	4	0,750	
A10	~30	11,476	10,747	60	0	0,729	
T1	28,5	10,990	9,866	60	20	1,124	+
T2	28,5	10,624	10,066	60	10	0,558	+

Table 4: Fire classification of samples according to ISO 4589

LOI level	Classification of fire	Chemical
≤23	Flammable material	
24-28	Limited fire retardant material	Control, WPP
29-35	Fire retardant material	A1, A10, T1, T2

Figure 1: The images of samples after LOI test

3.2 Brightness and Colour Properties

The brightness (80°) values were inreased by usage of antimony trioxide and titanium dioxide according to that of pine wood. This is clearly seeen Figure 2. The brightness of the samples were increased when ratio of antimony trioxide increased from 2% to 10% for antimony trioxide. Similar results were also seen in 2% and 5% ratios of titanium dioxide. The highest values of the brightness were obtained from A10 samples. No significant difference was found between ΔE values of samples with antimony trioxide and titanium dioxide with samples based on Duncan test as displayed in Table 5.

Table 5: Statistical analysis results and homogeneity groups of the brightness, ΔE and roughness test results

Sample designation	Brightness			ΔE	Rz (µm)
	20°	60°	80°		
Control	0,24a* (0,05)**	1,76a (0,59)	69,66a (4,43)	2,80a (1,49)	8,90b (1,51)
WPP	4,96ab (2,15)	24,32b (5,01)	80,08b (2,61)	2,30a (1,04)	6,02ab (3,26)
A1	9,25bc (5,75)	38,36cd (13,24)	93,03c (1,16)	2,38a (1,48)	5,90ab (4,02)
A2	9,75bc (1,24)	41,73d (3,85)	98,02d (2,84)	2,44a (1,26)	5,51ab (3,90)
A10	9,17bc (2,59)	38,95cd (5,55)	112,74f*** (3,74)	2,40a (0,53)	2,78a (1,53)
T1	11,37c (8,59)	39,62d (10,91)	107,81e*** (2,21)	3,32a (0,31)	4,10a (1,34)
T2	7,15bc (2,97)	29,64bc (7,53)	110,61ef*** (3,33)	2,48a (1,16)	3,98a (1,93)

*Groups with same letters in column indicate that there is no statistical difference ($p < 0.05$) between the samples according to Duncan's multiply range tests which were performed separately for each group.

** The values in the parentheses are standard deviations.

*** Because UV filter is not used, the results are more than a hundred.

Figure 3 shows ΔE values of all samples. There were no apparent differences between the WPP and antimony trioxide for ΔE. As you can see Table 6, all samples are taken part into so little differences group. It was observed that ΔE is not significantly changed by the addition of 5 wt % of antimony trioxide ratios. However, the addition of antimony trioxide content above 5 wt%, ΔE decreased gradually. ΔE was found to be 2,38-2,44 for WPP with applied by 10% antimony trioxide, and 2,48-3,32 for WPP with applied by 5% titanium dioxide. While titanium dioxide ratios increased, ΔE increased slightly. The reason of this is that titanium dioxide improves brightness and smoothness (Stoneburner, 2014).

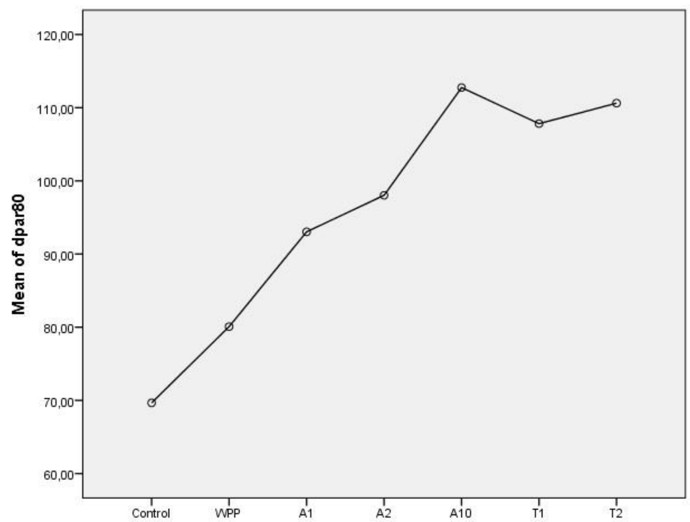

Figure 2: Brightness values (80°) of the samples

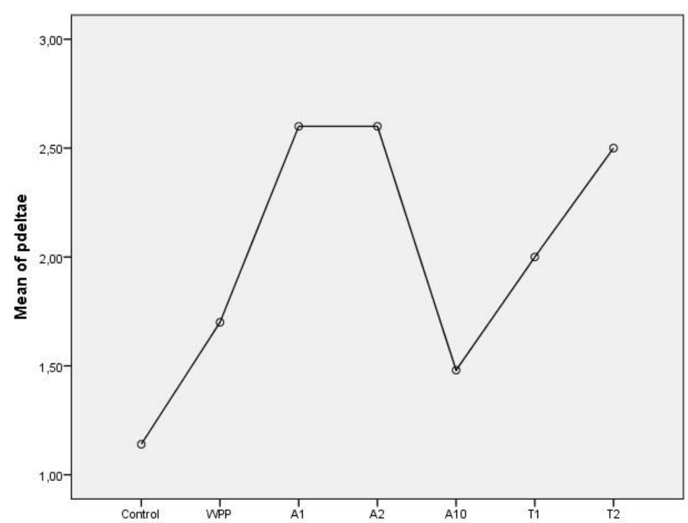

Figure 3: ΔE values of the samples

Table 6: Color ΔE differences (Heidelberg, 2008)

0-1	Unseen differences
1-2	So little differences
2-3,5	Intermediate differences
3,5-5	Apparent differences
>5	Obvious differences

3.3 Surface Roughness

Table 5 and Figure 4 indicates R_z values of the samples. The highest R_z value of 8,90µm was found for control sample. R_z values of WPP samples with added antimony trioxide were decreased ranging from 2% to 10%. R_z values of WPP samples with added titanium dioxide were also reduced ranging from 2% to 5%. The minimum R_z value was found for A10 samples while the control had the highest R_z value which was indicated by statistical test. Both WPP samples with antimony trioxide and titanium dioxide for the minimum R_z value resulted in 2,78 µm and 3,98 µm, respectively. The quality of coating applied to surface of wood which being a nonhomogenous material is affected by several factors such as roughness, porosity, species, density and interaction between coating and the substrate (Cheng and Sun et al., 2006; Ozdemir et al., 2015). The component of used fire retardants chemicals would be considered one of the mentioned factors influencing roughness as well as bonding between wood preservative paint and the pine wood surface in this study.

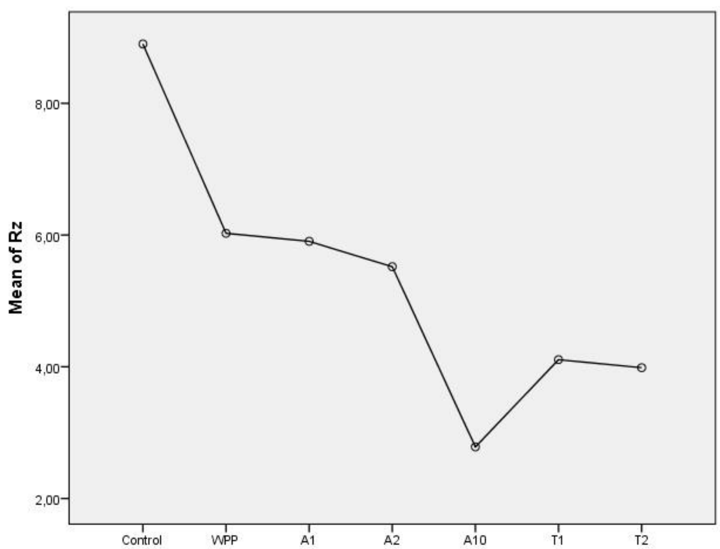

Figure 4: R_z values of the samples

3.4 Physical Properties

The water absorption and thickness swelling results of samples after immersion in distilled water for 120 hours are given in Figure 5 and Figure 6. It was seen that the increasing of water immersion time resulted in WA and TS values to increase for all samples. While the water absorption and thickness swelling of control sample were higher than those of painted samples. The usage of antimony trioxide and titanium dioxide decreased WA and TS. The minimum value for WA was achieved from T2 sample. It is known that fire retardant chemicals prevent the samples to intake water by penetrating to the lignocellulosic material (Donmez et al., 2016). Some researchers have reported that fire retardants such as zinc borate, aluminium trihydrate, aluminium trihydroxide, sodium aluminate) reduced water absorption and thickness swelling (Gnatowski and Burnaby 2005;Hashim et al., 2009;Donmez et al., 2016).

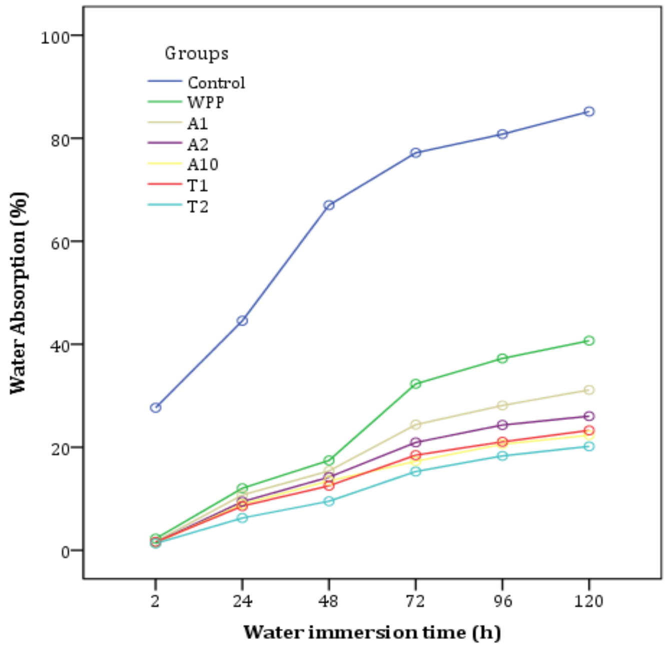

Figure 5: Long-term water absorption of the samples

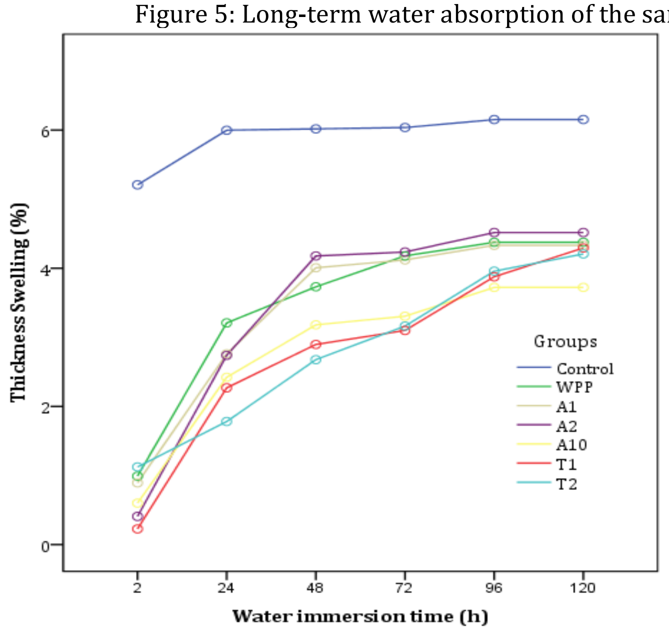

Figure 6: Long-term thickness swelling of the samples

4 CONCLUSION

The reaction to fire properties, surface and physical properties of the samples with various loading antimony trioxide and titanium dioxide were studied in this work. The LOI results showed that pine wood surface painted with antimony trioxide and titanium dioxide had affirmative effects in comparison with control and WPP. A1, A10, T1 and T2 were in class of "fire retardant material" according to ASTM D 2863. Using A10 as a fire retardant exhibited the best result in terms of fire performance. As the increase in ratio of used chemicals for real fire test, it was concluded that the char weight of the samples was decreased. The long-term thickness swelling and water absorption values of painted with the chemicals have given better results than control. The ΔE of samples painted by using antimony trioxide and titanium dioxide did not change significantly. Increasing titanium dioxide has little improved the ΔE. The brightness value of samples increased while increasing ratio of chemicals. However, R_z values of the samples painted using antimony trioxide and titanium dioxide had a lower in comparison with control and WPP. With an increase in antimony trioxide and titanium dioxide loading, the R_z values decreased slightly.

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Formaldehyde Emissions and Effects On Health During Arrival of Furniture to Ultimate Consumer

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People spend most of their time in closed areas such as home, office, school. For this reason, indoor environment pollution has great importance for human health. In this environment, the formaldehyde gas in the indoor furniture produced by the synthetic resin made from the panels is gradually released into the living spaces. The indoor concentration of formaldehyde gas in ppm is higher than the international standard, that is, the comfort limit value accepted by the western countries, which causes considerable damage to human health, especially to children.

In this study; formaldehyde emission values of five different companies' wood-based panel products determined by three different methods in Turkey and in 50 furniture manufacturing facilities, 50 furniture stores, 50 new apartments; formaldehyde gas analyzes have been performed. As a result; on average, furniture manufacturing 0.45 ppm, in furniture store 0.37 ppm, in new apartments 0.11 ppm formaldehyde gas release has been measured.

Keywords: Formaldehyde, Furniture, Particleboard, MDF, Human health

1 INTRODUCTION

The simplest member of the aldehyde group, formaldehyde (H2C = O), is technically produced by the oxidation of methane and methanol. Formaldehyde can be generally described as a colorless, unscented substance. In forest products industry, urea is widely used as an adhesive in the production of wood-based composite materials such as chipboard, plywood and fiberboard by being condensed with melamine and phenol resins (Şahin, 2005).

Formaldehyde is classified by the International Agency for Research on Cancer as Group 2A as a carcinogenic substance (Soysal and Demiral , 2007). Studies have shown that formaldehyde contributes to the development of nasal and upper respiratory cancers and skin cancer (Muzi et al., 2004). The amount of formaldehyde in indoor environments is important because of the health effects and the common occurrence of indoor living areas as pollutants. Formaldehyde gas can enter the respiration of living things, the mouth and the skin through contact. In general, when the formaldehyde concentration exceeds a certain level and those suffering from formaldehyde may have complaints such as fatigue, headache (Emri et al., 2004).

Formaldehyde can be formic acid in the human body and is excreted in the urine. However, if formaldehyde is present in excess of a certain amount (> 1 ppm) in the human body, significant problems may occur in the central nervous system and respiratory tract(Emri et al., 2004).

Formaldehyde-based glues are preferred in the forest products industry due to their low price and ease of use. In the production of composite panel board (chipboard, fiberboard, plywood), it is used as cross-linking material. The high reactivity of formaldehyde allows it to pass easily to the atmosphere when it is in free state. Therefore, during the use of furniture and composite panel products manufactured using formaldehyde-based glue indoors, depending on atmospheric conditions, it may become formaldehyde emission in time (Şahin et al., 2011).

In a survey of urban and rural areas in Ankara, for the reason that formaldehyde levels in the living room and kitchen are higher than allowed and health problems such as eyebrows, runny nose, dry throat in home residents, formaldehyde level has been determined statistically significant high(Aksakal et al., 2005). The permissible exposure limit (PEL) for formaldehyde as determined by the OSHA (Agency for Safety and Health at Work) is 0.75 ppm for the 8 hour time average (TWA) (Vaizoğlu, 1998).

57 workers working in 100 furniture manufacturing factories in the Siteler Industrial Zone in Ankara stated that they were exposed to formaldehyde levels above 0.75 ppm and 1% of 229 workers were exposed to formaldehyde levels above 0.75 ppm for more than 8 hours (Evci et al. 2002).

A statistically significant relationship has been found between the levels of kitchen formaldehyde and the frequency of the occurrence of eyebrows, dry throat and runny nose in people living in these houses; complaints of eyebrows, dry throat and runny nose in households that kitchen formaldehyde level higher than 0.10 ppm is more frequent than those living in houses with lower formaldehyde levels than 0.10 ppm (Evci et al., 2002).

Formaldehyde has an unpleasant odor. Formaldehyde gas has an irritant effect on the skin, eyes and lungs. Some irritant effects can now occur even below 0.75 ppm PEL, which is reported by OSHA as the legal boundary (Rosenstock and Cullen, 2005). The formaldehyde level should normally be below 0.03 ppm in closed environments (CPSC, 1997).

Standard methods for the determination of formaldehyde emissions;

If the formaldehyde emission is expressed as the mixing of the wood-based material in contact with the air after the production process by dissolving the formaldehyde in the ambient relative humidity, it has been mentioned in the scientific publications as the important and remarkable chemical. Formaldehyde emission caused by especially wood-based materials is important due to environmental and health effects(Mentese, 2009).

According to formaldehyde emission rates in forest products industry the classification of the panel board products is shown in table 1.

Table 1: Formaldehyde emission limits of wood-based panels

Emission Class	Board Type	Formaldehyde Measurement Limit Values	Test Metod
E1	MDF, YL, OSB	≤0.124 mg/m^3 (0.09 ppm)	EN 717-1- Chamber Method
		≤8.0 mg/100g	EN 120 – Perforator Metod
		≤3.5 mg/m^2 h	EN 717-2- Gas Analysis Method
E2	MDF, YL, OSB	>0.124 mg/m^3 (0.09 ppm)	EN 717-1- Chamber Method
		>8.0 mg/100g ≤ 30 mg/100g	EN 120 – Perforator Metod
		>3.5 mg/m^{2}h ≤ 8 mg/m^{2}h	EN 717-2- Gas Analysis Method

Various standard methods are used for the determination of formaldehyde emissions. The relevant European Union, Japan and ISO standards are briefly summarized below (Salthammer and Mentese, 2008).

European Union Standards;

EN 717-1 (2004): Determination of release of formaldehyde from wood-based panels-Part 1: Emission of formaldehyde by Chamber method (Chamber method)

EN 717-2 (1994): Determination of formaldehyde release in wood-based panels-Part 2: Release of formaldehyde by gas analysis method (gas analysis method)

EN 717-1 (1996): Wood-based panels-Determination of formaldehyde release-Part 3: Formaldehyde release by bottle method (Bottle method)

EN 120 (1993): Wood-based panels-Determination of formaldehyde content- (Perforator method)

Japanese standards;

Japanese standard methods are very similar to the European Union standard methods, but there are some differences in the volume of the rooms used and the areas of the test materials.

JIS A 1460 (2001) and JAS MAFF 233 (2003): Building panels: Determination of formaldehyde emissions-desiccator method (Desiccator methods).

JIS A 1901 (2003): Determination of volatile organic compounds and aldehyde emissions from building materials-small chamber method (Small Chamber Method).

ISO standard;

ISO.7CD 12460 (2005): Chamber method

The purpose of this study is to convey the current effects of manufactured products on human health determining the formaldehyde emissions at each stage until the final consumption of the products produced using wood based plates and to remark and contribute for the preparation of legal regulations and limits on formaldehyde emissions for finished furniture in Turkey.

2 MATERIALS AND METHODS

2.1 Material

Particleboards used for formaldehyde emission tests have been obtained from five different factories that makes production in Turkey. During sampling; 18 mm has been preferred which constitutes a significant part of the production of plants in Turkey. A plate with an average density of 620-650 kg/m^3 in white color and a melamine coated upper and lower side has been used at an average of 2100 mm x 2800 mm from each factory and it is stated as A, B, C, D, E before giving company names.

2.2 Method

Kastamonu Entegre whose formaldehyde emission from particle boards is Türkak 's accredited. (TS EN 717-1 (chamber method), TS EN 717-2 (gas analysis method) and TS EN 120 (perforator method).

In Ankara and Bursa Inegol as the most common furniture production in Turkey as well as in Kastamonu Center selected as the pilot region, emission measurement points are determined. Totally, In 50 furniture manufacturing plants and 50 furniture stores measurements have been made. In Ankara,20 furniture manufacturing facilities, 20 furniture stores, 20 furniture manufacturing facilities, 20 furniture stores in Bursa İnegöl Region, 10 furniture manufacturing facilities and 10 furniture stores in the central region of Kastamonu.

In the center of Kastamonu, which was chosen as the pilot region and mostly provide furniture from Ankara Siteler and Bursa İnegöl, measurements were made in kitchen and hall of 50 new offices ready to sit in October 2017. The kitchens of the apartments are 10 square meters, the living room is 20 square meters, the kitchen furniture is made of 18 mm white double face coated chipboard and the flooring is made as 8 mm laminate parquet.

In this research, GANK-4 Formaldemeter device was used to determine furniture production facilities, furniture store measurements and formaldehyde emission measurements in salons and kitchens in new houses (Figure 1). Furniture production facilities, furniture store measurements and formaldehyde emission measurements in the salons and kitchens of new homes were made from the exact midpoint and 1 meter above the ground. Before each measurement of formaldehyde emissions, the humidity and temperature of the environment to be measured were measured with the Loyia H100 digital temperature and humidity meter. All measurements were made at 23 °C and 45% humidity.

Figure 1: GANK-4 Formaldemeter device

3 FINDINGS

3.1 Findings of Formaldehyde Emissions from Particle Boards

Formaldehyde emission value belongs to five different companies which makes production in Turkey were determined by perforator method, chamber method and gas analysis method and the results are given in table 2.

Table 2: Formaldehyde emission values of chip board samples

Chipboard Producers	TS EN 120 Perforator Metod (mg/100gr)	TS EN 717-1 Chamber Metod (ppm)	TS EN 717-2 Gas Analysis Metod (mg/m^2h)
A	15	0.12	3.8
B	16	0.11	3.6
C	19	0.14	3.9
D	13	0.11	3.5
E	10	0.09	3.1

According to the results in Table 2, value of 10-19 mg/100gr were obtained as a result of the perforator method measurements. While the samples according to the chamber method gave a minimum of 0.09 ppm and a maximum of 0.14 ppm, the value obtained according to the gas analysis method were determined as 3.1-3.9 mg/m^2h. The results obtained from E company are the lowest result in the three measurement methods according to the other firms, while the samples taken from C company gave the highest value.

3.2 Findings of Formaldehyde Emissions in Furniture Production Sites

In furniture manufacturing sites, 20 in the Siteler region in Ankara, 20 in the Bursa İnegöl region and also 10 in Kastamonu, were measured. The values of the measurements made in Table 3 are given.

Table 3: Measured formaldehyde emission values in furniture manufacturing plants

	≤ 0.3 ppm		0.4-0.5 ppm		≥ 0.6 ppm	
	Number	%	Number	%	Number	%
Ankara	1	5	18	90	1	5
Bursa	3	15	15	75	2	10
Kastamonu	-	-	8	80	2	20
Total	4	8	41	82	5	10

According to the results in Table 3, the results of measurements made at randomly selected furniture production facilities located in the Ankara site area resulted in value of 0.4-0.5 ppm at 90% and value of 0.6 ppm and 5% at 5%. 75% of firms measured in Bursa İnegöl and 80% in Kastamonu region are between 0.4-0.5 ppm. According to all the results made in the furniture production facilities, 8% is measured as ≤ 0.3 ppm, 82% is measured as 0.4-0.5 ppm, 10% is measured as 0.6 ppm. The lowest value of 0.3 ppm and the lowest value of 15% were determined in Bursa İnegöl region.

3.3 Findings of Formaldehyde Emissions in Furniture Stores

In furniture stores, 20 in the Siteler region in Ankara, 20 in the Bursa İnegöl region and also 10 in Kastamonu, were measured. The mean value of the measurements made are given in Table 4.

Table 4: Measured formaldehyde emission value in furniture manufacturing plants

	≤ 0.3 ppm		0.4-0.5 ppm		≥ 0.6 ppm	
	Number	%	Number	%	Number	%
Ankara	10	50	9	45	1	5
Bursa	3	15	15	75	2	10
Kastamonu	4	40	5	50	1	10
Total	17	34	29	58	4	18

In Table 4, as a result of the measurements made at the randomly selected furniture production facilities located in the Ankara site area, 50% ≤ 0.3 ppm, 45% 0.4-0.5 ppm value are obtained, 5% Value of 6 ppm and above were obtained. 75% of the stores measured in Bursa İnegöl and 50% in the Kastamonu region are between 0.4-0.5 ppm. According to all the results in the furniture stores, 34% ≤ 0.3 ppm, 58% 0.4-0.5 ppm and 18% was measured as ≥ 0.6 ppm. In the most of furniture stores, It is stated that the customers entering the store say there is a smell in the store.

3.4 Findings of Formaldehyde Emissions in Newly Built Apartments

The value of the emission measurements made with the GANK-4 Formaldemeter are given in Table 5.

Table 5: Measured formaldehyde emission value in newly built apartments

Kastamonu	≤ 0.03 ppm		0.04-0.09 ppm		0.1-0.2 ppm		≥ 0.2 ppm	
	Number	%	Number	%	Number	%	Number	%
Kitchen	5	10	17	34	23	46	5	10
Living Room	3	6	18	36	22	44	7	14

According to the measurement results in the new apartments 10% of kitchens in apartments ≤ 0.03 ppm, 34% in 0.4-0.9 ppm, 46% in 0.1-0.2 ppm, 6% of halls ≤ 0.03 ppm, 0.4-0.9 ppm, 44% 0.1-0.2 ppm.

4 RESULTS

In Turkey, in particle boards provided by five different manufacturers and mostly preferred in furniture production, as a result of the perforator method measurements, according to TS EN 13986 standard, the formaldehyde emission class is E2 (> 8 mg/100gr). According to the chamber method, the samples of A, B, C, D with regard to TS EN 13986 formaldehyde emission class E2 (> 0.09 ppm) and the sample E is E1 (≤ 0,09 ppm). According to the results of the gas analysis method, company samples A, B, C are of formaldehyde emission class E2 (> 3.5 mg / m^2h) with regard to TS EN 13986 standard and sample E1 (≤3.5 mg/m^2h) of D and E firms. According to these results, D and E companies samples with E2 with regard to perforator method and E1 with chamber and gas analysis method.

The values determined as 8% for ≤ 0.3 ppm, 82% for 0.4-0.5 ppm and 10% for ≤ 0.6 ppm in the measurements made at the furniture manufacturing plants in Ankara Siteler, Bursa İnegöl and Kastamonu Center. In the furniture stores, in area where board panel furniture is exhibited 34% ≤ 0.3 ppm, 58% 0.4-0.5 ppm, and 10% ≥ 0.6 ppm determined. In the center of Kastamonu, measurements made in kitchens and halls of a newly built 50-apartment house, 10% of kitchens ≤ 0.03 ppm, 34% of 0.04-0.09 ppm, 46% of 0.1-0.2 ppm, 10% of ≥ 0.2 ppm, 6% of the halls are ≤ 0.03 ppm, 36% are 0.04-0.09 ppm, 44% are 0.1-0.2 ppm, 14% is ≥ 0.2 ppm are measuerd.

The Consumer Product Safety Commission (CPSC) has publicly declared that formaldehyde levels should normally be below 0.03 ppm in closed environments. As a result of the studies, all the measurements in furniture production facilities and furniture stores exceeded 0.03 ppm. In the results of measurements made in 50 newly built dwellings, only 6% was below 0.03 ppm.

5 RECOMMENDATIONS

Formaldehyde-based glues are widely used in the forest industry. Formaldehyde is a well-known indoor pollutant and affects everybody, from customer to consumer, in the indoor environment. In Europe, products are certified with Blue Angel, Ecolabel and E1 certificates and only products with formaldehyde emission class E1 are allowed to be produced and imported. In the US, products with CARB certification are certified and only products with a formaldehyde emission of 0.09 ppm are allowed.

The Turkish Standards Institute has been issuing E1 certificates since 2013.This document is not compulsory but is provided at the request of the firm. As a result of the study; the chipboards supplied from the 5 major producers in our country are above the E1 level.In addition, formaldehyde gas emission value of the furniture production area and composite panel plates, from the production process to the consumer, are considerably high.

Formaldehyde emission value determined for wood composite sheet products in our country should be more strictly controlled by the state and companies should be supervised in this regard. A standard that sets out the emission value of finished furniture products should be studied, the emission values of the products reaching the last consumer should be controlled by the government in terms of human health. In addition, the constructions on the furniture which reach the final consumer such as paint, coating reduce formaldehyde release. However;if these structures are worn out over time, the release will increase rapidly, so the supervisor to be brought must oblige E1 in the bare plate. It is important for these regulations to go into effect without losing time, in order to protect human health in the living spaces, especially for children who are our future guarantees.

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ABSTRACT

About two million employees lose their lives from work-related diseases or accidents every year. Further, 317 million employees suffer from work-related diseases and 337 million work-related accidents per year are estimated. The incidence rate of these work-related diseases or accidents varies according to sectors. The wood manufacturing sector is one of the risky sub-sectors within the manufacturing sector in terms of work-related hazards. Furthermore, the vast majority of enterprises, operating in the manufacturing sector, are of micro-scale. Such enterprises have to cope with many business constrains and their ability to control risks is lower. Therefore, the use of personal protective equipment (PPE) remains the ultimate tool for micro-scale enterprises to protect their employees from occupational diseases and accidents. In this study, the types of PPE used, their usage rates, the motivations for not using them and other issues related to PPE in the micro-scale furniture and sawmill sub-sectors were investigated. The study was conducted in 120 micro-scale enterprises in Trabzon, Turkey. A structured face-to-face questionnaire survey was used to gather information from the owner/employees of the enterprises. It has been revealed that the use of PPE in the enterprises producing furniture was higher than in the sawmill and the most prevalent reason for PPE usage was to protect the employees from wood dust. About half of the owner/employees did not indicate any reason for not using the PPE. However, the remaining stated that they did not use personal protective equipments (PPEs) because these often made it difficult to work.

KEYWORDS: Personal protective equipment, wood working, furniture, sawmill

1 INTRODUCTION

About two million employees lose their lives from work-related diseases or accidents every year. Further, 317 million employees suffer from work-related diseases, and there are an estimated 337 million work-related accidents every year (ILO, 2009). The incidence rate of these work-related diseases or accidents varies according to sectors. The wood working sector is one of the risky sub-sectors within the manufacturing sector in terms of work-related hazards. Beery et al. (2014) reported that the total recordable nonfatal occupational injuries of U.S. private manufacturing sector had the second highest rate in 2011. The wood manufacturing sector, as a sub-sector of the main manufacturing sector, was also ranked second place due to the incidence of about 3 million injuries/illnesses in all industries that year. In their review study, Hasle and Limburg (2006) stated also that sectors such as agriculture, construction, wood industry and printing bear an elevated risk. Bello and Mijinyawa (2010) reported that as a result of manual handling involvements in sawmilling operations, workers are exposed to higher safety risks associated with log handling and machine operations, environmental hazards, work-related body injuries and in extreme cases, fatal accidents.

One of the factors affecting occupational diseases and the frequency of work-related accidents is the scale of the enterprises. Ma and Yuan (2009) reported that the safety climate in large enterprises in China`s manufacturing industry was significantly better than that in small and medium-sized enterprises (SMEs) and that safety trainings were performed rarely in SMEs. Boustras et al. (2015) revealed that the frequency of accidents was higher in big firms, but the number of occupational accidents was the highest in micro sized enterprises in south Cyprus. Sinclair and Cunningham (2014) report that firms with less than 10 employees carried out fewer safety activities than those with 10 to 19 employees and larger firms. Mayhew (2000) and Boustras et al. (2015) reported that there was very little research on micro-firms and the European Agency for Health and Safety at Work periodically carried out the enterprise survey to which micro-firms were not included, respectively. Masi and Cagno (2015) revealed that the existing studies neglected the analysis of the differences existing between a micro enterprise and a medium-large enterprise and that little attention was paid to the difference between the micro-, the small- and the medium-sized enterprises. Micheli and Cagno (2010) reported that these three different sized enterprises were bundled together and considered as a whole in opposition to the large enterprises and suggested that bundling should be avoided. Micheli and Cagno (2010) studied the work-related accidents by classifying the enterprises such as micro, small, and medium sized, which were engaged in metal working sector in Lecco, Italy. They found that 51% of the accidents occurred in micro-, 23% in small-, and 26% in medium-sized enterprises. The distribution of accident rates, which resulted in 40 or more inoperable cases, was 67% in micro-, 16% in small- and 17% in medium-sized enterprises.

Hazards in the wood working sector can be grouped as health and safety hazards. Safety hazards that cause immediate injury to a worker contain kickbacks, machine hazards, material, flying chips, tool projection, explosion and fire hazards, as well as electrical hazards. Most of the health hazards involve long-term exposure to definite substances, to extreme vibrations or noise levels. Health hazards can cause both acute and chronic health effects. The main health hazards consist of the following items: “Noise, vibration, wood dust-carcinogens and chemical hazards-from exposure to coatings, finishing, adhesives and solvent vapors” (Web-1, 2018). Holcroft and Punnett (2009) have also defined the various potential risk factors in wood products manufacturing: equipment reach requirements; lack of equipment safety devices (e.g., machine guard openings, poorly designed tool handles, and machine guarding); weight and location of manually handled loads; shift work; overtime; rapid work pace; repetitive work; and machine-pacing. Other factors involve demographics, lifestyle behaviours and experience of workers, ergonomic hazards, poor working conditions and business size and type.

Methods for controlling hazards (elimination, substitution, isolation, engineering control, administration control and personal protective equipment) should be used. In these hazard control methods, the most effective method is the elimination of the hazard from the workplace and the PPE is the least effective method (Web-2, 2018). However, these methods, except PPE, are not applicable to small-scale enterprises because of their limited source. PPE should be viewed as the last method of defence to protect workers from harm when other methods may not adequately control hazards (Worksafe Victoria, 2007).

Meleko et al. (2017) revealed that the odds of work related injury was lower among those who used PPE than their counterparts. The respondents who did not use PPEs properly and consistently were 3.43 times more likely to sustain occupational injury than respondents who used PPEs properly and consistently (Berhe et al., 2015). Health and safety regulations alone will not reduce, if not eliminate, the work environment related accidents in the wood furniture industry (Ratnasingam et al., 2011).

Personal protective equipment (PPE) represents any device or garment worn by a worker on the job to protect himself against injuries and the harmful effects of hazardous substances. A wide variety of effective PPEs can be readily obtained to protect workers' respiratory tracts, hearing eyes and body parts (e.g., hands, arms, head, and feet). Some of the PPEs typically required in wood working facilities are hard hats, safety glasses, goggles, and face shields; gloves; padded kickback aprons, vests and arm, groin and leg guards; lower-back supports; steel-shanked, steel-toed safety shoes with slip-resistant soles; earplugs and earmuffs; particulate-resistant and/or chemically resistant overalls; and respirators (Web-3, 2018).

According to the regulation on the use of PPEs at the workplace, they are provided free of charge by the employer and have to be kept in sufficient quantities in places where employees can easily reach in Turkey (Resmi Gazete, 2013). Unnikrishnan et al. (2015) reported that using PPE was one of the simple methods that could be easily put into practice without high capital cost. Protective clothing and equipment are a common risk control for employees exposed to chemicals, fumes, vapours or dusts. However, it is not advised to rely on protective clothing and equipment to control risk as it may not properly protect all employees from risks and can create new ones. As far as possible, control methods, except for the use of PPE, should be used to manage risks arising from the use of chemicals, fumes, vapours or dusts (Worksafe Victoria, 2007).

The law on occupational health and safety was enforced in 2012 and was applied to all kind of jobs and enterprises. The regulation on the use of PPEs at workplaces was enforced one year later in Turkey. According to this regulation "PPE is used when the risks cannot be prevented by technical measures or work organization and working methods and cannot be limited exactly. PPE is used to prevent occupational accidents or occupational diseases, to protect employees from health and safety risks and to improve health and safety conditions. The employer gives priority to collective protection measures and personal protection measures" (Resmi Gazete, 2013). Although there are legal regulations on the occupational health and safety in most countries, there are a number of studies reporting that small enterprises have issues to adhere to requirements of regulations (Hasle and Limborg, 2006).

The purpose of this study was to reveal the actual situation of the usage of PPEs and the barriers to their usage in the work environment of micro-scale enterprises in the wood working sectors, furniture and sawmill.

2 MATERIAL AND METHOD

2.1 Material

Micro-scale enterprises operating in the wood working sector are selected as the material. Occupational accidents and occupational diseases are at an increased risk in the enterprises covered by micro-scale wood working enterprises. In addition, only a few studies in literature have been conducted on micro-scale enterprises; therefore, the micro-scale sawmill and furniture sector in the province of Trabzon have been chosen for our study. The number of enterprises operating in the wood working sector in Trabzon according to the latest census conducted in industrial and workplace in Turkey in 2002 was 822. Among these, 98.3% of these enterprises were micro-scale. The number of the enterprises in the sawmill and furniture sector in Trabzon corresponded to 1.3% in Turkey (Web-4, 2015). By assuming that the results of this census performed in 2002 were not up to date, Top et al. (2018) found that the number of businesses in these two sectors was 885 in their survey conducted. The professional chamber records were used to find this number. Of the 885 enterprises, 374 were in the sawmill sector and 511 in the furniture sub-sector.

2.2 Method

As survey method, face-to-face interview was used for data collection (Arikan, 2011). In the implementation of the questionnaire, stratified sampling, one of the probability sampling methods, was used. In this method, the main population is divided into subpopulations, and the samples are selected by simple sampling from these subpopulations. In simple sampling, each element of the population has equal chance of entering the sampling and the weight to be given to each element in calculations is equal (Kilic, 2012). Accordingly, the number of samples is calculated according to Eq. (1).

$$n=[N\times t^2\times p\times q] / [(N-1) \times D^2+t^2\times p\times q] \quad (1)$$

Here; *n*: the number of samples, *t*: Confidence coefficient (1.96 for α=0,05), *N*: Main Population (885), *p*: The probability of presence of the desired property in the main population was taken as 0.9 since with stratified sampling, the population was divided within itself into subspaces with higher homogeneity (Arikan, 2011; Israel, 1992), *q*: Probability of absence of the property desired to be measured in the main population (1-p=0.1) and *D*: ± sampling error accepted according to the probability of presence of the property desired to be measured in the population (5% sampling error for the study was accepted). Accordingly, the sample number (n) is calculated as 120. The stratified partitioning of this sample size is calculated as 50 for the sawmill sector and 70 for the furniture sector in proportion to stratum size.

Cross tabs were used in the presentation of the data. Chi-square tests were used to investigate the relationship between categorical variables. In these tests, two hypotheses were established as follows and the hypotheses according to the obtained p value were accepted or rejected at the 5% significance level.

Ho: There is no difference between variables ($p > 0.05$).

Ha: There is a difference between variables ($p < 0.05$).

3 RESULTS

The PPEs used in wood working micro-scale enterprises, covered by this study, are summarized according to the sub-sectors in Table 1. According to the total values of the two sub-sectors, the most commonly used PPEs were found to be (i) masks and gloves (at the same rate), (ii) safety goggles and (iii) work shoes, respectively. According to the sub-sectors, the ranking was found to be different. In the furniture sub-sector, the top three PPEs were masks, gloves and goggles. In the sawmill sub-sector the PPEs were ranked as gloves, work shoes and goggles sawmill. In addition, 14 enterprises in total declared that no PPE was used. The ratio of the enterprises not using PPE in total frequency (261) and in all enterprises (118) were 5.4% and 11.9%, respectively. Among the 14 enterprises not using PPE, 11 operate in the furniture sub-sector, which corresponds to 78.6%.

Enterprises using masks as PPE belonged majorly to the furniture producing enterprises (76.5%) and timber producing enterprises (23.5% in). Accordingly, the use of protective goggles was recorded with 60.4% and 39.6% in the furniture and sawmill sectors, respectively. When mask usage was assessed according to the sub-sectors, it was the most used PPE in the furniture sector with 37.1%; and in the lumber sector it ranked fourth with 13.2%. The ratio of enterprises (68) in both sub-sectors that declared that they use masks against wood dust was 57.6%. The ratio of work shoes and ear protectors was greater in the sawmill sector, 80% to 20%. Overall the use was the least with 2.3% in the total of all sub-sectors.

The relationship between the use of PPEs and the sub-sectors presented in Table 1 was tested using the Chi-square test of independence. The difference between goggles, not using and overalls and sub-sectors was statistically not significant. Their p-values were found to be greater than 0.05 ($p > 0.05$). However, the difference between the remaining PPEs in Table 1 and sub-sectors was statistically significant ($p < 0.05$).

Table 1: Distribution of PPEs used by employees by sub-sectors

	Furniture			**Sawmill**			**Total**	
	N[4]	**Row N %**	**Column N %**	**N**	**Row N %**	**Column N %**	**N**	**% of Total**
Mask	52	76.5	37.1	16	23.5	13.2	68	26.1
Protective gloves	34	50	24.3	34	50	28.1	68	26.1
Goggles	29	60.4	20.7	19	39.6	15.7	48	18.4
Work shoes	8	23.5	5.7	26	76.5	21.5	34	13
Not using	11	78.6	7.9	3	21.4	2.5	14	5.4
Helmet	2	15.4	1.4	11	84.6	9.1	13	5
Ear protector	2	20	1.4	8	80	6.6	10	3.8
Overalls	2	33.3	1.4	4	66.7	3.3	6	2.3
Total	140	53.6	100	121	46.4	100	261	100

Table 2 shows the motivation for the usage of the PPEs in the enterprises. 39% of owner/employees did not declare any reason why PPE was used and represents the biggest group. The second strongest reason for PPE use was protection from wood dust with 11.8%. While the motivation of PPE use to protect the eyes against wood dust reached 5.1%, the motivation to use PPE to protect the lungs against wood dust reached 2.2%. When PPE usages for different reasons against the wood dust were bond, it was found that 25.7% of the reason of PPE use in total was to be protected against the dust. The use of PPE against wood dust for different reasons was found to be 34.7% in the furniture sector and 14.8% in the sawmill sector.

[4] Frequency of responds.

Table 2: The motivations of the PPE use according to sub-sectors

	Furniture			Sawmill			Total	
	N	Row N %	Column N %	N	Row N %	Column N %	N	% of Total
No purpose has been declared	30	56.6	40	23	43.4	37.7	53	39
To be protected from wood dust	12	75	16	4	25	6.6	16	11.8
To protect hands	1	11.1	1.3	8	88.9	13.1	9	6.6
To protect eyes against flying wood chips	5	55.6	6.7	4	44.4	6.6	9	6.6
Masks and goggles used when too much dust	7	77.8	9.3	2	22.2	3.3	9	6.6
For safety	1	11.1	1.3	8	88.9	13.1	9	6.6
To prevent inhalation of paint and varnish	8	100	10.7	0	0	0	8	5.9
Against the danger of falling logs	0	0	0	8	100	13.1	8	5.9
To protect eyes from wood dust	5	71.4	6.7	2	28.6	3.3	7	5.1
To protect the lungs against wood dust	2	66.7	2.7	1	33.3	1.6	3	2.2
To prevent work accidents	2	100	2.7	0	0	0	2	1.5
To protect from a long haul	2	100.0	2.7	0	0	0	2	1.5
To be protected from noise	0	0.0	0	1	100	1.6	1	0.7
Total	75	55.1	100	61	44.9	100	136	100

The presence of ventilation systems used to remove wood dust from the work atmosphere is summarized in Table 3. The application referred to herein was the removal of dust or contaminants in the working environment by means of a ventilator mounted on the workplace wall. As shown in Table 3, the ventilator usage in the furniture sector was greater than the sawmill sector. 92% of the sawmill producers had no ventilation. However, during company visits it was observed that the sawmill enterprises comprise wider as well as bigger open spaces and natural ventilation. According to the Chi-square test results, there was no difference (p-value 0.095 greater than 0.05) between the sub-sectors and the absence of mechanical ventilation in the enterprises.

Table 3: Situation of ventilation applications by sub-sector

		Furniture			Sawmill			Total	
		N	Row N %	Column N %	N	Row N %	Column N %	N	% of Total
Is there ventilation?	No	56	54.9	81.2	46	45.1	92	102	85.7
	Yes	13	76.5	18.8	4	23.5	8	17	14.3
Total		69	58	100	50	42	100	119	100

Dust removal facilities attached on the machines collect the sawdust emitted during the wood processing, and this decrease the dust mass in the work atmosphere. Table 4 shows whether or not there were the sawdust removal facilities on the machines where material processed. In both sub-sectors, the usage rate of such equipment was found to be about 50%. There was no relationship between sub-sectors and ownership of dust removal facilities (p-value 0.875 greater than 0.05).

Table 4: Whether or not enterprises have a system that absorbs the dust emitted during cutting

		Furniture			Sawmill			Total	
		N	Row N %	Column N %	N	Row N %	Column N %	N	% of Total
Is there a dust removal facilities in workplace?	No	35	58.3	51.5	25	41.7	50	60	50.8
	Yes	33	56.9	48.5	25	43.1	50	58	49.2
Total		68	57.6	100	50	42.4	100	118	100

Situation of the enterprises had both mechanical ventilation and dust removal facility by sub-sector was found as shown in Table 5. From this table it can be seen that 31 of 68 enterprises producing furniture had neither mechanical ventilation nor dust removal facility attached on the machines. This corresponds to 45.6% of the enterprises. Only 13.2% of enterprises had both mechanical ventilation and dust removal apparatus attached on the machine. For the sawmill sector, this ratio was 2%. In total, only 8.5% of enterprises had both ventilation and dust extraction equipment.

Table 5: Existence of mechanical ventilation and dust removal systems in enterprises

		Dust removal facilities								**Total**			
		Furniture				**Sawmill**							
		No	**% of Sector**	**Yes**	**% of Sector**	**No**	**% of Sector**	**Yes**	**% of Sector**	**No**	**%**	**Yes**	**%**
Mechanical ventilation	No	31	45.6	24	35.3	22	44	24	48	53	44.9	48	40.7
	Yes	4	5.9	9	13.2	3	6	1	2	7	5.9	10	8.5
Total		35	51.5	33	48.5	25	50	25	50	60	50.8	58	49.2

Table 6 shows the motivation for not using PPE. In total, 48.5% did not provide any reason. This was followed by PPEs "pose an obstacle for comfortable movement" with 16.9% and "not be unaccustomed to using PPE" with 9.2%. The ranking of the recorded motivation for not using personal protective equipment was the same in terms of sub-sectors and total of sub-sectors.

Table 6: Reasons for not using PPE or problems during their usage

	Furniture			**Sawmill**			**Total**	
	N	**Row N %**	**Column N %**	**N**	**Row N %**	**Column N %**	**N**	**% of Total**
Unstated	34	54	44.7	29	46	53.7	63	48.5
To pose an obstacle for comfortable movement	13	59.1	17.1	9	40.9	16.7	22	16.9
Not be unaccustomed to using PPE	7	58.3	9.2	5	41.7	9.3	12	9.2
The mask sweats, gets dirty and makes breathing difficult	7	87.5	9.2	1	12.5	1.9	8	6.2
No protector is needed when work is less	4	66.7	5.3	2	33.3	3.7	6	4.6
Work shoes are disturbing	3	60	3.9	2	40	3.7	5	3.8
PPEs are disturbing in hot weather in summer	4	80	5.3	1	20	1.9	5	3.8
Gloves are causing the danger because they slip and prevent the material from being felt	2	66.7	2.6	1	33.3	1.9	3	2.3
Gloves cause employees to make mistakes	1	50	1.3	1	50	1.9	2	1.5
Overalls reduce productivity of employees	0	0	0	1	100	1.9	1	0.8
Goggles hinder working because they get dusty	0	0	0	1	100	1.9	1	0.8
Little dust is generated when material is wet and work is performed in an open area	0	0	0	1	100	1.9	1	0.8
Machines do not generate much dust	1	100	1.3	0	0	0	1	0.8
Total	76	58.5	100	54	41.5	100	130	100

Table 7 summarizes the situation of PPE use among the owner/employees who did or did not have a health problem related to their occupation. Among those, 9.8% did not use any PPE despite the fact that they have a health problem related to their occupation. The ratio of PPE use of those who declared that they had no health problem related to their occupation was 4.7%. The group of employees with health problems declared that the mask was the most frequently used PPE (38.5%) in the furniture sector and gloves and work shoes in the sawmill sector (25%).

Table 7: Personal protective use of owner/employees with health problems

	Furniture			Sawmill			Total		
	N	**Row N %**	**Column N %**	**N**	**Row N %**	**Column N %**	**N**	**Row N %**	**Column N %**
Gloves	3	30	23.1	7	70	25	10	14.9	24.4
Safety shoes	1	12.5	7.7	7	87.5	25	8	24.2	19.5
Goggles	1	14.3	7.7	6	85.7	21.4	7	14.9	17.1
Mask	5	71.4	38.5	2	28.6	7.1	7	10.3	17.1
Helmet	0	0	0	4	100	14.3	4	33.3	9.8
Earmuffs	0	0	0	1	100	3.6	1	11.1	2.4
Not used	3	75	23.1	1	25	3.6	4	28.6	9.8
Overalls	0	0	0	0	0	0	0	0.0	0.0
Total	13	31.7	100	28	68.3	100	41	16.1	100.0

21 of the interviewed owner/employees declared health problems. The names of individual health problems and their frequencies are summarized in Table 8. The most common health problems in total were hearing loss, backache, shortness of breath and allergies. The most common health problem was hearing loss, with 75% reported in the lumber industry. However, 88.4% and 73.5% of the interviewees in the furniture and lumber sector declared that they had no health problems, respectively. When the relationship between the sub-sectors and the presence or absence of health problems was tested, Ho was rejected with a p-value 0.037. This means that there was a relationship between these two categorical variables.

Table 8: Occupational health problems declared by the owner/employees

	Furniture			Sawmill			Total	
	N	**Row N %**	**Column N %**	**N**	**Row N %**	**Column N %**	**N**	**% of Total**
No health problem	61	62.9	88.4	36	37.1	73.5	97	82.2
Hearing loss	2	25	2.9	6	75	12.2	8	6.8
Backache	1	20	1.4	4	80	8.2	5	4.2
Shortness of breath	1	50	1.4	1	50	2	2	1.7
Allergy	1	50	1.4	1	50	2	2	1.7
Tinnitus	1	100	1.4	0	0	0	1	0.8
The problem of not seeing	1	100	1.4	0	0	0	1	0.8
Respiratory problem	1	100	1.4	0	0	0	1	0.8
Nasal discharge	0	0	0	1	100	2	1	0.8
Total	69	58.5	100	49	41.5	100	118	100

4 DISCUSSION

Employees are exposed to hazards at their workplace. Several factors affect the incidence frequency of these hazards. Two of these factors are the business segment and the scale of an enterprise. Considering these two factors, enterprises surveyed in this study were both within the wood working sector and the micro-scale business class, where the risk factors are more and the number of accidents is high. Various methods can be applied to protect employees from workplace hazards, but using these methods, except use of PPE, is not feasible for micro-scale enterprises due to some difficulties these micro-scale businesses have. For enterprises in this scale, the use of PPE is the only way to protect employees from hazards. However, among all possibilities PPE represents the most inefficient protection method as they may create new risks and work problems (Worksafe Victoria, 2007). In this study, enterprises working in the wood sector and being micro-scale in Trabzon province, were studied. It was found that the overall ratio of PPEs use was low. Jerie (2012) reported that in the wood processing industries the use of PPE was poor and inappropriate and workers received a pair of security shoes and two overalls from employer every year. Taha (2000) and Meleko et al. (2017) in their studies found that 61% and 62.6% of employees in small-scale industry did not use PPE, respectively. The reason for the differences between our study and others mentioned above may be sector where the sampling was performed. Taha (2000), and Meleko et al. (2017) selected the small-scale enterprises operating in the different sectors, not in the same sector for their study. Bello and Mijinyawa (2012) also reported that the use of PPEs like earmuffs and hand gloves was ignored when the machines were on and when the undressed timbers and logs were moved, respectively and that there was no protective measurement to safeguard the employees against the chemical emission emitted during the processing of some certain wood species.

Wood dust is a risk factor for asthma or asthma symptoms, nasal impairment, acute or chronic impairment of lung function and dermal effects, mainly dermatitis (Schlünssen et al., 2008). Furthermore, wood dust and the chemicals used for finishing products are health hazards to wood workers and may cause skin and respiratory diseases (Web-3, 2018). In the Estonian companies surveyed, some well-known hazards were still not controlled effectively. The main problems involved wood dust, noise, chemicals and poor lighting (Reinhold et al., 2015). It has also been confirmed in our study that wood dust was the most common problem for the enterprises. Especially in the furniture sector, where sheets products (e.g. medium density fiberboard and particle board) were used as raw materials, disposable mask was the most common PPE and its usage ratio was 57.6%. Verma et al. (2010) found that in their work in sawmill and veneer/plywood factories, personal protective use varied from enterprise to enterprise and the ratio of respirator use was 77%. Their study covered 35 enterprises, of which 8 (23%) were micro-scale. They also reported that disposable and half-face masks were used.

Reinhold et al. (2015) reported that noise is a great issue as it exceeded the limit value in many cases in the wood, printing and mechanical industries. Verma et al. (2010) reported that the legal limit of 85 dB(A) was exceeded in sawmill and veneer/plywood factories in Ontario. Sound level measurement has not been conducted in our study but it is estimated that the noise level was high. The fact that hearing loss case was the top ranked health problem also supports this assumption. However, in this study, the use of earmuffs against noise was found at the second lowest ratio. The usage rate of earmuffs was higher in the sawmill than the furniture sector. Top et al. (2016) reported that the usage ratio of earmuffs was 4.3% in micro scale wood-product enterprises in Gumushane, Turkey. When compared to our study, ratios of earplug uses were close.

A majority of owner/employees had poor knowledge on occupational health and safety issues. When asked "Why are you using a personal protective equipment?", the largest group comprised those who did not specify any reason. Verma et al. (2010) reported that very little was known about occupational safety and health in small firms. They divided the micro-scale enterprises into two groups with 1-5 and 6-9 employees. The micro-scale enterprises constituted 22.9% of the total number of enterprises. In our study, all enterprises were micro-scale (1-9 workers). The second biggest reason for using PPEs was to protect against the different harms of the wood dust in total. In terms of sub-sectors, PPE against wood dust had the second largest average in the furniture sector.

Engineering control method, which is the one of the hazard control methods, can be used to hinder rising the wood dust generated during wood processing into the work atmosphere. For example, dust removal facilities attached on machines for hindering wood dust into the work atmosphere and ventilators on the wall for removing the airborne wood dust from the work atmosphere to the outside can be used. Reinhold et al. (2015) reported that lack of local ventilation lie behind the accumulation of chemicals in the workplace air. If dust removal facilities and ventilators are not available or inadequate, using masks against wood dust hazard represent the only hazard control method remaining. In this study, it was found that enterprises were inadequate in terms of systems which will prevent rising the wood dust emitted during material cutting into the working environment and remove airborne wood dust from the work atmosphere. Approximately half of the furniture sector enterprises, where dust was a bigger problem, had neither mechanical ventilation nor dust absorbers on machines. Schlünssen et al. (2008) found that about 90% of wood processing machines in the Danish furniture industry had local exhaust ventilation. However, they reported that the presence of exhaust ventilation was not a measure of exposure and that proper ventilation reduced the exposure to dust. It was reported that there was no ventilation system in the 45 small-scale enterprises producing furniture in Bursa province, Turkey (Erdinc and Pala, 2009).

In this study, 12 different motivation were declared as reasons for not using PPEs. The top ranked reason was that no reason was declared (in Table 6). The second strongest reason was found as to pose an obstacle for comfortable movement. Another common reason was that employees were not accustomed to using PPE. Jerie (2012) reported that some workers worn nasal masks and others kept them on their heads because they found it uncomfortable. The reasons for complaints arising from PPEs may be that the equipment is inadequate or that the size of PPEs do not conform to the employees' body measurements.

Whether PPEs used were adequate, and fit each employee on an individual basis has not been investigated in this study.

A relationship between sub-sectors and the presence of the illness related occupation, which owner/employees had, was revealed in this study. In other words, health problems related to occupation in the sawmill sector were more frequent in Trabzon. Working in a sawmill is one of the most dangerous occupations in the United States (Web-3, 2018). 21 of the owner/employees have declared health problems which were thought to be caused by working conditions. Social Security Institution of Turkey reported that 4 and 3 insured employees in the sawmill and furniture sector exposed to occupational diseases in 2016 (Web-5, 2018). The difference can be interpreted in two ways. Either all the illness related occupations cannot be detected or the number of uninsured employees in this sectors is high. Brhel (2003) reported a similar situation for the Czech Republic and stated that occupational respiratory illnesses were more frequent than official statistics reported by related institution.

The most common occupational health problems in this study were hearing loss, back pain and respiratory disturbances, respectively. Erdinc and Pala (2009) reported that the most common complaints among workers exposed to wood dust were found as “itching eyes, redness of the eyes, nasal blockade and runny nose”.

5 CONCLUSION

The use of PPE for controlling hazards represents a viable method for small-scale enterprises. However, there are problems with the personal protective use in micro-scale enterprises operating in the sawmill and furniture sector in Trabzon, Turkey. Though wood dust is the most common risk factor in the workplace in the furniture sub-sector, ventilation methods, hindering distribution of wood dust into the work atmosphere or removing the airborne wood dust from the work atmosphere to the outside, and use of PPE are inadequate. The rates of the PPEs used by employees vary between sub-sectors. Sub-sector has no effect on the use of some PPEs (e.g., goggles, overalls), mechanical ventilation and dust removal facility. There is a lack of information about PPE use since a significant part of PPE users was not able to identify why they used PPEs. There are also problems, which arise during the use of PPEs, and these problems can be the reason for not using PPEs. Health problems that are thought to be caused by working conditions are much higher than the official statistics.

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AUTHORS CONTRIBUTIONS

Y.T. designed and administered the study, gathered and analysed the data, wrote the manuscript and acted as principal author. H.A. and M.O. helped in the data collection and the manuscript evaluation and acted as co-authors.

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ABSTRACT

Soluble transition metal oxide catalysts (polyoxometalates, POMs) have received special attention due to their importance in a variety of industrial, pharmaceutical and biological applications. They were originally proposed as activating agents for oxygen delignification of wood pulp. They can react selectively with phenolic lignin structures in cellulose fiber and that can be regenerated with oxygen gas.

We were able to develop new green catalysts based on a special class of POMs for selective oxidation of lignin from cellulosic pulps and natural fibers in one or two stages. The experimental results in lab, and pilot scale are very promising, the brightness is higher than 80 %.

KEYWORDS: Polyoxometalates, Bleaching, Cellulose Pulps, Natural Fibers.

1 GENERAL CONSIDERATION

The oxidation of organic substrates by hydrogen peroxide is very attractive for a synthetic and industrial viewpoint since this reagent is relatively inexpensive, of low equivalent weight, environmentally clean and easy to handle. The help of metal catalysts are often required and a considerable effort has been devoted to the search for new efficient metal derivatives suited to the purpose (Scheldon, 1990; Land and Burgess, 2002; Tamini and Yeganeh, 2002; Pope, 1983; Pope and Muller, 1994; Hill and Prosser-McCartha, 2000).

Soluble transition metal oxide- based catalysts such as molybdenum and tungsten have been developed for the oxidation with aqueous H_2O_2. Great effort has been devoted to searching for efficient catalysts that can activate but not decompose hydrogen peroxide.

Polyoxometalates are currently of considerable interest for a variety of organic compound oxidations with the environmentally acceptable hydrogen peroxide as co-oxidant. Dioxygen complexes of group 6 transition elements have been known long time ago, the chemistry of Peroxo compounds of the transition elements was thoroughly reviewed (Dickmann and Pope, 1994; Conner and Ebsworth, 1996).

Mo(VI) and W(VI) form an enormous variety of polyanions (isopoly and heteropoly species). Addition of H_2O_2 to the molybdate and tungstate aqueous solutions generally leads to the formation of the simple monomeric or dimer complexes. If the concentration of H_2O_2 is fairly low, polynuclear peroxo complexes can be isolated.

The chemistry of transition metal peroxo – compounds has received special attention due to their importance in a variety of industrial, pharmaceutical and biological studies. They are widely used in organic chemistry, biochemistry, and have been applied also in bleaching processes (Bailay et al., 1995; Sato et al., 1998; Jorgensen, 1989; Burton and Gillitt, 2002; Deubel et al., 2000; Thompson and Griffith, 1996; Taube et al., 2001; Taube et al., 2002).

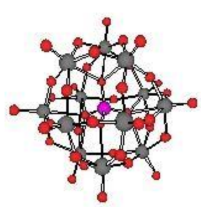
Polyoxometalates (POMs) were originally proposed as activating agents for oxygen delignification of wood pulp and have been widely investigate since (Weinstonck et al., 1996; Weinstonck et al., 1997; Sonnen et al., 1997; Evtuguin and Neto, 1997; Weinstonck et al., 1998; Weinstonck et al., 1999; Gaspar et al., 2004; Gamelas et al., 2007; Suchy and Argyupoulos, 2002). The starting point in POM bleaching research was originally to produce a biometric way of lignin decomposition. The activity of POMs is based on the idea that they react selectively with phenolic lignin structures in cellulose fiber and that they can often be regenerated with O_2. Moreover, POMs are remarkable stable at wide pH and temperature ranges. Although, POMs have been widely investigated, they have not applied in the wood pulp industry, this is most probably due to inefficiently and/or complexity of the processes presented.

The selective bleaching of wood pulp in conjunction with paper manufacture, one of the largest industries worlds – wide, has been associated with significant environmental impact. The industry has moved away from traditional Cl_2 based delignification process because of the potential environmental impact of chloro-aromatic by-products. The most attractive alternatives to Cl_2 based technology are O_2 and H_2O_2, both with respect to environment and economy (Atalla et al., 1998). Oxygen delignification can be considered as an intermediate step between kraft pulping and bleaching since up to about 50% of the residual lignin in kraft pulp can be removed by this stage. Extending a conventional O_2 delignification stage beyond it's currently limits would decrease bleach chemical demand with serious environmental benefits and significant increases on return on investment. Oxygen, while effective at depolymerizing and solubilizing lignin, is not sufficiently selective to fully delignify kraft pulp without extensive degradation (Evtuguin and Neto, 1997; Evtuguin et al., 1998a; Evtuguin et al., 1998b). One way to control the reactivity of O_2 is by using transition metal based oxidants reversible to meditate in the transfer of electron form lignin to oxygen, Ozon, while very effective at removing lignin, react rapidly with cellulose that high process selectivity is difficult to achieve on an industrial scale (Jorgensen, 1989).

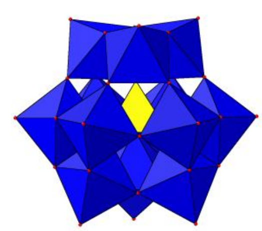
2 POLYOXOMETALATES

Polyoxometalates are a large and rapidly growing class of inexpensive, minimally or non- toxic complex compounds whose molecular properties are extensively modifiable through either additional or thermodynamic (one – pot) synthesis. They are comprised of early transition metals, usually in their d^0 electronic configurations (e.g Mo6+, W^{6+}, V^{5+} , …) bridged by oxygen's. The principal building blocks of POMs are MO_4 polyhedral or MO_6 octahedral that are linked one, two or occasionally three oxygen atoms. There are Two class of POMs: the isopolyanions. Which contain only the d metal cations and oxide anions and heteropolyanions, which contain one or more d and p cations, $X^{(n+)}$, in addition to the metal cations and oxide anions . All the physic-chemical properties of POMs that impact their applications in catalysis, material science, biology and medicine, including but not limited to redox potentials, acidities, polarities, solubility's, sizes, shapes and charges, can be readily and systematically altered. This versatility follows directly from the element composition and structures of the POMs, from the easy by which these can be modified.

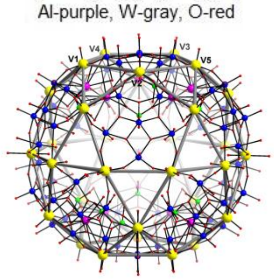
POMs are readily accessible synthetically because most of the p-, d- and f- block elements can function as the central "heteroatom", Xn+,in the general formula $XM_{12}O_{4}0^{(8-n)}$-, X^{n+} is located at the center of the tetrahedron inside the Keggin structure. Many of the d-, f- block metals can be substitute for one or more of the main metals, M, in the structure to give "mixed addenda anions". In the figure 1 are shown several polyoxometalates structure.



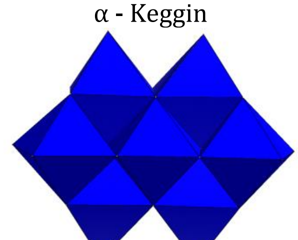
$[AlW_{11}O_{40}]^{6-}$ (Keggin)
Al-purple, W-gray, O-red



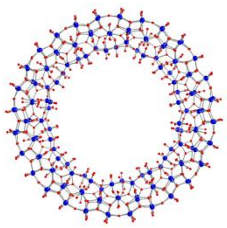
α - Keggin



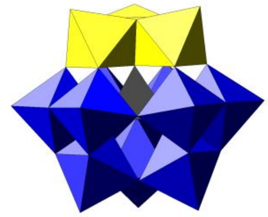
$Mo_{72}V_{30}$



Heptamolibdenate



Mo$_{154}$ball



β - Keggin 2

Figure 1: Atomic structure (left) and polyhedral (right) of polyoxometalate

Several attributes make POMs attractive for the bleaching and processing of cellulose pulps:

–POMs are readily prepared, often in a single step in water soluble oxoanions and suitable heteroatoms in acidic concentrations;

–most of the key physical properties of POMs that control their fundamental reactivities (redox potentials, acidities, charges, solubility's) can be controlled by choice of precursors and conditions;

–POMs are resistant to oxidation, many families of POMs can be reversible reduced, often by many electrons, in many cases, the reduced POM anions are ready oxidized by O_2.

–one of more of the d0 metal ions in the parent POM structure can be replaced by other d metal ions. In this way, it is possible to control the properties of POMs. These metal ion substituted POMs can remove electrons from organic substrates such as lignin and facile their transfer to O_2. The POMs used for the delignification of pulp must be reversible oxidants, capable of undergoing repeated cycles of reduction and reoxidation without degradation. The oxidized forms of POMs must have reduced potentials sufficiently positive to oxidative degrade lignin (enough positive to oxidize phenolic groups of lignin), while at the same time sufficiently negative such that re-oxidation with O_2 is possible (thermodynamically capable of transferring electrons from lignin to O_2).

The disadvantages of using POMs as catalysts for selective oxidation of lignin from pulps in the big quantity of the catalyst which is necessary in the delignification of pulp. Also, the slow reoxidation step limited the efficiency of the delignification, however, and their application as such is not feasible. POMs catalyst are not employed in wood pulp industry, due to the limited efficiency and process complexity, in particular the required high quantities of POM catalyst the needs to employed in stoichiometric amounts.

The process cycle delignification starts with the reaction of fully oxidized POM complexes under anaerobic conditions. At this stage, the POMs are reduced and oxidized lignin fragments are dissolved in the bleaching liquor. After the bleaching, the reduced POMs liquor can be reoxidized in a separate stage with O2. During the regeneration of the POM complexes, the dissolved lignins are converted to CO_2 and H_2O. The reaction are shown in the equations (1) and (2). Papers should use 10-point Cambria font. The styles available are bold, italic and underlined. It is recommended that text in figures should not smaller than 10-point font size.

$$\text{Pulp+POMPOM}_{ox}\rightarrow\text{Bleached pulp+ POM}_{red} \tag{1}$$

$$\text{POM}_{red}+ O_2+4H^+ \rightarrow\text{POM}_{ox} +2H_2O \tag{2}$$

The second generation of POMs has been developed. The first generations of POMs was able to operate only at acidic pH, the second generation of POMs is stable at pH level neutral. In this respect, the hydrolysis of cellulose is significantly reduced. Polyoxometalates $Na_6SIW_{10}V_2O_{40}$ was effective in reducing the kappa number of unbleached kraft pulp from about 30 to below 10 with limited loss viscosity.

The third generation of POMs operate under aerobic conditions (Evtuguin and Neto, 1997; Evtuguin et al., 1998a; Evtuguin et al., 1998b). The oxidation of lignin under an oxygen atmosphere occurs via its reaction with POM while at the same stage the reoxidant of a reduced form of POM by O_2 takes place. The presence of such a redox cycle could conceivably offer good process efficiency.

3 PEROXO- POLYOXOMETALATES

Peroxo- polyoxometalates (PPOMs) are a special class of POMS, which are widely used in stoichiometric and as well catalytic oxidants in organic chemistry and biochemistry (Jorgensen, 1989; Noygru et al., 2003; Adam et al., 2003; Arcoria et al., 1984; Wang et al., 2003; Mashewari et al., 2005). In particular, PPOMs are currently of considerable interest as catalyst for a variety of organic oxidation reactions with environmentally acceptable hydrogen peroxide as coactivating oxidants. Mo (VI) and W (VI) form an enormous variety of polyanions, addition of hydrogen peroxide to aqueous solution of MoO_4^{2-} and WO_4^{2-} ions, generally leads to the formation of the simple monomeric or polymeric complexes. If the concentration of hydrogen peroxide is keep fairly low, polynuclear complexes can be isolated

There has been much interest in the nature of isopoly species formed by acidification of aqueous solution of the MoO_4^{2-} and WO_4^{2-} ions, and a number if techniques have been applied to study these systems. It was showed that MoO_4^{2-} and WO_4^{2-} react catalytically with hydrogen peroxide in a basic aqueous solution form O_2 in quantitative yield through the intermediary of a diperoxo-dimetalate anions.

The ability of molybdate and tungstate to catalyze the acid hydrogen peroxide of kraft pulp was confirmed. The catalytic effect of molybdate was attributed to its ability to form under acidic conditions reactive diperoxo-complexes with hydrogen peroxide. Unfortunately the pronounced delignification observed was accompanied by sever viscosity loser.

We were able to develop new green catalysts based on special class of POMs for selective oxidation of lignin from cellulose materials (wood, agricultural wastes,…) and natural fibers (hemp, flax, ramie, nettle, jute…) (Sirghie et al., 2013; Patent, 2009a; Patent, 2009b; Patent, 2013; Patent, 2014).

4 EXPERIMENTAL

$Na_2MoO_4x2H_2O$, $Na_2WO_4x2H_2O$, MoO_3, WO_3, $NaOH$, H_3PO_4, H_2O_2 were used without further purification. The POMs were prepared according to know or little improved preparation (Pope , 1983).

The compounds were characterized by elemental analysis, thermogravimetry, FTIR, UV-VIS ad Raman spectra.

4.1 The bleaching of Eucalyptus pulp and hemp pulp

Were performed in two stages:

Stage 1: in a plastic bag 100 gr. Pulp was suspended in 1l water solution containing 0,01 gr. Catalysts, 1.5-2.0 gr H_2O_2,, the suspension was heated 1 hr. at 90 ℃ in a thermostat water bath without stirring. The suspension was cooled at room temperature, the pulp was filtered off, washed with small portions of water and the filtrate which contains catalysts, the concentration of the catalysts in aqueous solution was 0.05 M.

Stage 2: in a plastic bag, the pulp from stage 1 was suspended in 1L 0,1 N NaOH aqueous solution which contain 1.5 gr H_2O_2 and 2-3 gr Na_2SiO. The plastic bag with the mixture was heated 1hr. at 80 ℃ in thermostat water bath. After cooling at room temperature, the pulp was filtered off, washed with water at pH=6.0 and dry at room temperature.

The experiment results are presented in Table 1-2:

Table 14: The experimental results of bleaching Eucalyptus

Nr. crt.	Catalysts	Kappa	Viscosity, ml/g	Brightness, %
1.	Eucalyptus O_2 bleached	10.9	1075	64.9
2.	$Na_2H_3PV_2Mo_{10}O_{40}$	8.3	778	72.5
3.	$H_4SiMo_{12}O_{40}$	8.1	760	74.3
4.	$MoO(O_2)_2$	2.3	870	77.2
5.	$WO(O_2)_2$	2.1	862	78.1
6.	$Na_2Mo_2O_3(O_2)_4$	1.7	806	85.0
7.	$Na_2W_2O_3(O_2)_4$	1.7	811	84.4

Figure 2: Right: unbleached Eucalyptus pulp, Left : bleached Eucalyptus pulp

The bleaching of hemp was made using the same method as for Eucalyptus bleaching. The experimental results are presented in Table 2.

Table 2: The experimental results of hemp bleaching with POMs

Nr. crt.	Catalysts	Kappa	Viscosity, ml/g	Brightness, %
1	Unbleached hemp pulp	12.2	987	38.8
2	$MoO(O_2)_2$	2.4	850	78.5
3	$WO(O_2)_2$	2.5	861	76.7
4	$Na_2Mo_2O_3(O_2)_4$	1.2	794	83.5
5	$Na_2W_2O_3(O_2)_4$	1.1	798	84.5

Figure 3: Left: unbleached hemp, Right: bleached hemp

4.2 Bleaching of hemp and flax fibers in two stages

Stage 1: In a plastic bag, 50gr. Flax and hemp fibers were suspended in 0.8L aqueous solution which contain 0.001 gr catalysts, 1.0 - 1.5 gr. Hydrogen peroxide, the suspension was heated at 90 °C in a thermostat water bath 1hr. without stirring. The suspension was cooled at room temperature, filtered off, washed with water. The filtrate which contain catalysts was kept for the regeneration of catalyst.

Stage 2: In a plastic bag the hemp/flax fibers from stage no. 1, were suspended in 1L aqueous solution of 0.1N NaOH which contain 2.0 gr hydrogen peroxide and 1.0 - 1.5 gr Na_2SIO_3. The suspension was heated for

1hr. at 90 °C in a thermostat water bath. The suspension was filtered off, washed with water till pH=6.0 - 6.5 and dry at room temperature.

The experimental results are presented in table 3:

Table 3: Bleaching of hemp and flax fibers with POMs

Nr. crt.	Catalysts	Brightness %	
		Hemp	Flax
1	Unbleached fiber	27.4	26.2
2	$MoO(O_2)_2$	78.4	78.2
3	$WO(O_2)_2$	79.3	80.1
4	$Na_2Mo_2O_3(O_2)_4$	80.2	81.4
5	$Na_2W_2O_3(O_2)_4$	80.7	80.8

5 BLEACHING OF CELLULOSE MATERIALS AND NATURAL FIBERS IN ONE STAGE

Chemical oxidations are produced by radicals with unpaired electrons. In most cases, these radicals have high reactivity and short time. Radicals such as singlet oxygen, superoxide and hydroxyl radicals can react with ligniocellulose biomass.

In air, oxygen exists in a ground state as triplet oxygen ($^3O_2$). Triplet oxygen is characterized by two unpaired electrons with unpaired electrons with parallel spins in the outermost orbital. Triplet oxygen can change to a singlet state when it absorbs enough energy to reverse the spin of one of its unpaired electrons.

Singlet oxygen has a pair of electrons with antiparallel spin in the same orbital.

Singlet oxygen, superoxide and hydroxyl radicals are the important products of the reaction between sodium hypochlorite and hydrogen peroxide:

$$H_2O_2 + NaOCl \rightarrow O_2 + H_2O + NaCl \qquad (3)$$

Superoxide and hydroxyl radicals are important intermediates between oxygen and hydrogen peroxide. These radicals can participate in the degradation of lignin and carbohydrates.

Singlet oxygen has stronger degradability of lignin than ground state oxygen and singlet oxygen photo catalyzing consumer little chemicals and it is environmentally friendly. Some studies use singlet oxygen for pulp bleaching in recent years, it is necessary to study deeply this subject and it will have promising practical applications in the future.

We found a special class of polyoxometalates (A. Botar, G. Craciun and G. Dutuc, Private Communication, 2017) which are very good catalysts for selective oxidation of lignin from cellulose material pulps wastes and bast fibers is quite different than in the case of using POMs as green catalysts.

Working the bleaching process in one stage at 40 – 50 °C temperature, the experimental results for bleaching of cellulose waste pulps and natural fibers are very promising.

Figure 4: Kraft pulp: one and two stages bleaching with POM

Figure 5: Hemp fibers: one and two stages bleaching with POM

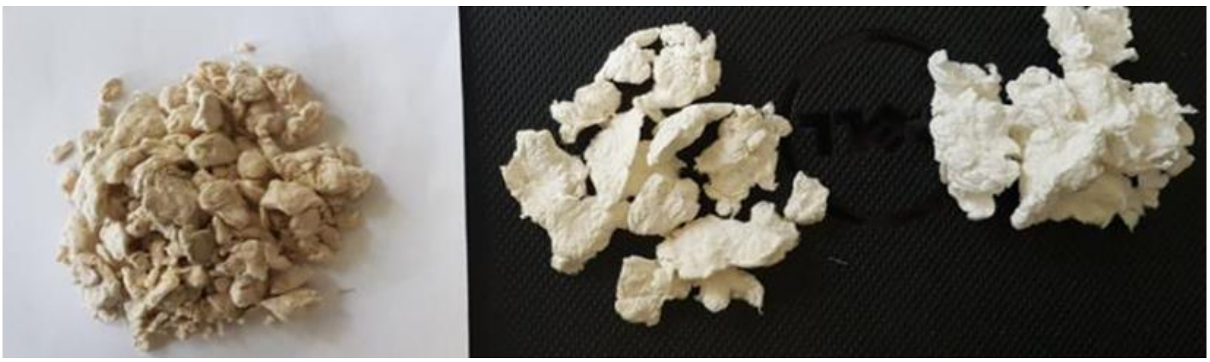


Figure 6: Wheat straw, soda O_2 natural pulp, one and two stages of bleaching with POM

Figure 7: Cotton linter natural fibers, one and two stages of bleaching with POM

6 RESULTS AND DISCUSSION

Polyoxometalates and especially Peroxo-polyoxometalates activated hydrogen peroxide, they can be considered as efficient and selective green catalysts for oxidation of lignin from cellulose materials and natural fibers.

There is a possibility to achieve brightness over 80% for the cellulose pulps and natural fibers using peroxometalates of Mo(VI) and W(VI) as green catalysts at a level of specific consumption of $1kg/to_{DBT}$. This can be achieved working in two stages without a significant decrease of bleached pulp viscosity. In the bleaching process of natural fibers using PPOMs of Mo(VI) and W(VI) as catalysts , the achieving brightness over 80% depends a lot of the presence of the mechanical impurities (sand, oil…) within the unbleached natural fibers. Therefore it is necessary the pretreatment of the unbleached natural fibers before of the bleaching process. The peroxometalates catalysts present in the filtrate of the first stage bleaching process, together with the dissolved lignin fragments can be easily regenerated with hydrogen peroxide treatment at a temperature of 70 – 80 °C. The lignin fragments are finally oxidized to CO_2 and H_2O. In the process of bleaching cellulose materials and natural fibers were used POMs isolated in solid phase, respectively directly synthetized in aqueous solution.

Because of economic reasons, in the pilot scale of cellulose pulps and natural fibers bleaching trials (samples of 20 – 30 kg), was used polyoxometalates catalysts directly synthetized in aqueous solutions the abstracts and full manuscripts are compiled into the conference Proceedings USB Flash disk.

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Effect of Glutaraldehyde, Waste Tea Wood Flours (WTWF) and Polycaprolactone (PCL) on the Some Properties of Thermoplastic Starch (TPS) Based Biocomposites

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ABSTRACT

In recent years, efforts to produce biocomposites that can degrade in the environment have increased rapidly. In this study, thermoplastic starch (TPS) based biocomposites were produced using waste tea wood flours (WTWF) as a lignocellulosic filler, glutaraldehyde (GA) as a the cross-linker and polycaprolactone (PCL) as an additional synthetic biodegradable polimeric matrix. The effects of lignocellulosic fiber (0 and 10%), glutaraldehyde (0- 5- 10%) and PCL (0 and 30%) were studied. GA and WTWF were added to the matrix based on wheat starch weight. PCL was added to the matrix based on thermoplastic starch weight. Density, tensile strength, tensile modulus, elongation at break, flexural strength, flexural modulus and impact strength of the manufactured samples were determined in accordance with ASTM D 792, ASTM D638, ASTM D790 and ASTM D256, respectively. Results showed that WTWF, GA and PCL had significant effect on the mechanical properties of the produced biocomposites. GA improved properties of biocomposites having no filler in it. Addition of PCL improved the tensile strength, flexural strength, elongation at break and impact strength while reducing density, tensile and flexural modulus values. On the other hand, mechanical properties of the composites were decreased with the rise of the GA amount in samples both WTF and PCL. Density values of the produced composites were decreased with the rise of the PCL and WTF amount. With the rise of the GA and WTF amount, impact strength of the composites was decreased.

KEYWORDS: Thermoplastic starch (TPS), glutaraldehyde, biocomposite, polycaprolactone (PCL), mechanical and physical properties

1 INTRODUCTION

Biocomposites are materials that can degrade in the environment. Recently the because of decreasing of natural resources and rising of environmental pollution, interest concerning biocomposite manufacturing from biodegradable polymers and organic materials increased. Some of these organic substances biodegradable polymers is and starch and polycaprolactone (PCL).

The starch is a organic material that composed of anhydroglucose units containing α-D-1-4 glycosidic linkages. The starch is a semicrystalline material having a crystalline structure of about 20-45%. Thermoplastic starch (TPS) is obtained by the application of heat, pressure, mechanical work or by addition of some plasticizers in the starch (Biliaderis et al., 1999; Lourdin et al., 1996; Lourdin et al., 1997). TPS products can be used to the place of non degradable petrochemical based products (Bastioli, 1998; Biliaderis et al., 1999; Tatarka and Cunningham, 1998; Willett and Shogren, 2002).

Polycaprolactone (PCL) was one of the earliest polymers synthesized in the early 1930s (Van Natta et al., 1934). Polycaprolactone (PCL) is an important polymer due to its mechanical properties and biodegradability. PCL is a hydrophobic, semi-crystalline polymer. Furthermore, its crystallinity tends to decrease with increasing molecular weight. Its low melting point (59–64 °C) and exceptional blend-compatibility has increased using of PCL in the biocomposite manufacturing.

In this study, effect of glutaraldehyde amount, lignocellulosic fiber loading, polycaprolactone (PCL) on thermoplastic starch (TPS) based biocomposites were investigated.

2 MATERIALS AND METHODS

Polycaprolactone (PCL) as a polymeric matrix, waste tea wood flours (WTWF) as a lignocellulosic filler and glutaraldehyde (GA) as the cross-linker were used in this study. Wheat flour and glycerol was used for TPS production. PCL was supplied Perstorp UK Limited in United Kingdom. Waste tea woods were provided from the local farmers in Rize/Turkey. These were granulated into fiber form using a Wiley mill and dried. Then, fibers screened and retained smaller fibers than 200 mesh-size screen, were used for manufacturing composite. GA was supplied from Sigma-Aldrich. Glycerol was supplied from Tekkim in Turkey.

2.1 Composite Manufacturing

The composition of thermoplastic starch based composites is shown in Table 1. Twelve different composites were manufactured. 500gr wheat starch, 600ml water and 200gr glycerol were mixed at 25°C and 200 rpm using a reactor for 30 min. Prior to gelatinization, 50gr WTWF for (TPS 7-8-9-10-11-12) groups and gluteraldehyde until 0-5-10% of wheat starch were added and were mixed at 180rpm for 20 min. The pH value of the mixture was adjusted to 4.0 by citric acid and was mixtured at 90°C for 25 min. Next, all mixture was placed in refrigerator bags and was gelatinized in hot water boiler at 90°C for 10 min. The gelatinized materials were cooled and cut in small parts. They were dried at 80 °C for 24 h. The dried materials were granulated by grinder. 30% PCL was added to TPS 4-5-6-10-11-12 groups. They were mixed with high-speed mixer (Teknomatik, Turkey), speed range 5–1000 rpm, for 5 min. All groups then were accomplished using a laboratory scale single screw extruder (Teknomatik, Turkey) to produce homogenous composite pellets. The extruder screw speed was set to 40 rpm and the temperature was set to 170 °C, 175 °C, 180 °C, 185 °C, and 190 °C for five heating zones. Pellets were cooled in water and granulated. Granulated pellets were dried at 80 °C for 24 h. These pellets then were compressed into a 4mm-thick 175 x 160mm panels at 220 °C temperature, 100 bar pressure and 10 pressing time. These panels were cut to the dimensions specified in the standards. After manufacturing, all tests samples were conditioned in a climatic room with the temperature of 20 °C and the relative humidity of 65%.

Table 1: The composition of thermoplastic starch based biocomposites

	Thermoplastic Starch (TPS)			**PCL**
Specimen ID	Wheat Starch	WTWF	Gluteraldehit	
TPS 1	100	0	0	0
TPS 2	100	0	5	0
TPS 3	100	0	10	0
TPS 4	100	0	0	30
TPS 5	100	0	5	30
TPS 6	100	0	10	30
TPS 7	100	10	0	0
TPS 8	100	10	5	0
TPS 9	100	10	10	0
TPS 10	100	10	0	30
TPS 11	100	10	5	30
TPS 12	100	10	10	30

Density, tensile strength, tensile modulus, elongation at break, flexural strength, flexural modulus and impact strength of the manufactured samples were determined in accordance with ASTM D 792, ASTM D638, ASTM D790 and ASTM D256, respectively.

3 RESULTS AND DISCUSSION

Table 2 show density values of manufactured samples. Density values of samples were determined as highest 1,449gr/cm^3 and least 1,272gr/cm^3. While addition of WTWF and PCL had statistically a significant effect (P<0,0001) on density values, GA loading had not statistically a significant effect (P=0,1431).

Interaction graph of density values was presented in Figure 1. X axis denoting the GA amount (%) while Y axis shows measured properties. Rectangular and triangle shapes present 0% WTWF samples and 10% WTWF samples, respectively. The density values of samples were decreased with addition of WTWF and PCL in the matrix. The reason for this is that density values of WTWF and PCL are less than density values of TPS.

Table 2: Density values of sample groups

Specimen ID	Density (gr/cm^3)
TPS 1	1,449
TPS 2	1,440
TPS 3	1,444
TPS 4	1,312
TPS 5	1,327
TPS 6	1,325
TPS 7	1,365
TPS 8	1,351
TPS 9	1,384
TPS 10	1,321
TPS 11	1,298
TPS 12	1,272

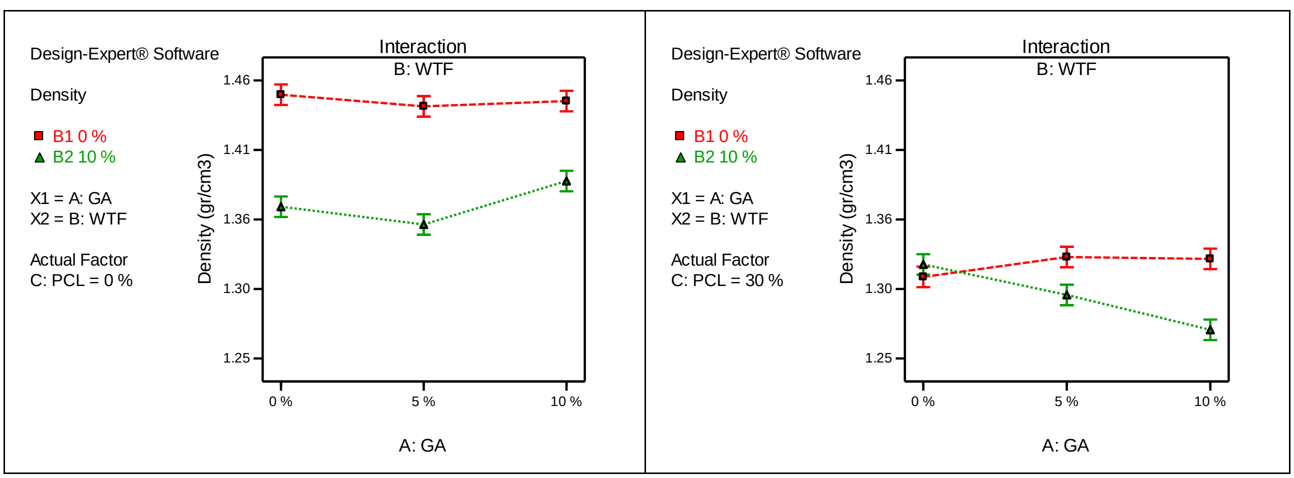

Figure 1: Interaction graph of GA, WTWF and PCL loading on density value

Mechanical properties of samples are shown in Table 3. Tensile properties include tensile strength, tensile modulus, and elongation at break. Tensile strength, tensile modulus, and elongation at break of the samples were in the range of 3,80–8,16 MPa, 119,11-800,05 MPa and 1,07-6,08 %, respectively.

Figure 2 shows the interaction graph of tensile strength. Statistical analysis showed that addition of WTWF and PCL had a significant effect on tensile strength, while GA loading had not a significant effect. The tensile strength values of samples were increased with addition of WTWF and PCL at samples with 0-5% GA, while were decreased with addition of WTWF and PCL at samples with 10% GA.

Table 3: Mechanical properties of sample groups

Specimen ID	Tensile Strength (MPa)	Tensile Modulus (MPa)	Elongation at break (%)	Flexural Strength (MPa)	Flexural Modulus (MPa)	Impact Strength (kj/m^2)
TPS 1	3,80	418,35	1,43	11,26	1415,93	1,65
TPS 2	4,68	400,65	1,70	13,24	946,11	1,39
TPS 3	6,65	545,97	1,53	15,11	1698,82	1,49
TPS 4	5,19	119,11	6,08	8,90	276,55	5,02
TPS 5	5,53	176,78	3,64	9,78	340,38	2,69
TPS 6	5,77	201,40	3,00	9,95	507,92	1,84
TPS 7	6,15	800,05	1,07	12,50	2396,07	1,36
TPS 8	5,83	648,04	1,16	10,62	2227,83	1,09
TPS 9	5,25	624,07	1,12	10,45	2362,84	1,16
TPS 10	8,16	445,84	2,17	14,79	1256,69	1,41
TPS 11	6,41	414,13	1,77	13,22	1081,08	1,19
TPS 12	4,58	387,57	1,46	10,32	1003,37	1,00

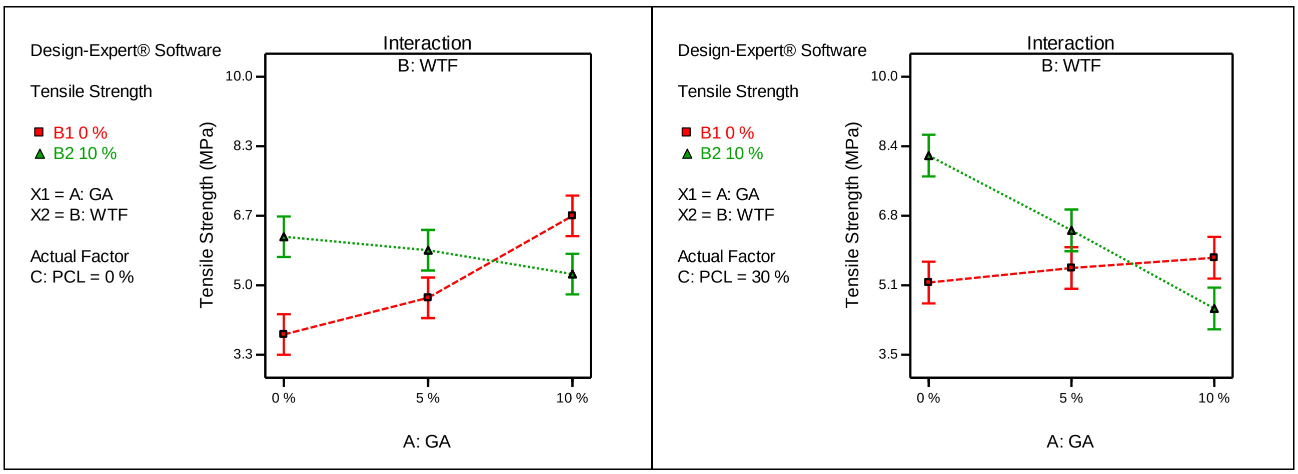

Figure 2: Interaction graph of GA, WTWF and PCL loading on tensile strength

Interaction graph of tensile modulus was presented in Figure 3. Addition of GA, WTWF and PCL had statistically a significant effect on tensile modulus. The tensile modulus values of samples were increased with addition of WTWF in the matrix, while were decreased with addition of PCL in it. This is because wood or lignocellulosic materials have higher modulus than thermoplastic polymer matrix Similar results for other studies were also reported (Klyyosov, 2007; Mengeloglu and Kabakci, 2008; Stark and Berger, 1997; Nunez et al., 2002; La Mantia et al., 2005). The tensile modulus values of samples were increased with addition of GA at samples with 0% WTWF.

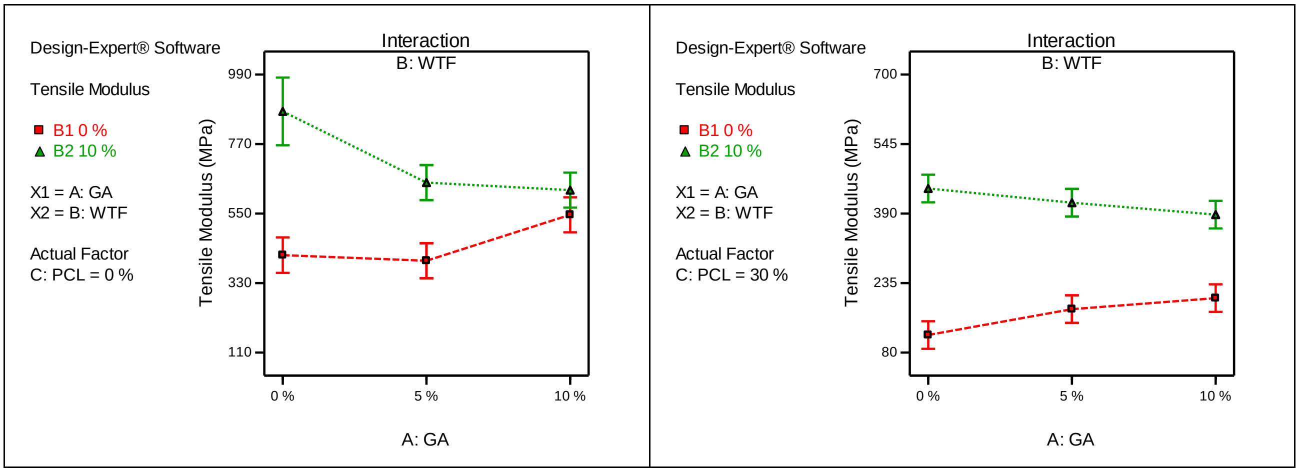

Figure 3: Interaction graph of GA, WTWF and PCL loading on tensile modulus

Figure 4 shows the interaction graph of elongation at break. Based on the statistical analysis, addition of GA, WTWF and PCL had a significant effect on elongation at break (P<0,0001). The elongation at break values of samples were decreased with addition of WTWF in the matrix, while were increased with addition of PCL in it. This is because manufactured composites became stiffer with addition of WTWF. Elongation at break values decrease usually with increased modulus in composites (Chan and Balke, 1997; Sain and Panthapulakkal, 2006). The tensile modulus values of samples were decreased with rising of GA loading at samples with 30% PCL.

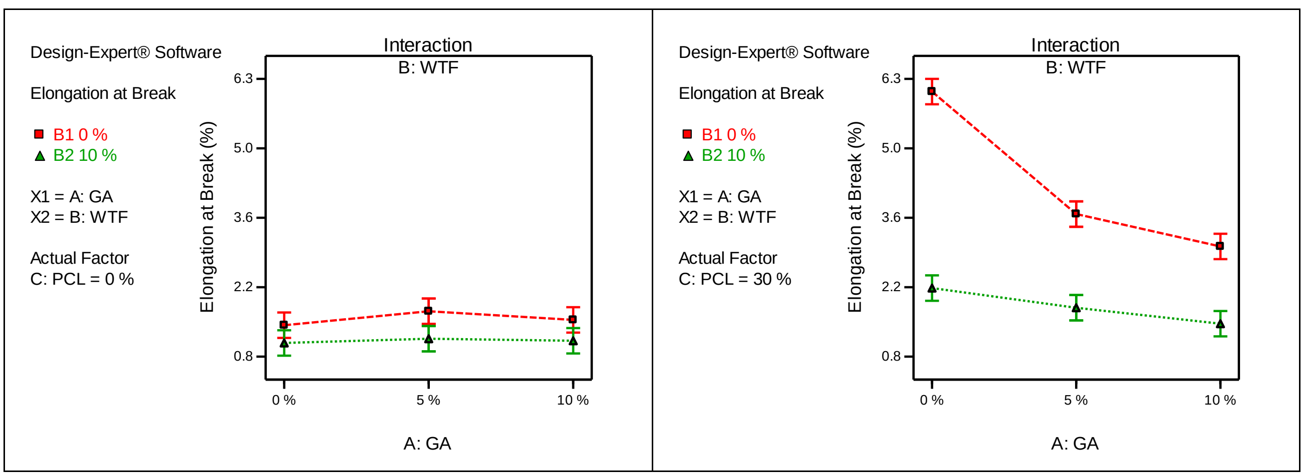

Figure 4: Interaction graph of GA, WTWF and PCL loading on elongation at break

Flexural properties include flexural strength and flexural modulus. Flexural strength and flexural modulus of the samples were in the range of 8,90–15,11 MPa and 276,55-2396,07 MPa, respectively. Interaction graph of flexural strength was presented in Figure 5. Statistical analysis showed that addition of GA and WTWF in the matrix had not a significant effect on tensile strength, while PCL loading had a significant effect in it. The flexural strength values of samples were increased with rising of GA loading at samples with 0% WTWF and 0-30% PCL, while were decreased with addition of GA at samples with 10% WTWF. The flexural strength values of samples were decreased with addition of PCL in the matrix. For polyolefin-based plastic lumber decking boards, ASTM D 6662 (2001) standard requires the minimum flexural strength of 6.9 MPa. The tested all samples provided the requirements of ASTM D 6662.

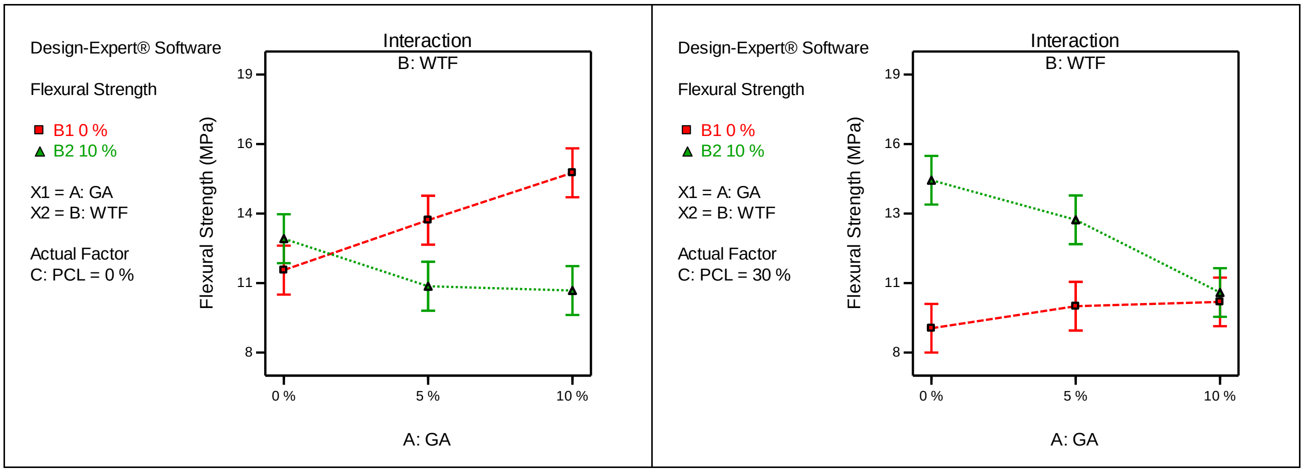

Figure 5: Interaction graph of GA, WTWF and PCL loading on flexural strength

Figure 6 shows the interaction graph of flexural modulus. Based on the statistical analysis, addition of GA, WTWF and PCL had a significant effect on flexural modulus (P<0,0001). The flexural modulus values of samples were increased with addition of WTWF in the matrix, while were decreased with addition of PCL in it. The flexural modulus values of samples were increased with rising of GA loading at samples with 0% WTWF and 30% PCL. The flexural modulus increase with addition of WTWF is because natural fibers have higher modulus than polymer matrix (Chaharmahali et al., 2010). ASTM D 6662 (2001) standard requires the minimum flexural modulus of 340 MPa. The other composites excluding TPS 4 provided the requirements of standards.

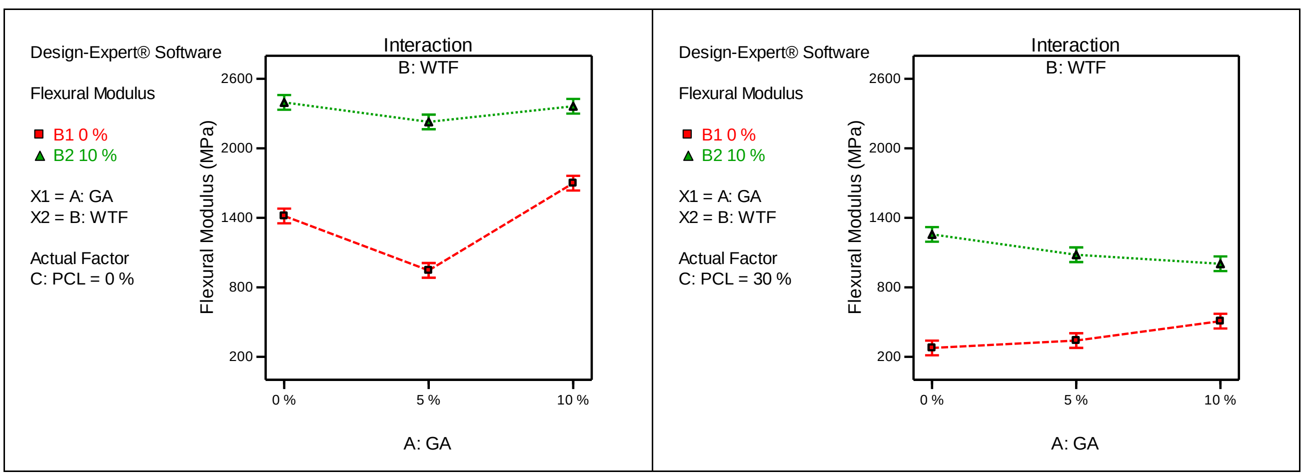

Figure 6: Interaction graph of GA, WTWF and PCL loading on flexural modulus

Interaction graph of impact strength was presented in Figure 7. Impact strength of the samples were in the range of 1,00–5,02 kj/m^2. Statistical analysis showed that addition of GA, WTWF and PCL in the matrix had a significant effect on impact strength (P<0,0001). The impact strength values of samples were decreased with addition of GA and WTWF in the matrix, while were increased with addition of PCL at samples with 0% WTWF.

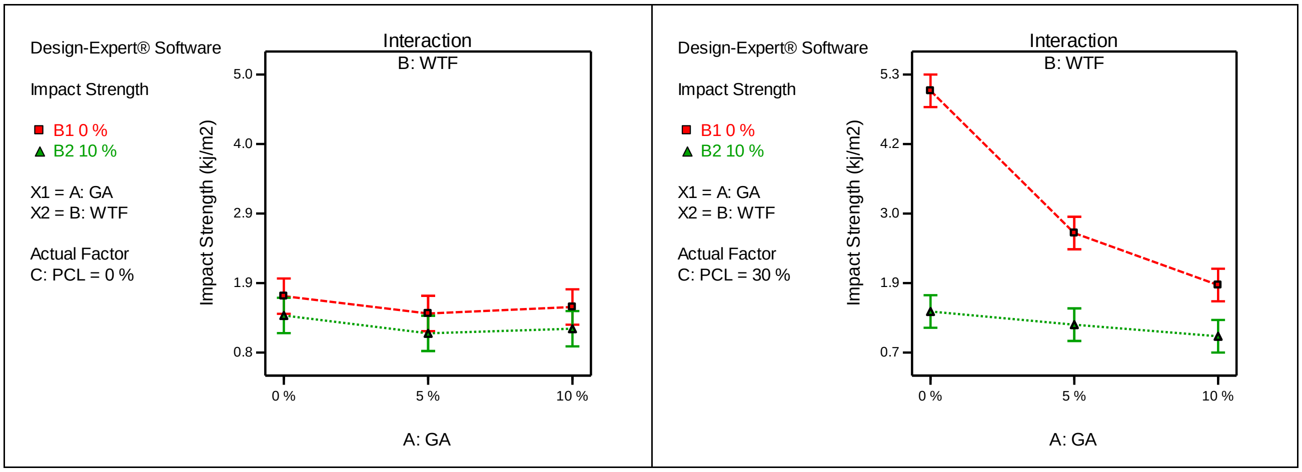

Figure 7: Interaction graph of GA, WTWF and PCL loading on impact strength

4 CONCLUSION

In this study, effect of glutaraldehyde amount, WTWF loading, PCL on thermoplastic starch (TPS) based biocomposites were investigated. Results showed that GA had significant effect on the tensile modulus, elongation at break, flexural modulus and impact strentgh of the produced biocomposites. WTWF had not significant effect on only flexural strength. PCL had significant effect of all mechanical properties. The tensile strength, tensile modulus, flexural strength and flexural modulus of samples were increased with addition of GA in samples with 0% WTWF. On the other hand, mechanical properties of the composites were decreased with the rise of the GA amount at samples with both WTF and PCL. Addition of PCL improved the tensile strength, flexural strength, elongation at break and impact strength while reducing density, tensile and flexural modulus values. Modulus values of composites were increased with addition WTWF in the matrix.

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ABSTRACT

The aim of this study is to develop durable and eco-friendly natural colorants by mixing liquid glass for the surface of wooden products and determine their desorption performance by leaching method. For this purpose, natural colorant was extracted from Licorice (*Glycyrrhiza glabra* L.), by ultrasonic-assisted method and mordanted with ferrous sulfate ($Fe_2(SO_4)_3.7H_2O$), aluminum sulfate ($KAl_2(SO_4)_3.18H_2O$), and vinegar (CH_3COOH). Wooden blocks were prepared from chestnut (Castanea sativa Mill.), mahogany (*Khaya ivorensis*) and Scots pine (*Pinus sylvestris* L.). Immersion and ultrasonic assisted methods were utilized for application of the dyestuff on the wood blocks. Leaching test application conditions included temperature (22 °C), pH (3, 7, and 11) and agitating speed (120 rpm).

The results showed that the leaching performance of some tested samples increased by percentage 96, 49 due to liquid glassed samples when compared with without liquid glassed (control) samples.

KEYWORDS: Natural dye, Licorice (*Glycyrrhiza glabra* L.), Liquid glass, Leaching

1 INTRODUCTION

Wood is the natural building material whose amount is constantly increasing. By using wood, the consumption of non-renewable materials can be reduced. Natural, renewable, and climate friendly, wood is a vital part of the green economy of the 21st Century. From home building to innovative uses in modern architecture, to the thousands of products we use every day, wood is a sustainable, green material that is truly our most natural resource (Web-1).

Beside many advantages of wood, it has some disadvantages too. It changes shape, because wood is a hygroscopic material. This means that it will adsorb surrounding condensable vapors and loses moisture to air below the fiber saturation point. Wood is suitable for discoloration, it can be decayed by biotic agents as fungi, bacteria and insects; and abiotic agents as sun, wind, water, certain chemicals and fire (Web-2).

Wood can be protected against biotic and abiotic agents by many protective materials. For the purpose of aesthetic and protection, many stain, coatings and paints are used which can ensure their long-term usage (Zhu, 2016). However, these protective and aesthetic materials for wood products have significant side effects on living things and environment. Generally, these synthetic materials contain “Volatile Organic Compounds” (VOCs) (Jinno, 2011). "Volatile" means that these chemicals evaporate or can easily get into the air at room temperature. "Organic" means these chemicals are carbon based. The term "chemical emissions" refers to VOCs as they evaporate into the air from products (Web-3). Unfortunately, these VOCs are hazardous for people and environment. Therefore, all of us face a variety of risks to our health as we go about our day-to-day lives. For short-term exposure, they can appear as eye, nose, and throat irritation, headaches, nausea/vomiting, dizziness, worsening of asthma symptoms. Additionally, for chronic exposures, they can be cause of cancer, liver, kidney and central nervous system damage (Wolkoff, 2001, Rennix et al. 2005). It has been determined that these solvents can cause miscarriages of pregnant womenbirth defects and children's learning disabilities (Web-4). It is stated that kids are more affected by VOC's since they have relatively higher respiratory rate, not established immune system, are closer to the ground, breathe more by mouth and not by nose. Therefore, children don't benefit from the advantage of nose filtering which is critical due to the fact that chemicals entering the body by high pulse rate diffuse to the tissues faster (Web-5).

Since early times, dyes derived from natural sources have emerged as an important alternative to synthetic dyes. Unfortunately, natural dyes, especially with the development of synthetic dyes in the 19th century largely lost its importance. However, in recent years, cases of cancer spread and became popular again with the love of nature natural dyeing and natural dyes has gained importance again (Güngörmez 2015). Recently international awareness of environment, ecology and pollution control created an upsurge on the interest of people to use more environmentally products. European Commission may induce European Union Member States to solicit the industries of paints, varnishes and flooring materials for taking measures, in order to reduce the VOC emissions resulting from the use of their products (Zhu, 2016). Avoiding further negative effects on sensitive people led to the development of zero VOCs emission that are natural dyes to satisfy for wood-based products. Natural dyes derived from flora and fauna are believed to be safe because of their non-toxic, non-carcinogenic and biodegradable nature.

Many researchers have investigated many efforts to reducing VOC's emission by various means. Goktas et al. (2008) investigated the development of environmentally friendly wood stains derived from laurel (*Laurus nobilis* L.), oleander (*Nerium Oleander* L.) Goktas et al. (2009)], madder root (*Rubia tinctorium* L.) Goktas et al. (2009)], walnut shell (Juglans regia) Goktas et al. (2008) extract and determined the color stability of the stains when exposed to ultra-violet (UV) light irradiation and. Theirs results showed that the extract provided some color stability after UV irradiation. Goktas et al. (2015) used walnut husk on wood materials and investigated the leaching performance of natural dye. Licorice (*Glycyrrhiza glabra* L.), Indigo (lsatis tinctoria L.) and pomegranate skin (*Punica granatum* L.) used as a natural colorant on wood samples and stained wood specimens were tested to evaluate the protection degree of liquid glass + natural stains against discoloration using cold check test. Researcher concluded that, natural colorants + liquid glass application provided very promising cold check test results as alternative colorants in near future (Goktas et al., 2014; 2017).

Licorice is a small perennial herb native to the Mediterranean region, central and southwest Asia. This herb is cultivated in Italy, Russia, France, UK, USA, Germany, Spain, China and Northern India (Parvaiz, 2014). Large-scale viable cultivation is seen in Spain, England and Sicily (Chopra, 1958) The dried, peeled or unpeeled underground stems and roots constitute the drug, known in the trade, as Liquorice is the major active constituent obtained from licorice roots, one of the most widely used in herbal preparations for the treatment of liver complaints (Dastagir, 2016). In literature studies, it has been reported that triterpene glycoside Glycyrrhizin acid is the primary coloring agent of the Licorice root (Arlı, 2002).

The licorice root and its extracts are used in soap making, textile, leather and chemical industry, metallurgy: Licorice foliage is used for manufacturing of watercolors, flourish, ink, blacking, shoe polish, leather tanning, foaming liquid for fire-extinguishers, dyeing wool and silk on the mordant in different tones, as bleach when simulating colors (Web-6, Güngörmez, 2015; Arlı, 2002). Licorice has been suggested as a natural dye after evaluation the color fastness to light of the plants were found as 3 and 6, to abrasion 2-3 and 4, toe wet spotting 3-4 and 4-5 dry water spotting 5 (Arlı, 2002). Licorice compounds found as natural materials for antimicrobial textiles (Alihosseini, 2016).

In this study, we have focused on the coloring wood material by Licorice (*Glycyrrhiza glabra* L.) extract+liquid glass and determined effect of liquid glass on leaching performance. Our theory was that, liquid glass could enhance the leaching performance of natural dye on wood materials. Because liquid glass is a strong hydrophobic material. Therefore, the research question of the study was "how effect the liquid glass on leaching performance against to leaching test".

2 MATERIAL AND METHOD

2.1 Materials

In this study, wood was prepared from chestnut (*Castanea sativa* Mill.), mahogany (*Khaya Ivorensis*) and Scots pine (Pinus sylvestris L.) Plant dyestuff was extracted from Licorice (*Glycyrrhiza glabra* L.) by ultrasonic-assisted method and mordant with ferrous sulfate ($Fe_2(SO_4)_3.7H_2O$), aluminum sulfate ($KAl_2(SO_4)_3.18H_2O$), and vinegar (CH_3COOH). For enhancing the durability of natural dye, liquid glass has been used.

2.2 Method

2.2.1 Preparing wood blocks

As wood material, Scots pine (*Pinus sylvestris*), chestnut (*Castanea sativa* Mill.), and mahogany (*Khaya ivorensis* A. Chev.) wood specimens commonly used in furniture and decoration industries in Turkey were chosen. The specimens were prepared from the sapwood parts of the first-class wood has smooth fiber, knotless and crack-free surfaces, no color and density differences, with annual rings perpendicular to the surfaces, in accordance with TS 2470 standards (2005). Wood samples prepared for leaching tests, by 19x19x19 mm dimensions and stored in climate cabinet at 20 ± 2 °C temperature and 65 ±5% relative humidity.

2.2.2 Natural dye extraction

For natural dye extraction procedures, an ultrasonic bath has been used. Sivakumar et al. (2011) suggested an improved method such as ultrasound to improve the major mechanism of natural dye extraction such as rupture the cell wall, release of natural dye and improve the transport of dye in to the external medium. Morever, it was found that the application of ultrasound can increase the extraction of dyes from different parts of various plant resources. So, for extraction process of this study, ultrasound assisted metod prefered. The Licorice (*Glycyrrhiza glabra* L.), was chosen as natural dye material and purchased from domestic market located in Turkey. Grounded plant's root particles mixed with distilled water having a 20/1 ratio of with 180W output power to a device is extracted in ultrasonic bath, (Elmasonic X-tra 150 H)) at 45 °C, for 180 minutes, Diminishing evaporation of water is brought to the initial level by the addition of water.

2.2.3 Dyeing of the wood

The extraction is filtered and mixed with mordant agents. Table 1 showed that the proportions of mordant agents. Air-dried wood specimens were placed into the dyebath container. The immersion method was applied for 60 min at 45 °C. Any extra solution left on the specimens was wiped with a clean cloth. Specimens were then left to air dry at 20±3 °C.

Table 1: Dye solution + mordant mixture ratios

Extracts	Mordant	Mixture (%)
Plant Extract	Control	0
	Ferrous sulfate ($Fe_2(SO_4)_37H_2O$)	3
	Alum ($Al_2(SO_4)_318H_2O$)	5
	Grape vinegar (CH_3COOH)	10

2.2.4 Leaching test

Leaching test application conditions included temperature (22 °C), pH (3, 7, and 11) and agitating speed (120 rpm). Residual dye concentration was determined using absorbance values measured before and after the treatment, at different (Table 2) nm with a UV spectrophotometer (Libra / Biochrom brand). Two wood samples from each group were placed into Erlenmeyer flask in 250 ml distilled water. Erlenmeyer flasks placed into shaking water bath (JSR/JSSP-30 T brand) during 120 minutes. In 5, 15, 30, 45, 60, 75, 90, 120 minutes, then some water was taken from Erlenmeyer to get amount of dye was absorbed into the water and measured by using UV spectrophotometer with reference to the maximum wavelength of each dye. Each experiment result was an average of five independent absorption tests.

3 RESULTS

UV spectrophotometer used in the leaching tests. Maximum wavelength and color intensity between wavelengths was determined for Licorice extracts and mordanting concentrations (Table 2). These parameters were used as a reference point to find adsorption of each colorant.

Table 2: Wavelength of dye

Type of Dye	**Max. wavelength (nm)**
Control (%100 Licorice)	213
Licorice +liquid glass	360
Licorice + Ferrous sulfate	201
Licorice + Ferrous sulfate+ liquid glass	357
Licorice + Alum	204
Licorice + Alum + liquid glass	356
Licorice + vinegar	217
Licorice + vinegar+ liquid glass	335

3.1 Leaching data of chestnut.

When examined Table 3, leaching data of chestnut at pH: 3, the Licorice + liquid glass (control) mixture leaching data is minimum (0,119 abs), and maximum leaching (2,486 abs) observed for control without liquid glass. At pH: 7, again the Licorice + without liquid glass (control) mixture leaching data is minimum (0,965 abs) for ferrous, and maximum leaching (3,296 abs) observed for vinegar without liquid glass. For pH: 11, the Licorice + liquid glass and alum mixture leaching data is minimum (0,265 abs), and maximum leaching (3,432 abs) observed for vinegar + without liquid glass.

Table 3: Leaching data (abs) of chestnut at 22 °C and 120 rpm

				Leaching time (min)						
		Dye extract	**Mordant**	**5**	**15**	**30**	**60**	**75**	**90**	**120**
chestnut	pH 3	Without liquid glass	Control	0,57	1,244	1,469	1,927	2,127	2,154	2,486
			Ferrous	0,362	0,553	0,673	0,839	0,994	1,062	1,199
			Alum	0,566	0,986	1,216	1,756	1,876	1,964	2,207
			Vinegar	0,784	1,085	1,427	1,833	2,013	2,163	2,416
		Liquid glass	Control	0,075	0,082	0,093	0,104	0,11	0,112	0,119
			Ferrous	0,076	0,085	0,095	0,111	0,117	0,123	0,133
			Alum	0,083	0,099	0,121	0,148	0,149	0,157	0,172
			Vinegar	0,107	0,135	0,163	0,196	0,208	0,22	0,24
	pH 7	Without liquid glass	Control	0,791	1,31	1,706	2,401	2,719	2,843	3,104
			Ferrous	0,239	0,359	0,506	0,677	0,774	0,839	0,965
			Alum	0,285	0,525	0,924	1,222	1,353	1,443	1,636
			Vinegar	0,972	1,463	1,888	2,515	2,754	2,944	3,296
		Liquid glass	Control	0,088	0,091	0,107	0,127	0,136	0,145	0,168
			Ferrous	0,073	0,081	0,088	0,099	0,105	0,11	0,119
			Alum	0,083	0,106	0,11	0,13	0,144	0,144	0,155
			Vinegar	0,126	0,164	0,204	0,253	0,276	0,297	0,33
	pH 11	Without liquid glass	Control	0,757	1,019	1,328	1,811	1,867	1,96	2,226
			Ferrous	1,713	1,79	1,855	2,029	2,037	2,062	2,162
			Alum	0,869	0,966	1,041	1,261	1,264	1,27	1,358
			Vinegar	0,932	1,445	1,944	2,626	2,919	3,021	3,432
		Liquid glass	Control	0,335	0,443	0,533	0,648	0,686	0,732	0,785
			Ferrous	0,204	0,227	0,256	0,276	0,29	0,299	0,309
			Alum	0,184	0,205	0,219	0,245	0,246	0,248	0,265
			Vinegar	0,282	0,358	0,42	0,492	0,528	0,572	0,625

3.2 Leaching data of mahogany

Leaching data of mahogany are given in the Table 4. According to results, leaching data of mahogany at pH: 3, the Licorice + liquid glass mixture leaching data is minimum (0,075 abs) (control-without mordant), and maximum leaching (0,833 abs) observed for alum without liquid glass. At pH: 7, again the Licorice + liquid glass (control) mixture leaching data is minimum (0,087 abs), and maximum leaching (3,296 abs) observed for control (without mordant) without liquid glass. For pH: 11, the Licorice + liquid glass and ferrous mixture leaching data is minimum (0,184 abs), and maximum leaching (2,076 abs) observed for ferrous + without liquid glass.

Table 4: Leaching data (abs) of mahogany at 22 ^{o}C and 120 rpm

				Leaching time (min)						
		Dye extract	Mordant	5	15	30	60	75	90	120
mahogany	pH 3	Without liquid glass	Control	0,167	0,445	0,491	0,573	0,609	0,621	0,664
			Ferrous	0,331	0,452	0,516	0,585	0,708	0,733	0,793
			Alum	0,392	0,528	0,598	0,716	0,763	0,8	0,833
			Vinegar	0,312	0,377	0,444	0,518	0,547	0,576	0,621
		Liquid glass	Control	0,067	0,068	0,07	0,072	0,073	0,073	0,075
			Ferrous	0,073	0,075	0,081	0,086	0,09	0,091	0,093
			Alum	0,077	0,085	0,091	0,096	0,099	0,1	0,105
			Vinegar	0,099	0,11	0,123	0,131	0,139	0,144	0,149
	pH 7	Without liquid glass	Control	0,972	1,463	1,888	2,515	2,754	2,944	3,296
			Ferrous	0,228	0,295	0,371	0,494	0,551	0,594	0,675
			Alum	0,398	0,438	0,512	0,633	0,679	0,723	0,813
			Vinegar	0,352	0,417	0,486	0,566	0,596	0,617	0,683
		Liquid glass	Control	0,071	0,072	0,074	0,082	0,083	0,086	0,087
			Ferrous	0,072	0,077	0,081	0,091	0,089	0,091	0,095
			Alum	0,077	0,083	0,088	0,094	0,102	0,103	0,108
			Vinegar	0,115	0,129	0,142	0,155	0,163	0,168	0,177
	pH 11	Without liquid glass	Control	0,471	0,565	0,64	0,772	0,789	0,809	0,846
			Ferrous	1,694	1,774	1,861	2,023	2,036	2,063	2,076
			Alum	0,83	0,909	0,98	1,083	1,12	1,126	1,127
			Vinegar	0,559	0,738	0,916	1,132	1,21	1,248	1,363
		Liquid glass	Control	0,221	0,245	0,269	0,291	0,306	0,316	0,336
			Ferrous	0,164	0,165	0,17	0,181	0,183	0,184	0,184
			Alum	0,163	0,17	0,174	0,182	0,185	0,19	0,194
			Vinegar	0,226	0,245	0,265	0,279	0,29	0,301	0,312

3.3 Leaching data of Scots pine

Leaching data of Scots pine is given in the Table 5. According to results, leaching data of mahogany at pH: 3, the Licorice + liquid glass (control) mixture leaching data is minimum (0,078 abs), and maximum leaching (1,323 abs) observed for alum without liquid glass. At pH: 7, again the Licorice + without liquid glass + vinegar mixture leaching data is minimum (0,919 abs), and maximum leaching (1,11 abs) observed for alum without liquid glass. For pH: 11, the Licorice + without liquid glass and ferrous mixture leaching data is minimum (0,188 abs), and maximum leaching (3,413 abs) observed for alum + without liquid glass.

Table 5: Leaching data (abs) of Scots pine at 22 °C and 120 rpm

				Leaching time (min)						
		Dye extract	Mordant	5	15	30	60	75	90	120
Scots pine	pH 3	Without liquid glass	Control	0,221	0,577	0,676	0,87	0,917	0,938	1,026
			Ferrous	0,368	0,592	0,691	0,885	1,052	1,125	1,233
			Alum	0,448	0,496	0,769	0,966	1,024	1,122	1,323
			Vinegar	0,372	0,604	0,612	0,743	0,798	0,87	0,943
		Liquid glass	Control	0,068	0,07	0,071	0,071	0,075	0,077	0,078
			Ferrous	0,071	0,072	0,077	0,084	0,085	0,087	0,092
			Alum	0,081	0,085	0,098	0,11	0,115	0,121	0,129
			Vinegar	0,095	0,114	0,131	0,146	0,156	0,162	0,176
	pH 7	Without liquid glass	Control	0,323	0,482	0,632	0,81	0,894	0,958	1,007
			Ferrous	0,293	0,442	0,593	0,797	0,909	0,983	1,078
			Alum	0,427	0,551	0,676	0,865	0,92	1,009	1,11
			Vinegar	0,369	0,507	0,591	0,746	0,783	0,855	0,919
		Liquid glass	Control	0,072	0,082	0,085	0,089	0,094	0,097	0,103
			Ferrous	0,077	0,079	0,086	0,09	0,094	0,099	0,103
			Alum	0,081	0,09	0,095	0,105	0,114	0,118	0,126
			Vinegar	0,109	0,127	0,151	0,177	0,193	0,202	0,217
	pH 11	Without liquid glass	Control	0,613	0,845	1,022	1,32	1,354	1,404	1,489
			Ferrous	1,653	1,81	1,946	2,207	2,228	2,235	2,294
			Alum	2,339	2,607	2,911	3,124	3,149	3,227	3,413
			Vinegar	1,002	1,349	1,708	2,11	2,248	2,381	2,519
		Liquid glass	Control	0,228	0,274	0,319	0,374	0,388	0,398	0,417
			Ferrous	0,162	0,165	0,178	0,179	0,183	0,186	0,188
			Alum	0,163	0,169	0,176	0,186	0,192	0,197	0,202
			Vinegar	0,22	0,243	0,268	0,304	0,327	0,344	0,363

4 CONCLUSIONS

In this study, effect of liquid glass has been investigated under different conditions by leaching method on stained wood material by Licorice (*Glycyrrhiza glabra* L.) extracts. Leaching test application conditions included temperature (22 °C), pH (3, 7, and 11) and agitating speed (120 rpm). For general evaluation, liquid glass, increased the leaching performance by 85, 32 % based on samples without liquid glass. The best performance gained on chestnut at pH: 3 by 90, 91% and the least level was observed on chestnut at pH: 11 by 77, 71 %. The dye desorption efficiency was affected by pH in the pH range of 3 -11. When we evaluate the general effect of pH degree on leaching performance, the course like that, pH 3 (0,778 abs), pH 7 (0,830 abs) and pH 11 (1,069 abs) is least effective. These results are compatible with literature (Yeniocak, 2018; Garg, 2004).

For mordant type, when we compare the data of hole control samples (without mordant), liquid glass enhanced the leaching performance by 71, 96 %. The best performance of liquid glass obtained with ferrous mordant with 87, 26 %, by comparing samples without glass. Between mordants, vinegar got lowest performance with 79, 70 %, by comparing samples without glass. Because of this, in wet environments, without additional protection measures, vinegar is not attractive mordant type against to leaching for licorice dyes on wood materials.

The mean leaching performances of wood types are ranked: Mahogany (0,519 abs), Scots pine (0,667 abs), and chestnut (0,890 abs). The best result obtained on Mahogany, on the other hand the worst result observed on chestnut. The value of mahogany is compatible with literature. Mahogany sawdust as a method used for dye removal from industrial effluents, acid yellow from wastewater, as an adsorbent (Malik, 2003).
The leaching performance of liquid glass by 85, 32 %, mostly meet our whole expectations. For whole preventing of leaching, liquid glass can be applied on wood samples in different proportions and separately with natural colorants. Natural dyes should be applied on wood materials because of their eco-friendly

properties, i.e., they do not create any environmental problems at the stage of production or use and maintains ecological balance.

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Evaluating Some Surface Properties of Thermally Compressed Paulownia Wood Materials

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EVALUATING SOME SURFACE PROPERTIES OF THERMALLY COMPRESSED PAULOWNIA WOOD MATERIALS

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ABSTRACT

The aim of this study is evaluating effect of thermal compression process on the some surface properties of Paulownia solid wood materials. The samples were exposed to thermal compression during 45 min. under different pressure (20 bar and 22.5 bar) and temperature (150°C and 170°C) levels. Totally four groups of thermally compressed samples were compared each other and with unmodified (control) group to evaluate the results. Roughness properties were determined with measuring arithmetical average roughness (Ra), maximum height (Ry), ten-spot average roughness (Rz), and root-mean-square deviation (Rq) according to JIS B 0601 standard. All roughness measurements were obtained at both parallel and perpendicular to grain. Wettability was determined with measuring contact angle (CA) changes according to time of the dripped droplet to the surface.

The obtained results indicated that wettability significantly changed according to control group. When the thermal compression process conditions were examined in detail, wettability results were similar in the change of pressure while, contact angle values was significantly increased with change of temperature. The another results indicated that surface roughness results changed significantly with thermal compression, only surface of 150°C - 20 bar condition group were similar with control group for all values at both direction. Otherwise, the samples exposed to 170°C - 20 bar condition were the lowest value especially perpendicular to grain direction. When results of the parallel to grain direction were investigated, the samples were only the lowest values in two measurements, while 150°C – 22,5 bar condition were the group had the lowest values in another measurements.

The results of this research revealed that thermal compression method could be used to change surface properties this fast-growing specie. Since the temperatures of the materials exposed to was close at thermal modification method, the study can be extended with trying these temperatures (such as 180 °C, 212°C) used.

KEYWORDS: Thermal compression, Paulownia, Wettability, Contact Angle, Surface Roughness

1 INTRODUCTION

- Fast-growing tree species and their woods become more preferable in recent years. However, usage area of their wood is limited due to low characteristic. Therefore, several modification methods have been tried to increase the characteristics.
- One of the modification method is thermal treatments that may be most-known due to common usage with publicity of commercial products. The methods can be performed to many wood specie; however it

changes physical and mechanical properties while increasing some physical properties such as stability and durability. The decreased properties is already low in wood of fast-growing tree species, thus it is causing more used in these species.

Paulownia is a deciduous species capable of achieving very high growth rates under favourable conditions. The wood of paulownia is soft, lightweight, ring-porous, straight-grained and mostly knot-free wood with a satiny luster (Kalaycioglu et al., 2004). According to Kaygin et al. (2015), density, hardness on every surface, bending strength and modulus of elasticity properties of Paulownia (*Paulownia elongata*) were found lower than Poplar (*Populus tremula*) and Juniper (*Juniperus excelsa*). Although characteristics of Paulownia subspecies (*P. elongata, P. tomentosa, P. fortunei* etc.) and origins (China, Turkey) are different, they have still lower than many other species (Kaymakci et al., 2013).

Kaygin et al. (2015) indicated that Paulownia had less structural integrity than compared species. Akyildiz and Kol (2010) indicated with mentioning Flynn and Holder (2001), Clad and Pommer (1980) indicated that Paulownia wood is used for a variety of applications such as furniture, construction, musical instrument, shipbuilding, aircraft, packing boxes, coffins, paper, plywood, cabinetmaking, and molding.

Thermal compression is a kind of modification method. It is related to viscoelastic behaviour, internal and microscopic structure of wood material. The temperature, pressure and duration levels determine the material characteristics particularly density and surface properties such as roughness, wettability, appearance. Surface properties of wood material is a determinant characteristic for usage area and surface treatments. It is affected from anatomic properties such as anisotropy, cell dimensions, wood specie, annual ring and leaf direction etc. and treatments such as coating, modification methods etc. İmirzi et al. (2014) studied thermal compression (with densification term) method to Scots pine wood samples and it was found that the surface roughness values were lower than untreated samples after some machining process (planing, circular sawing, sanding). Candan et al. (2013) studied thermal compression to Paulownia wood boards and they found that the process couldn't generate an enhancement in the dimensional stability while moisture content values decreased. However, the process caused increasing of surface density and hardness values.

The aim of this study was to investigate the change of surface roughness and wettability properties due to thermal modification duration and temperature on Paulownia wood.

2 MATERIAL AND METHODS

2.1 Material

Small-clear experimental Paulownia (*Paulownia spp.*) wood samples were used with dimensions of 50 mm by 50 mm by 18 mm were cut from commercially provided lumbers.

Thermal modification process was performed in a temperature-controlled oven and pressure-controlled chamber. Two treatment temperature and two pressure conditions were used with 45 min. duration and all experimental design of the thermal modification process was shown in Table 1. In addition, a control group with untreated samples were used to observe and investigate the changes. Ten samples were used for each group. All samples were conditioned at 20◦C (±2) and 65% (±5) relative humidity (RH) in a climate chamber until to reach equilibrium moisture content after thermal modification.

Table 1: Experimental design of the thermal modification process

Panel Group	**Treatment Conditions**		
	Temperature (°C)	**Duration (min)**	**Pressure (bar)**
Control	-	-	-
A	150	45	20,0
B	150	45	22,5
C	170	45	20,0
D	170	45	22,5

2.2 Method - Determination of Surface Roughness

The measurements were performed on both parallel (//) and perpendicular (┴) to the grain of each samples. Four roughness parameters were characterized by JIS B 0601 (2001) standard. Arithmetical average roughness (Ra), maximum height (Ry), ten-spot average roughness (Rz) and root-mean-square deviation (Rq) were considered to evaluate the surface roughness properties of the samples. Mitutoyo SJ-301 surface roughness tester known as a stylus type profile-meter was used for the tests (Figure 1) (Anon., 2002). Roughness values were measured with a sensitivity of 0.5μm. Measuring speed was 10 mm/min and λc value was 2.5mm x 5 = 12.5mm.

Figure 1: Surface Roughness Test Device (Mitutoyo Surftest SJ-301) (Anon., 2002)

2.3 Method - Determination of Wettability

Contact angle (CA) value utilized to determine the wettability characteristics of the samples. The values were determined using with a KSV Cam-101 Scientific Instrument (Helsinki, Finland). 5μL droplet of distilled water was as the liquid. After the droplet was dripped on the sample surface, the camera captured 30 images at 1-second intervals. CA from the images were measured with image processing in the device software. As seen in Figure 2, mean of two-contact angle values (from left and right) were used to analyse (Figure 2).

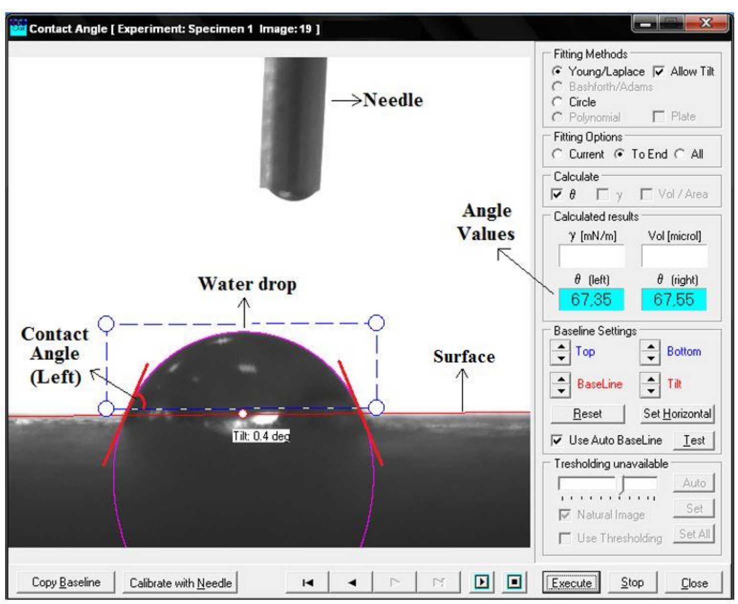

Figure 2: Digital image processing to measure contact angle at KSV Cam-101

For comparison all groups, multiple comparisons were first subjected to an analysis of variance (ANOVA), and significant differences between average values of control and treated samples were determined using Duncan's multiple range test with SPSS Software. P-values of 0,05 were considered to determine significance level.

3 RESULTS AND DISCUSSION

Control and treated sample groups were compared and homogeneity groups were determined for each test according to the Duncan's multiply range test. The surface roughness results can be seen in Table 2.

Table 2: The effect of thermal treatment with different durations on surface roughness in Rowan wood*

Treatment (°C)	Pressure (bar)	Ra (μm)		Ry (μm)		Rz (μm)		Rq (μm)	
		//	⊥	//	⊥	//	⊥	//	⊥
Control		$3,952^{b}$	$5,215^{bc}$	$21,781^{ab}$	$37,388^{b}$	$14,340^{ab}$	$26,207^{cd}$	$4,874^{b}$	$6,793^{bc}$
150	20,0	$4,000^{b}$	$6,104^{c}$	$24,757^{b}$	$40,816^{b}$	$15,962^{b}$	$28,283^{d}$	$5,077^{b}$	$7,797^{c}$
150	22,5	$2,771^{a}$	$4,068^{ab}$	$17,836^{a}$	$30,541^{a}$	$11,403^{a}$	$22,158^{bc}$	$3,574^{a}$	$5,459^{ab}$
170	20,0	$3,315^{ab}$	$3,810^{a}$	$19,883^{a}$	$27,578^{a}$	$12,628^{a}$	$19,748^{ab}$	$4,170^{ab}$	$4,989^{a}$
170	22,5	$2,6290^{a}$	$3,088^{a}$	$18,491^{a}$	$25,422^{a}$	$11,532^{a}$	$22,158^{bc}$	$3,456^{a}$	$4,268^{a}$

* The same letter on the numbers shows that there is no difference homogeneity groups in each column ($p<0.05$).

As seen in Table 2, statistically significant differences ($p < 0.05$) were found to exist as determined by Duncan's multiple-comparison tests. The surface roughness values (Ra, Ry, Rz, Rq) for control groups of Paulownia samples was found as 3,952 μm, 21,781 μm, 14,340 μm and 4,874 μm at parallel direction, while the values were found 5,215 μm, 37,388 μm, 26,207 μm and 6,793 μm at perpendicular direction, respectively. Results showed that there were two groups having significant difference at the all directions and all calculations. Roughness values of Control and 150°C – 20bar groups were higher lower than other three groups. When the pressure effect at the same temperature were investigated, there was significant change at 150°C temperature, while there is no significance at 170°C. Similar correlation can be seen in the temperature effect investigation. There was significant change at 20bar pressure, while there is no significance at 22,5 bar at the same temperatures.

The wettability (contact angle - CA) results were presented in Table 3.

Table 3: The effect of thermal treatment with different durations on wettability in Rowan wood*

Treatment (°C)	Pressure (bar)	Contact Angle (°)
Control		$30,632^{a}$
150	20,0	$59,980^{b}$
150	22,5	$53,799^{b}$
170	20,0	$82,586^{c}$
170	22,5	$84,782^{c}$

* The same letter on the numbers shows that there is no difference homogeneity groups in each column ($p<0.05$).

As seen in Table 3, statistically significant differences ($p < 0.05$) were found to exist as determined by Duncan's multiple-comparison tests. The CA values for all treated samples increased with increasing thermal compression treatment temperature and pressure according to control (untreated) samples. It was found that, the CA values were increased when the treatment temperature increased. However, there was no significant difference for different pressure levels at the same temperatures.

4 CONCLUSION

In this study, thermally compression modification method was used for trying to increase wood characteristics of a fast-growing specie Paulownia. There were two temperatures and two pressure levels to compare the surface roughness and wettability performance with untreated wood. Consequently, the following conclusions could be drawn from the results obtained in the present work.

The surface roughness properties of Paulownia wood samples did not significantly changed at per thermal compression process conditions for all directions. However, the significance was determined when the levels passing from "150°C – 20bar" to "150°C – 22,5bar". Bigger pin usage for surface roughness measurement or testing more samples could cause separating the groups, although coefficient variance was low as desired. Because more differences was observed in wettability tests.

The wettability properties of the samples changed significantly when the temperature changed. It can be said that thermal compression diminishes the hydrophilicity of the wood surface. At the 170 °C levels, the CA values reached until nearly 90° that shows the enough hydrophilic characteristic for a wood material. Hakkou (2005) indicated that investigation of the effect of temperature on wettability showed that it changes suddenly for temperatures between 130 and 160°C indicating that higher temperatures, generally used for heat treatment, are not necessary to modify wood hydrophilic properties. Similar changing was not determined at different pressure levels. However, the pressure levels and/or duration can be increased to affect the material properties and to obtain smoother surface. Because the material thickness can decrease up to the half in some studies. Moreover, the obtained contact angle values is proper for many surface treatments.

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The Effect of Modification with Epoxy and Polyester Resins on Some Mechanical Properties of Pine and Chestnut Woods

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ABSTRACT

In this study, the effects of epoxy and polyester resin applications on some mechanical strength properties of scots pine (*Pinus sylvestris* L.) and chestnut (*castanea sativa*) wood samples were investigated. Firstly, in the circular sawing machine, a different numbers of channels (2+1 and 3+2) were opened on the surfaces of wood samples. Then, these channels were filled with casting type epoxy and polyester resins. The density, modulus of repture (MOR), modulus of elasticity (MOE), and compression strength parallel to the grain (CS) tests were performed on the samples. According to the results of the study, the density values of pine and chestnut samples increased by 25% and 42%, respectively, depending on the number of channels after resin application. In addition, compared with epoxy resin applied samples, the density increase was higher in the polyester resin applied samples. After application of resins, a slight increase was observed in the MOR and MOE values of chestnut samples. However, CS values tend to decrease in these samples. In pine samples with resin applied, the strength properties (MOR, MOE and CS) decreased depending on the increase in the number of channels. Furthermore, the effect of the resin type on all strength properties of the samples was statistically insignificant.

KEYWORDS: Epoxy resin, Polyester resin, Wood material, Mechanical properties

1 INTRODUCTION

Wood is a material used by mankind since the dawn of time due to its high-quality properties. Wood which used to be used as a basic material in the construction of houses is now being used in designing the living spaces. Wood is indispensable both for living spaces and for its healthy and durable structure.

The warm image of natural wood let it be widely used in interior spaces, which led to new ideas. Since the beginning of the 21st century, interest in products such as wooden desks and tables has increased. When the products produced by natural wood are touched, they give the feeling of being just inside nature where the wood has been taken from. With concrete becoming more and more widespread, people's desire to get back to nature has motivated these designs to be even more involved in our life (Web-1). In recent years, products made from natural wood materials are very popular. Wood materials and various resins are generally used in combination in the manufacture of these products. Thus, very different types of designs are emerging and especially the aesthetic look is emphasized. In addition, with the use of resins, different wood defects can be removed. Many types of furniture and decoration elements are produced using natural wood. Some of these products are; table, coffee table, TV units, consoles, bookshelves, pendant lamps and wooden wall designs. In the production of these products, the most commonly used wood species are pine, maple, juniper, plane, walnut, oak, chestnut, mulberry, and ash. Epoxy and polyester resins are generally used to remove various wood defects (cracks, slits, knot fall, etc.) in furniture and decoration elements produced from natural wood. In addition, these resins are now often preferred for their aesthetic and decorative reasons, together with wood.

Epoxy resins can strongly adhere to many materials such as metal, plastic, glass, and wood (Bulmuş and Pişkin, 2000; Şahmetlioğlu, 2000). In addition, it has many important properties such as high mechanical strength, chemical resistance, corrosion resistance, dimensional stability, wetting and filling ability of fiber reinforcements (Kaw, 1997; Chung, 2010). Epoxy resins are used in marine, automotive, aerospace and construction industries due to their superior properties. It is also widely used in many applications such as coatings, adhesives, insulation materials and composite materials (Güzel, 2016). Polyester resins have high resistance to chemical and environmental influences. They also have high dimensional stability and low viscosity. They are less costly and harden faster than epoxy resins (Sezgin, 2018) but have higher shrinkage ratios after curing (Seyhan et al., 2007). Polyester resins are used in automotive industry, building constructions, marine applications and composite materials as a matrix. When compared to epoxy resin, their thermal, air and mechanical strength properties are low, so their use in high-performance composites is limited (Campbell, 2010; Sezgin, 2018).

The aim of this study is to determine the density and the mechanical strength properties of scots pine (*Pinus sylvestris* L.) and chestnut (*castanea sativa*) woods modified with epoxy and polyester resins.

2 MATERIALS AND METHODS

2.1 Wood Material

In this study, scotch pine (*Pinus sylvestris* L.) and chestnut (*castanea sativa*) woods were used. Wood materials were supplied by random selection method from a timber company in the Düzce city in Turkey. Attention was paid to ensure that no rot, knot, crack, color, or density differences were present in the samples (TS 2470 1976). A sufficient number of experimental samples were prepared with 20 × 20 × 340 mm (tangential direction × radial direction × longitudinal direction) dimensions from the sapwood parts of the wood materials which have air-dry moisture. Thereafter, a different number of channels (2+1 and 3+2) were opened with 2.4 mm wide and 7 mm depth to the samples subjected to be treated by resin, at corresponding pairs of surfaces (tangential section) using a circular saw machine (Figure 1).

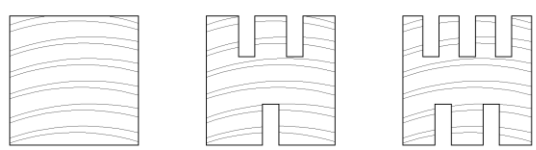

Figure 11: Appearance of cross sections of the samples

After opening channels, samples remained at a temperature of 20±2 °C and relative humidity of 65 ± 3% until they reached a stable weight (TS 2471 1976).

2.2 Resin Application

In the treatment of samples casting type epoxy and polyester resins were used. Some properties of these resins are given in Table 1.

Table 15: Properties of resins

Resin type	Viscosity (cpl)	Density (g/cm3) (20 ºC)	Gelling time (min.)	Elongation at break (%)	Hardness (Barkol)
Epoxy	156	1.2	110-130	1.0	66
Polyester	450	1.6	8	2.3	45

Before the resin processing, cross sections of the experimental samples were closed using paper tape to prevent resin leakage. When the resins were prepared, the hardener and/or accelerator mixture ratios were carried out in accordance with the manufacturers' recommendations. The channels opening into the samples were filled with the resin using an injector with the appropriate tip clearance under room conditions (20 ± 2 °C) (Figure 2).

Figure 2: Application of resins to wood samples

After filling the channels on the first surface with resin, the samples were left on the counter with a balanced scale for 48 hours. Then resin filling was performed on the channels on the second surface. The samples, in this case, were kept for about three weeks. After the resins had been thoroughly dried, the samples were passed through a calibrating sanding machine to remove excess resin on the surfaces. After, samples remained in a conditioning cabin (RH 65±3% and 20±2 °C) until they reached a stable weight (TS 2471 1976). Then, samples were cut into smaller samples according to the specified test standard. The test samples were prepared in the number as to 8 repetitions (n=8) for each variable.

2.3 Determination of Density

Air-dry density of the samples were determined according to TS 2472 (1976). The mass of each sample (M_{12}) was measured on an analytical balance, with a sensitivity of ±0.01 g. Dimensions (length, width, thickness) were measured with a vernier caliper having ±0.01 mm sensitivity, and volumes (V_{12}) were determined. The air-dry density (δ_{12}) was calculated using Eqs. 1.

$$\delta_{12} = M_{12} / V_{12} \quad (\text{g/cm}^3) \qquad (11)$$

2.4 Determination of MOR, MOE and CS Strength

Modulus of repture (MOR) (or bending strength) and modulus of elasticity (MOE) of the samples were determined according to TS 2474 (1976). The MOR and MOE values were calculated by using following Eqs. 2 and Eqs. 3.

$$MOR = 3P_{max}L / 2bd^2 \quad (\text{N/mm}^2) \qquad (2)$$

$$MOE = PL^3 / 4bd^3\Delta \quad (\text{N/mm}^2) \qquad (3)$$

where $P_{\max}$ is the maximum load when the sample is broken (N), L is the supporting span (mm), b is the width of the samples (mm), d is the thickness (depth) of the samples (mm), Δ deflection at mid-length below the proportion deflection limit (mm), and P is the load in N within the proportional deflection (N).

Compression strength parallel to the grain (CS) of the samples were determined according to ISO/DIS 13061-17 (2015). The CS values were calculated by using following Eqs. 4.

$$CS = P_{max} / bd \quad (\text{N/mm}^2) \qquad (4)$$

where $P_{\max}$ is the maximum load applied to the samples (N), b is the width of the samples (mm), d is the thickness of the samples (mm).

2.5 Statistical Analysis

The MSTAT-C software program was used for the evaluation of data. ANOVA (analysis of variance) tests were performed to determine the effect of resin type and number of channel on the density and mechanical properties (MOR, MOE and CS) of scotch pine and chestnut woods at the 0.05 significance level. Duncan's tests were conducted for comparisons of the means of the density and mechanical strength values of the wood samples.

3 RESULTS AND DİSCUSSİON

Arithmetic means of density, modulus of repture (MOR), modulus of elasticity (MOE), and compression strength parallel to the grain (CS) values of the wood samples are given in Table 2. Additionally, analysis of variance results of density, MOR, MOE, and CS measurements from wood samples resin applied are shown in Table 3.

Table 2: Arithmetic means of the density, MOR, MOE and CS values

Wood species	Resin type	Number of channel	Tests			
			Density (g/cm^3)	MOR (N/mm^2)	MOE (N/mm^2)	CS (N/mm^2)
Scotch pine	Epoxy	Control	0.545 (0.022)	95.69 (7.34)	10537 (758)	46.59 (3.57)
		2 + 1	0.611 (0.024)	87.73 (8.46)	10019 (684)	40.29 (3.72)
		3 + 2	0.660 (0.025)	89.51 (8.51)	9598 (724)	38.25 (3.16)
	Polyester	Control	0.545 (0.022)	95.69 (7.34)	10537 (758)	46.59 (3.57)
		2 + 1	0.636 (0.022)	94.75 (7.31)	9827 (636)	40.57 (3.29)
		3 + 2	0.682 (0.031)	86.47 (6.98)	8709 (631)	37.10 (2.51)
Chestnut	Epoxy	Control	0.438 (0.017)	55.61 (6.14)	4630 (354)	32.24 (2.13)
		2 + 1	0.537 (0.010)	59.35 (5.71)	4659 (265)	31.34 (1.57)
		3 + 2	0.614 (0.007)	61.34 (3.59)	4760 (169)	31.09 (1.22)
	Polyester	Control	0.438 (0.017)	55.61 (6.14)	4630 (354)	32.24 (2.13)
		2 + 1	0.556 (0.023)	60.35 (7.10)	4887 (439)	31.25 (1.70)
		3 + 2	0.622 (0.018)	55.22 (7.31)	4541 (447)	30.50 (1.58)

Values in parenthesis are standard deviations

Table 3: Analysis of variance results for density, MOE, MOR, and CS of resin applied wood samples

Wood species	Source	Density		MOR		MOE		CS	
		F-ratio	p-value	F-ratio	p-value	F-ratio	p-value	F-ratio	p-value
Scotch pine	Factor A	4.871	0.032*	0.372	-	3.365	0.073	0.091	-
	Factor B	106.472	0.000*	4.239	0.021*	16.593	0.000*	30.541	0.000*
	A*B	1.241	0.299	1.884	0.164	1.889	0.163	0.207	-
Chestn ut	Factor A	4.018	0.050*	0.933	-	0.001	-	0.200	-
	Factor B	496.561	0.000*	1.967	0.152	0.773	-	2.819	0.071
	A*B	1.482	0.238	1.587	0.216	1.616	0.210	0.132	-

A: Resin type, B: Number of channel, *:Significant at 95% confidence level

According to Table 3, the effect of resin type and number of channel factors on density in both wood species were found to be statistically significant. In addition, the effect of number of channel on MOR, MOE, and CS of the pine wood samples was significant, while the effect of the resin type was insignificant. On the other hand, both resin type and effect of number of channel on MOR, MOE, and CS of the chestnut wood samples were found to be insignificant ($P \leq 0.05$). In the pine and chestnut woods, comparison results of the Duncan's tests conducted for the factors of resin type and number of channel are given in Table 4.

Table 4: Duncan's test results for mean values

Wood species	Factor	Density (g/cm³)		MOR (N/mm²)		MOE (N/mm²)		CS (N/mm²)	
		Mean	HG	Mean	HG	Mean	HG	Mean	HG
Scotch pine	Resin type								
	Epoxy	0.606	b	90.98	a	10051	a	41.71	a
	Polyester	0.621	a	92.30	a	9691	a	41.42	a
	Number of channel								
	Control	0.545	c	95.69	a	10537	a	46.59	a
	2 + 1	0.623	b	91.24	ab	9923	b	40.43	b
	3 + 2	0.671	a	87.99	b	9154	c	37.67	c
Chestnut	Resin type								
	Epoxy	0.529	b	58.77	a	4683	a	31.56	a
	Polyester	0.539	a	57.06	a	4686	a	31.33	a
	Number of channel								
	Control	0.438	c	55.61	a	4630	a	32.24	a
	2 + 1	0.547	b	59.85	a	4773	a	31.29	ab
	3 + 2	0.618	a	58.28	a	4650	a	30.80	b

HG: Homogeneous group (different letters denote a significant difference)

Regarding resin type, the highest density for both wood species was found to be in the samples applied polyester resin and the lowest was found in the samples applied epoxy resin (Table 4). It is shown in Table 1 that the polyester resin used in the work has a higher density than the epoxy resin. With respect to number of channel, the highest density was found to be in the 3+2 channels opened samples, while the lowest was obtained in the control samples (Table 4). Depending on the increase in the number of channels, the density value of the samples also increased. In other words, the increase in the amount of resin applied to wood materials caused an increase in density. This can be explained by the fact that the densities of the resin filled in the opened channels are higher than the density of the wood materials. After resin application, density value of pine and chestnut samples increased up to 25% and 42% compared to control samples (Table 2).

According to Table 4, the difference between the MOR values of pine and chestnut wood samples at the resin type level was found to be statistically insignificant. The same applies to MOE and CS values. For pine wood samples, the highest MOR, MOE, and CS values at the number of channel level were found to be in the control samples, while the lowest values were obtained in the 3+2 channels opened samples. The increase in the number of channels caused a decrease in the mechanical strength properties (MOR, MOE, and CS) of the pine wood samples. MOR, MOE, and CS values decreased by 8%, 13%, and 19%, respectively, in the 3+2 channels opened samples compared to control pine wood samples. The increase in the number of channels in the sample is proportional to the amount of resin applied. Because of this, it may be effective in decreasing the strength values of pine samples in resins which are harder and brittle than wood materials. In the literature, it is reported that the resulting epoxy or polyester resins in liquid form transform into solid with a layer that is a hard, brittle and thermosetting cross-linked structure (Velde, 1992; Miyoshi, 2001; Sönmez and Budakçı, 2004; Campbell, 2010; Ting et al., 2011). Also, their structures which are prone to brittle (Ersoy, 2001), combustible and fragile, restrict the use of such resins (Güzel, 2016). Hardened resin layer's physical and mechanical properties depend on the functional group types of hardener, cross-link density between resin and hardener, molecular structure and hardening conditions of functional group bonds between resin and hardener (Şahmetlioğlu, 2000; Nohales et al., 2006; Montero et al., 2013: Güzel, 2016).

For the chestnut wood samples, no statistically significant difference was observed in terms of both MOR and MOE values between resin applied (channel opened) samples and control (no channel opened) samples (Table 4). It can be said that the chestnut wood samples and the resins exhibited similar behavior in terms of strength properties. In addition, with respect to number of channel, the highest CS value was obtained in the control samples, while the lowest value was found to be in the 3+2 channels opened samples. The CS value of chestnut wood samples tends to decrease due to the increase in the number of channel. CS value decreased by 4.5% in the 3+2 channels opened samples compared to control chestnut wood samples (Table 4).

4 CONCLUSION

In this study, the density and the some mechanical strength properties of pine and chestnut wood samples modified with epoxy and polyester resins were investigated. After resin applications, the density values of pine and chestnut samples increased up to 25% and 42%, respectively, depending on the number of channels. Compared to epoxy resin applied samples, the density increase was higher in polyester resin applied samples.

The effect of the type of resin on all selected mechanical properties (MOR, MOE, and CS) of pine and chestnut wood samples was found to be statistically insignificant. In other words, similar strength values were obtained in both epoxy and polyester resin applied samples.

In pine wood samples with resin applied, the strength values decrease depending on the increase in the number of channels. The MOR, MOE and CS values of these samples decrease by 8%, 13%, 19% respectively when compared to the control (untreated) pine samples. In chestnut samples, the effect of the number of channels on the mechanical strength was found to be statistically insignificant.

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Historical Value and Conservation Problems of Traditional Wooden Architecture in Turkey

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ABSTRACT

Wood is one of the oldest construction materials in Turkey, due to the presence of large forested areas. Wood can be used in different ways during the contraction of the walls. For example, only wood is used for building, or wood pieces, stones or bricks is used as infill material of framed structures. Even though many traditional wooden buildings have left their place in concrete, it is still possible to see the good examples of traditional wooden architecture today. However, due to conservation problems in rural areas, local people tend to give up living in wooden buildings. In addition, construction dates of traditional wooden buildings, which are important for identifying definitive architectural period, and for nomination and registration as cultural heritage, are generally unknown.

Here, we present a review of researches dating of historical buildings using dendrochronological methods; and multidisciplinary studies which reveal the historical value of wooden structures and develop conservation approaches. We believe that multidisciplinary studies combining dendrochronology, wood conservation and architectural features, will lead the quality refurbishment of wooden buildings and encourage building owners to protect their buildings and sustainable use of traditional wooden structures.

KEYWORDS: Dendrochronology, Wood Conservation, Traditional Wooden Architecture

1 INTRODUCTION

Wood, stone and adobe are the oldest and most widely used traditional construction materials in all over the world. Especially for rural traditional buildings, it was important to choose the easily accessible materials which were close to the building areas. This main understanding of using/choosing construction materials indicates that wooden buildings have direct connection with existence of forests. In Turkey – especially Black Sea Region- due to presence of large forested areas, wood has been one of the main construction materials.

Wood can be used in different parts of the buildings as construction elements in walls, floors, roofs etc.; infill materials in walls; covering materials in floors, roofs (Aydın and Lakot Alemdağ, 2014). It has been also used for doors, windows, stairs, ornaments etc. While some wooden buildings were built entirely of wood, in some of them wood was used together with stone, brick or adobe.

The wooden traditional construction techniques in Turkey can be classified according to the formation of the main walls as load bearing wooden walls and wood framed structures (Önel, 1975). In load bearing wooden wall technique, all the walls are built by placing one wooden wall element on top of another horizontally and anchored at corners (Uzun et al., 2018, Arun 2012). These kinds of buildings exist especially in Black Sea Region of Turkey, where large forest areas exist (Önel, 1975).

Wood framed structures need less wooden elements than load-bearing wooden walls. There are three common techniques for wood frame structures in Turkey as '*hımış*' - stones, bricks etc. are used as infill material, *'bağdadi'* - lath and plaster technique and wood cladding (Arun 2012). These kinds of buildings have been built mostly in Marmara Region, north and west parts of Anatolia and north parts of Central Anatolian Region (Aksoy and Ahunbay, 2005).

Turkey has a very old and qualified wooden architectural heritage. Even some of them were destroyed /disappeared in time and left their places to concrete buildings, lots of good examples are still exist in especially rural areas of Black Sea Region. The main conservation problem of these wooden buildings is caused by human influence like abandonment, lack of preservation awareness, unqualified interventions etc. (Uzun et al., 2018). Another main conservation problem is lack of laws in protecting them. Even some of the wooden buildings were registered by conservation councils in Turkey, lots of rural wooden buildings are not still protected by laws. People who keep living in these buildings do unqualified interventions to meet today's needs (Sezgin, 2006) and some people prefer to live in concrete buildings and abandon, destroy or sell to burn the old wooden buildings. It is important to make awareness about these buildings' cultural and historical values and offer a holistic conservation approach to propose qualified solutions.

Here, we present a review of researches dating of historical buildings using dendrochronological methods; and multidisciplinary studies which reveal the historical value of wooden structures and develop conservation approaches.

2 DENDROCHROLOGICAL DATING OF HISTORICAL BUILDINGS

Dendrochronology, which is defined as the science of dating based on tree-ring patterns, has been used widely to find out construction and/or restoration dates of historical buildings. The first comprehensive studies in our country were carried out by P. I. Kuniholm and his team, and many castles, mosques, churches and wooden buildings were dated with this method (Kuniholm, 2000).

In the early 2000s, dendrochronological dating in Turkey gained momentum with the modernization of Laboratory of Wood Anatomy and Tree-Ring Research, Istanbul University Faculty of Forestry. Examples of some dating studies are presented below:

Akkemik and Dağdeviren (2004) were dated the wooden samples from Balkapanı Han, Eminönü, Istanbul. As a result of the research, it was found that the timber was used between 1769-1774 and thought that the han, which had the features of the Byzantine period, was restored after the 1766 earthquake. Historical records confirmed that Balkapanı Han was damaged by the earthquake and restored by Sultan's order.

The six wooden mosques and two wooden houses were dated by Akkemik and Güzel (2004) using tree-ring analysis. Only the oak specimens could be dated in the research, as pine trees were often decayed and destroyed by insects, while both pines and oaks were used in the structures in the region. It was determined that the structures under investigation were built in the 18th and 19th centuries and the oldest one was Çamkışla Mosque built in 1741 (+3).

Akkemik ve Köse (2010) were established construction dates of four historical buildings from Tokat and Marzifon, Amasya. It was found that the Bedesten was built in 1425-1426, the Gülbahar Hatun Külliyesi in 1485-1486, the Deveciler Han in 1488-1489 in Tokat, and the historical Bedesten in 1672-1673 in Amasya-Merzifon. The results of the research had established the exact building dates of constructions which were estimated to have been made in any year within a period of 200 years.

3 MULTIDICIPLINARY STUDIES IN RECENT YEARS

It is clear that dendrochronology is an important tool to find out construction and restoration dates of historical wooden structures. The determination of the construction dates of the buildings clearly defines the architectural period in which the buildings were built, and on the other hand it is important for their registration as cultural heritage (Rochner et al., 2017). Quality examples of wooden architecture in Turkey is decreasing day by day. Dendrochronological studies that raise awareness about the historical value of buildings are not enough to take the necessary precautions to protect these buildings. Knowing why building owners give up wooden buildings, offering practical solutions to the problems they have experienced in wooden buildings, are also crucial for transferring the wooden architecture to the new generation. Therefore, multidisciplinary studies have been performed in recent years, which provide information to local people, public institutions, non-governmental organizations and related associations.

Okan et al. (2016) revealed ecotourism potential of traditional wooden architecture in Papart Valley. Research results emphasized that wooden architecture located in villages, highlands and winter quarters, which can be considered as hosting facilities for eco-tourists, was one of the strengths of Papart Valley. Because the construction dates were unknown, dendrochronological dating of a wooden house and its hayloft were performed to find out historical value of the wooden architecture. Dating results showed that both the house and the hayloft carry traces of its owners' more than 150-year history. One of the most important weakness was the lack of knowledge for the protection and maintenance of the wooden houses. Therefore, the research also offered precautions against observed insect and fungal damages.

Uzun et al. (2018) performed a multidisciplinary study to reveal the historical value of two wooden mosques in Samsun and to develop a construction approach. In the research, first general characteristics and architectural features of the mosques were defined. Then deterioration analysis was performed by using different colors and hatches to show each deterioration types. The research highlighted that the main conservation problems are caused by improper interventions and it is needed to cooperate with interest groups for improved protection of the mosques. Tree-ring dating of oak woods from the mosques were present valuable information about the history of the mosques. Karlı Mosque settled by Circassians was dated to 1870 in the period of Great Circassian Migration. The samples obtained from the wall and the ground beams of Dere Mosque were dated to different time periods, 1623+ and 1835, respectively. The two different dates suggest two possibilities: 1) support the rumor that the mosque moved from the original location; 2) replacement of the ground beams using a jacked-up technique.

4 CONCLUSIONS

We believe that multidisciplinary studies combining dendrochronology, wood conservation and architectural features, will lead the quality refurbishment of wooden buildings and encourage building owners to protect their buildings and sustainable use of traditional wooden structures.

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Determination of Pomegranate (*Punica Granatum* L.) Dye and Liquid Glass Painting (SiO_2) Mixture on Antimicrobial Activity and Wood Surfaces Protect Against the Development of Rot Fungi

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ABSTRACT

The aim of this study was to determine the antifungal and antimicrobial properties of pomegranate (Punica granatum L.) extract mixed with liquid glass when used as an environmentally friendly wood preservative. The extract was dissolved from pomegranate (*Punica granatum* L.) by using and ultrasound assisted method and applied to Scots pine (*pinus sylvestris* L.), mahogany (*Swietenia* sp.) and chestnut (*Castanea sativa* Mill.) wood blocks with the immersion (classic) methods. Ferrous sulfate ($Fe_2(SO_4)_3.7H_2O$), aluminum sulfate ($KAl_2(SO_4)_3 12H_2O$) and vinegar were used for mordants, results were compared with synthetic dye. Treated blocks were exposed to *Postia placenta* and *Trametes versicolor* attacks for 16 weeks, according the standard TS 5563-EN 113, 1996 method. Antimicrobial activity of the extracts was determined with the agar dilution method by using the disk diffusion method for bacteria. Results showed that the mordant mixes were considerably more resistant to fungal decay compared to their untreated and synthetic counter parts. Results showed that the mordant mixes were considerably more resistant to fungal decay compared to their untreated and synthetic counterparts. It has been observed that liquid glass has shown better protection on the chestnut and mahogany compared to pine trees. Natural dye we obtained has shown better protection more then, synthetic dye against brown rot (*Postia placenta*) and white rot (*Tramates versicolor*). As a result, it was found that pomegranate (*Punica granatum* L.) extracts, pomegranate (*Punica granatum* L.) + liquid glass and mordant mixes could be used as wood preservatives. Dyes extract used in the experiments was determined to prevent the antimicrobial activity.

KEYWORDS: Pomegranate, *Punica granatum* L., antimicrobial activity, white rot, brown rot.

1 INTRODUCTION

Recently there has been intense interest in natural dyeing. The reason for this is the standards of protection against environmental pollution by many countries against toxic and allergic effects caused by synthetic staining materials. In addition, people's confidence has been established that traditional natural dyeing materials are more environmentally friendly than synthetic materials. It has been reported that natural materials show better resistance to biotic agonists and are more compatible with the natural environment (Kamel et al., 2005)

Dyes; divided into two artificial and natural. The main materials used for the synthesis of artificial lacquers and pigments are coal tar compounds known as aromatic hydrocarbons. The petrochemical industry is gaining importance in providing these materials. Natural coloring materials are obtained from substances naturally found in nature. Vegetable stains are known to have some processing-after-coloring properties of plants found in nature. specific organs of some plants used for painting all parts of certain plants (flowers, leaves, seeds, roots and bark etc.) are used (Önal, 2000).

Recent studies were done on the use of natural dyes to protect wood. For example, Ozen et al. (2014) reported antimicrobial and antifungal properties of extracts from madder root (*Rubia tinctorium*) Goktas et al. (2010; 2007a, b) investigated the antifungal properties of extracts from *Musgari neglectum, Gynandriris sisyrinchium, Sternbergia candidum* and *Nerium oleander.*

Pomegranate skin is rich in tannin, it is widely used in leather processing industry, in the clarification of fruit juices and for the prevention of zinc poisoning. Moreover, pomegranate skin and flower are used in the production of dye and ink. Pomegranate seeds include as much oil as cotton seeds. Remaining pulp of it in oil production industry is the richest herbal source of estrogen hormone (Anonymous 1, 2014).

The focus of this study is on the antimicrobial effects and preservation of wood material against brown rot and white rot fungi by Pomegranate (*Punicagranatum*) extract. It is believed that finding eco-friendly colorants to overcome microorganism pollution will bring a new aspect with fewer side effects and less pollution.

2 MATERIAL AND METHOD

2.1 Materials

Scots pine (*pinus sylvestris* L.), mahogany (*Swietenia* sp.) and chestnut (*Castanea sativa* Mill.) Trees, which are widely used in the industry as wood materials, were used in the study. As a mordant; iron sulfate $Fe_2(SO_4)_3 .7H_2O$), aluminum sulfate ($Al_2(SO_4)_3 .7H_2O$) and grape circles (CH_3COOH). As a plant in the experiment; pomegranate (*Punica granatum* L.) was used and mixed with liquid glass.

2.2 Method

2.2.1 Preparing wood blocks

Examples of wood samples to be used in mushroom tests were prepared from Scots pine (*pinus sylvestris* L.), mahogany (*Swietenia* sp.) and chestnut (*Castanea sativa* Mill.) wood. The lumber supplied is branded according to TS 4176, after the tolerance cut, it is brought to exact dimensions and ready to use. Experimental specimens were prepared according to ASTM 1413-72, measuring 15x25x50 ± 1mm. Experimental samples were stored for up to about 12% humidity at a temperature of 20 ± 2 °C and 65 ± 5 % relative humidity (Peker 1997).

2.2.2 Natural dye extraction

Paint plant; Pomegranate (*Punicagranatum*) was purchased. Within a temperature-adjustable boiler, the temperature is 45 ° C in pure water at the rates specified in Table 1, and it is extracted in 180 minutes. At the end of the period, dyed water was filtered with a filter paper to obtain solid matter separated solid parts.

Table 1: Extraction conditions of dye

Dye extraction	**Extraction methods**	**Distilled water (g)/plant(g)**	**Ultrasonic output power (W)**	**Temperature (^{0}C)**	**Time (min)**
Pomegranate(*Punicagranatum*)	Ultrasonic	20/8	180	45	180

After extraction, the paint was mixed with the mordant materials at the ratios indicated in Table 2 and the mordant materials were dissolved and allowed to stand for 30 minutes to mature the chemical bond.

Table 2: Paint solution and mordant mixture ratios

Extract	Mordant	Mixed (%)
Pomegranate(*Punicagranatum*)	Control	0
	Iron sulfate	3
	Aluminum sulfate	5
	Vinegar	10

The dyes obtained after extraction were mixed with the liquid at the ratios indicated in Table 3 and allowed to dissolve the liquid and leave for 30 minutes to mature the chemical bond. As a result of various experiments, the optimum ratio was determined as 20%.

Table 3: Mixing ratios of paint solution

Extract	Mordant	Liquid glass (%)
Pomegranate(*Punicagranatum*)	Control Iron sulfate Aluminum sulfate Vinegar	20 %

2.2.3 Dyeing of the wood

Natural coatings mixed with liquid glass were applied to wooden specimens for 60 minutes by immersion at 45 °C in a temperature-adjustable boiler. Samples were dried before and after dye application until the texture reached constant weight.

2.2.4 Fungus test

Fungal decay tests were carried out according to TS EN 113 (2006) standards. In this experiment a white rot fungi, *Trametes versicolor* (L: Fr.) Pilat. (FFPRI 1030) and a brown rot fungi *Postia placenta* (Fr.) M.J. Larsen & Lombard (Mad-69S-R) were used.

For the reproduction of decayed fungus cultures; Laminar Flow Cabinet, 6x6 mm pieces from the fungal main culture were inoculated into sterile petri dishes and then left at 27 ° C for 10 days in the incubator. At the end of this training, those who suffered contamination were immediately removed from the testing process. Test specimens were placed in petri dishes at the end of the 10 day. The experimental specimens were removed from the air conditioning cabinet and the development was allowed to proceed for 16 weeks.

At the end of the 16-week waiting period, the parts were weighed and weight losses were calculated.

Weight loss (%) = (100 (T3 - T4) / T3)

T3: Oven dry weight of the test specimen before the vaccination

T4: The test sample was cleaned of fungi after 16 weeks after oven dry weight were placed in a drying oven.

2.2.5. Antimicrobial Activity test

The dye extracts used in the study were sterilized under sterile conditions with a 0.45 µm filter. Disc diffusion method was used for the inhibition effect of natural dyes on test bacteria.

Escherichia coli ATCC 25922, *Staphylococcus aureus* ATCC 6538 / P and *Candida utilis* CCTM La 991 were used as test microorganisms. The strains used in the study were obtained from Muğla Sıtkı Koçman University Mushroom Research Center.

3 RESULTS

3.1 Mass Losses and Extract Retentions of Wood Samples Treated with Pomegranate (*Punicagranatum*) and Mordant Mixtures Exposed to Rot Fungi

3.1.1 Brown rot fungi (*Postia placenta*) test results

Mass losses and mean extracts retentions of the wood samples that treated with Pomegranate (*Punicagranatum*) dye, some mordants, liquid glass and without liquid glass exposed to Postia placenta brown rot fungi are given in Table 1.

Table 4: Mean mass losses and extract retentions of wood species treated with Pomegranate (*Punicagranatum*) dye and mordant mixtures in consequence of *Postia Placenta* effect.

Mordant	Mixture	Scots Pine			Chestnut			Mahogany		
		Mean Retension (%)	Mean Mass Losses (%)	SD	Mean Retension (%)	Mean Mass Losses (%)	SD	Mean Retension (%)	Mean Mass Losses (%)	SD
Control (Non mordant)	Without liquid glass	2,03	32,15	12,01	1,83	2,99	0,49	2,48	2,04	0,41
	liquid glass	1,00	47,42	6,472	0,74	1,66	0,26	1,40	1,64	0,34
Ferrous sulphate	Without liquid glass	2,40	22,32	13,57	1,53	3,65	0,91	2,17	1,99	0,67
	Added liquid glass	1,26	35,79	8,59	1,10	0,99	0,54	1,23	0,32	0,14
Aluminum sulphate	Without liquid glass	2,22	18,20	14,49	1,48	3,29	0,78	2,47	2,45	0,26
	Added liquid glass	1,33	24,97	8,31	0,81	1,66	0,87	1,42	0,47	0,25
Vinegar	Without liquid glass	2,42	39,40	6,64	2,82	4,23	0,65	2,86	2,64	0,99
	Added liquid glass	1,05	42,54	14,22	0,95	0,71	0,54	1,30	0,51	0,30
Synthetic	Without liquid glass	5,25	27,25	10,25	1,25	2,92	0,80	1,42	2,24	0,83

Mass losses of the wood species that treated with Pomegranate (*Punicagranatum*) extract, some mordants, liquid glass and without liquid glass exposed to *Postia placenta* brown rot fungi have been detected varied. In order to find out factors that cause to differentiation, results of multiple variance analysis are given Table 5.

Table 5: Multiple variance analysis for mass losses of wood samples treated with natural dye obtained from granati fructuum (Punicagranatum) exposed to *Postia placenta*.

Factors	Total square	Degrees of freedom	Mean Square	*F*-Value	*P*-value (*P<0,05*)
Wood Species	25367,5	2	12683,7	305,48	0,000
Mordant	810,17	3	270,05	6,50	0,000
Mixture	92,47	1	92,47	2,22	0,139
Wood Species * Mordant	1702,43	6	283,73	6,83	0,000
Wood Species * Mixture	920,87	2	460,43	11,08	0,000
Mordant* Mixture	94,20	3	31,40	0,75	0,521
Wood Species * Mordant * Mixture	146,29	6	24,38	0,58	0,740
Error	3902,92	94	41,52		
Total	51194,4	118			
Corrected Total	33148,1	117			

According to results, wood species, mordant, wood species-mordant, wood species-mixture interactive factors were evaluated and found to be statistically significant on mass loss data of wood samples in consequence of brown rot fungi effect. (*P-value<0,05*).

According to results, mixture, mordant- mixture, wood species-mordant- mixture interactive factors were evaluated and found to be statistically insignificant on mass loss data of wood samples in consequence of brown rot fungi effect. (*P-value<0,05*).

Paired comparison regarding mass loss data of Pomegranate (*Punicagranatum*) extract and its concentration on mordant type level in consequence of brown rot fungi effect the Duncan test results are given in Table 6.

Table 6: Results of duncan test regarding mass loss on mordant type level of wood samples treated with natural dye obtained from Pomegranate (*Punicagranatum*) exposedto *Postia placenta.*

Mordant	Mean (%)	Homogeneity Group
Control	14,32	B
Ferrous sulphate	10,84	A
Aluminum sulphate	8,51	A*
Vinegar	16,02	B

*Duncan: 0,050 minimum mass loss

According to Duncan test, paired comparison which is regarding mass loss data in consequences of brown rot fungi effect on mordant type level ; aluminum sulphate group that used as a mordant has shown minimum mass loss data (8.51%). Vinegar group that used as a mordant has shown maximum mass loss data (16.02%).

Paired comparison regarding mass loss data of Pomegranate (*Punicagranatum*) extract and its concentration on wood type level in consequence of brown rot fungi effect the Duncan test results are given in Table 7.

Table 7: Results of Duncan test regarding mass loss on wood type level of wood samples treated with natural dye obtained from Pomegranate (*Punicagranatum*) exposed to *Postia placenta.*

Wood Species	Mean (%)	Homogeneity Group
Scots Pine	32,85	B
Chestnut	2,35	A
Mahogany	1,38	A*

*Duncan: 0,050 en düşük ağırlık kaybı

According to Duncan test, paired comparison which is regarding mass loss data consequences of brown rot fungi effect on wood species level ; Mohagany group has shown minimum mass loss data (1.38%). Scots pine group has shown maximum mass loss data (32.85%).

3.1.2 White rot fungi (*Tramates versicolor*) test results

Mass losses and mean extracts retentions of the wood samples treated with Pomegranate (*Punicagranatum*), some mordants, liquid glass and without liquid glass exposed to *Tramates versicolor* white rot fungi are given in Table 5.

Table 8: Mean mass losses and extract retentions of wood species treated with Pomegranate (*Punicagranatum*) dye and mordant mixtures in consequence of *Tramates versicolor* effect.

Mordant	Mixture	Scots Pine			Chestnut			Mahogany		
		Mean Retension (%)	Mean Mass Losses (%)	SD	Mean Retension (%)	Mean Mass Losses (%)	SD	Mean Retension (%)	Mean Mass Losses (%)	SD
Control (Non mordant)	Without liquid glass	0,35	16,76	10,40	2,23	1,50	0,52	2,78	1,62	0,47
	Added liquid glass	1,00	37,74	10,12	0,63	0,72	0,53	0,96	2,31	8,31
Ferrous sulphate	Without liquid glass	2,66	39,58	12,19	0,92	1,54	0,65	2,64	1,52	0,26
	Added liquid glass	1,90	32,52	11,08	1,07	1,18	0,70	1,30	0,76	0,24
Aluminum sulphate	Without liquid glass	4,85	25,33	9,39	1,76	0,68	0,93	2,54	1,60	0,30
	Added liquid glass	1,70	19,90	12,95	1,20	1,11	0,63	1,49	0,59	0,40
Vinegar	Without liquid glass	2,03	43,02	8,84	2,65	1,17	1,19	2,87	1,87	1,40
	Added liquid glass	1,10	50,66	14,31	0,90	0,59	0,35	1,48	1,38	1,06
Synthetic	Without liquid glass	5,38	23,12	12,51	1,51	2,90	0,81	1,41	1,17	0,44

Mass losses of the wood species that treated with Pomegranate (*Punicagranatum*) extract some mordants, liquid glass and without liquid glass exposed to *Tramates versicolor* white rot fungi have been detected varied. In order to find out factors that cause to differentiation, results of multiple variance analysis are given Table 9.

Table 9: Multiple variance analysis for mass losses of wood samples treated with natural dye obtained from Pomegranate (*Punicagranatum*) exposedto *Tramates versicolor.*

Factors	**Total square**	**Degrees of freedom**	**Mean Square**	***F*-Value**	***P*-value (*P<0,05*)**
Wood Species	26500,4	2	13250,2	283,42	0,000
Mordant	1046,51	3	348,83	7,46	0,000
Mixture	67,80	1	67,80	1,45	0,231
Wood Species * Mordant	2311,57	6	385,26	8,24	0,000
Wood Species * Mixture	94,82	2	47,41	1,01	0,367
Mordant* Mixture	610,61	3	203,53	4,35	0,006
Wood Species * Mordant * Mixture	728,06	6	121,34	2,59	0,023
Error	4394,57	94	46,75		
Total	53638,2	118			
Corrected Total	35999,6	117			

According to results, wood species, mordant, wood species-mordant, mordant-mixture, wood species-mordant-mixture interactive factors were evaluated and found to be statistically significant on mass loss data of wood samples in consequence of white rot fungi effect. (*P-value<0,05*).

According to results, mixture, wood species-mixture interactive factors were evaluated and found to be statistically insignificant on mass loss data of wood samples in consequence of white rot fungi effect. (*P-value<0,05*).

Paired comparison regarding mass loss data of Pomegranate (*Punicagranatum*) extract and its concentration on mordant type level in consequence of white rot fungi effect the Duncan test results are given in Table 10.

Table 10: Results of duncan test regarding mass loss on mordant type level of wood samples treated with natural dye obtained from Pomegranate (*Punicagranatum*) exposed to *Tramates versicolor.*

Mordant	**Mean (%)**	**Homogeneity Group**
Control	10,61	AB
Ferrous sulphate	12,85	B
Aluminum sulphate	8,20	A*
Vinegar	17,58	C

*Duncan: 0,050 minimum mass loss

According to Duncan test, paired comparison which is regarding mass loss data in consequences of white rot fungi effect on mordant type level; Aluminum sulphate group that used as a mordant has shown minimum mass loss data (8.20%). Vinegar group that used as a mordant has shown maximum mass loss data (17.58%).

Paired comparison which is regarding mass loss data of Pomegranate (*Punicagranatum*) extract and its concentration on wood type level in consequence of white rot fungi effect the Duncan test results are given in Table 11.

Table 11: Results of duncan test regarding mass loss on wood type level of wood samples treated with natural dye obtained from Pomegranate (*Punicagranatum*) exposed to *Tramates versicolor*

Wood Species	**Mean (%)**	**Homogeneity Group**
Scots Pine	33,19	B
Chestnut	0,95	A*
Mahogany	1,96	A

*Duncan: 0,050 minimum mass loss

According to Duncan test, paired comparison which is regarding mass loss data in consequences of white rot fungi effect on wood species level; Chestnut group has shown minimum mass loss data (0.95%). Scots pine group has shown maximum mass loss data (33.19%).

3.2 Antimicrobial Activity Results

Table 12 shows antimicrobial activity of Pomegranate (*Punicagranatum*) dye mixed with liquid glass and its concentration against test bacteria used in study.

Table 12: Antimicrobial activity of Pomegranate (*Punicagranatum*) dye and its concentration against test bacteria (Inhibition Zone, mm*)

Colorants	**Test bacteria**					
	Candidaalbicans		***Escherichia coli***		***Staphylococcusaureus***	
	24h	48h	24h	48h	24h	48h
Control (without liquid glass)	-	-	-	-	0,50	0,60
Control (liquid glass)	-	-	-	-	-	-
Dye + Ferrous sulphate (without liquid glass)	-	-	-	-	0,90	1,10
Dye + Ferrous sulphate (liquid glass)	-	-	0,50	0,50	0,70	0,80
Dye + Aluminum sulphate (without liquid glass)	-	-	0,60	0,60	0,80	0,80
Dye + Aluminum sulphate (liquid glass)	-	-	0,50	0,60	0,50	0,50
Dye + Vinegar (without liquid glass)	-	-	0,60	0,70	0,80	0,80
Dye + Vinegar (liquid glass)	-	-	0,50	0,60	-	0,90
Synthetic wood dye	-	-	-	-	-	-

Diameter of sterilized disk 0.6cm

It was observed that Pomegranate (*Punicagranatum*) dye + vinegar mixture has no antimicrobial activity against bacteria used in the test. Pomegranate (*Punicagranatum*) dye + liquid glass mixture and its mordant concentration didn't show antimicrobial activity against *Candidaalbicans* ATCC 10239 test microorganism. It was observed that Pomegranate (*Punicagranatum*) dye + liquid glass mixture and its non-mordant concentration and its ferrous sulfate mordant concentration have no antimicrobial activity against *Escherichia coli* ATCC 25922 test microorganism. Inhibition activity of Pomegranate (*Punicagranatum*) dye control group (without liquid glass) mixture was determined 0.50 cm end of the 24 hours against *Staphylococcus aureus* ATCC 6538/P test microorganism. Inhibition activity of Pomegranate (*Punicagranatum*) dye + control group (without liquid glass) mixture was determined 0.60 cm end of the 48 hours against *Staphylococcus aureus* ATCC 6538/P test microorganism. It was observed that control group (liquid glass added) has no antimicrobial activity against *Staphylococcus aureus* ATCC 6538/P test microorganism. Inhibition activity of the Pomegranate (*Punicagranatum*) dye + ferrous sulfate (liquid glass added) mordant concentration was determined 0.50 cm end of the 24 hours and 48 hours against *Escherichia coli* ATCC 25922 test microorganism. Inhibition activity of the Pomegranate (*Punicagranatum*) dye + ferrous sulfate mordant concentration (without liquid glass) was determined 0.90 cm and 1.10 cm end of the 24 hours and 48 hours respectively against *Staphylococcus aureus* ATCC 6538/P test microorganism. Inhibition activity of (*Punicagranatum*) dye + ferrous sulfate (liquid glass added) was determined 0.70 cm and 0.80 cm end of the 24 hours and 48 hours respectively. Inhibition activity of Pomegranate (*Punicagranatum*) dye + aluminum sulfate (liquid glass added) mordant concentration was determined 0.50 cm and 0.60 cm end of the 24 hours and 48 hours respectively against *Escherichia coli* ATCC 25922 test microorganism. Inhibition activity of Pomegranate (*Punicagranatum*) dye + aluminum sulfate (liquid glass added) mordant concentration was determined 0.50 cm and 0.50 cm end of the 24 hours and 48 hours respectively against *Staphylococcus aureus* ATCC 6538/P test microorganism. Inhibition activity of Pomegranate (*Punicagranatum*) dye + aluminum sulfate mordant concentration (without liquid glass) was determined 0.80 cm and 0.80 cm end of the 24 hours and 48 hours respectively against *Staphylococcus aureus* ATCC 6538/P test microorganism. Inhibition activity of Pomegranate (*Punicagranatum*) dye + aluminum sulfate mordant concentration (without liquid glass) was determined 0.60 cm and 0.60 cm end of the 24 hours and 48 hours respectively against *Escherichia coli* ATCC 25922 test microorganism. Inhibition activity of Pomegranate (*Punicagranatum*) dye + vinegar (liquid glass added) mordant concentration was determined 0.50 cm and 0.60 cm end of the 24 hours and 48 hours respectively against *Escherichia coli* ATCC 25922 test microorganism. Inhibition activity of Pomegranate (*Punicagranatum*) dye + vinegar (liquid glass added) mordant concentration was determined 0.90 cm end of the 48 hours against *Staphylococcus aureus* ATCC 6538/P test microorganism. Also it has not been observed any antimicrobial activity end of the 24 hours against *Staphylococcus aureus* ATCC 6538/P test microorganism. Inhibition activity of Pomegranate (*Punicagranatum*) dye + vinegar (without liquid glass) mordant concentration was determined 0.80 cm and 0.80 cm end of the 24 hours and 48 hours respectively against *Staphylococcus aureus* ATCC 6538/P test microorganism. Inhibition activity of Pomegranate (*Punicagranatum*) dye + vinegar (without liquid glass) mordant concentration was determined 0.60 cm and 0.70 cm end of the 24 hours and 48 hours respectively against *Escherichia coli* ATCC 25922 test microorganism. Synthetic wood dye did not show any antimicrobial activity against test microorganism.

4 CONCLUSIONS

4.1 According to brown rot (*Postiaplacenta*) results

Effective results were obtained from aluminum sulfate mordant without liquid glass for scots pine (18.20%), liquid glass added vinegar mordant for chestnut (0.71%) and liquid glass added ferrous sulphate mordant for mahogany (0.32%) among the test samples that Pomegranate (*Punicagranatum*) colorant applied.

The most prevalent mass loss data was observed on aluminum sulphate group that used as a mordant (8.51%) and maximum mass loss data was observed on vinegar group that used as a mordant (16.02%) in consequences of brown rot fungi effect on mordant level.

The minimum mass loss data was observed on mahogany group (1.38%) and maximum mass loss data was observed on scots pine group (32.5%) in consequences of brown rot fungi effect on wood species level.

It was observed that Pomegranate (*Punicagranatum*) dye shows more effective results rather than synthetic wood dyes.

4.2 According to white rot (*Tramatesversicolor*) results;

Effective results were obtained from control mordant without liquid glass for scots pine (16.76%), liquid glass added vinegar mordant for chestnut (0.59%) and liquid glass added aluminum sulphate mordant for mahogany (0.59%) among the test samples that Pomegranate (*Punicagranatum*) colorant applied against white rot fungi (*Tramatesversicolor)*.

The most prevalent mass loss data was observed on aluminum sulphate group that used as a mordant (8.20%) and maximum mass loss data was observed on vinegar group that used as a mordant (17.58%) consequences of white rot fungi effect on mordant level.

The minimum mass loss data was observed on chestnut group (0.95%) and maximum mass loss data was observed on scots pine group (33.19%) in consequences of white rot fungi effect on wood species level.

It was observed that Pomegranate (*Punicagranatum*) dye shows more effective results rather than synthetic wood dyes.

4.3 According to antimicrobial activity results;

All concentration we obtained from Pomegranate (*Punicagranatum*) dye didn't show antimicrobial activity against *Candidaalbicans* ATCC 10239 ATCC 6538/P test microorganism. In addition, all colorants except Pomegranate (*Punicagranatum*) dye + liquid glass mixture have shown antimicrobial activity against *Staphylococcus aureus* ATCC 6538/P test microorganism.

Ferrous sulfate (liquid glass added), aluminum sulfate (liquid glass and without liquid glass), vinegar (liquid glass and without liquid glass) concentration of Pomegranate (*Punicagranatum*) dye have shown antimicrobial activity against *Escherichia coli* ATCC 25922 test microorganism.

Synthetic wood dye didn't show antimicrobial activity against any microorganisms.

As a result, scientists should be concentrated on fieldwork in the matter of using of environmentally plant extracts as a wood preservative and wood colorant. It's estimated that plant extracts using as a wood preservative and wood colorant are eco-friendly, economic because they can offer substantial advantages for protection, providing adequate decay resistance against fungi at low cost, low mammalian toxicity, and ease of handling and treatment.

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THE INTERNATIONAL FOREST PRODUCTS CONGRESS

Evaluation of the Risks in Wood Harvesting Activities by The Preliminary Hazard Analysis (PHA)

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ABSTRACT

The first step of the wood harvesting process is the harvesting that include cutting-felling, pruning, peeling, and bucking. These activities involve a variety of hazards, because of in the work environment, done and machines used. Forestry operations are among the most difficult and risky. Taking the necessary precautions is crucial to ensure occupational health and safety in forest operations before the operations is done that identification and classification of hazards posed by these activities. In this study, it is aimed to determine the hazards that the trees cutting-felling, pruning and bucking activities carry in terms of occupational health and safety and evaluate them according to the preliminary hazard analysis (PHA) method. Preliminary hazard analysis method has been chosen as the risk analysis methods because of the necessity of documentation is less in the study, the ability to be done by an expert, the medium level of experience and the application of each sector. The hazards of these activities have are revealed by the literature survey and the field studies in the wood harvesting area in the Black Sea, Central Anatolia and Mediterranean regions of the Turkey. Twenty-nine hazardous situations were identified in the study, of which 12 were high risk, 9 were serious and 8 were intermediate risk. It is not possible that the working environment and all hazards in the forests that are living ecosystems and work material is heavy are completely removed. Intervening according to the importance classes of the hazards to minimize and the level of the risk to decrease should be taken precautions that determined in the study.

KEYWORDS: Risk analysis, PHA method, Wood harvesting, Forestry activities

1 INTRODUCTION

Forestry activities are considered in the 3D class according to the International Labor Organization (ILO) due to being dirty, difficult and dangerous (Poschen, 1993). These activities are located in the fourth risk class from the 5 risk group "Communiqué on the List of Risk Groups Related to Occupational Health and Safety" published in Turkey (CLRG, 2004). The wood production process is comprised of harvesting, extraction and transportation. The first step of the wood production process is the harvesting that include cutting-felling, pruning, peeling, and bucking. These works are among the most dangerous and risky works in terms of occupational health and safety due to the working conditions, the equipment used and the heavy workmanship. According to TS 18001 risk is the combination of the likelihood of a hazardous event or exposure to occur, and the severity of the injury or health impairment that may be caused by the event or exposure (TS 18001, 2008). The Risk assessment is, in short, a process involving the estimation of the size of the risk and the identification of whether the risk is on an acceptable level. The main aim of the risk assessment is to reduce all kinds of danger, risks and arising from working conditions and to decrease a level that does not affect human health (Tan, 2007).

Although the wood harvesting activities are an activity that has much more work accidents and occupational diseases, there is not much the records of the accident in the Social Security Institution (SSI).

This is due to the fact that until the recently the wood harvesting activities have been made through tender to the forest villagers or the forest villages development cooperatives in accordance with the relevant regulations of the forest law (Forest law, 1956). Seasonal wood workers do not have a health insurance system for wood harvesting works that they do. For this reason, there are no accurate records of occupational accidents, occupational diseases, or near miss events. The data needed for risk analysis were obtained from workplace records, the cards of used machines, field observations, the opinions of experienced wood employees and employers (Unver, 2013).

Serious forestry operation accidents occur worldwide at the rate of 4–10 per year (Web-1, 2017). Establishing and controlling the hazards of forestry activities for various reasons will reduce the risk of occupational accidents and diseases. There are various studies on the area of different activities in the forestry sector with the literature review and the field studies for determination of possible hazards and risk analysis. (Poschen, 1998; Gokbayrak, 2005; Kuruoglu et al., 2007; Agca, 2010; Ceylan and Bashelvacı, 2011; Tunay and Emir, 2015; Unver-Okan and Acar, 2015; Ayanoglu and Biberci, 2015; Calay, 2015; Unver-Okan et al., 2017).

Preliminary hazard analysis (PHA) is one of the most widespread methods for use in identification and qualitative or semi-qualitative risk analysis (Flaus, 2013). Its objective is to identify and categories hazards, hazardous situations and hazardous events that can cause harm to persons, facilities and systems (Vincoli, 2006; Tiusanen, 2014). Aydos (2015) defined the PHA as a hazard or risk inventory to be drawn up at the beginning of the activity to be undertaken and in consideration of general hazard groups. Thus, it may be possible to remove the risks or reduce them to acceptable levels by setting preventive control measures. The identified hazards are put in order through the risk assessment selection diagram and the precautions to be taken are determined according to priority sequence. Ericson (2005) emphasized that implementing this method before starting is functional in terms of ensuring a safe working environment and avoiding economic, ergonomic or environmental damage that may occur. The PHA method has a methodology that uses design and hazard information to strengthen the identification of hazard and causal factors (Figure 1).

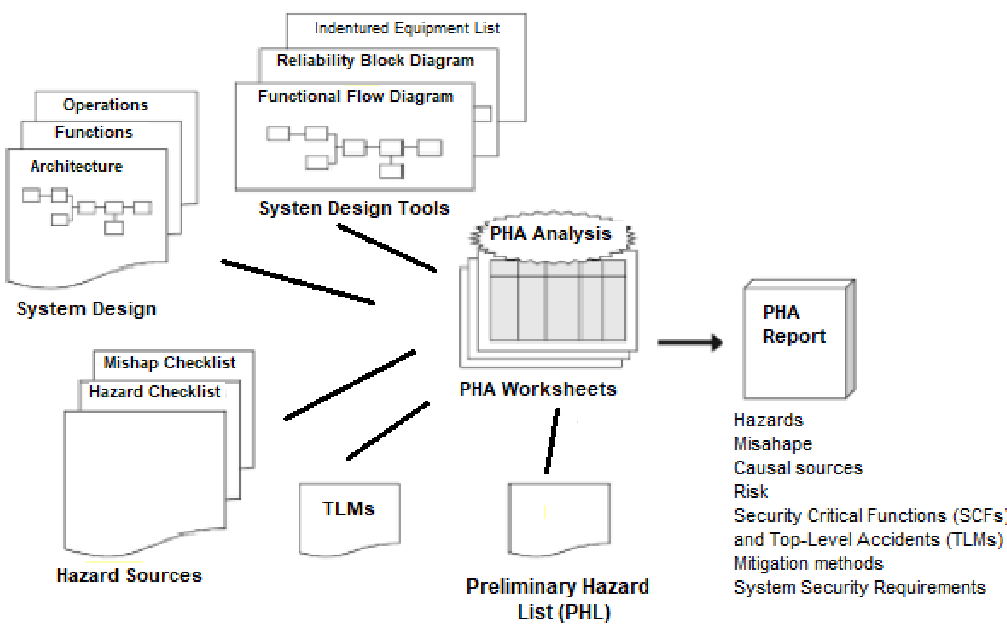

Figure 1: The PHA methodology

Taking the necessary precautions is crucial to ensure occupational health and safety in forest operations before the operations is done that identification and classification of hazards posed by these activities. In this study, it is aimed to determine the hazards of wood harvesting activities and classify them according to importance levels by using preliminary hazard analysis method.

2 MATERIAL AND METHOD

The field studies were carried out in the harvesting area of Bolu-Elmalık, Eskişehir-Değirmendere and Antalya-Düzlerçamı in Turkey. The studies were made in summer season of 2017 (Figure 2).

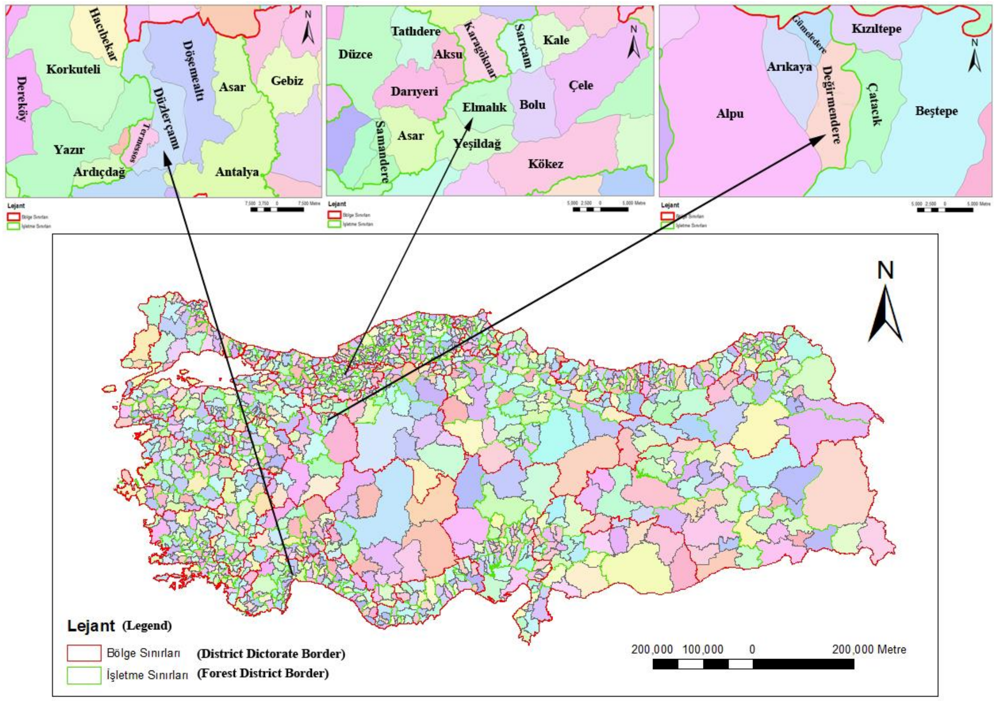

Figure 2: Map of the study areas

All of the cutting-felling, pruning, and bucking operations in the harvesting units were made with a medium sized chainsaw. These operations were carried out by seasonal chainsaw operator and forest workers. Within the scope of the study, total of 6 days were left in the harvesting units. During these days, the field observations were made to identify possible hazards that could arise from the work organization, because of the chainsaws used and the environment conditions. Taking into consideration the literature review and field observations, 29 possible hazards for cutting-felling, pruning, and bucking were identified.

The risk matrix method is used to determine the risk levels for the risks envisaged in the survey and to prioritize the control measures to be taken. Thus, it has been decided which risks need to be examined in more detail and whether the risks are acceptable or unacceptable (Table 1 and Table 2).

Table 1: Severity category ranks

Severity category	Rank	Description
Catastrophic	1	Major injury or death of personnel, irreversible environmental impact, 10 milyon $ < damage
Critical	2	Permanent disability, occupational disease in which at least 3 workers are hospitalized, significant environmental impact or $ 1 million - $ 10 million damage
Major	3	1 or more working days loss, moderate environmental impact, 100 thousand $ to 1 million $ damage
Minor	4	No loss of working day, minimum environmental impact $ 100 thousand > damage.

Table 2: Occurrency ranks (Rausand, 2004).

Occurrency Category	Rank	Description
Frequent	A	Once per month or more often
Probable	B	Once per year
Occasional	C	Once per 10 years
Remote	D	Once per 100 years
Improbable	E	Once per 1000 years or more seldom

The risk scores of the potential hazards were classified according to the risk assessment matrix calculated by mathematical multiplication of the probability and severity values (Table 3).

Table 3: Risk assessment matrix (Velioglu, 2016).

Frequency of Occurrence	Severity			
	Catastrophic (1)	Critical (2)	Marginal (3)	Negligible (4)
Frequent (A)	1A	2A	3A	4A
Probable (B)	1B	2B	3B	4B
Occasional (C)	1C	2C	3C	4C
Remote (D)	1D	2D	3D	4D
Improbable (E)	1E	2E	3E	4E

3 RESULTS AND DISCUSSION

Risk analysis was performed by preliminary hazard analysis method considering the results of field observations and literature review (Table 4).

Table 4: Risk analysis results

Hazard Class	Hazard	Risk	Rank	Degree
Work- sourced	Tree hanging	Fracture and death of the employee due to tree crushing	1B	Catastrophic
Work- sourced	Falling branches	Crush, broken and fatal work accident	1B	Catastrophic
Work- sourced	Falling branches	Crush, broken and fatal work accident	1B	Catastrophic
Work- sourced	Trunk under the tension	Death or injury	1C	Catastrophic
Work- sourced	Falling branches	Crush, broken and fatal work accident	1B	Catastrophic
Work- sourced	Trunk under the tension	Death or injury	1C	Catastrophic
Machine	Rotating or attaching chain saw	Death or injury	2B	Catastrophic

Machine	Recoil of chain saw	Death or injury	2B	Catastrophic
Chemical	Fuel-oil replenishment	Fire, environmental pollution, allergy	1C	Catastrophic
Worker-sourced	Incorrect determination of falling direction	Death or injury	1C	Catastrophic
Worker-sourced	Body injury	Death or injury	2B	Catastrophic
Worker-sourced	Walking over the overturned trunk	Injury	2A	Catastrophic
Worker-sourced	Uneducated	Death or injury	1B	Catastrophic
Worker-sourced	Non-use of PPE	Death, injury, occupational disease	1B	Catastrophic
Organizational	Working alone	Death or injury	2B	Catastrophic
Machine	Noise	Temporary or permanent hearing loss	3A	Critical
Study area	Rainfall	Death or injury	2C	Critical
Study area	Thunderbolt	Electric shock, tree or branch fall, forest fire	1D	Critical
Study area	Rough ground	Slipping, falling, hanging	3B	Critical
Organizational	Hygiene	Disease transmission, fatigue, distraction	3A	Critical
Work-sourced	Decayed trees	Crush, broken and fatal work accident	2C	Critical
Work-sourced	Inclined or double body	Uncontrolled actuation of the tree during harvesting in work-related accidents	2C	Critical
Worker-sourced	Attaching to electrical lines	Death or injury	1D	Critical
Worker-sourced	Incorrect posture	Musculoskeletal system disorders	3B	Critical
Machine	Vibration	Occupational disease	3C	Marginal
Machine	Chain breakage	Right hand and various parts of the body to injury	3D	Marginal
Machine	Incorrect transport of chain saw	Death or injury	2D	Marginal
Biological	Wild animals or insects	Death or injury, allergy	2D	Marginal
Psychological	Fatigue	Carelessness, unemployment resulting in loss of concentration	3C	Marginal
Organizational	Nutrition	Work accident due to carelessness, fatigue	3C	Marginal
Organizational	Visitors	Death or injury	2D	Marginal
Work sourced	Sun	Sunburn, excessive fluid loss, fatigue	3C	Marginal

According to the results of the preliminary hazard analyzes made, the distribution of possible hazards to the groups of hazardous sources has been determined (Table 5).

Table 5: Distribution of hazard groups

Group of Hazard	**Number of Hazard**	**Risk Degree**		
		Catastrophic	Critical	Marginal
Worker sourced	7	5	2	-
Work-sourced	5	3	2	-
Machine	6	2	1	3
Study area	4	-	3	1
Organizational	4	1	1	2
Chemical	1	1	-	-
Biological	1	-	-	1
Psychological	1	-	-	1

It was determined that on the logging operations areas 39.28% of the hazards identified were high, 32.15% were serious and 28.57% were in the middle risk class (Figure 3).

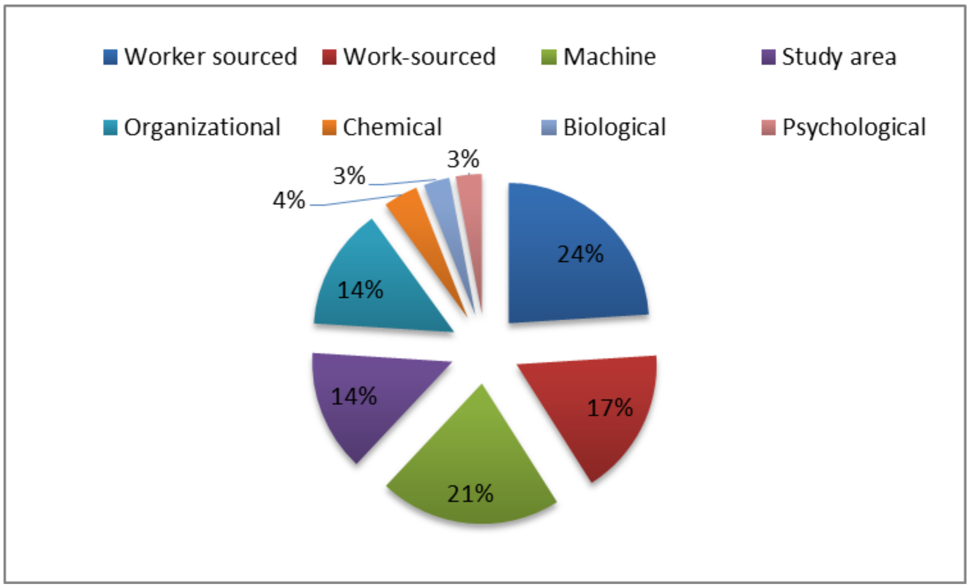

Figure 3. Percentage of hazard groups

As a result of the study, the most dangerous hazards during the logging off are found as workers' mistakes, improper use of chainsaws and difficulties of occupational. Similar to studies in Europe and New Zealand, it was found that the cutting and felling stage are the most risky of harvesting's stages. (Web-2, 2018; Web-3, 2016). In addition, it was determined that the mistakes made by the loggers during their work due to carelessness, inadequacy of work training or not using protective equipment which constitute the significant risks.

4 CONCLUSION AND RECOMMENDATION

In this study, the hazards of the logging off in terms of occupational health and safety were determined and evaluated by preliminary hazard analysis method. In the study, 28 hazardous situations were determinded and detected as 11 high risk, 9 severe risk and 8 intermediate risk.

It has been found that the cutting-felling is the stage in which the accident rate is highest in the forestry sector. As some of the most dangerous situations may stand out attached trees, uneducated workers, and no personal protective equipment.

- At least two-person teams should employe in terms of danger of wild animals, assistance in case of injury, and help in heavy work.
- Warning signs should affixe or cut-off area to prevent entering the logging operation area by persons outside.
- For logging operation areas should suitably use to the physical conditions such as sun, rain, floor structure.
- In harvesting, the employee should be only forest workers and loggers which educated by suitable institutions.
- It should use to personal protective equipment appropriate for the logging off.
- Chainsaws which periodically repaired and to be getting equipment should use.
- Noise and vibration levels of chainsaw should measure periodically and if the exposure is above the limit values, they should not use.

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The Effects of Water-Based Color-Protective Barriers on Natural Wood Veneer

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THE EFFECTS OF WATER-BASED COLOR-PROTECTIVE BARRIERS ON NATURAL WOOD VENEER

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ABSTRACT

In this study, the effects of water-based color-protective barriers on the color change of wooden veneers of various tree species were investigated. Wooden veneers of castanea, eucalyptus, and scots pine species - which are widely used industrially - were selected for this purpose. The wood veneers were then divided into two groups and two separate top surface prescriptions were applied to each group. In the first group, only varnish was applied. On the second group, a water-based color-protecting barrier and varnish application was used, and a total of 6 variation test samples were prepared, with and without water color-protecting barriers applied to each tree type. Test samples were tested on both UVA and UVB lamps in the QUV aging device. It has been determined that water-based color-protective barriers do not show a significant color change in the applied parts, and that the veneer experiences discoloration in the areas not subjected to color-protective barriers. These results can be regarded as an industrially significant result, helping to overcome problems associated with the weathering of varnished surfaces.

Keywords: Water based colour barrier, wooden coating, QUV

1 INTRODUCTION

Wood is a natural and renewable raw material that has been used in countless contexts by humans for centuries. Relevant literature puts the number of distinct wood products created to meet human needs at around ten thousand (Bozkurt and Erdin, 1997).

The application of surface treatment products and coatings can help protect, clean, and aesthetically enhance wooden furniture pieces in particular. However, the value and lifespan of wooden furniture can still be negatively impacted by numerous factors – such as the deformation of surface treatments and coating, or the discoloration of the wood itself by contact with harmful ultraviolet (UV) rays. It is well-known that every year considerable damage is done to outdoor wooden furniture and building materials by climatic factors like sunlight, moisture, and high temperatures. Cracking, fading, and hazing are the most common forms of outdoor damage to wood (Anonymous 2012, Anonymous, http://www.q-lab.com accessed on: 26 Dec. 2012)

As an organic material, wood is liable to undergo changes in size, color and biological formation; characteristics generally seen as problematic for users (Aytin et al., 2018). Shifts in color occur particularly quickly for wood used in exterior settings. Çakıcıer (2007) notes that wood extractives and lignin degradation are responsible for the yellow and brown hues commonly observed on weathered wood surfaces. Below are some examples of wood degradation as a result of external weather conditions. (Figure 1).

(a) (b) (c)

Figure 1. (a) Examples of wood degradation (Aytin et al., 2018)

Aside from in traditional buildings or furniture, wood is also commonly used on the likes of ships and yachts, where it may be negatively affected by direct contact with salt water, sunlight, rain, waves, and wind. As such, wood used in these kinds of environments must be naturally resistant to climatic factors or must be speciality materials with increased durability (http://gidbdergi.itu.edu.tr/sayilar/06/0602.pdf, Tunçel 2016). Similarly, the selection of surface treatment agents and coatings is particularly important where the durability of wood products is concerned.

Various surface degradations may occur on wood that is subjected to light, humidity, wind, and temperature common to salt-water settings. The weathering and degradation of wood, which usually begins with a change in its color, is said to have an effect on a number of other structural features. On a microscopic level, it has been observed that lignin degradation (caused by harmful UV rays) leads to the disruption of the middle lamella, cracks in the edged passages, and separations in the cell wall. As color is an aesthetic consideration for wood furniture, suffice it to say that the phenomenon of color changes in wood products is seen as a negative attribute (Ulay ve Çakıcıer, 2017).

In order to sustain the value and lifespan of wood materials used in exterior settings, it is necessary to develop tools to prevent lignin degradation and color changes; both conditions known to be affected by UV rays. In this regard, surface treatment agents and coatings for wood must primarily target and prevent lignin degradation.

Owing to the fact that the color of wood is an aesthetic matter and that it can be used to predict possible wood deformations, the quantifiability of color values and the ability to determine total color changes in wood are both vital. The CIELab color system is a conventional method for determine color values. It is a color system comprised of three coordinates L*, a*, and b* calculated using the tristimulus values X, Y, and Z. The "*" after each coordinate is used to differentiate the CIE formulas from previously developed color systems (Yeşil 2010).

Figure 2 shows the values of L*, a* and b* and their points of measurement (in accordance with the CIELab system)

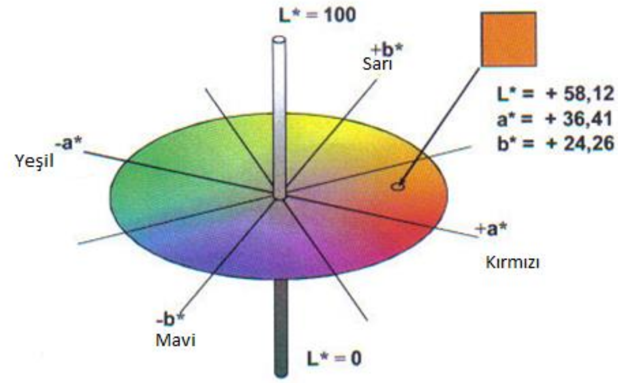

Figure 2. Determination of L *, a * and b * values according to CIELab color system. (Anonymous 2012)

In Figure 2, L* denotes the black-white axis (black is L*=0, white is L*=100), a* is the red-green axis (positive value is red, negative value is green), and b* is the yellow-blue axis (positive value is yellow, negative value is blue). The angle of L denotes the change of color in the wood; a tighter angle would mean the color has shifted towards red (a) while a wider angle would mean the color has shifted towards yellow (b).

Varnish (coating?) is used to give wood a layer of protection from external influences, and also for aesthetic reasons. It is a liquid agent comprised of soluble particles that create a transparent coating layer. Appropriate varnishes can vary depending on the conditions in which the wood is to be used and selecting the most suitable coating agent is of particular importance. The quality and durability of a given piece of wooden furniture is often dependent on the type of coating agent used (Kurtoğlu, 2000).

Water-based coatings are generally colorless, odourless, and non-yellowing; they dry via chemical reaction, and do not change the color of the surface onto which it is applied. The chemical reaction through which it dries makes the hardened layer irreversible (Yıldız, 1999). Water-based coating systems are some of the easiest to adjust and repair, both during application and afterwards. These coatings can be produced using many different resins, including (but not limited to) alkyd, polyester, acrylic and polyurethane. Glossy water-based varnishes do not contain coloring pigments, while matte varnishes contain matting agents. Designed for the polymerization of dispersion and emulsion, these coatings have become increasingly important in their industrial use. (Johnson, 1997).

Predictions and foresight into the climatic conditions that will be faced by surface-treated wood may help prevent or lessen the impact of weathering. To that end, it is possible to test the surface coating’s performance using various aging techniques.

Coated wood can be tested in specially prepared conditions to determine its performance under the influence of factors such as dampness, temperature, rain, and varying wavelenghts of sunlight. In the last century, natural test stations and specialised aging devices have been developed for use in laboratories (Aytin 2013). Aging techniques can be grouped into three different classifications: natural outdoor aging tests, accelerated outdoor aging tests, and finally accelerated laboratory aging tests (Çakıcıer, 2007). Once aged, coated wood surfaces can be tested for color changes, glossiness, coating thickness, adhesion, scratch-resistance and surface smoothness.

This study investigates the differences between two different water-based coating solutions by comparing how they affect discoloration on three different natural wood veneers on plywood; chestnut (castanae), eucalyptus, and Scots pine. The first solution is a water-based varnish, while the second is a combination of water-based varnish and water-based color-protecting barrier. It is estimated that the combined varnish+barrier coating solution will positively affect the possible color changes on the wood.

2 MATERIAL AND METHOD

The three types of natural veneer used in this study (Castanea, Eucalyptus and Scots pine) were randomly selected from the market of tree-types suitable for exterior uses. Next, the veneers were pressed onto plywood (50*50cm) at an industrial facility that produces plywood. In preparation for their accelerated weathering, the pieces of plywood were cut into strips measuring 7,8*30,5 cm. Later, the surface coating agents were applied to the test and control samples. The procedure for applying the surface treatments is listed below.

Table 1. Classification and properties of applied surface treatments.

Sample type	Type of coating solution applied	Defining features	Solid additives (%)	Application method	Application layers
Test group	AQUACOOLFX1707 Wood color-protecting barrier	Two component, water-based color-protective barrier with "New Generation Acrylic Resin" technology	25	"Conventional 1,8mm Spray gun"	2 layers
	AQUACOOLAG 4850 Parquet Varnish	Two component, water-based parquet varnish	31		2 layers
Control group	AQUACOOL AG 4850 Parquet Varnish	Two component, water-based parquet varnish	31	"Conventional 1,8mm Spray gun"	3 layers

In order for the dry film thickness in both groups to be similar, the 'control group' was coated in three layers of varnish, and the 'test group' in four. For each type of natural veneer, there was one 'control' and one 'test' sample, totaling six different panels. Each sample's surface was divided in two, with a line drawn down the middle. For each sample, AQUACOOL AG 4850 Parquet Varnish was applied on one side, and AQUACOOL AG 4850 Parquet Varnish with AQUACOOL FX 1707 color-protective barrier) on the other side. (Figure 3)

Figure 3. Test sample, color protective barrier and paint gun

One sample from each veneer type was subjected to accelerated aging for 144 hours with type-A UV lighting (labelled 'kuva' for the control group, and 'duva' for the test group). The other sample for each veneer was subjected to accelerated aging for the same amount of time under type-B UV lighting (labelled 'kuvb' for the control group, and 'duvb' for the test group). Table 2 shows the variations in veneer types and abbreviations used, while Table 3 describes the three-step aging process.

Table 2. Veneer variations and abbreviation index

Variation abbreviations	Variation name
Eucalyptus kuva	Eucalyptus with varnish control sample – UVA aged
Eucalyptus duva	Eucalyptus with varnish and barrier test sample – UVA aged
Eucalyptus kuvb	Eucalyptus with varnish control sample – UVB aged
Eucalyptus duvb	Eucalyptus with varnish and barrier test sample – UVB aged
Castenae kuva	Castenae with varnish control sample – UVA aged
Castanea duva	Castenae with varnish and barrier test sample – UVA aged
Castenae kuvb	Castenae with varnish control sample – UVB aged
Castenae duvb	Castenae with varnish and barrier test sample – UVB aged
Scots pine kuva	Scots pine with varnish control sample – UVA aged
Scots pine duva	Scots pine with varnish and barrier test sample – UVA aged
Scots pine kuvb	Scots pine with varnish control sample – UVB aged
Scots pine duvb	Scots pine with varnish and barrier test sample – UVB aged

Table 3. Aging program cycle (repeated)

Cycle phase	Factor	Temperature	Light intensity	Duration
1	UV	50°C	0.85 W/M2	8 hours
2	Spray			15 minutes
3	Condensation	40°C		3 hours 45 minutes
4	Final step - Go to step 1			

The color differences between the control and test groups were scrutinized. Each sample was analyzed using a Konica Minolta CD-600 brand spectrophotometer according to ISO 7724-2/1984 standards. (ΔE*) was calculated using the formula below, according to standard ISO 7724–3/1984.

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

Index;
ΔE* : The total color difference apparent in the samples after heating
ΔL* : Black-white color change
Δa* : Red-green color change
Δb* : Yellow-blue color change

3 FINDINGS

Table 4 presents the results of the multiple variance analysis for the castanae, eucalyptus and Scots pine veneers aged for 144 hours in UVA/UVB lights after being coated with varnish, and with the varnish and protective barrier combination.

Table 4. Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	AL	872.243(a)	11	79.295	20.866	0.000	0.793
	Aa	601.779(b)	11	54.707	152.233	0.000	0.965
	Ab	4862.567(c)	11	442.052	365.500	0.000	0.985
	AE	4708.722(d)	11	428.066	361.496	0.000	0.985
Intercept	AL	1516.720	1	1516.720	399.119	0.000	0.869
	Aa	1047.370	1	1047.370	2914.514	0.000	0.980
	Ab	5169.242	1	5169.242	4274.062	0.000	0.986
	AE	5324.604	1	5324.604	4496.561	0.000	0.987
Variation	AL	694.877	9	77.209	20.317	0.000	0.753
	Aa	503.372	9	55.930	155.637	0.000	0.959
	Ab	4591.324	9	510.147	421.803	0.000	0.984
	AE	4455.548	9	495.061	418.073	0.000	0.984
Error	AL	228.010	60	3.800			
	Aa	21.562	60	.359			
	Ab	72.567	60	1.209			
	AE	71.049	60	1.184			
Total	AL	2616.973	72				
	Aa	1670.711	72				
	Ab	10104.375	72				
	AE	10104.375	72				
Corrected Total	AL	1100.253	71	a R Squared = 0.793 (Adjusted R Squared =0 .755)			
	Aa	623.341	71	b R Squared = 0.965 (Adjusted R Squared = 0.959)			
	Ab	4935.134	71	c R Squared = 0.985 (Adjusted R Squared = 0.983)			
	AE	4779.771	71	d R Squared = 0.985 (Adjusted R Squared = 0.982)			

According to Table 4, the difference between the multiple color values for the veneers after 144 hours of aging under UVA and UVB lights was P≤0.95. To better understand these color differences, variations in wood type and its sub-variations were examined in an attempt to determine which color factor had the most effect on the total color differences (tables 4,5,6,7,8) Similarly, in order to determine similar groups among the tables the Duncan test was applied to averages, and the results displayed below.

Table 5 illustrates the results from the Duncan test, as well as the arithmetic averages (M) showing the specific color deviations.

Table 5. Results from the Duncan test, as well as the arithmetic averages (M) showing the specific color deviations.

Wood type	N	ΔL		Δa		Δb		ΔE	
		M	HG	M	HG	M	HG	M	HG
Eucalyptus	24	2.37	B	-2.32	A	-11.20	B	11.21	A
Castanea	24	5.52	A	-3.93	B	-7.31	A	7.65	B
Scots pine	24	5.86	A	-5.18	C	-6.90	A	6.92	C

Table 5 illustrates that ΔE is greatest for eucalyptus and smallest for scot's pine. To see total color changes, Table 6 outlines the sub variations for each veneer-type, along with its Duncan test result.

Table 6. ΔE averages and Duncan test results for each veneer sub variation

Wood type and sub-variation	N	ΔE				
		A	B	C	D	E
Eucalyptus duvb	6	0.48				
Castenae duvb	6	0.72				
Eucalyptus duva	6	0.76				
Scots pine duvb	6	0.93				
Scots pine duva	6	1.48				
Castanea duva	6	1.87				
Scots pine kuva	6		12.16			
Scots pine kuvb	6		13.09	13.09		
Castenae kuva	6			13.52	13.52	
Castenae kuvb	6				14.50	
Eucalyptus kuva	6					21.71
Eucalyptus kuvb	6					21.90
Sig.		0.055	0.143	0.496	0.124	0.757

Table 7 shows the average changes in brightness (ΔL) for each veneer, as well as their Duncan test results.

Table 7a. Brightness-related (ΔL) averages and Duncan test results

Wood type and sub-variation	N	ΔL					
		A	B	C	D	E	F
Eucalyptus duva	6	-0.77					
Eucalyptus duvb	6	-0.45					
Castanea duva	6	1.51	1.51				
Scots pine duvb	6		2.20				
Castenae duvb	6		3.48	3.48			
Scots pine duva	6		3.64	3.64			
Eucalyptus kuvb	6			5.02	5.02		
Eucalyptus kuva	6			5.72	5.72		
Castenae kuvb	6				6.99	6.99	
Scots pine kuvb	6					8.23	8.23
Scots pine kuva	6						9.38
Castenae kuva	6						10.11
Sig.		0.058	0.089	0.073	0.103	0.275	0.120

Table 7b. Average changes in red-green coloring (Δa) and Duncan test results

Wood type and sub-variation	N	Δa								
		A	B	C	D	E	F	G	H	I
Scots pine kuva	6	-8.49								
Castenae kuva	6		-7.70							
Scots pine kuvb	6		-7.05							
Castenae kuvb	6			-5.76						
Eucalyptus kuva	6				-5.04					
Eucalyptus kuvb	6					-4.26				

Scots pine duva	6						-3.16			
Scots pine duvb	6							-2.01		
Castenae duvb	6							-1.37	-1.37	
Castanea duva	6								-0.90	
Eucalyptus duvb	6									-0.05
Eucalyptus duva	6									0.06
Sig.		1.000	0.063	1.000	1.000	1.000	1.000	0.067	0.184	0.726

Table 7c. Average changes in yellow-blue coloring (Δa) and Duncan test results

Wood type and sub-variation	N	Δb						
		2	3	4	5	6	7	1
Eucalyptus kuvb	6	-21.90						
Eucalyptus kuva	6	-21.71						
Castenae kuvb	6		-14.50					
Castenae kuva	6		-13.52	-13.52				
Scots pine kuvb	6			-13.09	-13.09			
Scots pine kuva	6				-12.16			
Castanea duva	6					-1.87		
Scots pine duva	6					-1.48	-1.48	
Scots pine duvb	6					-0.85	-0.85	
Eucalyptus duva	6					-0.76	-0.76	
Eucalyptus duvb	6						-0.44	-0.44
Castenae duvb	6							0.67
Sig.		0.760	0.128	0.501	0.148	0.116	0.141	0.082

4 CONCLUSIONS

Both from the multiple variance analysis and from the Duncan test and averages, it can be observed that on all veneer types and under each UV type, the discoloration was less prominent on samples that had been coated with the color-protective barrier. A noticeable difference can be seen in the total discoloration of samples coated with only varnish, as opposed to varnish and protective barrier. Figure 4 presents the sampled panels before and after artificial weathering.

Figure 4. Eucalyptus, Castanae and Scots pine panels before and after weathering.

Modern technology has enabled the advent and frequent use of specialized varnishes which are resistant to UV rays. However, despite being successful in protecting themselves from UV rays, these varnishes are unable to protect the structural integrity of the wood onto which it is applied, resulting in discoloration.

As such, color-protective barriers – which have been demonstrated in this study to have significantly reduced discoloration on weathered wood – appear to be a new industrial option. This situation bears the utmost importance for relevant industries. For wooden furniture pieces where quality and aesthetics are prioritized, color-protective barriers appear to minimize the threat of discoloration. This development also has serious implications for the longevity of wooden furniture used in outdoor settings.

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Effect of Cement and Accelerator Types on the Physico-Mechanical Properties of Cement-Bonded Particleboards

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ABSTRACT

In this study, it is aimed to determine the effect of the use of different types cement and accelerator on the physico-mechanical properties of cement-bonded particleboards. Within this scope, two types of cements (calcium aluminate cement and Super white CEM I 52.5 R cement) and accelerators (aluminum sulfate and calcium chloride) were used in the production of boards. Therefore, CBPBs with 1200 kg/m^3 target density and 1/2.75 wood-cement ratio were produced. Based on cement weight 1.5% accelerators were used. A total of four experimental panels, two repetitions for each board group, were manufactured. The test results obtained were evaluated according to EN 634-2 (2009). According to result, density values of the boards were changed with using depending on cement and accelerator types. The use of super white cement and calcium chloride positively affected the both mechanical properties and dimensional stability of the boards. The use of calcium aluminate cement and aluminum sulfate resulted in lower strength properties.

KEYWORDS: Cement-bonded particleboard, cement types, accelerator, physico-mechanical properties

1 INTRODUCTION

Wood composites are products obtained by combining wood (fiber, particle or particle) with other materials (plastics, synthetic fibers, glue, fillers, cement etc.) under temperature and pressure (Moloney, 1993). Nowadays, the decline of forest areas and the increase in wood prices, as well as the development of the chemical and adhesive industry, have evolved in wood composite materials (Ayrılmıs et al., 2012).

Cement-Bonded Particleboards (CBPBs) are much more resistant to fire, fungi and insects, as well as strong resistance to outdoor weather conditions, sound and heat insulation and wood composites are advantageous both in terms of production line and binder cost. They are advantageous both in terms of production line and binder cost. Moreover, the ability of the cement to self-harden makes the production process more economical. Because simple machines can be used during the production phase and high temperature pressing is not required. Cement is also a much cheaper binder than adhesives. Therefore, the use of wood-cement composites is increasing (Tittelein et al., 2012).

Depending on the developments in concrete technology, high-performance concretes (HPC), which are superior in terms of strength and durability, are currently being developed from concrete produced from traditional portland cement (NSC) (Khaliq and Khan, 2015). The calcium aluminate cement (CAC) is composed of calcium oxide and alumina oxides. It has applications not only in infrastructure works such as sewerage networks but also in hydraulic dams where wear resistance is required at the same time. It is also a used as refractory material in kilns and steel industry (Karadeniz et al., 2007). The studies have shown that concretes produced with CAC are resistant to aggressive environmental conditions and corrosion (Scrivener at al., 1999). While the super white cement (SWC) gives a very high early strength compared to the gray cement with the superior strength characteristic. Stabilization value allows the production of stabilized products. In addition, the Product provides advantages in cement dosage as less cement is used to achieve the same target strength values. Super white cement is highly resistant to alkaline-silica reactions and has a long service life (Web-1, 2018)

Compatibility in wood-cement composites can be expressed as the hardening level of the cement after mixing water and a certain amount of wood with cement. It is stated that when the cement is mixed with the wood, it is compatible if there is no restriction in cement hardening, otherwise it is incompatible. The extractive substances and sugars in the wood delay the cement hydration and cause the crystal structures to change (Jorge et al., 2004). So the accelerators are used in wood-cement composites to reduce the adverse effect of wood on the cement hydration reaction. The studies have shown that different types of accelerators are significantly effective on hydration heat changes and technological properties of cementitious wood composites (Semple et al., 2000; Soriano et al., 2000; Yel, 2014).

Therefore, the main goal of this work was to find out the possibility of using calcium aluminate and super white cement for making cement-bonded particleboards. In addition, the effects of accelerator types on some mechanical and physical properties of boards produced have been investigated.

2 MATERIALS AND METHODS

2.1 Materials

The particles obtained from the poplar woods (*Populus Tremula L.)* were used in production of the boards. It was supplied as sawmill wastes by Trabzon Organized Industrial Zone, Turkey. ISIDAÇ 40 (calcium aluminate cement) and Super White CEM I 52,5 R cements used in the production were supplied by Çimsa Cement Industry and Trade Co., Turkey. The chemical properties of the CAC and SWC are given in Table 1.

Table 16: Chemical properties of the CAC and SWC

Chemical properties (%)	**CAC**	**SWC**
SiO_2	3,60	21,6
Al_2O_3	39,80	4,05
Fe_2O_3	17,05	0,26
CaO	36,20	65,7
MgO	0,65	1,30
SO_3	0,04	3,30
Loss of ignition	0,30	3,20
Na_2O	0,16	0,30
Chloride (CI-)	0,009	0,01

2.2 Methods

Firstly, sawmill wastes chipped using a drum chipper before grinded into smaller particles in a knife ring flaker. Then the wood particles were classified using a laboratory type vibrating screen. The particle size used in production is 0.5-3 mm. The wood-cement ratios were 1/2,75, based on the oven dry weight for the single layer CBPB manufacture. Solid Aluminum sulphate ($Al_2(SO_4)_3$), calcium chloride($CaCI_2$) was prepared 25% solution and the mixture was added. 1.5% used on both accelerator types based on the cement weight. Hand formed mats were compressed in a laboratory type hot press using a pressure of 18-20 kg/cm^3 for 4hrs. The press temperature is 60 °C. The amount of water used in production is determined according to the following formula (Simatumpang, 1979),

$$\text{Water (liter)} = 0.35C + (0.30 - MC)W \quad (1)$$

where C is the cement weight (kg), MC is moisture content (oven dry basis) of wood particles, and W is oven dry wood particle weight (kg).

The dimensions of the CBPBs were 42,5 x 42,5 x 1 cm. The target density was 1200 g/cm^3 . Two panels were made for each group. After pressing, the particleboards were conditioned for 30 days at a temperature of 20 ± 2°C and 65 ± 5% relative humidity and then cut to obtain test samples according to the European Standards. Experimental design is given in Table 2.

Table 2: Experimental desing

Board types	**Cement types**	**Accelerator types**
A	CAC	$Al_2(SO_4)_3$
B	CAC	$CaCI_2$
C	SWC	$Al_2(SO_4)_3$
D	SWC	$CaCI_2$

Density (D), water absorption (WA) and thickness swelling (TS), modulus of elasticity (MOE), modulus of rupture (MOR), internal bonding strength (IB) and screw withdrawal strength (WS) properties of the produced boards were determined according to EN 323, ASTM D1037, EN 317, EN 310, EN 319, EN 320, respectively. The test results obtained were evaluated according to EN 634-2 (2009). The data were analysed using SPSS 22 procedure for the analysis of variance (ANOVA) at 95% confident level ($P \leq 0.05$). Duncan test was performed to determine the difference between the groups. The general view of the CBPBs produced is given in figure 1.

Figure 1: General view of produced CBPBs

3 RESULT AND DISCUSSION

Physical properties of the cement bonded particleboards are presented in figure 2. The physical properties of the plates using SWC and ABC were higher when the results were examined. It was determined that the MC of the boards produced with $Al_2(SO_4)_3$ was higher than those produced with $CaCI_2$. This may be due to the hygroscopic nature of the $Al_2(SO_4)_3$ and its inability to form sufficient bonds with the wood phenol groups. According to EN 634-1 (1999); the MC of the CBPB should be between 6% and 12%. MC values of all board groups conform to the standard. The D values were found particularly higher in boards produced using SWC. It has been determined that the thicknesses of the boards are very effective on the D values. It has been found that the CAC produced boards have much more spring back than the SWC At the end of the 4 hour pressing period. Zhou and Kandem (2002) have determined that thickness changes due to spring back after pressing process. It has been found that the use of $CaCI_2$ in wood cement composites produced using waste railway sleepers reduced the WA values (Ashori, 2012). The maximum TS of CBPB should be 1,5% according to EN 634-2 (2009) standard. TS values of boards produced with SWC conformed to the EN standard. The dimensional stability of the boards was greatly increased with the use of SWC. The use of SWC in boards increased dimensional stability compared to CAC.

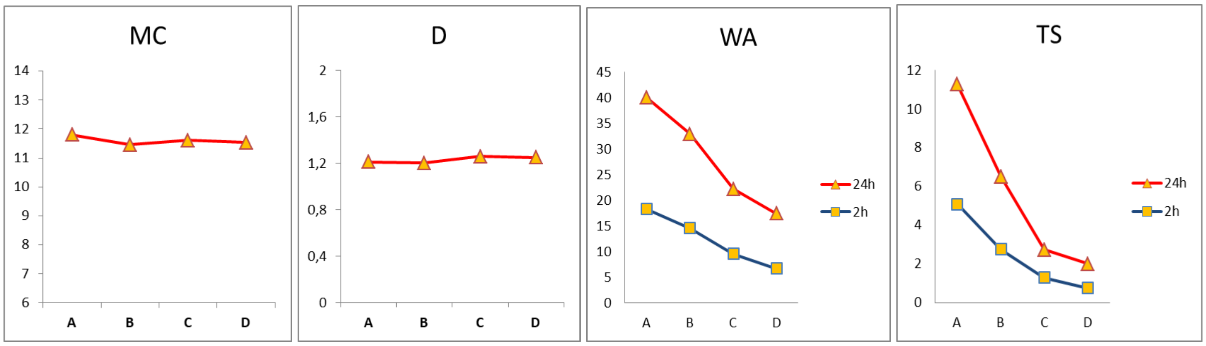

Figure 2: Properties of physical properties of the CBPBs

Mechanical properties of the CBPBs are presented in figure 3. It was determined that the curing accelerator and cement types affected the mechanical properties of the boards. The MOR, MOE, IB and WS values of CBPB increased parallel with using $CaCI_2$ and SWC. The MOR and MOE values should be 9 N/mm^2 and 4000 N/mm^2 according to EN 634-2 standard. The MOR and MOE values of boards produced with SWC conformed to the EN standard. The use of SWC and $CaCl_2$ increased the MOR and MOE by 40% and 45%, respectively. The Al^{+3} ion in the $Al_2(SO_4)_3$ complexes with polyphenol groups in the wood to prevent the delay of cement hydration. However, $CaCI_2$ has a more inhibitory effect on polyphenols (Yousuf, 1995). Therefore, the use of $CaCl_2$ in the boards resulted in higher mechanical properties. The SWC provides superiority to NSC with advantages such as aesthetics, high early strength, low alkalinity, durability and faster processing. it has been determined that the same performance is achieved even when using less than 50% of the NSC. When the dosage rate is increased, very high compressive strengths are obtained (Delibaş and Kırca, 2017).

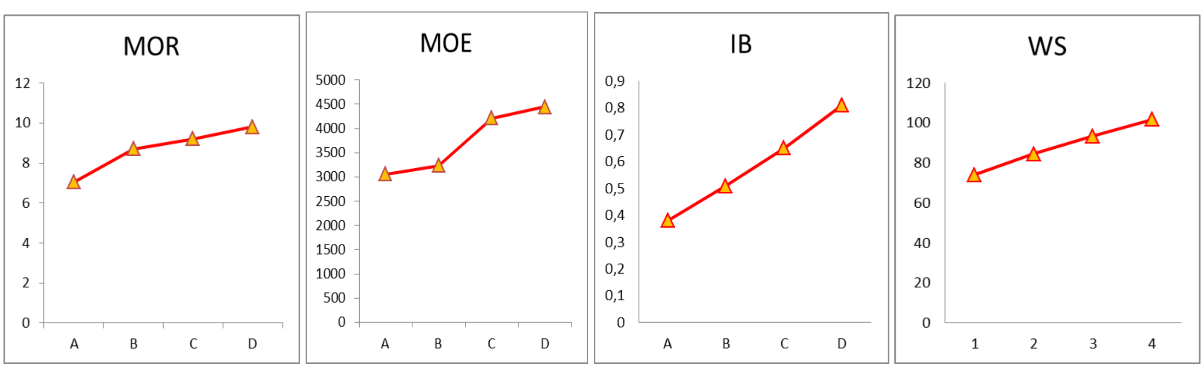

Figure 3: Properties of physical properties of the CBPBs

IB values should be 0,5 N/mm^2 according to EN 634-2 standard. Except for A type of the panels, other groups met the required level of IB values. The WS values are highest when $CACl_2$ and SWC are used. The SWC is a very hydraulically reactive linker due to the high content of C_3A and C_3S compounds in the structure. It has much higher performance than NSC due to its high reaction rate and gains earlier strength (Web-2, 2018). Cement and accelerator types have a significant effect on physical and mechanical properties based on the results of statistical analysis. The results of homogenous subsets of the board were given in Table 3.

Table 3: Homogenous subsets for physico-mechanical properties of boards

Board types	MC	D	WA	TS	MOR	MOE	IB	WS
A	a	b	d	d	d	d	d	d
B	b	b	c	c	c	c	c	c
C	b	a	b	b	b	b	b	b
D	b	a	a	a	a	a	a	a

4 CONCLUSION

The effects of cement and accelerator types on the physical and mechanical properties of CBPBs were investigated. Nowadays, the use of recycled materials is of great importance due to the decreasing natural resources. It has been determined that poplar sawmill waste used for this purpose is suitable for wood cement composites. Cement and accelerator types and their interaction significantly influenced the strength of CBPBs. It has been determined that the use of CAC is not suitable for CBPB for the under current production conditions. Therefore, the pressing time can be extended to produce with CAC. In addition, the laying height of boards produced using CAC is less than on SWC. This also leads to a sufficient bond between particle and cement due to the reduction in the amount of connecting. On the contrary, SWC has been found to be very suitable for CBPB production. $CaCl_2$ has been more compatible with CBPBs and improved properties as an accelerator type. The use of $CaCl_2$ increased the compatibility of cement with wood particles (figure 1).

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Determination of Importance Level of Wood Harvesting Activities and Occupational Safety Equipment by Smart Method

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ABSTRACT

Today, wood harvesting activities are shown as the "dangerous works" both in the International Labour Organization (ILO) and in various laws and regulations in Turkey. Wood harvesting process is comprised of three stages that are cutting-felling, extraction, and transport. The cutting is formed of sub-stages that are falling down, branching, bucking, and peeling. These activities have a lot of important risks due to steep slope, hard terrain, open air conditions, heavy work materials, insufficient mechanization and uneducated workers in terms of the occupational health and safety. It is not possible to completely remove the risks or replace them with less dangerous ones because the main risk sources for the logging operations are nature-based. For this reason, it is generally recommended using of suitable personal protective equipment. In this study, it was aimed to determine the importance level of the personal protective equipment used during the tree cutting activities in terms of occupational health and safety. In this context, the sub-stages of the cutting activity and used personal protective equipment were clearly stated, and it was taken total 24 expert's ideas including 10 practitioners from the forestry sector and 14 academics. Furthermore, the Simple Multi Attribute Rating Technique (SMART) has been used to determine the importance level of the sub-stages of the cutting activity and the personal protective equipment. As a result, the most important and the least important sub-stages were determined as the falling down (47%) and the peeling (16%), respectively. As for the personal protective equipment, participants rated for the most important equipment as head guard (24%) and the least important colored workwear (6%).

KEYWORDS: Wood harvesting, Personal protective equipment's, Expert opinion, SMART

1 INTRODUCTION

In recent years, raised awareness of the community has increased the importance of providing occupational health and safety in the working environment. According to the International Labor Organization (ILO) data, due to work accidents are leading to deaths and injuries in developing countries (ILO, 2014). An average of 2.7 million people die as a result of 313 million work accidents that are experienced every year in the world and 2 million occupational diseases (ILO, 2012; Hsu, 2010). In accordance with the statistics of work accidents while Turkey was ranked third in the world, is the first in Europe (Öçal and Çiçek, 2017).

Forestry activities consist of living and inanimate items interacting with each other. Because they are fulfilled in a large ecosystem, they need a versatile approach (Kines et al., 2007). In addition, bad working postures during these labor intensive works can lead to major occupational diseases such as musculoskeletal disorders (Unver-Okan et al., 2017).

One of the most risky and difficult of the forestry activities is the wood harvesting process which is carried out periodically every year (Gümüş and Türk, 2012). The wood harvesting process is comprised of three stages that are cutting-felling, extraction, and transport, respectively. The first stage is the felling which consist of some sub-stages that are falling down , branching, bucking and peeling (Figure 1).

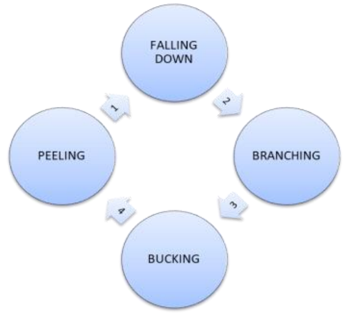

Figure 1: The Felling process

As it can be seen that in Figure 1, the first step of the wood harvesting process is felling that is comprised of falling, branching, bucking and peeling's sub-stages (ILO, 1998; Engür and İmer, 2016). In the wood harvesting, more work accidents and occupational disease may occur in the falling sub-stage. In order to prevent work accidents or occupational diseases is necessary a good plan for the falling stage in terms of the structure of the land and the tree, the technique used, the environment of the tree and the external factors. Main factors considered when the falling is planned; the structure of the tree, the shape of the branches and hills, the decay of the trunk, the presence of saplings around the tree, the distance to the surrounding trees, the terrain slope, snow load, (Engür, 2014) (Figure 2).


Figure 2: Factors affecting falling down

Logging operations involve a wide variety of hazards due to the nature of the forest, such as the working environment, wild animals, insects, poisonous plants etc. For the risks arising from these activities it is not possible to take measures such as "destroying the source or choosing the less dangerous" specified in the Occupational Health and Safety Law (Health and Safety Law, 2012). In the risk analysis of wood harvesting, it is large scale suggested to use engineering protection or personal protective equipment. Personal protective equipment (PPE) is a device or item designed to be worn or as protection against existing uncontrolled risks or to improve existing conditions, in order to ensure that employees work healty and safety (MLSS, 2006). The Regulation on the Use of Personal Protective Equipment at Workplaces is based on Article 30 of Labour Law No. 6331 and the EU Directive 89/656 / EEC (EU Directive, 1989; Labour Law, 2003). In this regulation, employees are obliged to use personal protective equipment related to the work they are doing while employers are obliged to provide protective equipment for employee (MLSS, 2006).

In Turkey, in accordance with the relevant provisions of the law of the forest taking into account economic and social conditions, logging operations are made by forest villagers or forest village development cooperatives (Forest Law, 1956). Moreover, these woodd harvesting activities have been made through contractors recently. For this reason, wood harvesting activities are generally made by those who do not have a occupation-related training, have learned work through experience, have low income levels and are less aware of occupation risks.

In studies are stated that forest workers have not used personal protective equipment for reasons such as fate approach, working environment or normalization of work-related hazards, ignorance, expensive materials or thinking of unsuaitable equipments. Gandaseca et al. (2001) found that 83% of workers in wood harvesting activities in the Eastern Black Sea Region did not use any protective clothing or equipment while 17% of the workers used boots and eye protectors (Gandaseca et al., 2001). By making personal interviews with forest workers and operators, it is found that workers do not use personal protective equipment, for they think that equipments are unsuitable for forest conditions, uncomfortable and heavy (Unver, 2013).

According to the International Labor Organization (ILO), only 2% of occupational accidents are unprotected accidents and 98% are accidents that are generally prevented. The most common injuries to workers in various job categories due to various reasons are head (15%), eye (8%), body (10%), arm (3%), hand (15%), 34%) (ILO, 1998). In Brazil, it has been shown that because of chain saws, it occured injuries at 37.4% in the hands and feet of the body (Sant'Anna and Malinovski, 1999). Enez et al. (2011), the forest workers and operators were used to gloves (54%), working safety shoes (9.3%), safe clothes (1.9%), head guard (1.6%), dust masks (0,8%), footwear (0.5%), and earplugs (0.5%). Therefore, it would be say where 72% of work accidents could be prevented or reduced by the use of PPE. The personal protective equipment that forest workers and operators in the felling stage must use is shown in Figure 3.

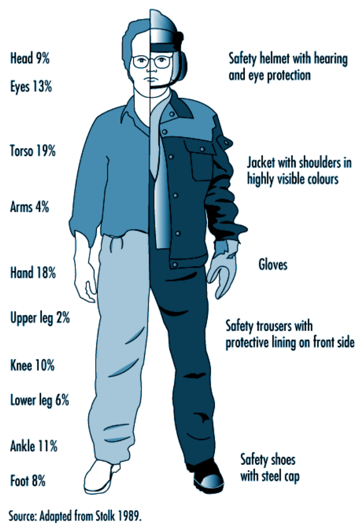

Figure 3: The PPE (Web- 1)

In this study, in terms of occupational health and safety it was aimed to determine the importance levels of the sub-stages of the cutting are falling down, branching, bucking and peeling and the chainsaw's operator to be used personal protective equipment, and the main factors to be aware of during falling down.

2 MATERIAL AND METHOD

The scope of the study, it is thought that the sub-stages of the cutting are falling down, branching, bucking and peeling. Determination of the falling down direction inculdes some criteria; tree inclination, branch and hill position, probability of hanging, direction of extraction, snow load, wind, decay in the trunk, sapling existence and terrain slope. It was thougth that chainsaw's operators should be use some the personal protective equipments that are head guard, eye and face protector, earpiece, gloves, steel-tipped shoes, colored workwear and durable pants.

In the study, while it was determined percentage weight of the each criteria, ıt was used the Rank Reciprocal (RR) method which is one of the versions of the Simple Multiattribute Rating Technique (SMART) methodology. In this study, a study paper was used to compare among criterias to determine the weights of the criterias (Table 1).

Table 1. The Study paper

Category	Criteria	Rank
The Felling sub-stages	Falling down	
	Branching	
	Bucking	
	Peeling	
The main factors in the falling down	**Criteria**	**Rank**
	Tree Inclination	
	Branch and Hill Position	
	Probability of Hanging	
	Direction of Extraction	
	Snow Load	
	Wind	
	Decay in The Trunk	
	Sapling Existence	
	Terrain Slope	
The PPE	**Criteria**	**Rank**
	Head Guard	
	Eye-Face Protector	
	Earpiece	
	Colored Workwear	
	Glove	
	Steel-Tipped Shoes	
	Durable Pants	
	Colored Workwear	

Determination of percentage weight of criteria, it was carried a total of 24 experts consisting of 14 academicians and 10 practitioners. Identification of target academicians; The study papers were sent via e-mail to a total of 33 academicians employed in Forestry Engineering departments of various Turkish universities. However, only 14, including professors, associate professors and assistant professors responded and were fulfilled. These academicians had carried out research on subjects such as Forest Harvesting and Forest Ergonomics. The practitioners were selected according to the volunteer principle among the forest engineers working within the scope of the Trabzon Forestry Regional Directorate and evaluated by means of face-to-face interview.

In this method, each criterion is valued from 1 to n. Whereas the criterion taken (1) is "the most important", taken the value of (n) the criterion is "the least significant" among criteria. More than one criterion can be assigned the same value when comparing criteria. The experts were well-informed and able to provide detailed information concerning forestry operations. After the expert evaluation, percentage weights of the criteria were calculated by using the equation (1) (Stillwell, et al., 1981).

$$wj(RR) = \frac{(\frac{1}{i})}{\sum_{j=1}^{n} \frac{1}{j}} \tag{1}$$

Here; i, the position of the wj in the sequence (i = 1, 2, ...n); n is the number of criterion. As w1 ≥ w2 ≥....≥ wn ≥ 0 ve Σwj = 1.0 is mandatory

3 RESULT AND DISCUSSION

In this study, it is considered that the sub-stages of the cutting are falling down, branching, bucking and peeling. These four criterias were compared each other. As a result of comparison, the percentage weights between the criterias were found as below (Table 2; Figure 4).

Table 2: The weights of the sub-stages of the cutting

Criteria	Percentage weight (%)
Falling down	45
Branching	20
Bucking	19
Peeling	16

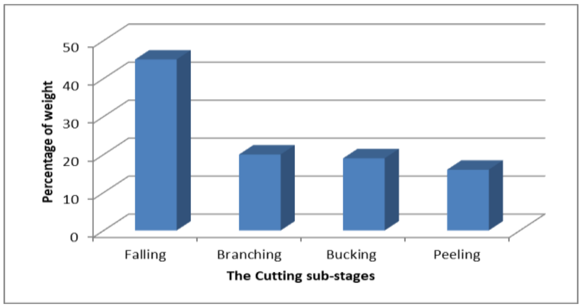

Figure 4: The cutting sub-stages weights

As seen in Table 2 and Figure 4, the most significant stage in cutting process was determined as falling down (45%), followed by branching (20%), bucking (19%) and peeling (16%). In this case, it can be said that an accident that may occur during the falling down stage may be much more severe than the other stages. The peeling process was the lowest because this study was carried out only on coniferous trees. Furthermore, the study was not be made on all harvesting unit and usually was be used simple hand tools such as axes and peeling iron (Gülci et al., 2017).

Since the falling down sub-stage is very dangerous in the wood harvesting process, any risk factors that affect the working should be considered in terms of occupational health and safety. The weight of the main factors to be aware of during falling down which are tree inclination, branch and hill position, probability of hanging, direction of extraction, snow load, wind, decay in the trunk, sapling existence and terrain slope (Table 3 and Figure 5).

Table 3**.** The weights of the main factors in the falling down

Criteria	Percentage weight (%)
Tree Inclination	19
Branch and Hill Position	13
Probability of Hanging	11
Direction of Extraction	8
Snow Load	10
Wind	9
Decay in The Trunk	8
Sapling Existence	8
Terrain Slope	14

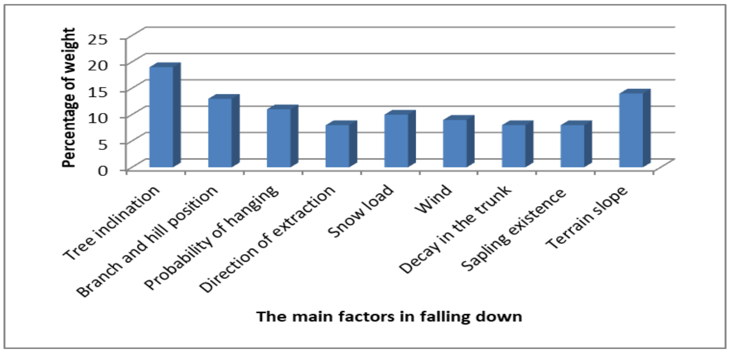

Figure 5: The main factors in the falling down

As seen in Table 3 ve Figure 5, the most significant criterion of the main factors to be aware of during falling down was determined tree incilination (%19) and terrain slope (%14) while the least important criterion was found as direction of extraction, decay in the trunk, and sapling existence (%8). The tree inclination is essential for determination of direction of falling down. During the falling down is noticed that according to the tree incilination, the felling notch and angle might be different (MYK, 2017).

The weight of PPE was found since they are to protect for the chainsaw's operators from work accidents (Table 4, Figure 6).

Table 4: The weights of the PPE

Criteria	Percentage weight (%)
Head Guard	24
Eye-Face Protector	21
Earpiece	9
Colored Workwear	5
Glove	11
Steel-Tipped Shoes	16
Durable Pants	14

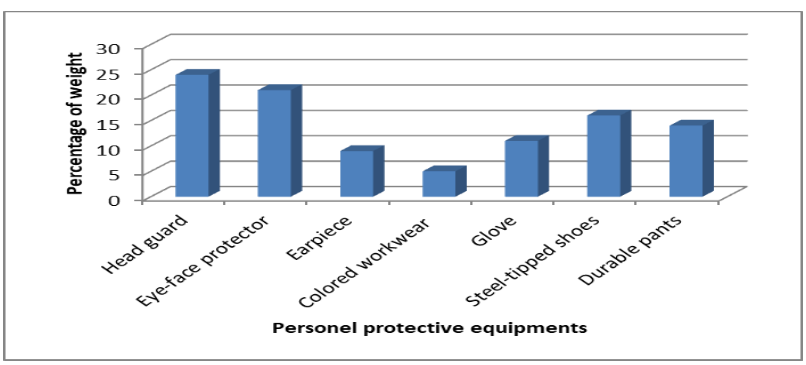

Figure 6: The PPE weights

As seen in Table 4 and Figure 6, the most significant of the chainsaw's operator to be used personal protective equipment were found as head guard (%24) and eye and face protector (%21). Not only logging operations but also all activities in the forest employee can across variety hazard which may be dropping piece of branch or cone. Because of that reason head guard was gotten the highest points. The least important equipments are the colored workwear and the earpiece. The colored workwears are used to increase the employee visibility in the forest. For this reason, it is not considered as significant to chainsaw operators who need to use it.

4 CONCLUSION AND RECOMMENDATION

As a result of the study, it is found that the falling down has the most priority of the cutting activity. This activity is the stage in which the risk and the severity of the accident are the greatest. The least important of is peeling, which is generally made with hand tools like robbery or ax instead of motor vehicles.

The most significant criterias of the main factors in the falling down was found as tree inclination and terrain slope, respectively. The most significant of the chainsaw's operator to be used personal protective equipments were found as head guard and eye - face protector while the least important is earpice, which is considered because it is recognized that the hearing loss can occur after long time.

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ABSTRACT

Residual woody biomass, which means the available woody portions of logging residues left on stand after logging operations, is crucial feedstock for various stakeholders such as forest industry and bioenergy sectors. It is essential to design cost-effective supply chain for residual biomass recovery. The objective of the study is to clarify supply chain possibilities for recovering of residual woody biomass through traditional wood harvesting system in Turkish forestry. Hence, this study considers the determining the source of available biomass potential and defining the residual biomass recovery options to supply market demands. The example of a case in Mediterranean Region of Turkey in pine forest was interpreted to constitute a supply chain and to minimize operational unit costs for more quality residual. Residual biomass was especially produced from branches and tree tops, the diameters of which were between 1.5 cm at the small end and 4 cm at top end with length of 1 m. It has the qualification to be utilized in both fuel and energy wood, and also chip wood because of rich in fiber content. Using of manual cut-to-length harvesting systems, between 4 % and 15 % of the total aboveground tree biomass was left on stand as logging residues, 50 % of which could be recovered as residual biomass with higher quality more than slash residues. Motor-manual harvesting and also manual extraction techniques were stated as preliminary solution for feasible biomass recovery. The loading and hauling of residual biomass in original condition regardless of chipping was the suitable in shorter transportation distances lower than 50 km. However, chipping in terminal or plant could be a possible best option for chip board industry or maybe bioenergy sector. The operational variables (yield, tree characteristics, etc.) and quality-based factors (biomass type, moisture content, energetic value, etc.) were significantly and relatively effective on productivity and realization cost of residual biomass recovery.

KEYWORDS: Residual woody biomass, biomass recovery, supply chain, logging operations

1 INTRODUCTION

In the worldwide, there is a growing universal awareness of the many values of forests, such as supplying wood for a variety of structural, domestic and industrial products. Forests are also a source of primary energy through the conversion of woody biomass into convenient solid, liquid or gaseous fuels to provide energy. As well, forests provide about 14% of world primary energy supplies and have the potential to meet up to 50% of world energy demands. Furthermore, about 55% of the 4 billion m^3 of wood used annually used by the world's population as fuelwood or charcoal to meet daily energy needs of directly heating and cooking, mainly in developing countries. Enhanced environmental concerns are encouraging alternative and renewable sources of energy (Hall, 2002). Increased use of renewable energy sources is a strategic goal for both industrialized and developing economies, which have a strong interest in economic growth and environmental pressure (Schandl et al., 2016; Eker et al., 2017). Therefore, human being has recently focused on the use of biomass for green energy, fuels, and materials for reducing the dependency on fossil fuels and petroleum as a result of rises in the prices of fossil-derived energy, exhaustion of renewable natural resources, global warming, carbon sequestration, and sustainable development (Eker, 2011).

Bioenergy are becoming increasingly interesting and important subjects for all shareholders. In particular, biomass energy allows for the clean disposal of by-products and the efficient use of natural resources. Furthermore, biomass energy offers the benefit of small-scale decentralized generation, which may overcome the limits of the obsolete and expanding distribution networks that characterize developing economies (Bazmi et al., 2015).

Forest biomass includes trees, shrubs, herbs, grasses, etc. and all waste biomass such as logging residues compiled from thin branches, damaged or unmerchantable stem sections, tops, barks, needles and stumps (Fig. 1) (Röser et al., 2008). They have been handled for energy resource generated directly or by conversion to gas, liquid or solid bio-fuels for use in cogeneration of heat and electricity, food for animal, in mulching and cosmetic industry, etc. in the worldwide. On the other hand, technological changes in the manufacture of wood products are increasing the range of types of fibres that can be processed. This increases potential demand for different types of biomass feedstocks and consequently for increased use of bioenergy as the commercial market expands.

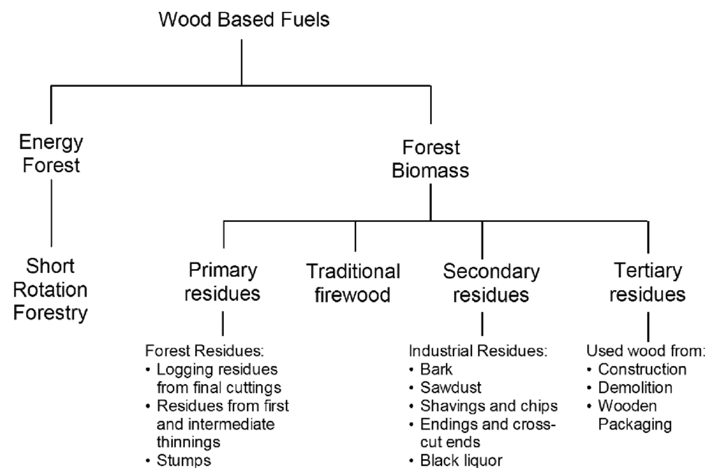

Figure 1. Classification of woody biomass (Röser et al., 2008)

Forest biomass can be a sustainable source of energy—a valuable renewable alternative to finite fossil-based energy sources, but only if the principle of sustainability is maintained. The focus of bioenergy initiatives is that the use of woody biomass for energy be efficient, economic and environmentally sustainable. Woody biomass is produced from conventional forestry systems where residual woody biomass is a by-product of timber production systems. Biomass production systems often use biomass that would otherwise be unmerchantable. Harvesting, handling and collection technologies are in the early stages of development but will not proceed further in the absence of demand-driven fibre (Hall, 2002).

Despite the common use of woody biomass from forest trees for bioenergy production in the worldwide (Björheden, 2008), it is at the beginning level and just began to be used in energy production at small scale with low capacity in Turkey. However, the uncertainty on the sustainable annual feedstock potential and supply possibilities on available woody biomass discourages of providers and retards the utilization progress. However, General Directorate of Forestry (GDF) in Turkey decided that the forest residues from red pine stands could be utilized as a target tree species for bioenergy utilization due to the fact that it is prevalent in forest (5.85 million ha, 26 % of the total forest area), fast growing, and fire risks of its fuel material accumulation (GDF, 2009). The high value, added value, and low value forest products obtained from red pine trees have been used in various industry sectors, who shares the all woody biomass themselves for own goals. This situation limits the use of industrial wood and merchantable firewood (mean diameter is about 7 cm and 1 m in length) in another sectors such as bioenergy. Furthermore, the state-owned GDF subsidizes the forest industry sector (especially fiber chipboard industry) for supplying of their raw material demands. On the other hand, the new renewable energy act stimulates and supports to use of woody biomass in energy production by undertaking of purchase guarantee with the higher price than some primary sources. Under the circumstances, there remains only one type woody material to be used in energy production, which is minimal value residual woody biomass - primary forest residues - such as logging residues from final cuttings, is the most challenging biomass resource (Eker, 2014). Therefore, it has been getting more important raw material for every shareholder such as forest villagers for low cost fuel wood supply, both energy producers and also chip-leaf industry for raw material. But, all pretenders desires to cellulosic woody parts of logging residues because of its fiber-rich and energy content as a source of fuel wood or chip wood. Besides, some customers who were chipboard manufacturer and firewood suppliers began to add and mix the thinner woody branches from residues by 20 % into purchased the woody products (Eker et al., 2013).

Although the presence of theoretical potential of residual woody biomass mainly from red pine forests, a small portion of the residual material have been rarely utilized by forest villagers for directly heating and cooking with traditional methods in the economically favourable forest sites such as having short extraction distance, large volume of biomass, low and gentle terrain slope. However, a topic that needs to be explained why it is not yet a common utilization of the residual biomass, and whether the exploitation is possible or not at the mountainous conditions and steep slopes with low site index. Since the critical handicap is the determination the economically viable biomass supply system, it should be known the available potential, sustainable supply possibilities and market security for woody biomass (Ghaffariyan, et al., 2015).

Woody biomass feedstock supply chains should have been capacity to support the biofuels and utilities industries. However, possible biomass feedstock supply and its associated logistics activities are persistent issues (Thomchick and Ruamsook, 2011). The following key issues have not been recognized or fully addressed: (i) existing forest products industry and associated demand requirements, (ii) extended supply chain through multiple industries adds complexity supplying woody biomass for biofuels through the consumer, (iii) resource limitations associated with multiple industries demanding the same feedstock (i.e., leaf and chip board industry), (iv) instability in the logging industry, (v) harvesting restrictions at ecologically-protected forest, and (vi) additional processing of biomass (i.e., chipping) required by biofuels and utilities industries that is not abundant in the current supply system. Additional issues include the transportation infrastructure requirements needed to move woody-biomass feedstock.

The low value of residual woody biomass and logistics challenges based on the costs of transportation from supply sources to a processing point can often exceed market values for the biomass itself. Therefore, making up a residual woody biomass supply chain needs to be defined that production forests where can be recovered residual woody materials; loggers who harvest and convert trees into logs or wood chips; forest product manufacturers whose process residues produce woody biomass; pre-processors who turn forest materials into processed woody biomass such as wood chips and pellets; and bio-refineries who convert woody biomass into heat, electricity, and etc. to serve different customers (Thomchick and Ruamsook, 2011).

Logistics of moving the products in the supply chain, encompassing key activities such as transportation, materials handling, and storage, so the components require a total supply chain perspective. Extant studies on woody biomass has a gap in research, coupled with the still evolving nature of the industry, lead to woody biomass supply chains that are currently not well perceived. The primary objective of the study is to clarify supply chain possibilities for recovering of residual woody biomass through traditional wood harvesting system in Turkish forestry. Another objective of the paper is to conceptualize potential supply chain scenarios associated with residual woody biomass. It is proposed a theoretical framework accompanied by appropriate scenarios-models to address the supply chain challenges. Hence, this study considers the determining the source of available biomass potential and defining the residual biomass recovery options to supply market demands. The example of a case in Mediterranean Region of Turkey in pine forest was interpreted to constitute a supply chain and to minimize operational unit costs for more quality residual.

2 METHOD

The study material was focused on residual woody biomass, which was especially produced from logging residues (branches and tree tops), the diameters of which were between 1.5 cm at the small end and 4 cm at top end with length of 1 m stick (Eker et al., 2017). Unlike the well-known definition (Hakkila, 1989; Leinonen, 2004), residual woody biomass defined that the finer and lignocellulosic portions of limbs and tree tops, which were generated during limbing and bucking or at the separated process. Twigs, needles, cones, stem barks and other harvesting residues (waste woods, stumps, etc.) or forest residues (culls, foliage, etc.), and loose or slash residual material were not also included to the definition of the biomass type. Residual biomass has the qualification to be utilized in both fuel and energy wood, and also chip wood because of rich in fiber content. The woody material mentioned in the study especially was procured after logging operations (Eker et al., 2013). So, only logging residues to produce residual woody biomass after clear cutting with cut-to length harvesting method in red pine forest (*Pinus brutia* Ten.) was taken into consideration in this concept. However, residual woody biomass harvesting and extraction were isolated from timber harvesting as an independent process.

To conceptualize woody biomass supply chain scenarios, the study draws insights from extensive review of literature. Previous studies, completed projects, journal articles and papers in the areas of supply chain and logistics, forest products, biomass feedstock, and bio-energy were selected from available materials. Other data and information sources were examined to clarify and verify insights of the key activities pertinent to the production and logistics functions of supplying woody biomass, and the properties that characterize each activity. Afterward, it was made connections between the key activities by exploring the conditions and interactions that influence the processes of supplying residual woody biomass. This gained us to integrate and establish information on the descriptions of potential woody biomass supply chain scenarios.

As well known, the supply systems for forest biomass have been classified according to product type or comminution and chipping place, where chipper characteristics act as an important main role (Talbot and Suadicani, 2005). Based on chipping, the alternative systems have been grouped in literature that; i) terrain, ii) roadside, iii) intermediate landing, and iv) terminal chipping (Ranta, 2002). Depending on the literature, it was possible to produce numerous system matrixes for available and reasonable residual biomass supply system for Turkish forestry (Eker, 2011). Three potential residual woody biomass supply chain scenarios/systems, which were favourable for Turkish forestry, were selected and identified in Figure 2, as well. They were roadside and terminal chipping, where residual woody biomass was sourcing from state forests after clear cutting operations. We briefly described each scenario/system in turn as follows, in Figure 2.

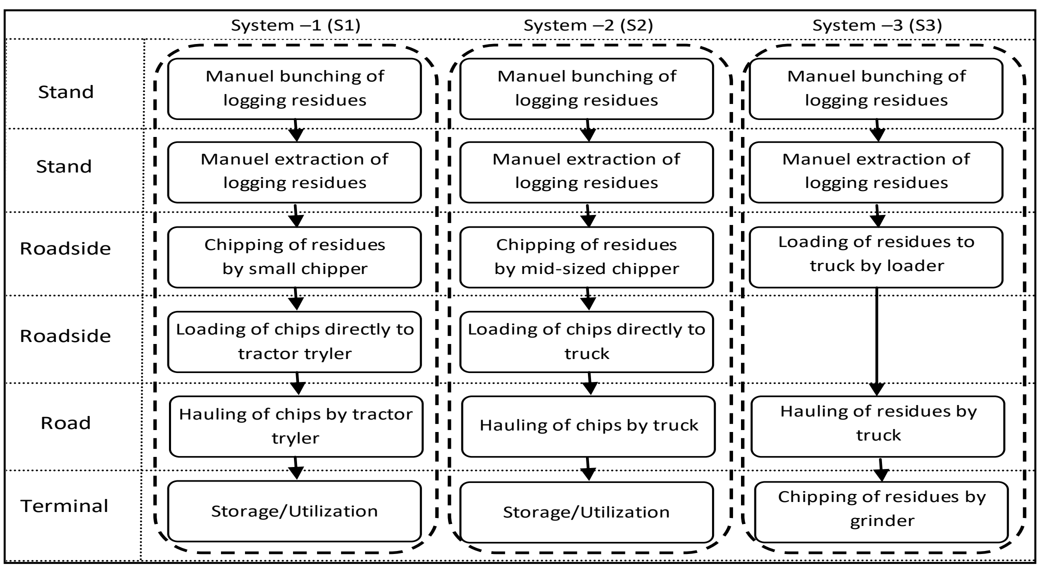

Figure 2. Probable supply system configuration about residual woody biomass (Eker, 2011)

In each supply system, at the stand level, the treatments for the harvesting and extraction of residual woody biomass recovered from logging residues can be different from each other depending on operation time and mode. Residual woody biomass harvesting from logging residues is trialed with three treatment procedure that are; it is conducted (i) as a tandem process while industrial and firewood production is simultaneously ongoing, where all merchantable and unmerchantable parts of a tree are still located at the stump site, (ii) as a sequential (post-harvest) process after the removal of all merchantable tree sections such as log, chip-board wood, and fuelwood, etc., where all residual material is scattered to stand floor and disaggregated form, and (iii) as a post-harvest process after the site preparation, where residual biomass is piled and aggregated in terrace strips (Eker et al., 2017).

However, processing of logging residues into woody biomass is performed by three work step as follows:

1. Chopping: The finer sections, having less than 4 cm diameter at the top end, of limbs and tops is motor-manually separated and fractionated by cutting of chainsaw. At the step, residual limbs and top are partitioned into parts nearly 1 m in length. Thus, 1 or more segregated piece of woody biomass including still finest branches, twigs, needles, and cones is obtained. Different from the others, chainsaw is only used in the treatment for chopping works.

2. Handling: The utilizable woody section of residual material or chopped woody material is manually processed and purified from very thin lateral-side branches, twigs, needles, and cones by means of a hand axe or indigenous machete. The handled woody material is manually partitioned into 1 meter length, as well. Thus, cleaned and delimbed residual woody biomass (stick) is achieved.

3. Piling: The processed woody biomass in the form of stick with the length of 1 m is thrown towards accumulation point which is a center point of a few felled tree intervals, where the woody biomass cumulated and non-uniformly stacked prior to extraction to facilitate easily removal.

3 RESULT AND DISCUSSION

Residual woody biomass is a low value by-product and can be only derived from a harvested tree. LR biomass quantity was depended on tree characteristics and limited by the size of the area, allowable cutting rate, the number of trees and single tree biomass per hectares. Silvicultural prescriptions (thinning, clearcutting, etc.), harvesting methods (whole tree, CTL, etc.), and other uncontrolled factors (site productivity, cutting operator's behavior, etc.) can alter the capability of available LR wood ratio. It means that LR wood harvesting is a sequential and secondarily process of industrial round-wood and firewood harvesting (Eker et al, 2017).

The main source of residual woody material is commercial wood supply, which has been managed by General Directorate of Forestry (GDF) in Turkey. Traditionally, cut-to-length (CTL) harvesting method has been used in harvest operations (Eker et al., 2009). In CTL method, industrial stem wood and fuel/firewood is harvested where the tree is felled, delimbed and cross-cut to the top by chainsaw, and debarked with log debarker or axes, and the branches are cut into pieces for only fuelwood production within framework of standards, and all harvest residues are left on the site. In pursuit of harvesting, the stem assortments and fuelwood as a merchantable woody product are extracted to roadside by various techniques. Somewhere nearest to forest roads, a small portion of the harvest residues can be legally collected by forest villagers as subvention with low sale-stumpage price so that it can be used in generally home heating and rarely cooking through directly firing as conventional fuelwood. After the all removal operations, the remaining residues scattered to stand surface are accumulated to precise strips and piled there like that a terrace as parallel to contour line, with 3 to 7 meter intervals and different length depending on hillside width, in order to support the natural or artificial regeneration as a site preparation like that a soil scarification and to provide the forest fuel reduction due to high risk of forest fire in brutian pine forest (Eker et al., 2013). This situation illustrates that there is a both theoretical and technical residual biomass potential for energy in Turkey. The residual woody biomass can be obtained from the pro-processing of the residual branches and tree tops to convert into woody material like a stick.

Only fiber-rich contented-lignocellulosic-fraction of the logging residues, is considered, called as "residual woody biomass", obtained from unmerchantable branches and tops of a tree, top end diameter of which was equal or smaller than 4 cm and small end diameter was equal or higher than 1.5 cm, with 1 m in length. Processing of thinnest branches, twigs, and needles from the logging residues, increased the quality of the woody biomass as a delimbed energy wood (Heikkila, 2006), and cleaned material even though it increased the processing time. These kinds of primary forest residues are considered to be the most appropriate source of woody biomass for energy or fuel wood or wood fiber, as well.

Knowledge on the forest biomass resources is a basic step and it can be used in decision making in the planning of harvest operations and bioenergy investments (Malinen et al., 2001). In nationwide, previous studies (Sun et al., 1980; Durkaya et al., 2009; Saraçoğlu, 2010; Eker, 2011) was carried out to calculate resource focused residual biomass potential by means of developing some coefficient. They determined that the theoretical potential of logging residues was 5-7 million green ton within all forest lands in Turkey (Kaygusuz and Türker, 2002; Demirbaş, 2008; GDF, 2009) based on the removals of tree volume.

Based on directly measurements, Eker et al. (2013) determined that the residual woody biomass was 55.8 kg (29.6 oven dry kg) per tree and average 9.8 t (6.4 oven dry ton) per hectares, which biomass could be used as a fuel wood or energy wood (approx. 4300-4700 kcal kg-1 in net calorific value, and also chippable material (called as raw chip wood) due to fiber content. Whereas the amount of logging residue ratio per tree biomass was 8 % and the removable residual woody biomass at the wet basis was about 4 % per tree biomass, which dictated that the recovery rate of residual woody biomass was averaged 50 percent of the total residues left in stand even though manual collection was used in all treatment like that in Figure 3.

According to last statistical inventory (GDF, 2015) annual allowable cut in red pine forest is averaged 5 million m3, which means that the technical and environmental potential of residual woody biomass wood can be 300000 green ton per year. In the Mediterranean forest regions, the technical potential of forest residues with shrubs for bioenergy is amount 650000 ton per year (Saraçoğlu, 2015). In a part of Mediterranean forest regions in Turkey, Çoban and Eker (2014) previously calculated by using of some coefficients the spatially and economic potential as nearly 61000 ton per year within 30 km radius area. The literature highlights that it is possible to reveal that the residual biomass availability rate was depended on industrial round wood production (Guo, 2011). In absolute terms, the amount of residual woody biomass obtained from logging residues in final felling operations has recently been estimated between 4 and 8 dry t ha^{-1}(Eker et al., 2017). The estimated theoretical residual woody biomass potential was only based on the logging residues and did not include secondary and tertiary wood residues and wastes (Eker, 2014). It is assumed that a recovery factor, 7–20% green tons of total wood production volume (Eker, 2011; Eker et al., 2013), can be used to estimate the theoretical potential of logging residues to substitute the energy wood supply .

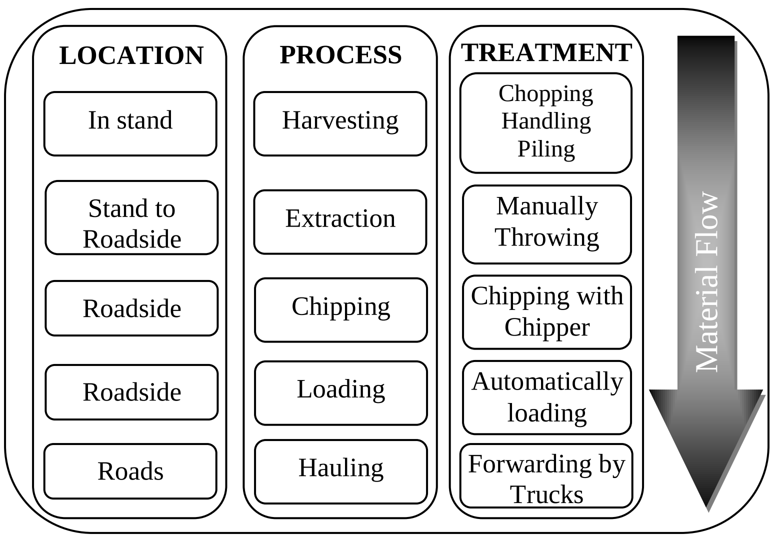

Figure 3. Available supply chain for residual woody biomass recovery in Turkish forestry

In Figure 2, the structured supply chain illustrates that it is theoretically and technically possible residual woody biomass recovery from red pine residuals by means of the manual harvesting and extraction with the various treatments under the steep terrain and mountainous conditions after regeneration felling. Eker et al. (2013) was tested the structured system and determined that the available costs were the function of theoretical feasibility, technical applicability, and economic viability in terms of harvesting and extraction costs. As a result of their study; 1 green ton of residual woody biomass was harvested and extracted by averaged 20.67 € in red pine stands. As well, the costs dictated that the harvesting and extraction cost of 1 stacked cubic meter was 5.56 € $stere^{-1}$ and unit cost for 1 GJ energy equivalent was 1.10 € with the available costs. However, harvesting and extraction cost per hectare was 265.34 € within the available cost content However, they exposed that the productivity and cost value of the different alternative techniques for harvesting and extraction should be searched for sustainable residual wood supply. It is also necessary for assisting managers, investors, or all stakeholders when deciding how to develop an actual harvesting and extraction system for their specific circumstances as feasibility study.

The recovery options for the supply chain needs to large capital investments (Karha, 2011) and many different harvesting systems has been developed for efficient procurement of residual woody biomass such as integrated harvesting of roundwood with residue harvesting. The easiest way to develop and improve the actual harvesting system can contain adding the logging residue production to the existing industrial wood harvesting without any alteration on routine system. The elementary step allows recovering only available residues (Ghaffariyan et al., 2015). To recover full potential yield of residual woody biomass, harvesting method, CTL or whole tree harvesting, is perceived as a deterministic component. For example, CTL affects the recoverable amount of logging residues and also residual woody biomass, where nutrient-rich limbs and top sections of a tree are left in stand. But the method led to increase of harvesting cost between 40-50 % opposite to whole tree harvesting (Spinelli et al., 2014). Furthermore, various mechanized systems have been used in harvesting and extraction activities for the residues (Leinonen, 2004).

Mechanized extraction method with farm tractors was more effective than manual methods with own original site and material characteristics. Animal extraction was slightly productive within only shorter than 75 m extraction distance, because of bulk density of residual woody biomass. Extraction of residual wood with tractors allows decreasing to extraction costs through longer extraction distance over 100 m. The longer extraction distances entail forwarding (Han et al., 2004) with tractors rather than manual throwing or carrying, or skidding with animal. Even if the throwing extraction is the simplest and cheapest techniques but it cannot be viable in every stand characteristics with lower slopes and longer extraction distances, in terms of extraction costs (Eker et al., 2013).

Considering of fiber content, calorific value, mass density, and bulk volume; it is appearing that residual woody biomass supply has not a competitive cost as a raw wood material opposite to firewood and chipboard wood (Eker et al., 2017). But, the difference between the costs can be eliminated by systemic improvements on biomass supply system to reduce the overall costs due to the raw material requirements of the wood-based sectors. Therefore, it is possible to argue that manual harvesting and extraction system costs for residual woody biomass supply is nearest to feasible for now, unless the harvesting method is changed and/or mechanization level is upgraded. However, although different mechanized methods exist for harvesting, processing, and extraction of logging residues, the performance and operational cost of which at the unfavorable terrain conditions can be prohibitive fact for mountainously karstic red pine forest as an example (Eker et al., 2013). If done improvements on infrastructure of tertiary or skidding road density to use small scale biomass harvesting technology, then mechanization level also can be upgraded.

4 CONCLUSION

The results reflect that the supply system can be realized on residual woody procurement in state-owned and regularly managed forests. The results support the conclusion that logging residues has theoretical, technical, and available potential, so it can be used a source of woody biomass for both fuel wood in bioenergy sector and traditional heating-cooking, and also was chip wood. The previous studies presents that it can be achieved the feasible results for residual woody biomass production under different treatments and various extraction techniques.

In the preliminary supply system, manual handling and piling, and manual extraction for the cost effective woody biomass recovery is a viable alternative option for red pine forest until a new system developed like that extraction of tree crown with mechanization. The manual methods may return some profits under the suitable conditions in terms of terrain and material characteristics, where terrain conditions is not too difficult for mechanized methods. The productivity and profitability of harvesting and extraction options can be also effected a number of factors such as moisture content, terrain slope, extraction distance, and amount of logging residues per ha. However, the manual supply techniques can create employment opportunity for self-employed forest villagers and opportunity to expand customers' product range and to increase amount of utilizable wood products. This can increase both the amount of available woody product, net income, and added value from a tree.

Manual extraction with throwing downhill is implementable for steep slopes with the middle extraction distances. Nevertheless, it is possible some improvements, including the accumulation of experiences, on the actual harvesting and extraction techniques to facilitate the operations, and to increase productivity and cost-efficiency. It should be noted that the processing (handling, collection, and piling) of slash logging residues to produce residual woody biomass can be done after round-wood harvesting to reduce the moisture content and to increase the visibility of the woody material. The workers should be trained about specification of woody biomass and product quality which biomass type can be collected and processed for recovering residual woody biomass.

Further studies are required to analyze other supply chain alternatives such as whole tree or entire crown logging, and also actual situation in tending and thinning operations. It should be experienced various extraction techniques for collecting and removing of residual woody biomass such as polyethylene log chute system, manual or mechanical bunching system, or mechanized collection and forwarder. Additionally, the influence of the chipping and hauling operations to be used in the woody biomass supply on productivity and system costs must be taken into consideration in future studies to complete the economic assessment. As well, forestry and renewable energy sector should continue to explore the new effective and profitable ways to increase the use of logging residues as a source of woody biomass. Increased demands on woody biomass to meet the needing raw material both energy and fuel, more industry and bioenergy plant will be developed in near future to use residual material in a sustainable content.

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The Effect of Degradation Time on the Mechanical Properties of Polycaprolactone (PCL) Based Biodegradable Composites through 18 Months of Laboratory Soil Test

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The Effect of Degradation Time on the Mechanical Properties of Polycaprolactone (PCL) Based Biodegradable Composites through 18 Months of Laboratory Soil Test

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ABSTRACT

Biodegradable polymers and their composites are gaining importance over the years. In this study, Polycaprolactone (PCL) based biocomposites were produced using PCL, polyvinyl alcohol (PVA)/Starch mixture and polyethylene (PE) as a polymeric matrix and Turkish Red Pine Pruning waste flours (RPWF) a lignocellulosic filler. This complex formulation was determined based on the knowledge gained from pre-trials and utilization of Central Composite Design. Forest soil was collected from arid regions of Konya and transferred to Laboratory. Soil elements were determined. Biocomposites were manufactured through combination of extruder and injection molding processes. Density, tensile strength, tensile modulus, elongation at break, flexural strength, flexural modulus and impact strength of the manufactured samples were determined in accordance with ASTM D 792, ASTM D638, ASTM D790 and ASTM D256, respectively. Results showed that RPWF, PE and degradation time have a significant effect on mechanical properties. After soil test, RPWF and PE had a significant effect on tensile strength, tensile modulus and elongation at break values. Similar results were also observed for flexural and impact properties.

KEYWORDS: Polycaprolactone (PCL), polyvinyl alcohol (PVA), biodegradable, mechanical and physical properties

1 INTRODUCTION

Biodegradable composites can be defined as a material having either biodegradable polymer or biodegradable filler in their formulations (Yu and Chen, 2009; Polymers and Av, 2017). Most common biodegradable plastics are starch, protein, polylactic acid (PLA) and polyhydroxyalkonates (PHA), driven from renewable resource and polycaprolactone (PCL), petroleum driven from petrochemicals. The most commonly used one is starch since it can be used as plastic matrix and also as a plastic filler (Walenta et al., 2001a and 2001b; Laohakunjit and Noomhorm, 2004; Zhang and Han, 2006; Hanna and Xu, 2009; Inman, 2010). However, some of their drawbacks prevent them from being good alternative to other synthetic plastics. In our previous study, biodegradable composite materials using starch and wood flour were manufactured. In other studies similar composites were produced using various wood and agricultural waste based fibres or flours (Yew et al., 2005; Kim et al., 2012; Oliveira and Schmidt, 2017). However, this type of material still prone to hydrolyses in short time when in contact with water. That's why the use of starch in combination with other biodegradable plastic is advised in many applications. Biodegradable polymers and their composites are gaining importance over the years.

In previous study, Polycaprolactone (PCL) based biocomposites were produced using PCL, polyvinyl alcohol (PVA)/Starch mixture and polyethylene (PE) as a polymeric matrix and Turkish Red Pine Pruning waste flours (RPWF) a lignocellulosic filler. Composite materials having combination of PVA-starch and PCL have provided valuable properties that may open different application areas. The objective of this study is to determine the effect of degradation time on the mechanical properties of the PCL based biodegradable composites during 18 months of laboratory soil test.

2 MATERIALS AND METHODS

Summary of the experimental design and description of the manufactured samples were presented in Table 1 and Table 2, respectively. PCL, PVA-Starch mixture (Figure 1) and PE were used as thermoplastic matrix. Turkish red pine pruning waste (RPW) was used as lignocellulosic filler. Depending on the formulation given PCL, dried PVA-starch pellets, PE and RPW were dry-mixed in a high-intensity mixer to produce a homogeneous blend. These blends were compounded in a single-screw extruder at 40 rpm screw speed in the temperatures (barrel to die) of 170-175-180-185-190°C. Extruded samples were cooled in water pool and subsequently granulated into pellets. The pellets were dried in oven at 103±2 °C for 24 hours. Dried pellets were injection molded using an HDX-88 Injection Molding Machine to produce standard test samples.

Table 1: Summary of the experimental design

Analysis Type:	**Response Surface Method**		**Variance (nm)**	
Desing Model:	**Quadratic**		**Levels:2**	
	Factors	***Type***	***Low Actual***	***High Actual***
A	RPW(%)	Numeric	4.39	25.61
B	PE (%)	Numeric	1.46	8.54

Table 2: Description of the manufactured samples

ID	**Neat PCL (%)**	**RPWF (%)**	**PE(%)**	**PVA-Starch (%)**
PCL0	55.00	15.00	0.00	30
PCL1	64.15	4.39	1.46	30
PCL2	42.93	25.61	1.46	30
PCL3	65.00	0.00	5.00	30
PCL4	50.00	15.00	5.00	30
PCL5	35.00	30.00	5.00	30
PCL6	57.07	4.39	8.54	30
PCL7	35.85	25.61	8.54	30
PCL8	45.00	15.00	10.00	30

Forest soil was collected from arid regions of Konya and transferred to Laboratory. Water holding capacity of the soil was determined. Field capacity and wilting point were calculated as 35% and 15%, respectively. Samples were put into the flowerpots and covered by forest soil. They were watered up to field capacity. After 6, 12 and 18 months, samples were taken out of soil, cleaned and tested (Figure 2). Density, tensile strength, tensile modulus, elongation at break, flexural strength, flexural modulus and impact strength of the manufactured samples were determined in accordance with ASTM D 792, ASTM D638, ASTM D790 and ASTM D256, respectively.

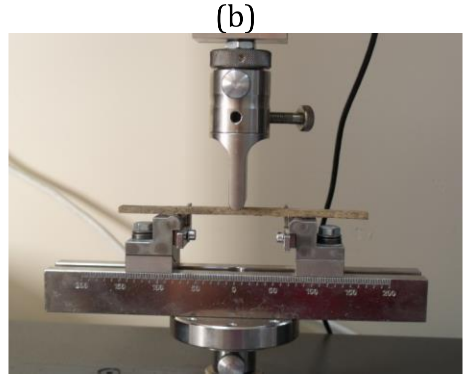

(a) (b)

Figure 1: PVA-Starch blend; PVA-Starch mixture in IKA reactor (a) and dried-pelletized mixture (b)

(a)

(b)

(c)



(d)

Figure 2: Samples were taken out of soil (a), cleaned from dirt (b), conditioned in environmental chamber(c) and tested (d)

3 RESULTS AND DISCUSSION

Densities of the all produced samples were measured. Statistical analysis was performed and interaction graph was made (Figure 3). Density values were reduced with degradation time. Samples having higher RPWF loading had higher density values. Combination of the polymer and lignocellulosic filler usually increased density of the resulting composite materials since lignocellulosic material usually has about 1.5 g/cm^3 density (cell wall density).

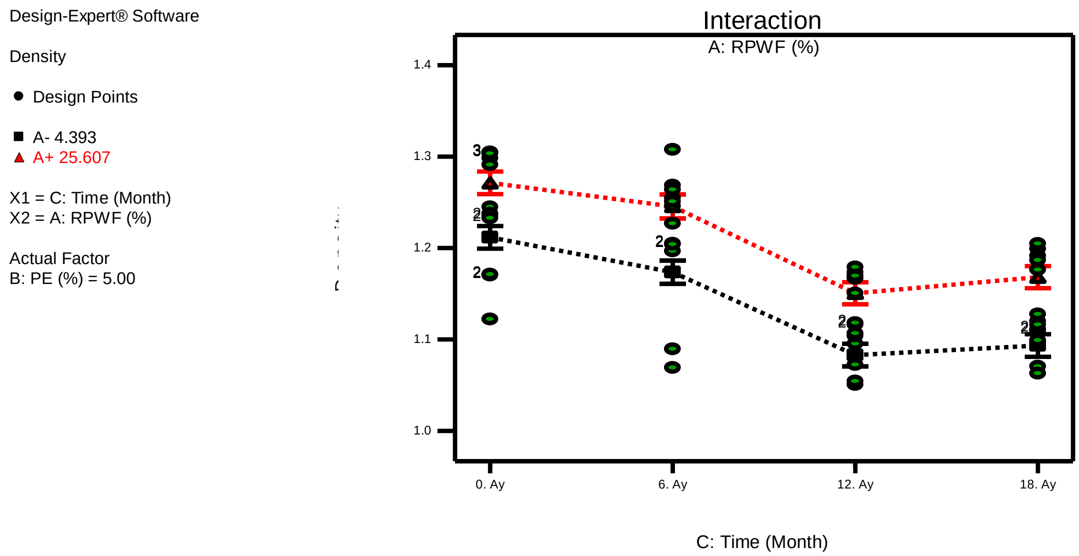


Figure 3: Interaction graph of density

Interaction graph of the tensile strength (TS) was presented in Figure 4. Statistical analysis showed that all factors had significant effect on tensile properties. Among them RPWF loading and degradation time had biggest effect ($P<0.0001$). TS values were reduced with time but samples having high RPW loading provided significantly higher tensile strength values.

Interaction graph of tensile modulus (TM) and elongation at break (EatB) values were also presented in Figure 5 and Figure 6, respectively. All three factors had significant effect on TM and EatB values. Biggest effect was shown by factors of RPWF loading and degradation time. Higher RPWF loading provided better TM values regardless of degradation time. However, with degradation time, all TM values were reduced up to 12 month period. Surprisingly TM values showed some improvements after 12 months.

In the case of EatB values, samples having lower amount of RPWF provided higher EatB values but these values were reduced with degradation time.

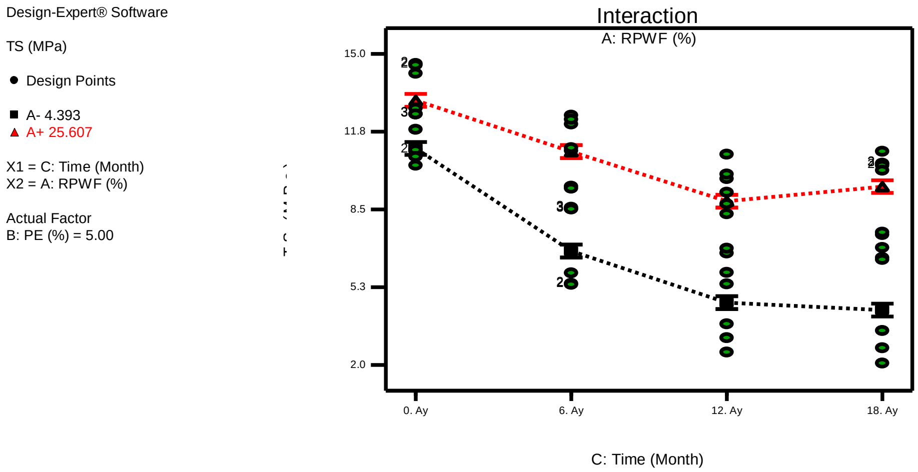


Figure 4: Interaction graph of tensile strength

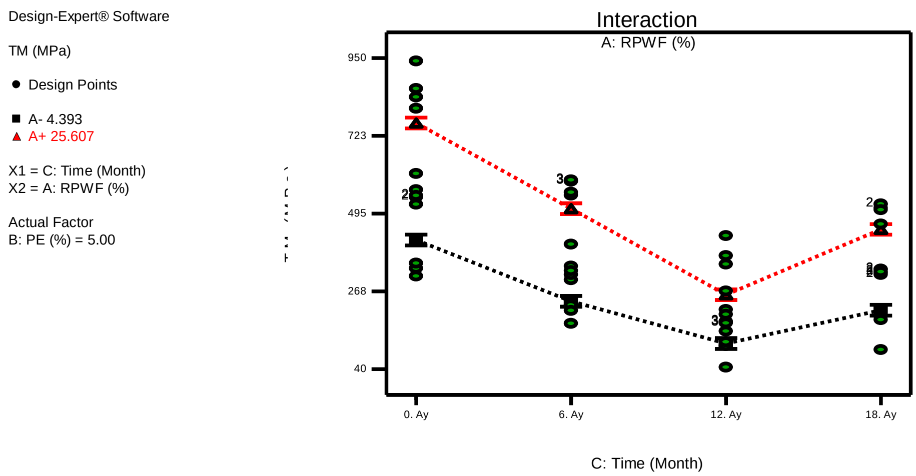


Figure 5: Interaction graph of tensile modulus

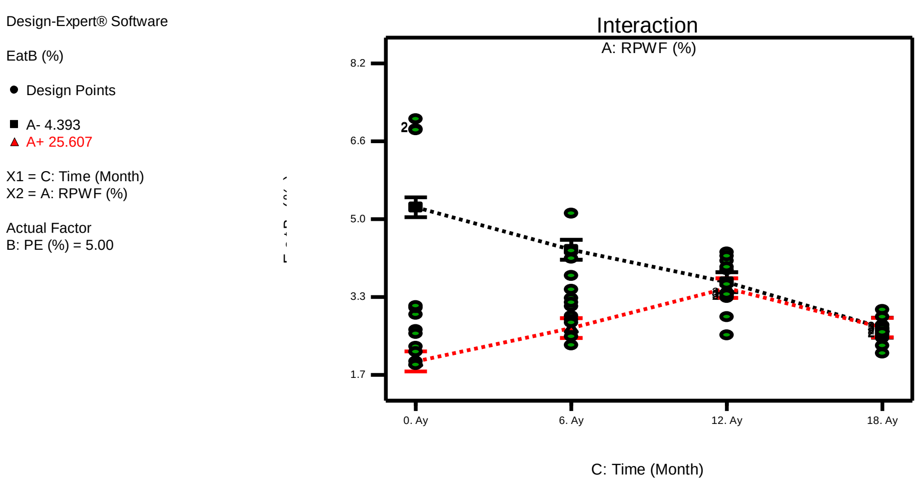


Figure 6: Interaction graph of elongation at break (EatB)

Interaction graphs of the flexural strength and flexural modulus values were presented in Figure 7 and Figure 8. Similar to the Tensile test, samples having high RPWF loading provided significantly higher flexural properties compared samples having lower RPWF loading. Once again flexural properties showed some increase after 12 months of soil burial test.

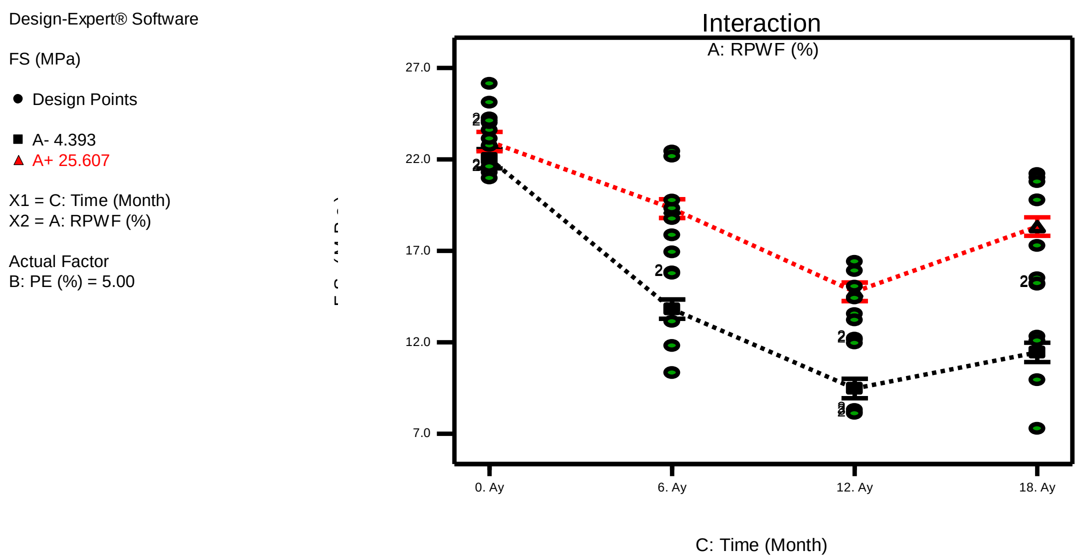


Figure 7: Interaction graph of flexural strength

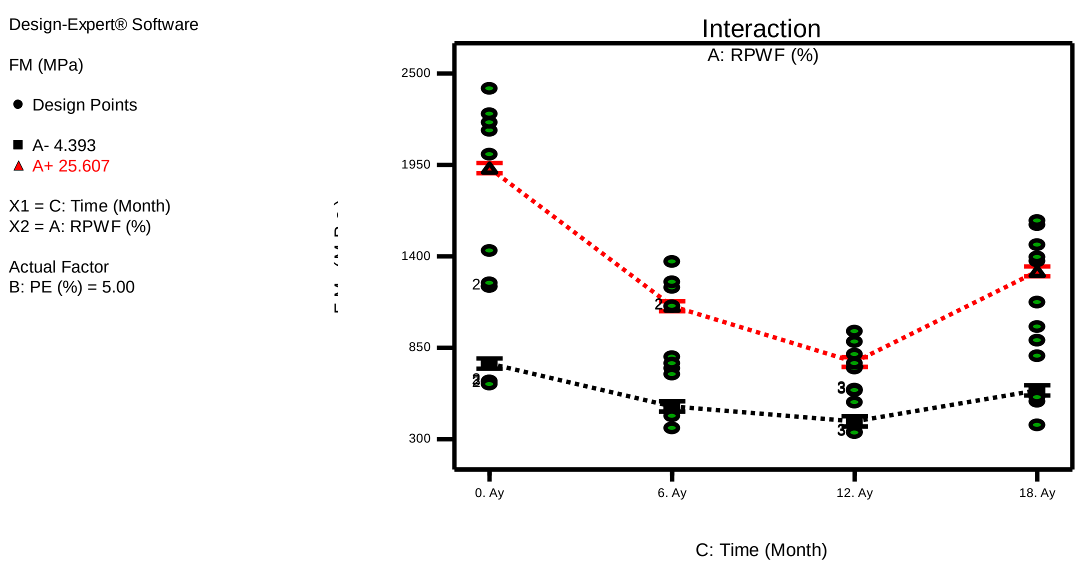


Figure 8: Interaction graph of flexural modulus

Interaction graph of the impact strength values was presented in Figure 9. Samples having high RPWF loading provided significantly lower impact strengths compared to samples having lower RPWF loading.

Samples having high RPWF loading has maintained IS values throughout soil burial test while IS of samples with lower RPWF loading were reduced with degradation time.

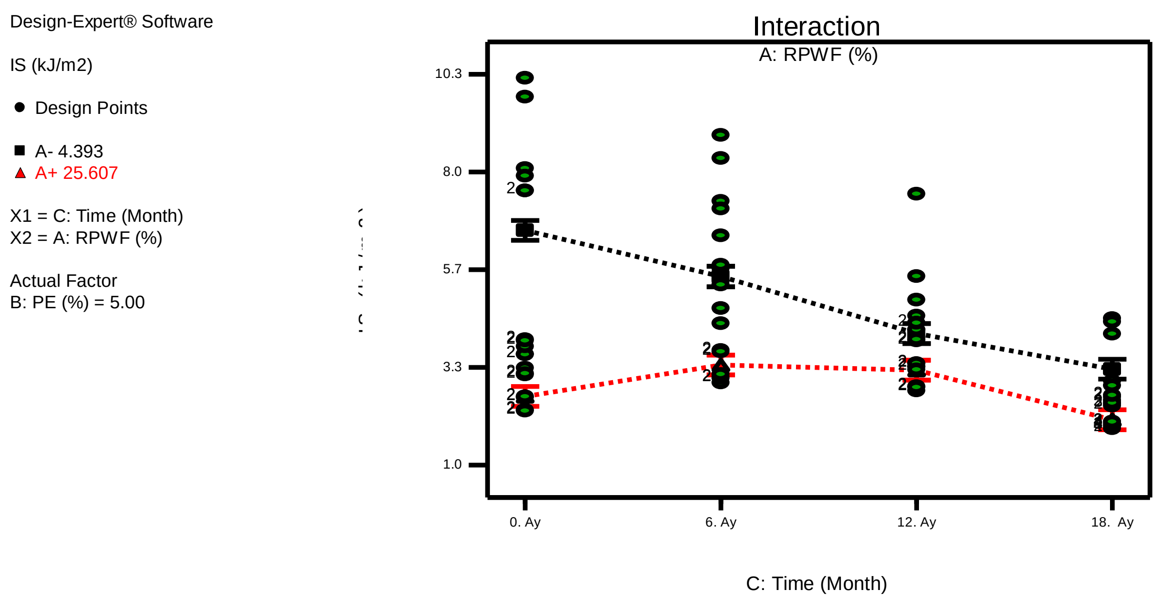


Figure 9: Interaction graph of impact strength

Morphology of the samples was also studied through scanning electron microscopy (SEM) analysis. SEM images of PCL5 sample (surface and fractured) was taken before and after 18 months of soil burial test (Figure 10). SEM images taken from fractured samples presented at the left side and SEM images from surface of the samples presented at the right side. Upper SEM images belong to samples before soil burial test and bottom images from samples after 18 months of soil burial test. Fractured surface images showed that there are no big differences on the fractured-surfaces of the samples (0 month versus 18 months of burial test). There were only some small cracks around RPWF. In the case of SEM images taken from the surface of the samples, after 18 months of soil burial test, there were big and deep cracks on the surface of the samples.

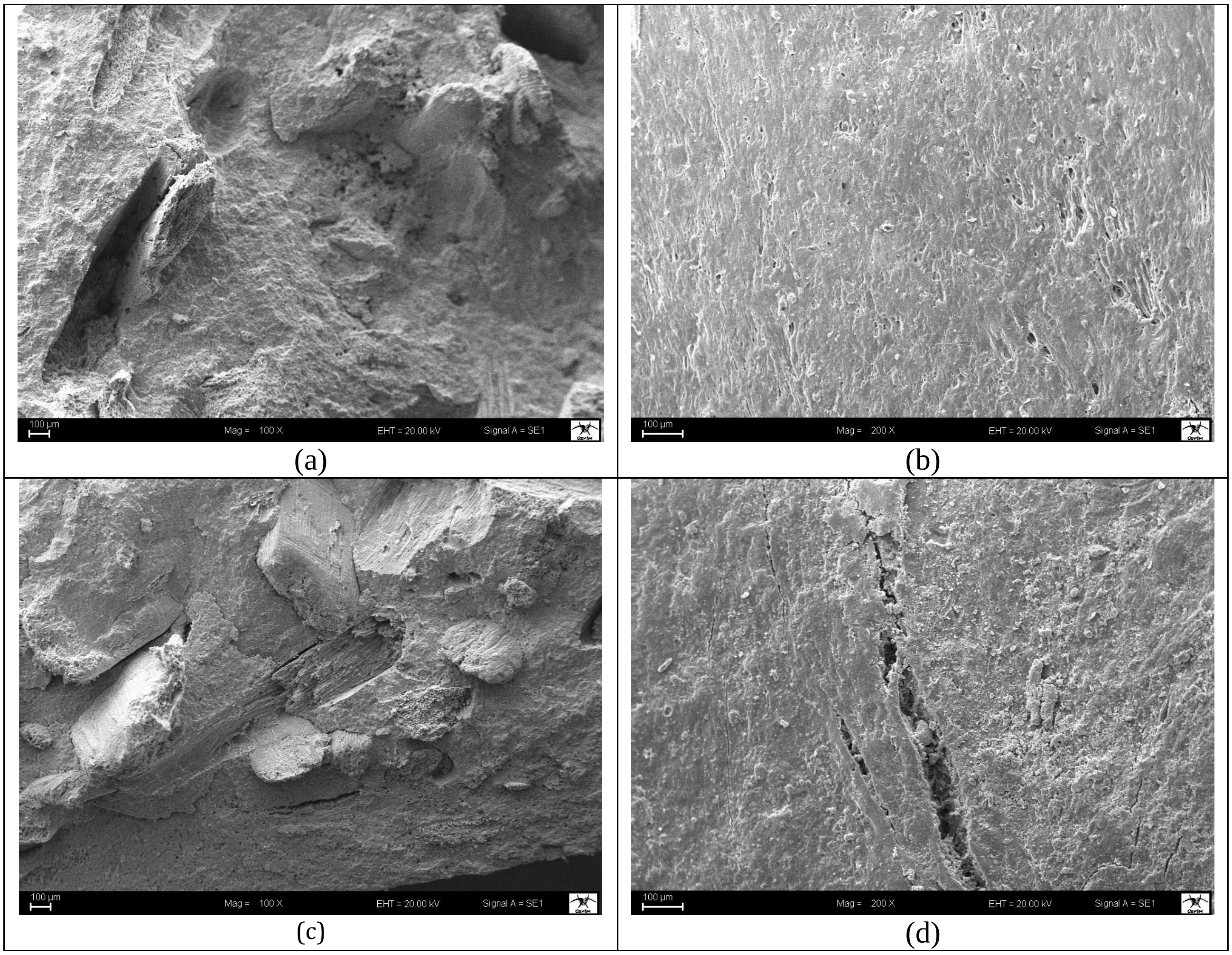


Figure 10: Scanning electron microscopy images of surface and fractured PNC5 samples; (a) Before Soil-fractured surface, (b) Before Soil- surface (c) After 18 months soil burial-fractured surface, (d) After 18 months soil burial-surface

4 CONCLUSION

Biodegradable composites were successfully manufactured and 18 months of soil burial test were conducted. The following conclusions were reached;

- RPWF and degradation time have a significant effect on mechanical properties.
- Higher RPWF loading provided higher density and modulus values regardless of degradation time.
- SEM results showed that cracks are present on sample surface but not as much in fractured surface.

5 ACKNOWLEDGEMENTS

This research was supported by The Scientific & Technological Research Council of Turkey (Project # TOVAG 113O254).

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Gel Permeative Chromatography (GPC) Analysis of Polycaprolactone (PCL) Based Biodegradable Composites through Laboratory Soil Test

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ABSTRACT

Biodegradability is an important asset for a polymer for their acceptance by the society due to the increased environmental awareness people over the years. In this study, Polycaprolactone (PCL) based biocomposites were produced using PCL, polyvinyl alcohol (PVA)/Starch mixture and polyethylene (PE) as a polymeric matrix and Turkish Red Pine Pruning waste flours (RPWF) a lignocellulosic filler. Biocomposites were manufactured through combination of extruder and injection molding processes. Forest soil was collected from arid regions of Konya and transferred to Laboratory. During 18 Months of soil test, degradation of PCL was monitored using Gel Permeative Chromatography (GPC). Results showed major factor on GPC results were RPWF and degradation time. Especially at higher level of lignocellulosic filler use, there is a linear relation between filler and degradation time.

KEYWORDS: Gel Permeative chromatograph (GPC), Polycaprolactone (PCL), polyvinyl alcohol (PVA), biodegradable, mechanical and physical properties

1 INTRODUCTION

Petrochemicals driven non-biodegradable plastics cause serious environmental problems since they produce greenhouse gas during their manufacturing and wastes after their disposal. Even though they seem to be used for a long time due to newly add application areas, reliable and repeatable product quality and cost advantages, research towards finding alternative resources and using them continue.

That's why past 30 years, biodegradable plastics and new manufacturing methods have been studied intensively (Van de velde and Kiekens, 2002; Kolybaba et al., 2003; Yu and Chen, 2009; Leja and Lewandowicz, 2010; Averous and Pollet, 2012;). Biodegradation is the decomposition of organic material to the carbon, hydrogen and oxygen by microorganisms. Most common biodegradable plastics are starch (Walenta et al., 2001a and 2001b; Laohakunjit and Noomhorm, 2004; Zhang and Han, 2006; Hanna and Xu, 2009; Inman, 2010), protein, polylactic asit (PLA) (Viera et al., 2011; Gorrasi and Pantani, 2013) and polyhydroxyalkonates (PHA), driven from renewable resource and polycaprolactone (PCL) (Viera et al., 2011), petroleum driven from petrochemicals. Among them, the most commonly used one is starch since it can be used as plastic matrix and also a plastic filler. However, its drawbacks prevent them from being good alternative to other synthetic plastics. That's why they need to be combined with other biodegradable plastics for many application areas.

Biodegradable plastics are commonly used in the areas of packaging, agricultural mulch films and medical applications (Davis and Song, 2006). The usage of low density polyethylene (LDPE) based agricultural films are increasing in Turkey and in the World. After usage, these materials produce great amount of waste on the agricultural land. The use of biodegradable plastic instead, would be a better option.

Biodegradable plastics are known for being environmental friendly and being used as an alternative to petroleum driven plastics. They are also known for medical applications like tissue engineering, surgery ropes and drug delivery systems. In those applications, they are taken advantage of biodegradability of plastics. There is a need to increase application areas of biodegradability of plastics beyond the packaging, agricultural mulch films and medical applications.

In our previous study, biodegradable composite materials using starch and wood flour were manufactured. However, this type of material still prone to hydrolyses in short time when in contact with water. That's why the use of starch in combination with other biodegradable plastic is advised in many applications. The objective of this study is to manufacture biocomposites using combination of biodegradable polymers and monitor their degradation under soil with GPC analysis.

2 MATERIALS AND METHODS

Summary of the experimental design and description of the manufactured samples were presented in Table 1 and Table 2, respectively. PCL, PVA-Starch mixture and PE were used as thermoplastic matrix. Turkish red pine pruning waste (RPW) was used as lignocellulosic filler. Depending on the formulation given PCL, dried PVA-starch pellets, PE and RPW were dry-mixed in a high-intensity mixer to produce a homogeneous blend. These blends were compounded in a single-screw extruder at 40 rpm screw speed in the temperatures (barrel to die) of 170-175-180-185-190°C. Extruded samples were cooled in water pool and subsequently granulated into pellets. The pellets were dried in oven at 103±2 °C for 24 hours. Dried pellets were injection molded using an HDX-88 Injection Molding Machine to produce standard test samples.

Table 1: Summary of the experimental design

Analysis Type:	**Response Surface Method**		**Variance (nm)**	
Desing Model:	**Quadratic**		**Levels:2**	
	Factors	***Type***	***Low Actual***	***High Actual***
A	RPW(%)	Numeric	4.39	25.61
B	PE (%)	Numeric	1.46	8.54

Table 2: Description of the manufactured samples

ID	**Neat PCL (%)**	**RPWF (%)**	**PE(%)**	**PVA-Starch (%)**
PCL0	55.00	15.00	0.00	30
PCL1	64.15	4.39	1.46	30
PCL2	42.93	25.61	1.46	30

PCL3	65.00	0.00	5.00	30
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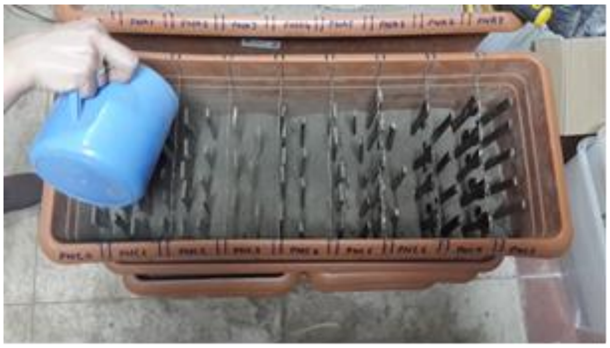
PCL5	35.00	30.00	5.00	30
PCL6	57.07	4.39	8.54	30
PCL7	35.85	25.61	8.54	30
PCL8	45.00	15.00	10.00	30

Forest soil was collected from arid regions of Konya and transferred to Laboratory. Samples were put into the flowerpots and covered by forest soil. They were watered up to field capacity (Figure 1).



(a)

(b)

Figure 1: Samples were put under soil (a) and watered up to the field capacity (b)

For GPC Analysis; samples were taken out of soil, cleaned and weighed before testing. Before running test GPC was cleaned with 2-propanol for 120 min. Flow was 1ml/h. Later eluent THF was run for 180 min. GPC was calibrated. 0,5g kompozit powder was mixed with 50 mL for 60 min. Mixture was filtered with 45 µm Agilent brand nylon filter. Samples passing 45 µm filter was injected 20 µlL volume of the system. Analysis was accomplished at 25°C column temperature, 33-35 bar colon pressure and 35°C RID detector temp. One agilent brand Polargel-M guard 50 x 7.5 mm column and 2 agilent brand Polargel-M 300 x 7.5 mm column were used for analysis (Figure 2).

(a)

(b)

(c) (d)

Figure 2: Samples were cleaned from dirt (a), granulated with IKA (b), diluted in THF (c) and tested in GPC (d)

3 RESULTS AND DISCUSSION

After soil burial test, maximum molecular weight loss of the samples were determined and results were analysed. Statistical analysis showed that both RPWF loading and degradation time had significant effect on molecular weight of the PCL matrix. Interaction graph of the result is presented in Figure 3. In first 6 month period, samples with low and high RPWF loading have provided similar molecular weight degradation (10%). After 6 months, on the other hand, high RPWF loading samples lost more molecular weight. After 18 months of burial test, samples with high RPWF loading lost around 40% of its molecular weight. However, it was still around 10% for samples having low RPWF loading. Arvanitoyannis et al. (1998) reported that there is close relation between degradation and excess of the microorganism to lignocellulosic materials. We believe that at high RPWF loading, water and microorganism had a better chance of excessing the lignocellulosic materials resulting in increased molecular weight reduction of the PCL matrix.

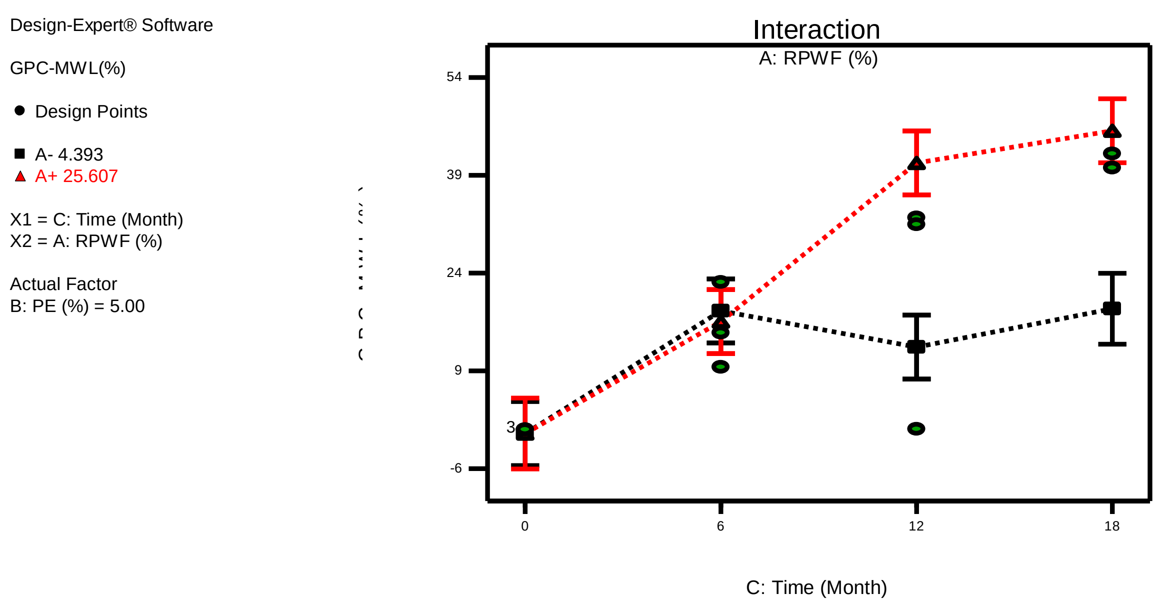


Figure 3: GPC- Maximum Weight Lost (GPC-MWL)

Produced composite materials were buried under soil which is collected from Konya region. Tensile, flexural and impact samples were kept under soil over 18 months of period. Samples were taken out every six months and weight losses were measured. Weight loss percentage interaction graphs of tensile, flexural and impact samples were shown in Figure 4, Figure 5 and Figure 6, respectively. Based on the statistical analysis, RPWF loading had no significant effect on weight loss for tensile and flexural samples ($P=0.1268$, $P=0.2108$, respectively). In the case of impact samples, it had significant effect on weight loss ($P=0.0039$). Even though PE amount had some effect on weight loss, degradation time has the most important effect on weight loss for all samples ($P<0.0001$). Among them, impact samples had the highest weight loss compared to tensile and impact samples. It is believed that higher surface area of the impact samples (being in almost half the size of other samples) increased the wear of the samples under soil.

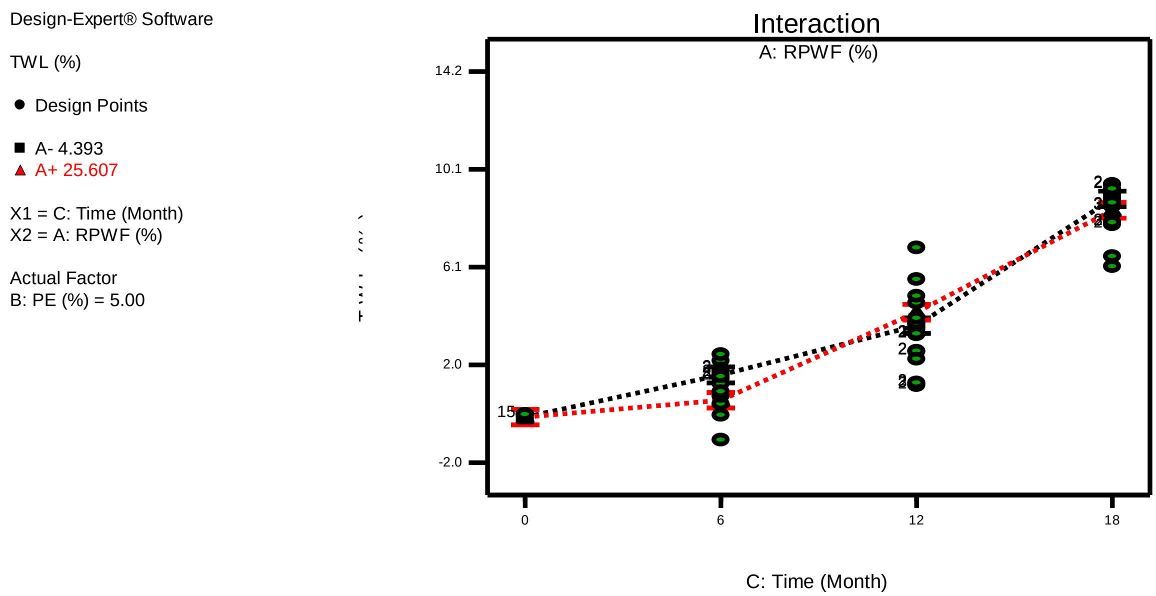


Figure 4: Weight loss of tensile samples (TWL)

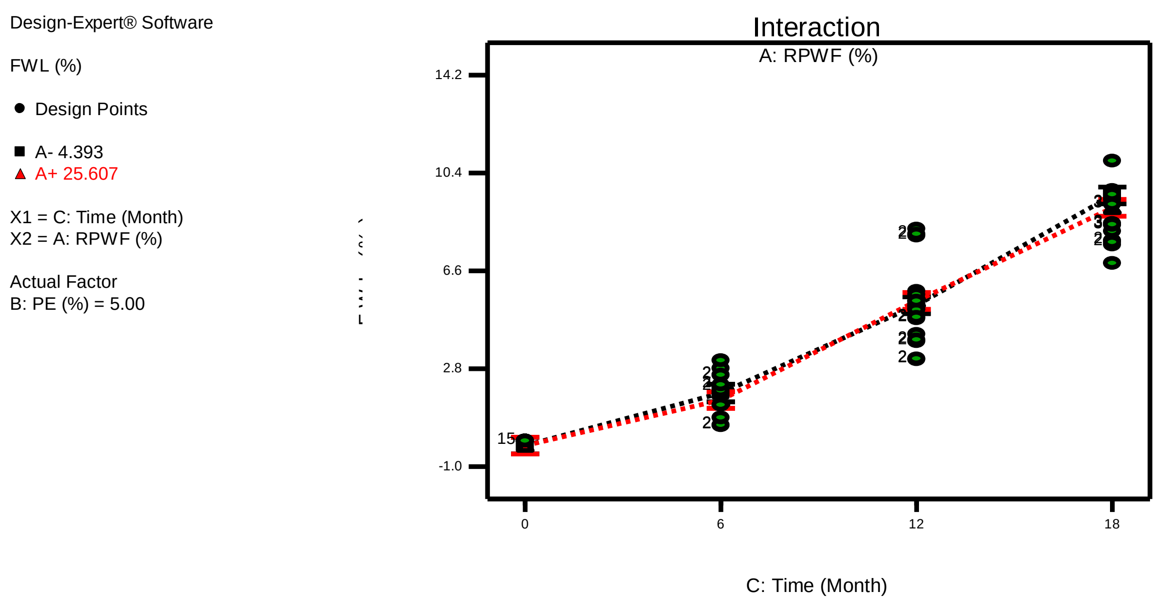


Figure 5: Weight loss of flexural samples (FWL)

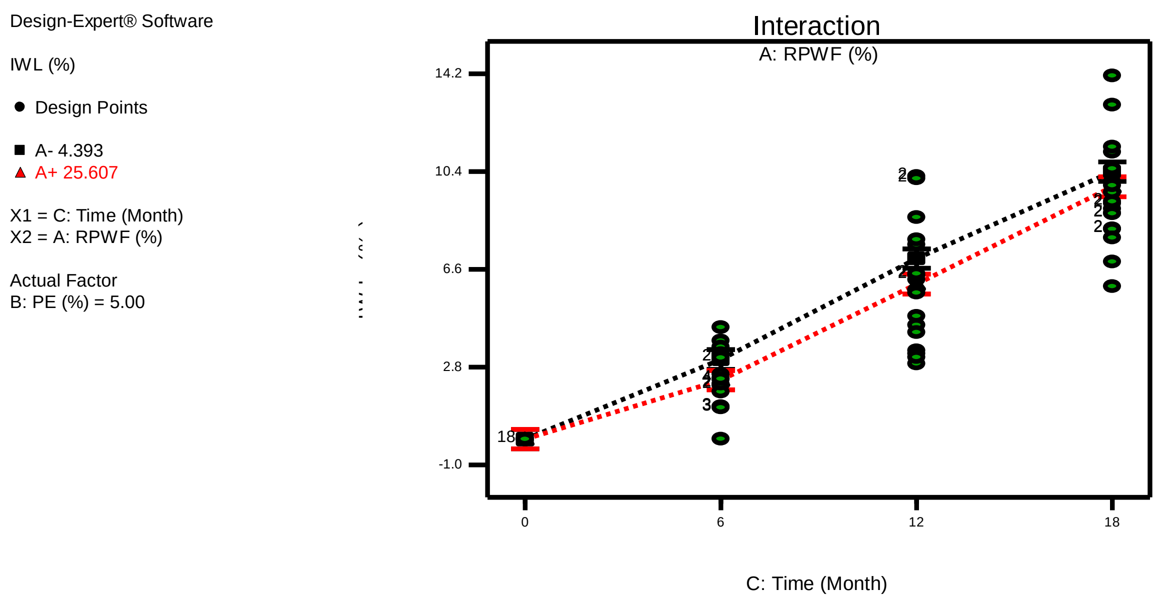


Figure 6: Weight loss of impact samples (IWL)

4 CONCLUSION

Biodegradable composites were successfully manufactured and 18 months of soil burial test were conducted. Based on the GPC analyses following conclusions were reached;

RPWF concentration and degradation time have a significant effect on GPC molecular weight. Especially at high RPWF loading, there is a linear correlation between degradation amount and filler loading.

GPC can be used to monitor degradation of polymers but needs further studies to compare and correlate them to standard weight loss methods.

5 ACKNOWLEDGEMENTS

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Effects of Heat-Treatment and Varnish Application on the Colour Change of Pine and Ash Laminated Veneer Lumbers

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ABSTRACT

Heat treatment temperatures and varnish effects on colour properties of pine (*Pinus sylvestris* L.) and ash (*Fraxinus americana*) laminated veneer lumbers (LVL) were evaluated. In the first instance the wood lumbers were exposed to heat treatment with the temperatures of 190 and 212 ºC for 1.5 and 2 h, respectively. After heat treatment process, LVLs were manufactured from heat treated pine and ash veneers with polyurethane (PU) and melamine urea –formaldehyde (MUF) adhesives and one surface of them varnished with yacht varnish. A spectrophotometer was employed to determine colour change of heat-treated and varnished specimens. The samples had significant discoloration as a result of heat exposure and varnish application. Colour difference of the specimens increased as a result of all treatment temperatures. Varnish application caused a significant colour change for both tree species.

KEYWORDS: Colour, Heat-treatment, Varnish, ThermoWood.

1 INTRODUCTION

Wood material has been used in many purposes for indoor and outdoor construction/furniture materials. In the outdoor applications the wood condition is exposed many destroying factors which is a combination of factors such as solar irradiation, moisture, wind, heat/cold, oxygen and atmospheric pollutants and these factors degrade the components and changes its colour. The ultraviolet (UV) light which is the dangerous one, depolymerizes lignin in the wood cell walls and after depolymerization reactions, with the water degradation products removes and it results in surface erosion (Williams, 2005; Hon,1991; Evens et al., 1992; Hon, 2001). The photochemical degradation begins due to UV, which changes aesthetic appearance of wood materials and wood becomes pale or greyish, yellowish or darkened mostly depending on the extractive compounds (Hon, 2001; Feist, 1983; Ayadi et al., 2003).

To minimize the effects of weathering deterioration, it is necessary to identify the causative factors and to improve wood properties against to weathering deterioration. Heat treatment is a well-known method to develop some physical properties of wood. It gives wood a nice darker colour. However, it improves the dimensional stability of wood and gives a nice darker colour, it makes wood susceptible against to photodegradation. Several investigations have shown that weathering causes poor aesthetics surface for heat-treated wood which are discoloration and surface checking when it exposed to UV radiation (Sivonen et al., 2002; Syrjänen et al., 2000; Mayes et al., 2002).

To protect wood against to these kinds of deteriorations several methods has been used for many years. The surface of the wood is protected by the surface treatments and besides it is getting aesthetically beautiful appearance. One of the commonly used method is varnishing.

In this study, the effect of heat treatment temperature and varnish application on laminated veneer lumber which produced heat-treated and untreated ash and pine wood species was investigated.

2 MATERIAL AND METHOD

2.1 Wood Species

In this study, Ash (*Fraxinus americana*) and Yellow Pine (*Pinus slyvestris* L.) species, which find a significant use in trade, have been used. Heat treated by ThermoWood method and untreated Ash and Yellow Pine timbers were supplied from the Novawood in Gerede, Bolu. In addition, attention has been paid to the fact that lumber is perfect, that there is no reaction wood, and that it has not been damaged by fungi and insects. Both tree species were heat treated at 190 and 212 ° C for 1.5 and 2 hours, respectively.

2.2 Heat Treatmet

Heat treatment by ThermoWood method takes place in three stages. Increasing the temperature and drying at high temperature: Using the heat and water vapor, the oven temperature is quickly increased to 100 ° C and then raised to 130 ° C, during this time the high temperature drying is performed and the moisture in the wood is tried to be reduced to almost zero level. Heat treatment: After high temperature drying, the temperature in the oven is raised from 185 ° C to 212 ° C. When the desired temperature is reached, this temperature is maintained for 2 - 3 hours depending on the usage of the material. Cooling and conditioning: At the final stage, temperature is lowered by water spraying. When the temperature reaches 80-90ºC, the wood material is re-moistened to bring the moisture content to a level of 4-7%.

2.3 Lamination

The heat-treated and untreated timbers were cut to lamellas at a measurement of 110x500 mm and a thickness of 5 mm and they kept at room temperature for 30 days. Then the lamella is divided into two groups before the lamination process. In the production of laminated wood material, AkzoNobel brand Melamine-Urea Formaldehyde (MUF) was used for the first group lamellas and Akfix Brand Polyurethane (PU) was used for another group of lamellas as glue types. The properties of the adhesives are in the following table.

Table 1: Adhesive Properties

Adhesive	Density (20 ˚C) (Kg/m^3)	pH (-25 ˚C)	Viscosity (20 ˚C) (mPs)	Amount of Solid (%)	Amount of Application (g/m^2)
MUF	1270	9,5-10,7	10.000-25.000	65-69	250-450
PU	1100	-	5.000-15.000	-	140-240

2.4 Varnish Application

In varnishing process yacht varnish (one component alkyd-based varnish) which is frequently used in outdoor applications is used. Prior to varnishing, the surface of all samples was sanded and smoothed. The principles specified in ASTM-D 3023 (2011) have been respected in the varnishing of the test sample. At the same time, when the varnish had been applying, the manufacturer's recommendations were considered. It was applied on the single surface with the roller as a 2-layer, 125 g / m^2 varnish falls to each layer and waited

24 hours between the layers. There were control samples (non-varnished samples) for each variation. The specimens which were completed varnishing were kept under normal weather conditions for two months. The table showing varnish properties is as follows;

Table 2: Varnish Properties

Varnish Type	Density (20 °C) (g/cm³)	Component	Dust Drying Time	Amount of Solid (%)	Touch Drying Time
Yatch Varnish	0,9-1,00	Single	3-4 hours	40-45	6-8 hours

2.5 Colour Measurement

The colors of samples were measured by an 8 mm in diameter with 10° observer angle using with a spectrophotometer according to the CIE L* a* b* system to express the color change (Figure 1).

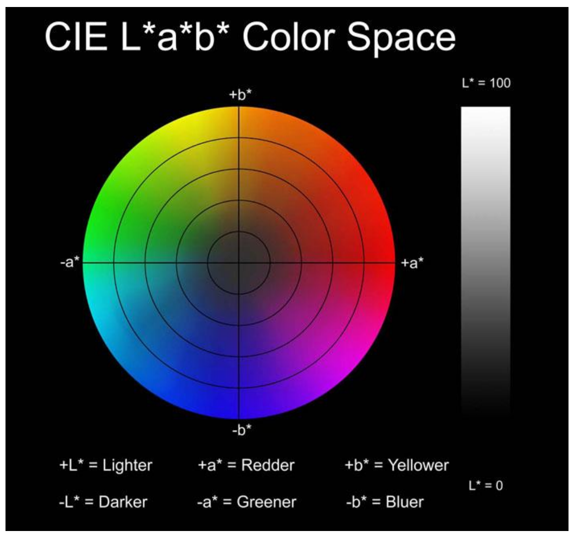

Figure 1: CIE Lab colour space: L is always positive and represents lightness; a> 0 represents red component, a<0 represents green component; b>0 represents yellow component, b<0 represents blue component.

The measurements were recorded at the same points on surface of each sample before and after varnishing. Initially, to determine the effect of heat treatment on colour change, before and after heat treatment the colour of samples was measured. Measurement of the total colour change, the equation 1 was used,

$$\Delta L^* = L_{ut} - L_{ht} \quad (1)$$

$$\Delta a^* = a_{ut} - a_{ht} \quad (2)$$

$$\Delta b^* = b_{ut} - b_{ht} \quad (3)$$

$$\Delta E^* = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \quad (4)$$

where ΔE* is total colour change; ΔL* is lightness difference, Lut/ht is untreated/heat treated lightness; Δa* is green/red coloration difference; aut/ht is untreated/heat treated green/red coloration; Δb* is yellow/blue coloration difference; b ut/ht is untreated/heat treated yellow/blue coloration.

3 RESULTS AND DISCUSSION

Heat-treatment at increasing temperature causes a darker and more brownish colour on wood which is desirable for the last user but with heat treatment the wood becomes more susceptible to ultra-violet radiation. To protect of wood surface becomes a necessity with coatings, paints and varnishes. In figure 2 it is obvious that the heat treatment and varnish cause a darker colour on wood samples especially ash wood samples.

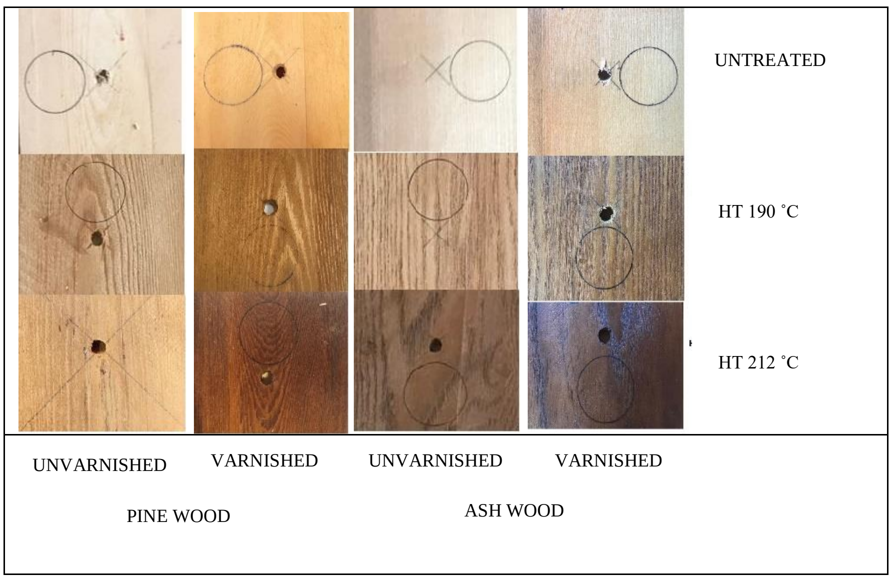

Figure 2: The colour change caused by heat treatment process and varnish on wood samples

3.1 Colour Change after Heat Treatment

Table 1 shows the changes of L*, a*, b*, and E* according to the temperature of treatment. While the increase in ΔL* indicates that the samples become darker, negative values of Δa* and Δb* indicate a tendency of wood surface to become red hue and yellow hue.

Table 2: Colour change caused by heat treatment

Wood Species	Heat Treatment Temperature	ΔL	Δa	Δb	Total Color Change ΔE*
Pine	190 °C	24,98	-3,30	-5,10	29,06
	212°C	32,68	-3,13	-2,11	35,92
Ash	190 °C	20,89	-3,74	-4,90	22,02
	212°C	30,46	-4,12	-3,13	31,06

It is obvious in the figure 3 that with the increasing treatment temperature, total colour change values increased. This means the wood samples were darker than the untreated samples (Figure 2). In literature, there are several studies which obtained similar results (Bekhta and Niemz,2003). Thermal treatment makes wood more brownish. It is a desirable property by user and industry.

This darkening in the colour may be due to degradation of hemicelluloses therewith an increase in percentage of lignin (Kamdem et al., 2002).

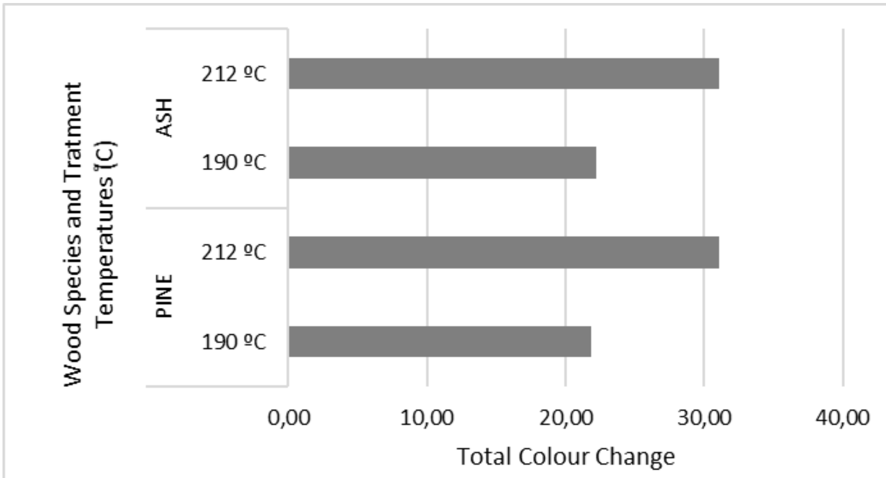

Figure 3: Total colour change caused by heat treatment process

The most total colour change became the samples that heat treated at 212 ˚C for both pine and ash wood species (Figure 3). Intensive heat treatment conditions changed the original colour of wood samples significantly. It is obvious when the positive ΔL* values of samples are examined. Some reactions such as oxidative and/or hydrolytic discolouring reaction causes the colour change during heat treatment (Sundqvist, 2002). It was indicated that the colour changes occurring after heat treatment most probably become because of the modification of polysaccharide structures, the vaporization of colorant extracts and rapid oxidation of lignin and some chemical elements at high temperature (Şahin and Korkut, 2016).

3.2 Colour Change after Varnish Application

Table 2 shows the changes of L*, a*, b*, and E* according to the temperature of treatment. While the positive values of ΔL* indicates that the samples become darker, decrease of ΔL* indicates that the samples become lighter; negative values of Δa* and Δb* indicate a tendency of wood surface to become red hue and yellow hue. Lightness (L*) value of all the control and heat-treated samples has decreased after the varnish applications and the samples have darkened (Figure 2). Pelit (2017) achieved similar results in a study using different varnishes. When working with four different varieties, the result is that all the varnishes darken the colour of the wood samples. It has seen that in Table 3 ΔL* value has been similar for all pine wood samples (control and heat-treated wood samples) but there is significant difference between untreated (control) and heat-treated ash wood samples.

Table 3: Colour change caused by varnish

Wood Species	**Heat Treatment Temperature**	**ΔL**	**Δa**	**Δb**	**Total Color Change ΔE***
Pine	Control	5,83	-1,45	-10,26	12,06
	190 ˚C	9,83	-4,55	-5,04	12,21
	212 ˚C	12,30	-4,28	1,86	13,48
Ash	Control	6,39	-1,38	-8,72	11,20
	190 ˚C	16,75	-2,65	-0,72	18,09
	212 ˚C	16,56	0,71	4,38	17,64

By the varnishing the positive value of ΔL* indicated that the almost all heat-treated samples at temperature 190 and 212 °C were getting darker. With the effect of varnishing, the total colour change decreased for heat-treated at temperature both 190 °C and 212 when the compared the colour change after heat treatment.

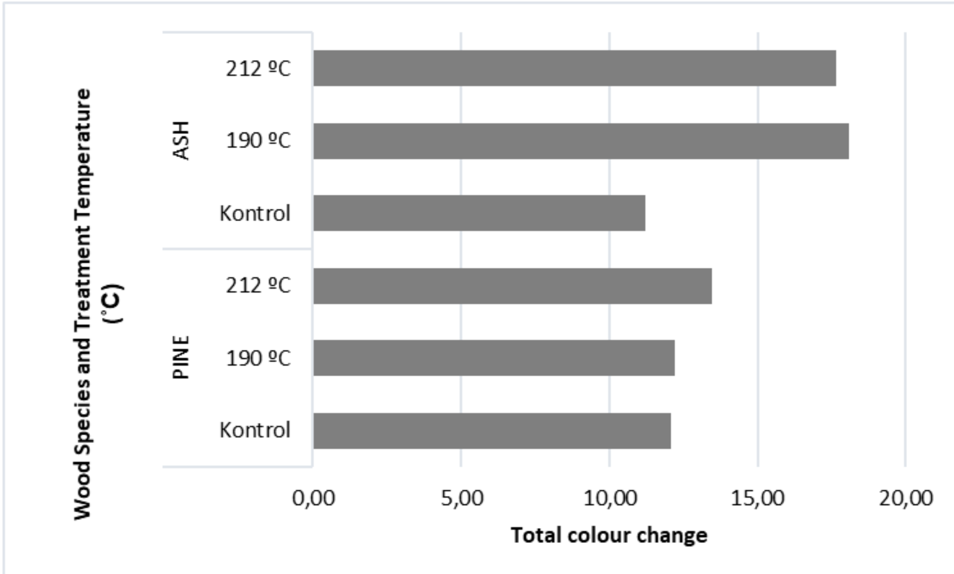

Figure 4: Total colour change caused by varnish apply

The maximum total colour change caused by the varnish took place in ash wood. Total colour changes of ash wood at 190 and 212˚C were visibly more than the total colour change in the heat-treated pine wood samples.

4 CONCLUSION

Intensive heat treatment conditions changed the original colour of wood samples significantly. It is apparent that the colour of wood became darker when the positive ΔL* values of samples are examined. Some reactions such as oxidative and/or hydrolytic discolouring reaction causes the colour change during heat treatment. Varnishing is a method to protect wood against to mostly ultra-violet radiation and applying varnish causes dark colour on the wood which is mostly desirable for final user.

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Influence of wooden outdoor furniture finished surfaces water absorption on and the properties of coating films

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ABSTRACT

The aim of this study is to investigate the effects of repeating water absorption of wooden outdoor furniture finished surfaces n wood coatings and finished surfaces. During the testing the influence of five cycles of water absorption on the quality finished surfaces and tensile strength of coating films will be measured. In this contribution there is researched the correlation among the changing the quality of physical-mechanical and appearance properties of tested wood based samples finished surfaces and the changing the tensile strength of coating films prepared from the same coating materials.

The testing method was coming from the standard EN 927 – 5. The reached results can improve the predictive the durability of coating materials after influence of the water.

KEYWORDS: Water absorption, coating films tensile strength, adhesion 4 - 8 keywords

1 INTRODUCTION

The design of any exterior coating for massive wood requires control of many factors in order to maximise the durability of wood products. Water plays the key role in the factors with the influence on durability of wood products in exterior, because wood is the subject to biological as well as physical and chemical degradation.

Water absorption by finished surfaces can modify the physical properties of coatings and may cause chemical change; transmission through the coating also causes swelling, shrinkage and movement of the substrate. The high permeability of some kinds of wood is at variance with many of the requirements of moisture control, and indeed. In the next step for the prediction of behaviour water in wood the research must be aimed in considering the role of water in exterior wood coating behaviours are:

How should the moisture transmission characteristics of coating systems be specified to ensure optimum performance and durability?

How influences have the kinds of wood on the water permeability of finished surfaces of wood products?

How influence have the number of repeated cycles of samples floating on water.

It is important to recognize the transport of liquid water in organic polymers (wood is blend of organic polymers) is mainly controlled by diffusion (e.g.Siau, 1984, Bagda, 1990, Thomas, 1991. The diffusion through the matrix due to concentration gradient can be of two different mechanisms, activated diffusion through the homogenous polymer matrix and non – activated diffusion trough pores and defects. Contains of pigments adding to the coating materials have very important influence in permeability of water going through the coating films. The diffusion in the homogenous polymer matrix can be divided into three basic cases (Blahnik, 1983)

Case I or Fickian diffusion, where the speed of diffusion is much smaller than the speed of relaxation in the polymer

Case II diffusion, where the speed of diffusion is very fast in comparison with relaxation processes

Non-Fickian diffusion, which appears, when the speed of diffusion and relaxation are comparable

When we want to measure the permeability of water and moisture trough coatings on wood is normally higher than the measured permeability through free films. They report the following reasons for this discrepancy:

- The uneven swelling of the wood substrate compared to the swelling of the coating
- Fibres from the substrate penetrate the coating film, thus reducing the net thickness
- The interface between the coating and the wood is larger than its geometrical surface
- The surface of wood is more hydrophilic than the coating
- Cracks and inhomogeneity of the coating on wood are difficult to control.

The aim of this article is to investigate multiple reps of water floating. For testing the influence of multiple reps of water floating on the amount water absorption we investigated finished surfaces according to European standard 927-5: 2006 Paints and varnishes Coating materials and coating systems for exterior wood – Part 5 Assessment of the liquid water permeability

2 USED METHODS

Principle

The coating under test is applied to the face of defined test panel where the remaining face and sides are carefully sealed using a sealer of defined mandatory low permeability. The samples are floating face down by the tested finished surface for 24 h in one cycle. The properties of water permeability are assessed by measuring the mass of water uptake over a 72 h period of a coated test panel exposed to liquid water.

Results are expressed as water absorption of coated wood panels in grams per square metre test surface per 72 h.

Used equipment: air conditioner, laboratory weight Kern, laboratory temperature oven,

Testing procedure of prepared samples

24 h floating face down in deionized water, such that the test face is fully submerged
3 h drying at (20 ±2) °C and a relative humidity of (65 ± 5) % in accordance with ISO 554
3 h drying at 50 °C
18 h drying at (20±2) °C and a relative humidity of (65±5) % in accordance with ISO 554
Absorption cycle weigh the test panels to the nearest 0,01 g and record the initial mass before ***(m_0)***
After 72 h remove the test panels from the water, blot lightly to remove any water droplets and wig.
Record elapsed time and mass (***m_1)***

Water absorption ***m*** per square metre of test surface for the test panels by dividing the water uptake by the measured test area of each of test panels

$$m_1 - m_0 = m \tag{1}$$

Tested samples of wood:

massive spruce dimensions (150 ± 2) mm x (70 ± 2) mm x (20 ± 2) mm 5 samples;
massive acacia dimensions (150 ± 2) mm x (70 ± 2) mm x (20 ± 2) mm, 5 samples,
5 samples of glass dimensions (150 ± 2) mm x (70 ± 2) mm x (20 ± 2) mm

Tested coated materials:

AXAPUR gloss U1010 transparent polyurethane lacquers, Solvent opaque lacquer Profi Lazúra S1025

3 RESULTS

In the table 1 and in the figure 1 there are published the results of the investigation the influence of repeating the floating tests of the liquid water permeability on the tested samples assessment. That means the ability of a coating system to allow the transmission of water as liquid or vapour. In the table 1 there is ability of water permeability expressed as the stable mass we can achieved

Table 17: Water permeability in depends of used coating materials and massive wood materials

	Units	**tested finished surfaces**			
Coating		**U1010**	**U1010**	**S1025**	**S1025**
Massive surfaces		**Massive spruce**	**Massive acacia**	**Massive spruce**	**Massive acacia**
Sorption 1 cycle 24 h floating 72 h drying					
Mean value	$g.m^{-2}$	74,27	3,60	46,00	22,80
Maximum	$g.m^{-2}$	111,33	5,33	53,33	26,00
Minimum	$g.m^{-2}$	53,33	2,00	28,67	16,67
Standard deviation	$g.m^{-2}$	21,19	1,16	9,05	3,36
confidence level α	%	95	95	95	95
Sorption 2 cycle 24 h floating (together 48 h of floating 2 x72 hours of drying					
Mean value	$g.m^{-2}$	128,67	8,80	73,73	26,27
Maximum	$g.m^{-2}$	146,00	9,33	88,00	28,67
Minimum	$g.m^{-2}$	112,00	8,00	56,67	23,33
Standard deviation	$g.m^{-2}$	11,10	0,50	12,21	2,17
confidence level α	%	95	95	95	95
Sorption 3 cycle 24 h floating (together 72 h of floating 3 x72 hours of drying					
Mean value	$g.m^{-2}$	197,47	43,60	86,13	29,60
Maximum	$g.m^{-2}$	262,67	52,67	96,00	31,33
Minimum	$g.m^{-2}$	139,33	32,00	69,33	28,67
Standard deviation	$g.m^{-2}$	45,16	7,26	9,86	1,00
confidence level α	%	95	95	95	95
Sorption 4 cycle 24 h floating (together 96 h of floating 4 x72 hours of drying					
Mean value	$g.m^{-2}$	79,33	32,80	90,80	51,87
Maximum	$g.m^{-2}$	91,33	45,33	103,33	57,33
Minimum	$g.m^{-2}$	68,00	20,67	82,67	45,33
Standard deviation	$g.m^{-2}$	9,34	8,71	7,17	4,39
confidence level α	%	95	95	95	95

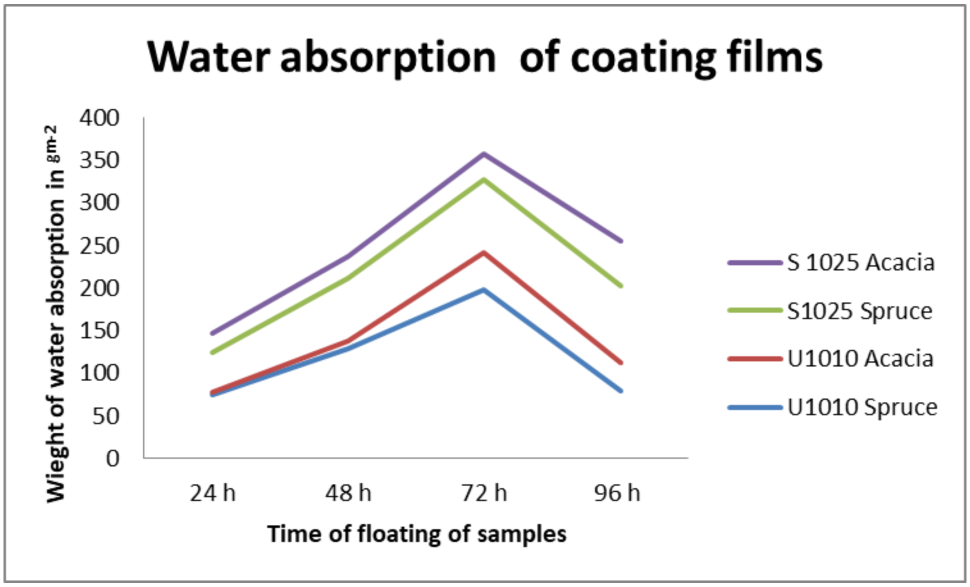

Figure 12: Dependence of water absorption on the repeated wetting time on the applicate coating materials Axapur U1010 and S 1025 on the used massive wood spruce and acacia

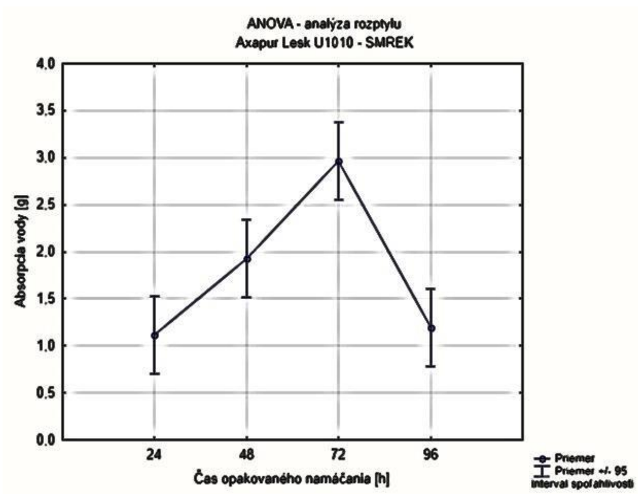

Figure 13: The ANOVA statistical test of Axapur Lesk U1010 on spruce

Table 18: ANOVA statistical test of Axapur Lesk U1010 on spruce

ANOVA						
Source of variability	SS	difference	MS	F	Value P	F krit
Between selections	11,0491	3	3,68306	19,4062	1,4E-05	3,238872
Entire selections	3,0366	16	0,189788			
total	**14,085**	**19**				

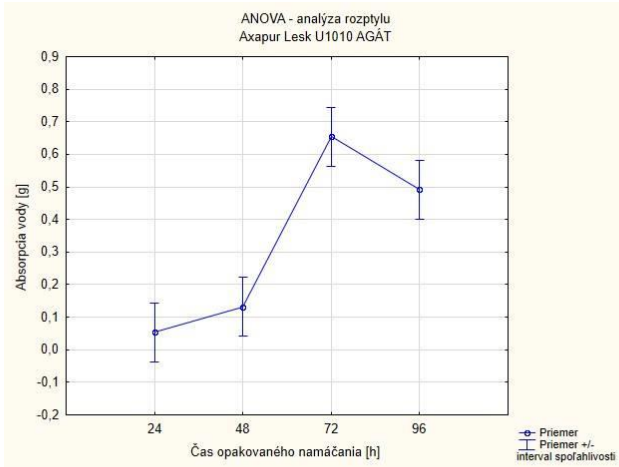

Figure 14: The ANOVA statistical test of Axapur gloss U1010 on acacia

Table 19: ANOVA statistical test of Axapur gloss U1010 on acacia

ANOVA						
Source of variability	SS	difference	MS	F	Value P	F krit
Between selections	1,23282	3	0,41094	44,91148	5,12E-08	3,238872
Entire selections	0,1464	16	0,00915			
total	**1,37922**	**19**				

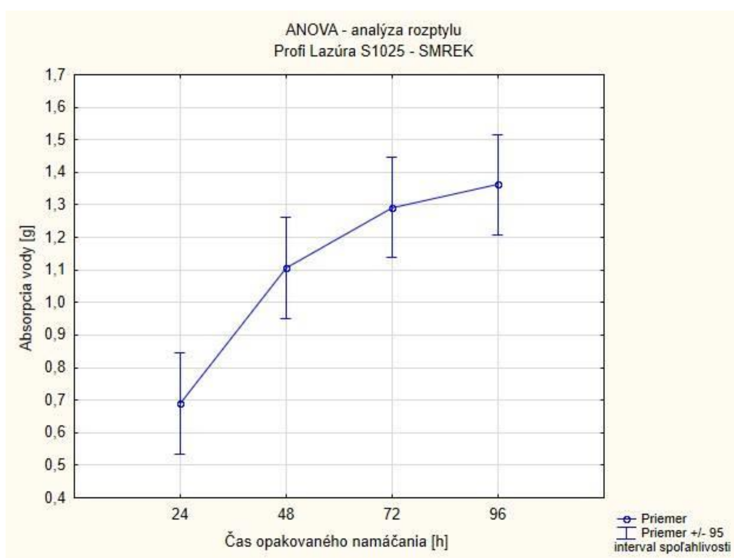

Figure 15: The ANOVA statistical test of Profi Lazura S1025 on spruce

Table 20: ANOVA statistical test of Profi Lazura S1025 on spruce

ANOVA						
Source of variability	SS	differ	MS	F	Value P	F krit
Between selections	1,365095	3	0,455032	17,0392	3,09E-05	3,238872
Entire selections	0,42728	16	0,026705			
total	**1,792375**	**19**				

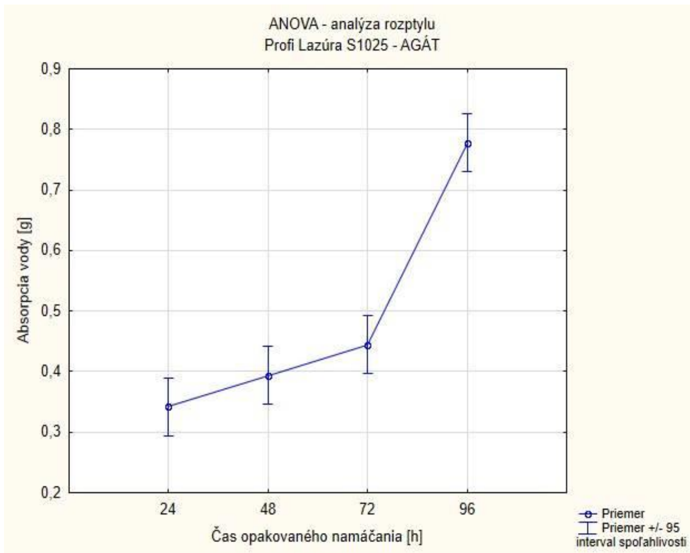

Figure 16: ANOVA statistical test of Profi Lazura S1025 on acacia

Table 21: The ANOVA statistical test of Profi Lazura S1025 on acacia

ANOVA						
Source of variability	SS	differ	MS	F	Value P	F krit
Between selections	0,580895	3	0,193632	75,9339	1,11E-09	3,238872
Entire selections	0,0408	16	0,00255			
total	**0,621695**	**19**				

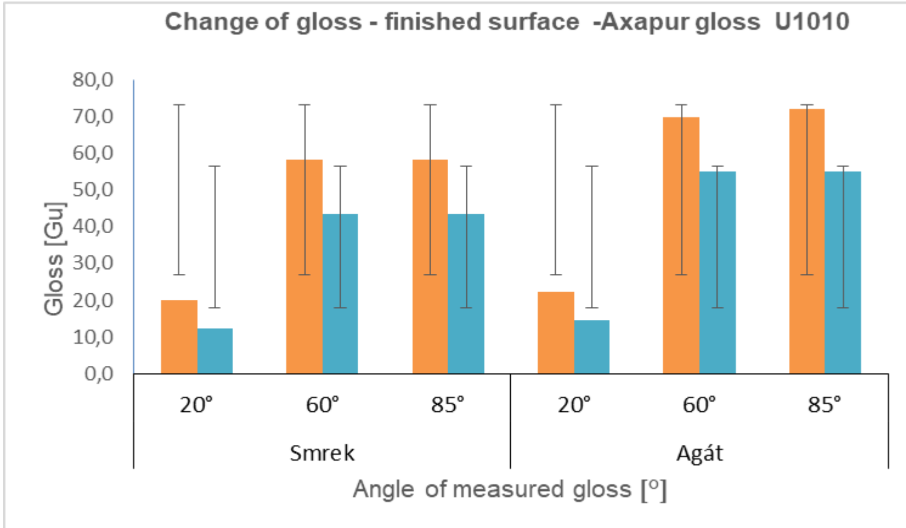

Figure 17: Gloss of finished surfaces by Axapur Gloss U1010 before floating and after 96 hours of floating, orange before and blue after.

4 CONCLUSIONS

Very important role in the water permeability and water absorption plays used massive material. The kind of wood acacia has marked more belter the resistance of water absorption than spruce. We can constant Acacia is more suitable for outdoor application the spruce without regardless the kind of used coating materials wood.

Chemical base of coating materials is very important factor on which the water permeability depends. On the figure 1 and in the table 1 it is to watch the differences between synthetic paint S 1025 and U 1010, where U 1010 is more applicable for finishing massive for exterior exposition than this type of synthetic materials.

The time of exposition finished surfaces to water during the floating has the impact on the aging of coating films without influence of kinds of wood and chemical bases of coating materials.

5 ACKNOWLEDGEMENTS

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THE INTERNATIONAL FOREST PRODUCTS CONGRESS

Optimization of Veneer Drying Temperature for the Best Mechanical Properties of Plywood via Artificial Neural Network

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ABSTRACT

The drying of veneer is an essential part of the veneer-producing process to aid the gluing during the manufacture of the plywood and laminated veneer lumber. Determining the optimum veneer drying temperature without decreasing of mechanical properties is also very important from industrial viewpoint. Due to the high drying costs, increased temperatures are being used commonly in plywood industry to reduce the overall drying time and increase capacity. However, high drying temperatures can alter some physical, mechanical and chemical characteristics of wood and cause some drying-related defects. In this study, it was aimed to predict the optimum drying temperature for alder and scots pine veneers via artificial neural network modelling for optimum mechanical properties. Therefore, mechanical strength values of plywood panels manufactured from alder and scots pine veneers were dried at temperatures of 110, 130, 150, 170, 190 and 210°C. Shear strength, bending strength and modulus of elasticity of the plywood panels were experimentally determined according to EN 314-1 and EN 310 standards. Then, the mechanical strength values based on veneer drying temperatures are subjected to prediction by artificial neural network modelling. As a results of this study, the optimum drying temperature values were obtained as 165, 162 and 161˚C in Scots pine plywood and 190, 195 and 196˚C in alder plywood, for best shear strength, bending strength and modulus of elasticity values, respectively.

KEYWORDS: Veneer Dying Temperature, Alder, Scots Pine, Artificial Neural Network, Mechanical Properties

1 INTRODUCTION

Plywood is a wood composite with good physical and mechanical properties and can be used for different applications such as the manufacturing of furniture, musical instruments, means of transportation, packings, sporting goods, as well as in constructions (Bekhta and Salca, 2018). Its production in the World and Europe in 2016 exceeded 159 and 8 million cubic meters, respectively (FAO, 2018). European Union (EU) imports of panels (mainly plywood) increased 9% to Euro 2.79 billion in 2017. This follows a 3% rise in 2016 and an 11% increase in 2015. Most of this gain was due to a rise in plywood imports from Russia and other Eastern European countries. The value of EU plywood imports from China and tropical countries was generally stable or declining in 2017 (Industry News and Markets, 2018).

Drying veneer sheets is an essential part of the veneer manufacturing process. Veneer drying often becomes a production bottleneck because of inefficient equipment and methods. The purpose of veneer drying is to reduce its moisture content to a range suitable for gluing (Aydin and Colakoglu, 2008). Drying process accounts for some 70 percent of the thermal energy consumed in plywood production and approximately 60 percent of the mill's total energy requirement. Although drying temperatures of between 90-160°C may be considered normal, increased temperatures are being used to reduce the overall drying time and increase capacity (FAO 1990). Reductions in drying time and energy consumption offer the wood industries a great potential for economic benefit (Aydin, 2014). It was concluded that the high-temperature drying practice can save energy and drying time by 44 and 25 %, respectively, in comparison with the conventional temperature drying (Theppaya and Prasertsan, 2004). Also, the economic benefits of quick drying of veneers at high temperature, this process can be effective on some mechanical, physical and chemical properties of wood (Ozsahin and Aydin, 2014).

Determination of the optimum veneer drying temperature without loss of mechanical strength is also very important from industrial view point. For this aim, a lot of temperature values need to be tested to determine the optimum values that cause the loss of much time and energy and high costs. Therefore, it is important to find more economic methods providing desirable results concerning technological properties (Demirkir et al., 2013). Artificial neural networks (ANNs) have been widely used in the field of wood (Esteban et al., 2011). The neural network most commonly used is the multilayer perception, whose nature as a universal function approximation makes it a powerful tool for modelling complex relations between variables (Fernandez et al., 2012). ANNs are capable of processing information in a parallel distributed manner, learning complex cause-and-effect relationships between input and output data, dealing with nonlinear problems, generalizing from known tasks or examples to unknown tasks. ANNs are good for tasks involving incomplete data sets, fuzzy or incomplete information, and for highly complex and ill-defined problems, where people usually decide on an intuitional basis. Moreover, they can be faster, cheaper and more adaptable than traditional methods (Ceylan, 2008; Ozsahin and Aydin, 2014).

This study is aimed to predict the optimum drying temperature for alder and Scots pine veneers via artificial neural network for best mechanical properties by using experimental data. The main purpose was to obtain the intermediate values not measured from the experimental study by artificial neural network modelling and to estimate the optimum temperature values for each wood species giving the highest mechanical strength values.

2 MATERIALS AND METHOD

Scots pine (*Pinus slyvestris*) and alder logs (*Alnus glutinosa* subsp. *barbata*) were used in this study. The logs were obtained from Trabzon region. While the alder logs were peeled freshly, scots pine logs were steamed for 12-16 hours before veneer production. A rotary type peeler (Valette&Garreau - Vichy, France) with a maximum horizontal holding capacity of 800 mm was used for veneer manufacturing and rotary cut veneer sheets with dimensions of 500x500 mm by 2 mm were clipped. Vertical opening was 0.5 mm and horizontal opening was 85% of the veneer thickness in veneer manufacturing process. After rotary peeling, spruce and beech veneer sheets were divided into six groups. The veneers were oven-dried at 110°C, 130°C, 150°C, 170°C, 190°C and 210°C for 5-7% moisture content in a laboratory scale jet veneer dryer (manufactured by Hildebrand Holztechnik GmbH).

Three-ply-plywood panels with 6 mm thick were manufactured by using urea formaldehyde (UF) glue resin with 55% solid content. The formulations of adhesive mixture are given in Table 1. Two replicate panels were manufactured for all test groups. Approximately 160 g/m^2 adhesive mixture was spread on single surfaces of veneers by using a four roller gluing machine. In the manufacturing of plywood panels, hot pressing time was 6 minutes, press pressure were 1.2 MPa for alder and 0.8 MPa for scots pine, and press temperature was 110°C.

Table 1: Formulations of adhesive mixtures used for the manufacturing of plywood panels

Ingredients of Adhesive	**Parts by weight**
UF resin (with 55% solid)	100
Wheat flour	30
Hardener (NH_4Cl with 15 % concentration)	10

Shear strength test was carried out for plywood panels manufactured according to EN 314-1 (1998) standard. Thirty samples were used for the evaluation of plywood shear strength. Before the shear strength tests, samples obtained from the panels manufactured with UF glue were immersed for 24 hours in water at

20±3°C. Bending strength and modulus of elasticity tests was carried out for plywood panels manufactured according to EN 310 (1993) standard. Twelve samples were used for the evaluation of plywood bending strength and modulus of elasticity.

ANN was used to predict the shear strength, bending strength and modulus of elasticity values in response to the other veneer drying temperatures not obtained from this experimental study. In this way, it was aimed to reveal the optimum veneer drying temperature for each wood species to obtain the highest shear strength, bending strength and modulus of elasticity. In the ANN modelling for the present work; wood species and drying temperatures were considered as the prime processing variables. The proposed ANN models was designed by software developed using the MATLAB Neural Network Toolbox. The data were obtained from the experimental study. To examine the effects of wood species and drying temperatures on shear strength, bending strength and modulus of elasticity; the experimental data were grouped into training data and test data. Among these data, 8 samples were selected for ANN training process, while the remaining 4 samples were used to verify the generalization capability of ANN. The data sets used in the training and prediction models are shown in Table 2. The shear strength, bending strength and modulus of elasticity results obtained experimentally also presented in Table 2.

The obtained predicted values as a result of the testing process were compared with the real (measured) values. The models providing the best prediction values with respect to the root mean-square error (RMSE) ratio, calculated with Eq. 1, the mean absolute percentage error (MAPE) ratio, calculated with Eq. 2 and coefficient of determination (R^2) with Eq. 3 was chosen as the prediction models.

$$\mathrm{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(t_i - td_i\right)^2} \tag{1}$$

$$\mathrm{MAPE} = \frac{1}{N}\left(\sum_{i=1}^{N}\left[\left|\frac{t_i - td_i}{t_i}\right|\right]\right)\times 100 \tag{2}$$

$$\mathrm{R}^2 = 1 - \frac{\sum_{i=1}^{N}(t_i - td_i)^2}{\sum_{i=1}^{N}(t_i - \bar{t})^2} \tag{3}$$

In Equations 1, 2 and 3, t_i is the actual output values, td_i is the neural network predicted values, and N is the number of objects.

Table 2: Training and testing data set and shear strength, bending strength and modulus of elasticity prediction models results

Training Data										
Wood Species	Drying Temperature (°C)	Shear Strength (N/mm^2)			Bending Strength (N/mm^2)			Modulus of Elasticity (N/mm^2)		
		Actual	Predicted	Error (%)	Actual	Predicted	Error (%)	Actual	Predicted	Error (%)
Scots pine	110	1.342	1.342	0.002	65.733	65.753	-0.031	4868.228	4870.060	-0.038
Scots pine	150	1.447	1.448	-0.015	87.611	87.586	0.029	5509.160	5508.783	0.007
Scots pine	170	1.719	1.719	0.002	88.231	88.228	0.004	5518.530	5518.553	0.000
Scots pine	210	1.006	1.006	-0.002	56.018	56.013	0.008	4618.743	4618.774	-0.001
Alder	130	1.212	1.212	0.042	63.057	63.328	-0.430	4360.011	4377.383	-0.398
Alder	150	1.404	1.403	0.041	65.413	65.063	0.536	4424.940	4406.832	0.409
Alder	190	1.888	1.888	-0.016	71.250	71.331	-0.114	4878.719	4879.752	-0.021
Alder	210	1.181	1.181	-0.012	58.839	58.835	0.006	3701.773	3702.047	-0.007
	MAPE	0.017			0.145			0.110		
	RMSE	0.000			0.160			8.905		
Testing Data										
	Drying Temperature (°C)	Shear Strength (N/mm^2)			Bending Strength (N/mm^2)			Modulus of Elasticity (N/mm^2)		
		Actual	Predicted	Error (%)	Actual	Predicted	Error (%)	Actual	Predicted	Error (%)
Scots pine	130	1.391	1.343	3.460	77.073	77.058	0.019	5201.858	5164.226	0.723
Scots pine	190	1.252	1.137	9.177	62.548	63.003	-0.728	5081.412	5128.929	-0.935
Alder	110	1.257	1.290	-2.626	64.471	62.341	3.303	4336.573	4371.079	-0.796
Alder	170	1.426	1.485	-4.089	65.550	67.787	-3.413	4499.033	4520.922	-0.487
MAPE		4.838			1.866			0.735		
RMSE		0.071			1.561			36.551		

Figure 1 shows the ANN models containing one input layer, one hidden layers and one output layer. The selected ANN models represents the prediction models that produced the closest values to the measured values for the shear strength, bending strength and modulus of elasticity. The wood species and drying temperatures were used as the input variables, while the shear strength, bending strength and modulus of elasticity values was used as the output variable in the ANN models. The processing element numbers (neurons) of the hidden layers were 4, 3 and 3 for the models in Figure 1.

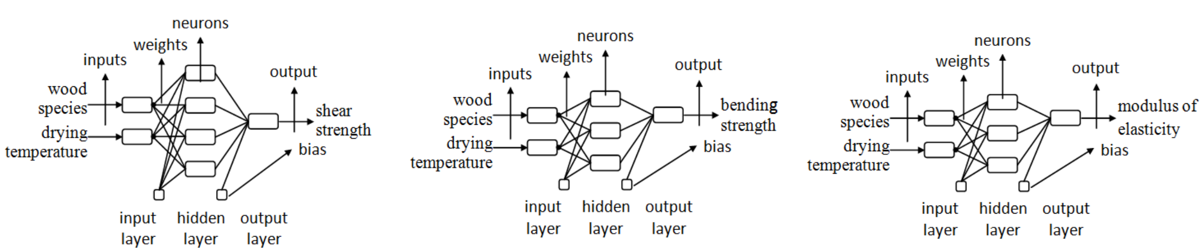

Figure 1: The ANN architecture selected as the prediction models

A feed forward and back propagation multilayer ANN was used for solving problems, and the network training and testing was carried out using the MATLAB software package. In this study, the hyperbolic tangent sigmoid function (tansig) and the linear transfer function (purelin) were used as the activation transfer functions, the levenberg marquardt algorithm (trainlm) was used as the training algorithm, the gradient descent with a momentum back propagation algorithm (traingdm) was used as the learning rule, and the mean square error (MSE) with Eq. 4 was used as the performance function.

$$\text{MSE} = \frac{1}{N}\sum_{i=1}^{N}(t_i - td_i)^2 \tag{4}$$

Where, t_i is the actual output (targeted values), td_i is the neural network output (predicted values), and N is the total number of training patterns.

To ensure an equal contribution of each parameter in the models, the training and test were normalized (-1, 1 range) due to the use of the hyperbolic tangent sigmoid function in the models and network, which allowed the data to be translated into the original value, with a reverse normalizing process for the interpretation of the results. The normalization (scaling) operations were carried out by using Eq. 5.

$$\text{X}_{\text{norm}} = 2 \times \frac{\text{X} - \text{X}_{\text{min}}}{\text{X}_{\text{max}} - \text{X}_{\text{min}}} - 1 \tag{5}$$

Where, X_{norm} is the normalized value of a variable X (real value of the variable), and X_{max} and X_{min} are the maximum and minimum values of X, respectively.

3 RESULTS AND DISCUSSION

3.1 Experimental Results

The shear strength, bending strength and modulus of elasticity values of plywood panels manufactured with UF glue were presented in Table 2, based on veneer wood species and veneer drying temperatures.

As can be seen from Table 2, the highest shear strength, bending strength and modulus of elasticity values were obtained experimentally from 170°C for Scots pine plywood, while 190°C drying temperature yielded the best shear strength, bending strength and modulus of elasticity values both for alder plywood.

3.2 Artificial Neural Network Results

Changes of shear strength, bending strength and modulus of elasticity depending on the veneer drying temperature were modelled with obtained network parameters. The amount of error variation depending on iteration of the selected ANN was shown in Figure 2.

Shear strength Bending strength Modulus of elasticity

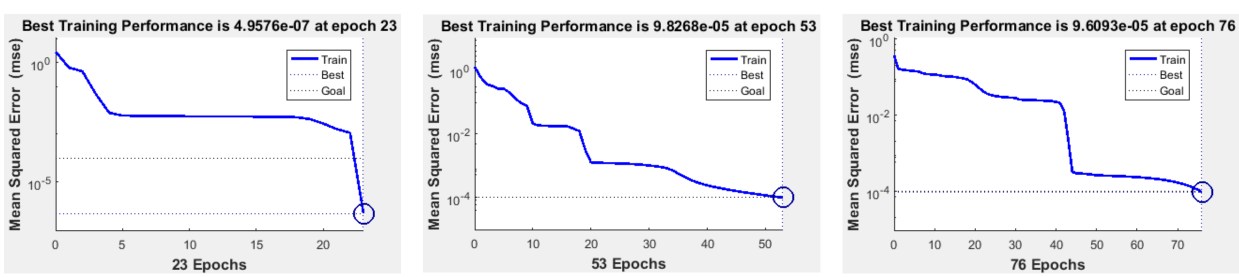

Figure 2: A plot of error variation depending on iteration of the ANNs

Figure 3 shows the relationship between the real values and calculated values obtained by the prediction models. The comparative plots of these values are given in Figure 4.

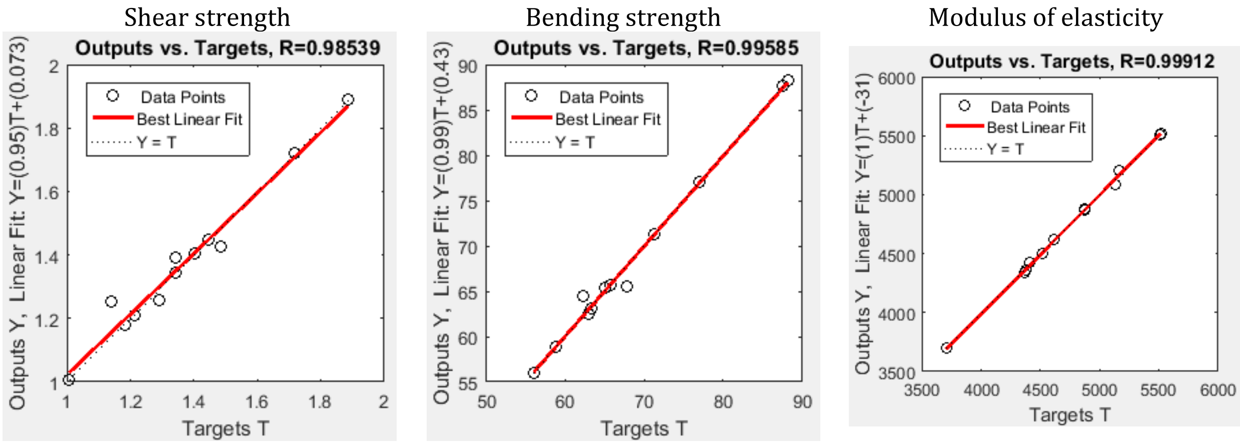

Figure 3: The relationship between experimental results and ANN predicted results

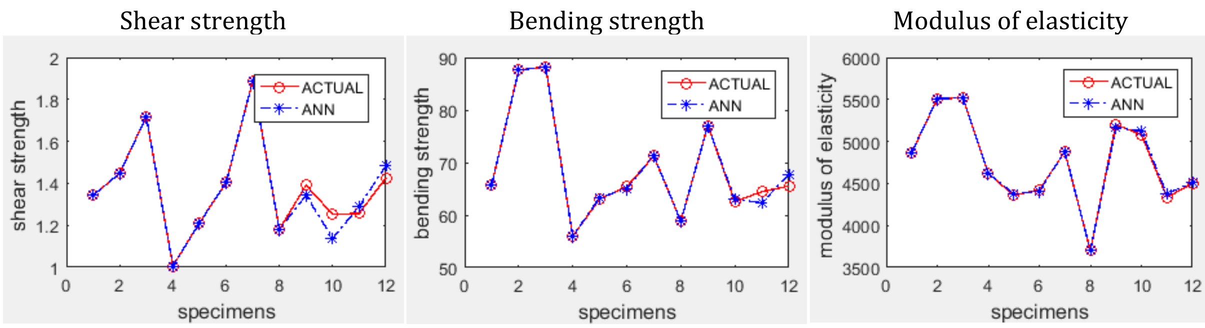

Figure 4: The comparison of the real and calculated values

In order to assess the validity of the networks and their accuracy, it is often useful to perform regression analysis between the network response and the corresponding target. The regression curves of the output variables for the experiment and ANN data set are shown in Figure 3 (shear strength, R = 0.98539; bending strength, R = 0.99585; modulus of elasticity, R = 0.99912). As the correlation coefficients approach 1, prediction accuracy increases and indicates good agreement between the experimental results and the models predication. This value supports the applicability of using ANNs in the present study.

Comparisons of the results between the outcomes of ANN modelling and experimental values for the shear strength, bending strength and modulus of elasticity values are plotted in Figure 4. The results of graphic comparisons showed similarities between the experimental study and the ANN models and supported the reliability of the models.

The results indicate a consistent agreement between the outcomes of the ANN modelling and the experimental results. MAPE was used to evaluate the performance of the proposed ANN in the prediction technique. The maximum absolute percentage errors (MAPE) for shear strength, bending strength and modulus of elasticity were 0.017, 0.145 and 0.110 % for training and 4.838%, 1.866% and 0.735 %for testing, respectively. These levels of error are satisfactory for the shear strength, bending strength and modulus of elasticity. As seen from the results, the ANN approach has a sufficient accuracy rate for the prediction of shear strength, bending strength and modulus of elasticity values of plywood.

The intermediate values not obtained from the experimental study for shear strength, bending strength and modulus of elasticity were predicted from the designed ANN modelling. The shear strength, bending strength and modulus of elasticity values predicted by the ANN models for different drying temperature are shown in Figure 5, 6 and 7.

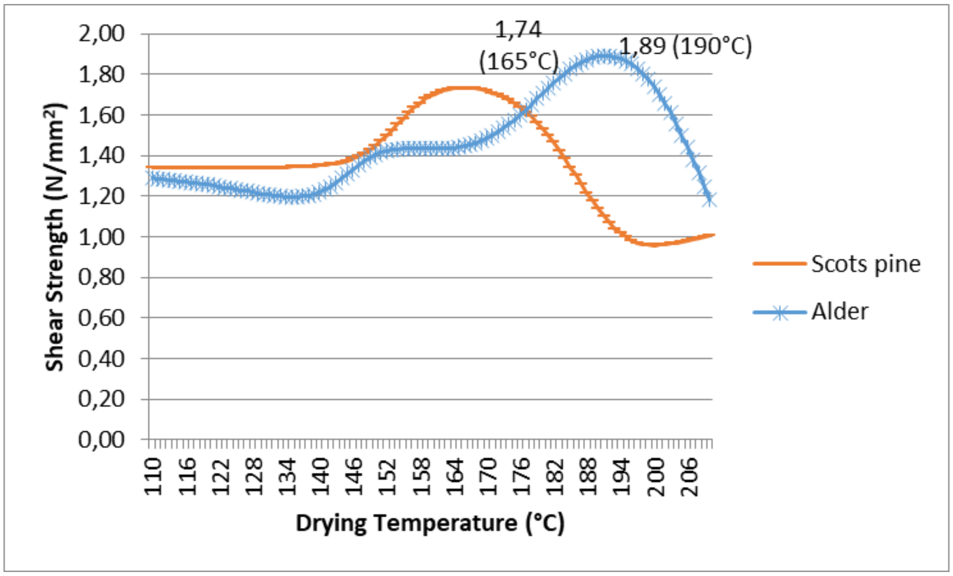

Figure 5: The change of shear strength with increasing drying temperature

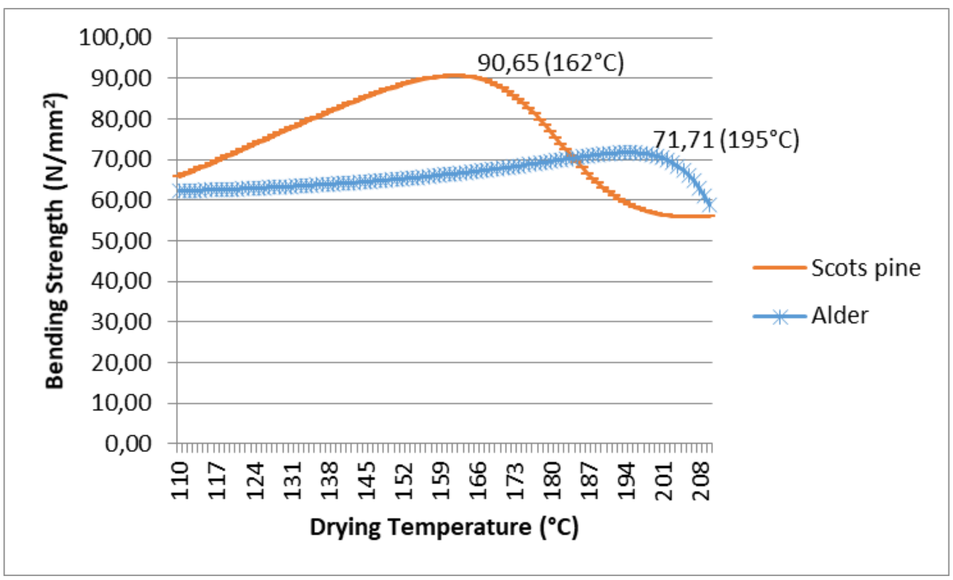

Figure 6: The change of bending strength with increasing drying temperature

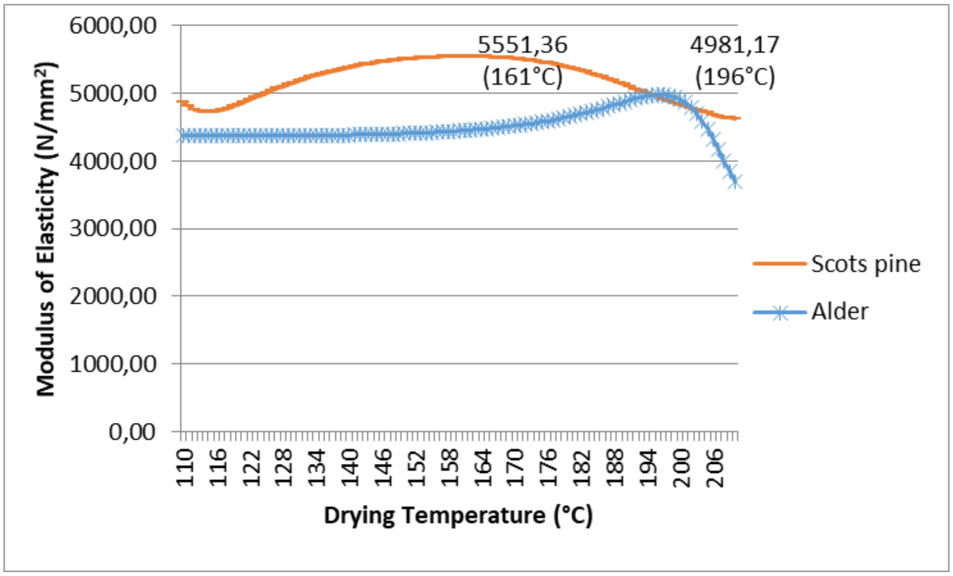

Figure 7: The change of modulus of elasticity with increasing drying temperature

According to Figure 5, 6 and 7, the optimum drying temperature values yielded the highest shear strength, bending strength and modulus of elasticity were found as 165, 162 and 161˚C for Scots pine and 190, 195 and 196˚C for alder, respectively. Plywood manufacturers prefer veneer to be dried at the highest possible temperature for a short time, without having the veneer degraded by excessive heat (Shen, 1958). Drying temperatures between 90-160°C are considered normal in veneer drying process, but the use of higher drying temperatures are giving rise to a reduction in drying time and increased capacity (FAO, 1990). On the other hand, high drying temperatures cause changes in the physical, mechanical and chemical characteristics of wood because of surface inactivation (Lehtinen et al., 1997; Sernek, 2002). In addition, veneer drying temperature affects the veneer-water relationships. Concerning this issue, Aydin (2014) studied the effects of veneer drying at high temperature on equilibrium moisture content, and reported that high temperature veneer drying caused a significant decrease in equilibrium moisture content values of plywood produced from beech, spruce and alder veneers. The water-absorbing capacity of veneer is reduced by increasing the drying temperature with a constant time, or by increasing the drying time at a constant temperature. The reduced water-absorbing capacity of the veneer could be a contributing factor in producing inferior glue bonds because of reduction in wettability of the veneer by the glue (Currier, 1958). It was also indicated in literature that, during a drying process, significant reduction in bonding ability occurs at the end of drying, when the evaporative cooling effect decreases and the wood surface temperature approaches that of the air in the dryer (Suchsland and Stevens, 1968). However, severe surface inactivation occurs at the drying temperature of 160°C and higher (Christiansen, 1990). According to the ANN models used in the present study, the decreases in mechanical strength values with increasing drying temperature has also been started from about 165-170°C for Scots pine and 195-200°C for alder (See Figure 5, 6 and 7).

Christiansen (1990) stated that surface inactivation is more prevalent in some wood species than in others and the highest safe drying temperatures for avoiding inactivation in wood varies with species. For example, southern pine was indicated to be the most susceptible species for inactivation, followed by ponderosa pine, then douglas-fir, western white pine and larch. Therefore, it can be considered normal that the optimum veneer drying temperature values (presenting the highest mechanical strength values) were different for Scots pine and alder plywood panels in the present study. Ozsahin and Aydin (2014) determined that the optimum drying temperature values yielded the highest bonding strength were obtained as 169˚C for urea formaldehyde and 125˚C for phenol formaldehyde adhesive in beech plywood while 162˚C for urea formaldehyde and 151˚C for phenol formaldehyde in spruce plywood panels. Demirkir et al. (2013) found that optimum veneer drying temperature ranges giving the highest bonding strength values were determined as 154 -160°C for panels with phenol formaldehyde. In this study, it was determined as 160-165°C for Scots pine plywood produced with urea formaldehyde. In a study conducted by Lehtinen (1998) on spruce plywood, it was also concluded that bending strength increased by 6.3–12% when the veneer drying temperature was increased from 110°C to 180°C.

At ANN design, some experimental results were used for training and some others were used for testing (Table 2). On the other hand, some data values for the Scots pine samples dried at 190°C was not available in training set. However, the strength values for this temperature was available for alder samples (Table 2). It was stated in literature that, ANNs are capable of processing information in a parallel distributed manner, learning complex cause and effect relationships between input and output data, dealing with nonlinear problems, generalizing from known tasks or examples to unknown tasks. ANNs are good for tasks involving incomplete data sets, fuzzy or incomplete information, and for highly complex and ill-defined problems for which humans would usually decide on an intuitional basis. Moreover, they can be more adaptable than traditional methods and ANNs technology brings completely different concepts to computing (Ceylan, 2008). As a consequence, the knowledge of the neural network is spread overall the links in network with their weight values. So, the lack of some data in a trained ANN does not significantly affect the network to produce accurate information.

4 CONCLUSIONS

Increased temperatures are being used in plywood industry to reduce the overall drying time and increase capacity because of the high cost of drying process. However, high drying temperatures can cause some drying related defects. In the manufacturing of plywood, veneers should be dried as quickly as possible with high temperatures without losing mechanical properties. The optimum veneer drying temperature gives the highest mechanical strength values of plywood can be different depending on the wood species from which the veneers manufactured. These types of experimental studies need much time and high testing cost. Therefore, ANN modelling method can be used as a predictive method to determine the appropriate drying conditions for best mechanical properties. In the present study, the optimum drying temperatures for Scots pine and alder veneers were predicted by ANN modelling for best mechanical properties by using experimental data. As a results, the optimum drying temperature values were obtained as 165, 162 and 161˚C in Scots pine plywood and 190, 195 and 196˚C in alder plywood, for best shear strength, bending strength and modulus of elasticity values, respectively. It can be concluded from this study that the ANN method is reasonable for the modelling (the optimization) of shear strength, bending strength and modulus of elasticity at various drying temperature without needing the experimental study again and again.

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ABSTRACT

In the present study, an artificial neural network (ANN) model was developed for modeling the effects of wood species, number of knives, feed rate and cutting depth on the surface roughness of wood processed with a planer. The required data for training and testing of the model were obtained from the experimental results of Demirci (2013). The ANN model having the best prediction performance was determined by means of statistical and graphical comparisons. When the experimental data were compared with the results obtained by ANN, it was shown that ANN is quite successful in predicting the surface roughness values of wood. Consequently, satisfactory results can be obtained by the ANN instead of conducting time-consuming and costly experimental activities.

KEYWORDS: Artificial neural networks, Surface roughness, Planing, Modeling

1 INTRODUCTION

Surface roughness is a significant factor in evaluating the quality of wood surfaces (Singer and Özşahin, 2018). It is defined as fine irregularities on a machined surface (Magoss, 2008). The surface roughness of wood and wood products can be assessed both quantitatively and qualitatively (Sofuoglu, 2015). Although several surface roughness measurement methods (laser, light sectioning, pneumatic, stylus, etc.) are available, there is no accepted standard method for determining the surface roughness of wood and wood products (Hiziroglu et al., 2013). The stylus method is commonly employed to measure surface irregularities (Tan et al., 2012). The height, width and shape of the peaks and valleys caused by the machining operations or the other factors can be measured to detect irregularities (Magoss, 2008).

Wood products are formed after various steps including sawing, planing, and sanding (Sofuoğlu and Kurtoğlu, 2015). The aesthetic value of the final product depends on its surface quality. The surface quality of machined wood is influenced by many factors related to wood properties and machining conditions. The important properties of wood are the wood species, density, moisture content and its anatomical properties. In the wood machining process, the cutting speed, tooth bite, dullness of knife, cutting angle and cutting direction are important process parameters influencing the outcome (**Csanády** et al., 2015). The evaluation of these factors is very significant to improve the surface quality of the final product. Otherwise, the surface roughness of wood influences the performances of finishing and gluing activities (Söğütlü et al., 2016).

The studies in the relevant literature mainly focused on evaluating the effects of various parameters on the surface roughness of wood (Efe et al., 2003; Malkoçoğlu, 2007; Usta et al., 2007; Aslan et al., 2008; Demirci, 2013; Sofuoğlu and Kurtoğlu, 2015; Rolleri et al., 2016). In the light of these studies, it can be said that the appropriate selection of machining conditions is significant to achieve better surface quality and to avoid undesired negative results. However, the extensive tests carried out for detecting the optimum values of process parameters give rise to high costs and the loss of much time and energy. The modeling can be employed to detect the suitable combinations of parameters in the woodworking process. Thus, the number of tests required for investigation of the effects of various parameters on the surface roughness of wood can be decreased. Moreover, the use of a modeling method can help to evaluate the performance of a machining process by carrying out less experimental activities. In recent years, artificial neural networks (ANNs), one of the most powerful modeling methods, have attracted the attention of many researchers due to their capability in modeling complex relations between variables (Joo et al., 2014). Several studies have focused on the ANN method to solve various problems in the field of wood science. Rojas-Espinoza and Ortíz-Iribarren (2010), Yildirim et al. (2011), Özşahin (2012), Demirkir et al. (2013), Ozsahin (2013), Tiryaki et al. (2014), Sofuoglu (2015), Akyüz et al. (2017), Tiryaki et al. (2017), and Ozsahin and Murat (2018) are some of these studies.

In the literature, the impacts of various parameters on the surface roughness of wood were discussed in detail. However, the number of studies regarding the prediction of the surface roughness of wood is quite limited. Therefore, the objectives of this study were to design an ANN model for predicting the effects of wood species, number of knives, feed rate and cutting depth on the surface roughness of wood, to examine the effects of the parameters on surface roughness, and to optimize the considered parameters by using the developed ANN model.

2 MATERIALS AND METHODS

2.1 Materials

The data used in this study were provided from a previous study by Demirci (2013). The experimental process carried out by the author can be explained as follows. Scots pine (*Pinus sylvestris* L.), Turkish beech (*Fagus orientalis* L.), walnut (*Juglans regia* L.), chestnut (*Castanea sativa* M.) and African mahogany (*Khaya sp.*), which were selected as materials of the experiments, were randomly supplied from the timber industries in Turkey. The samples prepared for the experiments were conditioned at a temperature of 20 ± 2 ^{o}C and 65 ± 3% relative humidity until they reached stable weight. The moisture content and density values of the wood species were determined according to TS 2470 (1976) and TS 2471 (1976). The samples with the moisture content of about 12% were planed at 1, 2 and 4 mm cutting depth, 5 and 9 m/min feed rate and using 2 and 4 knives. The surface roughness of each sample was measured by using a Mitutoyo Sj-301 device. The measuring range was 12.5 mm, the measuring speed was chosen as 0.25 mm/s, the diameter of the measurement needle was 5 μmR, and the stylus tip angle was 90^{o}. The surface roughness values were determined by a sensitivity of ± 0.01 μm. The scanning length (lt) was chosen as 12 mm; the sampling length was taken as 2.5 mm. Roughness average (R_a) was used to evaluate surface quality of the samples. The measurements were carried out according to TS 6956 (1989) and TS 930 (1989).

2.2 Artificial Neural Networks

The ANN is a powerful modeling tool capable of learning complex nonlinear and multivariable relationships between variables of systems or processes without the need of any assumptions (Choudhury et al., 2012; Özşahin, 2012). This technique is effectively employed to solve problems in many applications such as nonlinear function estimation, data sorting, pattern recognition, optimization, clustering, and simulation (Yadav and Chandel, 2014).

A feed-forward multilayer perceptron (MLP), which is the most commonly used network in applications, comprises one input layer, *t* hidden layer(s) and one output layer (Ouarda and Shu, 2009). The input layer collects the incoming data for the ANN and then passes these data to the hidden layer. The hidden layer is responsible for processing the information and for sending the processed information to the output layer. The output layer receives the information and generates output data (Canakci et al., 2012). A schematic illustration of a MLP architecture is shown in Figure 1.

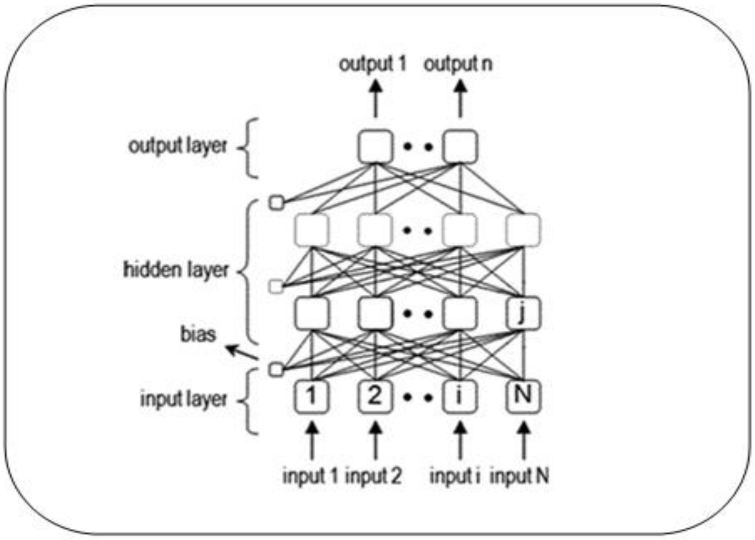

Figure 1: A schematic illustration of a MLP architecture

The layers of a neural network are composed of a series of processing elements (neurons). Each neuron in a layer is connected with each neuron in the next layer through communication links (connections). Each connection has a weight (w_{ij}) that determines the strength of the influence between the interconnected neurons (Özşahin, 2012). Any neuron in the network takes information (x_i) from all the neurons of the previous layer. It gathers information (net$_j$) weighted by factors corresponding to the connection and the bias (θ_j). Outputs (y_j) are calculated by applying a mathematical function (f(.)) to net$_j$. This process is formulated by Eqs. (1) and (2) (Ozsahin, 2013).

$$\text{net}_j = \sum_{i=1}^{n} x_i w_{ij} - \theta_j \tag{1}$$

$$y_j = f(\text{net}_j) \tag{2}$$

Training and testing are two main processing stages of ANNs. During the training process, the values of weights and biases are adjusted to minimize differences between observed and predicted values. In the testing phase, the network is checked with a dataset not previously utilized for the training process (Jalali-Heravi, 2008). Once the network is trained/learned, it can be used to predict the outcomes of different input sets (Yildirim et al., 2011).

2.3 Artificial Neural Networks Analysis

In this study, wood species, number of knives, feed rate and cutting depth were used as the input variables, while surface roughness was used as the output variable. The MATLAB software package was used for the training and optimization of ANNs. The data were obtained from the experimental results of Demirci (2013). To examine the effects of wood species, number of knives, feed rate and cutting depth on the surface roughness of wood, the experimental data were grouped into training, validation and testing data. Forty data (66.66% of total data) were used for the training of ANNs. The remaining twenty data points were equally divided for validation (16.67% of total data) and testing (16.67% of total data) processes. The data sets are shown in Table 1.

Table 1: Actual and predicted values of R_a and their percentage errors

Wood species	Number of knives	Feed Rate (m/min)	Cutting Depth (mm)	Mean R_a (µm)		
				Actual	Predicted	Error (%)
Scots pine	**2**	**5**	**1**	**3.55**	**3.44**	**3.22**
Scots pine	2	5	2	3.63	3.48	4.14
Scots pine	2	5	4	3.76	3.63	3.49
Scots pine	2	9	1	3.75	3.86	-2.88
Scots pine	***2***	***9***	***2***	***3.98***	***3.97***	***0.29***
Scots pine	2	9	4	3.99	4.28	-7.28
Scots pine	4	5	1	2.87	3.29	-14.51
Scots pine	4	5	2	3.19	3.32	-3.97
Scots pine	**4**	**5**	**4**	**3.64**	**3.47**	**4.69**
Scots pine	4	9	1	3.04	3.29	-8.37
Scots pine	***4***	***9***	***2***	***3.53***	***3.33***	***5.65***
Scots pine	4	9	4	3.74	3.51	6.02
Turkish beech	2	5	1	3.87	3.92	-1.28
Turkish beech	2	5	2	4.19	4.10	2.16
Turkish beech	***2***	***5***	***4***	***5.08***	***4.74***	***6.69***
Turkish beech	**2**	**9**	**1**	**4.67**	**5.02**	**-7.55**
Turkish beech	2	9	2	5.61	5.31	5.37
Turkish beech	2	9	4	6.31	6.09	3.48
Turkish beech	4	5	1	3.55	3.48	1.84
Turkish beech	***4***	***5***	***2***	***3.96***	***3.67***	***7.30***
Turkish beech	4	5	4	4.02	4.50	-11.85
Turkish beech	4	9	1	4.07	3.53	13.18
Turkish beech	4	9	2	4.30	3.76	12.65
Turkish beech	**4**	**9**	**4**	**4.98**	**4.70**	**5.65**
Walnut	2	5	1	5.35	5.44	-1.59
Walnut	**2**	**5**	**2**	**5.56**	**5.97**	**-7.37**
Walnut	2	5	4	6.56	6.73	-2.59
Walnut	2	9	1	6.72	6.90	-2.63
Walnut	2	9	2	7.13	7.24	-1.56
Walnut	***2***	***9***	***4***	***6.80***	***7.32***	***-7.59***
Walnut	**4**	**5**	**1**	**3.72**	**4.57**	**-22.77**
Walnut	4	5	2	5.82	5.23	10.11
Walnut	4	5	4	6.08	6.10	-0.32
Walnut	4	9	1	4.15	4.77	-15.05
Walnut	***4***	***9***	***2***	***6.71***	***5.42***	***19.17***
Walnut	4	9	4	6.71	6.80	-1.39
Chestnut	2	5	1	7.49	7.15	4.53
Chestnut	2	5	2	6.16	6.35	-3.01
Chestnut	***2***	***5***	***4***	***6.62***	***6.09***	***8.00***
Chestnut	2	9	1	7.57	7.51	0.79

Chestnut	**2**	**9**	**2**	**6.32**	**6.45**	**-2.09**
Chestnut	2	9	4	6.57	6.60	-0.39
Chestnut	***4***	***5***	***1***	***6.48***	***6.29***	***2.95***
Chestnut	4	5	2	9.77	9.78	-0.12
Chestnut	4	5	4	5.21	5.26	-0.87
Chestnut	**4**	**9**	**1**	**6.55**	**7.20**	**-9.96**
Chestnut	4	9	2	8.81	8.82	-0.13
Chestnut	4	9	4	6.09	6.06	0.42
African Mahogany	**2**	**5**	**1**	**5.83**	**5.71**	**2.09**
African Mahogany	2	5	2	7.19	7.18	0.09
African Mahogany	2	5	4	8.32	8.33	-0.06
African Mahogany	2	9	1	7.97	7.97	0.05
African Mahogany	2	9	2	10.01	9.99	0.25
African Mahogany	***2***	***9***	***4***	***7.99***	***8.70***	***-8.83***
African Mahogany	4	5	1	5.56	5.58	-0.37
African Mahogany	**4**	**5**	**2**	**6.86**	**6.98**	**-1.75**
African Mahogany	4	5	4	7.18	7.31	-1.82
African Mahogany	4	9	1	6.35	6.28	1.14
African Mahogany	4	9	2	7.22	7.11	1.51
African Mahogany	***4***	***9***	***4***	***7.81***	***7.32***	***6.25***
			MAPE	3.83	RMSE	0.25
			MAPE	**6.71**	**RMSE**	**0.40**
			MAPE	***7.27***	***RMSE***	***0.57***

Note: Bold values: validation data, bold italic values: testing data, the other values: training data

The determination of the optimal network architecture is one of the most important tasks (Kalteh, 2013). The training was performed to establish models with different configurations and learning parameters. To determine the performance of the networks, the models were checked using the test data which were not used for the training process. As a result, the model presented in Figure 2 was chosen as the optimal architecture of the network. As seen in Figure 2, the network consists of one input layer, two hidden layers and one output layer. The neuron numbers in the hidden layers are, in order, two and six. The first and fourth layers include the input variables (wood species, number of knives, feed rate and cutting depth) and the output variable (surface roughness), respectively.

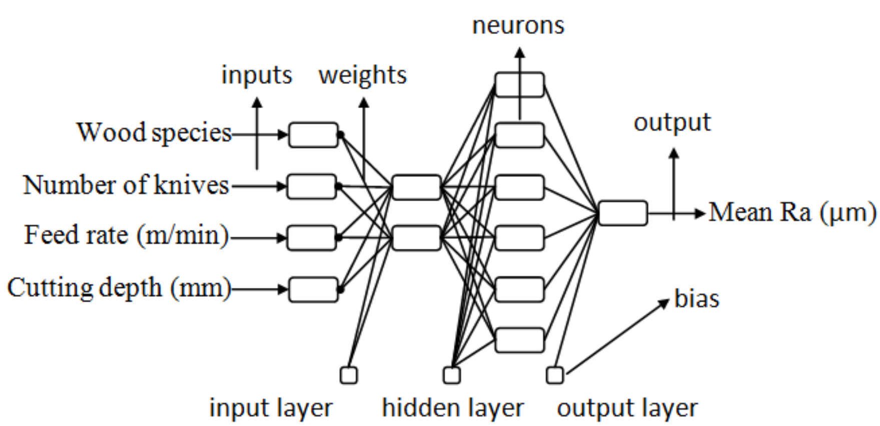

Figure 2: The proposed network architecture for surface roughness

The data were normalized within a range of -1 to 1. A feed-forward and back-propagation multilayer ANN was preferred to solve the problem. The activation functions were the hyperbolic tangent sigmoid function (tansig) and the linear transfer function (purelin) in the hidden layers and the output layer, respectively. The Levenberg–Marquardt algorithm (trainlm) was used as the training algorithm. The learning rule was the gradient descent with a momentum back propagation algorithm (traingdm). The mean square error (MSE) given in Eq. (3) was used as the performance function. Table 2 shows the connection weights and biases of the model.

$$\mathrm{MSE} = \frac{1}{N}\sum_{i=1}^{N}(t_i - td_i)^2 \tag{3}$$

where t_i is the actual output, td_i is the ANN output, and N is the total number of measurements.

Table 2: Connection weights and biases of the model

Hidden layer 1			**Hidden layer 2**							**Output layer**	
neuron1	**neuron2**	**bias1**	**neuron1**	**neuron2**	**neuron3**	**neuron4**	**neuron5**	**neuron6**	**bias2**	**neuron1**	**bias3**
1.88185	-1.26010	-1.15675	-4.11941	-2.91902	5.50453	3.52141	5.34490	-3.26998	2.88436	-1.02140	0.04173
0.17571	2.36919	2.57184	-1.86529	2.56244	1.43092	0.46874	1.91734	0.68971	2.85664	-1.16294	
0.04829	-0.33033								-0.99265	-2.05700	
0.45313	-0.12315								1.91330	-0.54355	
									-0.20828	1.42953	
									-4.07675	-1.52037	

The prediction ability of the model was evaluated using the following indicators: the root mean square error (RMSE), the mean absolute percentage error (MAPE), and coefficients of determination (R^2). The RMSE, MAPE and R^2 values were calculated using Eqs. (4) - (6), respectively. The lower error values represent the more accurate estimation results. The higher R^2 values imply a high similarity between targeted and predicted outputs.

$$\mathrm{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(t_i - td_i)^2} \tag{4}$$

$$\mathrm{MAPE} = \frac{1}{N}\left(\sum_{i=1}^{N}\left[\left|\frac{t_i - td_i}{t_i}\right|\right]\right) \times 100 \tag{5}$$

$$R^2 = 1 - \frac{\sum_{i=1}^{N}(t_i - td_i)^2}{\sum_{i=1}^{N}(t_i - \bar{t})^2} \tag{6}$$

where $\bar{t}$ is the average of predicted outputs.

3 RESULTS AND DISCUSSION

An ANN model was developed for modeling the effects of wood species, number of knives, feed rate and cutting depth on the surface roughness of wood processed with a planer. The network architecture of the prediction model has one input layer with four neurons, two hidden layers with two and six neurons and one output layer with one neuron. The ANN was trained, validated and tested with the help of 60 data. The performance function reached the minimum value (0.012581) at the end of 42 epochs. The error variation depending on the iteration of the ANN can be seen from the graphic in Figure 3.

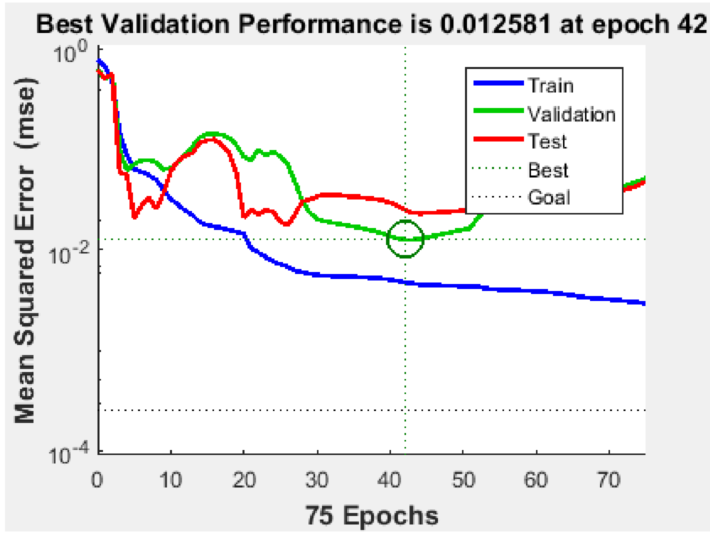

Figure 3: The training, validation and testing errors versus number of epochs

Graphical and statistical comparisons were used to evaluate the performance of the prediction model. The predicted outputs, the measured values, the percentage errors, and the MAPE and RMSE values are given in Table 1. When the table is examined, it can be seen that the ANN outputs are very close to the actual outputs.

As stated previously, MAPE, RMSE and R^2 were computed to evaluate the prediction capability of the model. The MAPE values are 3.83% for the training data, 6.71% for the validation data and 7.27% for the testing data. Furthermore, the RMSE values are 0.25%, 0.40% and 0.57% for the training, validation and testing data, respectively. The statistical results, namely MAPE and RMSE, are within an acceptable range. The regression curves demonstrating the power of similarity between the real values and the ANN outputs are presented in Figure 4 (R=0.99116 for training, R=0.96033 for validation and R=0.95063 for testing). The R^2 values were found as 0.982, 0.922 and 0.904 for the training, validation and testing data, respectively. The low values of MAPE and RMSE and the high values of R^2 have indicated that ANNs are highly suitable to model the surface roughness of wood.

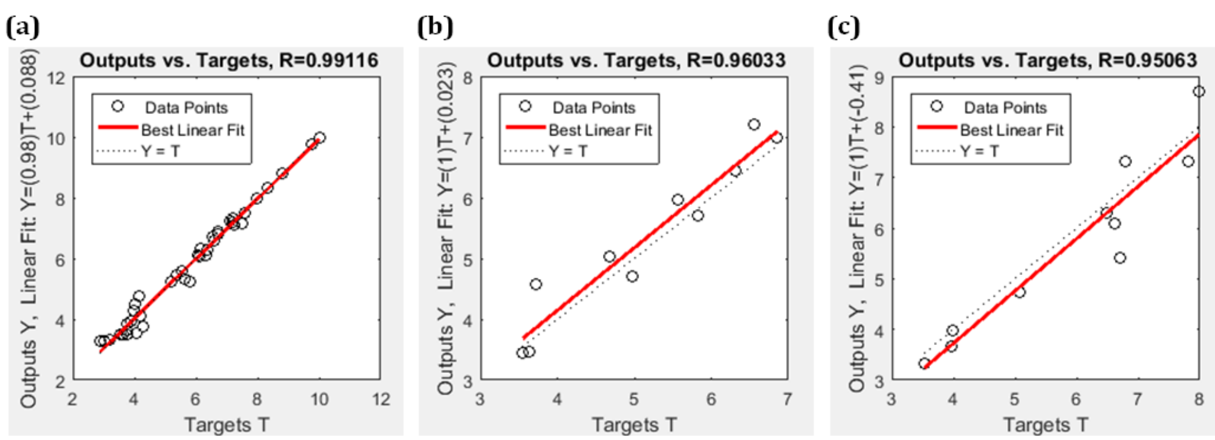

Figure 4: Relationship between the network responses and the real values for surface roughness: (a) training, (b) validation and (c) testing

The comparisons of the actual and predicted values are presented graphically in Figures 5, 6 and 7. As seen in these figures, the surface roughness values predicted by ANNs are very close to the actual values. The results of the comparison plots supported the reliability of the proposed model.

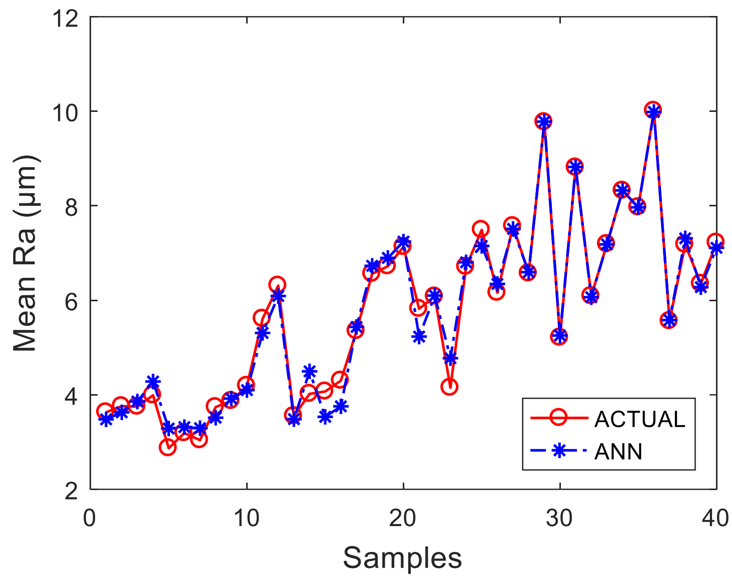

Figure 5: The comparison of the measured and predicted values for the training set

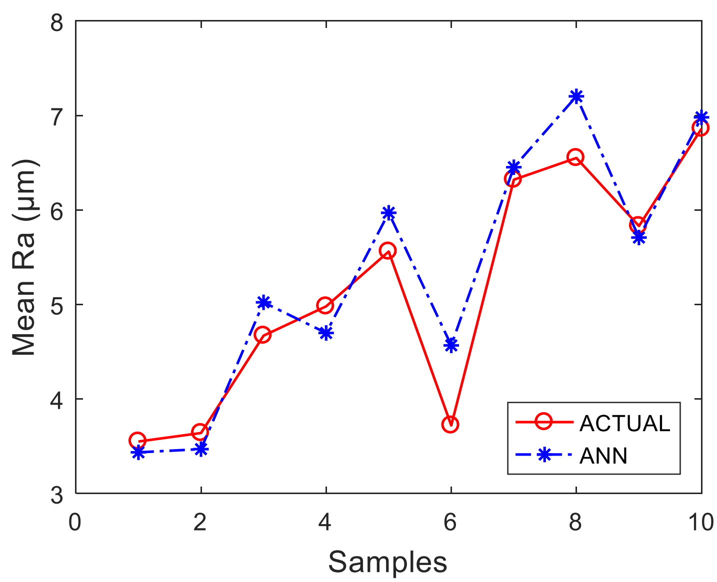

Figure 6: The comparison of the measured and predicted values for the validation set

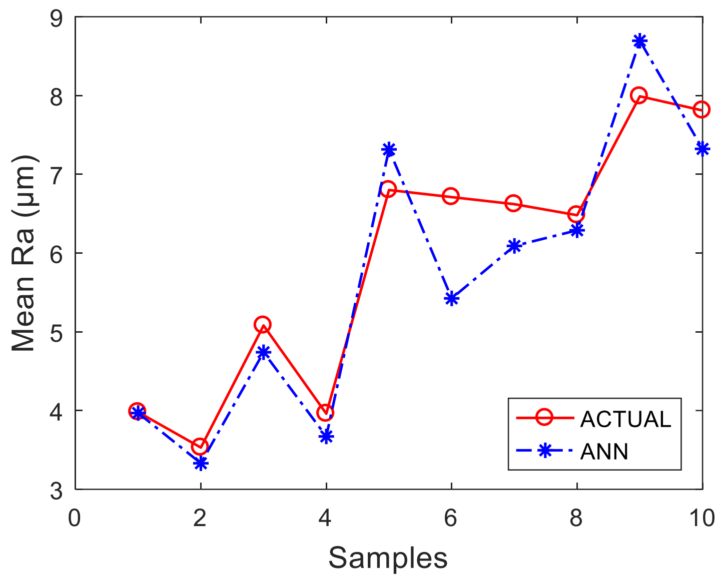

Figure 7: The comparison of the measured and predicted values for the testing set

The trained ANN models can calculate all intermediate values for the optimization studies. In this study, wood species and number of knives were fixed as Scots pine and 2, respectively, and the effect of cutting depth (mm) and feed rate (m/min) on surface roughness was predicted. Furthermore, in another trial, wood species and number of knives were fixed as walnut and 3, respectively, and cutting depth (mm) and feed rate (m/min) were changed. The intermediate R_a values not provided from the experimental study were determined for different cutting depths and feed rates by the ANN model, and are presented in Figures 8 and 9. The optimization of R_a values based on cutting depths and feed rates can be performed via an analysis of responses of the prediction model. According to Figures 8 and 9, the surface roughness of wood decreases with the decreasing feed rate and cutting depth. Similar results were reported by several researchers (Stumbo, 1960; Efe et al., 2003; Usta et al., 2007; Tiryaki et al., 2014).

Figure 8: The effect of cutting depth and feed rate on the surface roughness of Scots pine wood

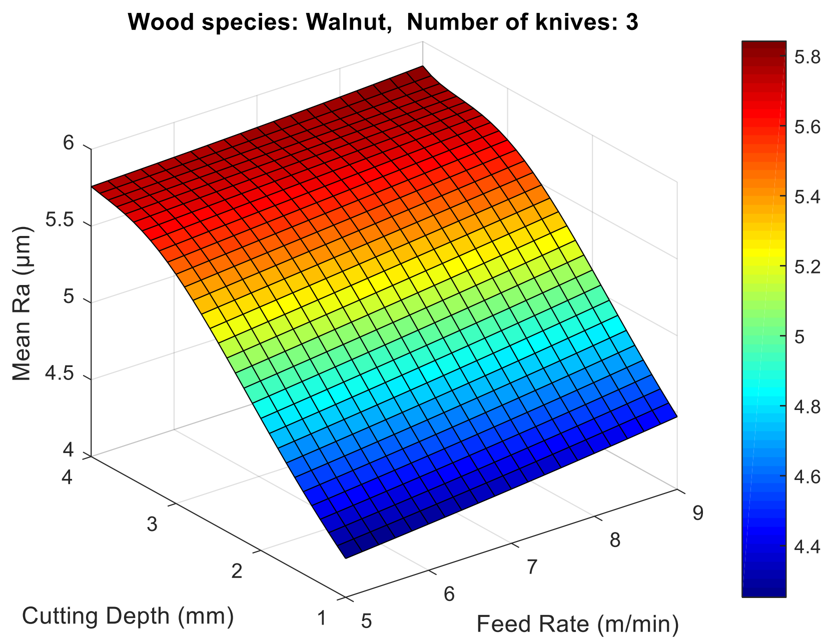

Figure 9: The effect of cutting depth and feed rate on the surface roughness of walnut wood

The determination of optimal machining parameters is very significant to achieve better surface quality and to remain more competitive in the market (Gowd et al., 2014). In this perspective, the present optimization study provides useful information to improve the surface quality of machined wood. Furthermore, the prediction model enabled us to better understand how different processing conditions influence the surface roughness of wood.

4 CONCLUSION

In this study, the effects of wood species, number of knives, feed rate and cutting depth on the surface roughness of wood in the planing process were modeled by ANNs. To examine the effects of the parameters, a multilayer neural network was devised based on the experimental data of Demirci (2013).

The results of this study indicated that the ANN is highly appropriate to predict the surface roughness values of wood under given conditions. The surface roughness values predicted by the model showed similarity with the values measured experimentally. In the ANN analysis, the MAPE, RMSE and R^2 values were found as 7.27%, 0.57% and 0.904 for the testing phase, respectively. When the complexity of the relations between the variables is considered, it can be said that the results are highly satisfactory.

The surface roughness values corresponding to the intermediate values of the machining parameters that were not considered in the experimental process were predicted by the ANN model. It was observed that the surface roughness of wood increases with an increase in feed rate and cutting depth.

In the study, the well-trained ANN model has been proved to be a successful tool for modeling the surface roughness of wood. The results of the research indicated that satisfactory results can be obtained by ANNs instead of conducting time-consuming and costly experimental activities.

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Colour in Thermally Modified Wood of Pine, Ash and Spruce

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ABSTRACT

The effect of high temperature on colour of pine (*Pinus sylvestris* L.), ash (*Fraxinus americana*) and spruce (*Picea abies*) wood species were investigated in this study. For this purpose, wood species were treated with heat by using ThermoWood method at temperatures 190 and 212 °C for 1.5-2 hours, respectively. The results show that increasing heat treatment temperature caused dark colour on the samples compared with untreated ones. Heat treatment changes physical properties of wood species. So, it becomes available for outdoor application. Among these physical properties colour is important for industry especially decorative purposes.

KEYWORDS: Colour, Heat-treatment, Thermowood, Physical properties.

1 INTRODUCTION

Wood material is a material which has excellent properties such as easy-workability, aesthetic appearance, a renewable and sustainable natural material when compared to other materials. However; as an organic material, wood is susceptible against to several environmental factors such as water, light, heat and microorganisms. For using wood at outdoor application, it is necessary to protect it with some modification methods. The chemical treatments are the most widely used methods for wood preservation however, by the increasing environmental awareness some preservatives which have high toxicity have been prohibited in many countries. The heat treatment has been accepted as an alternative preservation method both to improve the properties of wood and environmental friendly (Esteves and Pereira, 2008).

During the thermal modification, the wood species are heated slowly up to 180–230°C in protective vapor (Finnish Thermo Wood Handbook, 2003). By heat treatment, the hydrophilic structure of the wood is changed by modifying the chemical structure of some wood components (Raimo et al. 1996:142). By the effect of heat treatment, water intake to the interior of the wood is prevented and acquired resistance against decay. Because wood material consists of three main components, which are cellulose, lignin and hemicelluloses. Hemicelluloses are the main subscriber to the hygroscopicity of fibers. By the heat treatment hydroxyl groups are replaced by hydrophobic O-acetyl groups (Kocaefe et al. 2008). Due to degradation of hemicelluloses density values are diminish. Therefore, the lignin percentage increase in heat treated wood comparing normal wood (Tjeedsma et al., 1998) and wood colour is getting darker.

The new properties of the treated material present several interesting aspects for exterior and interior applications. Therefore, the thermal modification can be taken account of a sustainable expedience to add value to wood. Heat-treated wood represents desirable darken colour (Johansson, 2008:148; Mohebby and Sanaei, 2005).

In this study, the influence of thermal treatment temperature on colour property which is important for user and outdoor application resistance of ash, pine and spruce wood species was investigated.

2 MATERIAL AND METHOD

2.1 Wood Species

In this study, Ash (*Fraxinus americana*), Spruce (*Picea abies*) and Yellow Pine (*Pinus slyvestris* L.) species, which find a significant use in trade, have been used. Heat treated by ThermoWood method and untreated Ash and Yellow Pine timbers were supplied from the Novawood in Gerede, Bolu. In addition, attention has been paid to the fact that lumber is perfect, that there is no reaction wood, and that it has not been damaged by fungi and insects. Both tree species were heat treated at 190 and 212 ° C for 1.5 and 2 hours, respectively.

2.2 Heat Treatmet

Heat treatment by ThermoWood method takes place in three stages;

Increasing the temperature and drying at high temperature: Using the heat and water vapor, the oven temperature is quickly increased to 100 ° C and then raised to 130 ° C, during this time the high temperature drying is performed and the moisture in the wood is tried to be reduced to almost zero level.

Heat treatment: After high temperature drying, the temperature in the oven is raised from 185 ° C to 212 ° C. When the desired temperature is reached, this temperature is maintained for 2 - 3 hours depending on the usage of the material.

Cooling and conditioning: At the final stage, temperature is lowered by water spraying. When the temperature reaches 80-90ºC, the wood material is re-moistened to bring the moisture content to a level of 4-7%.

2.3 Colour Measurement

The colors of samples were measured by an 8 mm in diameter with 10° observer angle using with a spectrophotometer according to the CIE L* a* b* system to express the color change (Figure 1).

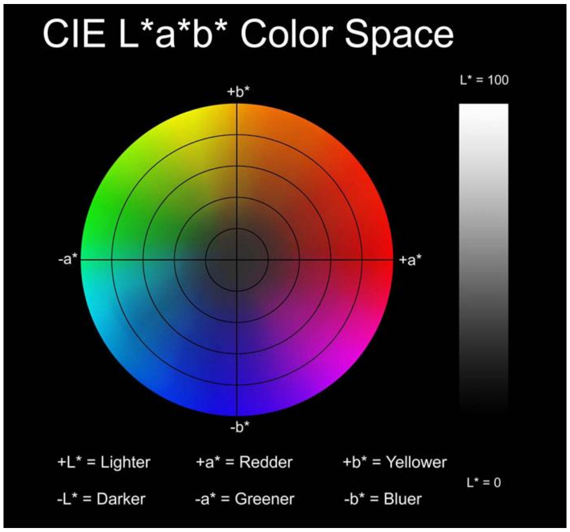


Figure 1: CIE Lab colour space: L is always positive and represents lightness; a> 0 represents red component, a<0 represents green component; b>0 represents yellow component, b<0 represents blue component.

The measurements were recorded at the same points on surface of each sample before and after varnishing. Initially, to determine the effect of heat treatment on colour change, before and after heat treatment the colour of samples was measured. Measurement of the total colour change, the equation 1 was used,

$$\Delta L^{*}= L_{ut}-L_{ht} \quad (1)$$

$$\Delta a^{*}=a_{ut}-a_{ht} \quad (2)$$

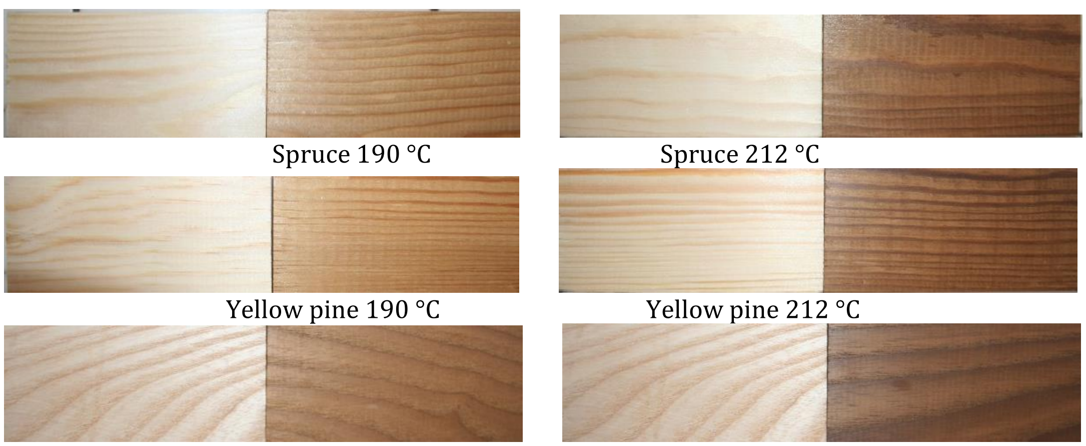
$$\Delta b^{*}=b_{ut}-b_{ht} \quad (3)$$

$$\Delta E^{*}= \sqrt{\Delta L^{*2}+\Delta a^{*2}+\Delta b^{*2}} \quad (4)$$

where ΔE* is total colour change; ΔL* is lightness difference, Lut/ht is untreated/heat treated lightness; Δa* is green/red coloration difference; aut/ht is untreated/heat treated green/red coloration; Δb* is yellow/blue coloration difference; b ut/ht is untreated/heat treated yellow/blue coloration.

3 RESULTS AND DISCUSSION

Heat-treatment at increasing temperature causes a darker and more brownish colour on wood which is desirable for the last user but with heat treatment the wood becomes more susceptible to ultra-violet radiation. To protect of wood surface becomes a necessity with coatings, paints and varnishes. In figure 2 it is obvious that the heat treatment causes darken colour on wood samples especially ash wood samples.



Spruce 190 °C Spruce 212 °C

Yellow pine 190 °C Yellow pine 212 °C

Ash 190 °C Ash 212 °C

Figure 2: The colour change caused by heat treatment process on wood samples

Table 1 shows the changes of L*, a*, b*, and E* according to the temperature of treatment. While the positive valuse in ΔL* indicates that the samples become darker, negative values of Δa* and Δb* indicate a tendency of wood surface to become red hue and yellow hue.

Table 1: Colour change caused by heat treatment

Wood Species	Treatment Temperature (˚C)	ΔL	Δa	Δb	ΔE
Ash	190	23,96	-3,01	-6,98	25,16
	212	37,18	-2,47	4,32	37,54
Spruce	190	20,2	-4,57	-7,05	21,96

	212	34,06	-6,08	-5,31	35,14
Pine	190	20,08	-3,76	-0,55	21,21
	212	30,87	-4,42	-2,5	31,81

It is obvious in the figure 3 that with the increasing treatment temperature, total colour change values increased. This means the wood samples were darker than the untreated samples. In literature, there are several studies which obtained similar results (Bekhta and Niemz,2003). Thermal treatment makes wood more brownish and it is a desirable property by user and industry.

This darkening in the colour may be due to degradation of hemicelluloses therewith an increase in percentage of lignin (Kamdem et al., 2002: 3).

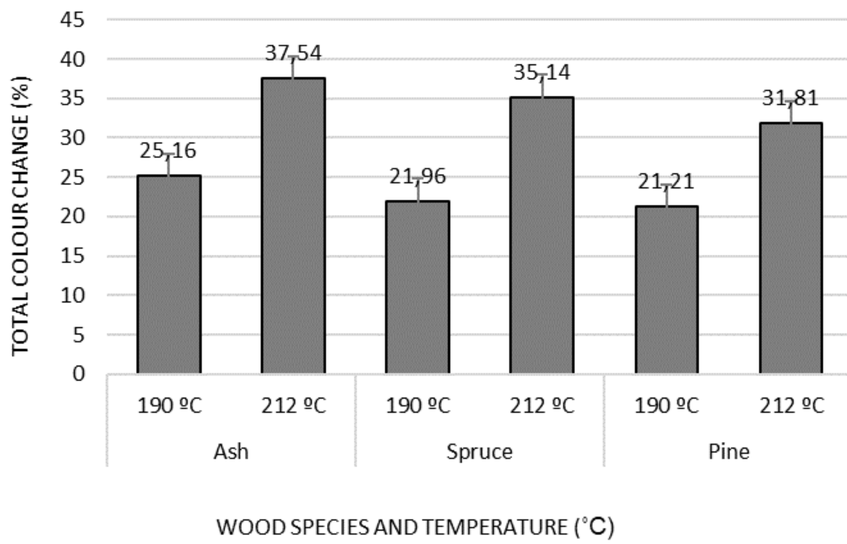


Figure 3: Total colour change caused by heat treatment process

The maximum total colour change caused by the heat treatment took place in ash wood at temperature 212°C. The colour of pine wood samples which were treated at 190°C were affected less from heat-treatment. Total colour changes of heat treated wood samples at 190°C were visibly less than the total colour change in the heat-treated wood samples at temperature 212°C.

4 CONCLUSION

Heat treatment at high temperature changed the colour of wood samples clearly. It is obvious that the colour of wood became darker when the positive ΔL^* values of samples are examined. Some reactions such as oxidative and/or hydrolytic discolouring reaction causes the colour change during heat treatment. This discolouration is mostly a desirable property for in service life of wood material.

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Costing Practices with Industry 4.0 Approach

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ABSTRACT

The costing practices in industrial enterprises are not yet achieved at the desired levels. It is known that some certain factors incur the expenses of all processes that are effective in the emergence of a product and that these expenses have effects on the parts that form the product in different rates. In other words, the statements of cost and profit planned by the manager does not coincide with the figures occurred at the end of the period. Businesses generally defines the difference between the planned and actual statements as an invisible expense. In fact, this creates an unavoidable situation for businesses which is expressed as the forced acceptance of these uncertainties. One of the biggest financial error that arises as a result of this is that the cost of a product does not reflect its real value and accordingly the profitability ratios cannot be estimated correctly.

The prevention of the financial losses resulting from the inability to calculate unforeseen expenses goes through the accurate reflection of all the factors that affect the cost of a product. The key factor underlying this is the requirement of quickly gathering and processing the clear data from all the variables in the production areas and external factors under a single source (big data). In order this to happen, a smart costing system must be established. The "Industry 4.0" concept, which has been widely spoken recently and is referred to as the 4th Industrial Revolution, has put the smart factories on the agenda. In this way, Industry 4.0 and smart factories will allow businesses to eliminate all the disadvantages mentioned above.

Within the framework of this academic research, the radical changes that Industry 4.0 approach will bring about in product costing are explained by sectoral examples.

KEYWORDS: Industry 4.0, Smart Costing, Smart Factories, Forest Products Industry

1 INDUSTRY 4.0 CONCEPT

Manufacturing industry has a huge importance for national economy with providing employment, and generating finished and semi-finished goods. Therefore, renewal and development in industry is a necessity to be effective in international competition. The development of the manufacturing industry is a result of the revolutionary differentiations occurred until 21st century, and it has evolved to the present day.

The rapidly developing industry in the world is following the technology closely and is moving towards a rapid digital transformation. Developments such as robotic production models, object detection systems, cloud technologies, collecting data network in a single centre, 3D printers, and the ability of each object to communicate through the internet with the strengthening of IT and integrating these systems to the industry and this transformation in all processes is called Industry 4.0.

There exist factors that affect all kinds of companies in all sizes in Turkish economy. In cases where these processes are not properly managed, execution of the operations is difficult. For this reason, the integration of industrial enterprises into industry 4.0 has great importance (Fırat, 2016).

The rapid digitalization of the world, and the development of information technologies (IT) affect socio-economic life in all aspects. As a result of the rapid development and use of IT in international trade, the variability of market demands also complicates the control of complex production processes. The industry needs to maintain an innovative approach to survive in this competitive environment and to increase revenue. The integration of IT and robotic control mechanisms with each other, the collection of all data in a center, and for it to be available when it needs to be processed are elements of the Industry 4.0 concept (Tuncel, 2017).

2 COST ANALYSIS IN MANUFACTURING ENTERPRISES

There are two basic elements of superiority in competition between countries. These are cost and technological differences (Bashimov, 2017).

The reason for the differentiation in the price of the product at the end of the process in the enterprises with the same raw material inputs is the efficient operation of the enterprise and the ability to use scarce resources in the best way. Hence, it is important to note that all these resources are accurately reflected on the product when pricing. In addition, new technologies used in the machinery, workflow, and production process will reduce the costs to the extent that it minimizes the use of time and energy.

2.1 The Logic of the Costing System

It is observed that the majority of SMEs in Turkey do not have a systematic costing. In general, the logic of cost systematics is based on raw material inputs. In this systematic, expenses are reflected as directly and indirectly. When raw material expense and computable labor are directly reflected; overhead expenses, indirect labor etc. is reflected as a percentage of computational labor. In addition, in some enterprises direct labor (computable labor) is reflected due to the expense of raw materials. Therefore, this type of calculation method does not reflect the reality causes high profitability or damage.

2.2 Current Costing Practices in Forest Products Industry

Turkey has problems at the point of determining the cost in furniture industry (Aras, 2007). The reasons for this can be shown as lack of information, shortage of qualified personnel etc. Due to the reasons mentioned above, the actual cost cannot be calculated in the furniture sector before the product is produced.

There are many factors affecting the cost of furniture industry. Proximity to raw materials, insufficiency of production materials, price increases, and wastage rates affect negatively the costs. These negative factors bring some problems in marketing. There is a shortage of qualified personnel in the furniture industry. This is especially common in SMEs. This affects the quality standards of the products produced (İnal&Toksarı, 2006). This situation leads to loss of customers and financial damage.

Today, companies at a global level face tough competition. So there is a serious pressure to increase efficiency and to ensure low production costs. Activity-Based Costing (ABC) Method seems as a good method to be able to make more accurate costing. Because the ABC system performs the identification and analysis of each workstation. Thus, the cost will be more objective (Almedia&Cunha, 2017).

The flow chart of ABC method is given in detail in Figure 1. According to this, the sources in ABC method, their management, cost management with activities and industrial costing components are given to the sub-headings.

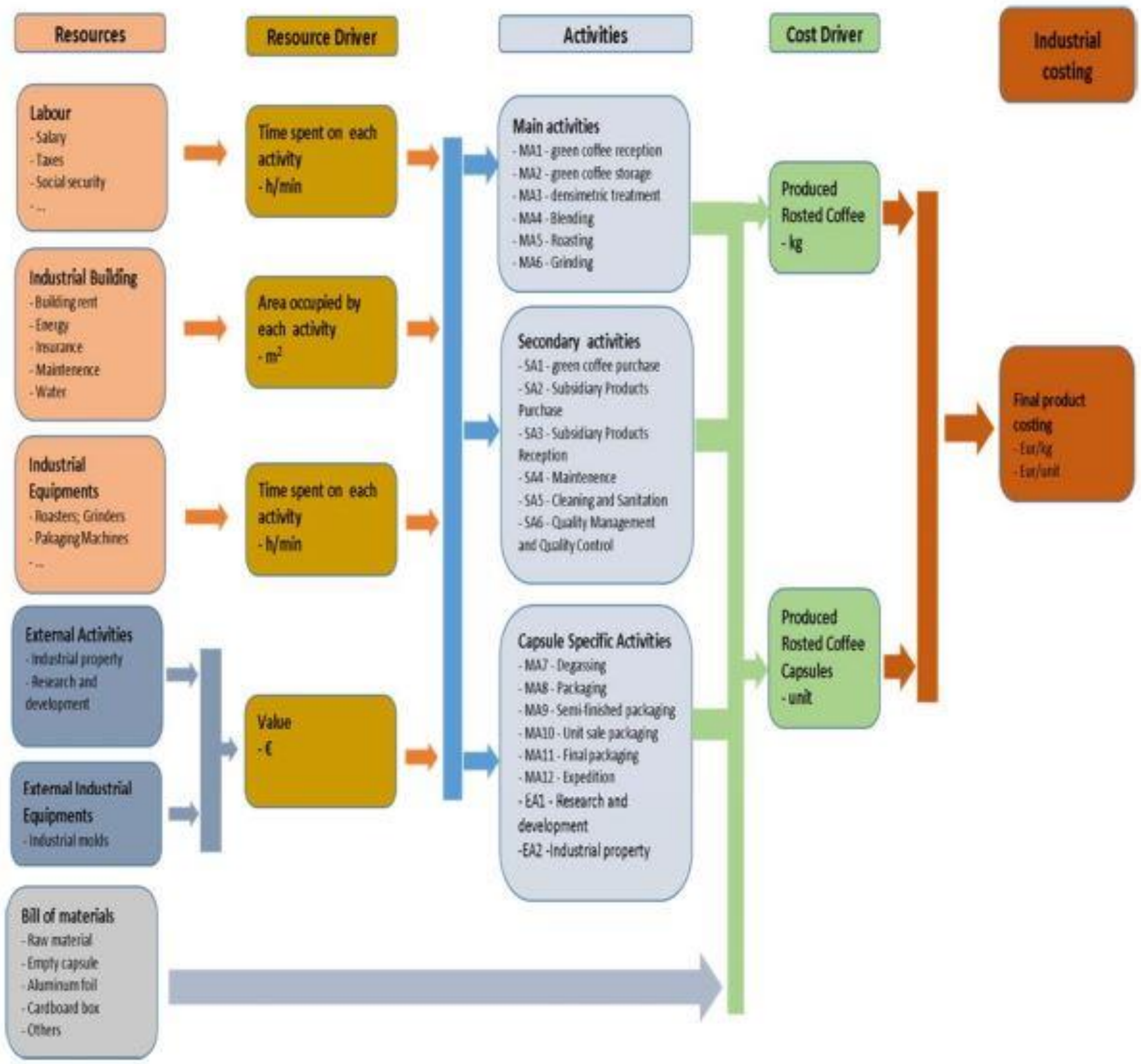

Figure 1: ABC Flow Chart (Almeida&Cunha, 2017)

Tanrıtanır, the processes related to the products determined in an enterprise which produce small scale panel furniture were modeled (2004). In order to calculate the costs of these products, job descriptions were made and production times were determined. As a result of the simulation made by using all these data, the cost of operations with the FTM method related to the product/products has been calculated.

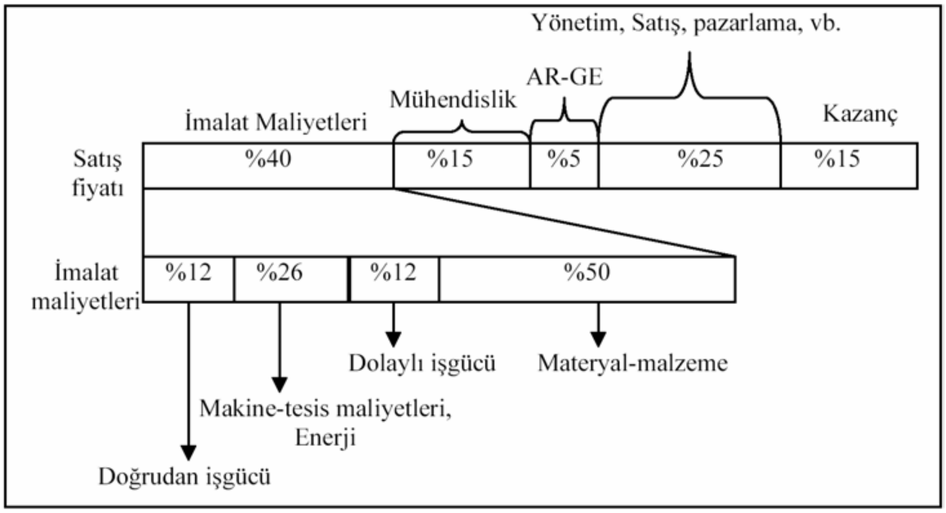

Figure 2: Proportions of Cost Factors in Production Enterprises

In a scientific study conducted by Özbirecikli and Tüfekçi (2018), various surveys were conducted in 66 furniture production enterprises operating in Antakya region. According to the data obtained from this study, approximately half of the companies surveyed used standard costing and the other half used the actual costing method. In addition, it is determined that the majority of the companies make a break-even point in the decision-making process, but they do not analyze material and labor costs with contribution analysis, and they do not use modern management accounting approaches.

2.3 Intelligent Costing System

The cost analysis in furniture enterprises is not at the desired depth (detail). In the current situation, the cost analyzes carried out within the scope of ERP (Enterprise Resource Planning) systems used by our enterprises are theoretically not based on static data. Therefore, year-end profit / loss statements of the companies are also affected by this. Since the companies cannot see the profit / loss tables momentarily, they do not have the chance to make cost simulations related to their future plans and cannot be managed rationally.

The factors that are effective in product or service costs are directly / indirectly affected by many parameters that provide input to the company. The economic structure of the country, price changes in raw material inputs, interest rates, exchange rate fluctuations, increases in labor costs etc. can be counted in this context. What should be done here is to reflect all factors accurately on the product or service and trace the effects of their instantaneous changes.

Nowadays, cost analysis modules in existing programs are proportionally reflecting such expenses so the sub-collection reflection is logarithmically increasing. As a result of such a calculation, the actual cost cannot be seen clearly because the actual cost cannot be reached.

3 INDUSTRY 4.0 EXAMPLE IN COST ANALYSIS

Industry 4.0 is used in many areas and it has potential to be used in cost analysis with no doubt. In the scope of the invention made by Tuncel and Candan (2017), smart costing method has been developed in furniture industry and forest products industry. Patent applications have been filed with the Turkish Patent and Trademark Authority for this invention. The advantages of this new method can be summarized as follows:

- Operating capacity and real cost calculation
- Instant calculation of costs
- Include all elements that make up cost
- Updating any change in any of the components

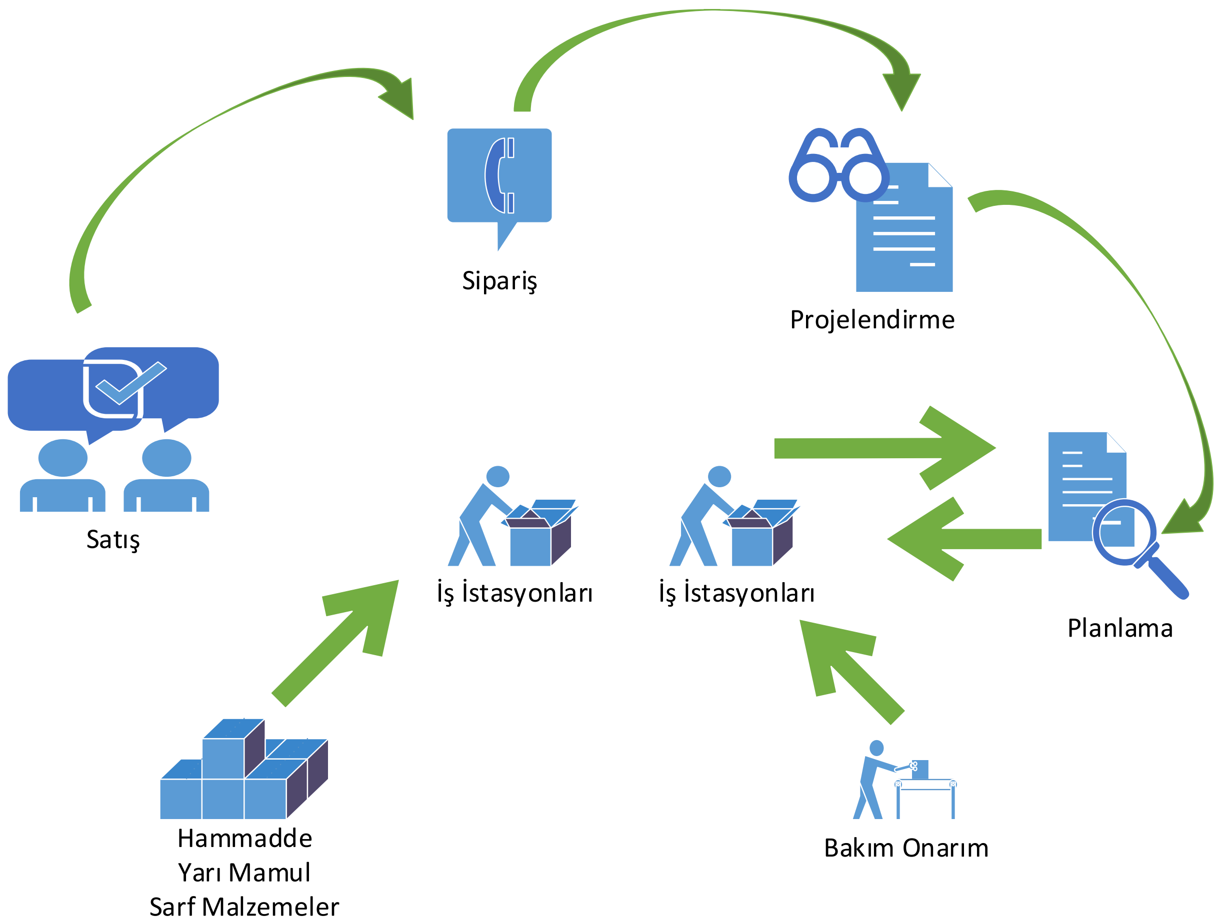

Figure 3: Smart Cost Analysis System Flow Chart

Flow chart of smart cost analysis system that applied for patent in figure 3 has given. According to this, after sale order of the company opens or creates project. In the continuation of the process, the loading and offering of raw materials are carried out by the planning unit. After that, the production process starts and all of these processes are monitored and analyzed by the intelligent costing system.

Thus, the unit costs of all elements that effects production can affect the product instantly. Efficiency of the process can be measured with stored and refined data from the feedback received from the field and intervention areas are seen if necessary.

4 CONCLUSION AND RECOMMENDATIONS

In terms of the development and profitability of the forest products industry, the intelligent costing system has the potential to play a very important role. Today, increase of firms operating in the same sectors, revolutionary changes in technology, change in consumer behavior, differentiation of materials and production processes, rapid expansion of e-commerce and international trade lead to an increasing competition between firms and countries as well. At this point, determining the cost accurately and instantaneously will provide a greater advantage in the competition. The developed smart costing system is capable of being used not only in the forest products industry and the furniture industry, but also in all industries.

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Innovative Approaches in Wood Industry

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ABSTRACT

For businesses to act in accordance with the developing technology will enable them to differentiate from their competitors with innovative approaches in a competitive environment. In addition to competitive elements such as cost, aesthetics, functionality, etc., all the innovative approaches of a business from design to final product are also an important mechanism in getting the edge over the competition.

Innovative thinking has different and important effects on the development of business models. Traditional revenue models involve unforeseen risks. For example, wrong and weak preferences that may occur in the parameters such as selection of job type and job site, determination of target group, pricing policy etc. can cause the related business model to fail. It is, however, possible to prevent financial losses by exhibiting the innovative approaches that minimize these risks.

In order businesses to survive, it has become essential to maximize their profitability because of the high-ranking competition as a result of the global economy. In this context, the businesses that operate efficiently are able to achieve the desired profit margins. Otherwise it has become nearly impossible for them to survive.

In the wood industry, the final products are produced by passing the raw material obtained from forest resources through various processes. Within all this complex structure, the businesses often suffer financial losses or cannot take huge leaps because of traditional habits. Apart from this, the handling of production processes and marketing the products with a new perspective form an important basis for the economic breakthroughs.

Within the framework of this academic research, the effects of the innovative methods and the transformations that these methods would bring in to the wood industry besides its traditional structure are examined.

KEYWORDS: Innovative approach, Wood industry, Sectoral competition

1 INNOVATION PERCEPTION OF ENTERPRISES

1.1. What is Innovation?

Innovation is an approach that encompasses all the processes carried out to develop new or improved products, services, or production methods and to make them commercially viable (Çetin).

Oslo Guide, a joint-publication of OECDO and Eurostat, and translated into Turkish by TÜBİTAK, describes "innovation" as follows: "An innovation is the execution of a new or significantly improved product (good or service), or a process, a new marketing method or a new organizational method in inter-business applications, workplace organization or external relations." (Oslo Manual 2006). As can be understood from this definition, innovation cannot be isolated from any of an enterprise's activities, in fact, it means an integrated approach covering an enterprise's all activities.

Innovation is doable by turning new ideas and discoveries into commercial benefits for the sustainability of the enterprises. That is, innovation management is a process where the introduction of new ideas turns into financial gain (Taşkın, 2014).

1.2. Innovation Requirement

The competitive conditions in which the enterprises operate are constantly changing with the influence of the environment and technology. Innovation and R&D in this changing environment is indispensable in terms of the development of an enterprise. Being constantly dynamic and in change-oriented activities in order to be at the top of a competition bring success to an enterprise. Certainly, being in search of innovation in business model and differentiating from other competitors bring efficiency and success (Karayılmazlar, Çabuk et al., 2006).

In enterprises which adopt traditional management approach, the expected change and innovation do not occur at desired level due to the management's attitude. As a result, the enterprise lags behind its competitors over time and loses market share.

Enterprises are not able to increase productivity and quality without R&D and adding knowledge to processes. It is also not possible to increase the volume of their trades unless new products are developed that contain knowledge.

It is possible for enterprises to create higher added-value with people with a high level of knowledge and a high investigative personality. However, for enterprises it does not go further than low-cost and less intelligent labor employment since the goal is to produce low-cost products without added-value (Kavrakoğlu, 2016).

The development and change in wood industry have preferred or transferred of what has been done until today. From now on, it is necessary to adopt "more creative production approach than imitationist one. For this, employees must be motivated, encouraged in creativity and innovation, and a productive environment needs to be established to improve innovation." (Karayılmazlar, Çabuk et al., 2006).

2 INNOVATION APPROACH

2.1 Innovation and R&D Concepts

Innovation can be done in the total process cycle as well as in entire process and its sub-processes. Innovation should not be considered like R&D. One has to make an expense for the research to be carried out and consequently a new product or service can be created in accordance with information obtained. Innovation, however, can be done in every topic and in every field and the outcome that is achieved as a result of the change of a current method or process is also an innovation. The important thing at this point is whether innovation provides added-value and whether it creates plus-value to the enterprise. If answers to these questions are "yes", it can be said that one is doing an innovative work.

According to the OECD Frascati manual, the definition of R&D is given as "R&D comprise creative and systematic work undertaken in order to increase the stock of knowledge -including knowledge of humankind, culture and society -and to devise new applications of available knowledge.” (Gök, 2002).

2.2. Innovation Areas

Innovation can be applied to all processes of an enterprise, but these areas have been categorized in a close-approaches in the literature. The Oslo guide has been grouped under four titles to cover these areas.

a-Product Innovation: It is the introduction of a new or significantly improved product or service according to their current characteristics and intended use (Oslo Manual, 2006). Here, the term of product has been used as to cover products and services. It includes innovative work to be done in anywhere of the entire flow from innovations to be done in the processes to innovations occurring during the use of end-consumers in the production of product or service.

Innovation in the way of the deliverance of a product or service (i.e. in efficiency or use of capacity) can include the change in the current production method such as increasing the efficiency of the production using the same production model but new additional equipment or increasing the capacity using different production models.

b-Process Innovation: It is the application of a new or significantly improved production or delivery method (Karayılmazlar, Çabuk et al., 2006). With innovations to be done in the processes, the unit production time can be shortened, delivery costs can be reduced or innovations can be conceived to enhance quality with making significant differences for the costumers.

c-Marketing Innovation: It is a new marketing method that involves the important changes in the designing or packaging the product, the position of it in market, and presentation and pricing of it (Karayılmazlar, Çabuk et al., 2006). It can be thought as a way for an enterprise to enter new markets to increase the sales, to develop different marketing strategies or to develop new methods that can respond to customer demands more successfully.

d-Organizational Innovation: It is a new organizational method in the commercial application of an enterprise, in the workplace organization or in the external relations (Karayılmazlar, Çabuk et al., 2006). It is anticipated that the constitution of a new structure that has not been implemented before in the organizational structure and increasing the satisfactory of employees and customers within it.

In the classification of the innovation process of which the short descriptions and scopes are given above, the possible subheadings with the headings are shown in Fig. 1. It is divided into four main themes and each theme has been detailed thoroughly.

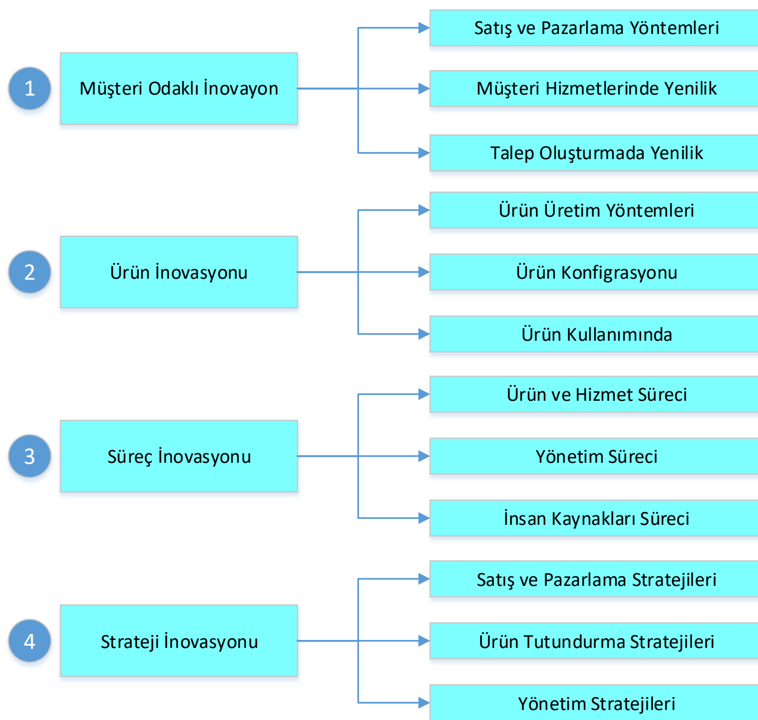

Figure 1: Innovation Themes

2.3. Interaction in Innovation

There are two different interactions that trigger the formation of innovation. The first is the innovation that is shaped by finding solutions to unmet needs and problems in current applications (Brem and Voigt, 2009) This is called market-demanding innovation and market pull. A schematic diagram of how the market pull works is given in Fig. 2. The emergence of LPG-powered automobiles is a good example for this. High fuel prices, especially in Turkey, have led the consumers to more affordable fuels. Then, LPG products which can be installed to the vehicles afterward have emerged.

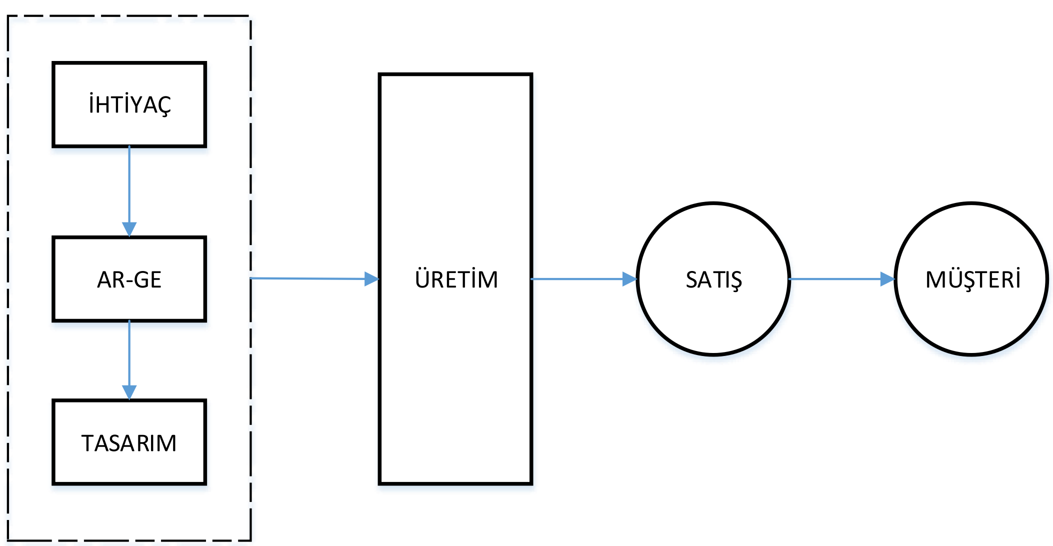

Figure 2: Market Based Innovation Process

As known, cars are out of factory having gasoline or diesel-powered engines. The same engine is put into operation by the installation of LPG tank and equipment particularly for pulling the cost of gasoline down.

The second is the innovation method which is developed with R&D studies and carried out with the use of new technology or new materials and brings more effective solutions along with. This is called the technology push because of the development of the technology. The best example of this type of innovation that is formed by the technology push and schematically shown in Fig. 3 is smart phones.

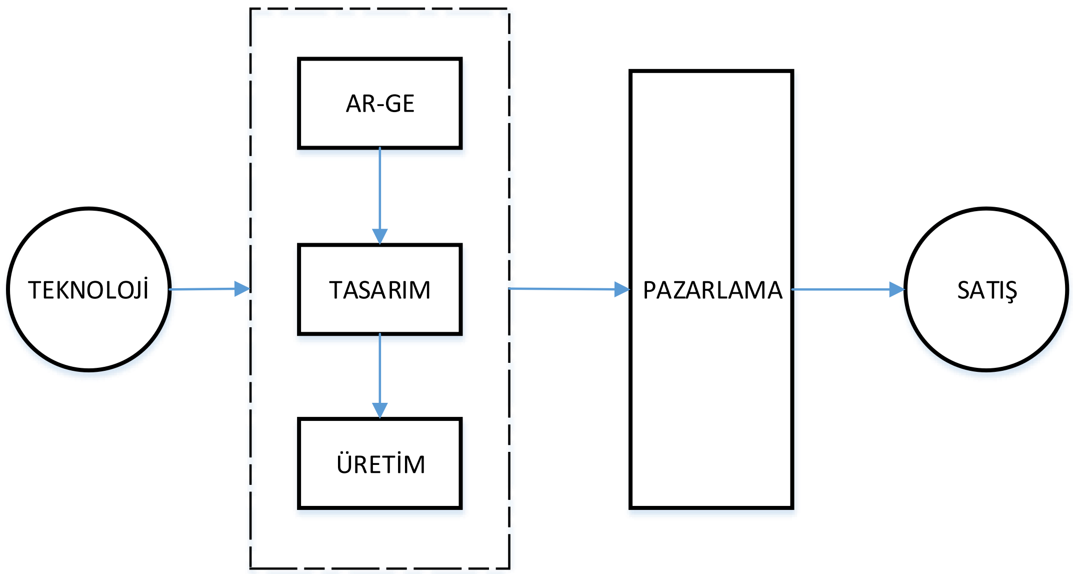

Figure 3: Technology Based Innovation Process

An enterprise's innovation capacity is closely related to its competitiveness. The strength of competitiveness and innovation of enterprises depend on the size of the enterprise and the orientation to exportation (Cao, 2004). According to this definition, as a result of the aforementioned processes of innovation, the enforced improvement by the demand from the market or the development of technology becomes important in terms of the development and continuity for an enterprise. The failure of an enterprise in developing an innovation lags it behind its competitors which would result an enterprise to collapse in future. For instance, it is known that some of globally-known companies in 90's have become collapsed today.

3 INNOVATION IN FURNITURE MANUFACTURING OPERATION

The furniture industry in Turkey is predominantly occupied by workshops and small-scale enterprises, which adopt traditional methods. In recent years, however, the number of medium and large-scale enterprises has started to increase rapidly. According to SGK data of 2014, the furniture industry is in the 4th place with 20.867 enterprises in the manufacturing industry. It is in the 7th place with 165,118 employees. At the end of 2014, it is estimated that the worth of the production of the furniture industry is 19 billion USD and of the consumption is 14 billion USD in Turkey (Orta Anadolu İhracatçı Birlikleri Genel Sekreterliği, 2016).

The European Union Furniture Industry has undergone significant changes in recent years. The main factors that trigger this change are the desire of the exporter to enhance the quality, design and innovation value (European Commission Furniture Industry).

In addition to the increasing globalization and digitization of markets, relying on only innovation and design are not enough to protect the intellectual property rights. Rapid and strong research and innovation also require financial support. In this context, SMEs do not have sufficient financial strength and hence the level of innovation does not develop at the same rate.

As a result of being in a search of a solution to the demands and problems in the furniture industry, hinges with brakes on cabinet doors, which can be described as an innovation pull, can be given as an example. The brake system that was firstly installed to the cabinet doors as a separate apparatus can be produced integrated with the hinges in parallel with the technological improvement. Also, the examples to the innovation push in the furniture industry are laminate flooring and sofa beds, where a sofa have a mechanism which turns into a bed. Use of solid wood in the production of flooring for a long period of time has caused resource shortage and led to new search and together with developing material and processing techniques, HDF (high density fiberboard), which is a wood-based material, and laminated flooring materials of which upper side has wood-like patterns have been produced. Particularly in places where the use of wood is requested, laminated flooring -laminating wooden sheets to counter material- has been brought into service.

In 2015, as a result of the study initiated to solve the capacity problem experienced in the CNC surface finishing machine in an office furniture producing enterprise, to which consultancy services are provided, machine capacity is increased by 100% and unit processing time is shortened with the novel approach in the production process. In this study, every stage of the current business process was examined to reach the solution and brainstorming has been done with the engineers in the enterprise on which phase of the process the improvement can be done. At the end of the study, with a developed method the number of parts processed by the machine in one operation was increased to two and the capacity increased twice. In Fig. 4, the current situation and the result after the innovation are shown schematically.

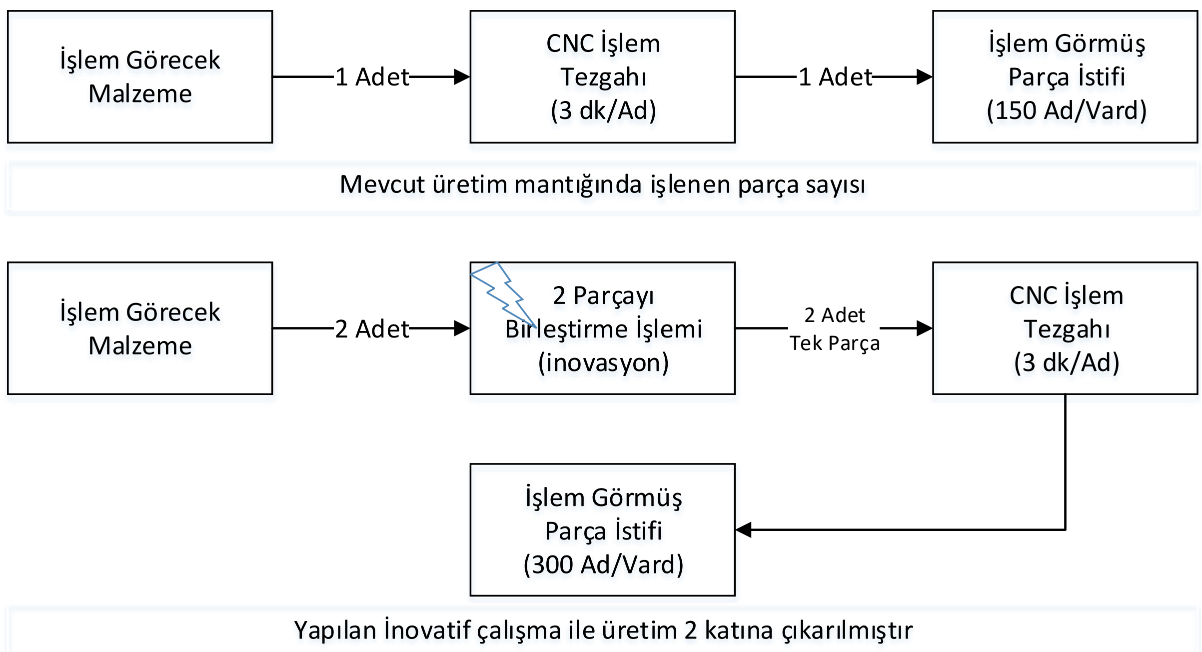

Figure 4: Innovation example in CNC table

Innovation here has emerged with the enforcement of conditions and is a good example for the innovation pull.

Another example for the innovation in the Turkish Furniture Industry in recent years is "smart bed" products. Various smart beds were developed under the brand "MedBed" and several patent applications were made by Zeki Candan, Faculty Member of Istanbul University Forest Products Engineering Department and Özkan Ocak, Forest Products Engineer. The body temperature of the person lying on the bed, especially the infants, is detected and when the emergency is arisen, the situation is automatically transmitted to the relatives and doctor of the person lying and emergency medical service (Smart Bed: "MedBed, 2015).

Actually, there are many innovations that have been done in wood sector with the enforcement of the conditions. However, because of the lack of recording and that the concept of innovation is not fully known in the sector, innovations are not emerged or neither attributed so.

3.1. Meaning of Innovation in Furniture Industry

The sector closely follows the development of Machinery Park by importing the technology. However, it is a disadvantage that the number of enterprises aiming to improve by investing only in machinery is high. In fact, it shows that the industry cannot provide real development. One of the most important deficits of the furniture industry is the slow pace of work on managerial structuring. In fact, this shows that the industry has not developed fully. One of the most important deficiency of the furniture industry is the slow pace of work on managerial structure. Particularly investment on white-collar personnel is extremely low and employment of engineer is not sufficient. This also affects the work or analysis that can be done on innovation.

Today, there are many furniture enterprises that can be said large-scale in terms of their structures. When these companies are examined, it seems that managing some of these enterprises as a large-scale workshop leads to the formation of idle capacity. However, unnecessary machinery investment can be prevented by using the available capacity efficiently. The most important work to be done for this is the establishment of managerial infrastructure.

The flaws in the establishment of the concept of innovation in the industry and having lower R&D investments of the enterprises than that of in UN countries are caused by this gap. It is seen that in the furniture sector, where engineering studies should be predominant, the enterprises still work on the initiative of the chief. The enterprises in furniture industry need to carry out the operations with a professional engineering approach. Otherwise, the intensive competition around the world is expected to continue to take the enterprises down.

4 CONCLUSION AND RECOMMENDATIONS

The opportunities of innovation management available to industry needs to be analyzed and evaluated correctly. Adopting an innovative approach to stand out of the competition should be the management's priority. In this regard, as stated in the research done by Taşkın (Taşkın 2014), the lack of training of the employees needs to be eliminated to be able to seize the innovation approach in the furniture production enterprises.

As mentioned above, managerial structures must be rearranged and shaped according to modern management approach so that enterprises can successfully carry out the innovative work.

Leaving the classical management approach behind and moving towards a more participatory structure will spread innovative approach to the basis.

In order to ensure full participation in the innovation approach, the enterprise management should be open to new ideas. In addition, a functioning proposal and performance evaluation system will stimulate employee motivation and innovative approach.

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Employing a Multi-Criteria Decision Making Method to Evaluate Engineered Wood Products and Timber

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ABSTRACT

In the present study, a decision-making model was devised to evaluate parallel strand lumber (PSL), laminated strand lumber (LSL), laminated veneer lumber (LVL), glued laminated timber (GLT) and timber. Assessment criteria were identified based on the literature review. The fuzzy analytic hierarchy process (AHP), one of the multi-criteria decision making (MCDM) methods, was employed to obtain the weights of the criteria and to determine the ranking of the alternatives. The results showed that LVL is the best alternative. Consequently, the evaluation model and results can assist building designers in making decisions during the selection of wood products.

KEYWORDS: Multi-criteria decision making, Fuzzy analytic hierarchy process, Engineered wood products, Timber

1 INTRODUCTION

Timber is one of the oldest known materials used in construction. Engineered wood products (EWPs) have been developed to overcome some of major limits in timber dimensions and natural defects found in sawn wood (Prachasaree and Limkatanyu, 2013). Glued laminated timber (GLT), laminated veneer lumber (LVL), parallel strand lumber (PSL) and laminated strand lumber (LSL) are some of the EWPs. These EWPs are generally used as structural members in constructions (Hwang and Komatsu, 2002; Milner and Woodard, 2016). GLT is created by adhesively bonding together individual pieces of lumber. The desired length is obtained from various lengths joined together with scarf or finger joints (Yang et al., 2008). LVL is produced by laminating thin wood veneers that are arranged parallel to the length of the material and bonded using an adhesive (Oh, 2011). PSL is manufactured by adhesively bonding long, thin and narrow strands of wood under high pressure (Arwade et al., 2009). LSL is composed of oriented wood flakes that are glued and compressed to form panels up to 90 mm thick (Moses et al., 2003). Figure 1 shows the schematic drawing of the above mentioned EWPs.

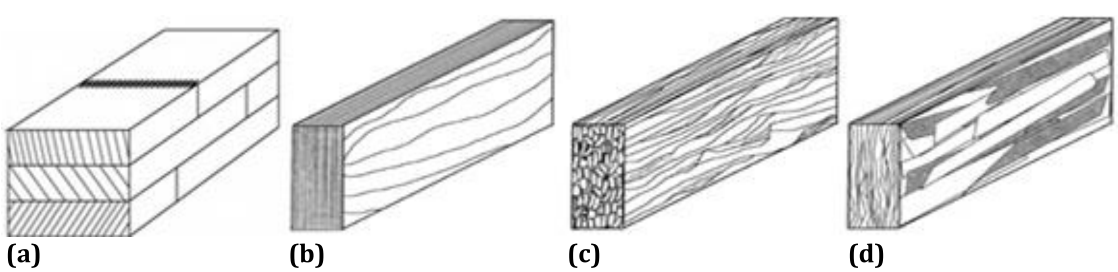

Figure 1: Schematic drawing of (a) GLT (Web-1), (b) LVL (Snow, 2006), (c) PSL (Snow, 2006) and (d) LSL (Snow, 2006)

The selection of the best wood product for load-bearing applications is a complex task owing to the diversity of criteria that should be considered. The evaluation of the EWPs and timber has multi-level and multi-factor aspects. Therefore, this problem can be regarded as multi-criteria decision making (MCDM). However, assigning a rating to the performance of wood products is difficult due to the anisotropic and heterogeneous nature of wood. For this reason, the fuzzy analytic hierarchy process (AHP), which is one of the most popular and trustable fuzzy MCDM methods, was preferred to obtain the weights of the criteria and to rank the alternatives.

The fuzzy AHP method has been widely used to solve decision problems. Kahraman et al. (2003) employed the fuzzy AHP approach in the selection of the best facility location alternative by taking into account quantitative and qualitative factors. Kahraman et al. (2004) compared the catering firms in Turkey by applying fuzzy AHP. Bozbura et al. (2007) utilized fuzzy AHP to prioritize human capital measurement indicators. Haghighi et al. (2010) used fuzzy AHP to prioritize effective factors on e-banking development in Iran. Lin (2010) prioritized course website quality factors by using the fuzzy AHP method. Chen et al. (2011) used fuzzy AHP in the selection of the best environment-watershed plan. Kilincci and Onal (2011) used the fuzzy AHP approach to solve the supplier selection problem. Lee et al. (2011) prioritized hydrogen energy technologies by employing fuzzy AHP. Somsuk and Laosirihongthong (2014) utilized the fuzzy AHP method to prioritize the factors that affect the success of university business incubators. Moreover, the MCDM methods have been successfully applied to various fields of wood science for the prioritization of criteria/factors and the evaluation of alternatives. These MCDM applications to wood science include bridge material selection (Smith et al., 1995), the selection of the most suitable alternative for supplying poplar wood (Azizi, 2008), the classification of wood products according to their effects on the environment (Lipušček et al., 2010), the determination of the best choice for the development and investment of construction panels (Azizi and Modarres, 2011), the selection of the best imported medium density fiberboard (MDF) product (Azizi et al., 2012), the evaluation of different types of building construction (Kuzman and Grošelj, 2012), the prioritization of effective factors on the markets of particleboard and MDF (Sarfi et al., 2013), and the determination of nanocomposites possessing optimal properties (Karakuş et al., 2017).

Consequently, the fuzzy AHP method has been widely utilized in many fields. Moreover, the MCDM methods have been successfully employed to solve various decision problems in the field of wood science. However, there is no information on the use of a MCDM method to evaluate PSL, LSL, LVL, GLT and timber. Therefore, the purposes of this study are to evaluate these materials and to select the best alternative for load-bearing applications by using fuzzy AHP.

2 MATERIALS AND METHODS

2.1 Fuzzy Sets and Fuzzy Numbers

The fuzzy logic (Zadeh, 1965) was designed to represent vague, ambiguous or imprecise information. A fuzzy set is a class of objectives with continuum grades of membership ranging between 0 and 1 (Kilincci and Onal, 2011). If the assigned value is 1, the entity belongs fully to the set. If the value is 0, the entity does not belong to the set. Lastly, if the value lies between 0 and 1, the entity belongs partially to the set (Kahraman and Kaya, 2010). The fuzzy set theory is a valuable tool to strengthen the comprehensiveness and reasonableness of the decision-making process (Seçme et al., 2009).

In the literature, triangular and trapezoidal fuzzy numbers are usually employed to represent the linguistic terms. In this study, triangular fuzzy numbers (TFNs) were used due to their ease of calculation. A TFN is denoted as (l, m, u), where $l \leq m \leq u$. The membership function of a TFN can be defined as below.

$$\mu_{\tilde{A}}(x) = \begin{cases} 0, & x < l \text{ or } x > u \\ (x-l)/(m-l), & l \leq x \leq m \\ (u-x)/(u-m), & m \leq x \leq u \end{cases} \qquad (1)$$

The arithmetic operations for two TFNs $\tilde{A}_1$ and $\tilde{A}_2$ are as follows (Lee et al., 2011):

$$\tilde{A}_1 \oplus \tilde{A}_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \qquad (2)$$

$$\tilde{A}_1 \otimes \tilde{A}_2 = (l_1 l_2, m_1 m_2, u_1 u_2) \tag{3}$$

$$\tilde{A}_1^{-1} = (1/u_1, 1/m_1, 1/l_1) \tag{4}$$

The triangular fuzzy conversion scale used to convert linguistic scales into fuzzy scales is presented in Table 1.

Table 1: Fuzzy expressions of linguistic terms

Linguistic scale	**Triangular fuzzy scale**
Equally important	(1,1,3)
Moderately important	(1,3,5)
Fairly important	(3,5,7)
Very strongly important	(5,7,9)
Absolutely important	(7,9,9)

2.2 Fuzzy Analytic Hierarchy Process Method

The AHP method was introduced by Saaty (1977). This method consists of four main steps: (1) structuring the problem into a hierarchical model; (2) making pair-wise comparisons; (3) measuring the consistency of comparisons and (4) synthesis of results (Nikou and Mezei, 2013). In the first step, the objectives, criteria and alternatives are arranged in a hierarchical structure. The goal is expressed at the top-most level. The intermediate levels correspond to criteria. The alternatives are situated at the last level. The n elements in the same level are compared using a scale of 1–9. The inconsistencies in the decision process can be detected by calculating a consistency ratio (CR). If the CR is less than 0.10, comparisons can be thought of as being acceptable. At the last step, the individual priorities at different levels are aggregated to obtain overall priorities of alternatives (Albayrak and Erensal, 2004).

Different studies applied various modifications of AHP. In the current study, Chang's (Chang, 1996) extent analysis method was used to obtain the weights of the criteria and to rank the alternatives. This method employs linguistic variables to express human judgments. The steps of Chang's approach can be summarized as follows (Somsuk and Laosirihongthong, 2014):

Step 1: The value of fuzzy synthetic extent with respect to the i^{th} object is computed using Eq. (5).

$$S_i = \sum_{j=1}^{m} M_{g_i}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1} \tag{5}$$

where $M_{g_i}^j$ shows the TFN related to j target according to i criteria.

Step 2: The degree of possibility of $S_i = (l_i, m_i, u_i) \geq S_j = (l_j, m_j, u_j)$ is computed using Eq. (6).

$$V(S_i \geq S_j) = \begin{cases} 1, & m_i \geq m_j \\ 0, & l_j \geq u_i \\ \frac{l_j - u_i}{(m_i - u_i) - (m_j - l_j)}, & \text{otherwise} \end{cases} \tag{6}$$

where $i = 1,2,\ldots,n$, $j = 1,2,\ldots m$ and $i \neq j$.

Step 3: The degree of possibility of S_i over all the other $(n-1)$ fuzzy numbers is calculated as below.

$$V(S_i \geq S_j | j = 1,2,\ldots m;\ i \neq j) = \min V(S_i \geq S_j | j = 1,2,\ldots m;\ i \neq j) \tag{7}$$

Step 4: Compute the weight vector $W = (w_1, w_2, \ldots, w_n)^T$ of the fuzzy matrix as follows: Assume that $w_i' = \min V(S_i \geq S_j | j = 1,2,\ldots m;\ i \neq j)$

$$w_i = \frac{w_i'}{\sum_{i=1}^{n} w_i'} \tag{8}$$

where w_i is a non-fuzzy value.

2.3 Fuzzy Analytic Hierarchy Process Analysis

The evaluation model used in this study includes three basic stages: (1) identification of the main criteria, sub-criteria and alternatives, (2) prioritization of the criteria by fuzzy AHP, and (3) evaluation of the alternatives and determination of the final ranking by fuzzy AHP. In order to achieve the objective, a hierarchical structure of the decision problem that consists of four levels was constructed. A schematic illustration of the hierarchical structure is shown in Figure 2.

The first level of the hierarchy represents the goal. The second level consists of the main criteria. Various sets of the sub-criteria are listed in the third level of the hierarchy. The main criteria are economic factors (C1), environmental factors (C2), technical factors (C3) and social factors (C4). The economic criterion includes four sub-criteria: acquisition cost (C11), disposal cost (C12), maintenance cost (C13), and longevity of the material (C14). The environmental criterion covers four sub-criteria: impacts on the ecosystem throughout the life cycle (C21), toxic property (C22), and recyclable material (C23). The technical criterion consists of seven sub-criteria: bending strength (C31), modulus of elasticity (C32), compression strength perpendicular to grain (C33), compression strength parallel to grain (C34), impact bending (C35), nail and screw holding ability (C36), and machinability (C37). The social criterion is made of four sub-criteria: fire safety (C41), earthquake safety (C42), aesthetic (C43), and impact on construction time (C44). The last level belongs to the alternatives determined as PSL, LSL, LVL, GLT and timber.

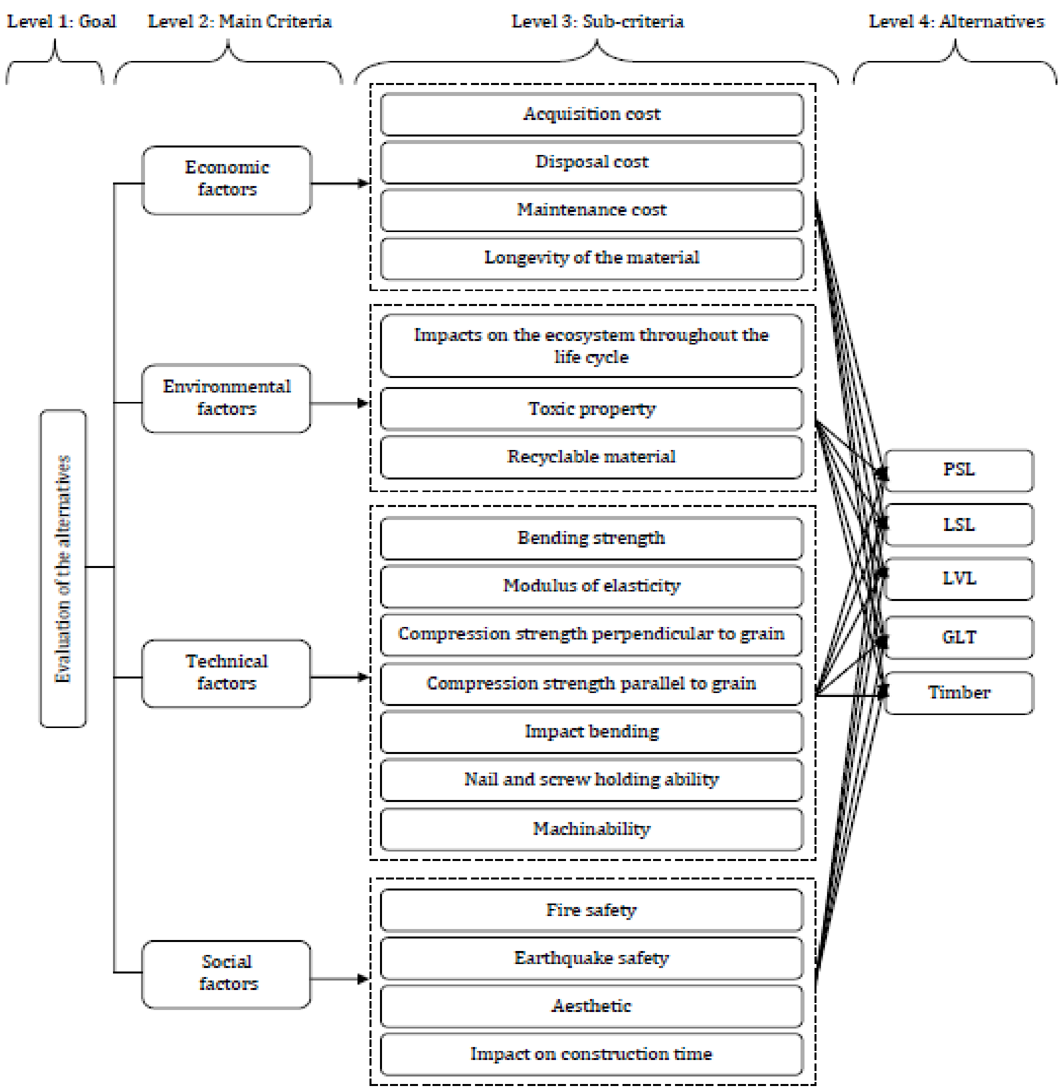

Figure 2: The hierarchical structure of the decision problem

As stated previously, the fuzzy AHP method was utilized to obtain the weights of the criteria and to rank the alternatives. The first step is to obtain the weights of the criteria from the comparison matrices by Chang's approach. The next step is to evaluate five alternatives by utilizing 5×5 comparison matrices. The last step is to synthesize the weights to get the final result. A decision making group consisting of five experts was constructed to evaluate each element. The questionnaire used to collect the data was either emailed or hand-delivered to the experts. The experts carried out pair-wise comparisons by employing the linguistic terms given in Table 1. Then, the linguistic terms were converted to TFNs. The geometric means of the fuzzy values were computed to obtain the overall results of each matrix. The priorities of the criteria were obtained from the pair-wise comparison matrices. The comparison matrices of the criteria can be seen from Tables 2-6.

Table 2: The comparison matrix of the main criteria

Criterion	C1	C2	C3	C4	Weight
C1	(1.00, 1.00, 1.00)	(1.00, 1.29, 2.45)	(0.15, 0.21, 0.37)	(0.42, 0.57, 1.12)	0.152
C2	(0.41, 0.78, 1.00)	(1.00, 1.00, 1.00)	(0.23, 0.31, 0.64)	(0.44, 0.64, 1.48)	0.103
C3	(2.67, 4.83, 6.88)	(1.55, 3.27, 4.43)	(1.00, 1.00, 1.00)	(0.90, 1.43, 2.33)	0.487
C4	(0.89, 1.75, 2.41)	(0.68, 1.55, 2.26)	(0.43, 0.70, 1.11)	(1.00, 1.00, 1.00)	0.258

Table 3: The comparison matrix of the sub-criteria within economic factors

Criterion	C11	C12	C13	C14	Weight
C11	(1.00, 1.00, 1.00)	(3.27, 4.43, 6.87)	(2.14, 4.36, 6.43)	(0.32, 0.39, 0.90)	0.447
C12	(0.15, 0.23, 0.31)	(1.00, 1.00, 1.00)	(0.47, 0.64, 1.40)	(0.21, 0.29, 0.58)	0.017
C13	(0.16, 0.23, 0.47)	(0.71, 1.55, 2.14)	(1.00, 1.00, 1.00)	(0.30, 0.34, 0.68)	0.095
C14	(1.11, 2.54, 3.16)	(1.72, 3.50, 4.66)	(1.48, 2.95, 3.38)	(1.00, 1.00, 1.00)	0.441

Table 4: The comparison matrix of the sub-criteria within environmental factors

Criterion	C21	C22	C23	Weight
C21	(1.00, 1.00, 1.00)	(1.09, 1.58, 2.29)	(1.00, 1.55, 3.68)	0.418
C22	(0.44, 0.63, 0.92)	(1.00, 1.00, 1.00)	(0.44, 0.80, 1.63)	0.265
C23	(0.27, 0.64, 1.00)	(0.61, 1.25, 2.26)	(1.00, 1.00, 1.00)	0.317

Table 5: The comparison matrix of the sub-criteria within technical factors

Criterion	C31	C32	C33	C34	C35	C36	C37	Weight
C31	(1.00, 1.00, 1.00)	(1.00, 1.18, 3.00)	(0.90, 1.38, 3.16)	(0.90, 1.38, 3.16)	(0.80, 1.38, 2.29)	(1.55, 2.95, 5.16)	(1.72, 3.16, 5.43)	0.181
C32	(0.33, 0.84, 1.00)	(1.00, 1.00, 1.00)	(1.38, 2.29, 4.58)	(1.00, 1.48, 3.32)	(0.61, 1.25, 2.26)	(1.55, 2.95, 5.16)	(2.14, 3.50, 5.81)	0.186
C33	(0.32, 0.72, 1.11)	(0.22, 0.44, 0.72)	(1.00, 1.00, 1.00)	(0.72, 0.95, 2.41)	(0.36, 0.72, 1.53)	(0.82, 1.53, 3.00)	(1.25, 2.54, 4.36)	0.145
C34	(0.32, 0.72, 1.11)	(0.30, 0.68, 1.00)	(0.42, 1.05, 1.38)	(1.00, 1.00, 1.00)	(0.46, 0.82, 1.53)	(1.12, 2.37, 4.15)	(2.14, 4.36, 6.43)	0.169
C35	(0.44, 0.72, 1.25)	(0.44, 0.80, 1.63)	(0.65, 1.38, 2.81)	(0.65, 1.23, 2.18)	(1.00, 1.00, 1.00)	(0.72, 1.48, 2.95)	(1.55, 2.81, 4.66)	0.159
C36	(0.19, 0.34, 0.64)	(0.19, 0.34, 0.64)	(0.33, 0.65, 1.23)	(0.24, 0.42, 0.89)	(0.34, 0.68, 1.38)	(1.00, 1.00, 1.00)	(1.72, 2.54, 4.90)	0.119
C37	(0.18, 0.32, 0.58)	(0.17, 0.29, 0.47)	(0.23, 0.39, 0.80)	(0.16, 0.23, 0.47)	(0.21, 0.36, 0.64)	(0.20, 0.39, 0.58)	(1.00, 1.00, 1.00)	0.041

Table 6: The comparison matrix of the sub-criteria within social factors

Criterion	C41	C42	C43	C44	Weight
C41	(1.00, 1.00, 1.00)	(0.68, 1.07, 2.14)	(3.62, 5.91, 8.00)	(1.72, 3.94, 6.02)	0.485
C42	(0.47, 0.93, 1.48)	(1.00, 1.00, 1.00)	(2.81, 4.21, 6.42)	(2.95, 5.16, 7.24)	0.471
C43	(0.12, 0.17, 0.28)	(0.16, 0.24, 0.36)	(1.00, 1.00, 1.00)	(0.54, 1.05, 1.63)	0.003
C44	(0.17, 0.25, 0.58)	(0.14, 0.19, 0.34)	(0.61, 0.95, 1.84)	(1.00, 1.00, 1.00)	0.041

As an example, the calculation of the weights of the main criteria was explained below. Based on the first step of the fuzzy AHP procedure, the values of the fuzzy synthetic extent for the main criteria matrix were calculated as follows:

$S_{C1} = (2.56, 3.07, 4.94) \otimes (1/30.49,\ 1/21.32,\ 1/13.76) = (0.08, 0.14, 0.36)$

S_{C2} = (2.07, 2.73, 4.12) ⊗ (1/30.49 , 1/21.32 , 1/13.76) = (0.07, 0.13, 0.30)

S_{C3} = (6.12, 10.53, 14.65) ⊗ (1/30.49 , 1/21.32 , 1/13.76) = (0.20, 0.49, 1.06)

S_{C4} = (3.00, 5.00, 6.77) ⊗ (1/30.49 , 1/21.32 , 1/13.76) = (0.10, 0.23, 0.49)

Then, the degrees of possibility of the fuzzy values were determined according to Eq. (6) as given in Table 7.

Table 7: The values of $V(S_i \geq S_j)$

$V(S_{C1} \geq S_j)$	Value	$V(S_{C2} \geq S_j)$	Value	$V(S_{C3} \geq S_j)$	Value	$V(S_{C4} \geq S_j)$	Value
$V(S_{C1} \geq S_{C2})$	1.00	$V(S_{C2} \geq S_{C1})$	0.93	$V(S_{C3} \geq S_{C1})$	1.00	$V(S_{C4} \geq S_{C1})$	1.00
$V(S_{C1} \geq S_{C3})$	0.31	$V(S_{C2} \geq S_{C3})$	0.21	$V(S_{C3} \geq S_{C2})$	1.00	$V(S_{C4} \geq S_{C2})$	1.00
$V(S_{C1} \geq S_{C4})$	0.74	$V(S_{C2} \geq S_{C4})$	0.65	$V(S_{C3} \geq S_{C4})$	1.00	$V(S_{C4} \geq S_{C3})$	0.53

The minimum of the degrees of possibility was determined as follows:

$d'(C1)$ = min(1.00, 0.31, 0.74) = 0.31

$d'(C2)$ = min(0.93, 0.21, 0.65) = 0.21

$d'(C3)$ = min(1.00, 1.00, 1.00) = 1.00

$d'(C4)$ = min(1.00, 1.00, 0.53) = 0.53

Thereafter, the normalized weight vector was found as $W = (0.152, 0.103, 0.487, 0.258)^T$. According to the weight vector, the technical criterion is the most significant main criterion. The same procedure was applied to the other matrices. The comparisons of the alternatives are given in Tables 8-25. The weights obtained for each element are summarized in Table 26. The ranking of the alternatives was determined based on the weights given in Table 26. In other words, the priority weights of the alternatives with respect to the main criteria were combined, and the priority values of the alternatives were determined. The priority values for the alternatives were found as (0.233, 0.220, 0.239, 0.201, 0.107). The results of this study showed that the best alternative is LVL.

Table 8: The evaluation of the alternatives with respect to acquisition cost

Alternative	PSL	LSL	LVL	GLT	Timber	Weight
PSL	(1.00, 1.00, 1.00)	(0.36, 0.72, 1.53)	(0.44, 1.12, 1.53)	(0.31, 0.47, 0.89)	(0.22, 0.28, 0.61)	0.108
LSL	(0.65, 1.38, 2.81)	(1.00, 1.00, 1.00)	(0.58, 1.16, 2.04)	(0.58, 0.75, 1.66)	(0.23, 0.37, 0.75)	0.175
LVL	(0.65, 0.89, 2.29)	(0.49, 0.86, 1.72)	(1.00, 1.00, 1.00)	(0.36, 0.58, 1.38)	(0.17, 0.25, 0.58)	0.142
GLT	(1.12, 2.11, 3.21)	(0.60, 1.33, 1.72)	(0.72, 1.72, 2.81)	(1.00, 1.00, 1.00)	(0.17, 0.24, 0.54)	0.207
Timber	(1.63, 3.55, 4.58)	(1.33, 2.67, 4.36)	(1.72, 3.94, 6.02)	(1.84, 4.14, 6.02)	(1.00, 1.00, 1.00)	0.368

Table 9: The evaluation of the alternatives with respect to disposal cost

Alternative	PSL	LSL	LVL	GLT	Timber	Weight
PSL	(1.00, 1.00, 1.00)	(0.68, 0.90, 2.14)	(0.24, 0.54, 0.72)	(0.23, 0.32, 0.72)	(0.19, 0.30, 0.80)	0.087
LSL	(0.47, 1.11, 1.48)	(1.00, 1.00, 1.00)	(0.23, 0.47, 0.80)	(0.23, 0.32, 0.72)	(0.16, 0.25, 0.52)	0.061
LVL	(1.38, 1.84, 4.14)	(1.25, 2.14, 4.36)	(1.00, 1.00, 1.00)	(0.38, 0.52, 1.55)	(0.15, 0.21, 0.42)	0.215
GLT	(1.38, 3.16, 4.36)	(1.38, 3.16, 4.36)	(0.64, 1.93, 2.63)	(1.00, 1.00, 1.00)	(0.21, 0.29, 0.58)	0.265
Timber	(1.25, 3.32, 5.35)	(1.93, 4.08, 6.12)	(2.37, 4.66, 6.77)	(1.72, 3.50, 4.66)	(1.00, 1.00, 1.00)	0.372

Table 10: The evaluation of the alternatives with respect to maintenance cost

Alternative	PSL	LSL	LVL	GLT	Timber	Weight
PSL	(1.00, 1.00, 1.00)	(1.25, 1.72, 3.94)	(0.47, 1.11, 1.48)	(1.25, 1.63, 3.55)	(1.00, 1.66, 2.67)	0.243
LSL	(0.25, 0.58, 0.80)	(1.00, 1.00, 1.00)	(0.34, 0.80, 1.38)	(1.12, 1.53, 3.38)	(0.93, 1.50, 2.14)	0.208
LVL	(0.68, 0.90, 2.14)	(0.72, 1.25, 2.95)	(1.00, 1.00, 1.00)	(1.25, 1.72, 3.94)	(1.07, 1.84, 3.32)	0.238
GLT	(0.28, 0.61, 0.80)	(0.30, 0.65, 0.89)	(0.25, 0.58, 0.80)	(1.00, 1.00, 1.00)	(0.78, 1.55, 2.95)	0.172
Timber	(0.37, 0.60, 1.00)	(0.47, 0.67, 1.07)	(0.30, 0.54, 0.93)	(0.34, 0.64, 1.29)	(1.00, 1.00, 1.00)	0.139

Table 11: The evaluation of the alternatives with respect to longevity of the material

Alternative	PSL	LSL	LVL	GLT	Timber	Weight
PSL	(1.00, 1.00, 1.00)	(1.25, 1.38, 3.55)	(0.64, 1.93, 2.63)	(1.12, 2.37, 4.15)	(2.04, 4.43, 6.33)	0.283
LSL	(0.28, 0.72, 0.80)	(1.00, 1.00, 1.00)	(0.47, 1.25, 1.90)	(1.00, 2.00, 3.00)	(2.04, 4.43, 6.33)	0.259
LVL	(0.38, 0.52, 1.55)	(0.53, 0.80, 2.14)	(1.00, 1.00, 1.00)	(0.84, 1.93, 3.11)	(2.29, 3.50, 5.24)	0.239
GLT	(0.24, 0.42, 0.89)	(0.33, 0.50, 1.00)	(0.32, 0.52, 1.18)	(1.00, 1.00, 1.00)	(1.66, 2.95, 4.66)	0.186
Timber	(0.16, 0.23, 0.49)	(0.16, 0.23, 0.49)	(0.19, 0.29, 0.44)	(0.21, 0.34, 0.60)	(1.00, 1.00, 1.00)	0.033

Table 12: The evaluation of the alternatives with respect to impacts on the ecosystem throughout the life cycle

Alternative	PSL	LSL	LVL	GLT	Timber	Weight
PSL	(1.00, 1.00, 1.00)	(1.00, 1.00, 3.00)	(0.37, 1.00, 1.38)	(0.25, 0.35, 0.90)	(0.16, 0.22, 0.44)	0.117
LSL	(0.33, 1.00, 1.00)	(1.00, 1.00, 1.00)	(0.27, 0.64, 1.00)	(0.28, 0.42, 1.25)	(0.16, 0.22, 0.44)	0.055
LVL	(0.72, 1.00, 2.67)	(1.00, 1.55, 3.68)	(1.00, 1.00, 1.00)	(0.38, 0.52, 1.55)	(0.16, 0.22, 0.44)	0.175
GLT	(1.11, 2.85, 4.08)	(0.80, 2.41, 3.62)	(0.64, 1.93, 2.63)	(1.00, 1.00, 1.00)	(0.18, 0.27, 0.68)	0.247
Timber	(2.29, 4.58, 6.43)	(2.29, 4.58, 6.43)	(2.29, 4.58, 6.43)	(1.48, 3.74, 5.62)	(1.00, 1.00, 1.00)	0.406

Table 13: The evaluation of the alternatives with respect to toxic property

Alternative	PSL	LSL	LVL	GLT	Timber	Weight
PSL	(1.00, 1.00, 1.00)	(1.00, 1.00, 3.00)	(0.27, 0.64, 1.00)	(0.19, 0.30, 0.80)	(0.14, 0.18, 0.32)	0.062
LSL	(0.33, 1.00, 1.00)	(1.00, 1.00, 1.00)	(0.27, 0.64, 1.00)	(0.19, 0.30, 0.80)	(0.14, 0.18, 0.32)	0.000
LVL	(1.00, 1.55, 3.68)	(1.00, 1.55, 3.68)	(1.00, 1.00, 1.00)	(0.26, 0.37, 1.00)	(0.14, 0.18, 0.32)	0.164
GLT	(1.25, 3.32, 5.35)	(1.25, 3.32, 5.35)	(1.00, 2.67, 3.88)	(1.00, 1.00, 1.00)	(0.18, 0.27, 0.68)	0.308
Timber	(3.16, 5.43, 7.24)	(3.16, 5.43, 7.24)	(3.16, 5.43, 7.24)	(1.48, 3.74, 5.62)	(1.00, 1.00, 1.00)	0.466

Table 14: The evaluation of the alternatives with respect to recyclable material

Alternative	PSL	LSL	LVL	GLT	Timber	Weight
PSL	(1.00, 1.00, 1.00)	(1.00, 1.00, 3.00)	(0.25, 0.58, 0.80)	(0.24, 0.42, 0.89)	(0.19, 0.29, 0.44)	0.105
LSL	(0.33, 1.00, 1.00)	(1.00, 1.00, 1.00)	(0.32, 0.72, 1.11)	(0.30, 0.47, 0.95)	(0.24, 0.32, 0.47)	0.051
LVL	(1.25, 1.72, 3.94)	(0.90, 1.38, 3.16)	(1.00, 1.00, 1.00)	(0.28, 0.52, 1.38)	(0.20, 0.31, 0.48)	0.200
GLT	(1.12, 2.37, 4.15)	(1.05, 2.14, 3.33)	(0.72, 1.93, 3.62)	(1.00, 1.00, 1.00)	(0.25, 0.33, 0.84)	0.267
Timber	(2.29, 3.50, 5.24)	(2.14, 3.16, 4.21)	(2.07, 3.27, 4.99)	(1.18, 3.00, 4.08)	(1.00, 1.00, 1.00)	0.377

Table 15: The evaluation of the alternatives with respect to bending strength

Alternative	PSL	LSL	LVL	GLT	Timber	Weight
PSL	(1.00, 1.00, 1.00)	(0.72, 1.25, 2.95)	(0.27, 0.64, 1.00)	(1.12, 2.37, 4.15)	(2.85, 5.08, 6.88)	0.270
LSL	(0.34, 0.80, 1.38)	(1.00, 1.00, 1.00)	(0.42, 1.00, 1.90)	(1.05, 2.14, 3.33)	(2.29, 4.58, 6.43)	0.260
LVL	(1.00, 1.55, 3.68)	(0.53, 1.00, 2.37)	(1.00, 1.00, 1.00)	(1.12, 2.37, 4.15)	(2.29, 3.68, 5.81)	0.262
GLT	(0.24, 0.42, 0.89)	(0.30, 0.47, 0.95)	(0.24, 0.42, 0.89)	(1.00, 1.00, 1.00)	(1.55, 2.81, 4.66)	0.179
Timber	(0.15, 0.20, 0.35)	(0.16, 0.22, 0.44)	(0.17, 0.27, 0.44)	(0.21, 0.36, 0.64)	(1.00, 1.00, 1.00)	0.029

Table 16: The evaluation of the alternatives with respect to modulus of elasticity

Alternative	PSL	LSL	LVL	GLT	Timber	Weight
PSL	(1.00, 1.00, 1.00)	(0.72, 1.25, 2.95)	(0.27, 0.64, 1.00)	(1.12, 2.37, 4.15)	(2.85, 5.08, 6.88)	0.270
LSL	(0.34, 0.80, 1.38)	(1.00, 1.00, 1.00)	(0.42, 1.00, 1.90)	(1.05, 2.14, 3.33)	(2.29, 4.58, 6.43)	0.260
LVL	(1.00, 1.55, 3.68)	(0.53, 1.00, 2.37)	(1.00, 1.00, 1.00)	(1.12, 2.37, 4.15)	(2.29, 3.68, 5.81)	0.262
GLT	(0.24, 0.42, 0.89)	(0.30, 0.47, 0.95)	(0.24, 0.42, 0.89)	(1.00, 1.00, 1.00)	(1.55, 2.81, 4.66)	0.179
Timber	(0.15, 0.20, 0.35)	(0.16, 0.22, 0.44)	(0.17, 0.27, 0.44)	(0.21, 0.36, 0.64)	(1.00, 1.00, 1.00)	0.029

Table 17: The evaluation of the alternatives with respect to compression strength perpendicular to grain

Alternative	PSL	LSL	LVL	GLT	Timber	Weight
PSL	(1.00, 1.00, 1.00)	(1.00, 1.93, 4.08)	(0.64, 1.93, 2.63)	(1.40, 2.11, 4.00)	(2.95, 5.16, 7.24)	0.308
LSL	(0.25, 0.52, 1.00)	(1.00, 1.00, 1.00)	(0.47, 1.25, 1.90)	(0.93, 1.66, 2.95)	(2.41, 4.51, 6.54)	0.259
LVL	(0.38, 0.52, 1.55)	(0.53, 0.80, 2.14)	(1.00, 1.00, 1.00)	(0.90, 1.72, 3.50)	(2.67, 3.88, 6.21)	0.251
GLT	(0.25, 0.47, 0.71)	(0.34, 0.60, 1.07)	(0.29, 0.58, 1.11)	(1.00, 1.00, 1.00)	(1.55, 2.81, 4.66)	0.180
Timber	(0.14, 0.19, 0.34)	(0.15, 0.22, 0.42)	(0.16, 0.26, 0.37)	(0.21, 0.36, 0.64)	(1.00, 1.00, 1.00)	0.002

Table 18: The evaluation of the alternatives with respect to compression strength parallel to grain

Alternative	PSL	LSL	LVL	GLT	Timber	Weight
PSL	(1.00, 1.00, 1.00)	(1.00, 1.55, 3.68)	(0.42, 1.00, 1.90)	(1.12, 2.37, 4.15)	(2.67, 4.83, 6.88)	0.277
LSL	(0.27, 0.64, 1.00)	(1.00, 1.00, 1.00)	(0.31, 0.64, 1.38)	(0.93, 2.07, 3.27)	(2.41, 4.51, 6.54)	0.251
LVL	(0.53, 1.00, 2.37)	(0.72, 1.55, 3.27)	(1.00, 1.00, 1.00)	(1.12, 2.37, 4.15)	(2.95, 4.15, 6.53)	0.270
GLT	(0.24, 0.42, 0.89)	(0.31, 0.48, 1.07)	(0.24, 0.42, 0.89)	(1.00, 1.00, 1.00)	(1.25, 2.54, 4.36)	0.173
Timber	(0.15, 0.21, 0.37)	(0.15, 0.22, 0.42)	(0.15, 0.24, 0.34)	(0.23, 0.39, 0.80)	(1.00, 1.00, 1.00)	0.029

Table 19: The evaluation of the alternatives with respect to impact bending

Alternative	PSL	LSL	LVL	GLT	Timber	Weight
PSL	(1.00, 1.00, 1.00)	(0.72, 1.25, 2.95)	(0.44, 1.12, 1.53)	(1.12, 2.37, 4.15)	(2.14, 4.36, 6.43)	0.262
LSL	(0.34, 0.80, 1.38)	(1.00, 1.00, 1.00)	(0.28, 0.72, 0.80)	(0.72, 1.93, 3.62)	(1.55, 3.68, 5.72)	0.237
LVL	(0.65, 0.89, 2.29)	(1.25, 1.38, 3.55)	(1.00, 1.00, 1.00)	(1.00, 2.29, 4.08)	(2.29, 4.58, 6.43)	0.263
GLT	(0.24, 0.42, 0.89)	(0.28, 0.52, 1.38)	(0.25, 0.44, 1.00)	(1.00, 1.00, 1.00)	(1.55, 2.95, 5.16)	0.190
Timber	(0.16, 0.23, 0.47)	(0.17, 0.27, 0.64)	(0.16, 0.22, 0.44)	(0.19, 0.34, 0.64)	(1.00, 1.00, 1.00)	0.048

Table 20: The evaluation of the alternatives with respect to nail and screw holding ability

Alternative	PSL	LSL	LVL	GLT	Timber	Weight
PSL	(1.00, 1.00, 1.00)	(0.53, 1.00, 2.37)	(0.34, 0.80, 1.38)	(0.57, 1.12, 1.81)	(0.76, 1.38, 2.41)	0.206
LSL	(0.42, 1.00, 1.90)	(1.00, 1.00, 1.00)	(0.42, 0.89, 1.48)	(0.80, 1.38, 2.29)	(1.05, 1.63, 2.71)	0.216
LVL	(0.72, 1.25, 2.95)	(0.68, 1.12, 2.37)	(1.00, 1.00, 1.00)	(0.72, 1.40, 2.37)	(0.97, 1.38, 2.85)	0.221
GLT	(0.55, 0.89, 1.75)	(0.44, 0.72, 1.25)	(0.42, 0.71, 1.38)	(1.00, 1.00, 1.00)	(0.90, 1.72, 3.50)	0.201
Timber	(0.41, 0.72, 1.31)	(0.37, 0.61, 0.95)	(0.35, 0.72, 1.04)	(0.29, 0.58, 1.11)	(1.00, 1.00, 1.00)	0.156

Table 21: The evaluation of the alternatives with respect to machinability

Alternative	PSL	LSL	LVL	GLT	Timber	Weight
PSL	(1.00, 1.00, 1.00)	(0.72, 0.80, 2.41)	(0.21, 0.42, 0.64)	(0.30, 0.34, 0.68)	(0.30, 0.42, 0.75)	0.126
LSL	(0.42, 1.25, 1.38)	(1.00, 1.00, 1.00)	(0.22, 0.42, 0.68)	(0.34, 0.42, 1.05)	(0.32, 0.47, 0.93)	0.123
LVL	(1.55, 2.37, 4.66)	(1.48, 2.41, 4.58)	(1.00, 1.00, 1.00)	(0.47, 0.52, 1.31)	(0.64, 0.80, 1.81)	0.239
GLT	(1.48, 2.95, 3.38)	(0.95, 2.41, 2.95)	(0.76, 1.93, 2.14)	(1.00, 1.00, 1.00)	(0.64, 0.80, 1.81)	0.266
Timber	(1.33, 2.37, 3.38)	(1.07, 2.14, 3.16)	(0.55, 1.25, 1.55)	(0.55, 1.25, 1.55)	(1.00, 1.00, 1.00)	0.246

Table 22: The evaluation of the alternatives with respect to fire safety

Alternative	PSL	LSL	LVL	GLT	Timber	Weight
PSL	(1.00, 1.00, 1.00)	(1.00, 1.25, 3.32)	(0.42, 1.00, 1.25)	(1.25, 1.72, 3.94)	(1.72, 3.94, 6.02)	0.250
LSL	(0.30, 0.80, 1.00)	(1.00, 1.00, 1.00)	(0.37, 1.00, 1.38)	(1.25, 1.72, 3.94)	(1.72, 3.94, 6.02)	0.244
LVL	(0.80, 1.00, 2.41)	(0.72, 1.00, 2.67)	(1.00, 1.00, 1.00)	(1.55, 1.90, 4.21)	(2.04, 4.43, 6.33)	0.256
GLT	(0.25, 0.58, 0.80)	(0.25, 0.58, 0.80)	(0.24, 0.53, 0.64)	(1.00, 1.00, 1.00)	(1.48, 3.74, 5.62)	0.202
Timber	(0.17, 0.25, 0.58)	(0.17, 0.25, 0.58)	(0.16, 0.23, 0.49)	(0.18, 0.27, 0.68)	(1.00, 1.00, 1.00)	0.048

Table 23: The evaluation of the alternatives with respect to earthquake safety

Alternative	PSL	LSL	LVL	GLT	Timber	Weight
PSL	(1.00, 1.00, 1.00)	(1.00, 1.25, 3.32)	(0.35, 0.90, 1.11)	(1.12, 1.90, 3.74)	(2.85, 5.08, 6.88)	0.269
LSL	(0.30, 0.80, 1.00)	(1.00, 1.00, 1.00)	(0.44, 1.00, 1.18)	(1.00, 1.84, 3.68)	(3.16, 5.43, 7.24)	0.268
LVL	(0.90, 1.11, 2.85)	(0.84, 1.00, 2.29)	(1.00, 1.00, 1.00)	(0.90, 1.72, 3.50)	(2.29, 4.58, 6.43)	0.261
GLT	(0.27, 0.53, 0.89)	(0.27, 0.54, 1.00)	(0.29, 0.58, 1.11)	(1.00, 1.00, 1.00)	(2.41, 3.62, 5.91)	0.202
Timber	(0.15, 0.20, 0.35)	(0.14, 0.18, 0.32)	(0.16, 0.22, 0.44)	(0.17, 0.28, 0.42)	(1.00, 1.00, 1.00)	0.000

Table 24: The evaluation of the alternatives with respect to aesthetic

Alternative	PSL	LSL	LVL	GLT	Timber	Weight
PSL	(1.00, 1.00, 1.00)	(1.00, 1.25, 3.32)	(0.24, 0.54, 0.72)	(0.64, 0.84, 1.93)	(1.25, 1.69, 2.71)	0.217
LSL	(0.30, 0.80, 1.00)	(1.00, 1.00, 1.00)	(0.27, 0.68, 0.72)	(0.64, 0.84, 1.93)	(1.25, 1.69, 2.71)	0.196
LVL	(1.38, 1.84, 4.14)	(1.38, 1.48, 3.74)	(1.00, 1.00, 1.00)	(0.64, 1.05, 2.14)	(1.25, 1.69, 2.71)	0.254
GLT	(0.52, 1.18, 1.55)	(0.52, 1.18, 1.55)	(0.47, 0.95, 1.55)	(1.00, 1.00, 1.00)	(1.05, 1.72, 3.00)	0.228
Timber	(0.37, 0.59, 0.80)	(0.37, 0.59, 0.80)	(0.37, 0.59, 0.80)	(0.33, 0.58, 0.95)	(1.00, 1.00, 1.00)	0.105

Table 25: The evaluation of the alternatives with respect to impact on construction time

Alternative	PSL	LSL	LVL	GLT	Timber	Weight
PSL	(1.00, 1.00, 1.00)	(1.00, 1.25, 3.32)	(0.33, 1.00, 1.00)	(0.38, 0.52, 1.55)	(0.33, 0.53, 1.11)	0.179
LSL	(0.30, 0.80, 1.00)	(1.00, 1.00, 1.00)	(0.30, 0.80, 1.00)	(0.36, 0.47, 1.25)	(0.30, 0.44, 0.80)	0.128
LVL	(1.00, 1.00, 3.00)	(1.00, 1.25, 3.32)	(1.00, 1.00, 1.00)	(0.38, 0.52, 1.55)	(0.31, 0.47, 0.89)	0.192
GLT	(0.64, 1.93, 2.63)	(0.80, 2.14, 2.81)	(0.64, 1.93, 2.63)	(1.00, 1.00, 1.00)	(0.36, 0.58, 1.38)	0.239
Timber	(0.90, 1.90, 3.00)	(1.25, 2.26, 3.38)	(1.12, 2.11, 3.21)	(0.72, 1.72, 2.81)	(1.00, 1.00, 1.00)	0.262

3 RESULTS AND DISCUSSION

In this study, the fuzzy AHP method was used to evaluate a set of alternatives with respect to different criteria. After building the hierarchy model, a questionnaire was devised for the prioritization of the criteria and evaluation of the alternatives. The experts were asked to rate the elements in a five-point scale (1 = "equally important" to 5 = "absolutely important"). The rating of each expert was used to obtain the weights of the criteria and to determine the ranking of the alternatives. After the pair-wise comparison matrices were formed, the steps of Chang's approach were carried out to obtain the final result. The computed weights are summarized in Table 26.

The priorities of the main criteria were obtained from the pair-wise comparison matrix. From Table 2, it is possible to see that the weights of the economic, environmental, technical and social factors are 0.152, 0.103, 0.487 and 0.258, respectively. Based on the results, it can be said that the technical criterion is a more significant main criterion than the others.

As stated above, technical factors with a priority value of 0.487 should be considered as the most significant main criterion. The highest weighted sub-criteria of this main criterion are modulus of elasticity (0.186), bending strength (0.181) and compression strength parallel to grain (0.169). The second highest weighted main criterion is social factors (0.258), and the highest weighted sub-criterion of this main criterion is fire safety with a weight of 0.485. It is followed by earthquake safety (0.471). The third highest weighted main criterion is economic factors (0.152). When the weights obtained for the sub-criteria of economic factors are analyzed, it is observed that the highest weighted sub-criterion is acquisition cost with a weight of

0.447. It is followed by longevity of the material (0.441). The results presented in Table 2 show that the lowest weighted main criterion is environmental factors (0.103). The ranking of the sub-criteria of this main criterion in descending order with respective weights is impacts on the ecosystem throughout the life cycle (0.418) > recyclable material (0.317) > toxic property (0.265). Namely, impact on the ecosystem throughout the life cycle is a more important sub-criterion when compared with recyclable material and toxic property.

After determining the weights, the priority values of the alternatives were found. In other words, the resulting priority vectors were weighted by the priority vectors of the fourth level in order to achieve the priorities of the alternatives. The ranking of the alternatives in descending order with respective weights is LVL (0.239) > PSL (0.233) > LSL (0.220) > GLT (0.201) > Timber (0.107). According to the results, LVL is the most preferred alternative because it has the highest priority weight and PSL is the next recommended alternative.

Table 26: Summary of the weights

Main criteria	Sub-criteria	Global Weight*	PSL	LSL	LVL	GLT	Timber
Economic factors (0.152)	Acquisition cost (0.447)	0.068	0.108	0.175	0.142	0.207	0.368
	Disposal cost (0.017)	0.002	0.087	0.061	0.215	0.265	0.372
	Maintenance cost (0.095)	0.014	0.243	0.208	0.238	0.172	0.139
	Longevity of the material (0.441)	0.067	0.283	0.259	0.239	0.186	0.033
Environmental factors (0.103)	Impacts on the ecosystem throughout the life cycle (0.418)	0.043	0.117	0.055	0.175	0.247	0.406
	Toxic property (0.265)	0.027	0.062	0.000	0.164	0.308	0.466
	Recyclable material (0.317)	0.033	0.105	0.051	0.200	0.267	0.377
Technical factors (0.487)	Bending strength (0.181)	0.088	0.270	0.260	0.262	0.179	0.029
	Modulus of elasticity (0.186)	0.091	0.270	0.260	0.262	0.179	0.029
	Compression strength perpendicular to grain (0.145)	0.071	0.308	0.259	0.251	0.180	0.002
	Compression strength parallel to grain (0.169)	0.082	0.277	0.251	0.270	0.173	0.029
	Impact bending (0.159)	0.077	0.262	0.237	0.263	0.190	0.048
	Nail and screw holding ability (0.119)	0.058	0.206	0.216	0.221	0.201	0.156
	Machinability (0.041)	0.020	0.126	0.123	0.239	0.266	0.246
Social factors (0.258)	Fire safety (0.485)	0.125	0.250	0.244	0.256	0.202	0.048
	Earthquake safety (0.471)	0.122	0.269	0.268	0.261	0.202	0.000
	Aesthetic (0.003)	0.001	0.217	0.196	0.254	0.228	0.105
	Impact on construction time (0.041)	0.011	0.179	0.128	0.192	0.239	0.262

Note: The data given in parenthesis are the weights obtained by the pair-wise comparisons.
*The global weight was found by multiplying the local weight of an element with its corresponding weight.

4 CONCLUSION

In the present study, an evaluation model was devised to determine an alternative which possesses the best properties for load-bearing applications. The model was based on the comparisons of wood alternatives according to identified criteria. The fuzzy AHP method was employed to obtain the weights of the criteria and to rank the alternatives. In the light of the aim, four main criteria were determined, namely economic, environmental, technical and social factors. Then, each main criterion was subdivided into various sub-criteria. Finally, the evaluation model was implemented to select the best alternative for load-bearing applications. It was shown that the suggested method can be effectively utilized as a decision-making tool to select the most suitable alternative. The method is capable of handling multiple criteria and enables us to evaluate PSL, LSL, LVL, GLT and timber. Based on the priority values, it can be said that LVL is a more suitable alternative when compared with the others.

In conclusion, the evaluation model and results can assist building designers in making decisions during the selection of wood products. Furthermore, this study can present a route map to researchers to evaluate wood alternatives.

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ABSTRACT

When used in outdoor applications, unprotected wood develops color differences, cracks, and rough surface due to a number of deteriorating factors and eventually surface and performance of wood change in a short time. Various applications can be used to overcome such problems. In this study, we compared nano-scale (zinc oxide, copper oxide), micro-scale (MCQ - micronized copper quat) and common wood preservatives CCA (copper chrome arsenic) and ACQ (alkaline copper quat) in treated wood in terms of their effectiveness against mold fungi before and after artificial weathering process. Wood specimens were treated with the prepared solutions of nano copper oxide, nano zinc oxide, micronized copper quat, CCA and ACQ by vacuum methods. Accelerated weathering tests were performed in Xenon arc radiation cabinet with cycles of water spraying. Test parameters were arranged according to outdoor conditions. The test consisted of cycles of 102 min of radiation followed by 18 min of water spray in the same radiation conditions. The total duration of the test was 288 h for 3 specimens per each treatment group. Artificially weathered and treated wood specimens were evaluated for resistance to mold fungi according to the ASTM D4445 by employing three mold fungi. Following incubation with the fungi, the specimens were visually rated on a scale of 0–5. The mold scoring results collected before and after artificial weathering process showed that CCA and MCQ-treated specimens had the best performance properties; however, nano zinc oxide-treated wood specimens had the weakest performance against mold fungi.

KEYWORDS: Artificial weathering, Mold growth, Micronized copper, Nano copper, Nano zinc

1 INTRODUCTION

Wood and wood based materials in outdoors may lose their appearance and performance properties by time due to a number of biotic and abiotic factors. Color differences, cracks, and rough surface may occur within a few years in unprotected wood. These undesired formations could be avoided by various applications such as coatings, paints and varnish since such coating materials include special additives in their formulations i.e. UV absorbents, pigments, etc. On the other hand, micronized and nano-scale active ingredients for wood protecting chemicals have become important instruments in the wood protection industry. Novel systems with nano or micronized particles may have superior properties when compared to conventional wood preservatives (Clausen 2007; Matsunaga et al. 2007; Clausen et al. 2010, 2011; Akhtari and Nicholas 2013; Lykidis et al. 2013; Mantanis et al. 2014).

The main advantage of nano- or macro-scale wood preservation systems is to allow chemical substances to penetrate deeper into the wood uniformly (Mantanis et al. 2014; Mantanis and Jones 2012; Freeman and McIntyre 2008; Kartal et al. 2009). Research continues to explain the performance of nano- and micro-based wood preservative chemicals against leaching and weathering (Terzi et al. 2016; Mantanis et al. 2014). Terzi et al. (2016) reported that nano-particle forms of some metal oxides for wood protection were successful in terms of biological resistance and leaching. In this study, only nano-B_2O_3 treated and weathered specimens were not effective in preventing decay by *Gloeophyllum trabeum*. Mantanis et al. (2014) focused on the resistance of pinewood treated with zinc and copper based nano chemicals and mold-rating results showed that only nanozinc borate could inhibit the mold growth. CCA treated wood were more effective then MCQ and ACQ and nano-CuO treated wood specimens against decay fungi in soil block tests (Kartal et al.

2015). According to the recent studies, the effectiveness of nano and micronized particles-treated wood has not been fully elucidated and further research is needed.

The objective of this study is to evaluate mold resistance of nano and micronized particles-treated wood specimens after artificial weathering process compare with common preservatives.

2 MATERIALS AND METHODS

2.1 Wood specimens and treatments

The following commercial wood preservatives and nano particles were tested in the study (% m/m):

i) ACQ - water soluble form of Cu: Osmose Celcure AC-500 (Osmose Naturewood) (Osmose UK Protim Solignum Ltd): Quat (benzalkonium chloride) (4.8%), copper carbonate hydroxide (16.53%), boric acid (5%)-Preservative solution type: Water based

ii) Micronized ACQ - micronized form of Cu: Osmose Micro Pro, (Celcure MC) (Osmose UK Protim Solignum Ltd): Quat (benzalkonium chloride (10%), micronized copper carbonate hydroxide (17.39%), boric acid (5.23%)-Preservative solution type: Water based

iii) Nano-CuO - nano form of Cu: (NanoArc, 97.5%, 23-37 nm APS Powder, Alfa Aesar, Germany): CuO (97.5%)- Preservative solution type: Ammonia (Merk, 25%)

iv) CCA: Osmose K-33 e water soluble form of Cu: (Osmose UK Protim Solignum Ltd) CuO (10.5%), chromic acid (29.9%), arsenic penta oxide As_2O_5 (20%), water (39.6%)-Preservative solution type: Water based

v) Nano-ZnO – nano form of Zn: (NanoArc, 99%, 40-100 nm APS Powder, Alfa Aesar, Germany): ZnO (99%) - Preservative solution type: Ethanol (Merck, %99.9) based

Preservative solutions were adjusted in order to reach a target elemental Cu and Zn retention level of 0.64 kg m^3 in treated wood specimens.

Wood specimens (3 mm x 45 mm x 135 mm) were cut from the sapwood portions of Scots pine (*Pinus sylvestris L.*) lumber. The wood specimens (2 - 4 growth rings/cm) were free of knots and visible deposits of resins, and showed no visible evidence of infection from mold, stain, or wood-degrading fungi.

The specimens were conditioned to a moisture content of 10-12% in a conditioning room at 22 °C and 65% relative humidity (RH) for 2 weeks before preservative treatment. Pre-weighed wood specimens were vacuum treated for 40 min at 100 mm Hg with each treatment according to the AWPA standard E10 method (AWPA 2012). All the specimens were treated to a target retention of 0.64 kg/m^3 based on Cu and Zn elements, individually. After treatment, the specimens were blotted-dry and re-weighed to check solution uptake.

2.2 Accelerated weathering tests

Accelerated weathering tests were performed in Xenon arc radiation cabinet (Atlas Xenotest Alpha+, ATLAS), which included water spraying according to ISO 4892-2-A1 (ISO, 2006). The radiation source was a Xenon arc lamp (300 to 400 nm), using borosilicate filters. The test consisted of cycles of 102 min of radiation, a black body temperature of 65±5% followed by 18 min of water spray at the same radiation conditions, and a relative approximately of 100%. The total duration of the test was 288 h (144 h x 2 periods) for 3 specimens (3 mm x 45 mm x 135 mm) per each test group.

2.3 Mold resistance tests

Artificially weathered and treated wood specimens were evaluated for resistance to mold fungi according to the ASTM D4445. Wood specimens (7 mm tangential x 20 mm radial x 7 cm long) for mold resistance tests cut from the artificially aged wood specimens (3 mm x 45 mm x 135 mm). Three mold fungi, *Aspergillus niger, Penicillium fellutanum,* and *Trichoderma harzianum* were grown and maintained on 2% malt agar. Wood specimens (5 specimens per group) were sprayed with 1 ml of mixed mold spore suspension of the three fungi and incubated at 27 °C and 80% RH for 4 weeks. All fungi were obtained from the USDA Forest Service Forest Products Laboratory, Madison, WI, USA.

A mixed spore suspension of the three test fungi was prepared by washing the surface of individual 2-wk-old petri plate cultures with 10-15 ml of sterile DI water. Washings were combined in a spray bottle and diluted to approximately 100 ml with DI water to yield approximately 3 x 107 spores ml-1. The spray bottle was adjusted to deliver 1 ml of inoculum per spray. Wood specimens were sprayed with 1 ml of mixed mold spore suspension and incubated at 27 °C and 80% RH for 12 wk. Following incubation, specimens were visually rated on a scale of 0-5, with 0 indicating the specimen is completely free of mold growth and 5 indicating the specimen was completely covered with mold growth (0: no growth, 1: 20% coverage with mold fungi, 2: 40%, 3: 60%, 4: 80%, 5:100%).

3 RESULTS AND DISCUSSION

Average ratings of weathered and un-weathered wood specimens for resistance to the mold fungi are shown in Fig. 1. Generally, artificial weathering and treatment processes improved the mold resistance of specimens except that ACQ treated – weathered and nano ZnO treated – unweathered specimens. Mold resistance of control specimens were improved after the artificial weathering process and average mold ratings down under 1.0 from 5.0. Similar results were obtained in previous studies (Schoeman and Dickinson 1997; Cerniglia and Crow 1981. These results could be supported by the products of lignin photodegradation since the lignin sub-units released during photodegradation are aromatic and therefore fungitoxic (Schoeman and Dickinson 1997; Cerniglia and Crow 1981).

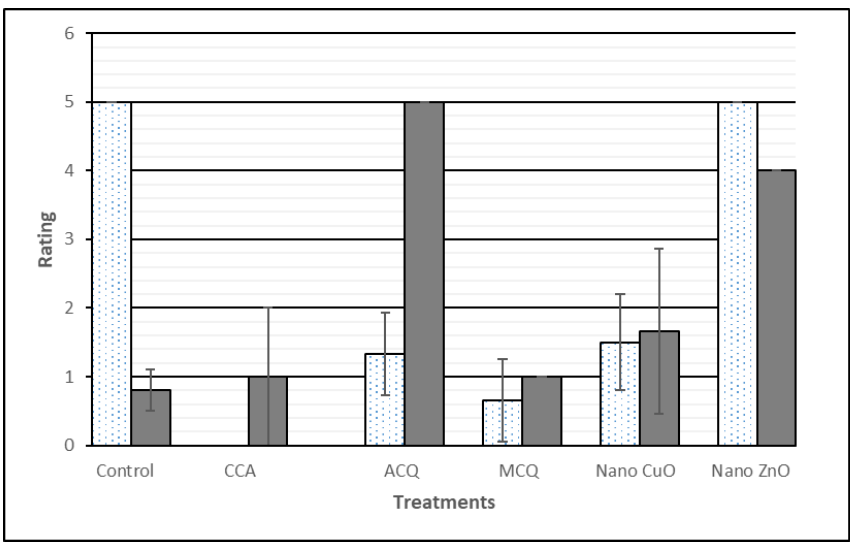

Figure 1: Average mold ratings for un-weathered (dotted bars) and weathered (filled bars) wood specimens (after 4 weeks): 0 indicates no mold growth, 1 = 20%, 2 = 40%, 3 = 60%, 4 = 80%, and 5 = 100% mold coverage.

The nano or micronized particle based preservatives used in this study did not prevent the growth of mold fungi on un-weathered wood specimens as well as CCA. Mold growth was not observed in the specimens impregnated with CCA during the test period. In contrast, MCQ and CCA treated and weathered specimen groups had similar mold inhibition effects on the wood specimens. Nano CuO treated specimens had also a good performance against mold growth. The worst mold inhibition performance was observed in nano ZnO treated wood specimens, regardless of weathered or unweathered. Mold inhibitor effectiveness of CCA and MCQ treated wood specimens were as good as weathered control specimens.

As we have stated in this study, it has been shown that nano-ZnO does not provide adequate protection against mold growth on the wood surface at previous studies (Kartal et al. 2009 and Mantanis et al. 2014). In contrast to previous studies, the growth of mold fungi on nano-CuO impregnated wood specimens was inhibited in this study. In previous studies, specimens were impregnated with a water-based nano-CuO suspension, while in this study, specimens were impregnated with an ammonia-based nano CuO solution (Kartal et al. 2009 and Mantanis et al. 2014). Gobakken and Westin (2008) showed that copper-organic based preservative (Wolmanit CX8, BASF/Wolman) treated pine wood specimens resisted against mold fungi after the 3.5 years natural weathering process.

These results supported that most Cu based preservatives have a desirable performance against mold fungi after artificial or natural weathering process.

4 CONCLUSION

This study reported on the resistance of pine wood vacuum treated with nano and micro particle based wood protection solutions versus CCA and ACQ as common wood protection system against mold fungi before and after weathering process. Results showed that the mold fungi were noticeably inhibited by MCQ, CCA and also nano CuO, while the nano ZnO did not inhibit the mold growth on wood specimens. It was also shown that the artificial weathering process improves the natural durability of wood against mold fungi. We can also offer ammonia-based nano CuO impregnation solution rather than water-based solution for an effective protection against mold fungi.

5 ACKNOWLEDGEMENTS

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The Effect of Some Technological Properties of Plywood Panels on Seismic Resistant Performance of Wooden Shear Wall

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ABSTRACT

Wooden buildings with many advantages such as being lightness, durability, earthquake resistant, healthy, insulating, and aesthetic are suitable for all kinds places especially in earthquake zones. The aim of this study is to investigate the effect of some technological properties of the plywood panels manufactured from some wood species grown in Turkey on seismic resistant performance of shear walls. Two different wood species (scots pine, spruce) and two different number of layers (5 and 7) were used in this study. Phenol formaldehyde resin was used as adhesive for plywood panels manufacturing. Bending strength and modulus of elasticity and density of plywood panels manufactured in an industrial plant were determined according to TS EN 310 and TS EN 323, respectively. Plywood panels were tested on full scale shear wall to determine the actual structural performance, maximum load and maximum displacement under the monotonic load according to ASTM E72. As a result of the study, the bending strength and modulus of elasticity values increased with number of layers for scots pine while the values decreased with number of layers for spruce. It was determined that maximum load values were increased for shear wall of each group with increasing bending strength and modulus of elasticity values of the plywood panels, while maximum displacement values of them were decreased.

KEYWORDS: Shear Wall, Plywood, Scots Pine, Spruce, Seismic Resistant Performance

1 INTRODUCTION

Light-frame wood construction is the primary building method for residential and light commercial structures and represents the largest portion of buildings in the United States. In recent years, light-wood framing has become a growing trend in midrise commercial and residential structures in part because of its economical construction technique, its wide availability of materials, and more recently because of its sustainability (APA, 2007; Phillps, 2015). Wood diaphragms (walls, floors, and ceilings), which provide lateral stability, are important components of these structures. They consist of framing (studs, joists, and blocking), sheathing (wood structural panels), and fasteners (nails, screws, and staples), which connect the sheathing to the framing (Demirkir et al., 2012).

Structural systems with massive wooden shear walls are becoming widespread in construction practice, particularly for pre-cast buildings. These structural systems have excellent thermal and acoustic insulation performance (Pozza et al., 2014). The shear walls are used as lateral resistant system in platform frame construction in North America whereas in Japan and other eastern Asian countries, it is preferred as consisting of post and beam structures with wood to wood connections in traditional construction (Gu, 2006). However, wood construction has not been widely used in Turkey. In Turkey, concrete buildings are preferred over wooden structures. Although Turkey is an earthquake country, there is few research on wood construction. Turkey does not have enough knowledge concerning the earthquake performance of wood based materials (Demirkir et al., 2012). In light-frame wood structures, shear walls are popular structural systems to resist lateral forces acting on buildings such as wind and earthquake loading (Neuenhofer, 2006). A typical light-frame shear wall is composed of sawn lumber framing members to which sheathing panels are attached with dowel-type fasteners such as nails or staples (Seim et al., 2016). Plywood and OSB are the best sheathing materials for resisting earthquake loads, because they are able to tolerate the greatest amount of displacement before failing. Moreover, when a wood-frame house is properly designed and constructed, plywood sheathing will not decay, and hence, will retain sufficient strength in the long term (Nanami et al., 2000; Demirkir et al., 2012).

A shear wall has two structural functions: lateral strength and stiffness. A shear wall must provide the necessary lateral strength to resist horizontal forces, such as those from wind or from an earthquake. When shear walls are strong enough, they transfer these horizontal forces to the next element in the load path below them, such as other shear walls, floors, foundation walls, slabs, or footings, primarily through the lateral resistance of the fasteners, which are usually nails (Palka, 1995). In general, the strength, stability, and life of a structure largely depend on the strength, rigidity, and durability of the joints (Scholten, 1965). In the case of shear walls sheathed with wooden structural panels, the strength primarily comes from the strength of the sheathing fasteners (McCormick, 2005). The stiffness of a shear wall depends on the combined stiffness of its three components: lumber, sheathing, and fasteners. The connections, such as sheathing nails, in the shear walls provide ductility, damping, and energy dissipation through mechanisms such as internal friction, unrecoverable damage, connection failure, and yielding of the metal fasteners (Chui et al., 1998; Lam et al., 1997). Altering the initial stiffness, resistance, or energy dissipation capacity of a lateral load resisting system can affect the performance of a structure (Dinehart and Shenton, 1998). However, their structural behaviour, especially under seismic action, is still required to be demonstrated, since their resistance, stiffness, ductility and dissipative properties must be fully assessed (Demirkir et al., 2012).

The evaluation of seismic performance of shear walls is essential for the seismic design of timber structures especially if the mechanical properties of the structures are governed by those of shear wall elements. The seismic performance of shear walls can be determined by the following criteria from the reversed cyclic and monotonic lateral loading tests, the initial stiffness, the yield strength, the ultimate strength, the ductility and the hysteresis damping (Yasumura et al., 2006).

Even though Turkey is an earthquake country, new developments and studies about the wooden buildings have not been followed in the country, causing there is few research on wood construction. The aim of this study is to investigate the effect of some technological properties of the plywood panels manufactured from some wood species grown in Turkey on seismic resistant performance of shear walls.

2 MATERIALS AND METHOD

2.1 Wood Material, Manufacturing of Plywood

Scots pine (*Pinus slyvestris*) and spruce (*Picea orientalis L.*) were used in this study. The logs were obtained from Trabzon region. The logs were steamed for 12-16 hours before veneer production. A rotary type peeler (Valette&Garreau - Vichy, France) with a maximum horizontal holding capacity of 800 mm was used for veneer manufacturing and rotary cut veneer sheets with dimensions of 1.2x2.4 m by 2 mm were clipped. Vertical opening was 0.5 mm and horizontal opening was 85% of the veneer thickness in veneer manufacturing process. After rotary peeling, the veneer sheets were oven-dried at 110°C, for 5-7% moisture content in a laboratory scale jet veneer dryer (manufactured by Hildebrand Holztechnik GmbH).

Five and seven-ply plywood panels, 10 and 14 mm thick, were manufactured by using phenol formaldehyde (PF) glue resin with 47% solid content. Veneer sheets were conditioned to approximately 6–7% moisture content in a conditioning chamber before gluing. The glue was applied at a rate of 160 g/m^2 to the single surface of veneer by using a four-roller spreader. The assembled samples were pressed in a hot press at a pressure of 8 kg/cm^2 and at 140°C for 10 and 14 min. Two replicate plywood panels were manufactured from each group.

2.2 Bending Strength, Modulus of Elasticity and Density

Bending strength and modulus of elasticity tests was carried out for plywood panels manufactured according to EN 310 (1993) standard. Twenty samples were used for the evaluation of plywood bending strength and modulus of elasticity. Density of plywood panels manufactured in industrial plant were determined according to EN 323 (1993). Twenty samples were used for the evaluation of plywood density.

2.3 Manufacturing of Shear Wall Sheathed Plywood and Determination of Its Seismic Resistant Performance

The test specimen, 2.4 by 2.4 m, was assembled to frame as shown in Figure 1. The frame elements are made of spruce timber in 5x10 cm sizes, and the upper and the edges are made of two pieces of timber beam. 12 pieces of 0.05x0.1x2.4m = 0.012 m^3 timber was used for each group test frame. Two repetitive systems were installed for each test group. The connection to the concrete floor of the frame system was made with appropriate fasteners (Figure 2). The plywood panels were fastened frame with 8d (76mm) common nails. The distance between the fasteners was 76 mm at the edge of the panel and 152 mm at the centre of the panel.

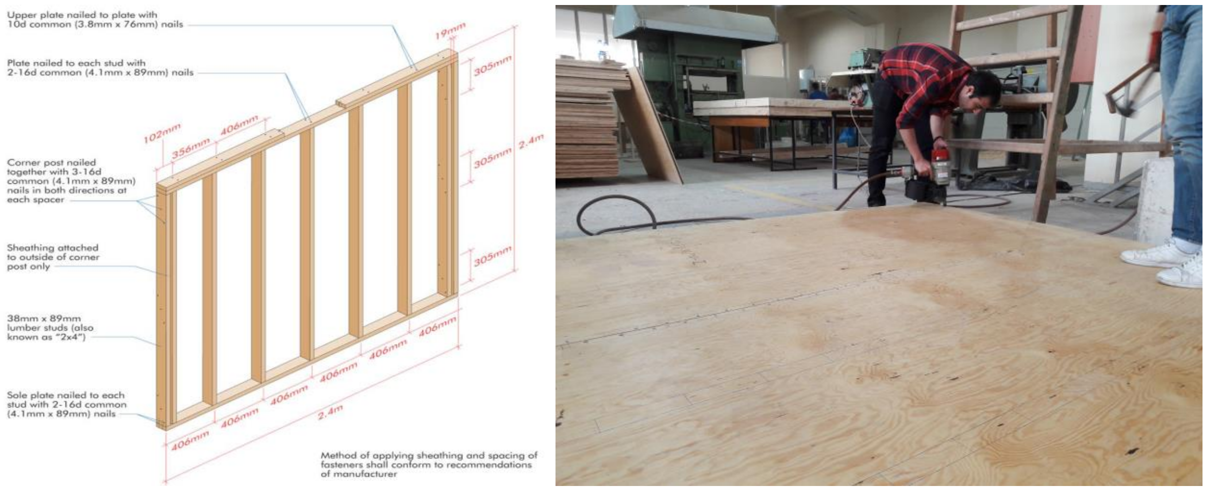

Figure 1: Standard wood frame and plywood sheathing

Figure 2: Mounting of shear wall to floor

Shear wall analysis test was carried out under linear load according to ASTM E72 (2014) standard. The schematic representation and visual representation of the test setup is given in Figure 3.

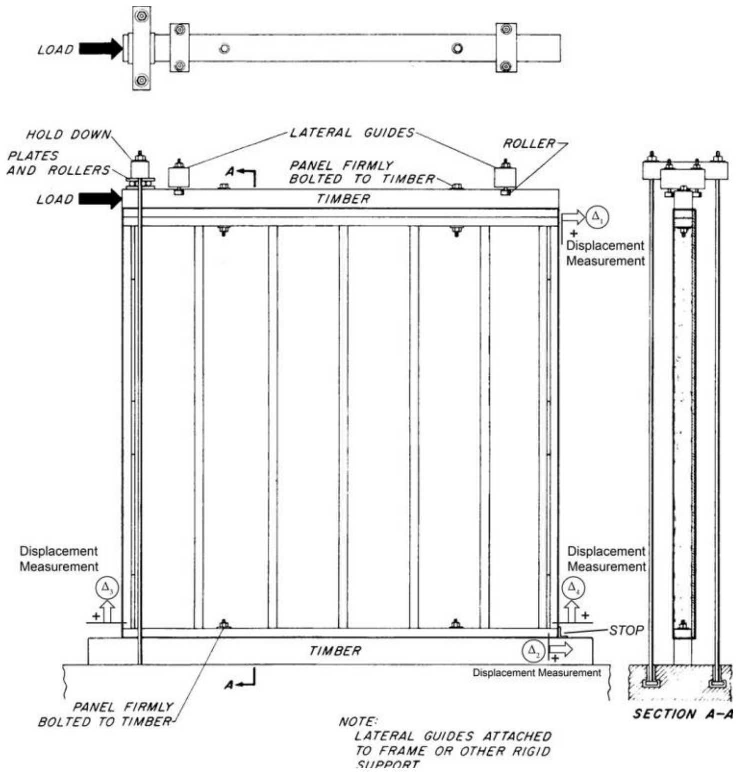

Figure 3: Racking load assembly

Shear wall analyses were carried out according to the ASTM E72 (2014) standard for displacements under loads of 354 kg, 712 kg and 1071 kg. The load was then loaded up to the maximum load that the shear wall could carry and displacements at the maximum load were determined. Initial stiffness, by selecting the points closest to 10 and 40% of the maximum load and fitting a straight line to the intervening points, were also calculated from this test.

3 RESULTS AND DISCUSSION

The density, bending strength and modulus of elasticity values of the plywood panels are given in Table 1 according to wood species and number of layers. Besides, stiffness, maximum load and maximum displacement at maximum load values of the shear wall sheathed Scots pine and spruce plywood are given in Table 1. Deformations at the end of the test of the shear walls using two plywood panels in the frame are shown in Figure 4-7.

Table 1: Test results of some technological properties of plywood and shear wall

Wood Species	Number of Layers	Density (g/cm^3)	Bending Strength (N/mm^2)	Modulus of Elasticity (N/mm^2)	Maximum Load (kg)	Maximum displacement (mm)	Stiffness (kN/mm)
Scots pine	5	0.585	64.27	7432.92	3876	61.64	1.28
	7	0.663	76.39	9878.15	4685	44.22	1.81
Spruce	5	0.510	53.24	6279.11	4329	69.34	0.99
	7	0.487	44.84	5527.11	3071	79.65	1.01

Figure 4: Deformations at the end of the experiment in the shear wall sheathed 5-ply Scots pine plywood

Figure 5: Deformations at the end of the experiment in the shear wall sheathed 7-ply Scots pine plywood

Figure 6: Deformations at the end of the experiment in the shear wall sheathed 5-ply spruce plywood

Figure 7: Deformations at the end of the experiment in the shear wall sheathed 7-ply spruce plywood

According to the obtained results, the bending strength values of the plywood panels with 7 layers were found higher than those of the panels with 5 layers in the Scots pine plywood. In spruce plywood, the panels with 5 layers gave slightly higher values. It might be explained the effect of density of the panels on mechanical properties. Because density values of 7-ply spruce plywood panels were lower than 5-ply spruce plywood panels. It is known that panels density has positive effect on the bending strength (Demirkır et al., 2013). It is stated that the mechanical properties of the plywood produced from the veneers of density woods are higher (Bal and Bektaş, 2013). When examined in terms of wood species, the highest density values were found in Scots pine plywood and the lowest values in spruce plywood. The primary impact on the density of the plywood is wood specie (Demirkır, 2012). Demirkır et al. (2013) also stated that the difference in density values of plywood panels might be resulted from the raw material density. In the literature, the density of the Scots pine wood is determined as 0.49 g/cm^3, and the density of spruce wood is determined as 0.43 g/cm^3 (Bozkurt and Erdin, 1992). As similar with the results in present study, Peker and Tan (2014) found that the bending strength and modulus of elasticity values decreased with the increase in the number of layers in spruce plywood. The bending strength values of all plywood panels met the requirements (40 N/mm^2) given in DIN 68705-3.

As can be seen from Table 1, the maximum load values of the shear wall sheathed plywood panels increased with increasing the bending strength and modulus of elasticity values of the panels. However, maximum displacements at maximum load are reduced by increasing these values. It is stated that the lateral load resistance of a timber frame system depends on the rigidity of the timber, the coating material and the connecting elements used on the shear wall. (Li et al., 2007). The lateral resistance of shear walls is generally influenced by 4 factors which are stiffness, bending strength, resistance at break and ductility (Demirkir, 2012). Stiffness defined as the rigidity of an object is one of the most important factors affecting stability of buildings. The highest rigidity value was obtained from Scots pine 7-ply plywood panels as seen in Table 1.

4 CONCLUSIONS

Recently, it is focused on awareness of earthquake and development of earthquake-resistant structures in Turkey. Prime Ministry Disaster and Emergency Management Presidency has announced that studies about designing of the earthquake resistant building, materials and standards are supported under the earthquake strategy and action plan 2012-2023 Strategy B.1.3. Wooden buildings with many advantages such as being lightness, durability, earthquake resistant, healthy, insulating, and aesthetic are suitable for all kinds places especially earthquake zones. However, Turkey does not have enough knowledge concerning the earthquake performance of wood based materials. If studies regarding wooden structures and materials are increased, more natural and safe buildings can be built. The aim of this study is to investigate the effect of some technological properties of the plywood panels manufactured from some wood species grown in Turkey on seismic resistant performance of shear walls. As a result of the study, the bending strength and modulus of elasticity values increased with number of layers for scots pine while the values decreased with number of layers for spruce. It was determined to increase maximum load and decrease maximum displacement for shear wall of each group with increasing bending strength and modulus of elasticity values of the plywood panels.

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Effect of Drying Types and Polystyrene Density on Thermal Conductivity of Polystrene Composite Particleboard

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ABSTRACT

Thermal conductivity of wood material is superior to other building materials because of its porous structure. Thermal conductivity is a very important parameter in determining heat transfer rate and is required for development of drying models in industrial operations such as adhesive cure rate. Thermal conductivity is used to estimate the ability of insulation of material. Thermal conductivity of wood material has varied according to wood species, direction of wood fiber, resin type, and addictive members used in manufacture of wood composite panels.

The aim of the study is to produce a new wood composite material with insulating properties by using insulating material called as polystyrene instead of formaldehyde based adhesives as bonding material. Five different wood species (beech, poplar, alder, pine, spruce), six different polystyrene species with different density values were used in this study and three layers particleboard in 18 mm thickness was produced. Urea formaldehyde resin (UF) was used in conventional panels manufacturing as adhesive. Technical drying was applied half of the test groups, while the other group was conditioned until reach to 12% equilibrium moisture content at room temperature as natural before manufacturing process to determine the effect of drying. The thermal conductivity of new composite panels were determined according to ASTM C 518 & ISO 8301.

According to the results from the study, thermal conductivity values obtained from natural drying were found to be higher than technical drying. The type of binder that gives the lowest thermal conductivity values among tree species in natural drying is generally S5. The lowest values in technical drying were obtained from panels bonded with XPS.

KEYWORDS: Thermal Conductivity, Polystyrene Composite Particleboard, Drying Types

1 INTRODUCTION

Reducing energy consumption of buildings is required in order to counteract global warming induced by carbon dioxide, and thermal insulation of a building is an important part of this process. One of the development concepts used in the design of insulation materials is to aim to achieve a low thermal conductivity (*k*-value). An alternative development concept is to aim to use environmentally friendly products. One aspect of being environmentally friendly is effective utilization of unused resources. Using agricultural wastes, forest product wastes, textile wastes, and so on, as the raw materials of thermal insulation products is favorable for working towards a sustainable society based on resource recycling (Sekino, 2016). Many types of insulation materials are available which differ with regard to thermal properties and many other material properties as well as cost. Current thermal insulation materials in the construction market are generally inorganic materials e.g. extruded polystyrene (XPS), expanded polystyrene (EPS), polyisocyanurate and polyurethane foam (Cetiner and Shea, 2018). Expanded polystyrene is proved to be an excellent insulating medium which exhibits consistent thermal performance over the range of temperatures normally encountered in buildings (Lakatos and Kalmar, 2012). Expanded polystyrene has a thermal conductivity coefficient λ=0.03 w/mK, which has led to the wide use of polystyrene panels for the rehabilitation and thermal insulation of buildings (Claudiu et al., 2015). Expanded polystyrene, commonly known as styrofoam, is a polymer material present in a wide variety of products used in daily life, ranging from disposable goods to construction materials, due to its low cost, durability, and light weight (Jang et al., 2018). Its manufacture involves the heating of expandable beads of polystyrene with steam, and the placement of these heated expanded polystyrene beads into moulds to create prismatic blocks of EPS (Horvath, 1994). EPS has a very low density. An individual bead of EPS would be approximately spher-ical and contains only about 2% of polystyrene and about 98% of air (Dissanayake et al., 2017). The EPS is a chemically inert material not biodegradable, ie, it does not decompose, does not disintegrate, does not disappear in the environment and does not contain CFCs, consequently the EPS does not chemically contaminate the soil, water or air. However it can be an environmental problem if not recycled because it is considered an eternal material and it takes up too much space (due to its low density) (Schmidt et al., 2011.). Hence, reuse of EPS is beneficial in terms of environmental protection (Fernando et al., 2017). Wood–styrofoam composite (WSC) panels may be a very suitable solution for environmental pollution caused by styrofoam waste and also formaldehyde released from wood based panels (Demirkir et al., 2013).

Due to the increasing demand for wood products and the decreasing in the quality and presence of wood raw materials, the importance of composite wood products has increased steadily. This has led to an enormous increase in the use of adhesives in the forest products industry and has improved the use of wood raw materials resources. It is stated that adhesives used in about 70% of application in forest product industry (Aydin et al., 2010). Among the wide range of adhesives/resins employed in the wood industry, the most important are the amino resins. These include urea-formaldehyde (UF) resins, melamine-formaldehyde (MF) resins and melamine-urea-formaldehyde (MUF) resins. Their widespread use is due mainly to low cost and good performance. UF resins are commonly used in the manufacture of wood products, especially PB and MDF, due to their high reactivity, low cost and excellent adhesion to wood (Gonçalves et al., 2018). Over 90% of particleboard panels are bonded with urea formaldehyde resin which provides strong and durable bonds at a low cost (Nemli and Ozturk, 2006). The major disadvantages are the low moisture resistance and formaldehyde emission during the production and life time of the panels (Gonçalves et al., 2018). Formaldehyde is one of the most ubiquitous and priority pollutants indoors. Numerous studies have verified that short-term exposure to formaldehyde could cause eye, nose and throat irritation (Liang et al., 2016). The International Agency for Research on Cancer (IARC) classified formaldehyde as carcinogenic to humans, which led to stricter regulations on the emissions of formaldehyde (Resetco et al., 2016). Due to this carcinogenic nature, alternative, non-formaldehyde based adhesives, have been under intensive investigation to mitigate the emission problem (Sulaiman et al., 2018). Although some of these new adhesives have already been used in industrial applications, their supply is limited which may be due to the high modification costs or some their poor properties, for example, low wood resistance (Frang et al., 2013). Therefore, the chemicals and adhesives will use are both cheap and easily accessible and its technological properties qualify according to usage of wood based panels (Colak et al., 2016).

WSC can be manufactured without synthetic resins such as urea-formaldehyde or phenol-formaldehyde. Therefore WSC manufacturing can be suitable for both environmental and economic perspective. WSC manufacturing process also does not need a gluing machine or the preparation of glue mixture. So, the production process has been simplified (Demirkir et al., 2013).

The objective of this study was to investigate the thermal conductivity properties of particleboard manufactured with polystyrene instead of formaldehyde based adhesives used in particleboard production.

2 MATERIAL AND METHODS

Beech (*Fagus orientalis Lipsky*), poplar (*Populus deltoides I-77/51*), alder (*Alnus glutinosa subsp. barbata*), pine (*Pinus Silvestris*) and spruce (*Picea orientalis L.*) wood particles, were used in the manufacture of particleboards. They were chipped using a hacker chipper before the chips were reduced into smaller particles using a knife ring flaker. First, the wood particles were screened using a horizontal screen shaker.

The chips that pass through a 3 mm mesh screen and leave on a 1.5 mm mesh screen are classified in the middle layer and the chips that pass through a 1.5 mm mesh screen and leave on a 0.5 mm mesh screen are classified in the outer layer for use. After these processes, technical drying was applied half of the test groups (particles were dried using a lab-customized hot air-dryer at 90°C to 3% moisture content) while the other group was conditioned until reach to 12% equilibrium moisture content at room temperature as natural before manufacturing process to determine the effect of drying. Six different polystyrene species with different density values (10, 16, 20, 24, 30, 30-32 kg/m^3) instead of formaldehyde based adhesives were used in the manufacture of particleboards as bonding material. Urea formaldehyde resin (UF) was used in conventional panels manufacturing as adhesive. It was used urea formaldehyde resin with a solid content of 55%. Based on oven-dry particle weight, 8% and 10% resin were applied using an atomizing spray gun for the core and face layers, respectively. The ratio of the face thickness to the total thickness of a panel known as the shelling ratio was 0.40 for all samples. 20% solution of ammonium chloride (NH_4Cl) as a hardener was added at 1% in oven-dry-weight basis to resin.

In the production of polystyrene composite particleboard (PCP); the waste fragments of each polystyrene species were broken in a size of 1.5 - 3 mm in a polystyrene crusher. After these processes, the polystyrene chips were mixed homogeneously with 10% polystyrene for the outer layer and 8% for the middle layer based on the particle weight. It was formed PCP panel drafts. Polystyrene composite particleboards manufactured with 3 layer as shown in Figure 1. No hardener was used in the production of PCP panels.

Figure 1: Polystrene composite particleboards draft

Conventional and PCP panels were manufactured at a pressure of 23-25 kg cm^2 at 150°C for 10 min. The ratio of the face thickness to the total thickness of a panel known as the shelling ratio was 0.35 for all specimens. The dimensions and target density of particleboards were 55 cm × 55 cm × 1.8 cm, and 0.68 gr/cm^3, respectively. After pressing, panels were conditioned at a temperature of 20°C and 65% relative humidity for three weeks. Two panels for each panel type were produced. Types of test panels as well as bonding types are given in Table 1.

Table 1: Form of the groups according to bonding types

Groups	**Bonding Types**	**Density (kg/m3)**
Conventional (Control)	Urea Formaldehyde (UF)	-
S1	Expanded Polystyrene (EPS)	10
S2	EPS	16
S3	EPS	20
S4	EPS	24
S5	EPS	30
S6	Extruded Polystyrene (XPS)	30-32

The thermal conductivity of the panels were determined according to ASTM C 518 & ISO 8301 (2004). Sample size required is 300 x 300 x 18 mm. Two specimens were used for each test group. The Lasercomp Fox-314 Heat Flow Meter shown in Fig. 1 was used for the determination of thermal conductivity. The top and lower layers of it was set for 20°C and 40°C for all specimens, respectively. The panels temperature during the measurement of the thermal conductivity was maintained to these constant temperatures.

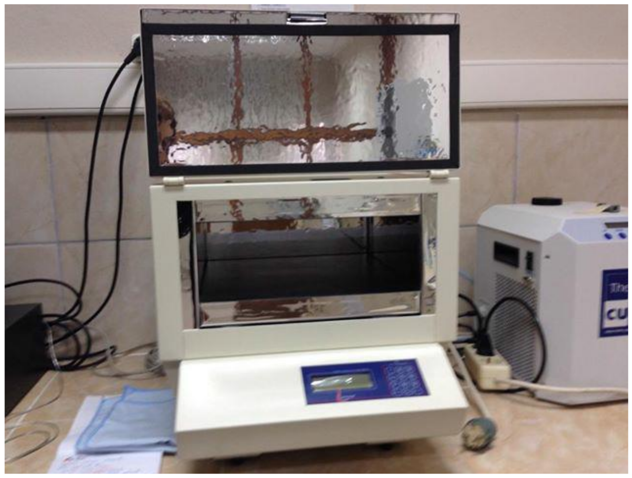

Figure 2: Lasercomp Fox-314 heat flow meter

3 RESULTS AND DISCUSSION

Average values of thermal conductivity of conventional particleboard (control) and polystyrene composite particleboard are given in Table 2. In Figure 3, it is shown that the effect of wood species, bonding types and drying technique on thermal conductivity of panels.

Table 2: Average values of thermal conductivity of panels (W/mK)

Drying Type	Wood Species	Control (UF)	S1	S2	S3	S4	S5	S6
Natural Drying	Beech	0,1048	0,1008	0,09891	0,09413	0,09467	0,09245	0,09945
	Poplar	0,0939	0,1004	0,09266	0,09276	0,09307	0,09529	0,09385
	Alder	0,1003	0,09674	0,09700	0,09668	0,09664	0,09385	0,09446
	Pine	0,1042	0,09705	0,09578	0,09482	0,09802	0,09428	0,09616
	Spruce	0,1047	0,1011	0,1023	0,09794	0,09739	0,09692	0,1017
Technical Drying	Beech	0,1048	0,08995	0,08742	0,09167	0,08866	0,08621	0,08221
	Poplar	0,0939	0,08250	0,08316	0,08443	0,08239	0,08461	0,08423
	Alder	0,1003	0,08642	0,08662	0,08957	0,08783	0,08398	0,07904
	Pine	0,1042	0,08128	0,08679	0,08602	0,08441	0,08557	0,07907
	Spruce	0,1047	0,09318	0,09075	0,08788	0,08783	0,08673	0,08266

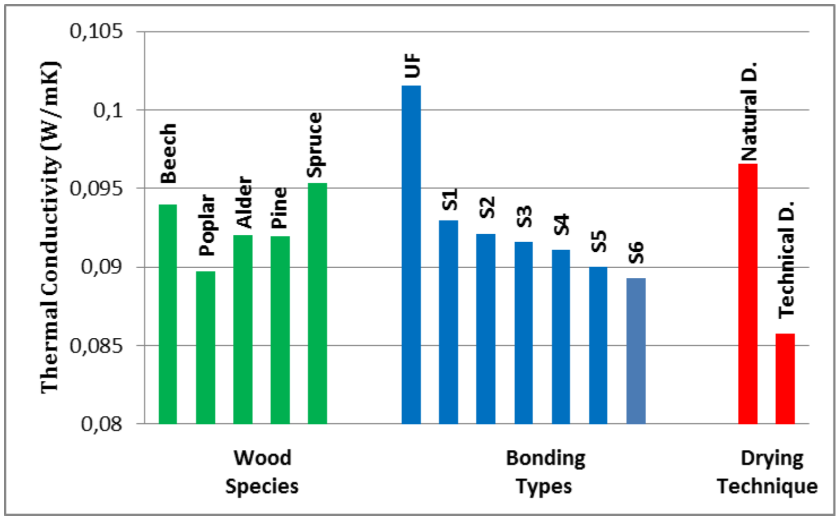

Figure 3: Effects of wood species, bonding types and drying technique on the thermal conductivity of particleboard (W/mK)

The heat conductivity of wood is dependent on a number of factors of varying degrees of importance. Some of the more significant variables affecting the rate of heat flow in wood are the following: (1) density of the wood; (2) moisture content of the wood; (3) direction of heat flow with respect to the grain: (4) kind, quantity, and distribution of extractives or chemical substances in the wood. Such as gums, tannins, or oils: (5) relative density of springwood and summerwood; (6) proportion of springwood and summerwood in the timber; (7) defects, like checks, knots, and cross grain structure (MacLean, 1941). Several studies about thermal conductivity of wooden materials showed that thermal conductivity was influenced from the thickness of composite materials, density, moisture content, the ratio of early and late wood zones, temperature, and flow direction of heat (Suleiman et al., 1999; Bader et al., 2007; Sonderegger and Niemz, 2009; Demirkir et al., 2013).

As can be seen from Table 2, the thermal conductivity values of conventional particleboards manufactured with urea formaldehyde adhesive were found to be higher than those of PCP panels. Generally, the lowest thermal conductivity values were obtained from the polystyrene composite particleboard bonded with S5 and XPS in the natural and technical drying, respectively.

According to the results from the study, thermal conductivity values obtained from natural drying were found to be higher than technical drying. In literature, the effect of the temperature on thermal conductivity of wood varied. Zhou et al. (2013) indicated for the MDF panels that thermal conductivity increased with the temperature up to 50°C and then decreased with increasing temperature in the range of 50°C to 100°C. On the other hand, it was stated that thermal conductivity of wood increases as temperature of the wood increases (Counturier et al., 1996). Tenwolde et al. (1988) also reported that the conductivity increased approximately 10 percent for every 50°C increase in temperature. The density of air filling the voids in the wood decreases as temperature increases, and this causes lower heat conduction through the voids (Suleiman et al., 1999; Aydin et al., 2015).

As shown in Figure 3, the usage of high density polystyrene in the manufacturing of PCP panels caused an decrease in thermal conductivity values. The panels manufactured from spruce gave the highest thermal conductivity values. The lowest values were found in the panels manufactured from poplar. It is known that density and moisture content have increasing effect on thermal conductivity of wood. As can be seen from Fig. 3, the lowest thermal conductivity values were determined for the panels obtained from poplar. The highest thermal conductivity values were obtained from spruce and beech. It was stated that the thermal conductivity of wood-based composites, as for wood, are strongly dependent on density and thermal conductivity of wood increases as density of the wood increases (Kamke and Zylkowski 1989; Kol and Altun 2009; Aydin et al., 2015). Also the extractive contents of spruce wood may have an increasing effect on the thermal conductivity of spruce particleboard panels. Simpson and Tenwolde stated that extractive content and a number of checks and knots in wood also play an important role on thermal conductivity (Demirkir et al, 2013).

4 CONCLUSION

The aim of the study was to investigate those effects of wood species, bonding types and drying technique on thermal conductivity properties of polystyrene wastes in particleboard production as a bonding material. Thermal conductivity values of traditional particleboard panels with urea formaldehyde adhesive were found to be higher than those of PCP panels. This study showed that particleboards produced from polystyrene wastes can be used as an alternative insulation material for internal use.

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Brand Management Strategies for Furniture Enterprises: Case Study of Ordu and Giresun

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ABSTRACT

In today's dynamic business world, enterprises which are innovative, open-minded, knowledge-creating can be kept their assets as powerful players on the market they are in. In this challenging competitive environment, enterprises need to have a realistic and sustainable vision. Sustainability is an important focus for enterprises. Being recognizable and easy accessibility are the goals of each enterprise. One of the necessities to achieve this is to have a brand that is effectively managed on the market. Creating effective brand value in the domestic and foreign markets requires the existence of strategic studies. In the competitive environment where change and transformation are very fast, brand concept is one of the most critical concepts for enterprises one of the most critical concepts for businesses to tell themselves and reach their customers.

One of the most important branches of the Turkish forest products industry is the furniture industry. Turkish furniture industry is a heterogeneous structure which is consisted numerous enterprises that is micro and macro structure. Because of these heterogeneous structures and the multiplicity of structural and economic problems they have, enterprises need the change and improvement Customers are at the forefront of effective determining factor when most of the businesses are taking a decision.

This study is aimed to determine brand management strategies of furniture enterprises. Accordingly, current brand studies, brand assets, future plans related to brands, how their brands are seen in comparison with other brands in the sector, and their views on how their brands are transforming have been tried to be determined. In this context, data were collected with survey method from 45 furniture enterprises reached from Ordu and Giresun provinces which are located in Blacksea Region of Turkey. The obtained data were analyzed in computer environment, evaluations were made and suggestions were developed.

KEYWORDS: Brand management, Turkish furniture industry, Furniture enterprises, SMEs.

1 INTRODUCTION

Nowadays, it can be said that the use of the brand as a marketing variable is an important competitive tool for businesses. For this reason, it is important for businesses to decide which brand strategy will apply. Whatever brand strategy is used, the foundation for the implementation of brand strategies (brand architecture) for businesses is a strategic tool. And it can be stated that the selected brand strategy will be a significant influence on the effectiveness of the marketing efforts of the enterprises (Sönmez, 2010).

The traditional approach is to communicate with the customer through only a few channels. Radio, television, printed media, etc., as it is not too difficult to convince the customer, and because the competition is not too much; most of the company's products could easily be sold, and the customer itself is not in big expectation. He basically looked at the functional benefits of the product he bought and bought the product or service accordingly. Today, competition is very intense and categorizing the customers does not make any sense. Consumers can compare all brands in a very short time. It basically focuses on its own benefit. Even in the face of a small mistake, the brand can leave. In such a challenging environment, the best means of competition is to 'become a brand'. The main goal of every company should be to build the brand in minds. The most competitive advantage in the current business world; It is a brand and it is to have branded products (web-4).

The main aim of the branding is to gain competitive advantage through distinctiveness, awareness and the emotional and benefit-based relationship established by the consumer and the customer. The branding effort may also aim to provide a distinction based on a product, idea or image. In order to create and manage a successful brand, it is necessary to recognize the target consumer or potential customers according to their motivation, enjoyment, preferences, needs, and expectations. In order to ensure successful branding, the processes such as identity, identity, positioning and awareness of the brand are carried out without supporting the objectives of the campaign and supporting each other (Alikişioğlu, 2012).

Whatever the size of their enterprise and what they do, there are certain features that make sense for current and potential employees. These features are the reasons why they prefer the enterprise. These features cause a sense of branding in the minds of people about the business. The studies have shown that employees who have a strong employer brand increase their level of commitment, increase their motivation and performances, increase the number and quality of applications and accumulate more qualified employees in their organizations, decrease recruitment costs, make long term impact, increase managerial satisfaction, culture, and their competitiveness (Chief, 2011).

The strategy is a kind of plan . However, the strategy is more dynamic than routine plans and requires that the competitors and their possible actions, that is, their likely course of action, that can affect the outcome of the business, are taken into account (Chief, 2011). Markets must have a vision that is aware of change, knows what to do when, and can make the brand live in the long run with integrated strategies. There will always be brands that make these two good (Web-4).

The brand strategy is expressed as a long-term plan to achieve the brand's goals. However, if there is a confusion that the brand is a product, name, website or logos in the company, it is necessary to understand that the concept of the brand is not only a complementary element, but also includes the values, feelings, habits and place where the consumer lives. Everyday, it enters a new brand and consumers fight with a physical or digital brand bombardment in the bazaar. Brands wanting to exist without being victims of the consumer's tiredness need to reflect their company's goals on their brands and determine their commitment to the consumer's contribution to his life with clear lines. While a new channel is added to the channels that the brand meets with the consumer every day, it needs that the communication, the word, the message and the visual in each channel show a consistent line, attitude and expression. Consistent activities that increase the brand's recognition acceleration also serve as a reinforcer in terms of customer loyalty. To carry out the communication demanded by the new generation consumers, to smooth the transition between the electronic devices, to adopt the language of the mark with the platform's own language and to make the messages invisible but powerful, are the notes leading to the success of the consistency move (Web-2).

Global companies, that is, brands operating in international markets, need to apply strategies that are in line with the local values of the different countries in which they operate. If not the local customer expectations, culture structure, habits, traditions, lifestyle etc, are understood and are not adapted accordingly, the products can not be kept in new and different markets, can't be successful and in a short time, they may have to leave the market or change products. While products are adapted accordingly to socio-cultural differences, the factors such as climatic conditions of the local bazaar, development levels of countries, religious structure, income level, packaging and labeling, taste should be considered. In addition, it is also possible for companies to maintain their brand identities there, using global messages, while making appropriate adjustments to their market. However, if the given current message is contradictory to the cultural or product that is adapted to the country, it may be necessary to create a completely new message (Web-3). It is stated that Turkish firms do not follow a certain analysis method when they enter new export markets and therefore major parts of the big picture are not noticed (Web-1).

One of the most important branches of the Turkish forest products industry is the furniture industry. Turkish furniture industry is a heterogeneous structure which is consisted numerous enterprises that is micro and macro structure. Because of these heterogeneous structures and the multiplicity of structural and economic problems they have, enterprises need the change and improvement Customers are at the forefront of effective determining factor when most of the business are taking a decision. This study is aimed to determine brand management strategies of furniture enterprises. Accordingly, current brand studies, brand assets, future plans related to brands, how their brands are seen in comparison with other brands in the sector, and their views on how their brands are transforming have been tried to be determined.

2 MATERIAL AND METHOD

The main purpose of the research is to determine brand management strategies of furniture companies. The brand assets of the furniture enterprises, the importance of perceiving the brand value and the importance given to the brand have been questioned.

The sample of the survey is limited to the provinces of Ordu and Giresun in the Black Sea region of Turkey. It has been actively tried to reach all the furniture enterprises operating in Ordu and Giresun.

The survey form was used as data and information gathering tool in the research. The prepared questionnaire was applied on a sample and the clarity and clarity of the questions on the questionnaire were tested. With the information gathered, necessary regulations were made in the questionnaire form and the questionnaire form was put into practice. Surveys were conducted with authorized interviewers at face-to-face meetings. Survey work was created via Google Drive and responded online by sending them to their email address. 45 enterprises responded the questionnaire forms. The survey was conducted in July and August 2018.

The data considered in the study consist of demographic information for determining the characteristics of the enterprises and statements aimed at evaluating the brand management strategies of the enterprises. , 5 Likert scale (Strongly Agree, Agree, Undecided, Disagree, Strongly Disagree), yes / no questions and multiple choice questions were used to the evaluations of the enterprises being questioned with 23 items.

3 FINDINGS

3.1 Demographic Information

The furniture enterprises participating in the survey, 66.7% were in Ordu (30 enterprises) and 33.3% were in Giresun (15 enterprises). 62.2% of Participating Enterprises are Private Company, 33.3% are Limited Companies and 4,4% are Joint Stock Companies. When the distribution of enterprises according to the years of establishment is examined, it is observed that the enterprises established between 2001 and 2010 (33.3%) and the enterprises established between 1981 and 1990 (31.1%) are concentrated. Then, 15.6% are from 1991-2000, 15.6% are from 2011 and after, and 4.4% are from 1980 and before.

55.6% of the respondents are business owners, 22.2% are professional managers, 11.1% are engineers / architects / technicians, 11.1% employee. 84.4% were male and 15.6% were female. 33.3% of the respondents were aged 33-39, 28.9% were aged 40-46, 13.3% were aged 47-53, 11.1% were aged 26-32, 6% 7 are 19-25, and 6.7% are in the 53 and over age group. According to educational status, 42.2% of respondents were university, 26.7% were vocational high school, 15.6% were high school, 8.9% were primary education, 4.4% were secondary education and 2.2% is postgraduate persons.

31.1% of the enterprises are in the organized industrial zone, 31.1% are in the urban neighborhood, 31.1% are the small industrial sites and 6.7% are in the free zones. Number of employees is between 1-9 in 64.4%, between 10-49 in 33.3%, and between 50-249 in 2.2%. There are no businesses with 250 employees. There are 9 engineers, 12 architects, 28 technicians and 11 industrial designers. It was stated by managers that 77.8% of the enterprises had medium level technology, 20% had high level technology and 2.2% had low level technology. The average capacity utilization rate of the enterprises in the last one year is 63% on average.

3.2 Assessment of Brands and Process for Orientation to National / International Target Markets

The ratios of strongly agree and agree responses from 23 questions prepared at the 5-Likert scale (Strongly Agree, Agree, Undecided, Disagree, Strongly Disagree) are as follows.

Table 1: Brand evaluations of enterprises.

	Percentage (%)
We are recognized by our customers (our target kit).	91%
It is important to give importance to the feelings and needs of the target group and to recognize them well.	89%
Customers can easily contact us when they have problems with our brand.	87%
Our mark affects our target customers' purchasing decision positively.	84%
We can perceive our customers' expectations / demands correctly	84%
We can quickly catch up with our clients' new demands or even more difficult expectations.	84%
It is important to whom our mark will address (target not set).	82%
Meeting our customer requirements is our high performance	82%
Positive relations with major customers / units in the sector	82%
Producing the right content for branding / branding is very important.	80%
We are striving to develop products and services that will strengthen our reputation and market perception	80%
We are a brand that can provide effective solutions to our customers' problems in short time.	80%
We follow the judgments and values created by our products and services in the market.	76%
We are recognized in the market we are in.	76%
We are a powerful player in the market we find.	62%
We have efforts to increase brand value.	60%
Our mark is in a "transformation / restructuring" process.	56%
We have an actively managed brand.	51%
We are actively using advertising channels on the domestic market.	40%
We have a brand value at Turkey market.	24%
We receive corporate communication consulting.	20%
We have a brand value in the overseas market.	13%
We are actively using advertising channels in international markets.	9%

In the brand communication, the percentage of the enterprises using social media is 86.7%. The most used social media channels in brand communication are Facebook and Twitter. This is followed by WhatsApp, Twitter, Google+ and Linkedin respectively. Youtube, Pinterest, Skype, Snapchat, social media channels have never been used. Firms that did not use any social media channels accounted for 4.4%. The distribution of social media usage according to the establishment years of the enterprises is shown in Table 2.

Table 2: Distribution of social media usage by establishment's years.

	Facebook	**Instagram**	**WhatsApp**	**Twitter**	**Google+**	**LinkedIn**	**Not Using**
1980 and before	2	2	1				
1981-1990	10	12	4	1	1	3	1
1991-2000	4	4	3		1		
2001-2010	13	11	8	3	1	1	
2011 and after	6	5	3	1			1
Total	**35**	**34**	**19**	**5**	**3**	**4**	**2**

Table 3: Usage rates of social media channels in communication.

Facebook	Instagram	WhatsApp	Twitter	Google+	LinkedIn	Not Using
78%	76%	42%	11%	7%	9%	4%

It is desired that the factors that play an important role in the continuity of the brand from the enterprises are marked. According to this, the answers given by the enterprises are shown in the table as percentage and frequency distribution. It is observed that enterprises are most likely to attach importance to an innovative, sustainable vision and trust-based criterion based on sound foundations.

Table 4: Distribution of factors that play a role in the continuity of the brand.

	Number of answers	Percentage %
Innovative, sustainable vision based on strong foundations	32	71,1%
To be dependable	28	62,2%
To be able to update the business according to the trends of the day	26	57,8%
Gaining reputation	25	55,6%
To be open to innovation	19	42,2%
To create a better impression	17	37,8%

73.3% of the enterprises gave a yes answer and 26.7% answered no, in the question "Do you produce content in the name of branding / brand development / sustainability recognition / development in social media?".

The first 3 tool markings which are most important for the brand promotion are requested to mark from the enterprises. According to the this, in decreasing order, it is arranged that 73.3% brochures / catalogs, 60% social media groups, 53.3% magazines / newspapers / other printed publications, 20% fairs / invitations and so on. events, 20% internet advertising, 17.8% TV commercials, 8.9% cinema.

4 CONCLUSION

In today's dynamic business world, enterprises which are innovative, open-minded, knowledge-creating can be kept their assets as powerful players on the market they are in. In this challenging competitive environment, enterprises need to have a realistic and sustainable vision. Sustainability is an important focus for enterprises. Being recognizable and easy accessibility are the goals of each enterprise. One of the necessities to achieve this is to have a brand that is effectively managed on the market. Creating effective brand value in the domestic and foreign markets requires the existence of strategic studies. In the competitive environment where change and transformation are very fast, brand concept is one of the most critical concepts for enterprises one of the most critical concepts for businesses to tell themselves and reach their customers.

In this context, data were collected with survey method from 45 furniture enterprises reached from Ordu and Giresun provinces which are located in Blacksea Region of Turkey. Given the demographic structure of the respondents, two-thirds of the enterprises are in Ordu and one-third of those are in Giresun. Private companies (62.2%) and enterprises established between 1981 and2010 are concentrated. The vast majority of respondents were business owners and university graduates. It has been determined that 77.8% of the enterprises have the moderate technology, 20% have high technology and average capacity utilization rate is 63% in the last one year.

Most of the furniture companies of Ordu and Giresun (91%) stated that they are recognized by the customers, namely the target groups. A similar majority (89%) stated that they agree that "it is important to pay attention to the feelings and needs of the target group and to recognize them well." The results show that Ordu and Giresun furniture firms are in good communication with their customers, they can correctly perceive their expectations / demands, and they are easily accessible to brands.

It is seen that brand images have a positive effect on the decision-making process of the customers and that they attach importance to the target groups of the companies. Enterprises stated that their customers are able to keep pace with their new demands or more difficult expectations and those they have a high level of success in meeting customer needs and are able to provide effective solutions to their customers' problems in a short period of time. It is seen that the relations with important customers/units in the sector are also positive.

Enterprises are aware that producing the right content for branding / branding is very important. They are also endeavouring to develop products and services that will strengthen their reputation and market perceptions. Enterprises are known in the market and they are following the judgments and values of the products and services in the market. 62% of the enterprises see themselves as a strong player on the market they are in. There are studies to increase brand value, and again at similar rates (56%), their brands are in a "transformation / restructuring" process. Noting all these positive views, only 51% of companies have indicated that I brands are effectively managed. The effective use of advertising channels in the domestic market (40%) was found to be quite low. in spite of the high recognition of their company in the market, the proportion of businesses indicating that they have a brand name in Turkey's market value was 24%. Participating in the survey indicated that only one of the furniture companies had corporate communication consultancy. Only 13% of firms have a brand value in the international market and 9% have used advertising channels effectively in international markets.

73.3% of the companies stated that they are producing content on the internet channels in the name of branding / brand development / sustainability recognition / development on social media. It is clear that businesses now appear to be on social media and their most popular social media tools are Facebook and Instagram.

The proportion of companies that do not use any social media channels is 4.4%. It can be considered that firms that responded favourably to using social media communication did not view this channel as a social media channel.

Brochures / catalogues (73,3%), social media groups (60%), magazines / newspapers / other printed publications (53,3%) are the most important means of brand promotion of businesses. Fair / invitation etc. events, internet advertising, TV commercials, cinema have become the least preferred brand promotion channels.

Looking at the general structures, it can be said that firms that are seen as micro, small and medium scale are known as brands on the market they are in, but they are not yet located in the domestic market all over the country. The fact that they are working on brand management shows that businesses are conscious of this issue and their awareness levels are in good condition. There are fewer companies that target overseas markets and work in this field. This may be attributed to the fact that the majority of businesses are micro and small-scale local businesses.

It seems that YouTube channel has never been used by enterprises. However, the prospective customer group in the near future is now heavily watching YouTube. Enterprises should also use the social media tools that young people in the 18-24 age group are heavily used to reach the new generation, that is, future customer mass.

5 ACKNOWLEDGEMENTS

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THE INTERNATIONAL FOREST PRODUCTS CONGRESS

Prediction of Bending Properties of Oriental Beech Wood Exposed to Temperature

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ABSTRACT

In this study bending properties of Oriental beech (*Fagus orientalis* L.) wood which exposed to temperature predicted using ultrasonic measurements. Samples exposed to 120, 150, 180 and 210°C temperature for 2, 5 and 8 hours by oven that operated in atmospheric environment. Static bending samples, 20x20x400mm, acclimatized at 65%RH and 20±1°C. Clear cubic samples, 20x20x20mm, prepared from the end of bending samples to conduct ultrasonic measurements. Epoch 650 ultrasonic flaw detector and contact type transducers that propagate longitudinal waves at 2.25Mhz frequency used to measure time of flight values. And then sound velocities calculated with time of flight values. At first non-destructive and then 3 points bending tests performed. Relations between E_{dyn} values that predicted by ultrasonic method and Modulus of Elasticity in bending (MOE) figured out by coefficient of determination. Coefficient of determination values varied from 0.74 to 0.82 and these results showed that bending properties of beech wood that exposed to temperature can be reasonable predicted using ultrasonic measurements.

KEYWORDS: Bending properties, Oriental beech, Ultrasound, Ultrasonic

1 INTRODUCTION

Decrease in existing wood resources and increase in wood processing cost are some of the reasons that made the relatively cost effective non-destructive testing much more popular to evaluate or classification of the wood. And, when relatively low-cost, safety and versatility taken into consideration, ultrasonic non-destructive testing and evaluation attracts attention (Oliveira and Sales, 2006).

Moisture Content (MC), temperature, creep, density, knots, number of annual growth rings and grain angle are some of the effects that affect the bending properties. Bending properties can be determined by destructive or non-destructive test methods. Traditional bending tests which used to determine MOE has some disadvantages such as high cost destruct the test material and not easy to perform quickly. Ultrasonic wave velocity (UWV) is an important parameter to characterize the materials properties without any deformation on their mass (Krauss and Kúdela, 2011). Elastic properties and density of the solid define the dynamic modulus of the elasticity (E_{dyn}) when ultrasonic wave propagation is used (Oliveira et al., 2005). UWV is advantageous than some other evaluation techniques when practicality taken into consideration (Esteban et al., 2009).

Measured properties of the wood material depend on some factors such as structure, environmental conditions, past of the sample and preferred test method. And, these properties are valid essential for mechanic properties. It's known that lots of factors affect the mechanical properties of wood. MC and temperature, some of the environmental factors, are important ones that affect wood properties. In general, mechanic properties increase when MC and temperature decrease (Gerhards, 1982).

Aim of this study is to evaluate the effect of temperature on modulus of elasticity in bending MOE of beech wood which is one of the important commercial tree species of Turkey and figure out the relation between static and ultrasonic test results.

2 MATERIAL AND METHOD

2.1 Material

Oriental beech (*Fagus orientalis L*) wood used in this study. Straight trunk and around 50-60cm diameter trees were harvested from Zonguldak-Devrek which is located in Western Black Sea region of Turkey. 2 meters long part of the log following the 1.3 meters section from the base used for sample preparation. Logs were sawn into planks using hydraulic band saw and then planks were air-dried. 22x70x500 mm laths were cut from planks and they exposed to four different temperature levels (120-150-180 and 210°C) for 2, 5 and 8 hours using an oven (NÜVE FN500, Ankara) which operated in an atmospheric environment. After exposure, 20x20x350 mm bending test samples were prepared from these planks to conduct static tests. For ultrasonic tests, 20x20x20 mm cubic test samples were prepared from the head of each static test samples. Each temperature and exposure duration groups had their own control samples. Therefore, all samples matched-up to ensure representing the correct and related group values. Samples were acclimatized at 65% RH and 20±1°C for around 6-8 weeks due to provide approx. constant weight and then tests were performed.

2.2 Method

Before the tests, densities of the samples were calculated according to TS 2472 (2005) using 20x20x20 mm cubic samples.

Static bending test performed using Universal Testing Machine (UTM) with 5 tonnes load cell. Modulus of elasticity in bending determined according to TS 2478 (2005) standard. Effective span of the 3 point bending test was 300 mm and load was applied from the middle of the effective span length and therefore the sample. Loading speed was set to 6 mm/m. Load-deformation curves were obtained by static tests while loading.

Modulus of elasticity was calculated with equation 1 by using deformation values that corresponding to per loading through the linear elastic region of these curves. Bending test configuration and sample are presented in figure 1.

$$\mathrm{E.M.} = \frac{\Delta F \times L^3}{\Delta d \times 4 \times b \times h^3} \quad (N/mm^2) \qquad (1)$$

where, E.M. modulus of elasticity in bending, ΔF differences between loadings (F2-F1), L distance between the span (mm), b sample width (mm), h sample thickness (mm), Δd (F2 – F1) total deflection amount (mm) which occurs due to increase in force.

Figure 18: Bending test configuration and sample

Ultrasonic measurements performed using Olympos EPOCH 650 ultrasonic flaw detector and contact type transducers which propagate 2.25 MHz longitudinal wave. UWV calculated by measured time of flight or propagation time values with distance-speed-time relationship. E_{dyn} was calculated with equation 2 by using UWV.

$$E_{\mathrm{dyn}} = \rho \, V^2 \, 10^{-6} \quad (2)$$

where E_{dyn} dynamic modulus of elasticitiy (N/mm^2), ρ density (kg/m^3) and V ultrasonic wave velocity (m/s).

3 RESULTS AND DISCUSSION

Average density, UWV, E_{dyn} and MOE values of Beech wood were presented in Table 1. Density of the control groups varied from 0.67-0.68 g/cm^3 but treated ones decreased up to 0.60 g/cm^3 (at 210°C and 8 hours) while temperature and exposure duration increased.

Table 22: Density, Sound Velocity, Edyn and MOE values of beech wood

Temp. °C	Hour	Density (g/cm^3)	Velocity (m/s)		E_{dyn} (N/mm^2)		MOE (N/mm^2)	
			Mean	Cov	Mean	Cov	Mean	Cov
120	Control	0.68	4329.35	2.89	12840.71	5.73	11528.72	6.74
	2	0.67	4454.32	3.51	13287.83	4.96	12030.48	3.73
	5	0.67	4467.91	3.41	13432.48	6.03	12367.77	7.76
	8	0.67	4489.65	5.30	13509.23	7.35	12589.31	8.80
150	Control	0.67	4435.79	4.73	13232.87	9.62	11741.33	11.09
	2	0.67	4434.03	4.68	13265.25	9.61	12306.97	7.32
	5	0.66	4441.67	4.08	13177.27	6.57	12235.11	6.23
	8	0.66	4402.07	4.82	12810.48	8.73	11790.96	7.58
180	Control	0.67	4430.02	5.20	13341.59	9.54	12195.06	8.64
	2	0.66	4220.59	4.09	11881.47	5.95	10941.45	10.01
	5	0.65	4210.80	5.16	11635.83	7.97	10002.33	6.87
	8	0.64	4129.84	5.63	11072.27	9.28	9409.887	5.96
210	Control	0.68	4212.58	3.47	12078.85	3.69	10957.6	5.23
	2	0.66	3981.87	5.27	10530.58	11.33	9893.02	8.91
	5	0.63	3881.43	5.03	9528.61	9.67	9240.46	7.06
	8	0.60	3773.48	5.54	8581.91	10.88	8437.71	9.77

Relation between average density and velocity values of beech wood were presented in figure 2. Some decrease in velocity seen while density decreased for 180-210°C groups but some increase in velocity seen while density decreased for 120°C group. When studies conducted by Oliveira and Sales (2006), Baradit and Niemz (2012) investigated it's seen that there is a relation between density and velocity but Ilic (2003) and Teles et al. (2011) reported neither negative nor positive relation. Therefore there is not a concurrence on this issue.

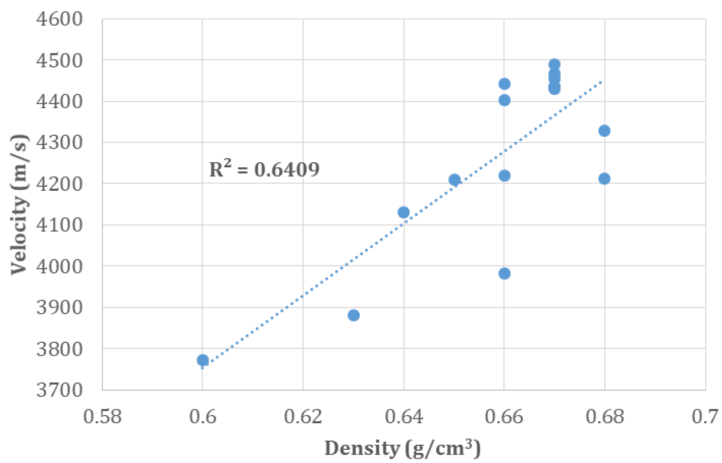

Figure 19: Relationship between average density and velocity

Average MOE values ranged from 8437.71 to 12589.31 N/mm^2. MOE values steadily increased (%9.19) at 120°C through the exposure duration. Slight increases observed for the beginning of the 150°C treatment then values decreased for 5 and 8 hours exposure durations. Anyhow, values obtained after 8 hours treatment was above than the control group. And, further progresses caused around 23% decrease in MOE with the increase in temperature and exposure duration. Coefficient of Variation of MOE values varied from 3.73 to 11.09%. According to Esteves and Pereira (2009) MOE increases by the heat treatment with short exposure duration and low temperature but decreases when temperature and exposure duration of the treatment are high and long, respectively. Reasons of the changes on mechanical properties were well discussed by Boonstra et al. (2007). Lower equilibrium moist content may positive affect the strength properties of heat treated wood but degradation of chemical compounds may make this effect invalid. And, it's believed that the essential reasons of the density decrease are the transformation of hemicellulose into other items due to degradation and evaporation of the extractives. According to Schaffer (1970) MOE more intensely is affected by the temperature above 225°C.

As seen in Table 1, average E_{dyn} values were ranged from 8581.91 to 13509.23 N/mm^2. E_{dyn} values steadily increased at 120°C through the exposure duration, but up to 28.95% (210°C-8 hour) decrease observed when temperature and exposure duration increased. Heat treatment can alter the material properties and invisible micro-cracks are some of the possible faults may take place after the treatment. And, according to Esteves and Pereira (2009) these micro-cracks may play an important role on the change of mechanic properties. Therefore, micro-cracks may be formed after the exposure to temperature and they may affect the E_{dyn} values. Non-destructive testing and evaluation require qualified user and complex tools. And it's required to pay attention that a few factors affect the NDT parameters (Llana et al., 2014).

As seen in Table 1, E_{dyn} values were higher than static MOE values. Oliveira et al (2002) reported that dynamic test results are around 17% higher than static test results. Even higher differences were reported by Smulski (1991). Divos et al. (2007) stated that MOE which determined by density and velocity is always higher than static MOE. And therefore it can be said that results of this study agree with the literature.

Relation between temperature dependent E_{dyn} and MOE were presented in figure 3 to 6. And it's seen that R2 values which ranged from 0.74 to 0.82 indicate strong relations between E_{dyn} and MOE. Correlation coefficients for non-destructive evaluation of wood are dependent on some factors such as used method, wood species, MC (Karlinasari et al., 2008; Teles et al., 2011). And, correlation coefficients of some hardwood species varied from 0.36 to 0.87 (Oliveira et al., 2002; Karlinasari et al., 2005; Baar et al., 2015).

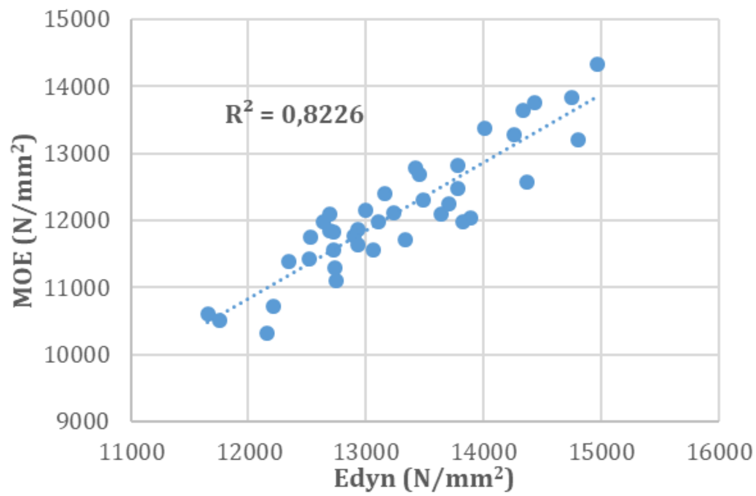

Figure 20: Relation between MOE and E_{dyn} for 120°C treatment

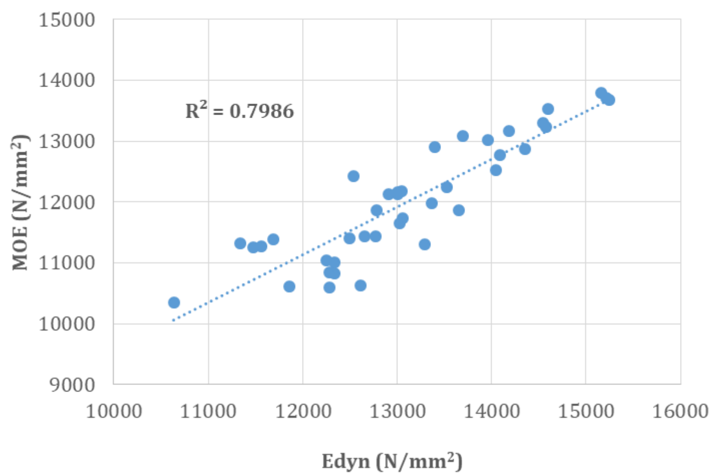

Figure 21: Relation between MOE and E_{dyn} for 150°C treatment

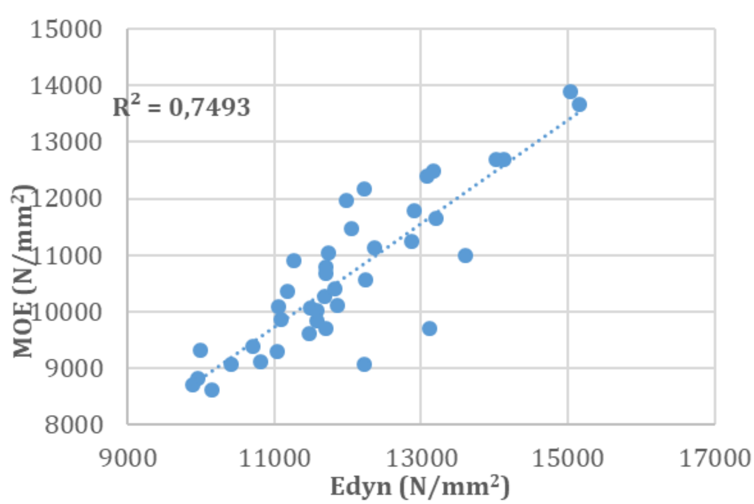

Figure 22: Relation between MOE and E_{dyn} for 180°C treatment

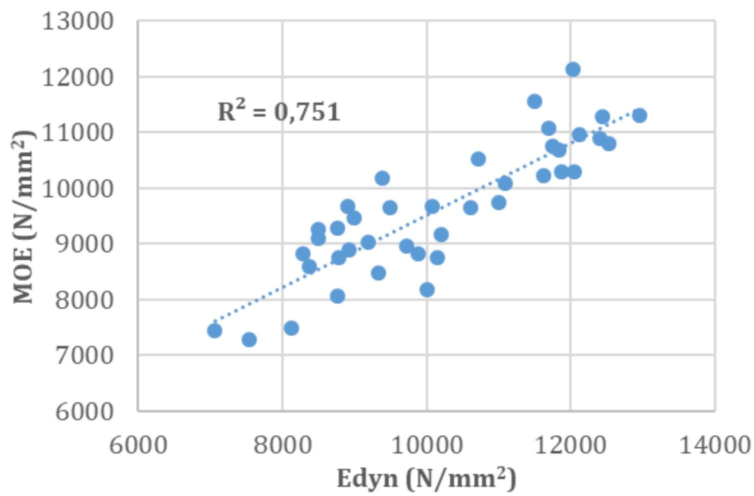

Figure 23: Relation between MOE and E_{dyn} for 210°C treatment

4 CONCLUSIONS

In this study, E_{dyn} which estimated by ultrasonic measurements and static MOE values of the beech wood that exposed to temperature were compared. It's seen that temperature and exposure duration have effects on modulus of elasticity. Slight increases were observed at the beginning of the treatment and low equilibrium moisture content may be one of the reasons of these increases. E_{dyn} and MOE values decreased when temperature and exposure duration increased. Results showed that correlation coefficients between predicted E_{dyn} and calculated static MOE were classified as strong. Ultrasonic wave propagation technique can be applicable to characterize the bending properties of tested wood species instead of using destructive tests. Ultrasonic technique may provide faster evaluation of the materials without any destruction and lets researchers to study on much larger sampling.

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ABSTRACT

Finite element analysis (FEA) has now become an essential and often indispensable part of engineering analysis and design. Finite element computer programs are commonly utilized in most fields of engineering for the analysis of structures, solid and fluid substances. In order to cope with the physical problems in engineering analysis and design, the finite element method (FEM) is employed. The main assumption of FEA is that sophisticated domains is discretized and presented by an assembly of simpler finite sized elements. To idealize physical issues to mathematical models, specific assumptions leading to differential equations with the mathematical models are necessary.

Modern engineering offers that a model may be used to predict beyond the test data. Thus, finite element model represent the definition of the progressive defect mode (i.e., crack, fracture, ductility, and brittle) of wood, as well as finger-joint timber beams and glue-laminated timber. Finite element model predicts properly nonlinear behavior of wood and mechanical connections and adhesive behavior under loading. The benefits of mathematical simulations are their efficacies that are associated with time, cost and decreased variability of outputs. However, FEA and several other quantitative analyzing methods are not anticipated to replace experimental observations. Rather, they are known to be powerful tools that have been allied with empirical monitoring and material characterization. In order to verify the numerical models using experimental study, material properties must be well known and entered into the program as engineering data.

There are numerous publications about finite element analysis of wood in the literature. Examining past studies this reviews study has been written. This review study provide information about the finite element models of wood and fasteners, damage distribution criteria of wooden materials and failure numerical model, material behavior.

KEYWORDS: Finite element method, wood, connections, numerical analysis, failure mode,

1 INTRODUCTION

The FEM is a numerical technique that solves problems by using partial differential equations. This method is one of the most common and effective numerical methods used to solve many problems in physics and engineering. It is costly and time-consuming to carry out experiments of complex structures and large-scale test elements. For this reason, finite element model strategies have been developed to determine the behavior of such structures.

Studies related to numerical modeling of wood structures started in a century ago (Polensek, 1976, Foschi, 1977). Today, commercial or custom end-user finite element analysis programs such as Ansys, Abaqus have been developed for nonlinear static and dynamic response analysis of wood products. Realistic FE analysis of wooden structures is realized by element approach nonlinear material modeling to consider the ductile and the fracture failure of wood.

There are generally three stages in the in the general procedure for fınıte element analysıs. Figure 1 shows stages of finite element analysis (Bathe, 2014). Pre-processing stage is concerned with the creation of the model and the element types, material properties, geometric models, mesh, boundary conditions and loading are defined. In the solution stage, physical and mechanical changes of the material under load are determined. Post-processing stage comprise complex routines, which are utilized for sorting, printing, and plotting data from a finite element solution.

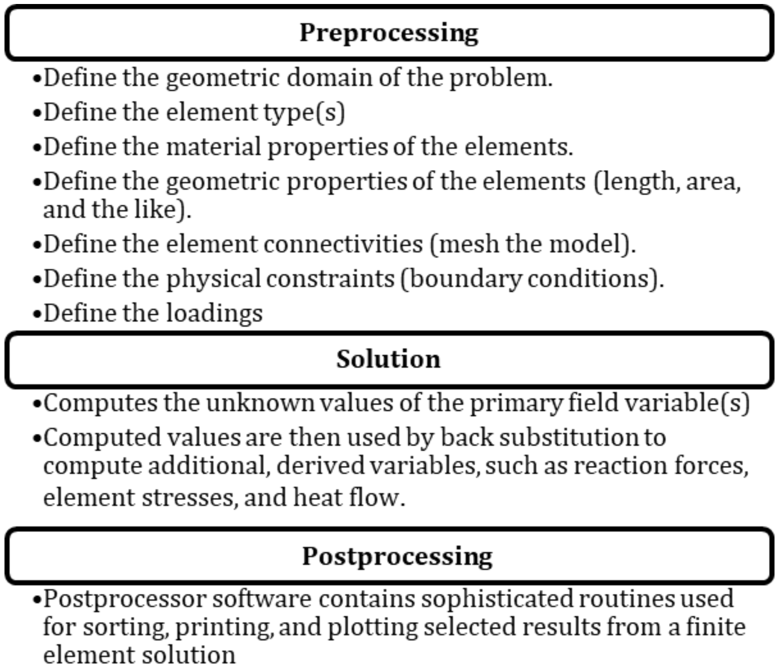


Figure 1: The stages of finite element analysis

2 MODELING OF MATERIALS BEHAVIOR

2.1 Modeling of Wood Material Behavior

Wood has been used as an essential structural material in building industry throughout the history. It is difficult to simulate wood material with numerical analysis because of its natural heterogeneous structure. Wood is not included in the material library of commercially available finite element software packages.. Therefore, researchers have created a model of wood materials with user-defined subroutines.

Wood is a complex material with different fiber directions. The relationships between stress and strain in the case of tension and compression are significantly varied in the three main wood directions which are defined in Figure 2 with namely radial (r), longitudinal (l), and tangential (t) directions (Schmidt et al., 2009). Wood and engineered wood materials are anisotropic (orthotropic or two-dimensionally isotropic) materials, and in each direction the behavior and strengths are also different s in tension and compression (Oudjene et al., 2009 , Valipour et. al., 2014).

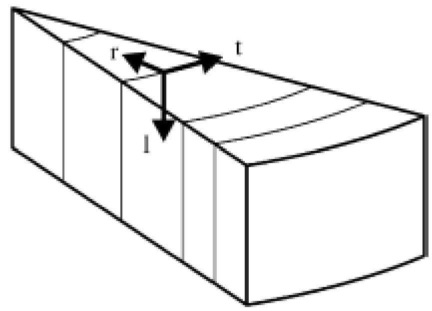


Figure 2: The material directions of wood (Schmidt et al., 2009)

In order to emulate the mechanical behavior of wood, various material models have been used. Wood is an anisotropic material owing to the presence of knots and defects and modeled as orthotropic material in numerical analysis (Mackerle, 2005). Previous research revealed that wood in tension could be modeled as linear orthotropic elastic materials in FEA, while orthotropic elasto-plastic materials is more preferable in compression (Guan and Zhu, 2009). The linear relationship between elastic strain and stress is given by Hooke's law. In numerical analysis, wood is generally regarded as an orthotropic material. Wood features are usually described using the engineering constants such as the elastic (E_r ; E_t ; E_l) and shear moduli (G_{rt} ; G_{tl}; G_{rl}) as well as Poisson's ratios (V_{rt} ; V_{tl}; V_{rl}) (Resch et al., 2010).

C is orthotropic elastic matrix .6 x 6/,

$$\underline{\underline{C}} = \begin{bmatrix} \frac{1}{E_r} & -\frac{\upsilon_{rt}}{E_t} & -\frac{\upsilon_{rl}}{E_l} & 0 & 0 & 0 \\ -\frac{\upsilon_{rt}}{E_t} & \frac{1}{E_t} & -\frac{\upsilon_{tl}}{E_l} & 0 & 0 & 0 \\ -\frac{\upsilon_{rl}}{E_l} & -\frac{\upsilon_{tl}}{E_l} & \frac{1}{E_l} & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{G_{rt}} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{G_{tl}} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1}{G_{rl}} \end{bmatrix}^{-1} . \qquad (1)$$

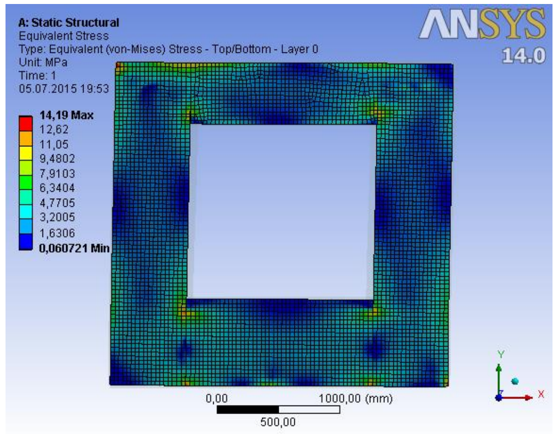
When tension or compression is applied, wood shows different failure behaviors, elastic moduli and strength. The plastic behavior of the wood materials is modeled using the stress–strain relationships obtained under tensile and compressive loading (Togay et al., 2017). A common design model of wood failure is obtained from the prediction of uniaxial tensile and compressive strength of specimens. While plastic behavior of wood elements in finite element analysis is obtained, the elastic stress limit in the stress-strain curves obtained from the uniaxial tests is zeroed. Plastic zone is recalculated according to the equations in the finite element law.

Wood has very different failure modes. Mackenzie-Helnwein et al. (2003) has described failure in 4 different ways, which are 1) Brittle tensile damage of fiber direction, 2) Brittle tensile damage which is perpendicular to the grain, 3) Ductile compressive response which is perpendicular to the grain, and 4) Compressive damage in fiber direction (4).

The failure state of wood is assessed with failure criterions including Tsai-Wu, Hill, Norris and more, in numerical analysis (Iraola et al., 2016). Failure criteria created for composite materials are also commonly utilized for wood. With Tsai- Wu failure criteria, shear failure, tension and compression failure for wood directions are defined (Resch and Kaliske, 2010).

Generally, in FE studies, the frame elements are modeled as beams, OSB, Plywood etc. are modeled as shells and nails are modeled as spring elements (Ayoub, 2007, Šilih et al., 2012, Foschi, 1977; Pang et al., 2010; Polensek, 1976; Richard et al., 2002, Anil et al. 2018). Wood with a heterogeneous structure and wood based materials (OSB, MDF, Playwood) are generally modeled as orthotropic materials (Andreasso et al., 2002; Baylor and Harte, 2013; Guan and Zhu, 2009; Valipour et al., 2014).

Togay et al., (2017) applied to FEA of light wood framed walls with and without openings, and found out successful agreement between the numerical and observational data. Figure 3 indicates that failure mainly occurred in wood framed shear wall.



a.

b.

Figure 3: Stress distribution in wood framed shear wall, a.) FE-model. b.) Experimental model

2.2 Modeling of Connection materials

In recent years, the use of wood in the building has gradually increased because of increased awareness of sustainable building materials and new developments in structural wood materials and connection techniques. The deformation behavior for mechanical connections gets more and more important (Schweigler et. al., 2018).

Connection elements provide continuous and complete load transfer from the roof to the structural foundation (Bredel, 2003, Salenikovich, 2000). Mechanical connections are an important part of wood structures in terms of load transfer. Connection elements are very important because of their ductility and energy dissipation capacities during an earthquake (Šilih et al., 2012). In wood building industry, wood–steel dowel-type connections are usually used. The connection exhibit linear and nonlinear behavior due to the relative slip of the assembled members, when connection elements are exposed to the load (Schweigler et. al., 2018).

In the recent past, the nonlinear laws for monotonic loads have been developed to examine the load bearing capacity and failure mode of mechanical connections, and numerous constitutive laws such as hysteretic models of various complexities (Humbert et al. 2014 , Xu et al., 2009 , Loo et al. 2012 , Blasseti et al., 2008, Boudaud et al. 2014), many experiments have been carried out (Foschi, 1977 , Andreasson et al. 2002, Meghlat et al. 2013 , Resch et al., 2010). A fundamental, To consider the failure of connection, analytical approach such as JOHANSEN-theory is introduced (Johansen, 1949) . Johansen's theory is also expressed as "European Yield Model" (EYM) in Eurocode 5.

Basically, the behavior of connection is defined by nonlinear load-slip relationship (Meghlat et al. 2013). The slip modulus of connections is determined by experimental shear test and ampirical formulas proposed by the Eurocode 5. The push-out shear tests are much more expensive in terms of time, manpower and resources. So, connection stiffness is calculated according to EC5 (2005) since the experimental shear tests take a long time in terms of time. The ductile capacity of dowel-type fasteners can be estimated by Johansen's yield theory (Premrov et al. 2007).

Generally, linear and nonlinear stiffness capacities are calculated to simulate dowel-type connections. The values of slip modulus calculated in numerical model of wood connection according to Eurocode 5. The nonlinear behavior of the connections is evaluated by the two slip module value as follow:. Kser for elastic range and Ku for plastic range (Meghlat et al., 2013). Generally, wood connection is modeled using the nonlinear link elements (springs) in numeric analysis (Humbert et al. 2014). The linear or nonlinear spring elements are used in the simplified finite element model of nails or screws. Figure 4 shows FEM of a wood connection.

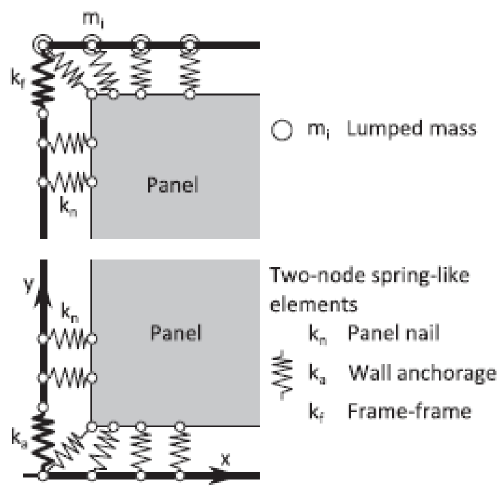


Figure 4: FEM of a wood connection (Humbert et al. 2014)

The numerical design of timber joints created by dowel-type fasteners (i.e., staples, nails and screws) is conducted by failure mode of the joint. The failure of structural wood connections is shown on a typical load–deflection curve of a joint in Figure 5 (Zarnani et al., 2014). In brittle failure mode, the fasteners deflection is in the elastic range, in mixed failure mode is plastic range, connection element provides, in ductile failure mode, the failure such as damages such as fastener bending and wood bearing occur (Cabreo et. Al., 2018).

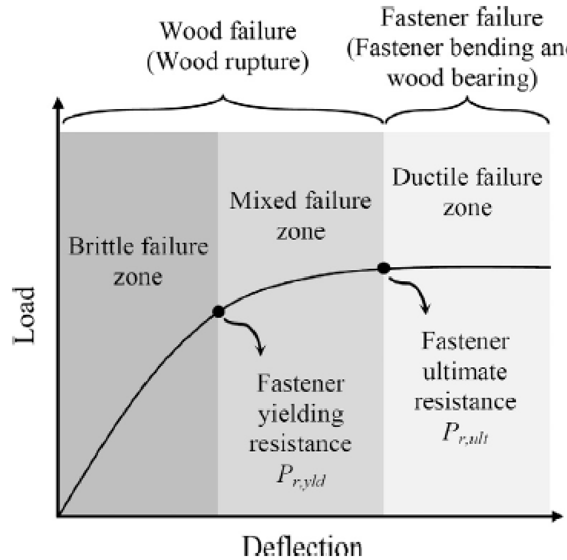


Figure 5: The occurrence zone of failure modes in wood connection

3 NUMERICAL FAILURE ANALYSIS OF WOOD

Due to the heterogeneous and anisotropic structure of wood, mechanical properties of wood show significantly differences under tension, compression and shear. After the wooden material reaches the elastic yield strength, wood shows a distinct plastic behavior and occur damage and failure. Different methods to describe failure behavior of wood been developed in the last decades.

It is necessary to know the damage and crack paths in order to be able to carry out the damage analyze in the finite element programs. Wood failure is determined by an interface element formulation in finite element model (Vasic et al., 2005). For the verification of the numerical models, many experimental studies have been carried out to research the fracture energy of wood materials. For the verification of numerical damage models of wooden materials, many experimental studies have been carried out.

Three wood cracking modes, which are linearly independent, are classified as Mode I, II, and III, and it is illustrated in Figure 6 (Konopka et al. 2017). Mode I, Mode II and Mode III respectively refers to crack opening under a tensile load, shear mode and tearing mode. In different failure modes, major differences have been detected in critical fracture energy G_c (Stanzl-Tschegg , 2009 , Konopka et al. 2017).

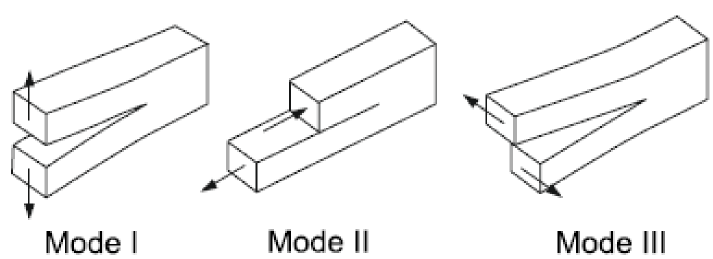


Figure 6: Failure modes (Konopka et al. 2017)

In Ansys software, there are two ways of modeling the interface delamination and Crack Growth Analysis with using either cohesive zone model (1) or VCCT-Based Crack Growth Simulation (2). In the First approach, Cohesive Zone model used with Interface Elements (Interface Delamination) and with Contact Elements for an interface modeling. The crack grows according to the defined material behavior. In the second approach, VCCT-Based Crack Growth Simulation is based on fracture criteria and fracture mechanics. Crack is initiated by a failure criterion and is developing along predefined path.

The damage model of wooden structures in the numerical analysis firstly was to utilize a plastic material formulation. Plastic material model approach is applied with Tsai-Wu failure criteria (Konopka et al. 2017) . Different numerical models for wood cracks simulations were discussed such as the lattice fracture model, the fictitious crack model as a cohesive zone model in the studies (Vasic et al. 2005).

FEM help describe the progressive failure mode of the finger-jointed beams and glued laminated timber, and it predicts properly nonlinear behavior of wood with failure and mechanical connections and adhesive behavior under tension, and shear. The behavior of thetimber has been assumed to describe with orthotropic elasto-plastic material model and the behavior of glue-lines in interlayer were modeled with the Cohesive Zone Model (CZM) of finite element code and proper damage law (Tran et all. 2015). CZM are used to simulate damage initiation and growth during loading (Dourado et al. 2018) .

An interface element formulation developed by Schmidt et al. (2009) consists of an anisotropic traction separation law for wood. For the cohesive model, the traction–separation law is mostly described by three cohesive parameters; maximum cohesive strength, initial stiffness and maximum displacements. The maximum displacements and cohesive strength can be determined by experiments (Tran et al. 2015, Lee et al., 2010).

According to the notation utilized for the Ansys software cohesive model, the adhesive parameters are considered to be the critical cohesive strength, the initial stiffness and the maximum displacements. Figure 7 demonstrates that the initial material stiffnesses, K_n and K_t, are basically attained by Khelifa et al. (2015).

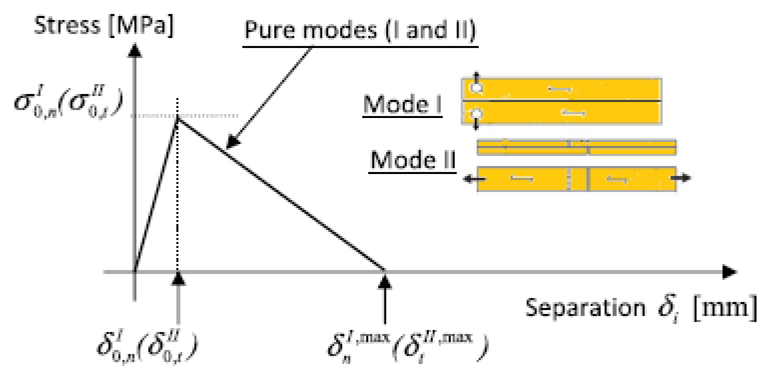
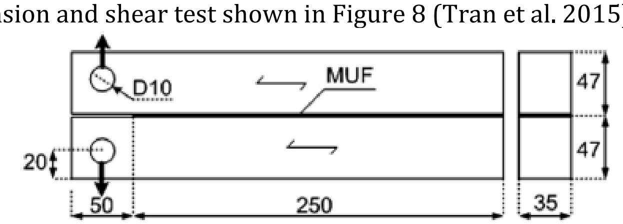
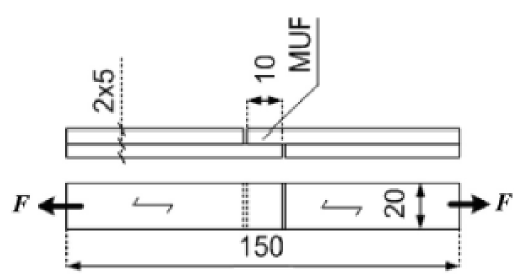


Figure 7: Typical cohesive traction-separation law with damage evolution in a Cohesive Zone Model

Generally, cohesive parameters in mode I and mode II are calculated by Double Cantilever Beam (DCB) test and experimental shear test, respectively (Fortino et al. 2012). The strength properties of the adhesive are determined according to tension and shear test shown in Figure 8 (Tran et al. 2015).



a.



b.

Figure 8: Schematic illustration of (a) tension test (b) shear test

FE analysis of finger-jointed wood beam under flexure loading was obtained by Tran et al. (2014). In this study, cohesive zone model in numerical simulations have been used to determine of the progressive damage of the glue-lines with in the finger-joint up to failure. The comparison of the numerical and experimental failure modes is shown in Figure 9.

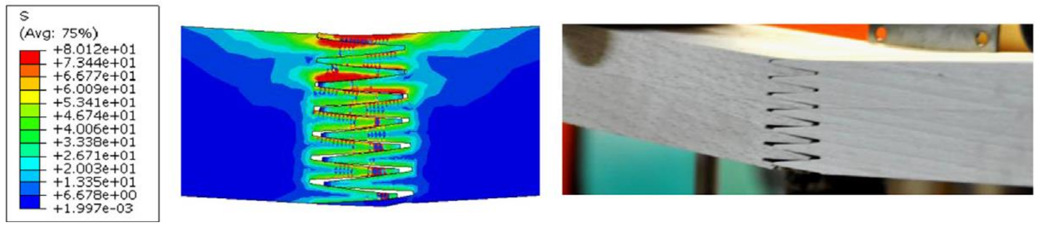


Figure 9: Numerical and Experimental failure modes of the finger-jointed wood beam (Tran et al. 2014)

4 CONCLUSIONS

Finite element analysis allows the determination of complex, difficult and impossible problems to be determined by experimental study using numerical model. Realistic FE analysis of wooden structures is realized by element approach non-linear material modeling taking the ductile and the brittle failure behavior of wood into account. Finite element model allows the description of the progressive failure mode (crack, fracture, ductility, brittle) of wood, finger-jointed and glued laminated timber. Also, numerical model of wood-mechanical connections allow analysis of the load carrying response and the construction failure.

Realistic FEM necessitate varying elements and constitutive formulas related to material, connection and path-following. Therefore, failure mechanisms such as plasticizing and cracking of wood are represented realistically, and they help a deeper analysis for the failure mechanisms. In addition, FEM also allow the realistic three-dimensional, physical and geometrical non-linear computation of wooden structures. Moreover, numerical model estimate the load-bearing capability and material behavior of wood more accurately.

The benefits of numerical simulations are their efficacy regarding time, cost and decreased changes in results. However, In order for the numerical model to be verified by experimental study, material properties must be well known and entered into the program as engineering data. Accurate determination of material behavior in finite element analysis is very important for the convergence behavior of real material. For this reason, the accurate knowledge of mechanical properties of materials seem to be essential.

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Shear Moduli Determination of Naturally Aged Black Pine Wood

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ABSTRACT

In this study shear moduli of naturally aged black pine wood predicted using ultrasonic measurements. Black pine timbers stored in a yard without any protection and exposed to rain, temperature, sunlight and etc. for approx. ten years. Clear 26 surface polyhedral test samples prepared from these timbers. All the samples acclimatized at constant temperature of 20±1°C and 65% relative humidity. And then ultrasonic measurements performed to predict shear moduli. Direct wave propagation method using two transducers chosen to conduct measurements. Olympus shear wave coupling medium used to ensure contact between transducers and sample surface and minimize the noise. Velocity of wave propagation calculated using time of flight values. And shear modulus of LR, LT and RT planes of wood calculated with density and velocity values. Results compared with the literature. It's seen that there were differences between results and literature data. But it's thought that making an inference can be validated when both aged and non-aged samples belong to same log.

KEYWORDS: Shear moduli, Black pine, Ultrasound, Ultrasonic Testing, Non-Destructive Testing

1 INTRODUCTION

As well know, materials exhibit different behaviour due to their structure and orthotropic nature of wood means that all the perpendicular planes have different behaviours. For example homogeneous materials have same properties through the directions but inhomogeneous such as wood has not. Therefore it's called as anisotropic material but in fact it has polar orthotropic structure due to its cylindrical trunk. Mechanic properties of wood can be divided into two: elastic and strength properties. And, elastic properties are important to build safe constructions. Elastic constants of wood consist of twelve parameters; three Young's modulus (L, R and T), three shear modulus (LR, LT and RT) and six Poisson ratios (LR, LT, RL, RT, TR and TL). Lots of studies concerned with strength properties of wood but when structural properties taken into consideration elastic properties though three principle axes must be known.

Non-destructive testing and evaluation (NDTE) of wood is relatively easy, cost effective and reliable evaluation method and is getting more common with the technological developments. According to Chen (2007) ultrasonic technique has capabilities and it is flexible and efficient non-destructive test method. Ultrasonic wave propagation is one of the common used NDTE techniques and elastic constants of wood can be modestly predicted using ultrasonic measurements. But, in this technique, not well qualified users and complicated tools required but also ability to give the meaning of the measured data. Therefore it's not that easy to perform such a study.

Hearmon (1965), Zimmer and Cost (1970), Preziosa t al. (1981) and Preziosa (1982) are the pioneering studies which performed to evaluate wood by ultrasonic wave propagation. Bucur (2006) provided lots of data on ultrasonic evaluation of wood. Lots of studies concerned with different ultrasonic properties such as velocity adjustment (Gonçalves et al. 2017), effects of fungi (Schubert et al. 2005), wood length and knot (Íñiguez et al. 2007), attenuation of shear wave on hardwood (Bucur and Feney 1992), determination shear moduli (Dackermann et al. 2016; Hering et al. 2012 and Bucur and Archer, 1984). Besides, these, there are different studies on determination of elastic or strength properties of both hard and soft wood species. But effect of natural aging on shear moduli which predicted by ultrasonic measurements is not available on the literature. And, from this point of view, this study aimed to investigate the effect of natural aging on shear properties of Black pine wood by using ultrasonic wave propagation.

2 MATERIAL AND METHOD

Black pine (*Pinus nigra* Arnold.) wood was used in this study. Sawn timber, seen in figure 1a, was stored in a yard without any protection and exposed to rain, temperature, sunlight and etc. for approx. ten years. Then, as seen in figure 1b annual ring orientation taken into consideration while they sawn with a band saw. 60x60x60mm cubic samples cut from these pieces. Only sapwood was used for sample preparation. As seen in figure 1c, 26 surface polyhedral non-destructive test samples prepared from these cubic samples and distance of all parallel surfaces were about 55±1mm. This geometry allow researcher to obtain all necessary data to create stiffness matrix of wood material.

Figure 24: Natural aged timber and sample preparation

All samples were acclimatized at 65% relative humidity and 20±1°C temperature using Memmert HCP108 (Memmert Gmbh, Germany) climate chamber. Acclimatization took around 8 weeks when all the samples weight became nearly constant. TS 2472 (2005) standard used to determine sample density. Densities calculated from the cubic samples and then polyhedral samples prepared. Therefore, polyhedral samples acclimatized again due to change of humidity while cutting processes done. Densities calculated using Eq. (1).

$$\delta r = mr/Vr \ (gr/cm^3) \quad (1)$$

where δr is density (g/cm^3), mr is weigh (g), and Vr is volume (cm^3).

Olympus EPOCH 650 flaw detector (Olympus, USA) was used to obtain shear wave velocities (SWV) through LR, LT, RT, RL, TL and TR planes. Panametrics NDT V153 contact type shear wave transducers (Panametrics, USA) that propagate at 1MHz used for propagation and Olympus SWC2 gel used not only to ensure contact of transducers but also minimise the noise and obtain better peak values with lower decibel.

As shown in Eqs. (2) - (3) - (4) below, shear modulus of LR, LT and RT planes were calculated using shear wave velocities (SWV) which calculated with the time of flight or wave propagation time of ultrasonic shear wave.

$$G_{LR} = \rho \left((V_{LR} + V_{RL}) / 2 \right)^2 10^{-6} \quad (2)$$

$$G_{LT} = \rho \left((V_{LT} + V_{TL}) / 2 \right)^2 10^{-6} \quad (3)$$

$$G_{RT} = \rho \left((V_{RT} + V_{TR}) / 2 \right)^2 10^{-6} \quad (4)$$

where G_{LR}, G_{LT} and G_{RT} are the shear modulus of LR, LT and RT planes (N/mm^2), ρ is the density (kg/m^3) and V_{LR}, V_{LT}, V_{RT}, V_{RL}, V_{TL} and V_{TR} are the shear wave velocities (m/s).

3 RESULTS AND DISCUSSIONS

Average time of flight values of the shear wave which propagated through the medium shown in Table 1. It's seen that time of the measured peak of LR, LT and RL were too close to each other as RT, TL and TR.

Table 23: Average time of flight values of shear wave propagation

	Time of Flight (μs)					
	LR	LT	RT	RL	TL	TR
Average	41.94	41.97	130.75	43.13	121.51	132.69
Std. Dev	0.84	0.42	5.45	1.2	3.5	7.16
CoV*	2.01	0.99	4.17	2.77	2.88	5.39

*Coefficient of Variation

Average density of the samples and shear wave velocities presented in Table 2. The order of the shear wave velocities was $V_{LR} > V_{LT} > V_{RT}$ and same order reported by Aydın et al. (2017) for Black pine and Aydın and Ciritcioğlu (2018) for Calabria pine.

Table 24: Average density of the samples and shear wave velocities

	Density (kg/m^3)	Shear Wave Velocities (m/s)					
		VLR	VLT	VRT	VRL	VTL	VTR
Average	545.41	1324.98	1323.61	422.79	1280.28	453.10	415.72
Std. Dev	7.67	22.6726	11.95	17.89	33.89	13.42	21.44
CoV*	1.41	1.71	0.90	4.23	2.64	2.96	5.15

*Coefficient of Variation

Shear wave velocity through LR, LT and RT planes calculated as 1302.63, 888.35 and 419.26 m/s, respectively. Aydın et al. (2017) reported these values as 1375, 1181 and 554 m/s respectively for the non-aged Black pine wood samples. And, these values were 5.55%, 32.99%, and 32.17% higher than results of naturally aged ones. RT/LT/LR ratios of shear wave velocity calculated as 1/2.12/3.11. Aydın et al. (2017) reported these values as 1/2.13/2.48 and ratios were in accordance with each other.

Table 25: Average shear moduli of the samples

	Shear Modulus (G) N/mm^2		
	GLR	GLT	GRT
Average	925.78	430.48	95.95
Std. Dev	34.31	10.72	5.67
CoV*	3.71	2.49	5.91

*Coefficient of Variation

According to obtained velocities and densities, G_{LR}, G_{LT} and G_{RT} values were calculated as 925.78, 430.48 and 95.95 N/mm^2, respectively as seen in Table 3. Aydın et al. (2017) reported these values as 1025.78, 755.36 and 166.34 N/mm^2, respectively. And, results of this study were 9.75%, 43.01%, and 42.32% lower than results of reported values. Also, 743, 527 and 159 N/mm^2 values were reported by Guntekin and Yılmaz Aydın (2016) for Black pine wood. According to Gillis (1972) order of the shear modulus values is $G_{LR} \approx G_{LT} > G_{RT}$ when symmetric triple point is appropriated. But, a proper symmetry may not be mentioned due to geometry of the wood cell. Besides, due to pith rays effect G_{LR} become higher than G_{LT} (Brabec et al. 2017). Accordingly results of this study ($G_{LR} > G_{LT} > G_{RT}$) obeys the literature data.

$G_{RT}/G_{LT}/G_{LR}$ ratios calculated as 1/4.49/9.65. According to Bodig and Jayne (1982) ratio both for soft and hardwood species is 1/9.4/10. But there are different ratios reported by Dackermann et al. (2016), Bergman et al. (2010) and Scheer (1986).

4 CONCLUSION

Shear moduli of naturally aged Black pine wood were predicted by ultrasonic wave propagation method and results are lower than non-aged wood. Differences varied from 9.7% to 43%. Propagation length of the ultrasonic wave was around 55mm and 64mm in this study and compared study, respectively. Also sample geometry was the same. Therefore it can be said that distance may not play a crucial role to differ values. But it's thought that making an inference can be validated when both aged and non-aged samples belong to same log. Therefore it's not possible to make an expression that reason of the reduction in shear moduli occurred due to ageing of the material. But it's clear that crucial differences figured out between the aged and non-aged samples of the Black pine wood.

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Risk Analysis Application in Furniture Production Systems: Fine Kinney Method

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Risk Analysis Application in Furniture Production Systems: Fine Kinney Method

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ABSTRACT

Industrial developments, technologically, have opened the way for people to change of their working conditions in production systems. While current developments increase the diversity of work, the work of the employees is easier in terms of physical work load, but they are concentrated in the mental angle, and things that need attention are increasing. All these developments require that business systems be evaluated within the framework of a system approach and that the workplace be designed and operated in accordance with the principles of occupational health and safety as a whole.

As well as being in many industrial manufacturing, furniture manufacturing enterprises also experience significant work-related accidents, deaths and loss of labor. When 98% of work accidents are thought to be preventable, it can be considered that such work accidents are caused by not taking adequate measures of occupational health and safety. In recent years, the legal regulations that are being pursued due to the increasing importance of occupational health and safety have forced businesses to conduct risk assessments.

In this study, it was aimed to determine the level of preventability of work accidents by applying the corrective and preventive actions to determine, evaluate and prevent the risks arising from the hazards the workers are exposed in furniture manufacturing sector. For this purpose, risks in a furniture manufacturing workshop operating in Istanbul province were evaluated using the Fine-Kinney method. Although the Fine Kinney method poses problems in quantifying possible relative values in assessing risks, It has some advantages in terms of accessibility, ease of use and workers' understanding. It is also a convenient and simple method for small and medium-sized businesses.

A table of risk values was created by using the probability, frequency and intensity values of the Fine-Kinney method in furniture manufacturing facility. As a result of the risk assessment, in the furniture manufacturing facility, to be 20 is very high, 29 is high, 27 is important and 1 is a possible risk; a total of 77 risks were identified. According to this, it is seen that 26.0% of the risk distribution is very high, 37.7% is high, 35.1% is important and 1.3% is in the possible risk category.

The risk groups are as follows:

- Very high risks; no precautions have been taken in response to emergency situations, deficiencies in electric and heating systems and air compressors, and the absence of environmental measurements to be made.
- High risks; ergonomic risk factors, lack of health examinations of employees, deficiencies in work equipment and misuse of equipment.
- Important risks; hygiene inadequacy, psychological risk factors, deficiencies in electrical and heating systems, deficiencies in work equipment and misuse of work equipment.
- Possible risks; unauthorized access to third parties' business environment.

After the risk assessment, the order of priority of the actions was determined according to the risk scores for all the identified risks, application report prepared. In the assessment of the risk made by the

assumption that the COSs are applied in line with this report; it was found 63 collapsible risks and 14 possible risk levels.

There is agreement between findings in this study and literature findings.

KEY WORDS: Furniture, Risk analysis, Fine Kinney method

1 INTRODUCTION

Turkey's furniture industry, working with largely traditional method of workshop-type is an industry dominated by small-scale enterprises. As of 2015, are working 12.484.113 worker under compulsory insurance, in at the total 1.611.292 workplace in Turkey. There are 20963 workplaces in the furniture manufacturing sector and 157503 people are employed. 99.8% of these enterprises are small (18016 workplaces) and medium scale (2911 workplaces) and 0.02% are large-scale (36 workplaces) enterprises (ÇSGB, 2014). Turkish Furniture sector has made important technological progress in recent years. 2015 exports of 2.193 million US dollars, while imports reached US $ 774 388 (Republic of Turkey Ministry of Economy, 2016). Furniture sector, in Turkey's foreign trade, exports constitute 1.5%, and 0.3% of imports. The furniture sector is one of the rare Turkish businesses that do non-foreign trade deficit not that (TOBB, 2013).

In the furniture manufacturing industry in Turkey at the between 2012-2016, respectively 1588, 4479, 5183, 5068 and 5013 work accident occurred (TMMOB, 2018). The mortality rate due to work accidents is around 15%, while in Germany this ratio is below 2%. As a result of the work accident, the average annual number incapacity is 1.8 million. The ratio of work accidents in the furniture manufacturing enterprises to total job accidents is about 2%. All of this, besides losing employees' lives, reduces quality of life, leads to loss of labor, increases health and operating costs. Work-related accidents result is expressed as 4% of national income in developing countries, the losses, the loss to Turkey in this area is estimated to be over US $ 30 billion. Every year, has an average of more than 1.6 million work day loss.

The basic foot of economic development is it industrialization. It has become important to reduce social and environmental problems that have arisen in the industrialization process, which have resulted in significant material and moral loss. In this context, reduction of socioeconomic losses caused by occupational accidents and occupational diseases is the foreground. It states that 80% of work accidents are attributed to the human factor, 18% to environmental factors, machinery and equipment factors and 2% to unknown factors. Accordingly, it can be said that 98% of work accidents can be avoided.

In 1919, the International Labor Organization (ILO) was established as a United Nations specialized agency working to improve social justice and international human and labor rights. The organization, tries to protect the rights and interests of workers by contract and recommendation decisions, to protect the women and child workers who are more abused in working life, and to remove child labor. The ILO, as with its intergovernmental organization, carries out all its activities in the framework of a trio of government-labor-employer representatives. The world health organization was established in 1946 by the 51 United Nations members (TMMOB, 2018).

Occupational health and safety is a subject that has become increasingly important day by day as a result of society's reactions to and the monetary costs associated with occupational accidents and diseases. Studies of both the state and private operations and workers increase daily in the field of occupational health and safety. The World Health Organization (WHO) and the International Labour Organization (ILO) have defined occupational health and safety as ensuring the adaptation of the work to the human and the each human to their work (MEGEP, 2017).

Turkey in occupational health and safety studies in recent years while saving improvements, infrastructure issues in theoretical and critical path is taken in the creation of scientific management regulations. Prior to 2012, occupational health and safety issues were regulated by the Labor Code, related regulations and some other general laws. Occupational accidents have become one of the leading causes constituting majority of efficiency losses today. Occupational accidents and diseases in businesses have necessitated taking legal precautions. Following the legal interventions that have gone into effect in the recent years, risk assessment implications are required in all businesses and awareness of all individuals working in occupational safety and health, and risk analysis have attempted to be raised in Turkey. In 2012, Law No. 6331 on Occupational Health and Safety was published in the Official Gazette. The OSH Act includes regulations on all businesses and businesses in both the public and private sectors, regardless of the area of activity or the number of employees, and includes employees, trainees, employers and their representatives.

There is a risk in the activities of all organizations. This corresponds to the essence of human existence as a living being who studies the world around under uncertainty. Risk management helps in making the most correct decisions in these circumstances and opportunities prediction of adverse events or circumstances that may affect the achievement of the goals of the organization and security personnel. Therefore, there is a need to make the identification, analysis, evaluation and treatment of risk, according to any activity, process, function or product. Risk change is monitored and analysis; after which the results are checked and the report is prepared (Beresutskyi ve Berezutskaya, 2015).

Risk assessment is part of the risk management. This is a structured process in which ways of achieving goals, analyzes of consequences and likelihood of hazardous events for a decision on the need for handling risk is identified. Risk assessment is a process that combines the identification, analysis and comparative assessment of risks. The risk can be estimated for the entire organization and its divisions, individual projects, activities or particular hazardous event. Implementation of risk assessment methods differs from sector to sector and certain techniques can be employed for all sectors while other techniques are only applicable in some sectors. Using the right risk assessment technique in the right place is sometimes as important as results of assessment. The technique to be used depends on the purpose of risk assessment, legal requirements, the needed result/information, data, time availability, requirement of team work, the volume of the work, complexity and type (Mullai, 2006). Therefore, in different situations can be applied different methods of risk assessment.

With the Law No. 6331: Occupational Safety and Health, risk assessment applications are required in all businesses (Korkut and Tetik, 2013). Risk assessment periods are described according to businesses' danger classes and on certain occasions (technological upgrades, new regulations, occupational accidents and diseases, near miss incidents and etc.) a reassessment is required before the due date. This law that went into effect in order to minimize occupational accidents and diseases has caused the conflict of which risk assessment method to be implemented.

Before implementing one of the risk assessment methods, a business is required to know the following definitions (Oturakçı et al., 2015);

Acceptable risk level: The risk level that is sufficient according to legal obligations and prevention policy of the business and does not cause harm to employees, the business or work equipment.

Prevention: all of the precautions that are planned and taken in order to remove or minimize risks regarding occupational health and safety on every phase of ongoing work in the business.

Near miss incident: The incident that happens in the business and has the potential to cause harm to employees, the business or work equipment but does not.

Risk: The possibility of loss, injury or any other harmful result caused by a hazard.

Risk assessment: Describing the hazards that exist in the business or might come from outside, grading and analyzing the risks which are caused by hazards and the factors that cause the hazards to turn into risks.

Hazard: The potential that exists in the business or might come from outside, affects, harms employees or cause harm to business.

The purpose of risk assessment is to diagnose preparations, procedures and checks which will be able to respond to hazards in business, and to minimize the effects of intentional or unintentional threats. There are two basic methods of analysis; qualitative analysis method and quantitative analysis method. Fine-Kinney, is a quantitative analysis method. Hybrids and AHP are also the methods used in risk analysis (Toptancı ve Erginel, 2017; Kokangül vd., 2017). Method of Fine-Kinney does not consider the physic-chemical and other properties of the materials but mainly relies on the personal perception of dangerous and harmful factors of the working area. It is not always correctly identified those workers who interrogated (Berezutskyi ve Berezutskaya, 2013; Berezutskyi ve Dreval, 1997).

In the literature, there are few studies undertaken using only the Fine Kinney risk assessment methodology. Babuţ et al. (2011) studied implementation steps and calculating tables. They indicated the points that were neglected in Kinney method and the possible threats that might be encountered in the implementation of the method. Besides, an assessment of the method was made and advantages and limitations of the method were stated (Babut et al., 2011). Özgür (2013) implemented Fine-Kinney risk assessment on steel plant and rolling plant sections of an iron and steel business. Within the context of steel plant and rolling plant sections of the studied business, mechanical maintenance and repair, electrical maintenance and quality control processes were analyzed along with main production process. In the study, 376 risks were analyzed and assessed (Özgür, 2013). Oturakçı et al. (2015), have applied in medium-sized to enterprises and the positive and negative effects of the scales of different interpolation methods have been analyzed (Oturakçı et al., 2015).

Hazard determination and risk assessment studies are an important element in occupational health and safety research. In OHSAS 18001, which is an international standard, risk has been defined as the combination of the results and occurrence probability of a determined hazardous event; moreover, risk assessment has been defined as the process of calculating the magnitude of the risk and deciding whether the risk is tolerable. Detecting the hazards before the damage occurs, determining the criticality levels and preparing the precautionary plans for each level are significant stages. The operations that make hazard detection and risk assessment important and that could manage this process successfully reduce both monetary and moral damages. As a practical matter, in the real world, a number of qualitative, quantitative and hybrid risk assessment methods are used.

The hazard elements determined in the field have been scored using the Fine Kinney risk assessment method. Fine Kinney risk assessment method has been examined.

2 MATERIAL AND METHODS

In this study, it was aimed to determine the risks arising from the hazards of workers in a furniture manufacturing workshop and to evaluate the risks by using the Fine-Kinney method and to determine how soon the job accidents could be avoided by applying corrective preventive actions to prevent the risks.

Developed by G.F. Kinney and A.D Wiruth in 1976, Fine-Kinney method is an easy-to-use and common method employed to mathematically assess accident control (Kinney and Wiruth, 1976). This method is commonly used in construction and cement industries and in the literature it is stated that it is also one of simple methods applicable to small and middle scaled businesses. In this method, which frequently uses statistical analysis of previous data, individuals to conduct analysis are required to be familiar with related theorems otherwise, the method cannot be used effectively and it might cause time loss. The Fine-Kinney method is a method of prioritizing which tasks should be prioritized according to the results of grading the risks and where the resources should be prioritized. Ratios of the risks are calculated by calculating the weight ratios and it is decided whether the measures should be taken or not. The method gives more realistic results in the sense that the workplace has the possibility to use the statistics. The method of Fine-Kinney is widely used for professional risk assessment widely. Approach at this method is based on hazards assessment in the workplace of worker by susceptibility the potential threats in the workplace and the consequences for health and /or safety of workers in the event that the threat is realized. This method is also based on the indication of danger (Brezutskyi ve Dreval, 1997; Kokangül vd., 2017).

Evaluation of risk R is performed by the formula (Stankovic ve Stankovic, 2013; Kowalczyk ve Nizankowski, 2012):

$$R = F \times P \times C \quad (1)$$

Here; F = Frequency, P = Probability, C = Consequences, R = Percentage of risk, the final risk.

The parameters used in this study are determined by using the values in the scales given in Table 2. The risks are first calculated by using Eq. (1), and the calculations are then rated according to the gradation of the risk scores listed in Table 2 (Subciller and Abali, 2015).

Table 1: Principles of Fine-Kinney's method

Frequency		Probability		Consequences	
Value	**Description of the criteria for frequency**	**Value**	**Description of the criteria for assessing the probability**	**Value**	**Description of the criteria for assessing the consequences**
10	Permanent	10	Predictable	100	Catastrophe, many victims
6	Regular (daily)	6	Possible	40	Alarm few victims
3	Occasionally (weekly)	3	Unusual, but possible	15	Very heavy, 1 person killed (immediately or over time)
2	Sometimes (monthly	1	Improbable, but possible at boundary conditions	7	Heavy, disability
1	Sometimes (annually)	0.5	Plausible, but unlikely	3	Serious injury and absenteeism
0.5	Very rare	0.2	Practically impossible	1	Minimum, enough first aid
0	Never	0.1	Virtually impossible		
		0	Absolutely impossible		

In their study in 1976, Kinney and Wiruth determined 'Might Well be Expected' with a scale-of-ten and identified it as an incident which has occurred before, has a possibility of occurring again and will occur in future. They exemplified it with deflagration of flammable materials in drying oven and designated 10 to this value. Another reference point 'Only Remotely Possible' is exemplified with explosion or leakage of compressed gas in container and appointed 1 to the situation. At the bottom of the probability scale, 'Virtually Impossible' is designated as 0.1. The intermediate values are designated based on experience.

In the same study, Kinney and Wiruth also prepared a scale table for frequency values. On this table, two reference points were determined. Reference values on frequency table are between 1 and 10 as in Probability Scale. Risks on frequency table are classified based on incidence frequency by hour, daily and annually. As seen in Table 2, if the frequency of the incident is by hour, then it is accepted as 'continuous' and frequency value used on occurrence of risk value is determined as '10', the lowest value as'1' and medium value as '3'.

Analysis of risk should lead to risk classification on the degree of seriousness (Table 2).

Table 2. Risk classification on the degree of seriousness

RISK	THE DEGREE OF SERIOUSNESS	REGULATORY PREVENTIVE ACTIONS
$R < 20$	Negligible risk	Acceptable
$20 \leq R < 70$	Low risk	Attention should be given
$70 \leq R < 200$	Medium risk	Correction required
$200 \leq R < 400$	High risk	Immediate correction is required
$R \geq 400$	Extreme risk	Stopping work should be considered

3 RESULTS AND DISCUSSION

Depending on the determined risk, probability, frequency and severity values are obtained from the table and these three factors are multiplied, and the risk score is calculated. The obtained risk scores are classified according to Table 3 and risk avoidance activities are planned according to risk priority order of each hazard.

After examinations carried out at a furniture manufacturing workshop, the existing hazards are defined first. The risks that could be caused by each of the identified hazards were identified and the effects of the risks identified. Riskin grading and definition have been made taking into account existing measures applied at work to prevent identified risks. The grading risks are placed in priority according to the risk values. The corrective preventive action (CPA) to be applied for preventing each risk identified and prioritized is determined by taking account of the priority of the transaction responsibilities and transaction dates of the CPAs. The same risks have been re-rated after the application of the CPAs, which should be applied in order to prevent the risks, and it has been evaluated whether the CPAs applied are adequate. Using the Fine-Kinney method, the result table was prepared. The subsequent process is continued through this table.

Employees in the furniture manufacturing sector face risks arising from physical, chemical, ergonomic and psychosocial risk factors. In this study; in order to determine the risks that the workers are exposed to in furniture manufacturing sector conducting necessary research and investigations and the results to be achieved doing the risk assessment by using the Fine-Kinney method taking the necessary precautions to prevent hazards and with the aim of determining at stage occupational accidents could be avoided has been fulfilled.

The risk assessment summary results using the Fine Kinney method are shown in Table 3.

Table 3: Evaluating the risks arising from risk factors by Fine-Kinney method - Workplace

Tablo 3.1: Activity area: Emergencies

SN	HAZARD	RISK	CURRENT STATE			PREVENTIVE ACTIVITY LATER	
			Risk Value	Risk Definition	Process Priority	Risk Value	Risk Definition
1	Emergency exit door not marked	Multiple death due to non-evacuation	600	Very high	1	20	Possible risk
2	Putting material out of front of the emergency exit door	Multiple deaths after delivery	600	Very high	1	20	Possible risk
3	No first aid trained personnel	Death / injury after first aid failure	240	High risk	2	10	Acceptable risk
4	Identification and training of support elements to serve in emergency situations	Multiple deaths, material loss after the inability to intervene in emergencies	600	Very high	1	50	Possible risk
5	No emergency exercises	Not knowing how to act in emergency situations, multiple deaths, financial loss	600	Very high	1	50	Possible risk
6	Customer and visit emergency evacuation	Multiple deaths	600	Very high	1	50	Possible risk
7	Employees do not know the phone numbers of organizations outside the office to be called in an emergency	Multiple deaths, material loss after the inability to intervene in emergencies	600	Very high	1	50	Possible risk
8	Do not mount portable fire extinguishing devices beyond 90 cm from the floor	Multiple deaths, financial loss after the failure to intervene in the fire	600	Very high	1	50	Possible risk
9	No workshop wheel extinguisher	Multiple deaths, financial loss after the failure to	600	Very high	1	50	Possible risk

		intervene in the fire					
10	Failure to properly dispose of portable fire extinguisher devices	Multiple deaths, financial loss after the failure to intervene in the fire	240	High risk	2	20	Possible risk
11	First aid is not possible due to lack of first aid materials	Death after first aid failure	120	Significant risk	3	20	Possible risk
12	2 portable fire extinguishers are empty	Multiple deaths, financial loss after the failure to intervene in the fire	240	High risk	2	10	Acceptable risk
13	Finding material to prevent passage through the emergency exit routes determined in the evacuation plan	Multiple deaths after the inability to deliver	600	Very high	1	50	Possible risk
14	Missing signs indicating emergency exit routes	Multiple deaths after the inability to deliver	300	High risk	1	25	Possible risk

Tablo 3.2: Activity area: Environment

SN	HAZARD	RISK	CURRENT STATE			PREVENTIVE ACTIVITY LATER	
			Risk Value	Risk Definition	Process Priority	Risk Value	Risk Definition
15	Work without giving OHS training to employees	Death	240	High risk	2	10	Acceptable risk
16	No periodic health examinations	Occupational disease	240	High risk	2	10	Acceptable risk
17	Uneven workshop environment	Damage resulting from injury due to accidental material damage	135	Significant risk	3	7.5	Acceptable risk
18	Unauthorized entry of third parties into the business environment	Occupational accidents	63	Possible risk	4	1.75	Acceptable risk
19	Smoking in the workshop	Fire explosion URG allergy	240	High risk	2	40	Possible risk
20	Eating and drinking in a dusty environment	Occupational Disease Fire	115	Possible risk	3	3.75	Acceptable risk
21	Role uncertainty	Psychosocial discomfort, material loss	126	Possible risk	3	1.75	Acceptable risk
22	Manual transportation	Musculoskeletal system injuries	270	High risk	2	15	Acceptable risk
23	Obligation of continuous standing	Musculoskeletal system diseases	540	Very high	1	45	Possible risk
24	Personal hygiene inadequacy	Disease	135	Significant risk	3	7.5	Acceptable risk
25	Inadequate health and safety signs	Death injury physical loss	90	Significant risk	3	3.75	Acceptable risk
76	No personal and total dust measurements at the workshop	Occupational disease	1440	Very high risk	1	10	Acceptable risk
77	No workshop noise measurements	Occupational disease	1440	Very high risk	1	10	Acceptable risk

Tablo 3.3: Activity area: Electricity

SN	HAZARD	RISK	CURRENT STATE			PREVENTIVE ACTIVITY LATER	
			Risk Value	Risk Definition	Process Priority	Risk Value	Risk Definition
26	The fuses in the electric panels do not have labels indicating where they are operating	Electric shock breaker death fire	120	Significant risk	3	10	Acceptable risk
27	Placing material on electric panel	Electric shock breaker death fire	80	Significant risk	3	20	Acceptable risk
28	No insulating mats in front of electrical panels	Electrostatic discharge post mortem	360	High risk	2	10	Acceptable risk

29	Insulated electrical cables	Electric shock breaker death fire	1440	Very high risk	1	4	Acceptable risk
30	Power line withdrawal not suitable for installation project	Electrostatic discharge death, fire	360	High risk	2	10	Acceptable risk
31	Overcurrent from power outlets	Fire	1440	Very high risk	1	10	Acceptable risk
32	No periodic control	Electrostatic discharge death, fire	1440	Very high risk	1	10	Acceptable risk
33	Leakage currents do not work electric panel	Electrostatic discharge death, fire	720	Very high risk	1	10	Acceptable risk
34	No cover	Electrostatic discharge post mortem	80	Significant risk	3	10	Acceptable risk
35	Defective pako switch	Electrostatic discharge death, fire	360	High risk	2	10	Acceptable risk
36	No electrical cabinet cover	Electrostatic discharge death, fire	240	High risk	2	10	Acceptable risk
37	Defective ceiling lighting	Slip, fall, injury	126	Significant risk	3	1.75	Acceptable risk
38	Defective ceiling lighting	Heavy object damage, injury	360	High risk	2	10	Acceptable risk
39	Dust-damaged electric panels	Electrostatic discharge death, fire	126	Significant risk	3	1.75	Acceptable risk

Tablo 3.4: Activity area: Heating

SN	HAZARD	RISK	CURRENT STATE			PREVENTIVE ACTIVITY LATER	
			Risk Value	Risk Definition	Process Priority	Risk Value	Risk Definition
40	No periodic check of the win	Fire, Explosion, Material Loss, Injury, Death	360	High risk	2	10	Acceptable risk
41	Maintenance records of heating boilers	Material Loss, Injury	135	Significant risk	3	3.75	Acceptable risk
42	No grounding	Fire, Injury, Death	360	High risk	2	10	Acceptable risk
43	No chimney cleaning and maintenance	Explosion, Fire, Injury, Death	720	Very high risk	1	10	Acceptable risk
44	Failure of authorized radiator fighter document	Injury, death, material loss	720	Very high risk	1	10	Acceptable risk

Tablo 3.5: Activity area: Storage

SN	HAZARD	RISK	CURRENT STATE			PREVENTIVE ACTIVITY LATER	
			Risk Value	Risk Definition	Process Priority	Risk Value	Risk Definition
45	Uneven storage environment	Damage resulting from tripping, Material damage	126	Significant risk	3	1.75	Acceptable risk
46	Sharp and pointed angles	Injury resulting from wearing the material	126	Significant risk	3	1.75	Acceptable risk
47	Not suitable storage of chemical substances	Flare, Fire	360	High risk	2	10	Acceptable risk
48	Reservation records not kept	Material damage	63	Significant risk	3	1.75	Acceptable risk

Tablo 3.6: Activity area: Work equipment

SN	HAZARD	RISK	CURRENT STATE			PREVENTIVE ACTIVITY LATER	
			Risk Value	Risk Definition	Process Priority	Risk Value	Risk Definition
49	Ribbon sanding machine no protective shield	Traumatic injury	126	Significant risk	3	1.75	Acceptable risk
50	Emergency button not available in sliver sanding machine	Loss of limb, injury	360	High risk	2	10	Acceptable risk
51	Automatic stopping of the tape	Loss of limb, injury	360	High risk	2	10	Acceptable

	when the belt of the sanding machine breaks						risk
52	No lighting lamp for turning machine	Injury to not see workpiece and cutting blades	135	Significant risk	3	3.75	Acceptable risk
53	The lathe is not fixed to the floor of the machine	Tipping over injury, Material damage	135	Significant risk	3	3.75	Acceptable risk
54	No lathe grounding of lathe machine	Electrostatic discharge post mortem	360	High risk	2	10	Acceptable risk
55	Lath operator's job suit not suitable	Wounded work wear	135	Significant risk	3	3.75	Acceptable risk
56	The local ventilation of the lathe does not work	Occupational disease	1440	Very high risk	1	10	Acceptable risk
57	The part of the band saw machine between the lower and upper pulley is open	Loss of lasers, resultant injury, injury	360	High risk	2	10	Acceptable risk
58	Do not check the joints of the band saw blade	Loss of tape, loss of the resultant limb, injury	360	High risk	2	10	Acceptable risk
59	Bandsaw machine operator not using PPE	Occupational disease, Injury	135	Significant risk	3	7.5	Acceptable risk
60	Constant tensioning of the band saw blade on a non-operating machine	Loss of tapered end of limb loss, Injury	360	High risk	2	10	Acceptable risk
61	Cutting small workpieces without using the apparatus in the band saw	Loss of limb, Injury	270	High risk	2	3.75	Acceptable risk
62	Bandsaw machine operator not using PPE*	Occupational disease, Injury	135	Significant risk	3	7.5	Acceptable risk
63	Do not clean workbench tape saw machine	Occupational disease	360	High risk	2	10	Acceptable risk
64	Female broken tray sawing	Workpiece jamming resultant limb loss, Injury	135	Significant risk	3	3.75	Acceptable risk
65	Lateral saw machine operator not working in proper position	The injury of the workpiece as a result of flushing	270	High risk	2	7.5	Acceptable risk
66	Manual cleaning of parts that accumulate on the flat sawing machine table	Loss of limb, Injury	270	High risk	2	3.75	Acceptable risk
67	Cutting length cuts in a horizontal sawing machine	Loss of limb, Injury	270	High risk	2	3.75	Acceptable risk
68	Cutting uncontrolled parts in a horizontal sawing machine	Loss of limb, Injury	270	High risk	2	7.5	Acceptable risk
69	Do not use the drill protector	Loss of limb, Injury	135	Significant risk	3	3.75	Acceptable risk
70	Hand holding of the mandrel without stopping the drill exactly	Loss of limb, Injury	135	Significant risk	3	3.75	Acceptable risk
71	Hand-held drilling of small workpieces	Loss of limb, Injury	90	Significant risk	3	7.5	Acceptable risk
72	No air compressor periodic control	Material damage, death	1440	Very high risk	1	10	Acceptable risk
73	It is dangerous for the control system to stop the compressor in case of danger. be in the region	Explosion, Multiple death	600	Very high risk	1	10	Acceptable risk
74	Missing planter knife clamping bolts	Loss of limb, Injury	135	Significant risk	3	7.5	Acceptable risk
75	Passing the workpiece over the blades when retracted	Loss of limb, Injury	90	Significant risk	3	10	Acceptable risk

When the risk assessment made using the US MIL STD 882-D system security program (5X5 Matrix) was examined in the furniture firm where the fieldwork was performed, it was seen that 64 risks were detected; 9 of them were high and 55 were medium risk. In the study, a total of 77 risks were identified, 20 of which very high, 29 were high, 27 were significant and, 1 was possible risk assessment using the Fine-Kinney method. The US MIL STD 882-D system security program (5X5 Matrix) method and the Fine-Kinney method scores were different, so no comparison of risk assessments was performed.

In the risk assessment conducted by the Fine-Kinney method, 26.0 percent of the risk was wery high, 37.7 percent of the risk was high, 35.1 percent of the risk was significant, and 1.3 percent of the risk was identified. The proportional distribution of risk definitions is shown in the graph Figure 1.

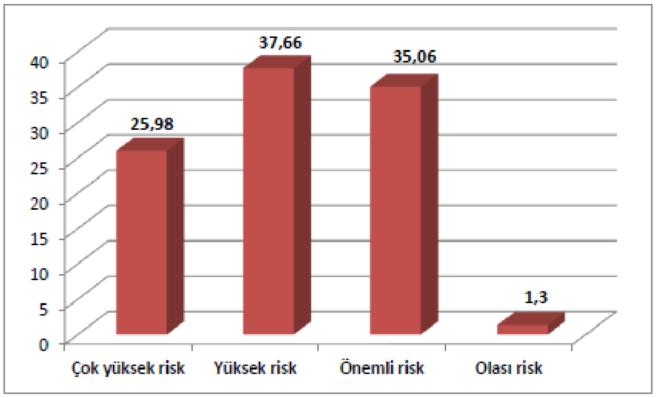

Figure 1: Proportional distribution of risk definitions

Very high risks requiring immediate measures or closing facilities, buildings and surrounding areas; it is seen that due to lack of precautions for intervention in case of emergency, lack of environment measurements to be made from deficiencies in electric and heating systems and air compressors.

The high risks that require corrective action in the short term seem to be due to lack of precautions to intervene in emergencies, due to deficiencies in electricity, and heating systems, ergonomic risk factors, lack of health inspections of employees, lack of work equipment and misuse of work equipment.

Significant risks that require corrective action in the long run; lack of hygiene, psychological risk factors, deficiencies in electrical and heating systems, deficiencies in work equipment and misuse of work equipment.

The risk of sustainability of their activities seems to stem from the unauthorized entry of third parties into the business environment, provided that the activities are sustainable.

The order of priority of transactions is determined according to risk scores for all risks identified after risk assessment. Based on the order of priority of operations, all the risks have been determined for CPAs. Dates and transaction responsibilities for the completion of the transactions of the identified CPAs have been determined and notified to the interested parties. It has been seen that 63 cases of 77 cases, which were identified in the reevaluation of the risk assessment, were reduced to the possible risk level of 14 cases.

When the studies in the literature are examined, in the analysis study conducted by Sönmez et al (2009); the level of lighting in furniture workshops was inadequate, the heating system was inadequate, the workers were exposed to noise and dust, and the work environment hygiene conditions were insufficient.

In the work performed by Gürleyen et al (2013) furniture workshops, work accidents are mostly caused by inappropriate environment conditions at workplaces, design and system errors for the establishment of workplaces, insufficient employees, insufficient trainings for employees and insufficient supervision or interaction between these factors .

Söğütlü and Eroğlu (2008) found that employees did not use machine protectors, physical conditions in furniture workshops were insufficient, and that employees did not have sufficient information on the use of infrastructure in their studies for examining the physical conditions of furniture enterprises operating in Ankara.

In this study, a risk assessment was made by using the Fine-Kinney method to determine the risks that employees are exposed to in the furniture manufacturing sector, and a field study was conducted in order to determine the precautions to avoid hazards and to determine when to prevent work accidents. Within the scope of the project study, a total of 77 risks were identified in the risk assessment using the Fine Kinney method, 20 of which were very high, 29 were high, 27 were significant and 1 was a possible risk.

At the end of this study;

The results of the risk assessment using the Fine Kinney method and the application of the method to prevent risks are determined and shared with the furniture workshop.

When field work was carried out, the workers at the furniture workshop were informed about physical, chemical, ergonomic and psychosocial risk factors in the furniture sector, CPAs that need to be applied to prevent risks, work accidents and occupational diseases.

After the joint work with the furniture workshop employer and job security specialist, employees were provided with job health safety training.

The suggestions for preventing risks in the wood and furniture sector are explained below. The recommendations were based on the literature survey conducted in the project study and the findings from the field study.

It is seen that employers in small-scale workplaces can not make environment measurements and periodic controls even though it is compulsory to comply with legal regulations because of insufficient financial resources and insufficient information. It has been assessed that the application of expenditure tax reductions to be made to legal regulations and environmental measurements and periodic checks to be made will result in the measurement of the environment and periodic checks.

There is a need to make expenditures for the implementation of some of the CPPs determined to prevent the risks identified at the workshops. Employers with insufficient economic conditions cannot implement corrective preventive actions that require expenditure. It has been considered that the implementation of the CPCs will be made operative for the implementation of the CPCs specified in the risk appraisal and for the reduction of the expenditure tax to be made by the employer or for the provision of long-term and low-

In the field study conducted, it was determined that workplace inspections were inadequate, especially in small-scale enterprises, and no workplace inspections were conducted in many small businesses. Employers who have made arrangements to increase workplace inspections are more likely to give more importance to occupational health and safety.

It is considered that the introduction of the National Occupational Standard for workers in the furniture and wood sector will contribute positively to the training of workers in the sector. After the introduction of the National Occupational Standard for workers in the furniture and wood sector, it is considered that non-employment of the non-professional qualification certificates will contribute positively to the provision of occupational health and safety.

One of the most important risks in the furniture sector is dust. In order to prevent or reduce dust generation and spread in the business environment of employers; it is considered that the application of the deductible tax deduction for the installation of ventilation systems, the application of the foundations of work equipment with dust extraction system and other engineering measures, or the granting of long term and low interest loans will contribute positively to the fight against dust.

Consequently, in furniture manufacturing workshops, two main applications should be prioritized within the scope of occupational health and safety precautions;

- Education
- Audit

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Usage Possibilities of Flaxseed (*Linum usitatissimum*) as Growth Medium for *Coniophora puteana Fungi*

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Usage Possibilities of Flaxseed (*Linum usitatissimum*) as Growth Medium for *Coniophora puteana Fungi*

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ABSTRACT

Flax (*Linum usitatissimum*) is blue-flowered and one-year-old culture plant. Its species name, "*usitatissimum*", means "most useful" in Latin. In this study, ground and unground flaxseeds forms were used as agar medium instead of commercially available malt extract agar culture media to growth of *Coniophora puteana* fungi species. Malt dextrose and potato dextrose agars were used as control samples. *Coniophora puteana* mushroom micelles were put on the cooling mediums and kept in the air conditioner cabinet. The rate of growth of the micelles was observed and measured 7 and 10 days later using the DigiMizer program. Afterwards, samples of *Pinus sylvestris* L. were placed on the petri dishes and weight losses were measured after 3 weeks. The weight losses obtained from the samples on flaxseed showed similar findings compared to the synthetic agar mediums in which the *Coniophera puteana* ideally growth.

KEYWORDS: Flaxseed, *Coniophora puteana*, Growth medium

1 INTRODUCTION

Linum usitatissimum is a one-year-old plant with blue flowers. The Latin meaning is 'very useful plant' and this qualification shows the importance of the flax in history (Blumenthal et al., 2000). Almost every part of the flax is widely cultivated for oil, fiber and nutritional value (Oomah, 2001). It was reported that flax was planted by the Greek and Romans (Ertuğ, 2000). Especially in Central Anatolia, it was extensively cultivated for seeds. The linseed oil obtained from the seeds of flax, which is called 'Zeyrek' or 'Zegrek', is used in meals (Fujita et al., 1995). This oil composition contains high levels of linoleic acid (Konuklugil and Bahadır, 2004). It has been used in many areas such as in wood protection industry as water repellent. However, it has been reported that linseed oil is not very effective against wood rot fungus (Humar and Lesar, 2013).

Flaxseed is the seed of the flax commonly referred to linseed (Bekhit et al., 2017). The seeds are 4-6 mm long, egg-shaped, flat, shiny, reddish brown in color, odorless, oily and flavorful (İşleroğlu et al, 2005). Flax seeds are rich in fat and protein. The oil content of the seeds varies between 35 and 45% depending on the flax varieties. In addition, the seed contains 35% crust, 28-30% protein, 6% mineral and ash (Carter, 1993; Yıldırım and Arslan, 2013). It has been reported that flaxseed is added to animal feeds to improve the reproductive performance and health of the animals (Turner et al., 2014). Flaxseed extract of Lignan have antioxidant and antimicrobial properties (Gaafar et al., 2013). In addition to all these medicinal properties, it is scientifically proven that flax can be used as a food preservative (Xu et al., 2008).

In laboratory experiments, different media are used to grow microorganisms. Searches were conducted using different mediums such as Malt Extract Agar (MEA), Potato Dextrose Agar (PDA), Minimal medium (MO) and Hagem medium (HO) for different microorganisms; *Gloeophyllum trabeum, Inocybe flocculosa var. crocifolia, Omphalotus olearius, Postia stiptica, Fomes fomentarius, Meripilus giganteus, Morchella hortensis, Collybia dryophyla* mycelium (Kalyoncu et al., 2008). Amartey et al. (2003) investigated that different growth mediums which consisted of Malt extract agar (MEA), Potato dextrose agar (PDA) as well as, YMPG agar (yeast extract, malt extract, bacto-peptone, glucose, asparagine and thiamine), YMPG agar (without amino acids) and Beech wood powder agar (BWA) for some wood decay fungi (*Phanerochaete chrysosporium, Phanerochaete sordida, Trametes versicolor, Bjerkandera adusta, Antrodia vaillantii* and *Leucogyrophana pinastri*). But, there is no study that uses the flax seed as growth medium for any microorganism until now. Flaxseed is generally found in unground (whole) seed, ground seed and linseed oil (İşleroğlu et al., 2005). In this study, ground and unground flaxseed were used as growth medium for *Coniophora puteana* fungi.

2 MATERIAL AND METHOD

2.1 Flax seed

Ground and unground flaxseeds were purchased from a commercial company in Trabzon/Turkey. Certain amounts of water were added to the flaxseeds to compare with each other. Malt dextrose and potato dextrose agars were used as control samples. Flaxseed contents and added water contents were given in Table 1.

Table 26: Flaxseeds contents and added water contents (gr)

Number	Medium	Flax seed content (gr)	Water content (gr)
1	Unground flaxseed	45	135
2	Unground flaxseed	45	180
3	Unground flaxseed	45	225
4	Ground flaxseed	30	120
5	Ground flaxseed	30	150
6	Ground flaxseed	30	180
7	Malt dextrose agar (Control)	-	-
8	Potato dextrose agar (Control)	-	-

2.2 Experiments

The mixtures were given in Figure 1. All contents were sterilized in an autoclave at 121 ° C for 20 minutes and poured into petri dishes.

Figure 25: Mixtures of flaxseed growth medium

Similarly, malt and potato dextrose control agars were sterilized and then poured into petri dishes. *Coniophora puteana* mushroom mycelium (1x1 cm) was added on the cooling mediums and kept in the air conditioner cabinet with 20± 2°C and 65±3 °C relative humidity conditions.

The rate of growth of the mycelles was observed and measured 7 and 10 days later. Growth rates were calculated using the DigiMizer program.

2.3 Fungal activity

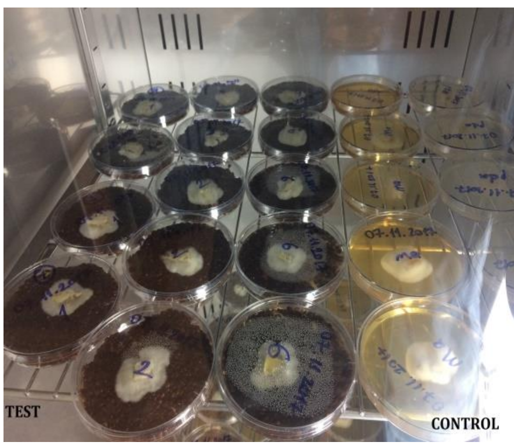
To have knowledge about the fungal activity of mycelium; *Pinus sylvestris* samples, prepared in size of 1.5 x 0.5 x 2.5 cm (tangential x radial x longitudinal), were added the all studied mediums and exposed to *Coniophora puteana* fungal attack. The mass losses of samples were measured after 3 weeks. The mass losses were calculated as shown Eq. (1)

$$\text{Mass loss}(\%) = (\text{mo} - \text{md})/_{\text{mo}}\ x100 \qquad (1)$$

Where:
mo is the oven dry mass prior to test, and md is the oven dry mass after the test.

3 RESULTS AND DISCUSSION

Mycelium growth on the unground and ground flaxseeds on 4th day was shown in Figure 2 and Figure 3.



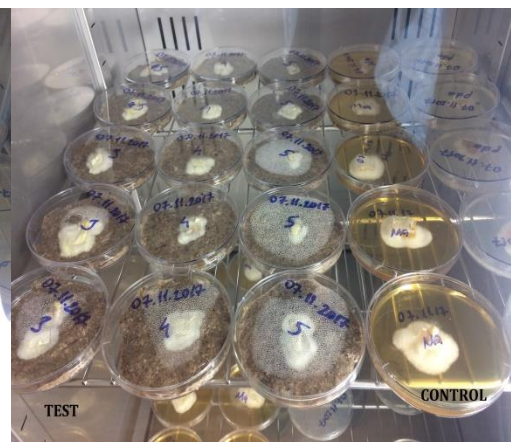


Figure 2: Mycelium growth on unground flaxseeds   Figure 3: Mycelium growth on the ground flaxseeds

As seen from the Figure 2 and 3, the mycelium growth rates are close to the mycelium growth rates on the malt dextrose agar which is one of the control mediums.

Mycelium growth rates (%) at the end of the 7th day were given in Table 2.

Table 2: Mycelium growth rates (%) at the end of the 7th day

Number	Medium	Mycelium growth rate (%)
1	Unground flax seed	94±1.2
2	Unground flax seed	94±1.7
3	Unground flax seed	95±2.3
4	Ground flax seed	93±1.5
5	Ground flax seed	93±0.9
6	Ground flax seed	93±1.2
7	Malt dextrose agar	100±0.0
8	Potato dextrose agar	100±0.1

At the end of the 7th day, the mycelium growth rates on the ground and unground flaxseed were close to each other and close to the control mediums (malt dextrose agar and potato dextrose agar). At the end of the 10th day, mycelium growth was 100% on the all mediums.

As can be seen Figure 4, after the development of mycelium was completed, the sterilized wood specimens of *Pinus sylvestris* were placed on the petri dishes.

Figure 4: *Pinus sylvestris* wood samples on the petri dishes

The mass losses of the wood samples exposed to the *Coniophora puteana* fungi attack were determined, 8 weeks later. The calculated mass losses were given in Table 3.

Table 3: Mass losses of wood samples after 8 weeks

Number	**Medium**	**Mass losses (%)**
1	Unground flaxseed	19±2.6
2	Unground flaxseed	19±3.2
3	Unground flaxseed	18±2.8
4	Ground flaxseed	17±1.9
5	Ground flaxseed	19±2.0
6	Ground flaxseed	18±2.4
7	Malt dextrose agar	23±1.1
8	Potato dextrose agar	21±1.9

According to the Table 3; whether ground or not ground of flaxseeds was not effect to the mass loss ratios, significantly. Because the highest mass loss was the same (19%) both ground and unground flaxseed samples. Mass loss was found to be less than the control mediums.

Antimicrobial properties of flaxseed were reported in many scientific studies. In a study, the antimicrobial properties of extracts of different concentrations (0.66, 1.00 and 1.33 mg/disc) of ethyl acetate, methanol, n-hexane, butanol, distilled water extracts of flax seeds against different microorganisms (*Bacillus cereus, Candida albicans, Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, Salmonella typhi, Staphylococcus aureus*) were tested (Bakht et al., 2011). Researchers reported that ethyl acetate and butanol extracts of samples reduced the growth of *Bacillus cereus*. Additionally, an antimicrobial property of ethanol and chloroform extracts of flaxseed was studied. Both of the extracts inhibited *Salmonella typhi, Enterococcus, Bacillus subtilis, Staphylococcus aureus* (Amin and Thakur, 2014). According to the results presented in all of these it can be evaluated as an interesting result that the growing up the fungi mycelium on the flaxseed which has also antimicrobial properties. While the flaxseed is sterile in the autoclave under the pressure and/or temperature, components of the flaxseeds that can support the growth of fungi may arise.

In the same duration and under the same conditions, flaxseed was tried as growth medium with different fungi mycelium such as *Pleurotus ostreatus* (PO), *Trametes versicolor* (TV), *Postia placenta* (PP), (Figure 5). Howeverthe best results were obtained from *Coniophora puteana* species.

Figure 5: Mycelium growth of different fungi on flaxseed medium

4 CONCLUSION

In this study, it was investigated the possibilities of the ground and unground flaxseeds forms as an agar medium instead of commercially available malt extract agar culture media to growth of *Coniophora puteana* fungi species. The best growth among the studied mushroom mycelium (*Pleurotus ostreatus, Trametes versicolor, Postia placenta*, *Coniophera puteana*) has observed in *Coniophera puteana* fungi. There was no significant difference in the ground or unground flaxseeds forms in terms of mycelium growth rate and wood mass losses. Mass loss was found to be less than the control mediums. For further studies, the flaxseed mediums can be diversified with the ground and unground options, different water contents and different additive materials. Additionally, variations can be attempted to standardize the usability of flaxseed as growth medium in laboratories.

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THE INTERNATIONAL FOREST PRODUCTS CONGRESS

The Effects of Primer Transport Techniques on Raw Wood Materials in Turkey

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ABSTRACT

Generally, there are two stages in the transportation of raw wood material from the forest. The first one is the primer transport that is the process of moving trees or logs from the cutting site to a landing or road side where they will be processed into logs or consolidated into larger loads for transport to a processing facility or other final destination. The second one is to transport the products from the stacked or main storage areas to trading storage and factories.

Primer transportation systems are commonly recognized as ground skidding systems, forwarders, cable systems, aerial systems, draught animals and other extraction systems (manual, pit-sawing, chute, winch truck, water). Primer wood transport, are heavy and quite costly in the mountainous terrain conditions. Because of difficulties in the primer transportations, instead of the human and animal forced transport systems, the machine usage has become more and more important during the primer transportation of raw wood material at the steep terrain. The primer transport methods with machines may cause technic, economic and environmental problems. One of these problems is the technical and physical defects on the wood raw materials.

In this study, the mechanized primer transportation systems (tractors and cable yarders) in Turkish forestry were introduced and each of them evaluated for the environmental and physical defects on raw wood materials. In addition to this, their work productivity of machine extraction systems and some research results obtained from some literature were given. At the end of this paper some assessments and recommendations were done.

KEYWORDS: Primer wood transport, tractors, cable yarders

1 INTRODUCTION

Primer transportation of raw wood material is heavy and quite costly in the mountainous terrain conditions. Because of difficulties in the primer transportation of harvested woody materials, machine usage has become more important during the forest operations at the steep terrain for productivity and work safety (Çağlar, 2016). In addition to these, some environmental and technical problems may occur when the forest machines have been used for primer transportation. One of them is quality and quantity losses that occur during primer transportation by machinery.

Generally, there are two stages in the transportation of forest products (such as raw wood material) from the forest. The first part is the primer transport or extraction which is the process of moving trees or logs from the place where it was originally cut down to a temporary storage areas, landings or road sides where they would be processed into logs or consolidated into larger loads for transport to a processing facility/mill or other final destination (Figure 1). The second one, called secondary transport, has dealt with the haulage of stacked road-side piles to log depots or mills (Çağlar, 2004).

According to Heinrich (1995), the extraction is the process of moving trees or logs from the cutting site to a landing or roadside where they would be processed into logs or consolidated into larger loads for transport to a processing facility or other final destination.

Öztürk et al, (2007) stated that approximately 75% of the Turkish forests are located on the lands greater than 40 % slopes. According to DPT (2007), its 50 % are located on the mountainous areas where the slope is over 44%. These mountainous and steep slope conditions have been negatively affected the raw wood materials, environment, forest stands during the primer transportation. Therefore, harvesting in mountainous regions has always posed a special difficulty. Due to same reasons, harvesting and transportation have also played a significant role at the steep terrain logging.

Turkey has 22.3 million hectares of forest. This amount of forested area is 28.6% of the general area of the country. The wood wealth of Turkish forests is 1.6 billion m^3 for the 2015 year. In the 2015 year, 18,3 million m^3 raw wood materials were harvested from the forests, and they were taken out of forest areas (OGM, 2015). Especially the primer transportation of these raw wood materials is expensive, difficult and time consuming on the steep terrain conditions. Due to these reason, the mechanized transportation systems have been developed since the turn of the century.

The secondary transportation of raw wood materials has been done, utilizing trucks, trailers or other small transportation vehicles from forests to log depots. However, in the primary transportation of raw wood or timber, there are different transportation means in practice.

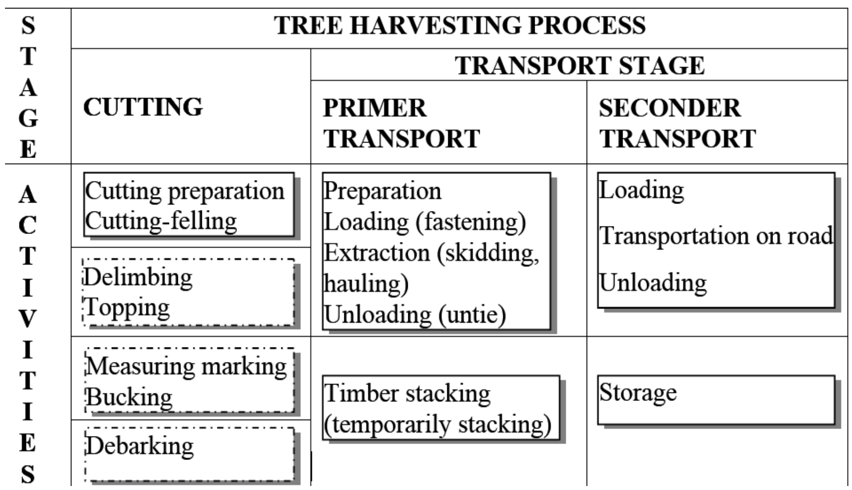

Figure 1: Motor-manual tree harvesting and transportation in Turkey (Karaman, 1997; Çağlar, 2016)

Generally in view of the power source of raw wood transportation methods from forest compartments, there are 3 different primer transportation systems. Those methods can be classified as human powered (by hand and gravity), animal powered and the machine powered transportation methods or the combination of all three methods in the primer transportation stage.

Different tools and methods are applied according to the technical, economic and ecological factors for the primer transportation of the raw wood materials. Heinrich (1995) recognized the classes of extraction systems as; ground skidding systems, forwarders, cable systems, aerial systems, draught animals, other extraction systems (manual, chute, truck winch, water, etc.). From the extraction systems given above, forwarders and aerials systems have not been used in Turkish forestry, so far. At the present situation,the Turkish logging works are heavily ground skidding oriented (by human, machine and animal power) and forest skyline systems in Turkey.

A main part of this study deals with the forest tractors and cable yarder systems that have been used in Turkish forestry. This mechanized systems were first introduced in the 1970s with the acquisition of Wyssen Baco and Hinteregger long distance yarders because forest road density was not as extensive as those today. Their productivities obtained from the literature were given. Each of primer transportation techniques for the above mentioned machines was evaluated in view of the physical defects observed and categorized on raw wood materials. In the end of this paper, some recommendations were done about transportation techniques to protect raw materials transported by this machines.

2. MECHANIZED PRIMARY TRANSPORTION SYSTEMS IN TURKEY

The percentage of the primary transportation by manually (with gravitation) on sloped areas is 72 % of the total primer transport in Turkey. This method is named as manual-gravity skidding. This is carried out as ground skidding, sliding or rolling up the logs from upwards to down slope (Erdaş and Acar, 1993). Manually ground skidding methods have been used for primer transportation of debarked logs for distances less than 200 m for slope between 35-65 % on ground (Erdaş et al, 2014). It is also used for the moving of the logs to hauling distance of the machines (Figure 2).

When the manually ground skidding methods used, the quality and quantity losses occur on transported raw wood materials. It is determined that in a study conducted by Gürtan (1975), an average 17% volume loss occurred on the logs when the manually skidding method were used in Trabzon and Artvin regions.

The draught animals (such as horse, ox, buffalo and mule) have been used with 15 % of total primer transportation in the flat ground (up to 20% slope) conditions (Erdaş and Acar, 1993; Erdaş et all, 2014). With paralleling the technological development in mechanized transportation systems at forestry, machine powered primer transport systems have also been employed in Turkish forestry.

In addition to these wood extraction systems, approximately 15 % of the timber is currently transported with mechanized transportation systems. Between these machine extraction systems, forest tractors have been employed in 8 % and forest skylines also have been employed in 5% of total primer transport (Erdaş and Acar, 1993).

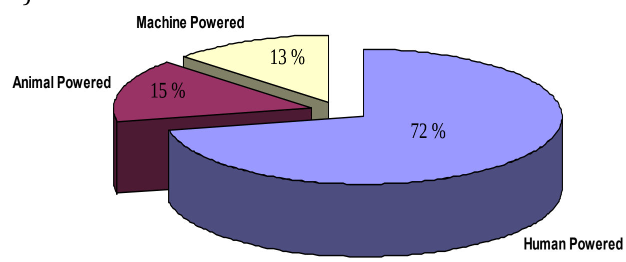

Figure 2: The usage percentages of primer wood transport methods in Turkish Forestry.

That mechanized primary transportation machines are modified farm tractors, forest tractors (skidders) and the forest skylines. The farm tractor types include Massey Ferguson, New Holland, and Fiat brand tractors. Generally modified farm tractors have been combined with light scale drums to haul small diameter wood materials.

There is no legal and technical regulations for the usage of tractors for the primer transportation in Turkey. For this reason, primer transportation by these machines are carried out irregularly, depending on the experience of forest workers (Türk and Gümüş, 2015). Hence, temporal and economic losses occurs in many parts of forest areas environmentally, physical damage on the logs as well as.

In this study, within the mechanized extraction systems used in Turkey, forest tractors (Mercedes MB Trac 800 and MB Trac 900) and the forest yarders/skylines (Koller K 300, Urus MIII and Gantner sledge skyline) were introduced and their productivities are given. A yarder (skyline) is a machine which uses a system of cables to pull or fly logs from the stump to the landing.

There have been several methods used to accomplish primary transportation in steep terrains of Turkey. One of the common methods is the aerial systems using skyline yardings where the machine does not remain in contact with the ground and the cut trees remain fully suspended in the air (Kellogg et al., 1996; Gümüş and Acar, 2010). The other method cable haulage and skidding which is utilizing any machine power such as forest tractors. In both cable haulage and skidding techniques by forest tractors, harvested woody material have been skidded on the ground surface from their stump to the landing areas.

Those productivities were obtained from literature that was conducted in mountainously mostly conducted in mountainously Eastern Black Sea Region of Turkey given both for forest tractor and forest skylines. Generally, the research methodology used for productivity measurement in the referenced studies is the cumulative (continuously) time measuring technique for both forest tractors and for forest yarders. In this measurement technique, time studies have been conducted during logging activities and each work phase duration is obtained by extraction from following work phase. In addition to this, the number of the forest workers who worked in primary transportation of raw wood materials changed up to 5 people.

2.1 Forest Tractors (Skidders) in Turkey

There are two different types of forest tractors (skidders) have been employed in Turkish forestry. These type forest tractors have been used for hauling large and heavy logs. These forest tractors' brand is Mercedes and named as MB Trac 800 and MB Trac 900 (Figure 3).

Daily transport capacity of MB Trac 900 tractor is 40-60 m^3 on the average. Drawing rope is 12 mm in diameter and the drum capacity of MB Trac traktors is 100-120 m length. Generally two workers are employed in operating the tractor. One of them is attaching the logs and the other untying the load (Acar, 2004).

Figure 3: MB-Trac 900Forest tractor hauling the large volume heavy logs (Photo. S.CAGLAR)

Technical specification of forest tractors: Mercedes MB Trac 900 tractor has 85 HP engine power. Its weight is 6000 kg, the hourly outputs is changeable between 3.30 – 8.40 m^3/hour. It has two drums with 12 mm hauling cable diameter. Cylinder Capacity of MB Trac 900 is 3780 cm^3 and it has 4 cylinders (Öztürk, 2005).

In a study realized by MB Trac 900, the hourly productivity was found as 6.360 m^3/hour for the 600 m skidding distance and for 300 m skidding distance was also found as 9.471 m^3 / hour. The cable hauling productivity of MB Trac 900 for average 30 m was determined as 13.954 m^3 / hour. Average cost per volume of MB 900 Trac is 9.80 \$/m^3 for 600 m skidding, 7.31 \$/m^3 for average 300 m skidding, and 4.65 \$/m^3 for average 30 m hauling distance (Öztürk, 2005).

In another study conducted in Giresun forest in Turkey, the hourly productivity of MB Trac 800 and MB Trac 900 forest tractors was determined as 2.280 m^3/hour and 1.980 respectively. The average hourly cost of these tractors was found as 6.30 \$/hour (Acar, 1998).

The productivity of MB Trac 900 was examined by Öztürk (2009) during the beech logs were skidded from downhill to uphill on skid strip road in Ordu, Turkey. The skidding distances of logs varied between 40-140 m. The hourly productivity of the MC Track 900 was determined as 14.41 m^3/hour for 55 m. skidding distance and 8.7 m^3/hour for 105 m skidding distance. The cost of the skidding was calculated as 5.22 m^3/ Turkish Liras (TL) for the 55 m. and 14.25 m^3/TL for the 105 m. skidding distance. The average volume for each shift is 1.49 m^3 and 2.13 m^3 respectively.

The productivity of MB Trac 900 forest tractors was determined by Çağlar (2016) at mixed forest stand with spruce and scots pine in Artvin, Turkey. Average cable hauling distance was determined 47.14 m from felling area to the uphill forest road side landing. The average slope of the harvesting area was 55% and the ground was covered by the Rhododendron intensively. The productivity of MB Trac 900 was determined as 4.17 m^3/hour for 47.14 m cable hauling distance. The average shift time was determined as 12.84 minute/shift and average volume for each shift was determined as 0.893 m^3/shift respectively.

2.2 Forest Yarder Systems in Turkey

Applying of skyline systems to logging operations in Turkish forestry was started after the end of 1970's. The most favourable using areas of the skylines are mountainous Eastern Black sea Region of Turkey (Aykut, Acar, Şentürk, 1997). The sledge skylines (such as Wyssen, Baco and Hinteregger brand) were used in the primer transportation of raw wood material in Eastern Black Sea Region of Turkey. After these sledge skyline systems, the mobile tower yarders (Koller K300 and Urus M III) were imported in the mid-1980s (Erdaş et al., 2014). In the 2018 year, Tajfun MOZ 300 mobile tower yarders were imported and they have been employed in Artvin Regional Directory of Forestry in Turkey. But, there is no research conducted with Tajfun mobile tower yarder to determine its productivity in Turkish forest as of today.

Cable logging can be carried out using ground pulling, highlead systems or with skyline systems. Skyline (yarder) systems enable timber to be fully suspended during transport and are therefore particularly environmentally friendly. Skyline systems can be classified according to their different characteristics (Trzesniowski, 1996). These forest skylines have been employed to transport harvested raw wood materials from forest compartment to the landing areas between 300-2000 m distances in Turkish forestry.

According to hauling distances, the transportation distance of forest skylines was classified as;

- Short distance yarders; these have less than 350 m transportation distance, such as Koller K300, Tajfun MOZ300 mobile tower yarders.
- Medium distanced yarders; these are enable to transport wood between 300–800 m transportation distances, for example Urus MIII type mobile skylines.
- Long distances skylines; these are also enable to transport wood between 800 – 2000 m for example Gantner USW and HSW type sledge skylines in Turkey (Çağlar, 2002; Acar, 2004, Öztürk et al, 2007).

These skylines have been employed as the main primary transportation systems in steep terrain and mountainously areas of Turkey. At present, because of the steep terrain condition of the Eastern Black Sea Region of Turkey, the Koller K300 and Urus MIII mobile tower yarders and the Gantner sledge yarders are being used for the primery transportation of the raw wood material.

Gümüş and Acar (2010) evaluated a consecutive skyline yarding system integrated with two different types of skyline yarding systems and the gravity skidding system, considering technical, economic and environmental aspects in primary forest transportation on steep terrain. It is found that the productivity of consecutive skyline yarding system was 4.97 m^3/hour, while the productivity of the gravity skidding system was 0.74 m^3/hour. Besides, the gravity skidding system caused more damages on skidded logs, residual trees, and forest soil than that of consecutive skyline yarding system.

2.2.1 Koller K300 Mobile Tower Yarder

The first Koller K300 mobil yarder was imported in 1982 and this particular model have commonly been used in logging operation in Turkey since then. There are two different types of Koller K300 tower yarder in Turkey. One of them is mounted on the 3-point link of 50 kW a farm tractor as seen Figure 4 (Çağlar, 2004). The other type of Koller K300 is trailer mounted yarder powered by its own motor. They are generally used for uphill logging (Acar, 2004). Three drum machines for uphill and downhill logging as well as flat terrain, mounted on a single axle trailer (Trzesniowski, 1996). Generally this type cable yarding systems are used for thinning, pre-harvesting and final harvest in sorts when the forest road network density enough.

The weight of Koller K 300 without the tractor is 1580 kg, skyline cable length and diameter are 300 m and 16 mm, respectively. The mainline length and diameter is also 300 with 10 mm diameters. The guyline length is 30 m and its diameter is 14 mm. The tower height is 7 m. and transportation capability for each journey 1.5 ton for hanged logs (Çağlar, 2002, Acar, 2004).

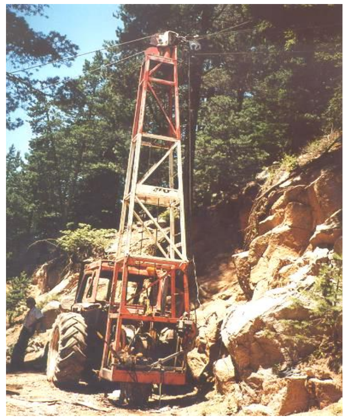

Figure 4: Koller K300 mobile Yarder

In a study realized by Çağlar, (2004) in Eastern Black Sea Region of Turkey by using Koller K300 short distance skyline, the Softwood timbers (*Abies nordmanniana* and *Picea orientalis*) were transported towards uphill. The daily productivity of Koller K300 was determined as 36.184 m^3/day for 280 m distance and 55 % skyline cable slope.

In Eastern Black Sea Region of Turkey by using of Koller K300 short distance skyline hardwood tranported. The work productivity was obtained 12.19 m^3/hour for 163 m and 28 % skyline slope (Aykut, Acar, Şentürk, 1997). In another study, conducted in mountainous Artvin region, softwood transported. The productivity was found 3.750 m^3/hour for 250 m distance by using Koller K300 skyline (Erdaş, Acar, 1995).

2.2.2 Urus MIII Mobile Tower Yarder

Urus MIII medium distance yarder is a truck mounted tower yarder with two or three axles. Its power is obtained from the truck that equipped with 150 HP engine. It has a separate cabin to control the yarde on the back of the truck's driver cabin (Figure 5). This skyline can be used for both uphill and downhill transport of timber. Hourly transport capacity of Urus MIII is 4-8 m^3 on the average with 4 employees (Çağlar, 2002).

Figure 5: Urus MIII mobile yarder in Turkey

Table 1: Technical Specification of Urus MIII Mobile Yarder

URUS MIII Mobile Yarders	Specifications
Base Machine:	Mercedes 1500T trucks
Weigth:	8500 kg
Height of tower:	8.7 m
Maximum number of drums:	4
Maximum cable speed:	6 m/s
Skyline line (diameter x length):	22 mm x 600/800 m
Main line (diameter x length):	10 mm x 600/800 m
Haulback line (diameter x length):	8 mm x 1200/1600 m
Auxiliary line (diameter x length):	8 mm x 600 m
Guyline (diameter x length):	16 mm x 50 m
Carriage:	Koller SKA 2.5

In a study conducted at Artvin Forest District in Turkey, the working productivity of Urus MIII mobile skyline measured and the productivity were calculated according to both for the total work place activity time with delay time and needed journey time not including delay time. It was determined as 3.84 m^3 /hour for total activity time consumption, and 4.27 m^3 /hour for needed journey time for 650 m distance and 41 % skyline slope (Çağlar, 2002).

2.2.3 Gantner Sledge Yarder

In view of their transportation distance, Gantner long distanced sledge skylines is used for up to 2000 m distance for the extraction of the raw wood material from compartment to forest road. Mostly Gantner sledge skylines have been installed at mountain station. This skyline also can be used for both uphill and downhill transportation of timbers. Gantner uses its engine power to pull the empty carriage to harvesting area, and it also benefit from gravity while transporting the log from forest to the forest road.

Generally, Gantner sledge skylines carries heavy timber from forest stand to the forest road up to 2000 m long distances. Because of the its long distance transportation capability, that skylines have not need high road density. But, their installation and dismounting is time consuming. As the forest road construction is expensive and difficult, they have been preferred for long distance.

Technical specifications of Gantner long distance sledge skylines are; they have a 45 HP Engine power. Skyline length and diameter is 2000 m, 24 mm respectively. Always the mainline length is longer then skyline length with 12 mm diameter. The maximum load weight capacity is 2.5 ton. Minimum worker needs of Gantner skyline is 4 people for logging operations.

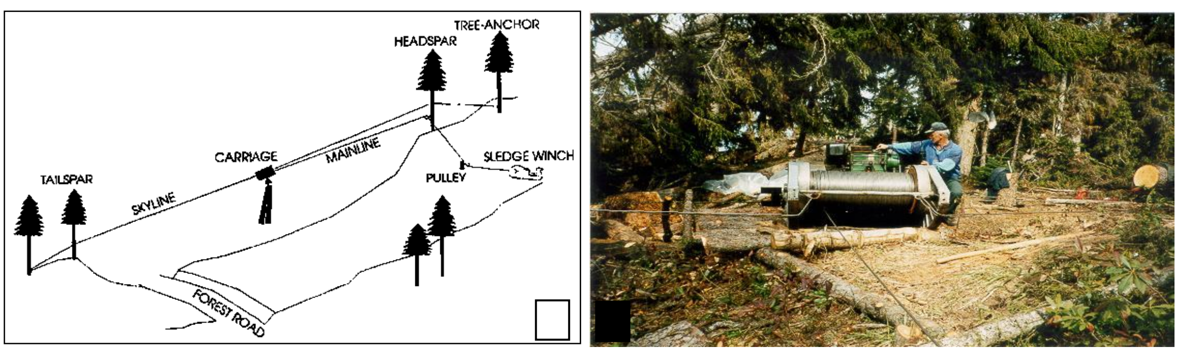

Figure 5: a) Sledge skyline carrying to downhill (Trzesniowski, 1996), b) Gantner sledge skyline in Turkey

In a study conducted on the productivity of the Gantner long-distance sledge skyline in two different study areas that the productivity was determined as 4.03 m^3/ hour for Alabalık study areas for 1200 m hauling distance and it was also found as 6.98 m^3/ hour for Soçidibi area for 700 m hauling distance in Turkey (Eker et all, 2001).

Inappropriate and poorly planned methods used for primary transportation stage may result in serious adverse effects on timber quality, residual trees, forest soil, and forest productivity (Gümüş and Acar, 2010). In Turkey, unfortunately, most logging operations are still carried out by untrained and unsupervised loggers and skidder drivers working without the benefit of topographic or stand maps, without planned log extraction paths, and without financial incentives to reduce the environmental impacts of their activities.

3. CONCLUSION AND RECOMMANDATION

In Turkey, most common system in logging is modified farm tractor skidding on the skid road and on the ground that have less than 25% slope. Especially, when the slope is greater than 35% on steep terrain conditions, the cable haulage methods have been used by utilizing both farm tractors and forest tractors in Turkey. If the forest road spacing longer is than 500 m and the ground slope is greater than 70% then the forest skylines have been used in mountainous areas of Turkey.

Especially when the selective cutting system is used, environmentally friendly logging systems (such as cable yarders) have been needed in Turkey. In spite of this reality, there is no adequate yarder systems in Turkey because of the associated cost. The ground-based skidding and winching systems (such as tractors) are not found environmentally friendly. These ground-based systems have been reported to cause large-scale environmental degradation and physical degradation of the woody materials.

There are some areas that certified by the Forest Stewardship Council (FSC) as in Turkey. This way, Reduced Impact Logging (RIL) principles could be introduced and mandated in sensitive forest areas. Within this context, forest machine operators, chainsaw operators, tractor operators and their assistants must be trained and certified for the environmentally friendly forest operations.

In this study, mechanized primer wood transport vehicles, such as forest tractors (MB Trac 800 and MB Trac 900) and short-medium-long distance forest skylines (Koller K300, Urus MIII and Gantner) have been introduced. Their productivities obtained from some literature also have been given in this study in briefly.

To prevent decrease in machine efficiency and to reduce fuel consumption, the maintenance of machinery must be performed in time according to technical specification. In addition to this, adequate number of spare parts should be maintained to prevent any loss of time in case of urgent maintenance works.

Environmental sensitivity, safely work activities and productivity should be taken as a top priority while planning, renting and installation of primer wood transport machines.

The staff problem should be solved to increase of workers' productivity. Workers' lodging, nutrition and safely working conditions should be provided. Persons who are not specialized in mechanized wood transport should not be employed for this purpose as tractors are expensive pieces of equipment and they cannot always be immediately repaired on site.

Forest tractors are the most employed primer transport vehicles all around the Turkish forest. Both Mercedes MB Trac 800 and MB Trac 900 skidders are useful for the areas that have adequate forest road density.

The productivity of mechanized primer transport machines is adequate if they have been employed as all time work and good organized in Turkey. But, the skylines in use have been getting old and they are subject to constant breakages. Because of this reason, they are not being employed economically.

Cable yarder system has an advantage over ground skidding system in that there is no need to bring in a heavy machinery into the forest. In view of the environmentally primer wood transport, the forest skylines were found to be positive on the environment. In comparison of the ground skidding methods between the forest skylines have positive effects on forest ecosystem. If the timbers had been transported by using the skidding method on the ground, it would have been very harmful for forest ecosystem, forest stand (Çağlar, 2004) and for physical damages on transported woody materials.

In view of the primer transport costs, generally it is stated at the literature that URUS MIII skylines were found more expensive than the Koller K300. The advantage of Gantner forest skylines is that they can be set up for longer distances. But, the rigging and dismounting time for these machines is longer than mobile skylines.

Koller K300 Short distance and Urus M III medium distance yarding systems needs a well designed and developed forest road networks. That forest skylines are appropriate for the mountainously Eastern Black Sea Region of Turkey and they are mostly employed at this region.

The Koller K300 skylines have been offered for the transportation of fuel-wood and low volume timber from a short distance. Between the mobile yarders URUS MIII is powerful and these cable yarders preferred for the heavy logs or forest products from the middle yarding distance. Gantner skylines are powerful and productive. It is an important machine for timber transportation at long distances. These machines are used where the transport distance is long or the road density is low (Acar et al., 2005).

Inappropriate and poorly planned methods used for primary transportation stage may result in serious adverse effects on timber quality, residual trees and forest soil (Gümüş and Acar, 2010). In Turkey, unfortunately, most logging operations are still carried out by untrained and unsupervised loggers and skidder drivers working without the benefit of topographic or stand maps, without planned log extraction paths, and without financial incentives to reduce the environmental impacts of their activities.

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Effects of Pressing Time on Some Technological Properties of Laminated Veneer Lumber (LVL) Produced Using Nylon Waste as Adhesive

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ABSTRACT

It is desired the wood composite materials which have broaden using areas in human residence have no negative effects on human health and environment. But because of formaldehyde content of most of resins used in wood based composite production, wood composite materials have been seen a threat on human health and environment. Therefore, numerous studies have been made to develop an effective method to decrease formaldehyde emission from the wood based panels and various methods have been tried.

The aim of the study was to investigate those effects of pressing time on some technological properties of nylon composite LVL. Poplar (Populus deltoides) veneers were used to produce nylon composite LVL. Three different pressing time (8, 10, 12 minutes) and pressing temperature 140 °C were chosen as press parameters in the manufacturing of nylon composite LVL. Bonding strength, bending strength, modulus of elasticity, density and equilibrium moisture content of nylon composite LVL panels were determined according to TS EN 314-1, TS EN 310, TS EN 323 and TS EN 322, respectively. The experimental results showed that technological properties of panels generally increased with decreasing pressing time.

KEYWORDS: Nylon Composite LVL, Pressing Time, Technological Properties

1 INTRODUCTION

Wood has characteristics that make it suitable for many uses. Laminated veneer lumber (LVL) is manufactured from veneers with equal or different thicknesses or wood species glued together, ensuring that grains are glued parallel (Gaff and Gašparík, 2015; Shukla and Kamdem, 2009). LVL panels are of great structural use due to their high mechanical strength, great dimensional stability and ability to receive preservative treatment (Kamala et al., 1999). It has potential for use in structural and nonstructural applications such as in the construction and furniture industries, as a material for flooring, as structural beams, headers, columns and in both residential and commercial applications and numerous interior and exterior application areas (Burdurlu et al., 2007; Souza et al., 2011; Melo and Menezzi, 2014).

LVL may be one of the most important solutions concerning raw material economy. It is also one of the well-known and commercially produced engineered wood products (EWPs) in the forest products market in North America and Europe. LVLs can be used for structural and non-structural purposes due to their high strength, dimensional stability, consistency, and treatability (Nelson, 1997).

Importance of wood based materials gradually increases due to growing demand to wood materials and existence and decreasing quality of raw materials. Therefore, use of adhesive extensively increases and use of raw material source develops in forest product industry. It is stated that adhesives used in about 70% of application in woodworking industry (Aydin et al., 2010). At present, urea formaldehyde and phenolic resins are the adhesives used mainly in plywood production and account for 87.1% and 9.6% of all adhesives used in plywood manufacture, respectively, in 2004 (Qian, 2006). Urea formaldehyde resin is non-flammable and resistant to changes in high temperature, light and corrosion.It has good adhesive strength is, a short curing time, simple production technology and low production costs. But it also has a number of disadvantages, such as a high curing shrinkage ratio, a brittle colloidal property, weak water resistance and formaldehyde emission. Phenolic resins are able to enhance bonding strength and water resistance, but they require a long curing time, high curing temperatures, and have high production costs and emit formaldehyde and phenol (Cui et al., 2010). Formaldehyde release depended on content of release causes adverse health effects such as eye and respiratory irritation, irritability, inability to concentrate and sleepiness (Colak and Colakoglu, 2004). Also, The International Agency for Research on Cancer (IARC) in 1995 attached to formaldehyde in terms of human health "Possible Carcinogenic Substances" class and the ratio of formaldehyde can release from wood based materials was limited in most of country (IARC, 2004; Colakoglu, 1993). After this area investigated comprehensively, IARC in June 2004 removed formaldehyde from "Possible Carcinogenic Substances" class and identified as an agent caused directly carcinogen for human (Jianying et al., 2010). It is started to prefer alternative adhesives or using formaldehyde scavenger prevented formaldehyde release in industry due to this disadvantage of formaldehyde based resins. Although some of these new adhesives have already been used in industrial applications, their supply is limited which may be due to the high modification costs or some their poor properties, for example, low wood resistance (Fang et al., 2013). Therefore, the chemicals and adhesives used are both cheap and easily accessible and its technological properties qualify according to usage of wood based panels (Colak et al., 2016).

Solid waste composition varies with changing consumption habits in Turkey, population growth, rising living standards, the increase in packaged product sales. Overall, 20% by weight and 50% by volume of the waste consists of packaging waste is formed (Official Gazette, 2014). Recycle of nylon constitutes an important part of packaging waste is gained importance due to both dissolution of nature for a long time and harmful gases are released by burning into the atmosphere (Colak et al., 2016). In literature, it was shown that the wood based panels obtain from using plastic and textile fiber waste are petrochemical materials as an adhesive gave successful results (Cui et al., 2010; Kajaks et al., 2012; Kofi, 2014). From there, it is thought that the nylon constitutes a serious waste of potential for our country and is a petrochemical is evaluated in LVL industry.

2 MATERIALS AND METHODS

Poplar logs were selected in the study. The LVLs used in this study were manufactured using rotary peeled veneers. Logs were not steamed or boiled prior to peeling. Rotary peeled veneers clipped into 500 mm long by 500 mm wide by 2 mm thickness and shipped to a manufacturing site. The veneers were pre-selected for strength and appearance. They were conditioned in an environmentally controlled room in relative humidity of 65 ± 5% and a temperature of 20 ± 2 °C until they reached the equilibrium moisture content of 12%.

The veneers were then dried to 6–8% moisture content with a veneer dryer. After drying, it was formed nylon composite LVL panel drafts. The draft of nylon composite LVL is shown in Figure 1.

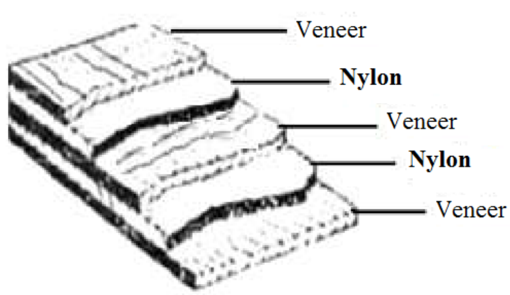

Figure 1: Draft of nylon composite LVL

Three-ply-LVL panels with 6 mm thick were manufactured by nylon wastes. The nylon wastes were lay outed at rates of 160 g/m^2 to the single surface of veneer. Hot press pressure was 8 kg/cm^2 for poplar while hot pressing time and temperature were 8, 10, 12 minute and 140°C, respectively. Two replicate panels were manufactured for each test groups. Also, the conventional plywood panels were manufactured with urea formaldehyde.

The specific gravity, shear strength, bending strength and modulus of elasticity of nylon composite LVL panels were determined according to TS EN 323-1 (1999), TS EN 314-1 (1998), and TS EN 310 (1999) standards, respectively.

Table 1: Press Parameters

GROUP	Bonding Types	Pressing Time (m)	Press Pressure (kg/cm^2)	Press Temperature (°C)
Control	UF (55% solid content)	6	8	110
A	Nylon	8	8	140
B	Nylon	10	8	140
C	Nylon	12	8	140

3 RESULTS AND DISCUSSION

Technological properties test results of nylon composite LVL panels according to press parameters were presented in Table 2 and Figure 2.

Table 2: Technological properties of nylon composite LVL panels

Test Methods	Control (UF)	8 minutes	10 minutes	12 minutes
Bonding strength (N/mm^2)	3,99 (0,42)	2.647 (0,61)	3.107 (0,25)	2.787 (0,39)
Bending Strength (N/mm^2)	100,44 (17,20)	95,43 (7,05)	85,76 (8,54)	54,79 (17,76)
Modulus of Elasticity (N/mm^2)	7338,01 (695,88)	6719,31 (302,49)	6095,12 (233,95)	4687,38) (772,39)
Density (gr/cm^3)	0,497 (0,03)	0,495 (0,05)	0,493 (0,02)	0,499 (0,06)
Equilibrium Moisture Content (%)	6,034 (1,38)	4,825 (0,31)	4,469 (0,32)	4,966 (0,65)

Values in parenthesis are standard deviations

Figure 2: Effects of wood pressing time on the technological properties of panels

The all of bonding strength values of nylon composite LVL panels were higher than 1 N/mm^2 determined according to DIN 68705-3 (2003). The bending strength and modulus of elasticity values of nylon composite LVL panels were higher than 40 and 4000 N/mm^2 determined according to DIN 68705-3 (2003), respectively. Generally, the lowest result is the C group. Colak et al. (2016) stated that molten state nylon, depend on both wood processing and wood anatomical structure, penetrates into porous structure of wood and filled cracks and cavities on surfaces, and this helps to have smoother veneer surfaces. In literature, it was stated that smooth surface veneer bonded better than rough surface veneer and so it shows better performance on mechanical properties (Frihart, 2005).

As a result; formaldehyde-free nylon composite LVL has been successfully produced using nylon waste as wood adhesive. This novel product shows considerable mechanical properties. The panels produced using 160 gr/m^2 nylon amount and 8 minute gave the best mechanical strength values. When this study applies in the LVL industry, can provide to both recycle nylon waste and prevent formaldehyde release. In addition, Nylon composite LVL waste can be used production of wood plastic composite panels.

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Comparison of Technological Properties of Particleboards Produced from Branch and Stem Wood of Sequoia

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ABSTRACT

Sequoia trees are the world's largest and longest living trees. The sequoia tree is commonly found in the United States of America. The tree is among the species that can be grown in Turkey, especially in the Black Sea Region. It is known that there are differences in technological features between the trunk and branch wood in the trees. In this study, the technological properties of particleboards produced from stem and branch woods of Sequoia species were compared.

Some mechanical properties such as bonding strength, bending strength, modulus of elasticity of the particleboard panels were determined according to EN 319, EN 310, respectively. Physical properties such as density and equilibrium moisture content were determined according to EN 323, EN 322, respectively. Also, thermal conductivity of particleboard panels was determined according to ASTM C 518 & ISO 8301.

As a result of the study, the technological properties of particleboards produced from branch wood were found to be higher than stem wood. In addition to, some technological properties of particleboards produced from stem and branch woods of the Sequoia, which has not been studied as much as its technological properties, have been investigated and partially tried to fill the literature space of Sequoia.

KEYWORDS: Particleboard, Branch Wood, Stem Wood, Technological Properties, Sequoia

1 INTRODUCTION

The Sequoia genus, a member of the taxodiaceae family of Sequia sempervirens, is thought to originate from an arm of the Rhombostrobus genus, which remains in the Cretaceous period (LaPasha and Miller, 1981). The only species present in the Sequoia genus is S. sempervirens D. Don. (Endl.) (Chadefaud and Emberger, 1960).

These trees can be 60-110 m long. The bodies are wide and have a red-brown, fibrillated shell of 35 cm thickness (these trees are also called "Redwood" because of the color of the shell) and do not contain resin channels. Sequoia sempervirens showing a monopodial growth has a conical crown structure. The branches hang downward and contain stomata on both sides of leaves 1 to 30 mm in height (Stebbins, 1948; Kırdök 2010). Annual rings are generally narrow, annual ring boundaries are prominent, transition from springwood to summerwood is instantaneous and summer wood is short (Bozkurt and Erdin, 1998).

As a result of recent researches and findings made in August 2006, it was determined that the world's largest known tree belongs to Sequoia sempervirens. Hyperion, the longest sequestered species, has a length of 115.61 meters and is located in Redwood National Park. Helios, also a Sequoia sempervirens species, was discovered in Redwood Park by Chris Atkins and Michael Taylor in July 2006. Helios is found to have reached a height of 114.58 meters as a result of the measurements made, and still holds the second highest tree in the world (Web-1, 2018). Sequoia is a high value timber material used in building construction (Bozkurt and Erdin, 1998). Coatings are used in the construction of construction timber, columns, beams, outdoor furnishings and musical instruments (Web-2, 2018).

The current spread of the Sequoia genus is the Pacific coast of the United States (U.S.) over 60 km from the southwest Oregon to northeastern California (Kırdök, 2010). In the nineteenth century, these trees were introduced to Europe. In Turkey, the change in forestry policy after 1950, allowed the importation of species which are imported from abroad, and has been one of the species S. sempervirens. In 1972, it was observed that S. Sempervirens, which started to adapt to the Eastern Black Sea coast, coalesced very well (Eyüboğlu et al., 1995). Sequia sempervirens (Coastal Sequoia), which grows as good as 400 m in our country and grows in moist, cool and deep soils, is suitable for the Black Sea coastal sector (Megep, 2007).

As is known, there are differences in the anatomical structure and other structural features of wood between the same kind of trees. For this reason, the micro-environmental factors that grow in each tree are different (Bozkurt, 1982). In fact, when comparing wood samples taken from various parts of the same tree, they show differences in their anatomical structure, physical characteristics and chemical structure (Bozkurt and Erdin, 2000). Wood anatomy research is usually focused on the body wood of trees. Today, however, research on the industrial use possibilities of branch wood and stem wood is also being carried out (Pulat and Yaman 2017). Ancestral roots, stem and branch wood have similar anatomical structures, as well as tracheid / trache cells, fibers, biofilms, longitudinal paranchotes, etc. (Tsoumis, 1968, Bozkurt, 1982, Yaman, 2014, Pulat, 2018) in terms of the quantitative properties of the anatomical elements such as the anatomical elements.

In this study, it is aimed to compare some technological properties of particleboards produced from stem and branch woods of the Sequoia. In addition to, some technological properties of particleboards produced from stem and branch woods of the Sequoia, which has not been studied as much as its technological properties, have been investigated and partially tried to fill the literature space of Sequoia.

2 MATERIAL AND METHODS

In this study, Sequoia (Sequoia sempervirens) wood was used as a wood species and UF resin was used product of particleboards.

Firstly, the bark of the Sequoia woods was robbed. Sequoia woods were cut 3cm in thickness. Wood materials were chipped using a chipper. Afterwards, the chips were reduced into suitable size particles using a knife flaker. After chipping, particles were screened on a sieve with the size of 3mm, 1.5mm and 0.5mm by alagier shaking screening machine. These particles are separated for use in surface and core layers. The boards were designed to consist of 40% particles at the surface layers and 60% at the core layer. Later, the particles were dried in an oven to a moisture content of 3% (oven temperature: 110 °C). Based on the oven dry particle weight, 10% (surface layer) and 8% (core layer) UF resin was used at particleboards. 2% Ammonium chloride was applied to the UF adhesive as based on the resin weight. Board mats with dimensions of 420mmx420mmx 12mm were hot pressed for 7 minutes to achieve a target board density of 650 kg/cm^3. Pressing pressure and temperature were 24-26kp/cm^2 and 150 °C, respectively. After pressing, the boards were stored in climate room for further 30 days at 25 °C and 65% relative humidity.

Bonding strength, bending strength, modulus of elasticity of the particleboard panels were determined according to EN 319, EN 310, respectively. Physical properties such as density and equilibrium moisture content were determined according to EN 323, EN 322, respectively. Also, thermal conductivity of particleboard panels was determined according to ASTM C 518 & ISO 8301.

3 RESULTS

Technological properties test results of the particleboards panels are given in Table 1.

Table 27: Technological properties test results

Technological Properties	Stem Wood	Branch Wood
Bonding strength (N/mm^2)	0.585 (0.12)	1.403 (0.19)
Bending strength (N/mm^2)	9.87 (1.92)	10.45 (1.07)
Modulus of Elasticity (N/mm^2)	1260 (331.15)	1175 (143.21)
Density (gr/cm^3)	0.676 (0.05)	0.657 (0.05)
Equilibrium Moisture Content (%)	6.27 (0.25)	5.63 (0.60)
Thermal Conductivity (W/mK)	0.1203	0.1018

Values in parenthesis are standard deviations

According to Table 1, bonding strength, bending strength and thermal conductivity of particleboards produced from branch wood were found to be higher than stem wood. Modulus of elasticity of particleboards produced from stem wood were found to be higher than branch wood.

4 CONCLUSIONS AND DISCUSSION

The mean values obtained for particleboards produced from branch woods (Table 1) were compared with particleboards produced from stem. Bonding strength for particleboards produced from branch woods was 1.403 N/mm^2, for particleboards produced from stem wood was 0.585 N/mm^2. Modulus of elasticity for particleboards produced from branch woods 1175 N/mm^2, for particleboards produced from stem wood was 1260 N/mm^2. Bending strength for particleboards produced from branch woods was 10.45 N/mm^2, for particleboards produced from stem wood was 9.87 N/mm^2. Thermal conductivity for particleboards produced from branch woods was 0.1018 W/mK for particleboards produced from stem wood was 0.1203 W/mK.

According to the findings obtained, it was seen that the sequoia particleboards produced from branch wood had higher technological values than the particleboards produced from stem wood. The stem and branch wood of the species show significant differences in qualitative and quantitative anatomical characteristics (Pulat and Yaman, 2017). Due to the fact that the annual rings and cell structures are different, the specific weight of the branch wood is higher than that of the stem wood. The cell walls of the branch wood are thicker and supportive cell tissue participation rate is higher. On average, branch wood is 25% higher in needle leaves than in stem wood, and 6% heavier in leafy trees (Kurtoğlu, 1984).

As and Büyüksarı (2016), some of the tree species grown in Turkey physico-mechanical properties of in terms they have of tree species in the study called classification of physico-mechanical properties have made distributions based upon existing or created the classes group.

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Some Properties of Fiberboard Manufactured with Wastes of Kraft Pulp Mill

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ABSTRACT

In this study, it was aimed to investigate the usability of some wastes such as wood chip screening rejects and kraft pulp screening rejects as fibrous materials in the manufacture of medium density fiberboard (MDF). Chip screening rejects were refined with a laboratory type refiner; however, pulp screening rejects were not refined.

These materials were added to commercial fibers with the rates of 10%, 30%. Fiberboards were manufactured using urea formaldehyde (UF) adhesive. Some properties of these fiberboards such as water absorption (WA), thickness swelling (TS), surface roughness parameters, color change, modulus of rupture (MOR) and modulus of elasticity (MOE) values were determined. As a result of these, it was found that all values showed different trend depending on rates and types of Kraft mill wastes. Generally, the use of these materials had positive effects on the panel properties.

KEYWORDS: Fiberboard, Pulp fiber, Kraft process, Screening rejects, wood chips

1 INTRODUCTION

The growing scarcity of raw materials and disruptions of industrial waste management are some of the main problems that cause inevitable negative effects for all industries and need to be solved with economically and reasonably.

Like other industries, the MDF industry faces the same problems and is also negatively affected by the decrease in the availability of raw materials (Akgül and Tozluoğlu, 2008). This important problem has led researchers to search alternative sources. Residues or by-products of forest, wood or paper products such as annual plants, harvesting residues, agricultural wastes, lumber plant wastes, furniture plant wastes, wood shavings or shreds of paper etc. can reuse as raw material (Akgül and Çamlibel, 2008).

Kraft is the most common chemical pulping method used in the worldwide (Vaaler and Moe, 2001; Enqvist, 2006). Plenty of wastes such as barks, pins, fines, oversize and overthick wood chips of screening, pulp and paper sludge, pulp screening reject, black liquor, etc. occur during all stages of this process (Gavrilescu, 2004; Bajpai, 2015). Although these wastes are considered as a problem, they could be useful for many industries as resources.

The size and shape of wood chips are very important in chemical pulping and especially in kraft pulping (Gullichsen, 1999). Unsuitable wood chips cause some problems such as pulping chemical penetration and lower pulp yield (Gullichsen, 1999; Eriksen et al, 1981; Web-1). Acceptable sizes of wood chips in kraft process are approximately 15-25 mm length, a width of 20 mm and 3-5 mm thickness (Gerald, 2006). In kraft pulping process, the oversized wood chips are rejected for pulping and sent to re-chipping while the fines are sent to burn for heat production (Bajpai, 2010). It is possible to produce refiner mechanical pulp (RMP) with small size of wood chips such as sawdust and shavings which are less suitable for kraft pulping due to their bulk (Web-2). Low cost, high values of yield (range of 85-95%), brightness, light scattering properties, smoothness, bulk and good formation are the major advantages of mechanical pulps (Bierman, 1996; Sundholm, 1999).

The pulp screening reject is another waste of the kraft pulping process. After separation of black liquor from the fiber, pulp screening performs to separate the undercooked, the coarser and nonfibrized fiber and fiber bundles from the pulp to produce accepted high-value pulp (Tikka et al. 1993; Kırcı 2000; Hart, 2011). Rejects from the pulp screening process are usually refined, screened and the final rejects are thickened and burned (Tikka et al. 1993; Bierman, 1996; Hart, 2011).

The objective of this study is to evaluate the usability of small size of wood chips, which are not suitable in sizes for pulping standards and pulp screening rejects obtained from kraft process, for the manufacture of medium density fiberboard (MDF) and determine the some properties such as water absorption (WA), thickness swelling (TS), surface roughness parameters, color change, modulus of rupture (MOR), modulus of elasticity for these MDF panels.

2 MATERIAL AND METHODS

In this study, commercial fibers (mixture of pine and beech) were used as raw material. Also, refiner mechanical pulp (RMP) fibers produced from wood chip screening rejects (the pin-chips) and kraft pulp screening rejects (PSR) obtained from Kraft pulp mill were taken as additive raw materials to commercial fibers.

Wood chip screening rejects (pin-chips) were refined by using disc refiner in a laboratory scale for refiner mechanical pulp (RMP) fibers. These fibers were air-dried and separated using laboratory mixer with 18.000 rpm speed for 2 minutes. Refiner mechanical pulp(RMP) fibers and pulp screening reject (PSR) fibers were mixed to commercial fibers with the additional rates of 10% and 30% for panel manufacturing. Fibers were dried to 2-3% moisture content. Urea formaldehyde (UF) at 12% rate was used as an adhesive. Paraffin emulsion as water repellent and ammonium chloride as hardener at 1% rates were added to UF adhesive. After the application of the adhesive, manually formed fiber mats were pressed at the hot press at 180 °C temperature for 7 min. Fiberboards were manufactured with 8 mm thickness and 750 kg/m^3 target density. These MDF panels were conditioned at 65 ± 5% RH and 20 ± 1 °C, in accordance with TS-642-ISO 554 (1997) and dimensioned for the tests according to TS-EN 326-1 (1999). Panel types and contents were represented in Table 1.

Table 1: Panel types and contents

Panel type	Content
A1	90% fiber +10 %RMP*
A2	70% fiber +30 % RMP*
B1	90% fiber +10 %PSR**
B2	70% fiber +30 %PSR**
Control	100% fiber

*RMP: Refiner mechanical pulp
**PSR: Pulp screening rejects

2.1 Water absorption and Thickness swelling

The water absorption(WA) and thickness swelling(TS) values of MDF samples for 2h-24h were determined according to EN 317 (1993) standard.

2.2 Modulus of rupture and Modulus of elasticity

The modulus of rupture (MOR) and modulus of elasticity (MOE) values of MDF samples were determined according to EN 310 (1993) standard.

2.3 Surface roughness parameters

The surface roughness parameters such as *R*a, *Rq* and *R*z of MDF samples were measured using Mitutoya Surftest SJ-210 instrument according to DIN 4768 (1990) standard.

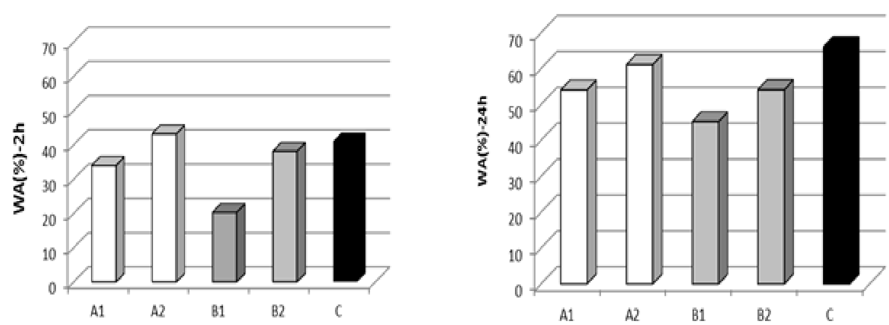
2.4 Color measurements

The color measurements of the MDF samples were carried out by using Konica Minolta CM-2600d spectrophotometer according to the CIE $L^*a^*b^*$ system (HunterLab, 2008). The Δa^*, Δb^*, ΔL^* and total color change (ΔE^*) of the MDF samples were determined.

3 RESULTS AND DISCUSSION

3.1 Water absorption and Thickness swelling

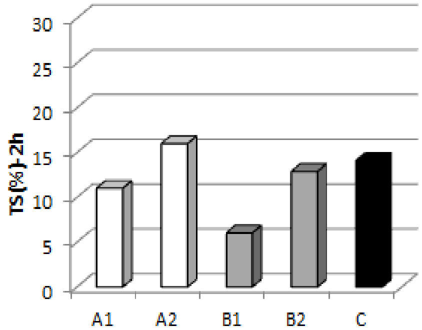
The water absorption(WA) and thickness swelling (TS) values of MDF samples after water immersion for 2 and 24 h are represented in Figure 1 and 2, respectively.



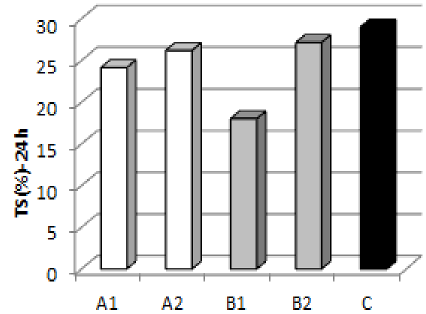
(a) (b)

Figure 1: (a)-WA values of MDF samples for 2h (b)- WA values of MDF samples for 24h

As can be seen from Figure 1a and 1b, average WA values changed depend on the type and rate of fibers. WA values of MDF samples for 2-24 h were found lower than WA values of control samples except for A2 group (2h) manufactured with rate of 30% RMP fibers. This group had slightly higher value. B1 group was found having the lowest WA values for both 2-24h. The best results were obtained with B group manufactured with PSR fibers compared to A group manufactured with RMP fibers. This situation could be reasoned because of fiber properties. The pulping process has an important effect on fiber properties (Clark, 1985; Smook, 2002; Migneault et.al, 2010). According to Luukko and Maloney (1996), mechanical pulp fibers are prone to swelling because of beaten fines.



(a)



(b)

Figure 2: (a)-TS values of MDF samples for 2h (b)- TS values of MDF samples for 24h

As can be seen from Figure 2a and 2b, average TS values of MDF samples showed similar trend with WA values of MDF samples. These values also changed depend on the type and rate of fibers. In general, TS values(2-24h) of A and B groups manufactured with RMP and PSR fibers were found more lower than those of control samples except for A2 group manufactured with rate of 30% RMP fiber (2h). A notable decrease was observed on the TS values(2-24h) of B1 groups manufactured with 10% addition of PSR fibers. Generally, higher TS values were obtained with RMP fibers. This could be attributed to the increased amount of fine in mechanical pulp.

3.2 Modulus of rupture and Modulus of elasticity

The modulus of rupture (MOR) and modulus of elasticity (MOE) values of MDF samples are represented in Figure 3 and 4, respectively.

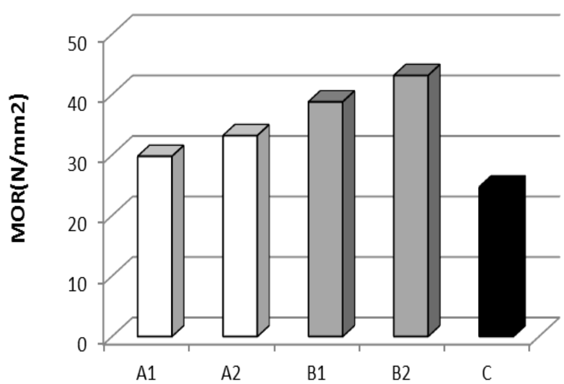


Figure 3: MOR values of MDF samples

As represented in Figure 3, the type and rate of raw material showed notable effect on the MOR values of MDF samples. All MOR values were recorded to be higher than control values. These values increased with increasing rate of RMP and PSR fibers. The better results were recorded with B group compared to A group. The highest MOR value of MDF samples was obtained from B2 group manufactured with rate of 30% PSR fibers. The addition of PSR fibers provided more improvement than the addition of RMP fibers on the MOR values of MDF samples.

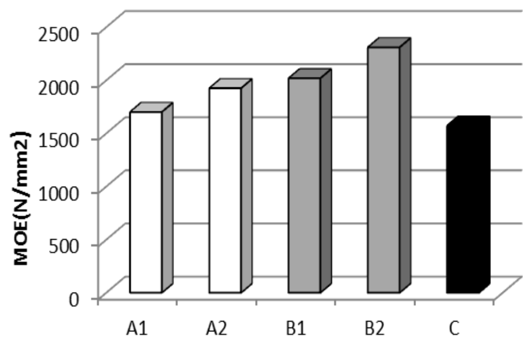


Figure 4: MOE values of MDF samples

As can be seen from Figure 4, MOE values showed similar tendency with MOR values of MDF samples. All MOE values of the samples clearly improved as rates of RMP and PSR fibers were increased from 10% to 30%. The highest MOE value of MDF samples was obtained from B2 group manufactured with rate of 30% PSR fibers.

Evaluating both MOR and MOE values together; it is clearly seen that the rate and type of fibers had an important effect on these values. All MOR and MOE values of A and B groups were found higher than those of control groups. PSR fibers provided better results. These results could be attributed to the structural properties of the fibers. PSR fibers are longer than RMP fibers because of their production process. It is well known that fiber length is a crucial parameter. Long fiber can have more fiber joints and therefore this could affect the strength properties of the final material. Also, chemical pulp fibers are more flexible compared to mechanical pulp fibers (Johansonn, 2011). Similar trend was observed by Nourbakhsh and Ashori (2009). According to their study, the usage of long fibers with high aspect ratio is one of the considerable parameters controlling the mechanical properties of composites.

3.3 Surface roughness parameters

The changes in surface roughness parameters such as *R*a, *Rq* and *R*z of MDF samples are represented in Figure 5, 6 and 7, respectively.

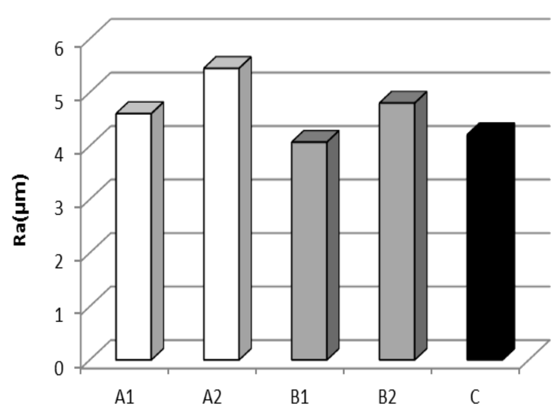


Figure 5: Ra values of MDF samples

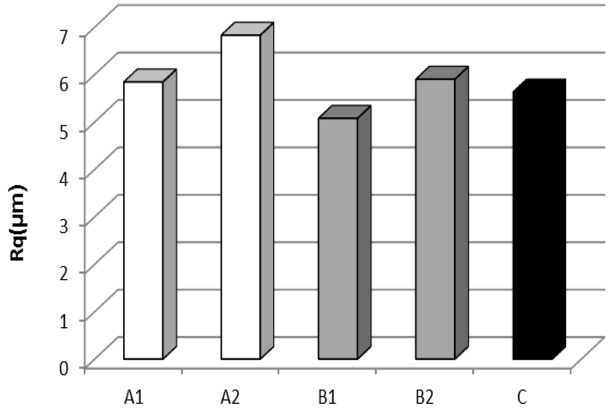


Figure 6: Rq values of MDF samples

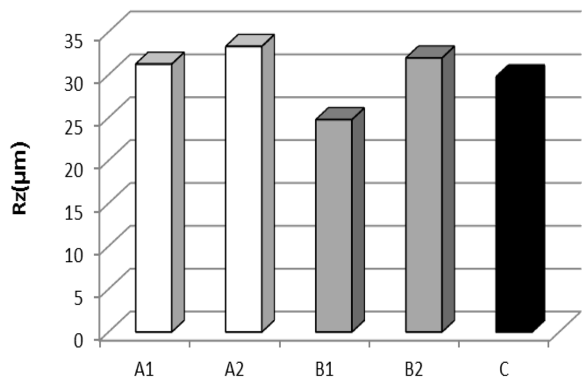


Figure 7: Rz values of MDF samples

As can be seen from Figure 5, 6 and 7, generally, all surface roughness parameters (R_a, R_q, R_z) of A and B groups showed differences depend on the rate and type of fibers used for MDF manufacturing. These values of A and B groups were generally found to be higher than those of control groups except for B1 group manufactured with rate of 10% PSR fibers. The higher surface roughness parameters (R_a, R_q, R_z) were obtained with A2 and B2 groups. The B1 group resulted in the smoothest surfaces with the Ra value of 4.07 µm, Rq value of 5.08 µm and an Rz value of 25.14 µm, while corresponding R_a, R_q and R_z values for the control samples were 4.21µm, 5.63 and 28.98 µm, respectively.

Especially, R_a, R_q, R_z were found higher for A group. As the additive rate of RMP was increased, surface roughness values might be increased due to the more fines and small fibers. The changes on the surface roughness parameters of samples could be reasoned from the structural properties of RMP and PSR fibers. It is clear to say that, structural properties of raw materials might cause some irregularities on the material surface, and these irregularities also affect surface parameters of final material. It is reported that the surface roughness degree is a function of production parameters and raw material properties (Hiziroglu and Kosonkorn, 2006).

3.4 Color measurements

The color measurement parameters (Δ*L**, Δ*a**, Δ*b**, Δ*E**) of MDF samples are given in Table 2, and Figure 8. The pictures of color changes occurred on the surfaces of MDF samples are presented in Figure 9.

Table 2: Color measurement parameters (Δ*L**, Δ*a**, Δ*b**)

Panel type	Δ*L**	Δ*a**	Δ*b**
A1	6.30	-1.60	-2.65
A2	8.48	-2.19	-0.53
B1	-1.68	-0.65	-2.11
B2	5.32	-0.98	-0.20
Control values were taken as references			

Referring to the results in Table 2, positive and negative ΔL* values were recorded for MDF samples. ΔL* value represents difference in darkness and lightness; positive "+" value of ΔL* indicates lighter and negative "-" value of ΔL* indicates darker (Web-3). According to results in Table 2, the ΔL* values increased with increasing rates of RMP and PSR fibers. While the highest positive ΔL* value was found to be 8.48 for A2 group manufactured with rate of 30% RMP fibers, the lowest value was found to be -1.68 for B1 group manufactured with rate of 10% PSR fibers. ΔL* values indicated that all MDF samples turned to lighter color except for B1 group. These differences between lightness or darkness of MDF panel groups can be clearly observed from Figure 9.

All Δa* values of MDF samples were found as negative and ranged from -0.65 to -2.19. This means that MDF samples had a tendency to green direction. Similarly, Δb* values were also found as negative and ranged from -0.20 to -2.65. These values were found in blue direction. In the color scale, + a* and - a* represent red and green directions; +b* and –b* represent yellow and blue directions, respectively (HunterLab, 2008).

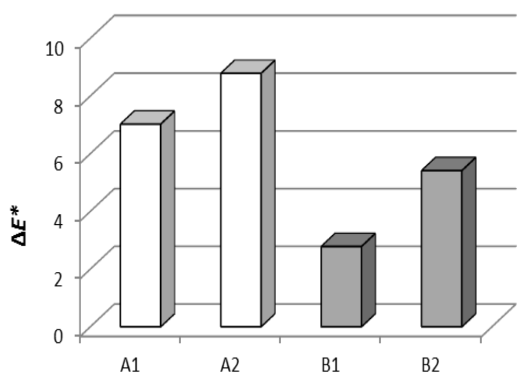


Figure 8: ΔE*values of MDF samples

As represented in Figure 9, it was found that the type and rate of raw material for panel manufacturing had effect on the total color change values of MDF samples. Especially, Δ*E** values increased with the increasing rates of RMP and PSR fibers. The highest Δ*E** value was determined to be 8.72 from A2 group manufactured with rate of 30% RMP fibers. The lowest Δ*E** value was recorded to be 2.78 from B1 group manufactured with rate of 10% PSR fibers. The highest color changes were obtained from A group manufactured with RMP fibers compared to B group manufactured with PSR fibers.

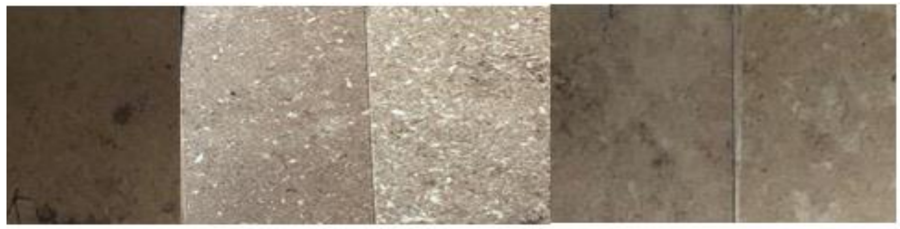


Figure 9 : Pictures of control and MDF samples manufactured with RMP and PSR fibers

The color changes of panel groups were cleary seen in Figure 9. A1 and A2 groups had more higher color change than B1, B2 groups and control group. This could be probably due to the differences in the structural properties of fibers. Mechanically produced pulp have some optical advantages such as brightness, light scattering properties (Sundholm, 1999). However, in kraft pulp production, chemical reactions of residual lignin with pulping chemicals cause dark brown color of pulp (Twede et al, 2014).

4 CONCLUSIONS

The fiber of refined chip screening rejects and pulp screening rejects obtained from kraft pulping process had positive effects on the MDF panel properties. In general, WA and TS values of each group for 2-24 h were found lower than those of control groups except for MDF panel manufactured with rate of 30% RMP. A considerable decrease was recorded on the WA and TS values(2-24h) of MDF panels manufactured with the rate of 10 % PSR fibers. All MOR and MOE values of each group were found higher than those of control groups and these values improved increasing rate of RMP and PSR fiber. The highest MOR and MOE values were obtained with rate of 30% PSR fibers. Surface roughness parameters of each group were generally found to be higher than those of control groups except for MDF panel manufactured with rate of 10% PSR fibers. The rougher surfaces were obtained with increasing rate of RMP and PSR fibers. The highest color changes were observed with the additive rates of RMP fibers.

Generally, the best results for all tests were recorded from MDF panels manufactured with PSR fibers. Results indicated that, some wastes of Kraft pulping process such as wood chip screening rejects and kraft pulp screening rejects as fibrous materials have potential for reuse as raw materials for medium density fiberboard (MDF) manufacturing.

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Investigation of Thermal Conductivity of Wood Sandwich Panels with Aluminium and Polypropylene Core

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ABSTRACT

Sandwich panels are obtained by placing thick but rather light core material between two thin and rigid lower and upper surface layers. Sandwich panels, especially due to their light weight, high "strength / weight" ratio and durability compared to conventional materials have many use areas such as aviation and space industry, maritime, automotive and building industry It is one of the biggest advantages that sandwich materials can be obtained from different materials and geometric structures by choosing the lower and upper surface layers and the core for various applications. The aim of this study is to investigate the thermal conductivity values of the sandwich panels, which are manufactured with different types of surface and core materials in sandwich panels. An aluminium and polypropylene as a core materials and alder, birch and scots pine wood veneers were used as wood species for surface panels for manufacturing of sandwich panels. A polyurethane modified epoxy- adhesive were used for binding of core layer to both surface layers. Thermal conductivity of sandwich panels was determined according to ASTM C 518 & ISO 8301. As a result of the study, the highest thermal conductivity values were obtained from aluminium core sandwich panels. The highest values were obtained from alder for the aluminium core panels and scots pine for the polypropylene core panels as wood species.

KEYWORDS: Sandwich Panel, Aluminium, Polypropylene, Core, Thermal Conductivity

1 INTRODUCTION

Sandwich panels are used for variety of structural applications, including building construction, transportation, decking, marine and aerospace because of their high energy absorption ability, high bending stiffness and light weight (Li et al., 2014; Aslan et al., 2017). They are favoured for their high specific strength and stiffness, corrosion resistance, tailor ability, and stability. Sandwich panels are very suitable for lightweight structures requiring high in-plane and flexural stiffness (Gustin et al., 2005). Sandwich panels are usually based on two thin face sheets with high stiffness and strength, and a compliant and light-weight core that maintains the distance between the faces and sustains deformation, often with insulation properties. By varying the material and thickness of core and face sheets, it is possible to obtain sandwich panels with different properties and performance (Steeves and Fleck, 2004). The properties of interest for core materials include, among others, low density and good thermal and acoustic insulation characteristics. Commonly used core materials are honeycombs, foams and balsa wood, but other alternatives of cellular core structures are being proposed (Lakreb et al., 2015).

Most of the sandwich panels are made of honeycomb and foam cores with surface materials (Pan et al., 2008; Vaziri et al., 2006; Qin and Wang, 2013). Especially, the sandwich panel composites that have open cells provide the multifunctional benefits to composite such as the high stiffness strength and high specific strength (Xiong et al., 2010; Joo et al., 2011; Xiong et al., 2016). Honeycomb sandwich structure consist of a thick layer (core) intercalated between two thin-stiff surface layers (skin). Honeycomb sandwich core is cellular solid that used void to decrease mass, while maintain qualities of stiffness and energy absorption. Honeycomb sandwich composite are widely used to replace traditional material in highly loaded application such as automotive and aviation industry (Newstead et al., 2008; Forsberg et al., 2006; Aslan et al., 2017).

With the increasing adversity of climate changes from global warming, discussions within the international community for establishing an appropriate response policy have become more urgent (Seo et al., 2011). In facing the global warming trend, there is a dire need for more effective measures to sustain comfortable temperatures in living environments. To sustain an indoor temperature that is independent of outdoor temperature fluctuations, materials need to be developed that have superior thermal insulation abilities (Kawasaki and Kawai, 2006). Thermal conductivity is a very important parameter in determining heat transfer rate and is required for development of thermal insulation of materials (Sahin Kol and Altun, 2009). Several studies about thermal conductivity of composite materials showed that thermal conductivity was influenced thickness of composite materials, density, moisture content, temperature, material space ratio and flow direction of heat (Suleiman et al., 1999; Bader et al., 2007; Sonderegger and Niemz, 2009; Aydin et al., 2015).

The aim of this study is to investigate the thermal conductivity values of the sandwich panels, which are manufactured with different types of surface and core materials in sandwich panels. An aluminium and polypropylene as a core materials and alder, birch and scots pine wood veneers were used as wood species for surface panels for manufacturing of sandwich panels.

2 MATERIALS AND METHOD

In this study, aluminium and polypropylene (PP) as honeycomb core materials and alder, birch and scots pine veneers as face sheet materials were prepared in 30 × 30 dimensions for the manufacture of sandwich panels. The polyurethane modified epoxy- adhesive were used for binding of core layer to both surface layers. The hardener was added in the adhesive at 20%. Figure 1 shows a sandwich panel production.

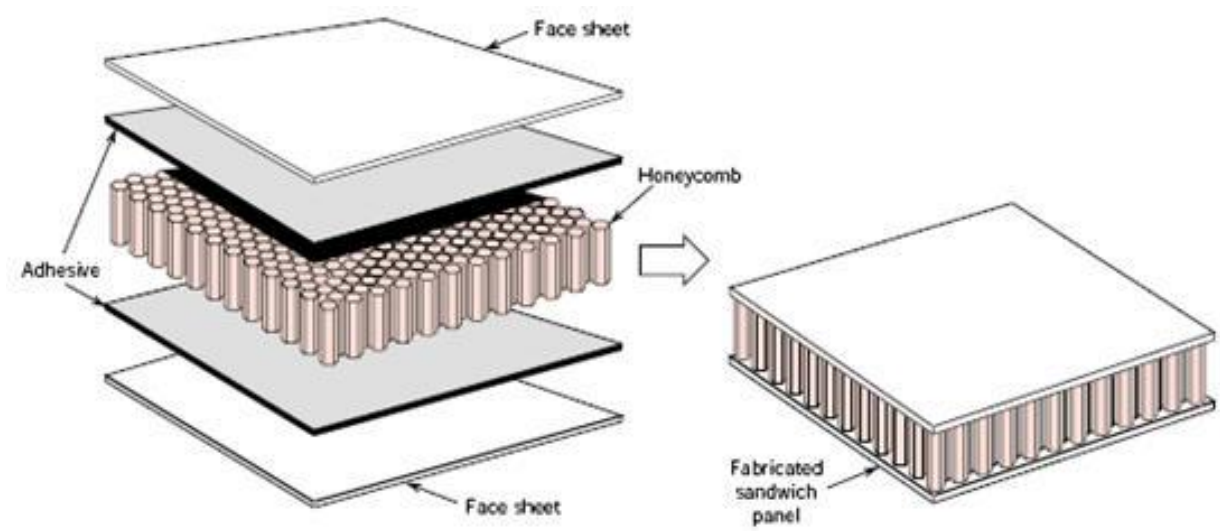

Figure 1: Sandwich panel production

Depending on the adhesive and surface materials used in this method, the sandwich composite panels were pressed at 80°C, under pressure of 10 kg/cm^2 and for 15 minutes and then are waited 24 hours in the press without temperature and pressure.

The thermal conductivity of the sandwich panels were determined according to ASTM C 518 & ISO 8301 (2004). Sample size required is 300x300xpanel thickness mm. Two specimens were used for each group. The tests were made at laboratory of Forest Industry Engineering in KTU. The Lasercomp Fox-314 Heat Flow Meter shown in Figure 2 was used for the determination of thermal conductivity.

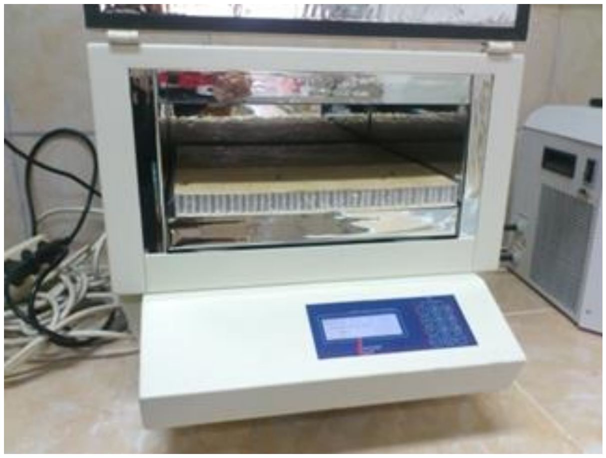

Figure 2: Lasercomp Fox-314 Heat Flow

3 RESULTS AND DISCUSSION

The thermal conductivity values of the sandwich panels are given in Figure 3 according to wood species and core materials.

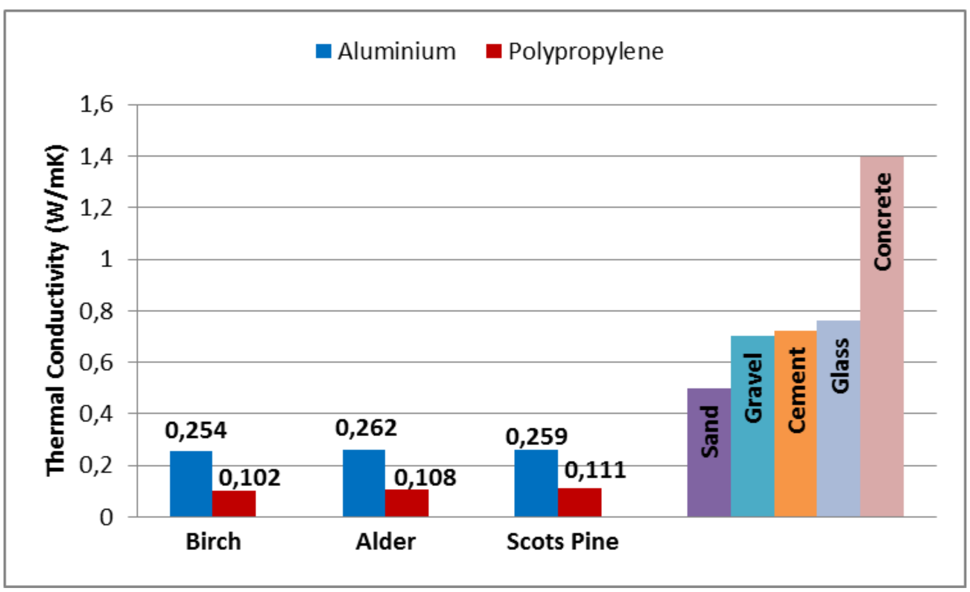

Figure 3: Thermal conductivity values of the sandwich panels and other materials (W/mK)

As can be seen that Figure 3, the highest values were obtained from alder for the aluminium core panels and scots pine for the polypropylene core panels as wood species. The highest thermal conductivity values were obtained from aluminum core sandwich panels. The thermal conductivity values of all sandwich panels were lower than the thermal conductivity values of other building materials. Thermal conductivity of wood based materials is vary according to wood species, direction of wood fiber, resin type, addictive members, impregnate materials and processes used in the manufacturing of wood based composite panels (Kamke et al.,1989; Sahin Kol et al.,2010; Kol et al., 2010; Demirkir et al., 2013). Also, several studies about thermal conductivity of composite materials showed that thermal conductivity was influenced thickness of composite materials, density, moisture content, temperature, material space ratio and flow direction of heat (Suleiman et al., 1999; Bader et al., 2007; Sonderegger and Niemz, 2009; Aydin et al., 2015).

4 CONCLUSIONS

The aim of this study is to investigate the thermal conductivity values of the sandwich panels, which are manufactured with different types of surface and core materials in sandwich panels. The thermal conductivity values of all sandwich panels were lower than the thermal conductivity values of other building materials. The thermal conductivity values of alder and scots pine sandwich panels panels were higher than those of birch sandwich panels as similar as density values. This study showed that sandwich panels produced from aluminium and polypropylene as a core materials and alder, birch and scots pine wood veneers can be used as an alternative insulation material.

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Overview of Furniture Advertising in Turkey

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ABSTRACT

Turkish furniture industry reflects its development with various parameters such as product structure including design, function and marketing strategies. The importance of the design parameter has increased in recent years which lead to innovative furniture manufacturing. Most of the enterprises have improved Research and Development departments working on the design and manufacturing techniques of the products. Consumer demands also play an important role on the innovation of the furniture design and production. As final consumer is the target for manufacturers, marketing issues also appear on stage. Information regarding consumer buying patterns is critically important in estimation of future demand levels. Manufacturers keep sales volume information each year to be able to foresee the trend in the furniture market and buying potentials of their customers. Key information such as current market trends and demand helps to identify the potential of the profit from the furniture market. Manufacturers use this information to identify needs, preferences and buying habits of their customers. Manufacturers work on strategies to call the attention of the consumers in every way. Promotion is the way to communicate with the customers for manufacturers. Commercials help the manufacturers introduce their products. Companies are in need to emphasize and distinguish their product from competitors. Product innovation, fashion and individuality are very important notions for growth in the market. The connection between Design-Research and Development enhances the product improvement. Therefore manufacturers aim to show their products to the consumers in the best way. In this study, advertising strategies of furniture manufacturers in Turkey are investigated by using selected TV, press and social media commercials.

KEYWORDS: Furniture commercials, Turkish furniture industry, Furniture commercials, Turkish furniture manufacturers

1 INTRODUCTION

Advertising plays a vital role in this competitive business environment. This study is confirmed to selected furniture brands in Turkey. The study area was confined to Istanbul and sample has been chosen from there. Exploratory Research Design has been adopted by emphasizing the celebrity impact on consumer buying decisions in selected brands of prepaid mobile services in Istanbul.

Data was collected from related journals, publications and from web-sites and popular search engines. (Jain and Girdhar,2014).

In addition to introducing a brand, another important mission of the advertisements is to persuade the consumer to buy the product. Buying impetus of the consumers activate with the advertisements. In order to ensure that the advertisements incline the consumers to buying behavior, the importance of research topics such as persuasive communication and consumer behaviors gradually increases. Advertising requires some constant foundations while developing creative strategies. These constant foundations are concrete data which has been revealed with the studies based on several variables such as demographic and sociocultural status, psychological structure, social origin etc. of the target group and obtained as a result of studies conducted for long years (İplikçi, 2015).

Some of the furniture advertising executives are shown in Fig. 1.

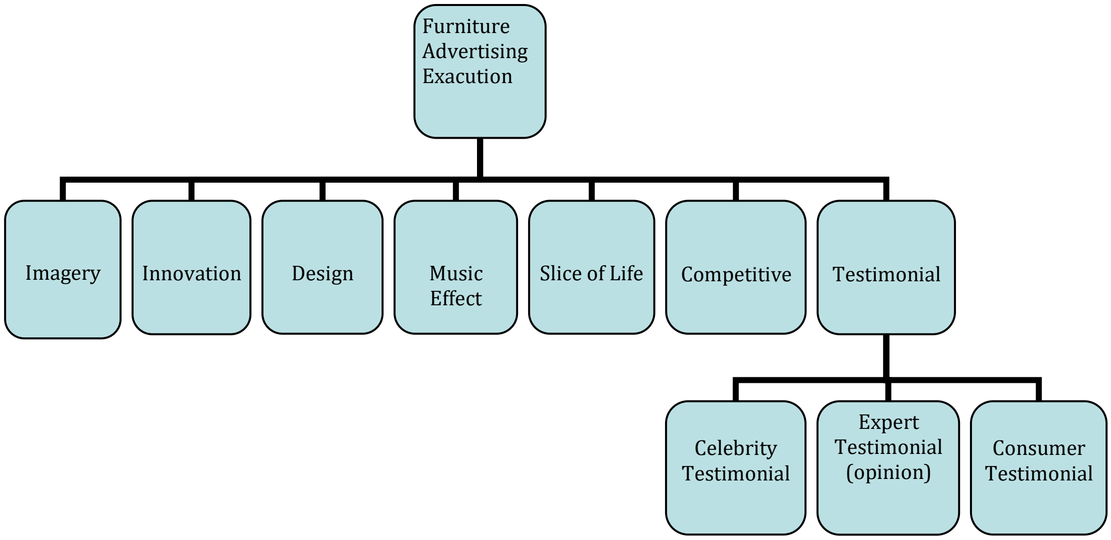

Figure 1: Some of the furniture advertising executives

1.1 Testimonial

Advertisement creators aim to constitute credibility and reliability, authenticity and sincerity on consumers towards the brand and/or the product by using testimonial advertisements (Gülmez, 2016). There are some categories for testimonial that have proven to be successful (Web-1).

a. **Real customers:** They can be the most informative as well as the most persuasive. The best tend to be fair, honest and thoughtfully written.

b. **Switchers:** One powerful approach is to feature customers explaining why they switched from Brand X to Brand Z. For example, they might explain what reservations they had to switching, what obstacles they had to overcome. And they might discuss the benefits they now enjoy that were missing before they switched. Another way to execute this idea is to feature people using the product for the first time, then comparing it to their current product and explaining why they have decided to switch. The "blind taste test" is one example of this approach.
c. **Experts:** The designer, the blogger who writes about furniture product category. These are people who influence others by their talent, knowledge and integrity.
d. **Celebrities:** Celebrities - whether local or international - bring instant recognition and interest. Celebrities endorsed advertisings helps in creating the awareness regarding the product brand, image and company's goodwill and provide all other important information required by the costumers.

1.2 Slice of Life

In slice-of-life ads the written message is more than just the words the characters speak. It is also the plotline, or action, that occurs within the advertisement.(Catherine, 1999).

1.3 Comparative

A common tactic for comparative advertising is the use of a fake product that represents a competitor. Ad viewers will associate the fake product with a competitor's product but since there is no precise comparison or trademark used it satisfies FTC rules. Another tactic is the use of an ad parody that viewers will associate with a competitor but does not reference them or their product directly (Web-2).

1.4 Music Effect

The study did for lyrics what psychologists have shown repeatedly about the power of melody in advertising – that there needs to be a clear fit between an ad's soundtrack and the message or product it is intended to promote. Impactful use of music requires creatives, planners, and clients to work in partnership to choose the right track.

"The right song or musical soundtrack to an ad can increase attention, enhance emotional response, influence intention to buy, and demonstrably increase sales (Web-3).

1.5 Innovation

The term "innovation" is thrown around a lot -- often times, it is used in a way that does not fit the actual definition of the word. Marketing and advertising professionals are particularly guilty of this frivolous use of the word. The inextricable link between technology and communications induces a fixation amongst advertising and marketing professionals on new ways to communicate and the technology that powers these new communication vehicles (Web-4).

1.6 Imagery

Imagery appeals are advertising techniques that induce consumers to generate vivid mental images on their own while processing advertisements. TV commercials often invite consumers to imagine themselves in the consumption experiences. (Petrova and Cialdini, 2005). A good example would be the advertisements about kid's furniture. Promoted through this series is a space for communication, creativity and games which serves incidentally as a place for the child to sleep. Thus, the bedroom is not only just a place, to sleep but rather a place to live and in which to take pleasure through shared activities with family or friends: it is a place where the child discovers his/her talents and where his/her personality blossoms(Cross,2004). When imagery-inducing appeals are used in advertisement, the extent to which consumers actually use mental imagery in processing the ad, is critical to the success of advertising imagery appeals (McInnis and Price 1987; Bone and Ellen 1992). Past research has suggested that consumers who use more extensive mental imagery while processing an ad have more positive evaluation and attitudes (Escalas, 2004).

1.7 Design

Advertising and design are readily distinguishable from other economic institutions because of their declared expertise in creating specifically cultural forms of communication. Further, these practices rely on the skills of cultural intermediaries: individuals whose job it is to develop these forms to mediate between, or more properly, articulate, the realms of production and consumption (Soar, 2002).

1.8 Overview of advertisement media

Advertising media enable goods, services, people and institutions to meet with the target audience through all the advertisements prepared. It is very important that the target is set correctly and right campaigns are prepared by the agencies so that the advertisements can have a lasting effect on the target audience of the brand. Therefore, the correct setting of the media in which an advertisement will be published allows the advertisement message to be successfully introduced to the target audience at the desired time and place (Elden, 2015).

Broadcasting advertisement media cover a wide range of advertising media such as radio and television which are of utmost importance since the very first day the advertising industry has emerged. They are considered as the most important tools of the advertisement world with their technical features allowing both visual and audio communication and their interesting contents (Kutlu, 2016).

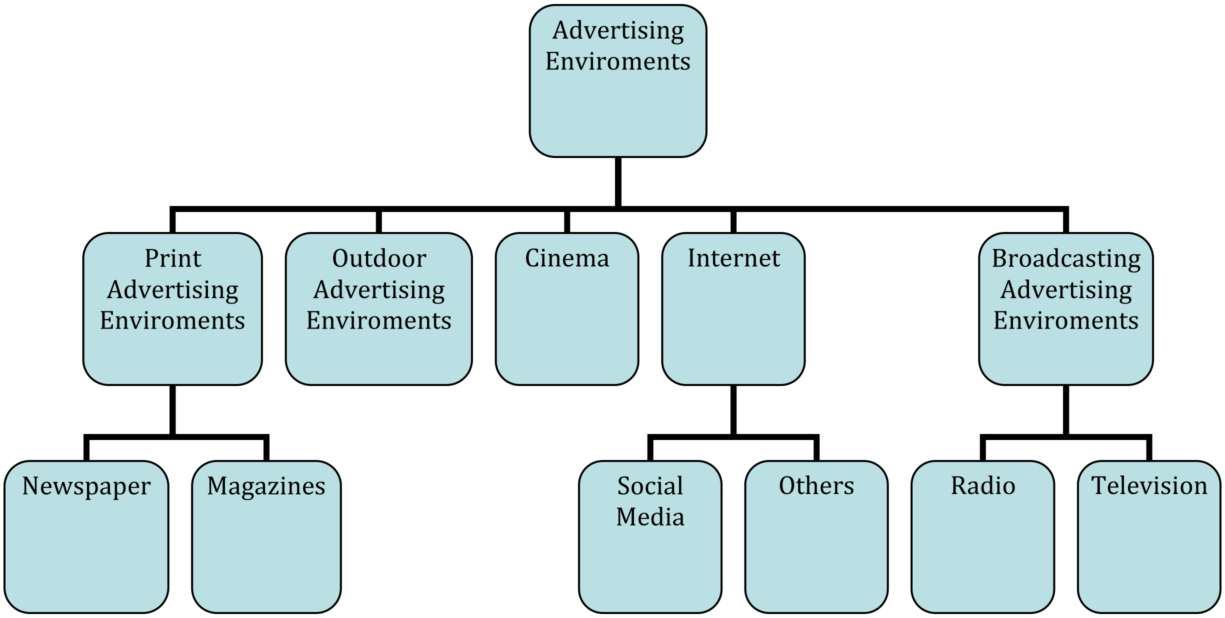

Figure 2: Overview of advertisement media.

In the present study, only television and internet commercials are considered.

- **Television**

Nowadays, advertisement types revealed together with the advancing technical features of television have begun to be applied. The advertisement types on television are:

Still advertisements, Animated advertisements, Special promotional advertisements, Advertorial, Promotional advertisements within the show, Product placement in TV series and shows etc.

As it is capable of addressing both the eyes and the ears, television is the most followed media by the target audiences all around the world. And brands influence the spectators more with their brand and product by combining their advertisements both with video and audio features. The fiction and story of television advertisements make the brand's awareness and memorability higher and easier than the other channels. In this context, brands want to reach their primary target audience with their commercial films (Web-5).

- **Internet**

The new technologies created to make the life easier and to meet the needs have made mobile phones to become an integral part of individuals. Consumers wanting to have the latest smart devices have caused consumption to increase in connection with the Internet. Internet usage as well as the mobile usage have increased. Internet is somehow unquestionably different from the newspapers, TV, radio, etc. other media channels and information centers such as libraries, exhibitions, fairs etc. with the massive amount of information and data it offers. Especially with the new generation information storage technologies, the problem of storing high volume of information and data has ended with the Internet. Thus, "With the visual motion, it has acquired a video, motion and audio quality equivalent to the television technology." As a result, the Internet advertising has been able to reach the target audiences of television and radio channels in addition to its targeted audience (Kutlu, 2016).

The increasing number of social networks during the recent years and the increase in the number of users and the creation of advertising areas with the introduction of innovations describe the reason of the migration of media investments to the digital world over the last 6 years.

The advertising opportunities provided by the channels in the communication of the brands on all the social media channels also provided an inexpensive and clear access to the target audience. Advertising campaigns with visual and video features on digital channels have effective social media advertising areas such as banner areas on websites, before the videos on YouTube and in banner areas of websites, in video ads on LinkedIn, in sponsored posts of Twitter, in Google Ads areas, viral marketing, page promotion ads, video and post promotion ads, middle column and side column banner ads on Facebook, post promotion ads on Instagram, and forwarding ads to increase the website clicks (Web-6).

2 MATERIAL AND METHOD

The furniture sector in Turkey is changing rapidly. It is developing from traditional production to modern production. This situation is more common in large and medium-sized enterprises in the sector. These sectors particularly provide important contributions to the sector's development and the country's economy with their institutional structure, advanced technology monitoring, standardization, R&D activities, high production capacities and export opportunities.

The appearance in Turkey's furniture sector is that it is mainly consisted of atelier type, small-scale businesses working with traditional methods. However, the number of medium and large-scale businesses has started to increase rapidly during the recent years. Rapidly developing and changing, the sector has a potential both in domestic and foreign markets based on the factors such as brand, quality, small- and large-scale businesses in the sector, geographical position, general growth policy of the country, young population, and improvement in per capita income. The furniture sector is also one of the leading sectors of our country in terms of added value, and its contribution to the country's economy continues to increase as one of the sectors that use domestic resources most in exports and have the least dependency on imported products (Arslan et al., 2009).

In this study, it is aimed to examine and analyze the advertisements on television and social media channels in order to determine the marketing strategy of furniture manufacturers in Turkey. The method can be evaluated as a descriptive-comparative study. Within the scope of the study, the furniture advertisements broadcasted on TV and posted online at prime time are taken into account. 20 furniture companies, who advertised on TV, Internet and social media during the determined period and mainly during the last two years (2016-2018), were identified, their advertisements were analyzed and interpreted in terms of content by comparing with the predetermined 11 parameters. As a result of the analysis of the advertisements, it's been observed that the vast majority of companies are recognized, large-scale companies in the sector. We did not use the names of the companies in our study, and their brands are coded as x1, x2, x3 etc.

Content analysis aims to reveal the criteria emphasized in advertisements based on the quantitative and qualitative contents of advertisement images, texts and messages. The data obtained was evaluated in Microsoft Excel 2017 and interpreted graphically.

3 FINDINGS

As a result of analyzing the furniture advertisements on TV and social media; the presence of parameters such as changing and joining properties, comfort, price/campaign, special day offerings, music effect, design, generation/age, imagery, colorful / joyful, fulfillment of consumer needs, celebrity testimonials and shows have been determined. Table 1 shows the data in the advertisement contents related to these 11 parameters identified.

Table 1: Comparison of advertisement contents of furniture companies

CRITERIONS/COMPANY	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	TOTAL
Comfort	+	+	+	+	+	+	+			+			+	+	+		+	+	+		**14**
Price / Campaign			+			+	+		+	+			+	+	+	+	+		+		**11**
Design		+				+	+	+				+	+	+		+		+	+	+	**11**
Fulfillment of the Consumer Needs	+				+		+		+						+	+	+	+	+	+	**10**
Changing And Joining Properties	+				+			+	+	+		+					+	+			**8**
Celebrities	+			+		+	+				+	+			+						**7**
Music Effects					+	+				+					+				+	+	**6**
Colorful / Joyful	+	+			+					+									+	+	**6**
Special Days Offerings				+	+										+	+			+		**5**
Generation / Age			+		+					+	+									+	**5**
Imagery										+				+				+		+	**4**
TOTAL	**5**	**3**	**3**	**3**	**7**	**5**	**5**	**2**	**3**	**7**	**2**	**3**	**3**	**4**	**6**	**4**	**4**	**5**	**7**	**6**	

The most emphasized topics in furniture advertisements are comfort, design, price/campaign, and fulfillment of needs, respectively. These criteria are followed by Changing and Joining Properties, Celebrities, Music Effects, Colorful/Joyful, Special Days Offerings, Generation/Age, and Imagery criteria in descending order. It's seen that the companies have included maximum 7 and minimum 2 criteria in their commercial films. When we look at furniture advertisements in general, it's seen that 4 criteria are emphasized on average. The message companies want to give in their advertisements or the features they emphasized according to 11 criteria identified are shown in Figure 3 in the descending order from the highest emphasis to least emphasis.

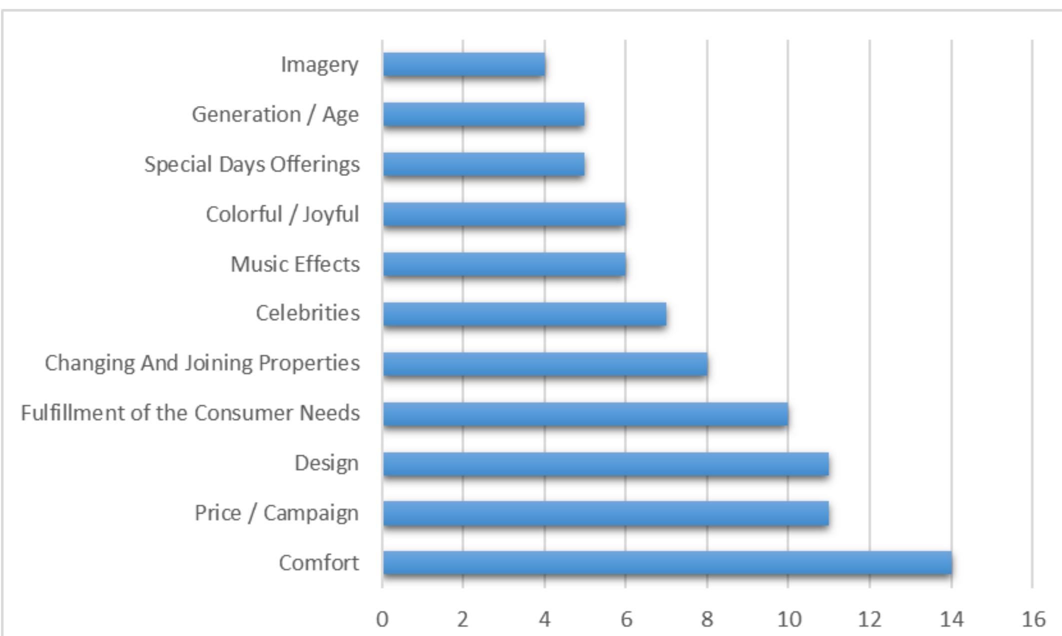

Figure3 : The most frequently used criteria / emphasized matter by the businesses.

Table 2: Evaluation of furniture companies through executions

COMPANY / CRITERIONS	Testimonial -Celebrıty	Testimonial-Expert	Testimonial-Consumer	Innovation	Design	Music Effect	Slice Of Life	Competitive	Imagery
X1	+			+	+				
X2					+				+
X3					+	+			+
X4					+	+			+
X5				+	+		+		+
X6	+				+		+		
X7		+		+			+		
X8					+		+		
X9					+	+	+		
X10					+				+
X11	+					+			
X12	+		+			+	+		
X13								+	
X14					+				+
X15	+					+			
X16	+		+		+				+
X17	+					+			
X18			+	+	+		+		
X19						+	+		+
X20				+	+				+
Total	7	1	3	5	13	8	8	1	9

"Design" is on top of the criteria critiques used to attract interest in furniture advertisements. This is followed by imaginary, music effect, slice of life and testimonial - celebrity. Innovation, Testimonial-Consumer, Testimonial-Expert and Competitive are the concepts used by few companies. On average, it's seen that 3 criteria were used in advertisements.

The evaluation of furniture company advertisements in descending order from highest to least based on execution is shown in Figure 4.

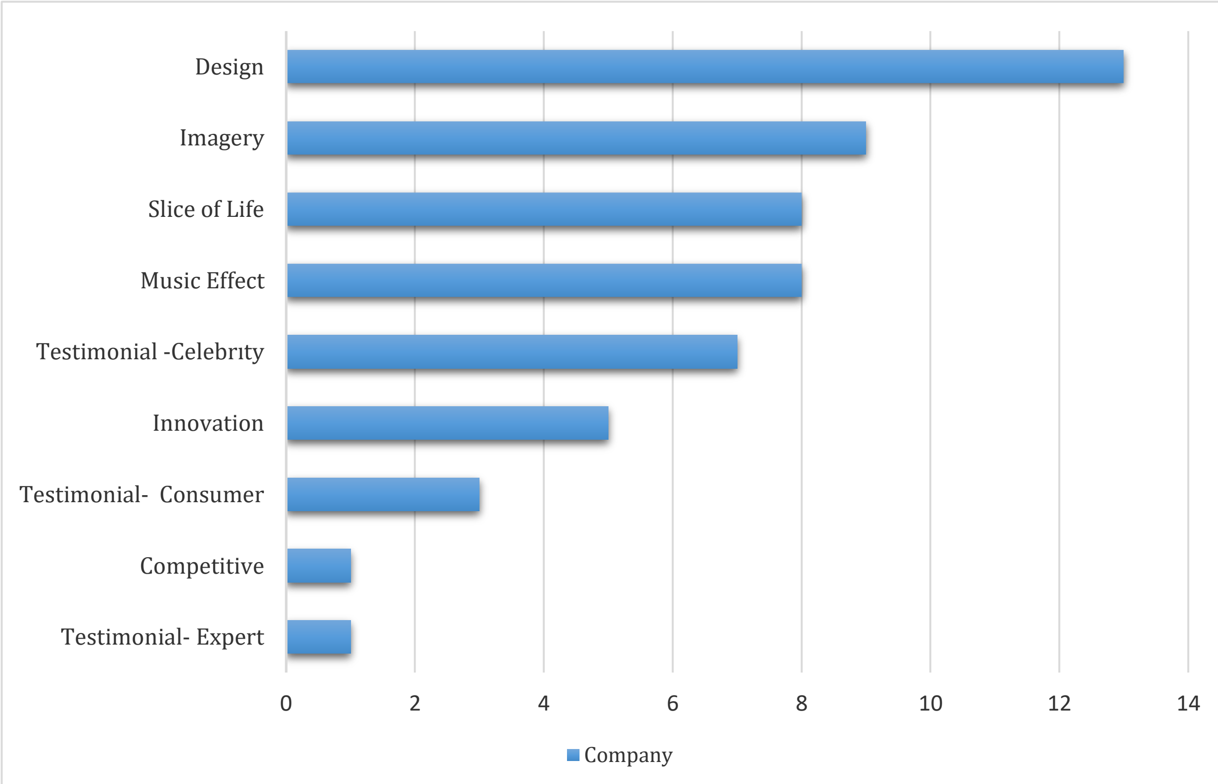

Figure 4: Evaluation of furniture company advertisements in descending order from highest to least based on execution

4 DISCUSSION AND CONCLUSION

In today's business world where customer requests are at the forefront and affect all processes of the companies, companies wanting to maintain continuity in the market are developing new strategies accordingly. While the brand creates the image of the companies in the eyes of the customers, the advertisements as a marketing component have a significant contribution on the remembrance, recognition, image and memorability of the companies. Advertisements are one of the most important factors affecting the purchasing decisions of the consumers. Although the advertisements are for satisfying the basic needs of the people such as being loved, being liked, belonging to a certain group and being appreciated, they also bring to the fore the feeling of satisfaction, being different and achievement for owning the advertised product for the consumers who are in need of power and success. In addition to the animated TV advertisements where recognition and memorability is much higher, it's also been determined that online social media channels allowing easy access to the consumers, who use TV and radio channels which are the most common communication tool in the world, are intensively used as an advertisement channel by the furniture companies in Turkey. In this study, advertisement contents of the furniture companies in Turkey on the Internet (social media) and prime time TV are analyzed. Values emphasized in the advertisements mainly during the last two years (2016-2018), the criteria considered as important by the companies are evaluated together with the texts, images and messages in the advertisements. Advertisements of total 20 furniture companies in determined media and time frame have been identified, and it's been observed that they focus on 11 individual criteria. Parameters identified as a result of analyzing the advertisements have been grouped, and 11 criteria are classified as follows: changing and joining properties, comfort, price/campaign, special day offerings, music effect, design, generation/age, imagery, colorful/joyful, fulfillment of consumer needs, celebrity testimonials and shows.

The most emphasized topics in furniture advertisements are comfort, design, price/campaign, and fulfillment of needs, respectively. The least emphasized criteria are Imagery, Generation/Age and Special Day Offerings.

When the furniture companies are evaluated according to the execution, it's seen that the design, imagery, slice of life and music effect concepts are used mostly. The least common concepts are Testimonial-Expert, Competitive and Testimonial-Consumer.

In the 20 commercial films analyzed, it's seen that mostly the comfort and price/campaign concepts are emphasized, design, fulfillment of consumer needs, changing and joining properties concepts are widely used, and these are followed by celebrities, colorful/joyful, special day offerings, generation/age and imagery concepts.

Consumer Delight and Consumer Satisfaction are deeply required by the business for its survival in this competitive era. For promoting the product consumption and creating awareness, companies use advertising campaigns to promote higher consumption of their products. Attractiveness of the celebrity plays an important factor in purchase decisions and product choices. The amount of money being spent on celebrity endorsements worldwide is increasing, which shows the effectiveness of celebrity endorsements in creating, reaching and appealing for the product (Jain and Girdhar, 2014). As McCraken (1989) points out, celebrities have the ability to present extra depth, power and delicacy meanings, and also present a lifestyle and personality that cannot be anonymously matched. Celebrities have the power to give a touch of glamour to the product they endorse through advertisements. McCraken (1989) found that the use of celebrity endorsers stand for an effective way of transferring meaning to brands as it is believed that celebrity endorsers bring their own emblematic meaning to the endorsement process and that this cultural meaning residing in the celebrity is passed on to the product which in turn is passed on to the consumer. Menon et al. (2001), has shown that the use of celebrities in advertisements can have a positive influence on the credibility, message recall, memory and likeability of the advertisements and finally on purchase intentions. Frazer and Brown, (2002) examined how audience members identified with celebrities, and how it affect their personal lives. They concluded that people selectively integrated the perceived values and behaviors they saw in celebrities they admired and adopted them into their own lives. According to Solomon et al. (2002), the reasons for using celebrity endorsements involve its potential to create awareness, positive feelings towards their advertising and brand. Celebrity endorsers are used to help provide personality to a product or a brand. For manufacturers of consumer goods and retailers it could be quite advantageous to apply similar models to sales to the consumer. (Groot and Musters, 2005). As seen in the examples from the world, the furniture companies in Turkey use celebrities in their advertisements to reach a higher number of consumers for increasing the awareness and memorability by using the popularity of that celebrity, in other words to attract the attention of the consumer. It's also observed that the consumers, who attach more importance to reliability more than money, are attracted by using a celebrity. According to the results of the study, it's observed that celebrities are also used in the advertisements in Turkey.

It's seen that the marketing activities of upper segment, boutique manufacturers addressing conscious, highly educated consumers with high life standards mostly do not contain advertisements. The companies in this segment mostly reach the customers through "word of mouth" method, and as they already operate with high profit margins, they do no try to increase it more by advertising too much.

Among the furniture companies operating in the sector as micro-, small-, medium- and large-scale and having a heterogeneous structure, it's been observed that only the advertisements of medium- and large-scale companies with high recognition level are mostly available. This is a matter that should be studied on the scale of companies, and it can be interpreted as the micro-, small- and medium-scale furniture companies advertise on different channels or otherwise do not invest in advertisements.

5 SUGGESTIONS

It is important that the advertisements address different generations in the furniture advertisements as they do in general. We can evaluate the criteria used in furniture advertisements in terms of generations X, Y and Z, which show great changes in terms of preferences, as follows: The generation X prefer sharp lines in terms of design at their living spaces, does not like risks, has a disciplined, authoritarian and traditional perspective, and reflects this perspective in their furniture choices. For the generation X, which changes furniture in every 8 years in average, design and innovation concepts mainly emphasized in the advertisements might be remarkable.

Generally asking for work environments in the comfort of home, preferring comfort and modern furniture and focusing on use, generation Y prioritizes functionality, comfort and freedom in furniture choices. As they grow together with the technology, they prefer technological products and they change furniture in every 3,5 - 4 years. It's been observed that the majority of the criteria emphasized in furniture advertisements are in line with the expectations of generation Y who are the decision-makers in buying furniture and at the age group of setting up a home.

Starting with those who were born in 2000, the generation Z includes individuals directing their families for preferring more technological furniture as they grow together with technology. With this awareness, it's seen that the furniture of brands developing products by using the state-of-the-art technology with USB portal for charging products such as smartphones, music players etc. appeals the generation Z. It is obvious that technological concepts will take place more in the advertising world with the further settlement of Industry 4.0 concept in the near future.

Furniture companies intensively featuring "price campaign" in their advertisements are aiming at customers who prioritize their budget most and want to buy affordable furniture with suitable features.

Companies using famous songs in their advertisements are aiming to draw attention of the consumers who are already the target audience of that song. The customer group attaching importance to visual and aesthetic concepts is appealed by emphasizing the "design" concept in advertisements. It's seen that concepts such as the imaginary world, colors and striking were mostly used in the advertisements targeting the customer group who would prefer kids' furniture.

As a result of advertisement analysis and overall evaluations, suggestions for the furniture companies in Turkey related to the advertisement contents are as follows:

Among the advertisements analyzed, it's seen that a commercial film emphasizing technology is very rare. Emergence of an innovation about technology every day shows that this concept should also be common in advertisements in the furniture sector.

Concepts such as Internet of things, robotics, big data and cloud technology, which are among the new concepts that direct the life today with Industry 4.0, have become a focus point in some big-scale businesses in the furniture sector that closely follow the developments in the furniture sector. An awareness must be created among the consumers that Industry 4.0 is also being adopted in the furniture sector by mentioning about this first in the advertisements.

It's been observed that concepts such as physical life, warranty period, after-sales service, quality, environmental awareness, recycling, environment and human friendly product concepts are not used or are not sufficiently emphasized. It's considered that it is important to use these concepts in the advertisements in order to increase the awareness of the consumers.

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Production Batch Size 1 as the Precursor for the Industry 4.0 Initiative

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ABSTRACT

In Europe, there has been promoted the trend of individually furnished interiors by furniture, which carries features of craftsmanship and is manufactured in an industrial manner.

The current level of network communications and the strong development of CNC woodworking machines make this type of production possible. The furniture company equipped with CNC technology has analysed the working time consumption in production and identified weaknesses places. A solution has been designed to speed up the response to the customer's wishes.

KEYWORDS: Furniture production, CNC woodworking machines, Customer, Individually furnished interiors, Batch size 1

1 INTRODUCTION

The subject of our research was a small furniture company with a turnover of approx. 2 million EUR per year, with unusually high production quality requirements. The main customers were Swiss, Belgian and Dutch companies demanding primarily dimensional accuracy and flawless finish. Production technology has been partly taken over from abroad and later refined by several years of experience. The technology consisted primarily of CNC machines by renowned German and Italian manufacturers. Dry finish was carried out on equipment by a major Spanish manufacturer, including computer control. The working team was made up of experienced furniture makers, some of whom had several decades of experience with production for Western European markets. Customers were happy with the quality of production, complaints were minimal, but justified, practically in all cases caused by a human factor failure. They were mostly mistakes due to manipulation, especially in the cleaning and packaging departments.

2 METHOD USED

The management of the company was not satisfied with the economic data, feeling that not all the processes in the company were efficient enough.

The first step was to investigate where ineffectiveness manifested itself. Machinery and sophisticated technology did not provide any apparent indication of ineffectiveness, but consumption of labor did. Therefore, extensive research has been undertaken in the field of labor consumption. In the first phase, working procedures were analyzed and then labor consumption was measured using standard methods at individual worksites in the production of a given set of products. The measurement of labor consumption took 14 months. The result was the determination of labor consumption for all 4,555 items in the finished production warehouse, which identified the point of inefficiency and its size. To save and manage data, it was necessary to use the Access database program, because the commonly used Excel was unable to work with such large data sets.

Worksites and machinery were also analyzed. It was necessary to precisely measure working times and adjustment times. Examples of measured values are listed in the table below. The data was then converted to adjustments of individual parts and then to furniture elements.

Table 1: Example of a portion of the original table of measured times

Adjusting elements of the packaging machine

		direct			with an extension			with 2 extensions		
		dismantling	moving	assembly	dismantling	moving	assembly	dismantling	moving	assembly
A	sliding wheel	0.31	0.28	0.31						
B	pressure roller for surface	0.441	0.27	0.364	0.535	0.463	0.629	0.629	0.656	0.894
C	straight roller (in axis), narrow	0.339	0.192	0.364	0.433	0.385	0.629	0.527	0.578	0.894
D	cranked roller (90° to axis), narrow	0.339	0.192	0.364	0.433	0.385	0.629	0.527	0.578	0.894
E	straight roller (in axis), wide	0.339	0.192	0.364	0.433	0.385	0.629	0.527	0.578	0.894
F	cranked roller (90° to axis), wide	0.339	0.192	0.364	0.433	0.385	0.629	0.527	0.578	0.894
G	steel wheel	0.339	0.192	0.364	0.433	0.385	0.629	0.527	0.578	0.894
H	arrow wheel	0.339	0.192	0.364	0.433	0.385	0.629	0.527	0.578	0.894
I	small white roller	0.339	0.192	0.364	0.433	0.385	0.629	0.527	0.578	0.894
J	shaped wheel	0.339	0.192	0.364	0.433	0.385	0.629	0.527	0.578	0.894
K	heating preparation	0.433	0.384	0.463	0.527	0.577	0.728	0.621	0.77	0.993
L	heating unit for edges	0.339	0.192	0.364	0.433	0.385	0.629	0.527	0.578	0.894
M	hot air gun	0.339	0.192	0.364	0.433	0.385	0.629	0.527	0.578	0.894
N	single lamp	0.339	0.192	0.364	0.433	0.385	0.629	0.527	0.578	0.894
O	flat lamp		0.27							
P	roller track 1	0.339	0.462	0.364	0.433	0.655	0.629	0.527		0.894
Q	roller track 2		0.462							
R	roller track 3		0.462							
S	side scrubbing		0.656							
T	top scrubbing		0.27							
U	hand sander	0.339	0.192	0.364	0.433	0.385	0.629	0.527	0.578	0.894
V	compressed air scrubbing	0.339	0.27	0.364						
adhesive	damper replacement, incl. cleaning	5,000								
	deploying a new foil while adjusting	5,000								

Source: made by author

The work was preceded by coding, dimensional analysis and sorting of all components and their subsequent surface finishing, coding of worksites, determination of the content of bags with fittings and a number of other supporting activities.

Images of the working day of individuals and pictures of operations were taken using time measuring. Based on the above, we were able to calculate, for example, time standards for individual jobs – see example in Table 2

Table 2: Example of part of the original table containing allocated times for individual furniture elements

Times allocated to worksites					05A	**operator**			6	TT		
					05B,D	**insertion**			1	TT		
WRAPPING MACHINE – BARBERÁN Updated 17.4.2007					**05C,E**	**removal**			2	TT		
Operation code	**Name of operation**		**Part code**	**Workpiece**	**Material**	**Clean dimension**			**Basic format**			**Standard**
						strength	**width**	**length**	**strength**	**width**	**length**	**min.**
1CRE401-05A0	Packaging	Wrap on BARBERAN D1CRE401 - operator	D1CRE401xx	Front CREA Line QS 140	MDF-R2	28	200	1056	28	200	2250	0.252
1CRE401-05A1	Packaging	Wrap on BARBERAN D1CRE401 - operator	D1CRE401xx	Front CREA Line QS 140	MDF-R2	28	200	1056	28	200	2250	0.252
1CRE402-05A0	Packaging	Wrap on BARBERAN D1CRE402 - operator	D1CRE402xx	Front CREA Line QS 160	MDF-R2	28	200	1256	28	205	1350	0.197
1CRE402-05A1	Packaging	Wrap on BARBERAN D1CRE402 - operator	D1CRE402xx	Front CREA Line QS 160	MDF-R2	28	200	1256	28	205	1350	0.197
1FIN403-05A0	Packaging	Wrap on BARBERAN D1FIN403 - operator	D1 FIN403xx	Front FINO BQS 120	MDF-FIno	28	140	1262	28	143	1350	0.167
1FIN404-05A0	Packaging	Wrap on BARBERAN D1FIN404 - operator	D1 FIN404xx	Front FINO BQS 140	MDF-FIno	28	140	1462	28	143	1550	0.181
1FIN406-05A0	Packaging	Wrap on BARBERAN D1FIN406 - operator	D1 FIN406xx	Front FINO BQS 160	MDF-FIno	28	140	1662	28	143	1750	0.194
1FIN407-05A0	Packaging	Wrap on BARBERAN D1FIN407 - operator	D1 FIN407xx	Front FINO BQS 180	MDF-FIno	28	140	1862	28	143	1950	0.208
1FIN501-05A0	Packaging	Wrap on BARBERAN D1FIN501 - operator	D1 FIN501xx	Side FIN0 BLS 190	MDF-FIno	28	140	1956	28	143	2050	0.214
1FIN503-05A0	Packaging	Wrap on BARBERAN D1FIN503 - operator	D1 FIN503xx	Side FIN0 BLS 210	MDF-FIno	28	140	2156	28	143	2250	0.227
1FIN504-05A0	Packaging	Wrap on BARBERAN D1FIN504 - operator	D1 FIN504xx	Side FIN0 BLS 220	MDF-FIno	28	140	2256	28	140	2350	0.233
1LEN402-05A0	Packaging	Wrap on BARBERAN D1LEN402 - operator	D1LEN402xx	Front LENIO RAHMEN BQS 120	MDF-R3	28	140	1196	28	143	1350	0.167
1LEN404-05A0	Packaging	Wrap on BARBERAN D1LEN404 - operator	D1LEN404xx	Front LENIO RAHMEN BQS 160	MDF-R3	28	140	1596	28	143	1750	0.194
1LEN405-05A0	Packaging	Wrap on BARBERAN D1LEN405 - operator	D1LEN405xx	Front LENIO RAHMEN BQS 180	MDF-R3	28	140	1796	28	143	1950	0.208

1LEN502-05A0	Packaging	Wrap on BARBERAN D1LEN502 - operator	D1LEN502xx	Side LEN0 RAHMEN BLS 210	MDF-R3	28	140	2090	28	143	2250	0.227
1LEN503-05A0	Packaging	Wrap on BARBERAN D1LEN503 - operator	D1LEN503xx	Side LEN0 RAHMEN BLS 220	MDF-R3	28	140	2190	28	143	2350	0.233
1M0V502-05A0	Packaging	Wrap on BARBERAN D1MOV502 - operator	D1 MCV502xx	Side MOVIE-LINE BLS 210 side	MDF-R3	25	160	2156	25	163	2300	0.227
1PRA403-05A0	Packaging	Wrap on BARBERAN D1PRA403 - operator	D1 PRA403xx	Front PRACTICO Kasten QS160	DTD	25	200	1506	25	205	1650	0.221
1PRA403-05A1	Packaging	Wrap on BARBERAN D1PRA403 - operator	D1 PRA403xx	Front PRACTICO Kasten QS160	DTD	25	200	1506	25	205	1650	0.221
1PRA403-05A2	Packaging	Wrap 1 in 5 .BARBERAN D1PRA403 - operator;	D1 PRA403xx	Front PRACTICO Kasten QS160	DTD	25	200	1506	25	205	1650	0.221
1PRA403-05A3	Packaging	Wrap 2 in 5 BARBERAN D1PRA403 - operator:	D1 PRA403xx	Front PRACTICO Kasten QS160	DTD	25	200	1506	25	205	1650	0.221
1PRA404-05A0	Packaging	Wrap on BARBERAN D1PRA404 - operator	D1 PRA404xx	Front PRACTICO Kasten QS180	DTD	25	200	1706	25	205	1850	0.235
1PRA404-05A1	Packaging	Wrap on BARBERAN D1PRA404 - operator	D1 PRA404xx	Front PRACTICO Kasten QS180	DTD	25	200	1706	25	205	1850	0.235
1PRA404-05A2	Packaging	Wrap 1 in 5 BARBERAN D1PRA404 - operator *	D1 PRA404xx	Front PRACTICO Kasten QS180	DTD	25	200	1706	25	205	1850	0.235
1PRA404-05A3	Packaging	Wrap 2nd in 5 BARBERAN D1PRA404 - Operator	D1 PRA404xx	Front PRACTICO Kasten QS180	DTD	25	200	1706	25	205	1850	0.235
1S0F503-05A0	Packaging	Wrap on BARBERAN D1SOF503 - operator	D1S0F503xx	Side S0FTLINE BLS 210	MDF-Soft	28	140	2156	28	143	2250	0.227
1SPI404-05A0	Packaging	Wrap on BARBERAN D1SPI404 - operator	D1SPI404xx	Front SPIRO Rahmen BQS 140	MDF-SpIro	28	180	1448	28	183	1600	0.172
1SPI404-05A2	Packaging	Wrap 1 in 5 BARBERAN D1SPI404 - operator	D1SPI404xx	Front SPIRO Rahmen BQS 140	MDF-SpIro	28	180	1448	28	183	1600	0.172
1SPI405-05A0	Packaging	Wrap on BARBERAN D1SPI405 - operator	D1SPI405xx	Front SPIRO Rahmen BQS 160	MDF-SpIro	28	180	1648	28	183	1800	0.181
1SPI405-05A2	Packaging	Wrap 1 in 5 BARBERAN D1SPI405 - operator	D1SPI405xx	Front SPIRO Rahmen BQS 160	MDF-SpIro	28	180	1648	28	183	1800	0.181

1SPI501-05A0	Packaging	Wrap on BARBERAN D1SPI501 - operator	D1SPI501xx	Side SPIR0 Rahmen BLS 200	MDF-SpIro	28	180	2042	28	183	2150	0.208
3B0D404-05A0	Packaging	Wrap on BARBERAN D3BOD404 - operator	D3B0D404xx	Front BODO Kopfteil BQS 200	MDF-R2	28	200	2060	28	205	2150	0.246
3B0D404-05A1	Packaging	Wrap on BARBERAN D3BOD404 - operator	D3B0D404xx	Front BODO Kopfteil BQS 200	MDF-R2	28	200	2060	28	205	2150	0.246
3B0D404-05A2	Packaging	Wrap 1 in 5 BARBERAN D3BOD404 - operator	D3B0D404xx	Front BODO Kopfteil BQS 200	MDF-R2	28	200	2060	28	205	2150	0.246

Source: made by author

3 IDENTIFICATION OF ELEMENTS OF INEFFICIENCY

According to the results of the measurements, it was necessary first to rule out the places with a high consumption of working time, which, however, cannot be rationally replaced by more efficient equipment when we factor in the current technological level. An example of such a place is the packing machine, which requires dozens of minutes to adjust, but it requires a minimum working time in operation. The efficiency of setting up such a machine is the subject of research by the manufacturers, but also, for example, by the University of Applied Science in Lemgo, Germany.

The individual allocated times were therefore combined into tables, for each product separately. These were tens of thousands of items, which eventually became the basis for rational production management and a transparent remuneration system.

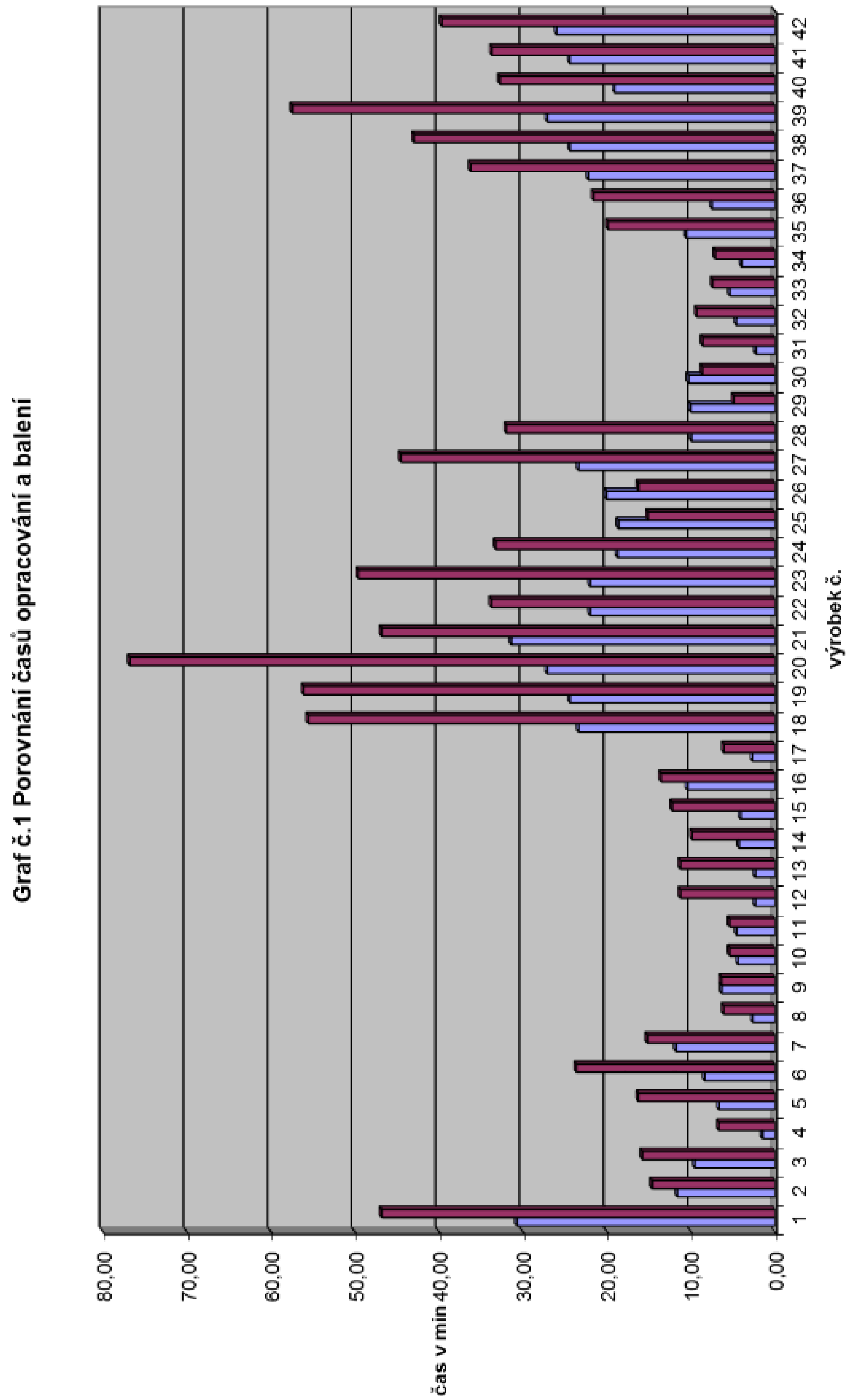

Figure 1: Comparison of processing and packing times
Source: made by author

After their comparison, it has been shown that the sum of the times, the transformations, i.e., for example, during machining, surface treatment, etc., for a single completed product, is comparable to or smaller than the times required for the cleaning of the parts after final processing and packaging. In the extreme case (product no. 20), the sum of the processing times is 2.83 times lower than the non-productive times associated with product cleaning and packaging.

Through demanding and accurate measurement we revealed the cause and magnitude of inefficiencies in the company, namely high labor consumption in the node of cleaning and packaging of finished products. By assigning hourly rates it was also possible to determine the value of labor consumption at this node.

4 PROPOSED SOLUTION

The differences between productive and non-productive production times are a known issue. The analysis carried out by Nemec (Bratislava, 1986) in the furniture industry of the Czechoslovak Socialist Republic shows that the component tTe when the value is added in the production process, represents only 1% - 2% of the total transformation time tpp. Such a value is not an exception in industry – Liker (Liker, Prague, 2008) mentions 2 – 3% for sophisticated industrial production of nuts. Time when the value is added therefore represents only a small fraction of the total time we need to produce the parts. However, it is clear that this the only time we may consider essential. Other times, such as for transportation, adjustment, control, etc., are times that are necessary, but not value-adding. We consider all these times multiplied by the exchange rate in this article as times of transformation, i.e. productive, whereas the times consumed after reaching the final shape and appearance of the product are considered to be unproductive. There is certainly room for further discussion about this gross division, but to solve the task at hand, it was a sufficiently conclusive calculation, leading to the discovery of inefficiencies in the manufacturing company.

It was noted that the company manufactures only goods in great variability required by customer orders. An analysis of the manufacturing process revealed that the machining and finishing sections meet the requirements of the production batch 1 system. This also corresponds to the established times of production of individual furniture elements. The quality of these elements, i.e. the proportion of scrap after operations, was approx. 1.7 % of the total. Overall, however, the share of scrap, including claims from customers, was reported at 5.5 %, while the share of damage caused by transportation was negligible due to sophisticated means of transport.

Therefore, the solution recommendations were clear. Install an automatic parts cleaning system, followed by a cardboard box manufacturing machine using the production batch 1 system. Both machines are computer-controlled, allowing data retrieval from performed operations. The company was already using the process of collecting data from the machining and finishing sections, and had time data on individual manufacturing operations. By installing the above equipment, it would obtain data that was missing so far, and the entire production system would get under software control. We can reasonably assume that the elimination of human factor from the cleaning and packaging processes will lead to a reduction of the necessary production time and, at the same time, to a reduction in scrap.

5 CONCLUSION

Identifying inefficiencies by measuring labor time consumption is a lengthy and costly method. However, it provides valuable data applicable to the strategy of eliminating inefficiencies in the production process and in other areas as well. CNC machine sensors may provide feedback for tracking completed manufacturing operations. In combination with the knowledge of the time consumption of individual production operations there emerges a scientific basis for process control using software tools, without which a competitive business cannot exist. Moreover, it is a good basis for network communication, which characterizes the emerging Industry 4.0 initiative.

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Effect of Heat Treatment on the Surface Characteristics of Bamboo (*Phyllostachys bambusoides*)

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ABSTRACT

This study aimed to investigate the changes in the surface roughness, surface colour and surface gloss of heat-treated bamboo (*Phyllostachys bambusoides*). Bamboo culms were obtained from Trabzon, Turkey. Bamboo samples used for this study were cut from middle section of bamboo culms, and node sections of the culms were removed. Bamboo samples, which were conditioned at 20°C and 65% relative humidity, were heated at 140°C, 170°C and 200°C with heating time of 2 and 4 hours. The results of heat treatment samples were compared with the control samples. The results showed that the surface colour of the heat-treated bamboo samples changed from light to dark and total colour change values (ΔE^*) increased depend on heating time and temperature. The gloss values decreased after 140°C and 4 hours of heat treatment. The mean surface roughness parameters (R_a and R_z) generally increased with higher temperature and longer heating time.

KEYWORDS: bamboo, heat treatment, surface roughness, colour, gloss

1 INTRODUCTION

Bamboo, being a cheap material, a renewable resource and having a fast growing rate, has high mechanical properties in woody materials (Wahab et al., 2005; Yun et al., 2016; Lee et al., 2016), and it is an alternative material to traditional timber for its many applications (Sulaeman et al. 2018). It grows plentifully in most of the tropical countries and it is a naturally occurring composite material. It has been widely used to produce bamboo-based composites, furniture, household products, building applications and construction as structural materials (Li, 2004; Meng et al., 2016). The physical and mechanical properties of bamboo degrade if it is not treated with impregnated chemicals. For this reason, it is necessary and important to impregnate the bamboo according to the places of use. The use of impregnated chemicals is not always effective because bamboo is not easily treated (Wahab et al., 2005). Therefore, heat treatment process has been applied as an alternative technique and studied by several researchers. Heat treatment of bamboo is considered to be a suitable method because it is non-toxic and chemistry is not needed (Leithoff and Peek, 2001), and heat treatment is an effective method of processing bamboo (Ohmae et al., 2009). One of the bamboo modification methods used to change surface colour and make better the dimensional stability of bamboo is heat treatment at high temperature (Zhang et al., 2013a). In addition, Qin and Yu (2009) reported that the reconstituted bamboo lumber was less influenced by the photo-irradiation after exposed to the artificial weathering as the increase of treated temperature.

Numerous researches have been carried out on the effect of heat treatment on the various properties of bamboo. The previous studies reported that the effect of heat treatment and/or steam heating on the basic density, strength properties and durability (Wahab et al., 2005), the chemical constituents (Salim et al., 2008), the water adsorption capacity (Ohmae et al., 2009), the bending properties and chemical composition (Zhao et al., 2010), the physical, mechanical and chemical properties (Manalo and Acda, 2009), (Zhang et al., 2013b), (Shangguan et al., 2016) and (Chung and Wang, 2017), the mass loss, colour difference and equilibrium moisture content (Nguyen et al., 2012), the changes in chemical composition (Bremer et al., 2013) and (Meng et al., 2016), the contact angle, surface free energy and equilibrium moisture content (Zhang and Yu, 2015), the fiber morphology, crystalline structure and mechanical properties (Yun et al., 2016), and density, hardness and resistivity against fungus (Abdullah and Nasution, 2018). There are few reports on the effects of heat treatment on the surface characteristics of bamboo. This information is of considerable importance for the usage areas of bamboo after heat treatment process. Nguyen et al. (2012) investigated the effect of thermal modification on the physical properties of two Vietnamese bamboo species, and found that the mass loss and equilibrium moisture content decreased with higher temperature and/or longer duration, and the colour of bamboo turns brown or dark brown during the modification. Zhang et al. (2013a) found that the total colour change (ΔE^*) of bamboo increased with higher pressure and longer duration. Zhang et al. (2013b) studied effect of thermal treatment on the physical and mechanical properties of *Phyllostachys pubescen* bamboo at temperatures of 100-220ºC, heated for 1-4 h, and found that the mass loss increased with increasing temperature and duration, the colour of heat-treated bamboo was darkened, modulus of rupture decreased above 160ºC, and modulus of elasticity decreased above 200ºC.

The aim of this study was to investigate the effects of heat treatment on surface characteristics of bamboo (*Phyllostachys bambusoides*), which is imported to Turkey and a variety of usage areas in Turkey, although not naturally occurring in Turkey. For this purpose, the surface roughness, colour changes and gloss values of heat-treated bamboo were tested. The evaluations were made by comparing them with control samples. Furthermore, knowledge of the changes in surface characteristics of heat-treated bamboo would allow the identification of heat treatment parameters for the usage areas of bamboo.

2 MATERIAL AND METHOD

The bamboo culms were harvested from Trabzon located in the East Black Sea region of Turkey. The height of the bamboo culms was about 8-9 m, and its diameters ranged from 30-45 mm. For this study, bottom diameters of culms were chosen and bamboo culms were conditioned at 20ºC and 65% relative humidity before sample preparation. The internode sections of culms only were used. The node sections of culms were removed because the nodes are different from internodes in physical and mechanical properties, and it reduces the mechanical properties of bamboo (Tomak et al., 2012). Each internode was cut for the experiment samples including control samples. In order to avoid crack formation during heat treatment, bamboo samples were conditioned at 20ºC and 65% relative humidity.

Heat treatment was carried out at a temperature of 140, 170 and 200ºC for 2 and 4 hours in a drying chamber. In addition, the surface roughness, the colour and gloss values of the control samples were determined in order to make a comparison.

2.1 Surface roughness measurements

The surface roughness measurements were performed using Time TR 100 surface roughness instrument according to DIN 4768 (1990). The mean roughness (R_a) and mean peak-to-valley height (R_z) were measured to determine surface roughness of bamboo samples. Ten measurements were recorded at the same points on the surface of the each sample before and after heat treatment, then the mean values were calculated.

2.2 Colour measurements

The colour parameters a^*, b^* and L^* were measured using Konica Minolta CM-2600d spectrophotometer according to the CIELAB colour scale (HunterLab, 2008). Colour measurements were performed in the middle of heat-treated and control bamboo samples. Twenty measurements were recorded for each treatment group. Δa^*, Δb^*, ΔL^* were determined according to the differences between final and initial values of a^*, b^*, L^* using below equation 1-3. The total colour difference (ΔE^*) was calculated from equation (4).

Where,

$\Delta a^* = a_f^* - a_i^*$ (1)

$\Delta b^* = b_f^* - b_i^*$ (2)

$\Delta L^* = L_f^* - L_i^*$ (3)

f means final values after heat treatment and i means initial values before heat treatment.

$\Delta E^* = [(\Delta a^*)^2 + (\Delta b^*)^2 + (\Delta L^*)^2]^{1/2}$ (4)

2. 3 Gloss measurements

The gloss values of samples were determined by Konica Minolta CM-2600d spectrophotometer from the surface of both heat-treated and control bamboo samples according to ISO 2470 (2001), and ten measurements were recorded for each treatment group and mean values were determined.

3 RESULTS AND DISCUSSION

3. 1 Surface Roughness

Surface roughness parameters (R_a and R_z) of bamboo samples after heat treatment are shown in Figure 1 and 2. As shown in Figure 1, R_a values of heat-treated bamboo samples increased compared with control samples. R_a values changed depend on heating time and temperature. Different trend was observed for these values. Generally, R_a values increased with increasing heating temperature without depend on heating time. Initially, R_a values for 140°C increased with increasing heating time. As the temperature reached to 170°C and 200 °C, these values decreased with increasing heating time. R_a value (0.36 μm) of control samples was significantly found lower than those of heat-treated samples. The highest and lowest R_a values were recorded to be 0.79 μm for 200°C-2h and 0.56 μm for 140°C-2h, respectively. The rougher surfaces were observed for 200°C.

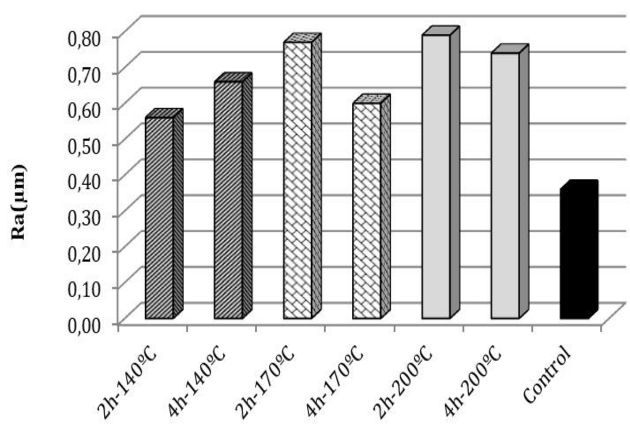

Figure 1: R_a values of bamboo samples

As can be seen from Figure 2, R_z values of heat-treated bamboo samples showed similar trend with R_a values of bamboo samples. At the beginning temperature (140°C) of heat treatment, R_z values increased with increasing heating time, but after this temperature, R_z values demonstrated a decrease with increasing heating time at 170°C and 200°C. The highest value was found to be 7.35 μm for 200°C-2h. Increasing temperature caused rougher surfaces compared to surface of control samples. R_z value (3.33 μm) of control samples was considerably found lower than those of heat-treated samples. The increased surface roughness values might be due to heat-treated bamboo surface become richer in lignin and poorer in cellulose and hemicellulose after heating (Meng et al., 2016). In addition, this situation can be explained by structural changes reasoned from chemical reactions occurred during heat treatment of bamboo. Some irregularities can observe on the material surface depend on various parameters. Hiziroglu and Zarate (2007) reported that the shape and size (width and height) of the irregularities occurred on surfaces are important to establish the final quality of products, and the surface roughness degree is a function of both production parameters and properties of raw materials.

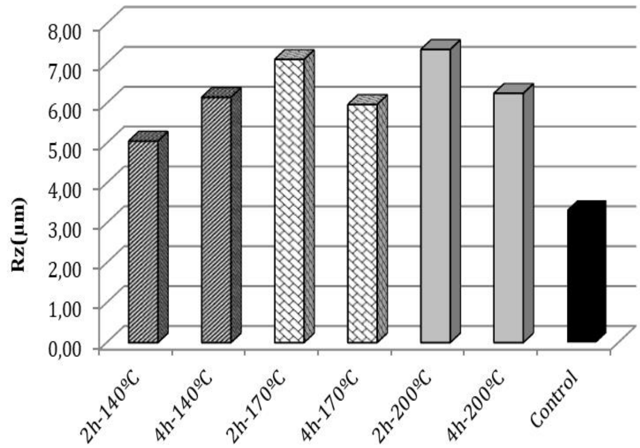

Figure 2: R_z values of bamboo samples

It is known that the surface roughness of wood decreases with increasing heat treatment temperature (Gunduz et al., 2008; Korkut et al., 2009; Korkut and Budakcı, 2010; Korkut et al., 2013). In contrast to wood, the surface roughness of bamboo increased as the heat treatment temperature increased in our study. The results showed that the surface of bamboo became rougher with increasing heating time and temperature.

3. 2 Colour change

Colour changes of bamboo samples after heat treatment are shown in Figure 3 and 4. Table 1 also summarizes the average colour values after heat treatment. As shown in Table 1, there was an important difference between ΔL^* values depend on heating time and temperature at the end of heat treatment. ΔL^* values were found as negative for all bamboo samples and these values changed between -0.39 and -22.40. In colour scale, L^* symbolizes lightness stability. Negative lightness stability (ΔL^*) shows a tendency of bamboo surface to become darker (HunterLab, 2008). These ΔL^* values indicate that the surface of bamboo samples became darker. The darkening effect occurred on the sample surface may be attributed to the increased temperature of heat treatment. Wood colour darkens because of some reactions such as hydrolytic discoloring reactions and/or different oxidative reactions occur in wood structure during the heat treatment (Sundqvist, 2002; Yildiz et al., 2011).

Table 1: Summary of bamboo colour parameters after heat treatment

Heating Temperature (ºC)	Heating Time (h)	ΔL^*	Δa^*	Δb^*
140	2	-2.95	0.73	1.42
	4	-0.39	1.52	3.77
170	2	-22.40	6.27	-0.55
	4	-17.31	7.07	-0.92
200	2	-18.83	7.95	-2.64
	4	-22.29	7.50	-6.22

According to HunterLab (2008), $+a^*$ and $-a^*$ indicate red and green; $+b^*$ and $-b^*$ indicate yellow and blue, respectively. As can be seen in Table 1, the Δa^* values of heat-treated bamboo samples were found as positive. These values ranged between 0.73 and 7.95. The greatest change for Δa^* was recorded as 7.95 at

200ºC for 2h. This means that Δa^* in the positive direction and the surface of bamboo samples turned to be reddish, especially after 140ºC temperature. In general, Δa^* values increased with increasing heating time and temperature. The Δb^* values of heat-treated bamboo samples were found as positive and negative (Table 1). Especially, Δb^* values were positive and the surface of bamboo samples started to turn yellow colour at 140ºC, afterwards these values were recorded as negative and the surface of samples turned to be bluish at 170ºC and 200ºC. Ngyuen et al. (2012) found that the colour change of two Vietnamese bamboo species increased from 130ºC to 220ºC for 2-5 h, and the colour of its became a darker colour with the increase modification temperature and duration.

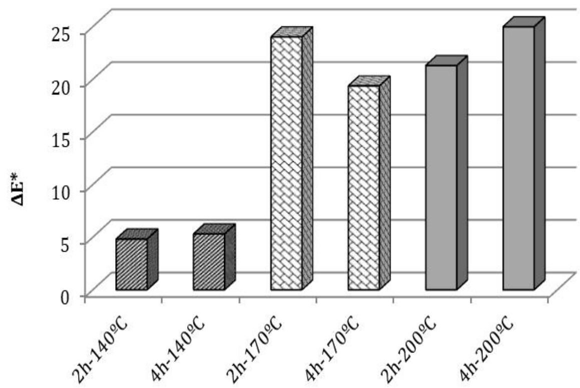

Figure 3: Total colour change (ΔE^*) values of bamboo samples

As shown in Figure 3, the heating time and temperature had a notable effect on the surface colour of bamboo samples. However, it was found that the heating temperature had more dominant effect than the heating time on the colour change (ΔE^*) of the samples. It was clearly seen that the ΔE^* increased with increasing temperature. Comparing to all ΔE^* values, the lowest colour changes were observed at 140ºC for 2h and 4h (4.81 to 5.30) and the lowest value was found to be 4.81 at 140ºC for 2h. The highest ΔE^* value was obtained to be 24.98 at 200ºC for 4h. Original light green colour of bamboo samples turned to dark brown colour after heat treatment, especially at 170ºC and 200ºC. The browning can be define as increased bluish colour at 170ºC and 200ºC. A picture of control and heat-treated bamboo samples at temperature of 140, 170, 200ºC for 4h is shown in Figure 4. This pictures show an observational evidence of effects of heat treatment on colour change of bamboo samples.

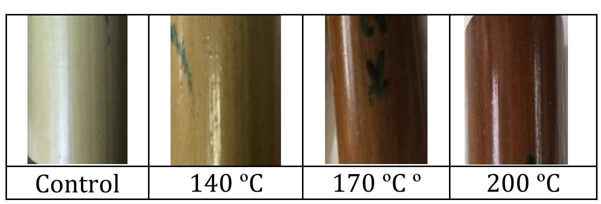

Figure 4: Pictures of control and heat treated bamboo samples at temperature of 140, 170, 200ºC for 4h

This colour change may be related to the lignin content on the surface of bamboo. Korkut et al. (2013) reported that wood colour changes on account of complex chemical degradation of lignin and extractives during heat treatment. Chemical compounds such as cellulose, hemicelluloses, lignin and extractives determine the colour of bamboo (Zhang et al. 2013a). Meng et al. (2016) found that hemicellulose contents decreased on the bamboo surface, whereas lignin contents increased on the bamboo surface after heat treatment. In addition, Zhao et al (2010) found that the lignin content increased and the hemicellulose content decreased for bamboo samples when the temperature was increased to 200ºC. All these findings confirm that the surface of the bamboo becomes darker with increasing heating temperature.

3. 3 Gloss

Figure 5 shows the gloss values of heat-treated and control bamboo samples. The gloss values of bamboo samples showed different trend depend on heating time and temperature. The highest gloss values were measured from the heat-treated samples at 140°C for 2h and 4h to be 13.92 and 12.73, respectively. The lowest gloss values were measured from the heat-treated samples at 200°C for 2h and 4h to be 4.98 and 4.47, respectively.

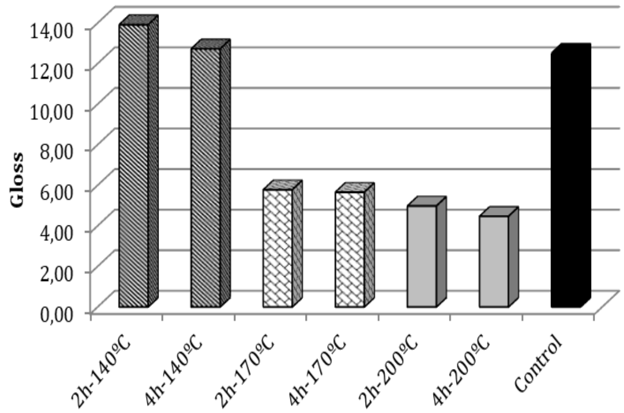

Figure 5: Gloss values of bamboo samples

While the gloss values of the bamboo samples increased at 140°C, these values showed clearly a decrease tendency at 170 and 200°C compared to the control samples. The result of the decrease in gloss of wood after heat treatment was reported that by Aksoy et al. (2011) for Scots pine wood, Korkut et al. (2013) for Wild cherry wood and Baysal et al. (2014) for Oriental beech.

The results also indicated that the heating temperature seems to be more effective than heating time on the gloss values of bamboo. The decrease in gloss of bamboo can be due to the darkness of bamboo surface with increasing treatment time and temperature, and can be explained by the fact that the lowest colour change is at 140ºC. The changes in the gloss of bamboo surface for 140, 170 and 200ºC were also proved by visual observation. Especially, it was noticed that there were notably some structural changes on the surface of bamboo samples. The surfaces of the samples were matted at 170 and 200ºC. This situation could be reasoned from the effect of various chemical reactions at high temperature. It is known that, bamboo comprises main components (cellulose, hemicellulose, lignin) and minor components (resins, waxes, tannins and inorganic salts) (Suleaman et al. 2018). It is thought that these components are responsible for the changes in the bamboo properties.

4 CONCLUSION

As conclusion, it was seen that the heating time and temperature had notable effects on the surface roughness, colour change and gloss values of bamboo samples. Surface roughness parameters (R_a and R_z) of bamboo samples increased, and the surface of bamboo became rougher after heat treatment. The colour of bamboo samples was affected by temperature and time of heat treatment process. ΔE^* values of samples increased with increasing heating time and temperature. The treatment changed the surface colour of bamboo samples from light green to dark brown at 170ºC and 200ºC. Gloss values of heat-treated bamboo samples increased at 140ºC , but then, decreased clearly at 170ºC and 200ºC. These findings demonstrated that heating temperature especially had more effect on the colour and gloss values of bamboo samples. The surface characteristics of bamboo changed at temperatures above 140ºC, and heat-treated bamboo samples exhibited a rougher, lower gloss and darker surface than control bamboo samples.

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Critical Buckling Load of the Side Walls of Cabinet Furniture

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ABSTRACT

Loss of furniture stability may constitute a rapidly occurring, direct hazard to the user's life or health. Studies conducted to date have concerned the effect of the type of material and method of back wall attachment on its stability. In contrast, practically no analogous data are available on the stability of side walls. In the case of loading with a vertical force applied on a furniture item supported at three corners all the elements are subjected to torsional strain. However, the static pattern changes when the structure is supported at four corners. Then loading of a piece of furniture with a vertical force results in slight displacements in the direction of the acting force, whereas buckling and considerable deflections are perpendicular to the direction of that load. This has a significant effect on side wall stability. For this reason it was decided in this study to determine the effect of side wall structure on stability (buckling) and postbuckling behaviour of side walls in cabinet furniture. The analyses consisted in numerical calculations using the Finite Element method. Three types of side wall structures were used: particleboard, honeycomb panel and board-on-frame. Values of critical forces, lateral deflections and normal stresses in the direction of the acting load were calculated. Testing results confirmed that the honeycomb panel provides the most advantageous structure for side walls.

KEYWORDS: furniture, side wall**,** honeycomb**,** buckling, postbuckling, numerical analysis

1 INTRODUCTION

Furniture durability, rigidity and stability of furniture are the most essential characteristics in terms of user safety. To date many studies have been conducted to describe rigidity and durability of furniture fastened in three corners (Ganowicz et al. 1978, Smardzewski et al. 2016). Tests have shown that torsional deformation of the structure depends solely on the torsional deformations of individual board elements in furniture (Fig.1a). In turn, rigidity of furniture depends on the rigidity and strength of joints, modulus of elasticity in shear, board thickness and their size dimensions (Smardzewski et al. 2014, Smardzewski 2015). A significant element addressed in furniture design is also connected with their stability. Loss of furniture stability may suddenly and directly threaten users' health or lives. This is particularly true in the case of furniture for children, since they are unable to promptly respond to direct hazard (Smardzewski 2015). Loss of stability may be a consequence of reaching critical load, resulting in structural failure due to considerable strains or due to bifurcation buckling, at which the structure starts to be deformed to a completely new form (Łodygowski and Kąkol, 2003). So far studies have been conducted on the effect of the type of material and manner of back wall attachment on its stability (Smardzewski and Dzięgielewski 1993). In this case tests were conducted on a piece of furniture fastened in four corners with various types of back wall assembly. Analyses showed the smallest deflections for the back wall made of particleboard placed in a groove (Smardzewski and Dzięgielewski 1993). In contrast, no such data are available on side wall stability. In the case of loading with a vertical force for a furniture item supported in three corners (Fig.1a) all the elements are subjected to torsional strain. Rigidity of the structure is then expressed as the quotient of force **F** and displacement **DF**. Nevertheless, the static model is changed when the structure is supported in four corners (Fig.1b). In this case loading of a furniture item with a vertical force **F** causes slight displacement **DF** in the direction of the force, while buckling and considerable deflections **w** are observed perpendicularly to the direction of this load.

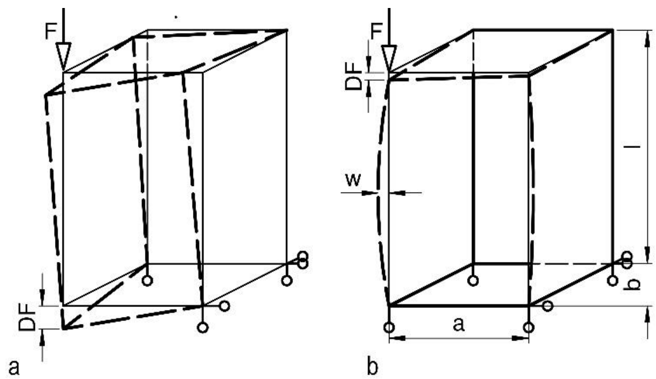

Figure 1: A scheme for the furniture strain under load:
a) element twisting, b) side wall buckling.

We need to observe here that the volume of deflection **w** and the value of critical force causing buckling of a side wall will depend on the type and thickness of used material. Moreover, in an attempt to minimise weight of furniture, popular particleboards are being replaced with honeycomb panels. This may have a significant effect on side wall stability. Thus in this study it was decided to determine the effect of side wall structure on stability (buckling) and postcritical (postbuckling) behaviour of side walls in cabinet furniture.

2 MATERIALS AND METHODS

2.1 Stability of thin panels

When investigating a freely supported rectangular board with dimensions **a** and **l** and thickness **t** (Fig.2) uniformly loaded with compressive force $\mathbf{s}_x$ along shorter sides **a**, the strain function **w** may be written in the form (Timoshenko and Woynowsky-Krieger , 1987; Yamaguchi, 1999):

(1) $$,\mathbf{w} = \mathbf{A}_{mn} sin\frac{\mathbf{m}\pi x}{\mathbf{a}} sin\frac{\mathbf{n}\pi y}{\mathbf{l}}$$

where **m** and **n** denote the number of sine half-waves in directions *x* and *y*. By introducing this equation to the general differential equation for the deflection of a rectangular board:

(2) $$,\mathbf{D}\left(\frac{\partial^4 \mathbf{w}}{\partial x^4} + 2\frac{\partial^4 \mathbf{w}}{\partial x^2 \partial y^2} + \frac{\partial^4 \mathbf{w}}{\partial y^4}\right) + \mathbf{t}\left(\sigma_x \frac{\partial^2 \mathbf{w}}{\partial x^2} + 2\tau_{xy}\frac{2\mathbf{w}}{\partial x \partial y} + \sigma_y \frac{\partial^2 \mathbf{w}}{\partial y^2}\right) = 0$$

where:

$\mathbf{D} = \frac{\mathbf{Et}^3}{12(1-\vartheta^2)}$, *E*- modulus of linear elasticity of the board, **u** - Poisson's ratio of the board, and adopting the assumption on balance of a deflected board (**w**≠0) we obtain an expression describing critical stresses causing loss of its stability:

(3) $$.\,\sigma_x = \frac{\pi^2 \mathbf{D}}{\mathbf{ta}^2}\mathbf{K}$$

Thus critical force $\mathbf{F}_{cr}$ causing loss of stability may be described as:

(4) $$F_{cr} = \frac{\pi^2 D}{a} K$$

where: α=**l/a** and $\mathbf{K} = \left(\frac{m}{\alpha} + n^2 \frac{\alpha}{m}\right)^2$. For a side wall of cabinet furniture subjected to uniform compression along edge **a** the value of coefficient **K** depends on the method of support and the **l/a** ratio (Fig. 2).

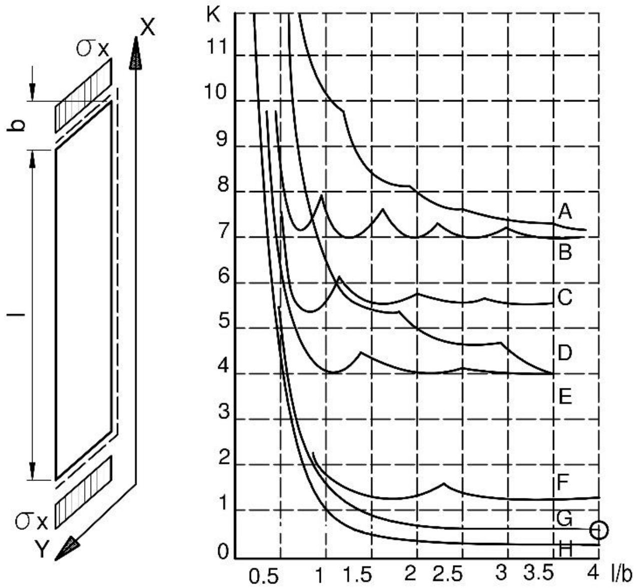

Figure 2: Variation in index **K** for a rectangular board uniformly compressed along edge *a* for various methods of margin support: A - four edges fastened,
B - two long edges fastened, shorter edges with articulated supports,
C - one longer edge fastened, three edges with articulated supports,
D - two shorter edges fastened, longer edges with articulated supports,
E - all four edges with articulated supports,
F - one longer edge fastened, the other longer edge free, the other edges with articulated supports,
G - one longer edge free, the other edges with articulated supports,
H - two longer edges free, shorter edges with articulated supports.

2.2 Side wall structure

For the purpose of these analyses virtual models were prepared for side walls with dimensions **t**=22 mm, **a**=400 mm, **l**=1800 mm. Three design solutions were selected: an element manufactured solely of particleboard PB, an element manufactured as honeycomb panel with a cardboard core with hexagonal cells, and a frame element manufactured as board-on-frame, but with not cardboard core (Fig. 3). In the case of honeycomb panels the frame on the circumference was manufactured from particleboard PB of 16 mm in thickness. Facing was made from HDF board of 3 mm in thickness. Faces were glued to the frame and the cardboard core using PVAc adhesive applied onto the HDF board at 120 g/m^2. Physic-mechanical properties of used boards were determined in accordance with respective standards (BS EN 310:1993, BS EN 322:1993, BS EN 323:1993) and presented in Table 1.

Table 1: Physic-mechanical properties of tested materials (laboratory conditions T=26 °C; H=40%)

Type of material	Thicknes [mm]	MC	Density	MOE	MOR
		[%]	[kg/m^3]	[MPa]	[MPa]
HDF	3.0	6.14/0.20	846/12	4071/416	41.0/4.0
PB	16	5.76/0.95	664/11	1672/100	6.6/0.9

/Standard deviation

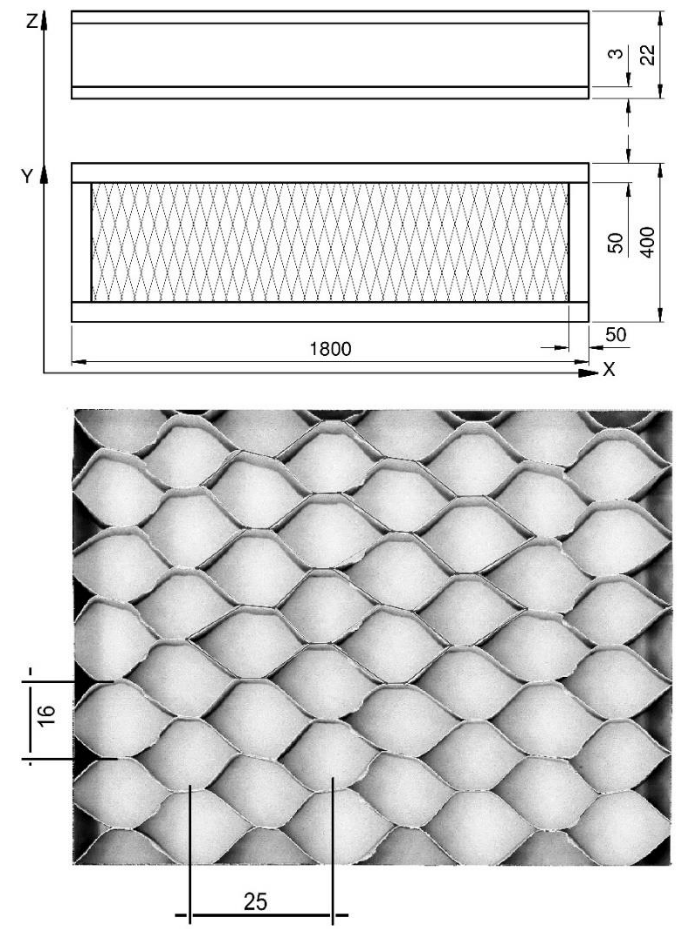

Figure 3: Dimensions of tested panels and the shape of core cells

In the case of hexagonal core cells (Fig. 4) it was decided to determine their relative density and elastic properties.

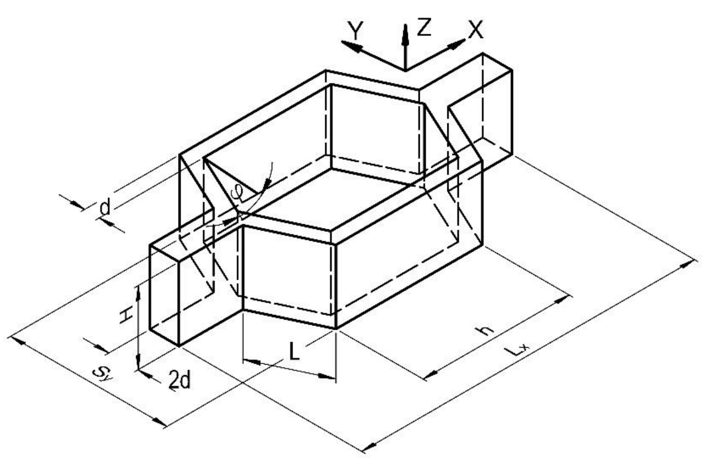

Figure 4: A hexagonal core cell

Relative density $\boldsymbol{\rho}$ is the ratio of cell density $\boldsymbol{\rho}^*$ to density of cell matter $\boldsymbol{\rho}_s$ and it is described in the form:

$$\rho = \frac{\rho^*}{\rho_s}, \tag{5}$$

where: cell density $\boldsymbol{\rho}^*$ is a ratio of cell mass to its volume, while density of cell matter $\boldsymbol{\rho}_s$ is the ratio of cell matter mass to the volume of cell matter. Moreover, considering that the cell wall height $\boldsymbol{H}$ is constant, the notation may take the final form as

$$\rho_p = \frac{F_s}{F^*}, \tag{6}$$

where: $\mathbf{F}_s$ and $\mathbf{F}^*$, respectively, is the surface area of the matter and the cell surface area. Finally the surface area of the rectangle, in which the honeycomb cell is inscribed, may be presented as:

$$\mathbf{F}^* = 4(\mathbf{L}\cos(\varphi) + \mathbf{d})\,(\mathbf{h} + \mathbf{L}\sin(\varphi) - \mathbf{d}\cot(\varepsilon)). \tag{7}$$

Using trigonometric relations seen in Fig. 4 the following were obtained:

$$\mathbf{F}_1 = 2\mathbf{L}\cos(\varphi)\,(\mathbf{h} - 2\mathbf{d}\cot(\varepsilon) + \mathbf{L}\sin(\varphi)), \tag{8}$$

$$\mathbf{F}_2 = 2\big((\mathbf{L}\cos(\varphi) + \mathbf{d}) - 2\mathbf{d}\big)(\mathbf{h} - 2\mathbf{d}\cot(\varepsilon)), \tag{9}$$

$$\mathbf{F}_3 = 2\mathbf{L}\sin(\varphi)\cos(\varphi)\,(\mathbf{L} - \mathbf{d}\cot(\varepsilon)). \tag{10}$$

Relative density $\boldsymbol{\rho}_p$ is thus the ratio of surface area of core matter $\mathbf{F}_s$ to the surface area of the rectangle, in which it is inscribed $\mathbf{F}^*$,

$$\rho = 1 - \frac{F_1 + F_2 + F_3}{F^*}. \tag{11}$$

For a single cell two longitudinal moduli of elasticity $\mathbf{E}_x$, $\mathbf{E}_y$ and two Poisson`s ratios υ_{xy}, υ_{yx} were established:

$$\mathbf{E}_x = \frac{\mathbf{E}_s \mathbf{d}^3\left(\frac{\mathbf{h}}{\mathbf{L}} + \sin(\varphi)\right)}{\mathbf{L}^3\cos^3(\varphi)}, \tag{12}$$

where: $\mathbf{E}_s$ - modulus of linear elasticity of the matter.

$$\mathbf{E}_y = \frac{\mathbf{E}_s \mathbf{d}^3\cos(\varphi)}{\mathbf{L}^3\left(\frac{\mathbf{h}}{\mathbf{L}} + \sin(\varphi)\right)\sin^2(\varphi)}, \tag{13}$$

$$\upsilon_{xy} = \frac{\sin(\varphi)\left(\frac{\mathbf{h}}{\mathbf{L}} + \sin(\varphi)\right)}{\cos^2(\varphi)}, \tag{14}$$

$$\upsilon_{yx} = \frac{\cos^2(\varphi)}{\left(\frac{\mathbf{h}}{\mathbf{L}} + \sin(\varphi)\right)\sin(\varphi)}. \tag{15}$$

Table 2 presents calculated values of elastic properties of the use

Table 2: Characteristic properties of the hexagonal cell

E_s	d	h	L	f	L_x	S_y	r	E_x	E_y	u_{xy}	u_{yx}
MPa	mm			°	mm			MPa			
6000	0.15	3.9	11.5	45	23.99	16.62	0.02493	0.0389	0.0178	0.1017	1.48

In view of the above-mentioned material data, for the investigated side wall with one longer edge being free and three other edges with articulated supports, the critical force causing buckling of the side wall of thickness **t**=22 mm is equal to:

(16) 16074 N.$F_{cr} = \frac{3.14^2(1672\cdot 22^3)}{400\cdot 12(1-0.3^2)}\cdot 0.4 =$

2.3 Numerical calculations

Numerical calculations were performed applying the Finite Element Method (FEM) with the use of the Abaqus v. 6.13-1 software. Selected side wall structures were modelled using rectangular, 8-node solid elements type C3D8R. On average 5500 elements and 12100 nodes were used. The grid model, the method of support and loading of tested structures are presented in Fig. 5. Elastic properties of the materials given in Tables 1 and 2 were applied. First values of critical forces $\mathbf{F}_{cr}$, were calculated, then deflections $\mathbf{U}_3$ and normal stresses $\mathbf{S}_{22}$ were calculated in the direction of loading in the postcritical range.

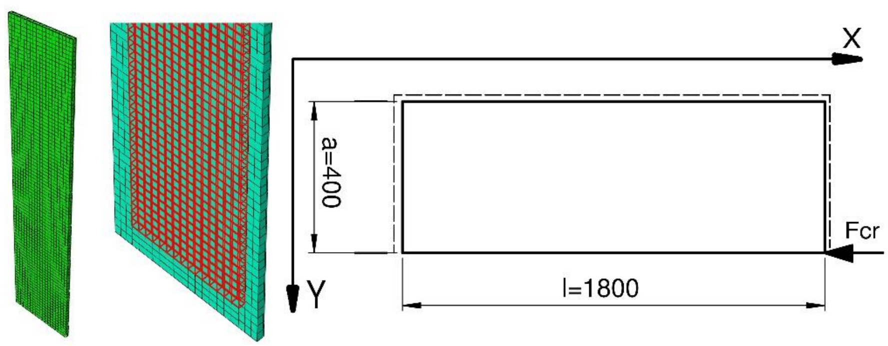

Figure 5: Grid model and loading method for the side wall

3 RESULTS AND DISCUSSION

Figure 6 presents the form of buckling of side walls under critical loading. It may be concluded from the figure that in the critical state the side walls manufactured from particleboard and from honeycomb panel exhibit a similar form of buckling by deflection of the face edge of the panel. In the case of the board-on-frame the central part of the facing suffered considerable buckling. For individual types of structures the value of critical force was as follows:

- particleboard: 16428 N,
- honeycomb panel with cardboard core: 29205 N,
- board-on-frame with not cardboard core: 5838 N.

It results from the given values that the side wall manufactured from honeycomb panel shows the highest value of critical force. This is a direct consequence of the high value of the modulus of linear elasticity of HDF facings (4071 MPa) as well as cardboard core binding these facings. Despite the low value of the modulus of linear elasticity of the honeycomb core (0.0389 MPa), its presence has a significant effect on the maintenance of facing stability. The structure with no core loses stability under a 5-fold lower critical load (5838 N). In the case of the side wall manufactured entirely from particleboard the value of critical force is almost 50% lower in relation to honeycomb panel and is equal to the value calculated analytically.

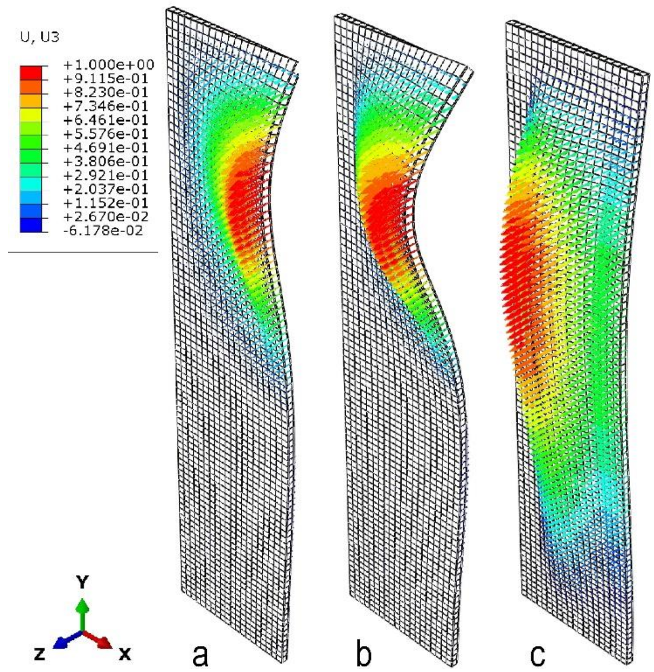

Figure 6: The form of buckling in the side wall under critical load:
a) particleboard, b) honeycomb panel, c) board-on-frame

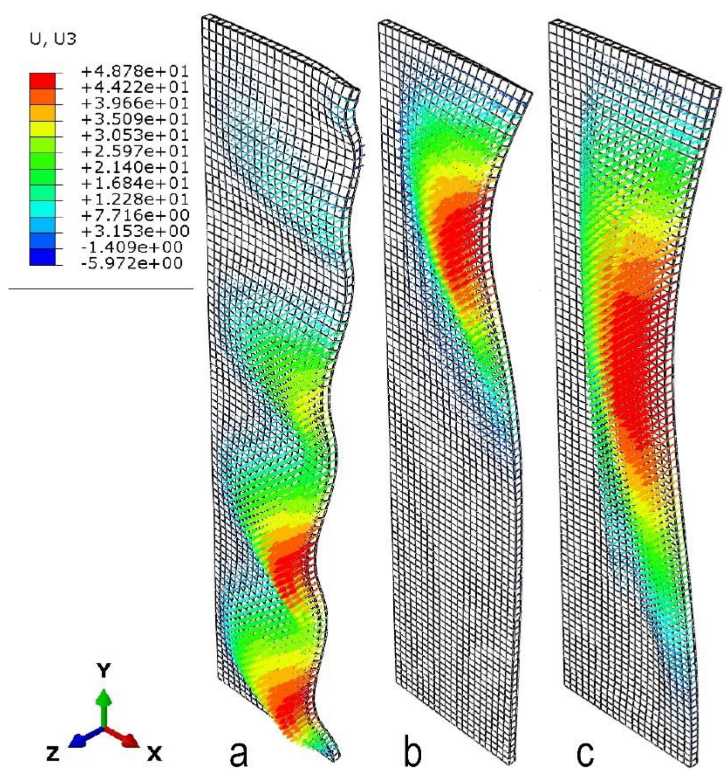

Figure 7: Form of buckling in the side wall at postcritical loading:
a) a) particleboard, b) honeycomb panel, c) board-on-frame

Figure 7 presents the form of buckling for analogous side walls in the postcritical state, i.e. when load exceeded the critical value. It may be concluded from this figure that in the postcritical state the side wall manufactured from particleboard suffers multiwave deflection. The side wall made from honeycomb panel retains the original form of buckling, while the side wall made from the board-on-frame suffers double buckling in the central part of facings. For this board respective transverse deflections $\mathbf{U}_3$ are 48 mm, 36 mm and 89 mm. Thus the most advantageous rigidity following bifurcation is found for honeycomb panels.

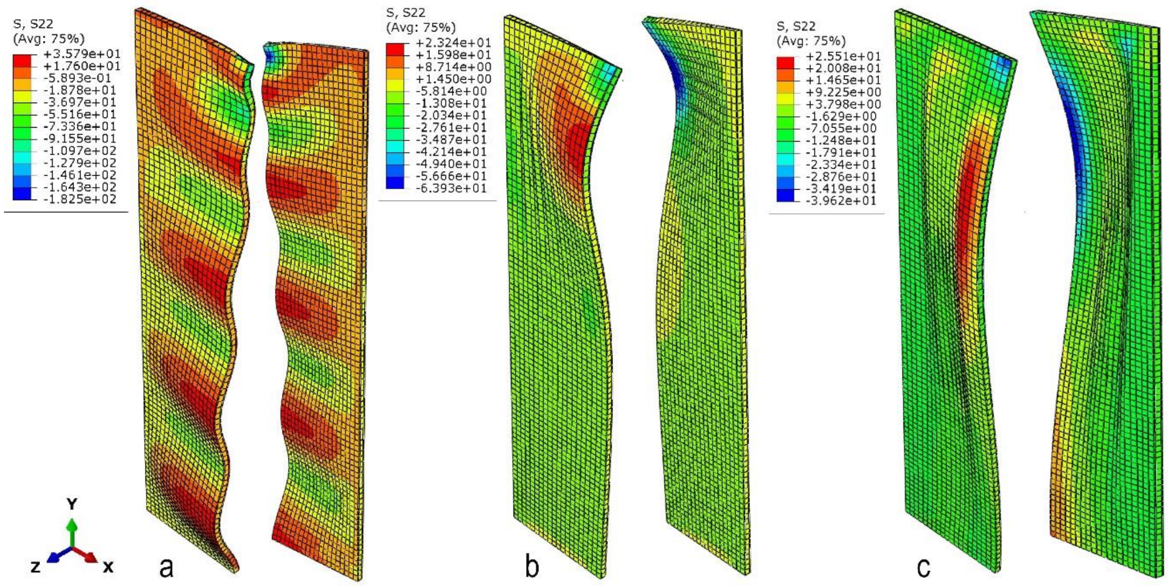

Figure 8: Distribution of normal stresses $\mathbf{s}_{22}$ in panels after exceeding critical loads:
a) particleboard, b) honeycomb panel, c) board-on-frame

In turn, Figure 8 presents the distribution of normal stresses in panels after critical loads are exceeded. This figure shows that for individual structures of side walls tensile stresses are 35.7 MPa, 23.2 MPa and 25.5 MPa, respectively. Compressive stresses were 182 MPa, 63.9 MPa and 39.6 MPa. It may be concluded from these data that a side wall manufactured from honeycomb panel exhibits the best properties for initial stability as well as very good mechanical strength parameters after critical loads are exceeded.

4 CONCLUSION

Conducted numerical calculations for the stability of side walls in cabinet furniture and the obtained results made it possible to formulate the following conclusions and observations:

- The side wall manufactured from honeycomb panel loses stability at the highest value of critical load, 2-fold greater in comparison to buckling of the same element made from particleboard,
- In the postcritical state the smallest deflections are found for elements made from honeycomb panel, while they are greatest for that of board-on-frame,
- Normal stresses have the most advantageous distributions in facings of the honeycomb panel and they are manifested in the sites of the greatest buckling amplitude,
- From the practical point of view it is recommended to use honeycomb panels to design side walls of cabinet furniture.

5 ACKNOWLEDGEMENTS

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The Effects of Pre-Ozone Treatment on Retention Levels and the Compression Strength of Spruce Wood Treated with ACQ and CCA

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ABSTRACT

In this study, ozone pre-treatment was applied to spruce wood samples. Spruce wood samples at equilibrium moisture content (EMC) were pre-treated using ozone for 30 and 60 min, respectively. The intensity of ozone was kept constant at 15 g/h for all variations. The ozone pre-treated spruce wood samples were then impregnated with 2.5 % Alkaline copper quat ((Celcure AC500) (ACQ)) and 1% copper chromium arsenic (CCA) solution by applying initial vacuum for 20 min and then free-pressure for 30 min. The retention levels and penetration depths were determined for each variation and control sample. The ozone pre-treatment increased the retention levels and penetration depths. It was found that the retention levels were 5.03 and 5.27 kg/m^3 for the ozone pre-treated (30 and 60 min) spruce for wood samples treated with 2.5% ACQ, while the retention level for control wood samples was 3.84 kg/m^3. The results showed that ozone pre-treatment enhanced the impregnation properties of spruce wood. In addition, the applied ozone pre-treatment increased compression strength parallel to grain values (CS).

KEYWORDS: Spruce; Ozone treatment; Penetration Depths; Retention; Mechanical Properties

1 INTRODUCTION

Spruce wood is one of the most important species in Turkey (OGM 2013). However, spruce wood is difficult to impregnate with wood preservatives (Ulvcrona 2006). Spruce wood is mostly used in the furniture industry and building sector. However, it has limited usages in the wood preservation industry because of its difficult impregnability. Investigations showed that high surface tension during the wood drying process causes the displacement of membranes as well as sealing off the pit aperture which is called pit aspiration (Bolton and Petty 1997, Fujii et al. 1997). Different pre-treatment methods were applied to improve the impregnation properties of such refractory wood species such as steaming, mechanical incising, drilling techniques and bio-incising (Mai et al. 2004, Schwarze et al. 2006, Lehringer et al. 2009, Dashti et al. 2012, Yildiz et al. 2012, Panek et al. 2013, He et al. 2014).

Investigations showed that drilling techniques (Lebow and Morrell 1993, Kartal and Lebow 2002), bio-treatment (Efransjah 1989, Militz 1993, Lehringer et al. 2011, Yildiz et al. 2012), chemical-treatment (Yildiz et al. 2010) and microwave-treatment (Ramezanpour et al. 2013, He et al. 2014) increased the retention levels and penetration depth. However, these pre-treatment methods decreased mechanical properties. The pre-treatments effects on retention levels, penetration depth and/or mechanical properties were summarized in Table 1.

Ozone is a gaseous unstable molecule composed of three oxygen (O_3) atoms. The disinfecting effect of the ozone is due to its strong oxidizing property. Ozone is the third most powerful oxidant known to carry fluorine and persulfate, along with its radical nature, due to its chemical structure (Bocci, 2006). In addition, ozone is also used in the bleaching process in pulp and paper production (Métais et al. 2011; Pouyet et al. 2014). In this study, it was aimed that impregnation properties could be improved by pre-treating spruce wood samples with ozone without decreasing mechanical properties.

Table 1 : Effect of the pre-treatment on some wood species

Pre-Treatment	Wood Species	Retention Levels	Penetration Depth	Mechanical Strength % Decrease			References
		% Increase		MOE	MOR	CS	
Bio-Treatment	Spruce Wood	-	-	9.3	17		Efransjah (1989)
Bio-Treatment	Spruce Wood	55	-	-	-	-	Militz (1993)
Drilling Tech.	Fir	95	-	-	-	-	Lebow and Morrell (1993)
Drilling Tech.	*Tsuga canadensis*	50	49-98	-	-	-	Kartal and Lebow (2002)
Chemical	Spruce Wood	48.6	-	-	-	12-31	Yildiz *et al.* (2010)
Bio-Treatment	Spruce Wood	-	-	15.2-29.9 (Brinell hardness)			Lehringer et al. (2011)
Bio-Treatment	Spruce Wood	103	-	-	-	14.4	Yildiz *et al.* (2012)
Microwave-Treatment	*Abies alba* L.	612	-	-	-	-	Ramezanpour *et al.* (2013)
Microwave-Treatment	Douglas Fir	123	-	2.5	14.5	-	He *at al.* (2014)

The main objective of the present research was to increase the penetration depth and retention levels of ozone pre-treated spruce wood impregnated with CCA and ACQ wood preservatives.

2 MATERIAL AND METHOD

2.1 Preparation of wood specimens

Spruce wood obtained from the Maçka in Trabzon province of Turkey was used in this study. Planks of 25 mm thickness with full log width and length were prepared. Planks were converted into longitudinal specimens of size 30 x 15 x 15 mm (L/W/T). The spruce wood samples were divided into nine groups (Table 2). The test spruce wood samples were conditioned in equilibrium moisture content until wood samples reached to 12% moisture content prior to ozone pre-treatment.

Table 2: Experimental design

Groups	Time of Ozone application [min]	Preservative Type	Concentration of preservative [%]
C	-	-	-
CQ	-	ACQ	2.5
CA	-	CCA	1
O1C	30	-	-
O1Q	30	ACQ	2.5
O1A	30	CCA	1
O2C	60	-	-
O2Q	60	ACQ	2.5
O2A	60	CCA	1

In this study, Chromated copper arsenate (CCA) type C was used, which is composed of 18.5% copper oxide (CuO), 34.0% arsenic pentoxide (As_2O_5) and 47.5% chromium trioxide (CrO_3). Solution of CCA (1%) was prepared for impregnation procedure.The Alkaline copper quat (ACQ) contains copper and a quaternary ammonium compound. The ACQ treatment solution was type Celcure AC 500 manufactured by Osmose company. Celcure AC 500 is composed of 16.63% basic copper carbonate, 5% 2-aminoethanol, 4.8% benzylammonium chloride. Solutions of ACQ (2.5%) were prepared for impregnation procedure (Table 2).

2.2 Ozone Treatment

Ozone (model: Enaly) with 15 g/h was used for the experiment and the ozone intensity was kept constant for all groups Ten replicates were used for each group. The spruce wood samples (O1C, O1Q, O1A, and O2C, O2Q, O2A) which had 12% initial moisture content (MC) were pre-treated with ozone for 30 and 60 min respectively, for all test groups.

2.3 Determination of preservative retention

2.3.1 Impregnation method

Before impregnation with wood preservatives, cross sections of the ozone pre-treated test samples were coated using two layers of paraffin to prevent the preservative flow through the longitudinal direction. Samples were then impregnated with either CCA or ACQ according to AWPA E10-01 (2001). Test specimens in solution were subjected to a pre-vacuum of 685 mmHg for 20 minutes followed by for 30 minutes kept under atmospheric condition.

After the impregnation the preservative retention was calculated as follows;

$$R = \frac{GXCX10}{V} \quad (kg/m^3) \tag{1}$$

Where R (retention) is the amount of wood preservative remained in the wood specimen (kg of preservative per m^3 of wood), G is the weight of the preservative solution absorbed by the block (W2-W1) g. C is the Grams of preservative in 100 g of treating solution, and V is the volume of the specimen (cm^3).

2.3.2 Measurement of penetration

The depth of preservative penetration was determined using Chrome Azurol S (color index No.43825, also known as mordant blue 29) reagent according to AWPA-A3-08 standard (AWPA 2010). To prepare this reagent, 0.5 g Chrome Azurol S and 5 g sodium acetate were dissolved in 80 ml distilled water and the solution was diluted to a volume of 300 mL. Then, this reagent was sprayed on the cross section of impregnated specimens. As a result, ACQ and CCA-impregnated areas appeared in blue color and untreated surfaces changed to red color. Depth of penetration was measured at eight different points in each specimen with a digital caliper with 0.1 mm precision. The maximum and minimum depths of penetration were then determined. In addition, the impregnation area (%) on the wood cross section was calculated by the aid of the software Image J program (https://imagej.nih.gov).

2.4 Mechanical Properties

2.4.1 The Compression Strength

The compression strength parallel to grain values for control samples (untreated) and test samples were recorded at Losenhausen and Mohr & Federhaff Universal Test Machine according to the Turkish Standards 2595 (TS 2595 1988).

The compression strength (CS) parallel to grain was calculated from the following formula;

$$CS = \frac{Fmax}{A \times b} \quad (kg/cm^2) \qquad (2)$$

Where: F*max* is the force applied on wood specimen (kg); A is the width of the sample (cm); and b is the height of the sample (cm).

2.5 Statistical Analyses

Statistical analyses were conducted using SPSS 22 software (http://www-01.ibm.com). The retention levels and mechanical properties results of spruce wood were compared using the Duncan homogeneity test at 95 % confidence level.

3 RESULTS AND DISCUSSION

The retention levels for the samples with and without the ozone pre-treatment and the Duncan test results homogeneity groups are given in Table 3. The ozone pre-treatment increased the retention levels up to 44.66%. The lowest increase in retention level (10.07%) was obtained in O1A while the highest increase was obtained in O2A groups (Table 3 and Figure 1).

Table 3: Retention levels ($kg.m^{-3}$) and penetration (%) of ACQ and CCA

	Retention [$kg.m^{-3}$]			Impregnated area*** [%]			Penetration Depth[mm]		
Groups	**means**	**HG***	**Std. dev.**	**means**	**HG***	**Std. dev.**	**means**	**HG***	**Std. dev.**
CA	1.91	(A)**	0.23	28.32	(A)	0.98	2.19	(A)	0.17
O1A	2.10	(AB)	0.56	43.44	(B)	2.78	3.66	(AB)	0.92
O2A	2.76	(B)	0.28	69.07	(C)	8.12	7.39	(D)	1.34
CQ	3.84	(C)	0.66	26.88	(A)	2.37	1.90	(A)	0.59
O1Q	5.03	(D)	0.49	75.16	(C)	2.59	5.79	(CD)	1.50
O2Q	5.27	(D)	0.32	71.06	(C)	0.97	4.97	(BC)	1.42

*: Homogeneity groups
** : Means with the same letter are not significantly different at $p < 0.05$. Comparisons were done within the each wood species group.
***: The impregnation area (%) on the wood cross section was calculated by the aid of the software Image J.

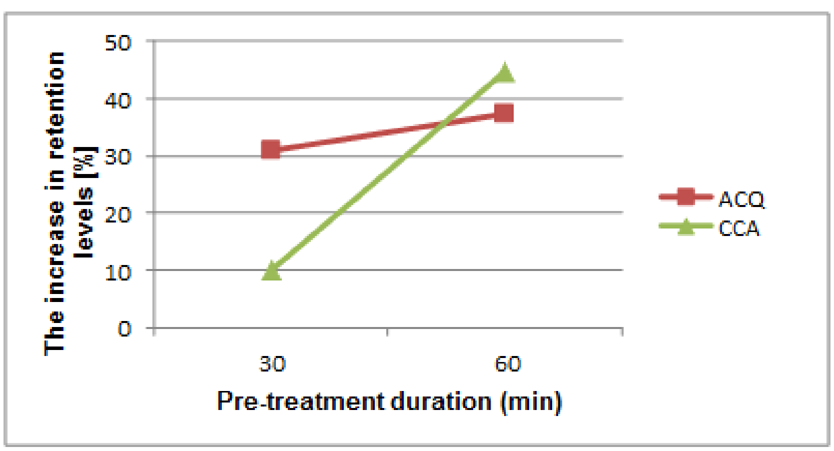

Figure 1: The increase in retention levels for the ozone pretreated wood samples treated with either CCA or ACQ compared to control samples

The impregnated areas of the samples with and without the ozone pre-treatment are given in Table 4. The ozone pre-treatment increased the impregnation area from 26.88 % to 75.16 % for the wood samples treated with 2.5% ACQ. The lowest treated area (43.44 %) was obtained in O1A while the highest impregnated area (75.16 %) was obtained in O1Q group (Figure 2).

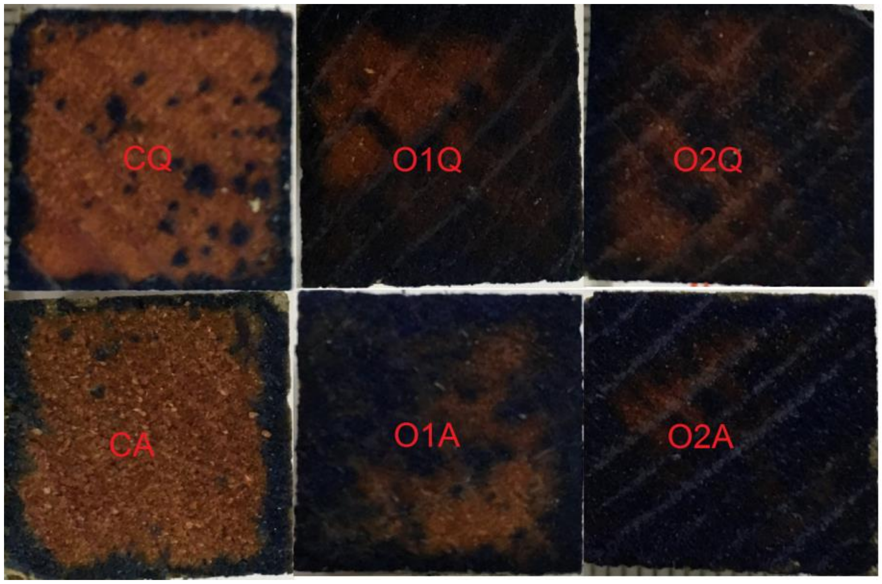

Figure 2: Cross-section of impregnated samples

The penetration depth of the samples with and without the ozone pre-treatment is given in Table 3. The ozone pre-treatment increased the penetration depth from 2.19 mm to 7.39 mm in O2A. The lowest penetration depth (3.66 mm) was obtained in O1A while the highest was obtained in O2A groups. The results showed that duration of ozone pre-treatment enhanced the impregnated area and penetration depth significantly for the wood samples treated with 1% CCA. However, there was no significant effect of ozone pre-treatment duration on the impregnated area and penetration depth for wood samples treated with 2.5% ACQ.

The data were statistically evaluated by one-way ANOVA to demonstrate the effect of ozone pre-treatment and wood samples without pre-treatment on retention levels (Table 4).

Table 4: ANOVA results on differences of retention levels

Variation Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	32.792	5	6.558	31.716	.000
Within Groups	2.895	14	.207		
Total	35.687	19			

Table 5 summarizes the effect of ozone pre-treatment at different durations on compression strength as compared to control groups. Ozone pretreatment (O1C and O2C) did not adversely affect the compression strength compared to the control samples(C). The results showed that ozone pretreatment had no significant effect on the compression strength of the wood samples compared to the control samples. However, wood preservatives both CCA and ACQ used in this study significantly increased the compression strength of the treated wood samples compared to the control samples. Different pre-treatment methods decreased the wood mechanical properties (Table 1). However, ozone pre-treatment did not adversely affect on wood mechanical properties.

Table 5: Compression strength values.

Groups	Compression Strength [$Kg.cm^{-2}$]		
	means	HG*	Std. dev.
C	318.08	(A)**	11.91
O1C	322.28	(A)	15.03
O2C	319.86	(A)	23.46
CA	397.04	(B)	28.60
O1A	414.07	(BC)	18.42
O2A	427.58	(C)	13.78
CQ	426.63	(C)	24.50
O1Q	418.00	(BC)	6.70
O2Q	421.19	(BC)	21.95

*: Homogeneity groups

** : Means with the same letter are not significantly different at $p < 0.05$. Comparisons were done within the each wood species group

The data were statistically evaluated by one-way ANOVA to demonstrate the effect of ozone pre-treatment and untreated wood samples on compression strength. Differences between test and control groups were statistically significant at 0.05 level (Table 6).

Table 6: ANOVA results on differences of compression strength

Variation Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	91169.613	8	11396.202	30.900	.000
Within Groups	11432.909	31	368.804		
Total	102602.522	39			

4 CONCLUSION

The results of this study indicated that the ozone pre-treatment increased the retention levels, penetration depth and compression strength. The reason for the increase in retention levels and penetration depth could be explained that the pit aspiration of spruce wood might cause deformation by ozone pre-treatment. However, further studies are needed to confirm the effects of ozone pre-treatment on wood porosity using SEM (Scanning Electron Microscope) and mercury porosity meter. Ozone pre-treatment could be a very good option to treat refractory wood species with wood preservation not only because of enhancing penetration depth, retention levels but also because of no adverse effect on wood mechanical properties.

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A Review of Log Degradation Resulting from Manual Felling and Ground-Oriented Harvesting in Turkey

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ABSTRACT

Forests in Turkey are generally situated on mountainous and treacherous terrains, making the initial phase of forest operations, a.k.a. primer transport, difficult. Primer transport includes manual felling of the marked trees from the stand, processing them on site, i.e. delimbing, debarking and bucking into merchantable sizes, and skidding the pieces, using human, animal or tractor power from stump to intermediate locations or road site landing zones to be loaded onto log trucks which would transport them to log depots or mills. Since both the level of logger professionalism and mechanization are considered as rather low to none-existent, the damage occurring on the final product, the logs, is worth mentioning. The compartments to be harvested are handed over to village cooperatives comprising of a number of abled individuals equipped with chainsaws and farm tractors. They have the initiative to enter the woods and carry out the given task. No harvesting scheme, micro level transport planning, is supplied and they do the job as they have observed from their elders over the years. Some degree of log degradation and devaluation has been reported through numerous studies. This study would summarize the wrongdoing in timber production. It is readily obvious that there is a drastic need in Turkey to upgrade the logger education and training, and mechanization must one way or another be embraced if forest operations and the resulting log quality are to improve.

KEYWORDS: Logger training, mechanization, log damages

1 INTRODUCTION

Turkey has, for quite a long time, involved in the timber and none-timber production, conservation, water production, erosion prevention, etc., phases of forestry within the broader concept of environmental awareness. Although it is one of the most biologically diverse countries of the world, the insensitive approaches exhibited towards environmental issues in the name of necessary steps for development are present everywhere and threatening the ecosystems (Sekercioglu et al., 2011). Despite such adversities, the national forest cover has mostly stayed steady and even increased for the last 45 years (Web-1, 2018);

- 1973 : 20.199.296 ha (26,1 % of *the total national land area),
- 1999 : 20.763.248 ha (26,7 % of *.),
- 2004 : 21.188.747 ha (27,2 % of *.),
- 2012 : 21.678.134 ha (27,7 % of *.),
- 2015 : 22.342.935 ha (28,6 % of *.).

As oppose to the global phenomenon of forest decline by 3 % for the last fifteen years, Turkey's success is noteworthy (Web-2, 2018). Today, annual increment is about 46 mil. m^3, approximately 2.1 m^3/ha, and the annual cut is about 18.5 mil. m^3 (16 mil. m^3 from the productive, 2.5 mil. m^3 from the unproductive forests), which can be translated in simpler terms that Turkey has been cutting almost 40% of what the country's forests have grown each year. The harvested timber has barely been feeding the domestic need because of the ever-growing demand coming from indigenous and multi-national board making mills stationed throughout the country. Kastamonu, the leading timber producing regional forest directorate in the country (5.7 mil m^3 annual increment), has two of such mills taking roughly 2 mil. m^3 annually. Timber quality is not an issue for such mills; however, it is crucially important for the lumber, furniture and pulp industries. Since logging is mostly manually driven in Turkey, the quality of the produced timber has always become an issue. For this reason, Turkey has never become a global actor in timber trading. Timber is graded in three categories, depending upon the intrinsic characteristics of tree trunks: low, medium and exceptional qualities. At this point, not only tree characteristics, but also the performances of loggers have been the decisive factors affecting the grading. The types of labor-intensive logging and transportation methods were investigated to explain the difficulties Turkish forestry has faced for a long time.

2 ACCESSIBILITY AND LOGGING PLANNING

Forest management has been practiced for a long time in Anatolia and accessibility has always been at the focal point in doing so. Since Turkish forests generally exist in treacherous mountainous terrain with more than 40 % slope (Caliskan, 2013), accessibility to the resource has crated challenges, and therefore Turkey has opted to build forest roads. They have been studied excessively and the results showed that they caused erosion and sedimentation, and fragmented the intact habitats (Ortage and Capen, 1999; Lugo and Gucinski, 2000; Forman et al., 2002; Heilman Jr. et al., 2002; Liu et al., 2014; Amin and Fazal, 2017). Forest roads have widely been accepted as the integral part of forests and forest management (Akay et al., 2012), however that should not mean they must be built, indefinitely. Some degree of forest road infrastructure is necessary to take the related services to the resource and the rest must be dealt with the other methods. One of such methods is mechanization. Today, it offers endless possibilities to tackle any type of terrain (Spinelli, et al., 2009). Engineering aspect of forest roads are thoroughly taught in forestry schools to forest engineering candidates, but no environmental awareness, showing what would happen if excessive amount of forest roads has been put on the field, has been mentioned. They join the work force of forest service thinking there is no other option but forest roads, to exploit the resources.

Figure 1: Aftermath of a hastily performed windstorm salvage operation

Although logging has also been taught with all aspects during a complete semester in forestry schools' curriculums, the logging planning has never been put to practice in the actual field works in Turkey. When the harvest is announced by the regional forester, the job is first up for grabs by the closest forest village cooperative, Turkish equivalent of logging company. If they refuse to take part in the process due to personnel and equipment deficiencies or accessibility difficulties, other possible candidates might take and perform the job. In either case, whoever gets the job the harvest duration is generally set for two months, then the track(s) or compartment(s) are assigned to the cooperative/company for the harvest to begin. It would be very helpful for the logging crews to follow a harvest scheme designating skid roads and tracks, showing the transportation direction, landing and restricted zones, i.e. riparian zones or wildlife passages, etc. However, the logging crews are supplied with no such drafts. When the job is finalized, it is not uncommon to see environmental degradation at its worse (Figure 1).

When the proper procedures are set prior to the harvest, the environmental adversities that are frequently seen in Turkish logging practices, could be kept at minimum. Research showed ground-based harvesting activities result in unwanted damage to forest floor when the area covered by skid trails were not laid properly (Froehlich et al., 1981; Olsen & Seifert, 1984; Garland, 1997; Wang et al., 2007; Ozturk, 2014; Nafaji et al., 2014). Especially in salvage operations resulting from windstorms, heavy show loads, insect infestations, fire, etc., the planning is rather crucial not to aggravate the already stressed stands further and to extract the merchantable timber efficiently. There are guidelines showing how the course of action would be in such dire circumstances (Web-3, 2018). Reduce impact logging (RIL) has been accepted as a new way of minimizing environmental effects of timber harvest since the end of 1980s. Directional felling is one of the heavily promoted methods in RIL (Figure 2). When coupled with a logging plan, studies has reported that the environmental damage has been reduced, the residual stand(s) have better been preserved, and the log value losses have been prevented (Han and Kellogg, 2000; Putz et al., 2008; Warkotsch, 2010; Van der Hout, 2014). When logging plans are devised as per harvest basis, timber extraction approach and what to do / not to do are already put in front the loggers to follow. Simple and effectiveness-proven such methods must be embraced in Turkish forestry.

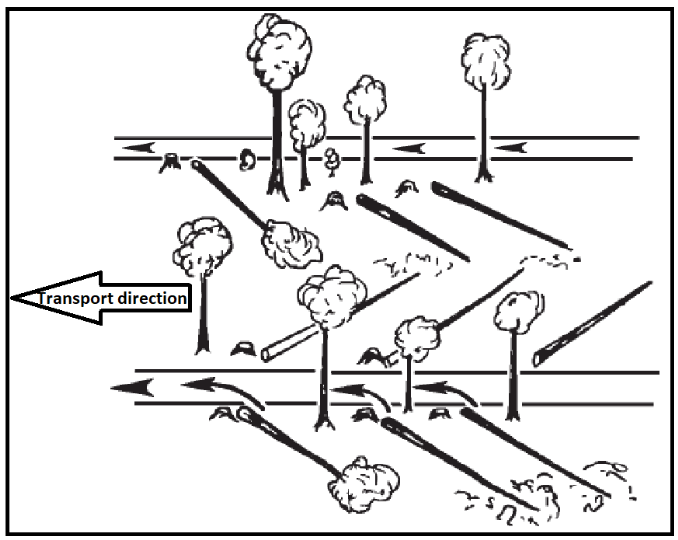

Figure 2: Directional felling on a planned harvest scheme (Van der Hout, 2014)

Technological advances especially in tracking (Global positioning systems (GPS)) and virtual visualization of any given topographical Earth surface (Goggle Earth) have gained considerable momentum for the last 20+ years. They are available and open-access in a wide array of choices. Turkish forest service has been encouraging the field personnel to integrate them into where they would provide efficiency. When the two has been combined, an effective logging-planning scheme can be generated for each harvest unit. First, a set of spatial coordinates would be recorded on a GPS during the timber cruising and then, the accumulated point cloud would be superimposed on Goggle Earth. The distribution of the cruised timber would show where an optimum network of skid roads/trails could be devised. When the loggers are asked to directionally fell the trees according to the skid roads/trails, the organization would function efficiently, eliminating the adversities (Altunel et al., 2016). The knowledge and planning means are all there for the officials to grasp. A little persuasion would correct many things.

3 LABOR FORCE (LOGGERS)

Forest villagers who have formed the forest cooperatives, constitute the backbone of Turkish logging. Those are the people residing and making a living inside or around the state forests in Turkey. Since Turkish forests are generally present in treacherous mountainous terrain with more than 40 % slope (Caliskan, 2013), and the other types of income generation, i.e. farming, husbandry and livestock, possibilities are rather limited to none-existent, forests and forestry related activities, primarily logging, and occasional none-forest products, are their main type of income opportunities. For such reasons, they are considered as the lowest income-generating group of people in Turkish society (Turker and Kaygusuz, 2001). Since this dilemma has long been known and still not properly solved, even today, forest service has been mandated by Turkish constitution to generate all the income-generating possibilities for these people forming 8.5 % of the current population of Turkey, 81 million as of 2018. When given the task, men or women all the abled members of the cooperatives take up the job(s) and perform what has been expected from them. Their acquaintance with logging has purely been upbringing from their elders. This has been how Turkish loggers have been raised for the last hundred years. Since no formal training has given to such people about the peculiarities or changing approaches to the task(s), they only perform traditional manual logging; felling, delimbing, barking (coniferous timber) and bucking the timber on site, using the chain saws and hand tools. They, then, extract the logs from the stands, utilizing mostly farm tractors and occasional tractor winches and temporarily store them in roadside landings. Finally, the stacked logs are loaded onto trucks and hauled either to mills or to log depots for subsequent auctioning by the forest service. Research showed that in favorable conditions, bucking length measurements were better achieved in mechanized processing and the cost was kept to a minimum, compared to the manual processing (Boston and Murphy, 2003; Spinelli et al., 2011). Longer the timber lengths, more revenue can be generated from saw logs (Conriade et al., 2003). However, cut to length system has always been the preferred method of timber production in Turkey. Both loggers' habit and road qualities have been the decisive factors in this situation. Although the national forest road network has constantly been extended, the vast majority of these roads are not suitable for the whole-stem transport, so the cut to length system has been adapted. However, net revenue generation from whole-tree processing and subsequent transport were reported to be higher (Adebayo et al, 2007). The value loss resulting from cut to length logging in Turkey is worth investigating.

Since the beginning of first ever forestry-related certification in Aladag forest directorate within Bolu regional forest directorate, new understanding has started setting in all aspects of forestry. Forest service has started paying attention to the safety and efficiencies of the loggers, thus training regimes have been drafted for the loggers to follow, and compliance has been required and monitored. The chamber of Turkish forest engineers has begun certifying the loggers for the forest service's jobs. There seemed to be some upgrades in terms of the loggers' safety and approaches to their profession. Although many things have seemed like according to the code in terms of professionalism, it is the tendency of Turkish loggers' mentality to appear as if they apply the procedures while being observed, but abandon them completely on their own. Despite such incompliance, these is no termination of either individual, besides physical incapability, or corporate contract(s) during a logging operation due to value loss to forest service's merchantable timber, remaining stand or environmental degradation. Field observations showed that the usage of wedges which are critical in directional felling are not mandated, but recommended. Thus, the occurrences of "hung trees" are common, jeopardizing the net value and the quality of the timber and remaining stand, respectively.

4 MECHANIZATION

Forests, due to raising demand for wood products, have started to be exploited all around the world at the beginning of the 20th century. The resources were vast, but the accessibility possibilities were limited. Thus, means for providing such access to forest areas were developed. The narrow-gauge railroads and stem-driven yarders were the pioneers of such innovations. Turkey met both of these early mechanization opportunities in the 1930s when the extremely rich old growth forests of today's Ayancik forest enterprise were given to a Belgium based international company to manage. Company erected main infrastructure to haul the timber (secondary transport) to the factory built in Ayancik, Turkey (Figure 3). It was an amazing feast of engineering for its day. Logging (primary transport) was done, utilizing mainly animal (horse, mule and oxen) and early tractor power.

Such transport infrastructure was necessary to extract timber out of the forests because there was no forest roads to do the job back then. Today, Turkey has more than 80% of the proposed 201,810 km national forest road network built (Demir, 2007). Forest roads have served the purpose of hauling the extracted timber and helped the logging to a degree. They as well link the communities to outside world and create recreational and many other opportunities (Lugo and Gucinski, 2000). Logging on the other hand has been realized, utilizing primarily animal and occasional men power; later farm tractors have gradually been integrated to logging and forestry works (Akay, 2005). When equipped with auxiliary attachments, farm tractors could fulfill the requirements of logging quite efficiently under favorable conditions (Spinelli, 1992). However, since they are not designed for treacherous mountain topography, they have a tendency to pose risks for their operators during forestry works (Ozden et al., 2011). The first and ever comprehensive mechanization attempt started in 1982 in Turkey with the acquisition of first mobile yarders (Koller and URUS), subsequent 4WD skidders (800, 900, 1000 and 1100 series Mercedes Benz TRACs) and other forestry related equipment (Demir and Ozturk, 2005) by Turkish forest service. Since the concept of yarding could not fully be understood, the machines could not be put to productive use and were grounded most of the time, the number of skilled operators could not be increased and the forest service could not convince the loggers to embrace the technology (Akay et al., 2008). Therefore, the yarders have not been renewed; the last remaining operational ones were withdrawn from their former sites and transferred to Artvin regional forest directorate where they have been revered, and efficiently been put to work since the very beginning (Ozturk and Demir, 2007; Caglar and Acar, 2005).

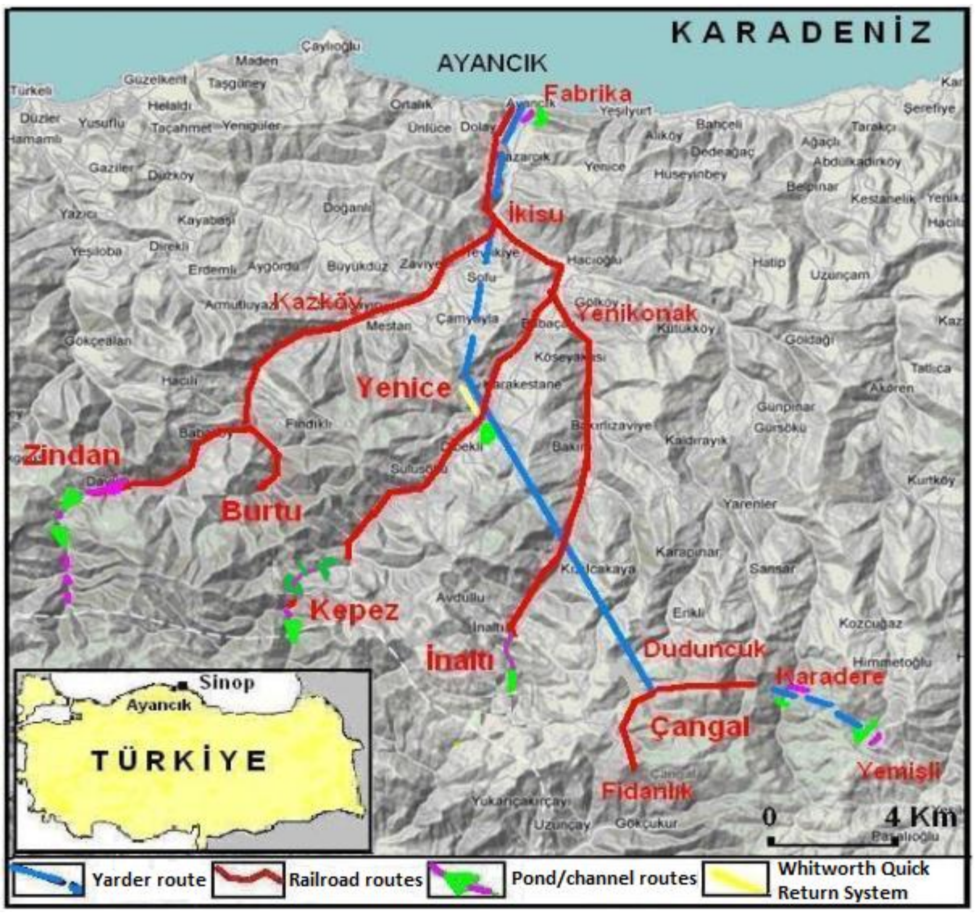

Figure 3: Ayancik forest transport infrastructure in the 1930s (Yılmaz, 2012)

Skidders on the other hand, have better been integrated into the logging because they were capable of doing the works that farm tractors could not (Ozturk and Senturk, 2010: Caglar, 2016). However, they also have nearly come to the end of their productive lives. Although not intended for rough forestry works, advancing technology has transformed the traditional farm tractor to better suit such arduous works (Ozturk, 2010). Today, Turkish forest service is reluctant to bring mechanization to logging under its jurisdiction, because forest village cooperatives (Turkish equivalent of loggers) vehemently oppose such advancements on the pretext that they would seriously cut the number of loggers from the forestry work, eliminating their major income generating possibility. There is no professional logging in Turkey, so any advancement that would affect the status of physical labor-intensive logging practice in the field, have been regarded as a threat and ousted. There have been some studies, which actually looked into the timber degradation resulting from ground-oriented logging in Turkey. They amounted up to 50% butt crack and 45% fraying (Bugday, 2011; Unver, 2008). It is generally one of the variables categorized and measured in such studies. However, the existing examples were far from representing the real value loss resulting from cut to length system. Logging is predominantly ground-oriented, and there are many factors negatively affecting the value of timber to be produced.

5 CONCLUSION

Industrial grade timber production started in the early 1930s in Turkey. The timber quality was exceptional, and the produced lumber was of export-grade quality. The operation was highly mechanized and professional for its day. However, such production was concentrated on a small piece of Turkish forests in Ayancık, Sinop. As the time passed and the Turkey made every effort to become an industrialized national, the forest management and its services expanded and reached every corner of the country. One might think, the good deeds experienced in the past must have set a good example for the future, and been the driving force behind such expansion, the answer would be, not quite so. Although attempted, Turkey cannot be considered as a mechanized country in forestry practice. Mechanization would bring quality and competitiveness, but those would be the merits that have long been dropped from the agenda of Turkish forestry. The proposed forest road network would seem right about to be completed in the near future, but the best thing those roads have so far accomplished, would be to fragment the intact habitats and to degrade the bio-diversity. Professional logging has still not evolved in Turkey, so no investment could be put to the system. Good or bad, logging knowledge has been thoroughly taught to forest engineers and forest rangers, but those have never been the actual figures doing the dirty work on the field. Flimsy supervision would not change anything. Misconception on peoples' judgement toward advancements and technology must be broken. Innovations must be well explained, people's worry about losing their livelihood must be eliminated. Against all these adversities, Turkey has seriously been caring for the last remaining forest areas and could be considered as successful. It is the purpose of studies like this, documenting the wrong and leading the way. There would be no pessimism toward nothing would ever change. The demand for the better would eventually bring the change in Turkish forestry.

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An overview on forest industry sector in Turkey: constraints, problems and solutions

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ABSTRACT

In this study, the effects on forest industry sector, price determination policies and past and present conditions of wood raw materials supplied from national forest resources to forest industry sector were examined in Turkey. The data which is obtained from literature review, legislation and applications are analysed using data analysis method, and then the subject is evaluated. With the establishment of the Republic of Turkey, it is accepted that the principle of operation and management of national forests is given to General Directorate of Forestry (GDF) which is state institution. Until the privatization of state-owned enterprises, Forest Products Industry Corporation (ORUS) and Turkey Pulp and Paper Factories (SEKA), a large part of the wood raw material produced from national forest resources supplied subsidy to these institutions by the GDF. At the end of the 20th century, forest industry sector in Turkey began to be represented by factories, plant and businesses established by private sector entrepreneurs. The GDF has lagged behind in new forest industry structure composed of private sector entrepreneurs; it reduced the cost of wood raw material production and prevented the real price from being produced in the wood raw material market, since GDF is a monopoly. Due to both the growth of the sector and the high prices of wood raw materials produced by the GDF, companies had to import wood raw materials. The GDF is the monopoly of wood raw materials; it is still on the market to present to estimated price with high costs of the wood raw material for buyers that have to buy. The GDF, which accepts high costs on the formation of wood raw material prices, declared that due to both high labor costs of production of the wood raw material and supporting the development of the forest village. But this high costs is still paid by forest industry firms who still receive wood raw materials from GDF. It is understood that raw material supply and pricing policies implemented by GDF constitute a major obstacle to the development of the sector. Nowadays, Turkey is structurally developed positively; both the sector and rural areas have been affected positively by this development. The change in the size and scope of rural development altered the concept of poor and poor forest villagers. The Law design to ensure the real prices of wood raw materials produced by GDF were accepted the Grand National Assembly of Turkey (TBMM) on April 19, 2018. This draft law introduces changes in 30 and 40 articles of the Forest Law 6831. With the amendment of this legislation, it is believed that GDF will eliminate unnecessary burden on wood raw materials costs and contribute to the development of private sector businesses operating in the forest industry sector. Thus, after privatization of ORUS, OGM will establish positive relationships with the forest industry sector in Turkey.

KEYWORDS: Forest resources, Forestry, Forest products industry, Marketing, Turkey.

1 INTRODUCTION

Forestry can be defined as planned, biological, technical, economic activities aimed at protecting forests, enlarging them, transforming them into qualified ones, making efforts to operate them with scientific principles while providing adequate forest products with collective continuity and services for the benefit of society (Eryılmaz and Tolunay, 2015).

In a narrow sense, forestry is made up entirely of forests in a continuous, planned, and rational manner, such as forestry, rehabilitation, maintenance and conservation, the acquisition of forest products, the submission of these products to the buyer, and the utilization of other services and products of the forests. Forestry in the narrow sense is also called "forest management".

In a broad sense forestry covers the whole of the work done inside and outside the forest until the crops are consumed by cultivating the forest and obtaining various products from it. In other words, the various wood raw materials of the forest products that are made entirely in forests, which constitute the narrow sense of forests such as the rearing, maintenance and repair of forests, preservation, various products from forests, offering these products to buyers and benefiting the community from other services and products of forests, it is possible to describe the whole of the activities inside and outside the forest as a result of the addition of the forest products and the commodities trade (Eryılmaz and Tolunay, 2015).

2 HISTORICAL DEVELOPMENT OF FORESTRY IN TURKEY

The developments in human-forest relations in Anatolia are similar to the developments in the other countries of the world. Civilizations that grew on the Anatolian lands used the country's forests for various purposes for many years. These uses are usually in the form of free and indiscriminate use. As a result of these injuries, forests decreased and agriculture has started to be done where forests were destroyed. (Tunçdilek, 1978).

As in many civilizations, excessive and irregular utilization of forests continued during the Ottoman Empire. It has emerged to ensure that the state's interest in forests is met by the needs of institutions such as shipyards, munitions and mints, as well as the palace and other public buildings. Thus, irregular tree cutting from some forests is forbidden by the people. The use of forests outside the areas restricted by the State has been liberated (Evcimen, 1978).

Efforts to prevent irregular use of forests during the Ottoman Empire period began in 1839. With this arrangement, the first forestry organization affiliated to the Trade Ministry was established (Özdönmez et. al., 1989).

In 1870, the first written forestry legislation "Forest Regulations" entered into force. This law is an important law with the features of being the first written forestry legislation called "Cibali Mubaha Forests", which everyone made use of the forests (Yund, 1957).

While the national liberation struggle was given in 1920, there was also interest in the forestry issue with the Law No. 39 in order to regulate the use of forests by the people (Eryılmaz and Tolunay, 2015).

After the declaration of the Republic, legal regulations in the field of forestry continued. The state has aimed to operate its own forests in accordance with the requirements of its technique and on the other hand has introduced rules for regulating the utilization of forests owned by someone other than the state (Özdönmez et. al., 1989).

1937 is a year in which important regulatory and organizational arrangements were made in forestry. These regulations consist of "Forest Law No. 3116" and "Organization Law on General Directorate of Forestry (GDF) No. 3204." With the Forest Law No. 3116, forests are considered as one of the important sources of the national economy and the state forests will be operated by the state for the benefit of the whole society. it is aimed to provide state supervision and control over forests belonging to someone else (Diker1947).

In 1956, the "Forest Law No. 6831" entered into force. The Forest Law No. 6831 adopts the forestry policy principles introduced by the Forest Law No. 3116 and the Forest Law No. 5653 prepared in addition to this law (Eryılmaz and Tolunay, 2015).

1969, Turkey’s Forestry had a year of important developments from the organizational point of view. At that time, problems of the country's forestry and forestry organizations in Turkey has started to become clear which tasks to be undertaken. It also emerged that forestry activities could not be done with an organization at the level of General Directorate. For this reason, in 1969, together with the Ministry of

Forestry, "General Directorate of Afforestation and Erosion Control (AGM)" was established. In 1970, organizations under the roof of the Ministry continued with the establishment of "General Directorate of Forestry Village Associations (ORKÖY)" and "General Directorate of Forest Products Industry Institution (ORÜS)". In the following years, the organization of the "National Parks and Hunting General Directorate (MPG)" and the ministry organization were completed.

In 1981 the Ministry of Forest was closed and the forestry activities were carried out by the General Directorate of Forestry.

In 1991, the Ministry of Forestry was established for the second time. General Directorate of Afforestation and Erosion Control (AGM), General Directorate of Forestry Village Affairs (ORKÖY), General Directorate of National Parks and Hunting and Wildlife (MPAG); As a subsidiary organization GDF and related organization General Directorate of Forest Products Industry (ORÜS) took place.

3 BACKGROUND OF FOREST INDUSTRY SECTOR IN TURKEY

The first factory belonging to the forest industry in Turkey was founded in Istanbul in the late 19th century. With the beginning of the planned period in 1963, a rapid development in the forest products industry was experienced.

In the last days of the Ottoman Empire and in the first years of the Republic, state forests were allowed to be operated by private and legal persons. As a result of this practice, domestic and foreign individuals and organizations have obtained permission to operate forests and have established forest industry factories (Kutluk, 1948).

The Forest Law No. 3116, which entered into force in 1937, was accepted as the principle of state management of forests. Business permits of private and legal entities operating in State Forests were revoked in Article 5 of this Law. In addition, these institutions and individuals were granted a period of 10 years to terminate their activities. On the other hand, some of these facilities belonging to the private sector were purchased by the General Directorate of Forestry. In these years, Ayancık, Bafra, Bolu, Pazarköy and Ulupınar Operations Departments affiliated to various private companies were bought from the private sector and nationalized (Eryılmaz and Tolunay, 2015).

State owned management in the forest products industry in Turkey began in 1944. In 1967, General Directorate of Forestry, Forest Products Department was established. However, the General Directorate of Forestry didn’t shown enough interest in the management of the forest industry. For this reason, Forest Products Industry Association (ORÜS) was established in 1970. Thus, the forest industry operations (Akkuş, Ardeşen, Borçka, Cide, Devrek, Dursunbey, Düzce, Eskipazar and Yenice) operating in the General Directorate of Forestry were organized by ORÜS.

ORÜS, after being organized as the General Directorate in 1970, realized its real development and fulfilled its pioneering role in the forest products industry.

In 1980, the state implemented privatization of public enterprises. In 1993, the ORÜS was included in the scope of the institutions to be privatized. Over time, the state realized the sale of private factories of the factories and enterprises of ORÜS. Thus, the activities of the state in the forest industry sector ended. (Özdönmez et. al., 1989).

4 TURKISH FOREST INDUSTRY AFTER ORÜS

As state organizations ORÜS and GDF were successful in the forestry and forest industry sector until 1992. In this period GDF was the only vendor producing raw materials in the sector. After privatization of the ORUS, GDF directed its raw material sales to the forest industry enterprises operating as a private sector.

The forest products sector developed and increased in number in Turkey in 2000s. Considering the general manufacturing industry and forest products industry data for 2004 under the general manufacturing industry in Turkey 211 046 Total business presence, this business of 24% of the forest products industry is creating (50 773 enterprises), 4% segment of the paper and paper products (8 917 enterprises) formed by the industry. In other words, 28% of the manufacturing industry (59 690 enterprises) belongs to the forest products industry structure on the basis of the number of establishments of the manufacturing industry (TOBB, 2015).

It is impossible to say that the number of industrial wood processing enterprises, and in particular the capacity of this type of development, has been planned and programmed. These institutions have faced increasingly raw material bottlenecks as the industry organization that is treated like this and the forests that are the source of raw materials have opened up the woodworking afterwards without regard to the efficiency.

5 A NEW LEGISLATION AND A NEW ERA

In Turkey, 99% of forests belong to the state. The task of managing and operating state forests was given to the GDF. The GDF takes into account the Forest Law No. 6831 in the management, management and management of state forests. The Forestry Law No. 6831 legally defines the 30, 34 and 40 items to be applied to the forestry work (forestation, maintenance, reconstruction, road construction, cutting, collecting, transportation, manufacturing) According to these items, the forestry work to be done in the state forests is primarily given to the forest villagers and the cooperatives established by these villagers. Private sector firms operating in the forest industry cannot receive the contracts they have made, although they can express that they can undertake these tasks. Forest villagers use labor-intensive technology in their forestry work. For this reason, Harvesting has done at high cost. High costs are reflected in wood product prices. In addition, subsidy payments made to the villagers further increase the price of wood. Private sector firms operating in the forest industry import high cost wood products from abroad rather than from the domestic market. For example, the domestic price of 90 euros can be purchased from abroad for 30 euros.

The GDF was made fundamental legal amendments in 30 and 40 items of Forest Law No. 6831 in 2018. These changes are given below.

The change in Article 30 of the Forest Law No. 6831 is as follows. With the amendment made in Article 30, the provision of the sale of standing trees was stipulated.

Before 2018 ARTICLE 30	New status of the ARTICLE 30
It is auctioning activity in market sales of products obtained from state forests. It is obligatory that the forest products to be supplied to the auction are adjusted in the quantity and qualification according to local needs and sales requisites. In cases where the necessity of public institutions and organizations is necessary and useful, or where it is necessary to make sales in a hurry, all kinds of forest products can be sold at the market price. The procedures and principles of written sales on this item shall be determined by the Council of Ministers.	Auction is auction sale in the market sales of forest products, including standing trees obtained from state forests. In cases where the necessity of public institutions and organizations is necessary and useful, or where it is necessary to make sales in a hurry, all kinds of forest products can be sold at the market price. Sales of forest products, including standing trees, in accordance with the plans of the management plan, can be done for years, not exceeding five years. "

The change in the 40th Article of the Forest Law No. 6831 is as follows. With the amendment made in article 40, entrepreneurs operating in the forest industry sector were given the opportunity to participate in tenders related to forestry activities in state forests.

Before 2018 ARTICLE 40	New status of the ARTICLE 40
Forest works such as forestation, maintenance, reconstruction, road construction, cutting, collecting, transportation, manufacturing in state forests; irrespective of which property border and forest organization boundaries they will work in the workplace and in the workplace, they are firstly taken into consideration by the cooperatives for the development of forest villages in and around the workplace and the distances to the villagers or work places in the workplace.	Forestry works such as afforestation, maintenance, reconstruction, cutting, collection, transportation, manufacture, which are made in state forests; irrespective of which property boundaries and forest organization boundaries they will work in the workplace and in the workplace, they are made primarily by taking into account the distances to and from the villagers, the workplace, and the labor force working in the forestry work cooperatives and the villagers in the workplace or in the forests around the workplace. But; the provisions of this paragraph shall not be applied in cases where the preparation of land preparations for afforestation activities is to be carried out by machine power.

6 CONCLUSION

The forest industry industrial sector, which started to take place in the industrial structure of the 1870s in our country, continued its development with the establishment of the first timber factory in Istanbul in 1892 and the increase of 33 timber factories in our country in 1938 and entered a rapid development process with the start of planned development periods in 1963. The establishment of Forest Products Industry Association (ORÜS), an affiliated budget organization of the Ministry of Forestry in 1970, and the establishment of this state in 1983 as an economic state organization, the forest products industry sector, which is an important development stage, the process of restructuring has entered into the process of restructuring. As a result of the privatization made between 1996 and 2000, the legal personality has gone to a structure in which the private sector dominates with the enduring ORUS.

However, the GDF has not adequately supported the private forest industry sector, which has begun to develop. This difference should be supported and implemented in 2018 and the changes made in Forest Law No. 6831 should be implemented.

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THE INTERNATIONAL FOREST PRODUCTS CONGRESS

Forest Industry Engineering Employment in Turkey: Why are we Unemployed?

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ABSTRACT

The first Forest Industry Engineering program in Turkey established in the Karadeniz Technical University (KTU), Faculty of Forestry in 1971. The Faculty of Forestry of Istanbul University (IU), which only studies Forestry Engineering, opened the Department of Forestry Industrial Engineering in 1982. In the mid-1980s in Turkey, significant developments took place in the social, political and cultural field. These developments and changes also reflected forestry and the forest industry sector. In this period, Forest Products Industry (ORUS) and Turkey Pulp and Paper Factories (SEKA) were the most important state owned enterprises operating in the forest industry sector. Forest Industry Engineers graduated from Forestry Faculties of IU and KTU were employed in the public ORUS and SEKA. However, after the privatization of these two institutions and their withdrawal from the forest products market, there was an uncertainty in terms of employment in the forest industry sector. Then, seven Forestry Faculties were established within the new universities in 1992, these faculties are based on the departmental model available in Forestry Faculties of IU and KTU. Thus, 7 new Forest Industrial Engineering Department was opened. Some of them have taken part in the activity and they have begun to graduate in a short time. Furthermore, in some faculties opened evening education program as well as normal education program. While "The law numbered 5531, Forest Engineering, Forest Industry Engineering and Woodworking Industrial Engineering" which entered into force in 2006 as a professional law, benefited persons belonging to the Forestry Engineers, the problem of unemployment of Forest Industry Engineers have not remedied. Since factory or plant are needed for employment of forest industry engineer. Forest Industry Engineers do not have professional organizations. Although they can become members of the Chamber of Forest Engineers (OMO), it is debatable that they are protected by this chamber.

KEYWORDS: Forestry, Forest industry, Forest industry engineering, Employment, Turkey

1 INTRODUCTION

There are three departments in our country that provide engineering training in forestry and forest products. These are Forestry Engineering, Forestry Industrial Engineering and Woodworking Industrial Engineering, respectively. Forestry engineering education has been going on in our country since 1857 and it is the oldest and most rooted forestry education. Forest Industry Engineering education started at Karadeniz Technical University (KTU) in 1971. Woodworking Industrial Engineering was founded in 1973 at the Hacettepe University, its first graduates were in 1978 (Eroğlu, 2008). Another Forest Industrial Engineering Department was established in the Faculty of Forestry of the University of Istanbul (IU) in 1982 and has been awarded thousands of graduates from KTU and IU for many years. Graduates, Turkey Cellulose and Paper Factories (SEKA), Forest Products Industry (ORUS), General Directorate of Forestry (GDF) as public institutions and the private sector-owned furniture factory and forest products have found jobs in business. However, after the privatization of these two institutions, there has been an uncertainty in terms of employment and these professionals have found employment only in the private sector. Then, established in 1992, new forest faculties were established in the universities and some faculties have opened secondary education programs as well as normal education programs, and as a result, the number of graduates has also increased rapidly. While some of the job positions can be made by forest industry engineers, machinery, chemistry, industry engineers worked in these professions, and this profession has left it in a very difficult situation. In 2006, 5531 numbered Forestry Engineering, Forestry Industrial Engineering and Woodworking Industrial Engineering Law entered into force as a professional law, and the unemployment problem of forest industry engineers also has not been solved by this law.

Today, there are 8 Forest Industry Engineering Department students in İstanbul University, Bursa Technical University, Karadeniz Technical University, Kahramanmaras Sutcu Imam University, Düzce University, Süleyman Demirel University, Bartın University and Kastamonu University Forestry Faculty. Today, there are a number of continuing problems in the employment of forest industry engineering.

This study includes some suggestions on the work that it can be done to improve the forest industry engineering profession and the employment level.

2 MATERIAL AND METHOD

The study used qualitative research data obtained by using data collection techniques such as current situation assessment, literature review, and document review to investigate the problems of the forest industry engineering profession. Yıldırım and Şimşek (2008) explained qualitative research method that A qualitative research process in which qualitative data gathering methods such as observation, interview and document analysis are used and the perceptions and events are revealed in a realistic and holistic manner in a natural environment. Researches and similar written documents containing information on related phenomena and events have been analyzed and associated with the subject and made meaningful.

3 FINDINDS

3.1 Improvement of forest industry engineering profession and employment level

- **Occupational Organization**

People are assets that have to live together in the nature and in a society. It is quite difficult to meet all your needs alone. For this reason, people are trying to establish organizations as a result of their collective life and to live these organizations in the direction of their aims (Buluç, 1997). Organization; briefly defined as social units established to achieve specific goals or as a social unit that consists of two or more individuals coordinated in a broader sense consciously functioning on a relatively constant basis to achieve a goal or a set of goals (Karataş, 2013). The most important organizations or non-governmental organizations in today's society that come together for these purposes are associations, trade unions, foundations, cooperatives and professional organizations. One of the most important characteristics of a profession is that it has to be loaded with social content and clear tasks in order to change the society and make the people who make up the society get better. Professions fulfill their responsibilities at the best level through professional associations representing all members of the profession. The purpose of professional organizations (union, association, trade union etc.) is to provide a better service by collecting professional and educational developments of professional members and to ensure that high standards are obtained as a result (Velioğlu, 1985).

There are various trade associations and professional organizations organized as in Turkey. Engineers and architectural organizations have come together in the Turkish Union of Engineers and Architects (TMMOB). TMMOB was established in 1954 with the Law No. 7303 and the Law No. 6235 amending the Decrees of Law No. 66 and No. 85.

TMMOB is a professional organization with the status of a public institution as defined in Article 135 of the Constitution. In its first establishment, TMMOB, which has 10 Chambers and approximately 8000 members, has approached 24 rooms and 500.000 members by 2015. The Chamber of Forest Engineers (OMO) is also a member of the professional organization of the forestry engineering profession, TMMOB. This professional organization has about 15,000 members (Ünal et al., 2018). Forest Industrial Engineers can become members of the Chamber of Forest Engineers in the TMMOB. In addition, the Forest Industry Engineers Association started its activities in 2013 and it has been carrying out a number of projects in terms of professional promotion and development.

Chamber of Forest Industrial Engineers should be established within TMMOB in terms of the development of the profession. Turkey Chambers and Stock Exchanges Union (TOBB), we believe that it is important to be represented.

It will be easier to reclaim the rights of Forest Industrial Engineers seized by other occupational groups. There is a same situation for our Aquaculture Engineering in our country. Members of these professions can become members of the Chamber of Agricultural Engineers (ZMO). The Department of Aquaculture Engineering shares the same situation with the Department of Forest Industrial Engineering.

- **Occupational Law**

In 2006, Law No. 5531 on "Forestry Engineering, Forestry Industrial Engineering and Woodworking Industrial Engineering" entered into force. The Law of Authority which entered into force is a milestone for our country forest engineering, forest industry engineering and woodwork industry engineering professions. According to the relevant law, the activity areas of three profession groups including forest industry engineering have been determined forestry and forest products office were established and the organization of the rights, powers, responsibilities and working principles in professional activities related to each engineering field (Öztürk et al., 2014). A significant increase in international trade requires a number of changes and regulations to be made in terms of forestry industry engineering, as the forest products industry has very different sub-sectors and each of these sub-sectors does not care about different science areas. 5531 numbered law should be adopted by the forestry products industrial sector (Korkut et al., 2011).

- **Regulation of engineering education according to industry expectations**

Engineering education should be updated to accommodate the industry expectations and to keep the computer and foreign language pre-program and laboratory applications up to date. Promotion of technical field trips to industry and invitation of sector representatives to the seminar / panel to introduce the sector should be provided to introduce the working areas of forest industry engineers (Korkut et al.). In recent years, there has been a growing demand for young Forest Industry Engineers, especially those who have made their military service in the furniture industry and have sufficient knowledge of foreign languages (Kurdoğlu et al., 2009).

4 CONCLUSION

In this study, the work to be done for the development of the forest industry engineering profession and the employment level has been examined under three headings. The most important of these is the construction of professional organizations under the roof of forest industry engineering. The establishment of the Chamber of Forest Industrial Engineers in the TMMOB is very important. it is necessary to revise the occupational law Law No. 5531 titled "Forestry Engineering, Forestry Industrial Engineering and Woodworking Industrial Engineering". Forest Industry Engineering training needs to be organized to meet industry expectations. A number of professional promotional activities should be carried out in cooperation with the industry. In recent years, especially in the furniture industry, the level of employment of engineers is steadily increasing.

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The Effects of H_2SO_4 Catalyst Amounts in Production Process on Cellulose Acetate Properties

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ABSTRACT

The aim of this study was to investigate the effects of H2SO4 catalyst usage at different rates in cellulose acetate synthesis on its properties. Cellulose acetate production was carried out at 0.01, 0.025, 0.05 or 0.1 parts H_2SO_4 at 20 °C with traditional acetic acid method. Cellulose acetate samples were investigated FT_IR spectroscopy, x-ray diffraction method and Differential Scanning Calorimeter methods. Free acidity of cellulose acetate was 12.06% for 0.01 part H_2SO_4 catalyst and 10.55% for 0.1 part H_2SO_4 catalyst ratio in process, respectively. Degree of substitution of cellulose acetate was found higher for 0.1 part H_2SO_4 catalyst than for the other catalyst ratios. The glass-transition temperature (Tg) and the decomposition temperature (Td) for 0.01 part H_2SO_4 catalyst in cellulose acetate production were determined 183.5 °C and 329.2 °C, respectively.

KEYWORDS: Cellulose acetate, Catalyst, Biodegradable polymer, Acetic acid

1 INTRODUCTION

Cellulose is the most abundant organic polymer providing by plants and its other resources but its properties in natural form limits its usage fields. Derivatization of cellulose is one of the most used ways to increase its usage fields by promoting its properties. For this aim, cellulose is reacted with different chemicals including acids, anhydrides or others for producing its ethers and esters or etc.

Cellulose acetate has been used for many applications for about 150 years and it is the most important organic acid ester of cellulose mostly produced from wood. It can be used for production of biodegradable films, membranes, plastic materials, biomedical applications, and raw materials for textile or cigarette filters (Law 2004, Law et al. 2004). The amount of acetyl group on main cellulose chain determines its usage fields because it changes its properties directly.

Acetylation of cellulose can be carried out in either homogenous or heterogeneous reaction paths (Steinmeier, 2004). Heterogeneous acetylation routes are generally preferred because of the higher price and the recovery problems of cellulose solvents. The majority of cellulose acetate in industrial scale is produced by heterogeneous route with conventional acetic acid method in which used acetic acid, acetic anhydride (esterification reagent) and sulfuric acid (catalysis). In this route, the forming reaction product is solved by acetic acid but cellulose doesn't.

In this paper, the effects of catalysis amount on the properties of cellulose acetate were studied. The chemical characterization and thermal properties of acetylated cellulose were also presented.

2 EXPERIMENTAL

2.1 Raw Materials

Eucalyptus low grade dissolving pulp was provided by Celltech. Other chemicals were purchased from Merck.

2.2 Characterization of Dissolving Pulp

Alpha cellulose content, viscosity, kappa number and alkaline solubility properties of dissolving pulp were determined according to TAPPI standards before starting the activation and acetylation of cellulose.

2.3 Purification of Dissolving Pulp

Dissolving pulp was reacted by %10 of NaOH solution for an hour at 20˚C (Cold Caustic Extraction). The mercerized dissolving pulp was washed by fresh water and then the water was removed by filtering equipment with a suction cell. The washing stage was repeated few times until pH value of the filtered water reaching 7.0-8.0. Dissolving pulp was dried until it became air-dried.

2.4 Activation Process

Acetylation of cellulose was carried out in three stages: activation, acetylation and precipitation. Starting with a well-defibrated pulp is necessary for homogenous acetylation. For this purpose, ten grams (10 gr) air-dried pulp was firstly activated by water and then filtered. Secondly, acetic acid was used for activation of pulp. All activation stages occurred under room temperature and constant stirring rate (500 rpm) for ten minute. At the end of every activation stage, the excess solvent (water or acetic acid) was removed by filtering and pressing. The schematic representation of the activation step of cellulose acetate production was given in Figure 1.

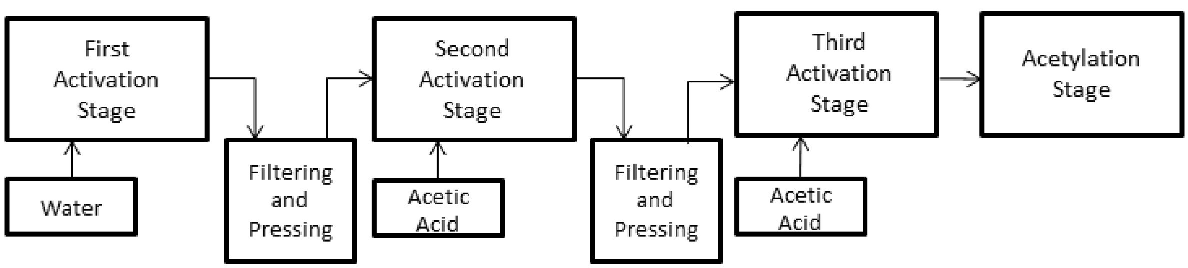

Figure 1: Activation stages of cellulose acetate production

2.5 Acetylation Process

After the completing activation, cellulose was acetylated in a 250 ml sealed beaker with a solution of acetic acid (50 parts), acetic anhydride (6 parts) and sulfuric acid (0.01, 0.025, 0.05 or 0.1 parts). The reaction mixture was gently stirred by a magnetic bar for 3 hours at 20°C.

2.6 Precipitation Process

At the end of the acetylation stage, salty water was used for precipitation of cellulose acetate dissolved in acetic acid – acetic anhydride solution. Salty water was prepared with 5 grams of sodium carbonate added in 5 L tap water. Cellulose acetate dope was poured into the salty water under constant stirring rate (500 rpm) and then precipitated cellulose acetate products were recovered by filtering. The products were washed extensively with water and dried at room temperature without vacuum.

2.7 Analysis of Acetylated Cellulose

2.7.1 Determination of Substitution Degree

Substitution degree of cellulose acetate was determined by Heterogeneous Saponification Method according to ASTM D 871-96. In this method, 0.5 gram cellulose acetate (oven dried) was immersed in 75% ethyl alcohol – water mixture in a sealed 250 ml Erlenmeyer flask and the flask was heated to 50 – 60 °C for 30 minutes in a water bath. At the end of the time, 40 ml of 0.5 N NaOH solution was added into the flask and waited for 15 minutes. After completing waiting time, the flask was removed from the water bath and allowed to stand at room temperature for about 48 or 72 hours depending on acetyl content of cellulose. Afterward, excess NaOH in the flask was titrated with 0.5 HCl solution using phenolphthalein as an indicator and excess about 1 ml of HCl solution was added to the flask. For diffusing NaOH from regenerated cellulose, the flask was stood for overnight at the room temperature. The disappearance of the pink colour indicates the neutralization of the NaOH completed. Calculation of the percentage of combined acetyl or acetic acid was performed by following equation:

Acetyl or Acetic acid, % =$[(D - C)\ N_a + (A - B)\ N_b] \times F/W$ (1)

Where;

- A: NaOH solution required for titration of the sample, mL,
- B: NaOH solution required for titration of the blank, mL,
- N_b: Normality of the NaOH solution,
- C: HCl required for titration of the sample, mL,
- D: HCl required for titration of the blank, mL,
- N_a: Normality of the HCl solution,
- F: 4.305 for acetyl or 6.005 for acetic acid, and
- W: Sample used g.

2.7.2 Determination of Free Acidity Amount

Free acidity amount of cellulose acetate samples were determined according to ASTM D 871-96. In this method 1 gr oven dried cellulose acetate sample was weighed in a sealed beaker and mixed with 30 ml water. The container was allowed to wait for 3 hours and the cellulose acetate suspension was filtered off under vacuum at the end of the waiting period. The filtrate was taken to a vessel and titrated with 0.01N NaOH solution in the presence of phenolftalein indicator solution.

Free Acidity, % = $[(A - B) \times N \times 0.06 \times 100]/w$ (2)

Where;

- A: NaOH solution required for titration of the sample, mL,
- B: NaOH solution required for titration of the blank, mL,
- N: Normality of the NaOH solution,
- W: Sample used g.

2.7.3 Fourier Transform Infrared Spectroscopy

Synthesized cellulose acetates were grinded in a Wiley mill and prepared for analysing in FTIR Spectroscopy. The test specimens were prepared by the KBr-disk method. FTIR spectra of cellulose acetates were collected on an FTIR ATR spectrophotometer (Perkin Elmer Spectrum 400). In the FT-IR (ATR) analysis, the working range was 4000-500 cm^{-1} with a specified spectral resolution of 4 cm^{-1}.

2.7.4 X-ray diffraction analysis

Dissolving pulp and cellulose acetates were grinded in a Wiley mill and prepared for analysing in XRD. X-ray diffraction analysis was used to investigate the crystallographic nature of dissolving pulp and cellulose acetates by a Rigaku Ultima-IV (Ni-filtered Cu-Ka, k = 0.154 nm) at 40 kV and 300 mA with a scanning speed of 1° min^{-1} and scanning angle range 5–50. The operating voltage and current were 40 kV and 30 mA, respectively.

2.7.5 Differential Scanning Calorimetry

DSC measurements were performed with a Netzsch Differential Scanning Calorimeter-type 200F3, at a constant N_2 flow-rate (30 $ml.min^{-1}$) ajd temperature ranging from 20 to 500°C. Heating rate in the DSC was 10°C min^{-1}.

3 RESULTS AND DISCUSSION

Dissolving pulp was characterized according to TAPPI standards mentioned before. Alpha cellulose content, viscosity and kappa number of dissolving pulp were determined as 88.7 %, 478.5 $cm^3\ g^{-1}$ and 1.0, respectively (Table 1). The pulp with determined properties was categorized as low-grade dissolving pulp. In Table 1, alkaline solubility properties of pulp were also determined and summarized.

Table 1: Properties of dissolving pulp before and after alkaline extraction

	Raw dissolving pulp	After alkaline treatment
Alpha cellulose (%)	88.7	95.7
Viscosity ($cm^3\ g^{-1}$)	478.5	522.2
Kappa number	1.0	0.97
Alkaline solubility		
R10 (%)	88.5	93.0
S 10 (%)	10.1	4.8
R 18 (%)	92.2	95.4
S 18 (%)	2.9	1.3

The pulps to be used for cellulose acetate production are expected to have low residual amount of residual extractive, hemicellulosic, lignin and free metal ions, a high brightness value and a homogeneously distributed average degree of polymerisation (viscosity). Dissolving pulps with these characteristics are defined as "acetate-grade" in the industry.

Many researchers tried to improve the quality of pulp from paper-grade to dissolving (Koepcke et al. 2008, 2010a and b; Ibarra et al. 2009, 2010a, b; Sixta and Schild 2009; Schild et al. 2010; Wollboldt et al. 2010; Gehmayr et al. 2011). Hot water, enzymes or hot or cold (20 - 40 ˚C) alkali extraction may be preferred to reduce the amount of residual hemicellulose present in the dissolving pulps (Sixta et al, 2006; Sixta, 2006; Gehmayr et al., 2011 and Borrega et al., 2013). Selectively extraction of hemicellulose from pulp, one of the most preferred way is cold caustic extraction (CCE) (Sixta et al., 2013).

To obtain a high purity cellulose acetate product, the dissolving pulp does not include any impurities, especially hemicelluloses, so; in this study, dissolving pulp was reacted by %10 of NaOH solution for an hour at 20˚C. With this one stage-alkaline extraction treatment, the alpha cellulose content of dissolving pulp was promoted from 88.7% to 95.7.

Ibarra et al., 2009 used monocomponent endoglucanase and xylanase enzymes and alkaline treatment for upgrading paper-grade pulps to dissolving pulps in their studies. 9% NaOH, 1 h at room temperature, and 4% consistency was the operation condition in the alkaline treatment. Glucose amounts in eucalypt kraft pulp and sisal soda/AQ pulp were increased from 81.7% to 95.6 and from 81.0% to 94.1, respectively.

9% NaOH, room temperature, 1 h and 4% pulp consistency conditions were selected to converting birch, eucalyptus and sisal pulps into dissolving pulps by Koepcke 2010c. Glucose amount in birch, eucalyptus and sisal pulps were 73.4%, 78.8 and 81.0, respectively. After alkaline extraction, glucose amounts were determined as 93.0%, 95.9 and 94.1, respectively.

It has been found that the increase in the amount of catalyst promoted the degree of substitution of cellulose acetate. Degree of substitution of cellulose acetate was found higher for 0.100 part H2SO4 catalyst than for the other catalyst amounts. Figure 2 shows the effects of catalyse amounts on substitution degree of cellulose acetate.

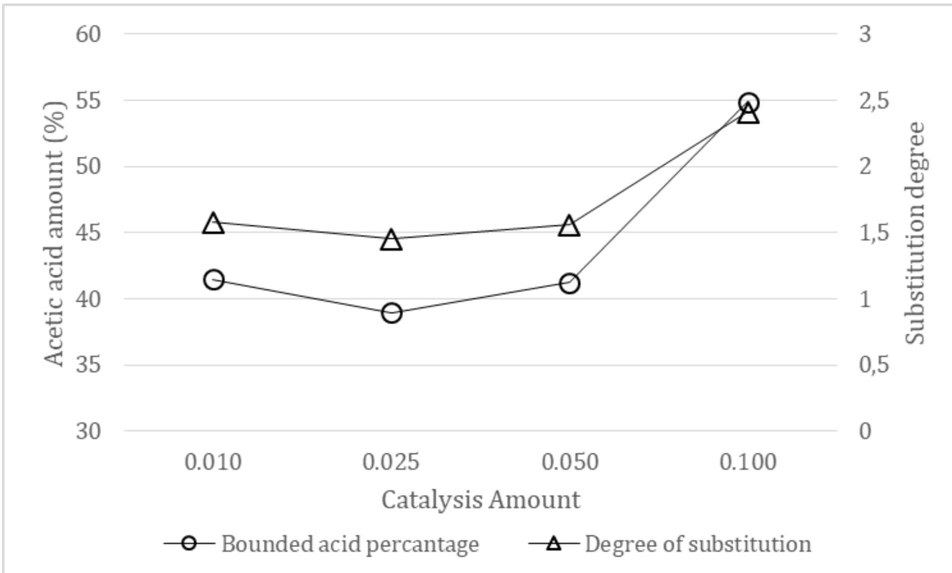

Figure 2: Effects of catalyse amounts on substitution degree of cellulose acetate.

Barkalow et al. (1989), acetylated mechanical wood pulp by acetic acid method in sulfuric acid catalyzed (1.5%, 3.0 and 6.0%). When the amount of catalyst was increased from 1.5% to 6%, the content of bound acetic acid increased from 53.15 to 62.00.

Zhang et al. (2013) studied on acetylation of rice straw (RS) with acetic anhydride catalysed by sulfuric acid and reported that the reaction time was shortened and cellulose acetates with a higher DS was synthesized as the amount of catalyst used increased.

Cellulose acetate samples were investigated with FTIR spectroscopy. FTIR spectra of cellulose acetate samples are shown in Figure 3. The ester carbonyl absorption peak at 1734 cm^{-1} verified ester bound. Figure 4 demonstrates that cellulose dissolved during acetylation reactions.

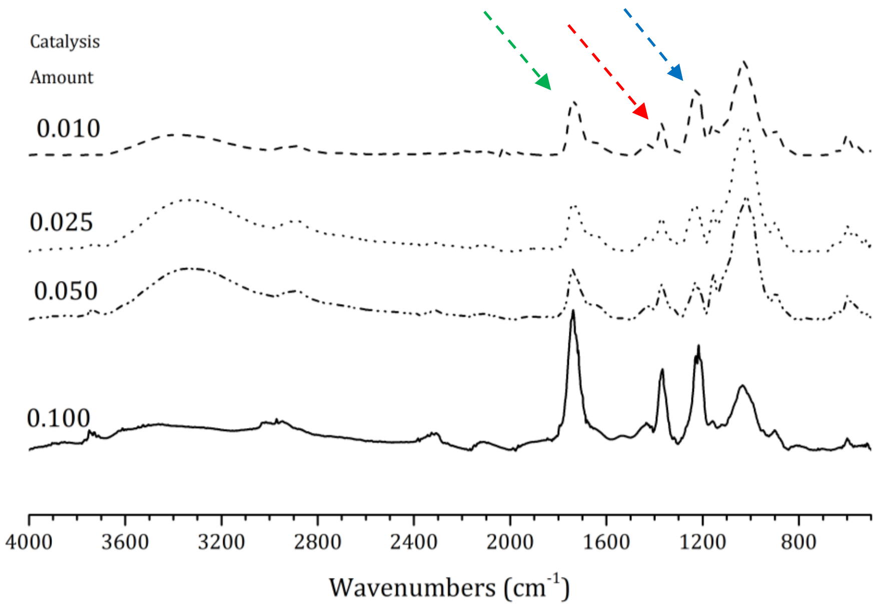

Figure 3: FTIR spectra of cellulose acetates

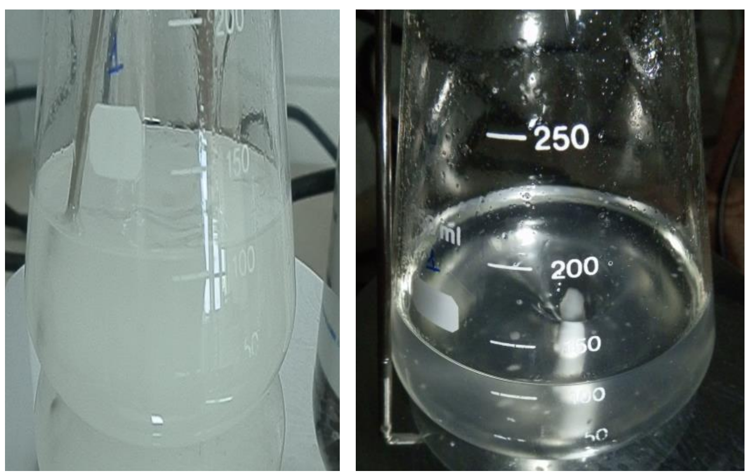

Figure 4: a. Cellulose in the beginning of acetylation reactions and b. clear acetylation system after completed acetylation reactions.

Free acid amount was enhanced from 12.06 % to 15.63% when the catalyst amount increased. But the further increase of catalyst amount did not help increase free acidity; instead, it diminished free acidity significantly (to 10.55). Changes in free acidity (%) was shown in Figure 5.

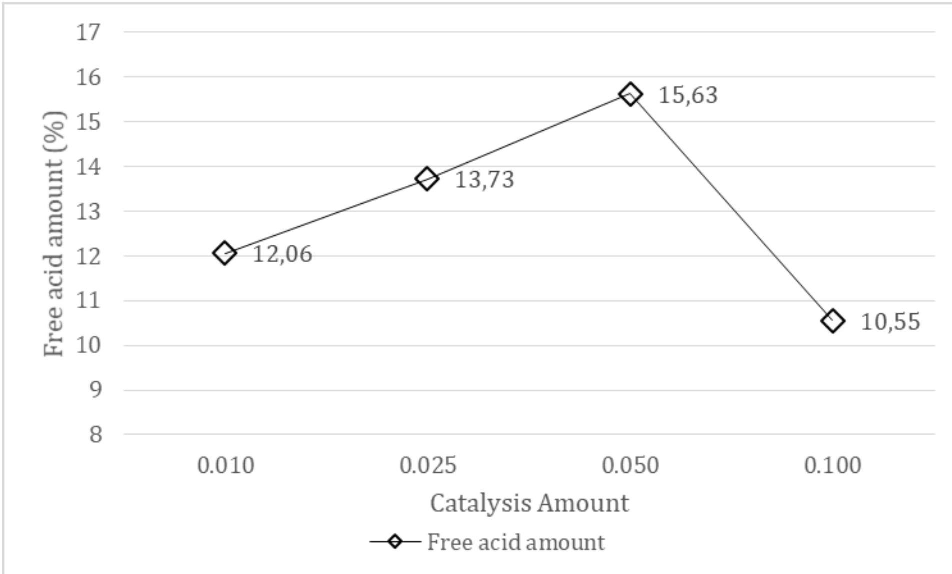

Figure 5: Changing in free acid amount of cellulose acetates sample with catalysis amount

Figure 6 shows X-ray diffraction patterns of cellulose acetate samples and dissolving pulps. When the x-ray diagrams of cellulose acetate samples obtained at 20 ° C by acetic acid method were examined, (101), (10-1) and (002) plane reflections decreased with respect to dissolving pulp used in the production of cellulose acetate.

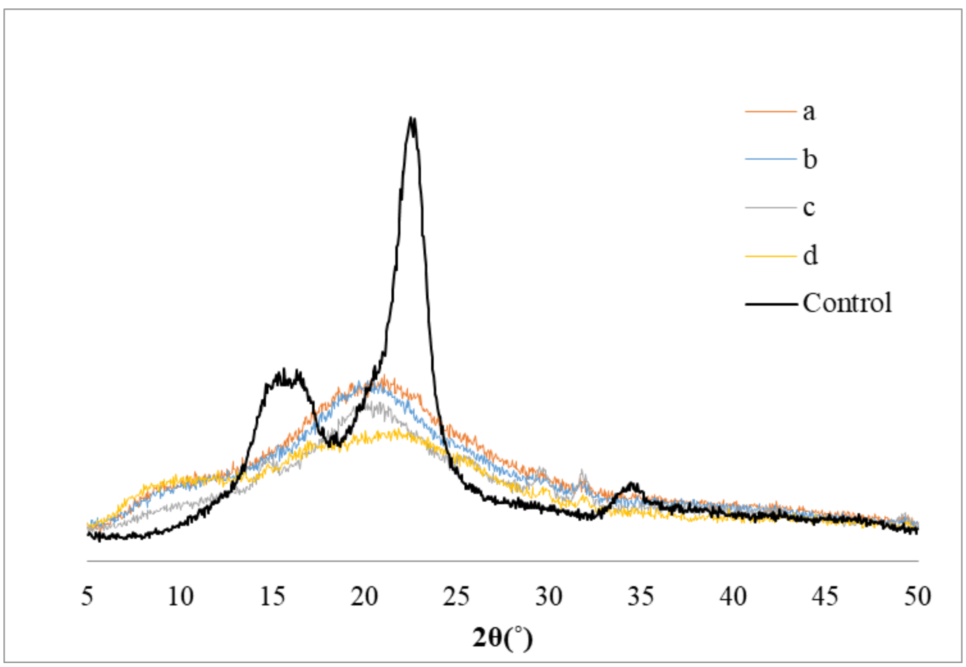

Figure 6: X-ray diffraction patterns of cellulose acetate samples and dissolving pulp (a: 0,010 part catalyst, b: 0,025 part catalyst, c: 0,050 part catalyst, d: 0,100 part catalyst and Control: alkali extracted dissolving pulp).

Figure 7 shows the effect of varying the amount of catalyst on the thermal properties. An endothermic change was observed in the range of 50 - 150˚C which means evaporation of water in particles. This was followed by, the first conversion of a polymer in the amorphous structure, glass transition behaviour. The glass-transition temperature (Tg) and the decomposition temperature (Td) for 0.010 part H_2SO_4 catalyst in cellulose acetate production were determined 183.5 °C and 329.2 °C, respectively. It was observed that increasing the amount of catalyst reduced the glass transition temperature of cellulose acetate first, while it was not effected crucially when the highest amount was reached.

Kamide and Saito (1985) studied the effects of the total substitution degree (SD) and the average molecular weight on glass transition (Tg), melting point (Tm) and thermal degradation (Td) values for cellulose acetate samples with different substitution degrees and different molecular weight distributions. They found that the increase in the substitution degree reduced the glass transition temperature of cellulose acetate.

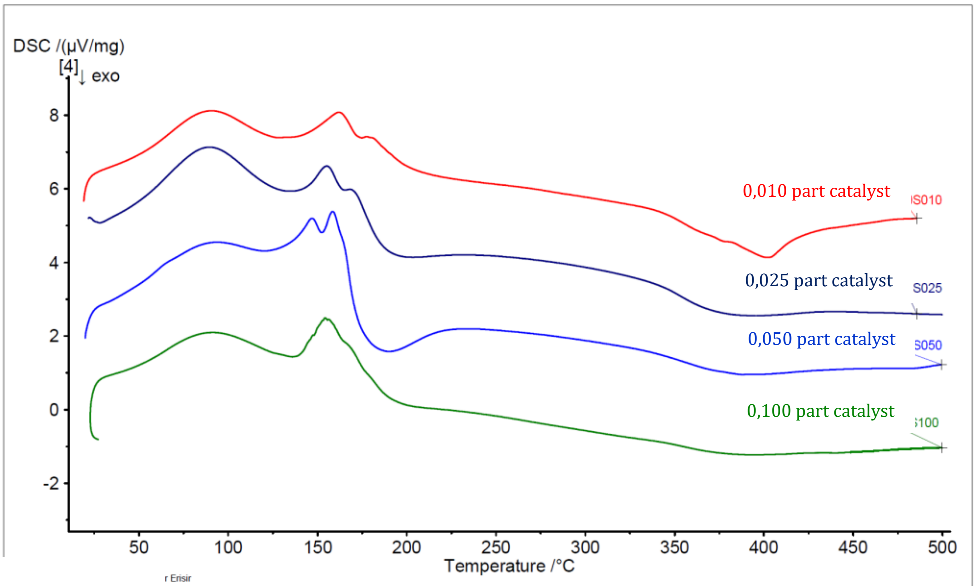

Figure 7: DSC curves of cellulose acetate

4 CONCLUSION

Cellulose acetate was prepared from low grade dissolving pulp purified by cold caustic extraction with conventional acetic acid method using different amounts of sulfuric acid as catalyst in glacial acetic acid at room temperature. XRD and FTIR results showed acetylation reactions were completed successfully. Amount of catalyst affected substitution degree, thermal properties and free acid amount of cellulose acetate.

5 ACKNOWLEDGEMENTS

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The Oxidative Pretreatments of Cellulose for Cellulosic Superabsorbents

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ABSTRACT

Cellulosic superabsorbents (SAP) are produced by using cellulose and cellulose derivative blends with different binding methods, generally. But cellulose in SAP leads decrease in water absorption and water bonding ability because of nonreactive character of cellulose based on its chemical structure. The oxidative pretreatments of cellulose were attempted for the resolve of disadvantage of cellulose in SAP, in this study. Hydrogen peroxide and TEMPO (2,2,6,6- tetramethylpiperidine-1-oxyl) were used for oxidative pretreatments of cellulose. Oxidized cellulose and carboxymethylcellulose (CMC) blended and cross-linked by epicholohydrin for cellulosic SAP production. Water absorption capacity of cellulosic SAP were determined in pH:2, 7 and 10. The results show that the oxidative pretreatments of cellulose had affirmative effect of water absorption capacity of cellulosic SAP according to control samples.

Keywords: Cellulose, Carboxymethylcellulose, Superabsorbents, Crosslinking, Epicholohydrin

1 INTRODUCTION

Superabsorbent hydrogels (SAP) are three-dimensional crosslinked hydrophilic polymers with the ability to absorb large quantities of water, saline or physiological saline solutions compared to ordinary absorbing materials (Chang et al., 2010). They are able to absorb water and other liquids tens to thousands times their own weight in a relatively short time. They can also retain a swollen state even under some pressure. They have superabsorbent properties conferred by their hydrophilic groups or domains. Given all these advantages, superabsorbent polymers are widely applied in various fields, such as in hygiene, medicine, nutrition, petrochemistry, agriculture, and horticulture (Sannino, 2009; Wu et al. 2012).

Most of the current SAPs available commercially are synthetic polymers based on acrylic acid or acrylamide, which are expensive, poorly degradable and harmful to the environment (Khoo et al. 2014). Some natural resources such as polysaccharides and inorganic clay minerals have also been used to produce superabsorbent polymers (Li et al. 2012). Cellulose and its derivatives is often used in the biomedical field, and cellulose-based superabsorbents (cel-SAP) have been prepared using radiation-induced and chemical crosslinking. (Rémond et al., 2010). In previous studies, it was determined that the main drawback of cel-SAPs is the decrease in swelling rate depend on cellulose content increases in cel-SAP (Chang et al., 2010; Bao et al., 2011; Hubbe, 2013).

In this study, it was aimed to be minimize the negative effect of high cellulose content in cel-SAP on swelling rate by using hydrogen peroxide and TEMPO (2,2,6,6- tetramethylpiperidine-1-oxyl) oxidative pretreatments of cellulose.

2 MATERIALS AND METHODS

2.1 Materials

Spruce dissolving pulp was used as cellulose resource (Borregaard). Alpha cellulose content, Kappa no and DP of spruce dissolving pulp were determined 95.2%, ≤1 and 1406, respectively. Carboxymethylcellulose (CMC) was purchased by Sigma Aldrich (Mw: 700000). Epichlorohydrin (ECH), NaOH, urea, hydrogen peroxide and TEMPO (2,2,6,6- tetramethylpiperidine-1-oxyl) were obtained as analytical-grade.

2.2 Methods

2.2.1 Oxidative pretreatments of cellulose

Hydrogen peroxide and TEMPO were used for oxidative pretreatments of cellulose (spruce dissolving pulp). Hydrogen peroxide, NaOH (o.d. dry pulp) and pulp consistency were selected as 10%, 3% and 10%, respectively. Temperature and pretreatment time were applied with 80 °C and 180 min, respectively.

Cellulose sample (5 g) was dispersed in water (375 mL), containing TEMPO (0.0625 g) and sodium bromide (0.625 g). TEMPO mediated oxidation was applied by adding NaClO solution containing 5 mmol NaClO to the cellulose suspension at room temperature. The cellulose suspension was stirred at pH 10 by continuous addition of 0.5 M NaOH. The TEMPO-oxidized cellulose thus obtained was washed thoroughly with ethanol by filtration (Puangsin et al 2013).

2.2.2 Preparation of cel-SAP

Untreated cellulose (UC) and oxidative pretreated cellulose (OPC) solutions were prepared as follows: 5 g spruce dissolving pulp cellulose samples (UC and OPC) were suspended into 195 g of 6 wt% NaOH/4 wt% urea/90 wt% water mixture with stirring and then was stored under refrigeration (-20 °C) for 12 h. The frozen solid was thawed and stirred with IKA Ultraturrax at 10000 rpm at room temperature to obtain a transparent cellulose solution. CMC was dissolved in the same solvent to obtain a polymer concentration. ECH and NH_4OH (25 ml) was added to the mixture as cross-linker, stirred at 40 °C for 4 h to obtain a homogeneous solution, and to prepare hydrogels. Cellulosic hydrogels were washed with ethanol and water to obtain hydrogels (Chang 2010). The conditions of cel-SAP preparation are presented in Table 1.

Table 1. Cel-SAP preparation conditions

Cellulose (%)	CMC (%)	Suspension (ml)	ECH (ml)	NH_4OH (ml)	Temperature (°C)	Time (hour)
10	90	200	25	25	40	4
30	70	200	25	25	40	4
50	50	200	25	25	40	4

2.2.3 Determination of Water Absorption Capacity

The synthesized cel-SAPs were immersed in water at constant room temperature (25 ° C) for 12 h. Water absorption capacity and swelling in acidic, alkaline and neutral conditions of cel-SAPs was determined by adjusting the water to pH 2, 7 and 10. Cel-SAPs were filtrated to remove excess distilled water. Water absorption capacity was calculated by the following eqution:

$$WAC = (M_2-M_1) / M_1 \quad (1)$$

Where, M1 and M2 are the mass of the dried and swollen sample, respectively. The WAC value was calculated as grams of water per gram of sample.

2.2.4 SEM Analysis

Surface properties of superabsorbents were investigated by scanning electron microscopy images (Jeol JSM-6060- Zeiss Evo LS-10). Cel-SAP sample were coated with Au before SEM observation.

3 RESULTS AND DISCUSSION

3.1 Water Absorption Capacity of Cel-SAPs

Cel-SAPs were prepared cellulose and CMC at different ratios (10/90, 30/70 and 50/50) by using ECH crosslinking method, as can be seen in Table 1. HCl (pH:2) and NaOH (pH:10) were used for acidic and basic adjustment, before water absorption capacity determination. The results of water absorption capacity in distilled water at 25 °C for cel-SAPs which were prepared with untreated cellulose (UC) and CMC mixture are presented in Figure 1.

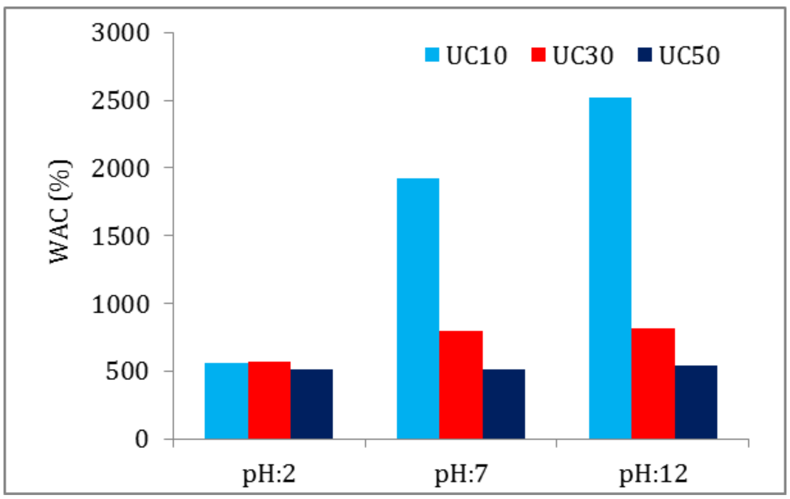


Figure 1: Water Absorption Capacity of Cel-SAPs which were prepared UC and CMC mixture

It was determined that water absorption capacity of cel-SAPs increased evidently with an increase CMC content in cel-SAPs. CMC has highly hydrophilic carboxyl group. These groups could absorb to enhance WAC of cel-SAPs (Wüstenberg, 2015). As can be seen in Fig 1, high UC content in cel-SAPs had negative effect on WAC of hydrogels. Chang et al. (2010) studied on water absorption capacity of cellulose/CMC hydrogel. They found that the highest WAC for cellulose /CMC (90/10) hydrogel was 1000% after immersing in distilled water for a week at 25 °C. CMC is a polyelectrolyte, which shows sensitivity to pH and ionic strength variations. Indeed the presence of CMC in a cellulose-based hydrogel provides the hydrogel itself with electrostatic charges anchored to the network, which have a double effect on the swelling capability. On one side, the electrostatic repulsion established between charges of the same sign forces the polymer chains to a more elongated state than that found in a neutral network, thus increasing the swelling. On the other, the counterions that are present in the gel to ensure macroscopic electrical neutrality induce more water to enter the network (Sannino, 2009).

WAC ratios of cel-SAPs which were prepared with hydrogen peroxide treated cellulose (HP-PC) and CMC mixture are presented in Fig 2. The results showed WAC in distilled water at 25 °C of cel-SAPs increased for pH:2 and pH:7, when it decreased for pH:10. Wu et al. (2012) investigated the absorption capacity of cellulosic superabsorbent composites in various solutions between pH:1 and pH:13. They found that absorption capacity of SAP composite was lower at pH:1 and pH:13 than neutral pH. They explained this finding that the screening effect of the Na+ counterions in the swelling medium led to decreased water absorption in highly alkaline solutions. WAC ratio found higher at 30% HP-PC content in cel-SAP than other HP-PC contents for pH:2 and pH:10, in this study.

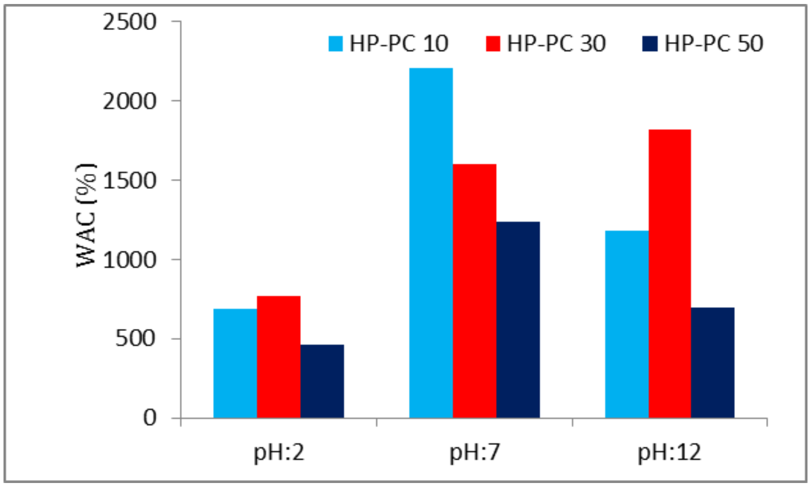


Figure 2: Water Absorption Capacity of Cel-SAPs which were prepared HP-PC and CMC mixture

TEMPO oxidative pretreatment applied to spruce dissolving pulp samples (T-PC), after blended with CMC at different ratios. Cel-SAPs formed T-PC and CMC mixture produced with epicholohydrin crosslinking method. WAC of cel-SAPs which formed T-PC and CMC mixture are presented in Fig 3.

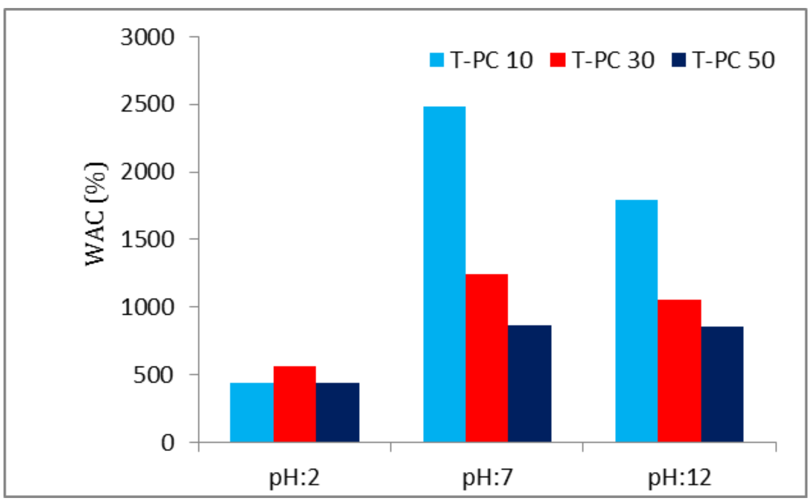
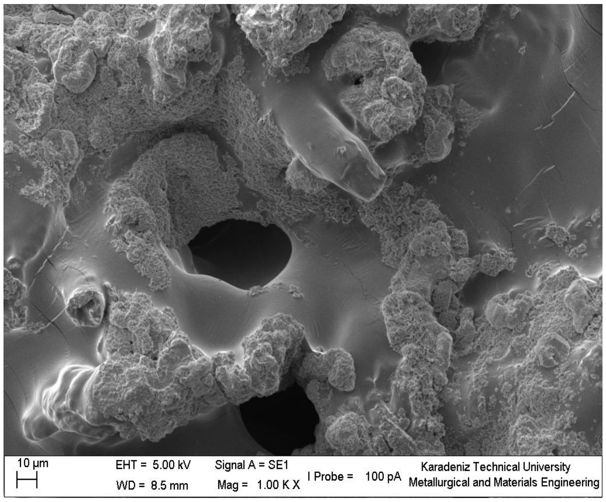


Figure 3: Water Absorption Capacity of Cel-SAPs which were prepared HP-PC and CMC mixture

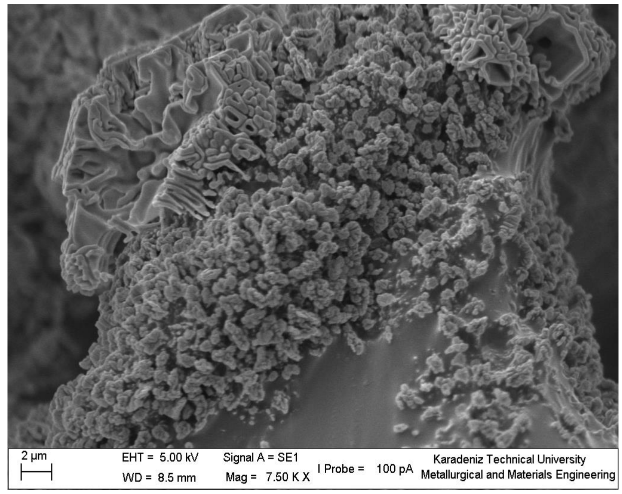
As can be seen in Fig 3, It was determined TEMPO oxidation pretreatment had more effective on WAC of cel-SAPs than hydrogen peroxide pretreatment. Saito and Isogai (2004) found that crystallinities and crystal sizes of cellulose I were nearly unchanged during the oxidation, and thus, carboxylate and aldehyde groups were introduced selectively on crystal surfaces and in disordered regions of the water-insoluble fractions. Water retention values of cotton linter could be increased from 60% to about 280% through the introduction of hydrophilic carboxylate groups and morphological changes from fibrous forms to short fragments by the TEMPO-mediated oxidation.

3.2 SEM Analysis

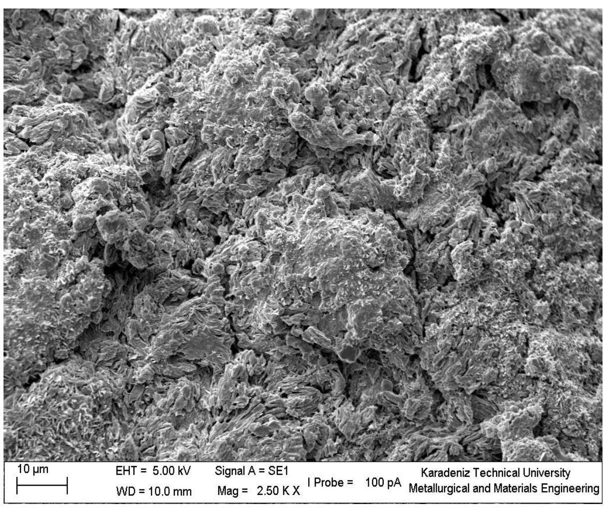
SEM photos of cel-SAPs which were formed UC, HP-PC and T-PC, and CMC are presented in Fig 4. SEM photos showed that its surface were uneven and wide surface area. It was determined that surface SEM photos of cel-SAPs were changed with oxidative pretreatments (hydrogen peroxide and TEMPO) of cellulose. It can be said that the ECH crosslinking mechanism between cellulose and CMC changes according to oxidative pretreatments.



(A)



(A)



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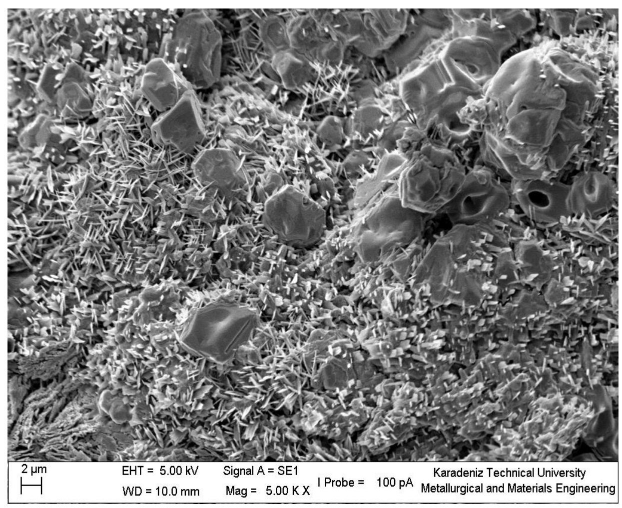

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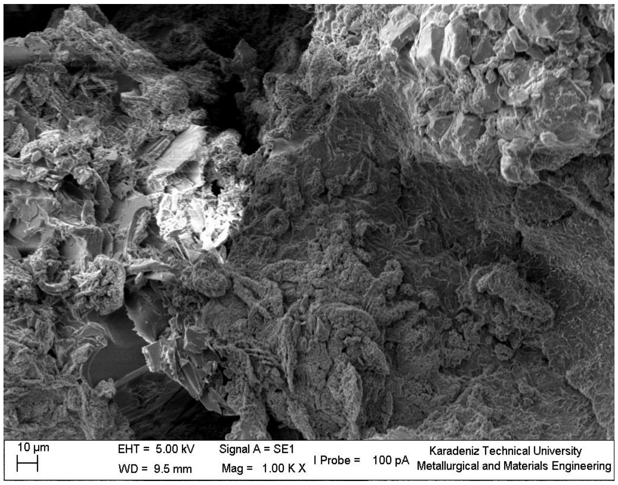
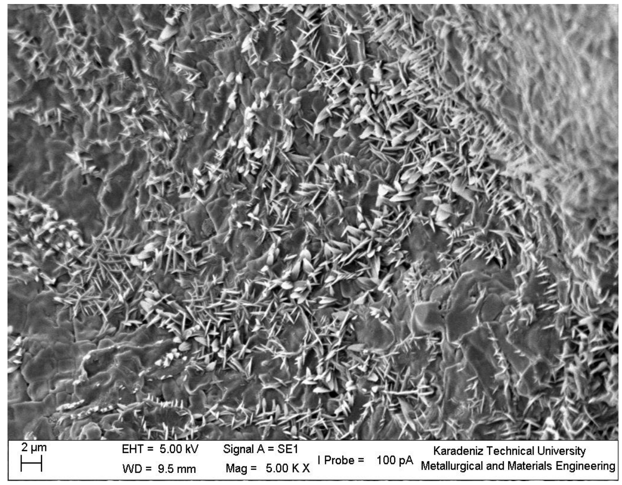


(C)



(C)

Figure 4: SEM photos of cel-SAPs (A)which were prepared UC and CMC mixture, (B) which prepared HP-PC and CMC mixture, (C) which were prepared T-PC and CMC mixture

4 CONCLUSION

It was determined that spruce dissolving pulp had affirmative effect on cel-SAPs compared to previous studies. TEMPO pretreatment had more effective on WAC at pH:7 of cel-SAPs than hydrogen peroxide pretreatment, but not at acidic medium (pH:2). It was found that WAC at basic medium (pH:10)of cel-SAP decreased with TEMPO and hydrogen peroxide pretreatments of cellulose.

5 ACKNOWLEDGEMENTS

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Surface Roughness of Composite Panels at Different Relative Humidity Levels

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Surface Roughness of Composite Panels at Different Relative Humidity Levels

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ABSTRACT

This paper describes a study of the quantify surface roughness of experimentally manufactured particleboards and sandwiched panels having fibers on the surface layers. Surface quality of specimens before and after overlaid with thin melamine impregnated papers were determined by employing a profilometer equipment. Roughness measurements and Janka hardness were carried out on the specimens conditioned at 60% and 95% relative humidity levels. Based on the findings in this work, surface roughness of the specimens exposed two relative humidity exposure showed significant difference from each other. Data determined in this study could be beneficial to understand behavior of such panels exposed different humidity levels.

KEYWORDS: Surface roughness, Composites, Hardness, Overlaying

1 INTRODUCTION

Wood composites such as particleboard and fiberboards are widely used as substrate for thin overlays to manufacture value-added panels. These overlaid panels are main members in production of furniture and cabinets. As it is a well-known fact that wood-based composites are hygroscopic material and their dimensional stability varies as function of relative humidity. Especially their surface quality depending on particle or fiber size on the face layer plays an important role on overall surface quality of panel. Bonding between thin overlay and substrate is important so-called telegraphing effect of the roughness of the substrate show through the overlay. Therefore, it is necessary to determine not only surface of the panel but also its roughness of overlaid member with changing relative humidity so that they can be used more efficiency for different types of applications.

Laminated and overlaid particleboard (PB) and medium density fiberboard (MDF) have been widely used manufacturing cupboards and kitchen cabinets in Europa and USA for over 35 years (KALAYCIOGLU AND Hiziroglu 2006, Tanrıtanır and Akbulut 1999). Overlaid wood composites consisted of two main layers. These layers are resistant decorative paper and composite panels. Surface roughness of wood composites has a major role at bonding quality and surface quality. An accepted quantitative method to measure the surface quality of wood composite panels (PB, MDF) has not been issued from any standards yet (Hızıroglu 1996, Hızıroglu et al 2004, Kutnar and Sernek 2007, Stumbo 1963). Most common method to evaluate the surface quality of composites are stylus method, providing well established numerical parameters (Hiziroglu and Kosonkorn 2006, Lemaster and Beal 1993, Peters and Cumming 1970, Peters and Mergen 1971, Drew WE. 1992).

Surface characteristics of the panels are more important when they are overlaid with decorative papers such as melamine impregnated papers. Any surface irregularities on the substrate may show through the overlay and papers, influencing overall quality of products. The stylus technique has been used to quantify the surface roughness of wood composites in several previous studies (Kilic et. al. 2006, Burdurlu et al. 2005, İmirzi et al. 2013). Surface roughness and surface stability of different type of panels were also researched another work. In one of the recent studies, it was found that surface roughness of laminated high-density fiberboard (HDF) did not influence the surface quality of overlaid samples. When they were soaked in water, high density fiberboard (HDF) panels had rougher surfaces than those of dry samples were soaked in water for three exposure times (Kalaycıoglu and Hızıroglu 2006). In another previous work, surface roughness of MDF was determined using a fine stylus technique. The results of the work showed that profilometer can be effectively used to evaluate surface roughness variation due to sanding of the panels (Hiziroglu and Kosonkorn, 2006). Although overlaying properties of composite panels manufactured from eastern redcedar were evaluated, there is very little or no information on surface roughness properties of overlaid eastern redcedar PB and MDF in the form of sandwich configuration. Therefore, the objective of this study was to evaluate surface roughness and Janka hardness of experimentally manufactured panels as function of humidity exposure levels. Data from this work could be beneficial for more efficient utilization of composite panel products with enhanced properties.

2 MATERIALS AND METHODS

2.1 Panel Manufacturing

Eastern redcedar (Juniperus virginiana L.) particles was supplied by a local sawmill in Oklahoma City. The particles contained both heartwood and softwood fractions of the trunk from Eastern redcedar trees. Particles were dried to 2-3% moisture content in a laboratory type oven in a 1.0 m3 capacity oven at the temperature of 67±2°C for 72 hours. Dried particles were classified into two particle sizes, namely fine and coarse, on a 20-mesh screen and 60 mesh, respectively. After screening urea formaldehyde (UF) is blended with particles, after blending form of particleboard were prepared. Experimental panels compressed at a temperature of 350°F and a pressure of 5.17 MPa for 5 minutes. All panels were pressed to a nominal thickness of 14 mm, and their target density was 0.70 g/cm3. Panels prepared with a length of 50 cm, width of 50 cm, and thickness of 14 mm. Manufacturing of composite panels is illustrated in Figure 1.

Figure 1: Manufacturing of Composite Panels

2.2 Roughness test of samples

Stylus method is a well-accepted one providing quantitative numerical values on the surface of sample . The profilometer consists of main unit and pick up which has a skid-type diamond stylus with 5 m tip radius and tracing span constant speed of 1 mm/s over 15.2 mm at a surface. The vertical displacement of the stylus is converted into an electrical signal by a linear displacement detector before the signals are amplified and converted into digital information. Roughness parameters such as average roughness (Ra), mean peak-to-valley height (Rz) and maximum roughness (Rmax) can be calculated from the digital information [18]. The calibration of the instrument was checked every 100 measurements by using a standard reference plate with Ra values of 3.02 μm and 0.48 μm. A cut-off length of 2.54 mm a parameter that differentiates roughness and waviness profiles from each other was used for the test specimens with the size of 12 cm by 5 cm were randomly taken from each type of panel at different thickness levels. A total of 20 samples were used for roughness measurements as illustrated in Figure 2.

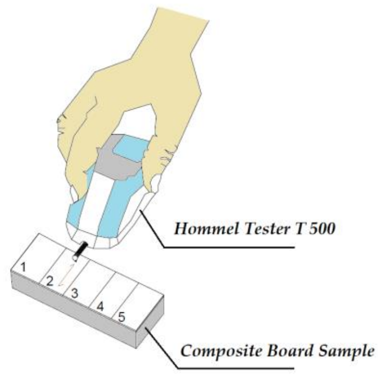

Figure 2: Roughness Test of Composite Panels Using Stylus method

2.3 Hardness test of samples

Hardness of the non-overlaid and overlaid composite specimens was tested by embedding a hemisphere steel having 11.2 mm diameter onto their tangential surface to the grain directions using a Comten 95 Series Universal Testing machine. Five measurements were taken from each sample and recorded in lbs to evaluate their Janka hardness, as illustrated in Figure 3 [18].

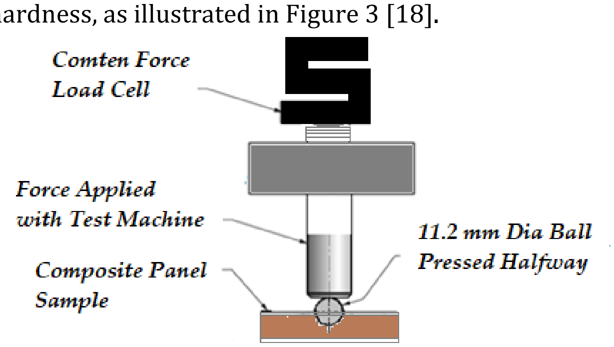

Figure 3: Janka hardness measurement with Comten 95 Series Universal Testing machine.

2.4 Overlaying and Relative Humidity Exposure Process

A total of ten, five for each type of wood panel composites with dimensions of 12 cm by 5 cm were overlaid with melamine based decorative paper having weight of 0.70 gr/m^2. The test samples overlaid 50 second at Carver press with a 165°C±5°C under pressure of 23 kgf/cm^2. Test samples were conditioned in a chamber with a temperature of 20°C and a relative humidity of 65% until they reach to the equilibrium moisture content before any roughness measurements were taken from their surface. Overlaying process of the specimens is shown in Figure 4.

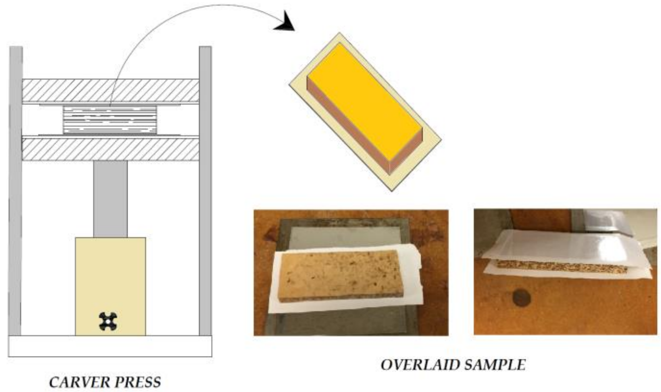

Figure 4: Overlaying Process on Carver laboratory press and overlaid samples.

After initial measurements were taken from their surface samples were placed in chamber having 95% relative humidity and kept for 10 days. In the next step individual samples were wait at an accuracy of 0.1 gr. Later roughness measurements from the samples of each samples were taken from the overlaid samples. Surface roughness of the samples was quantitatively evaluated at initial dry condition, and sequentially as they were exposed to relative humidity levels of 60% and 95%. Influence of humidity on roughness of overlaid and non-overlaid substrate is schematically in Figure 5.

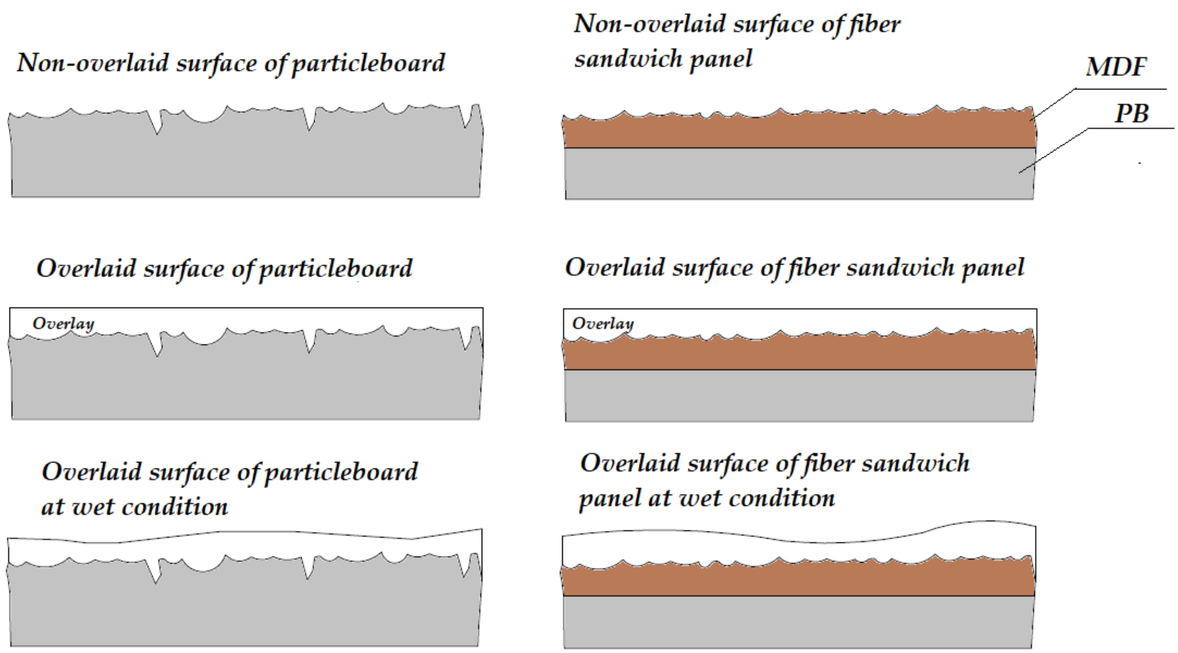

Figure 5: Influence of humidity on surface characteristics of composite panel.

2.5 Data Analysis

One-way analysis of variance (one-way ANOVA) was performed to analyze the significant differences of all parameters used in this study. All results were computed using IBM Statistical Package for the Social Sciences version 21 (SPSS) software (IBM Inc Armonk, NY. USA).

3 RESULTS AND DISCUSSION

Tables 1 and 2 displays roughness values of two types of panels. Overlaid samples having fiber layers on their surface had an average Ra value of 0.48 µm once they were exposed 60% and 95% relative humidity levels corresponding values were 0.62 µm and 1.67 µm, respectively.

Table 1: Surface roughness values of fiber-sandwich composite panels

Panel Types	Statistical Value	Surface Roughness		
		R*a* (µm)	Rz (µm)	R*max* (µm)
Non-Overlaid Fiber Sandwich Panel	Mean	6.02	41.15	49.12
	Standard Err.	0.56		0.32
Overlaid Fiber-Sw*	Mean	0.48	4.19	5.90
40% Relative-Humidity	Standard Err.	1.31	1.05	1.30
Overlaid Fiber-Sw*	Mean	0.62	3.97	6.90
60% Relative-Humidity	Standard Err.	1.31	1.29	1.31
Overlaid Fiber-Sw*	Mean	1.67	7.44	9.82
95% Relative-Humidity	Standart Err.	1.31	2.08	1.30

*Sw : Sandwich Panel

Obviously PB samples had much roughness initial average surface values however they had similar trend having higher R*a* values once they were exposed to 60% and 95% relative humidity levels as can be seen in table 2.

Table 2: Surface roughness values of particleboard panels

Panel Types	Statistical Value	Surface Roughness		
		R*a* (µm)	Rz (µm)	R*max* (µm)
Non-Overlaid PB*	Mean	8.73	57.22	74.46
40% Relative-Humidity	Standard Err.	2.19	9.35	12.27
Overlaid PB*	Mean	1.04	8.36	11.38
40% Relative-Humidity	Standard Err.	1.30	1.05	1.31
Overlaid PB*	Mean	1.74	10.33	18.37
60% Relative-Humidity	Standard Err.	1.31	1.29	1.31
Overlaid PB*	Mean	2.53	15.56	22.12
95% Relative-Humidity	Standard Err.	1.31	2.08	1.31

3.1 Effect of the Relative Humidity Level on Roughness Values of Fiber-Sandwich Panels

The analysis of variance related to the effectiveness of the humidity level on surface roughness and hardness properties of the samples, as displayed in Table 3.

Table 3: Analysis of variance related to the effect of surface roughness level based on the humidity and overlaid panels and non-overlaid panels

Applied Tests	**Mean Square**	**F value**	**Level of Significance ($p \leq 0.05$)**
Panel Types	442963.05	1800.42	0.000
Relative Humidity Levels	78314.04	99.88	0.000
Surface Roughness	85939.83	1975.73	0.001
Panel Types x Humidity Level	434.44	9.98	0.000
Panel Types x Surface Roughness	14895.04	342.43	0.000
Humidty Level x Surface Roughness	951.11	21.86	0.001
Panel Types x Humidity Level x Surface Roughness	131.51	3.02	0.000

Based on statistical analysis, significant difference was observed between surface roughness characteristics, composite panel types and humidity levels at a 95% confidence level. The humidity exposure process was found to be effective ($p < 0.05$) on surface roughness parameter values (R*a*, R*z* and R*max*) and wood composite panel types.

Table 4: Comparative test results for the effect of humidity level on various properties of the composite panel samples for homogeneity groups

Parameters	**Groups**	**HG.* A**	**HG.* B**	**HG.* C**	**HG.* D**
Materials	Overlaid Fiber-Sw*	4.34			
	Overlaid Particleboard		9.69		
	Non-Overlaid Fiber-Sw*			31.17	
	Non-Overlaid PB*				46.80
Humidity Levels	40 % Relative Humidity	20.66			
	60 % Relative Humidity		22.89		
	95 % Relative Humidity			26.61	
Surface Roughness Characteristics	Surface R*a*	4.36			
	Surface R*z*		27.54		
	Surface R*max*			37.10	

Table 4 also displays the Duncan test results related to the homogeneous subsets according to the values determined in this work. Homogeneity group values-A of 4.34μm, 20.66 μm and 4.36 μm were determined for material types, humidity levels and surface roughness characteristics respectively.

3.2. Evaluation of Surface Roughness Values at Fiber-Sandwich Panels

Both fiber-sandwich panel samples had higher surface roughness values at 95% humidity level. It appears that humidity level exposure effected surface quality of fiber-sandwich panels. In Figures 6 and 7 relationships between surface roughness parameters and humidity levels are illustrated.

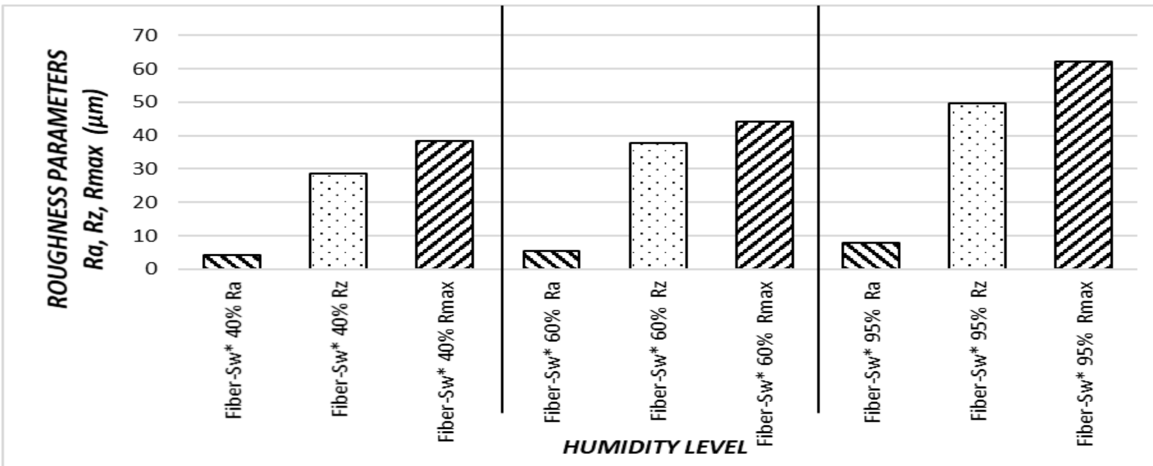

Figure 6: Average surface roughness values (R*a*, R*z*, R*max*) of the non-overlaid fiber sandwich panels (Fiber-Sw*) under effect of humidity

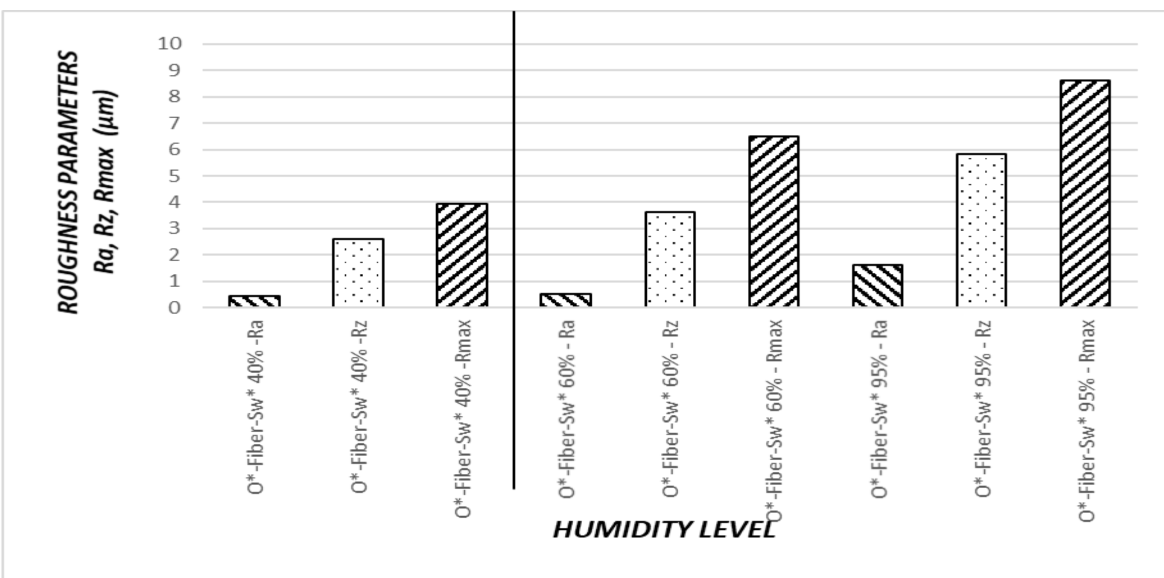

Figure 7: Average surface roughness values (R*a*, R*z*, R*max*) of the overlaid particleboard (O*-PB) under effect of humidity

3.3. Evaluation of Surface Roughness Values of Particleboard Panels

Both MDF-Sandwich panel samples have a higher surface roughness values at 95% humidity level. Humidity levels effected MDF sandwich panels directly and surface quality deteriorated with humidity. In Figures 8 and 9 relationships between surface parameters and humidity levels are illustrated.

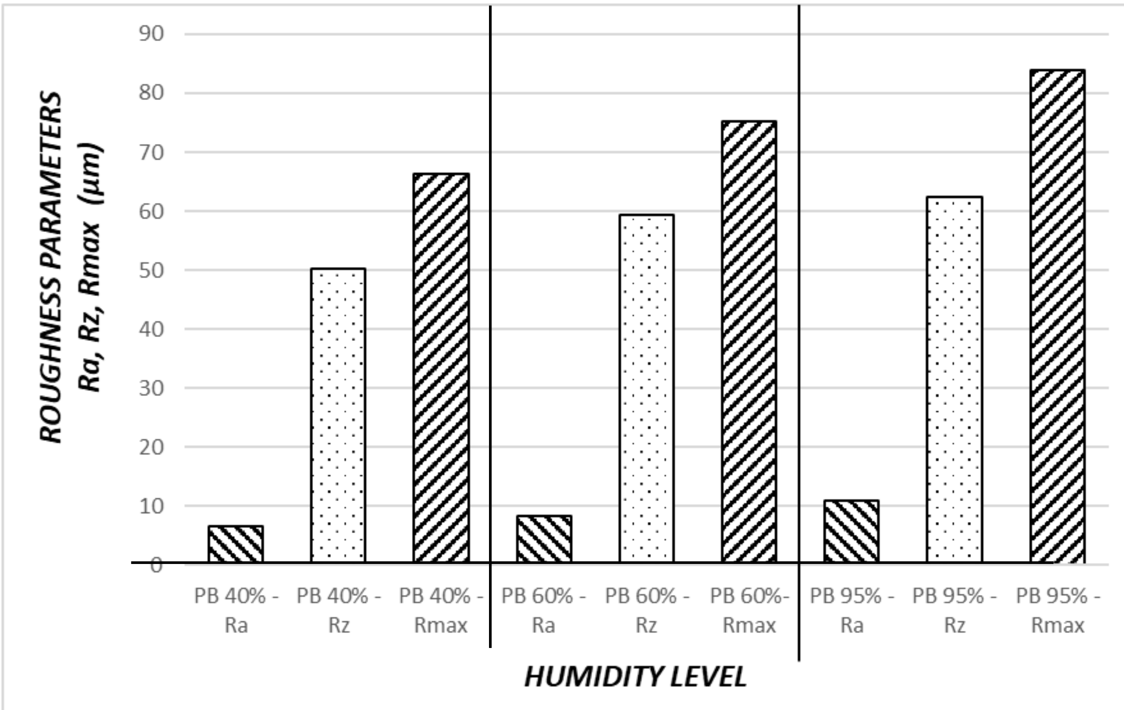

Figure 8. Average surface roughness values (R*a*, R*z*, R*max*) of the non-overlaid particleboard (PB) under effect of humidity

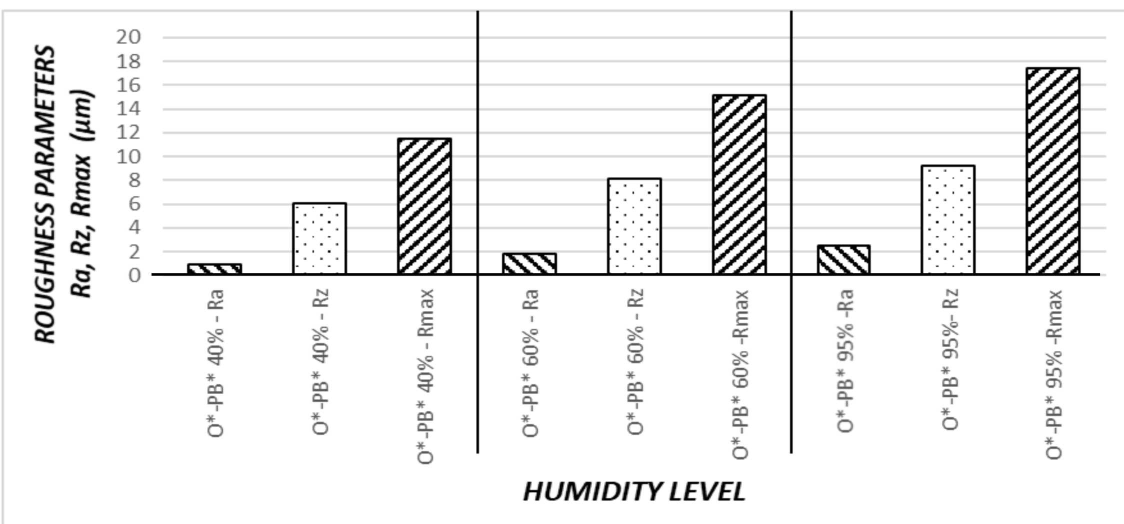

Figure 9: Average surface roughness values (R*a*, R*z*, R*max*) of the overlaid particleboard (O*-PB) under effect of humidity

3.4. Evaluation of Janka hardness values of the samples

Figure 10 illustrates overall hardness values of the specimens. The highest hardness value of 791 lbs was found for overlaid sandwich type control samples. Once these specimens were exposed to 60% and 95% relative humidity levels sequentially their hardness characteristics were adversely influenced as can be observed from Figure 10.

Overlaid of the same type of specimens had slightly higher hardness values which can be related to the brittleness of the overlay paper. Particleboard samples resulted in relatively lower hardness values as compared to those of sandwich type panels. It is fact that density of face layers of sandwich type samples having compact thin layers could be reason of such findings.

Lower hardness of particleboard samples could also be due to their single layer configuration. Similar to sandwich type panels overlaid particleboard specimens also had slightly enhanced hardness values which can also be due to brittleness of overlay paper.

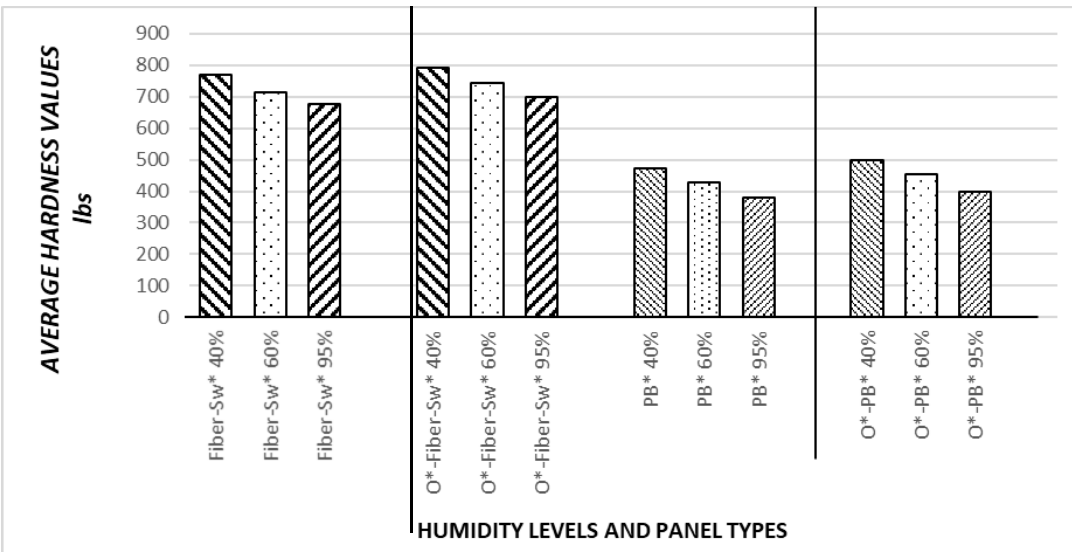

Figure 10: Average hardness values of composite panels

4 CONCLUSION

This study investigated the influence of humidity exposure surface quality and Janka hardness of overlaid and non-overlaid wood composites panels. Based on the findings in this work, overall surface roughness characteristics of samples exposed to different levels of humidity were enhanced as a result of overlaying. Data found in this work could be beneficial for more efficient use of overlaid and non-overlaid particleboards. In further studies, some of the other mechanical properties such as bending and compression strength in addition to dimensional stability of the samples would be investigated to have a better understanding of the behavior of overlaid panel samples.

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Evaluation of Connections Made by Different Wooden Materals and Bracket Under Cyclic Loads

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ABSTRACT

Non-structural components including office furniture, bookshelf, office equipment dresser ... which are used in the building during the earthquake, causes significant human and financial losses. In order to prevent injuries, non-structural components must be fixed by fasteners. The purpose of this study was to investigate the behavior of wooden connections made with different brackets under cyclic loading. For this purpose, connections on members from 3 different types of wooden materials including MDF and particleboard, along with 3 different brackets including four, six, and eight screws were manufactured. The 18 mm panel screws were used to fix the bracket on wooden materials. The manufactured connections were loaded under monotonic and cyclic load according to European standard EN 12512 and parameters such as impairment of strength, hysteresis, ductility, maximum load and displacement, and the stiffness were determined. During cyclic loading, the joints made by eight and six-screws brackets exhibited the highest and the minimum strength, respectively. The highest elastic stiffness was found for the six-screw bracket joint. The hysteresis in all joints was less than %20, which indicates the bracket joints are high resistance to cyclic loads.

KEYWORDS: Cyclic loading, Wood, Particleboard, MDF, Bracket, Ductility, Hysteresis

1 INTRODUCTION

In the design of buildings, two types of dead and live loads, are consider. Live loads are include earthquakes, storms, floods and tsunamis. The dead loads in building are divided into two categories of structural components (floors, walls, ceilings and trusses) and Non-structural components (bookshelves, office equipment cabinets, first aid kit) (Ebrahimi, Gh. 1388). A significant growth is observed in the use of wood equipment around the world. Such equipment can be referred to as office equipment cabinet, first aid kit and bookshelves which are widely used in hospitals, office buildings, residential and commercial buildings. Typical investment of building contents in new construction accounts for about 20% of the total cost for an office building, and can be as high as 44% for a hospital (Whittaker, 2003).

Although the use of these items and non-structural components are very useful; but in the event of an earthquake and natural disaster, overturning this equipment causes significant human and financial losses, suspending the business and causes delaying search and rescue missions due to the problem of access into the building and consequently increased casualties (Foo et al. 2004). Earthquakes do not always destroy buildings, but people are damaged by the overturn of non-structural components inside the building (Cimellaro et al. 2014). Previous earthquakes have shown that falling furniture is an important factor in many casualties and injuries (Haraoka et al. 2013). In the Hanshin Awaji Earthquake in 1995, in Japan, non-structural components fell over and scattered in about 60% of the houses that were not fully destroyed. Nearly half of the indoor injuries were due to falling or overturning of furniture (Tadokoro et al. 2000; Yoshida et al, 2011).

Various methods including the metal hooks, plastic fasteners and bracket are used to fix the non-structural components for providing indoor safety. Brackets are available in various sizes, shapes and designs and it is easily used to fix the building non-structural components such as bookshelves. The main role of the L-shaped metal bracket is to resist the shear force in the wall panels caused by wind or by a seismic event (Gavric et al. 2015). Metal brackets have some advantages such as elasticity in tension and pressure, easy to instal, low cost and shock resistance.

The purpose of this study was to investigate the strength of wood connection (MDF and particleboard) in connection with various brackets (AB 543, AB 645 and AB 993) under cyclic loading according to EN 12512.

2 MATERIALS AND METHODS

2.1 Materials

In this study, the MDF and particleboard panels were prepared from local producers in Iran. Angular brackets encoding AB 543, AB 645 and AB 993 were manufactured accordance to ETA-09/0322 (ETA). The 18 mm panel screws were used to fix the bracket on wooden materials and the bolts were used to connect the bracket to metal plate. Figure 1 shows the used metal connectors and fasteners.

AB 543 AB 645 AB 993

Brackets

Bolts

Fully threaded screw

Figure 1: Metal connectors and fasteners used in the test according to ETA-09/0322

2.2 Cyclic loading

Cyclic loading test was carried out according to EN 12512. In this test, the displacement control system (V) was used. Figure 2 illustrates the cyclic loading protocol. The yield point (V_y) as reference displacement during cyclic loading was determined by monotonic loading test according to method described by Munoz et al. (2008). Figure 3 illustrates the test configuration for monotonic and cyclic loading .

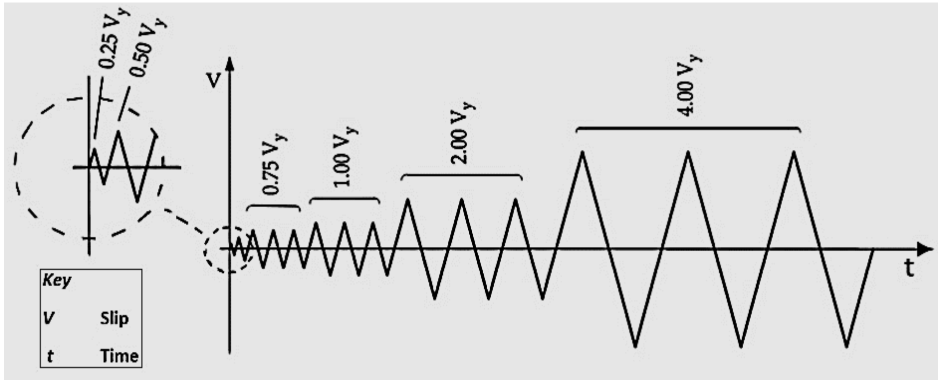


Figure 2: Cyclic procedure according to EN12512

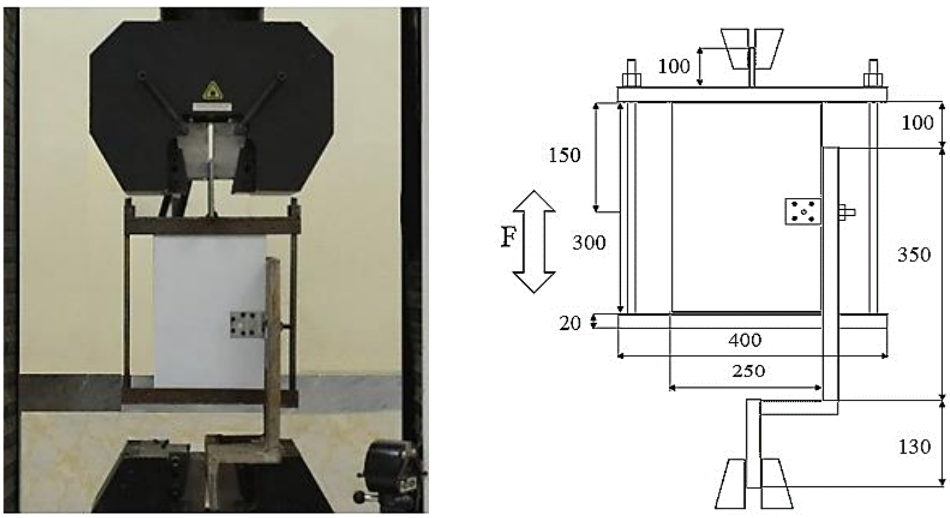


Figure 3: Elevation of test setup used for bracket connection loaded in shear

After each cyclic test, several mechanical properties were determined or calculated. These parameters are maximum load (F_{max}) and displacement (V_{max}), ultimate load (F_u) and displacement (V_u), yielding load (F_y) and displacement (V_y), initial (K_{el}) and plastic stiffness (K_{pl}), ductility ratio (D), the average strength degradation between the 1st and the 3rd maximum load cycle ($\Delta F_{1\text{-}3}$) an the energy dissipation properties are (measured by the quantities $\nu_{eq(1st)}$ and $\nu_{eq\,(3rd)}$).

, Eq. (1) was used to calculate the ductility. Ductility is the extent to which material can plastically deform without losing its load bearing capacity (Malo et al. 2011).

$$D = {V_u}/{V_y} \tag{1}$$

Dissipation of energy during cyclic loading is quantified by the equivalent viscous damping ratio (ν_{eq}). This non-dimensional factor demonstrates the hysteresis damping properties of connections under a specified loading regime and is determined by the methods specified in EN 12512 (2001) as the ratio between dissipated energy (E_d) of a half cycle and the relevant available potential energy (E_p) multiplied by 2π (Figure 4).

$$\nu_{eq} = \frac{E_d}{2\pi . E_p} \tag{2}$$

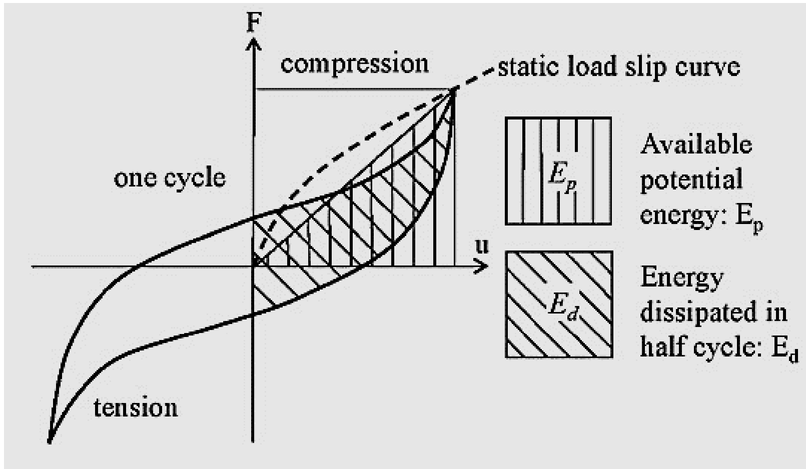
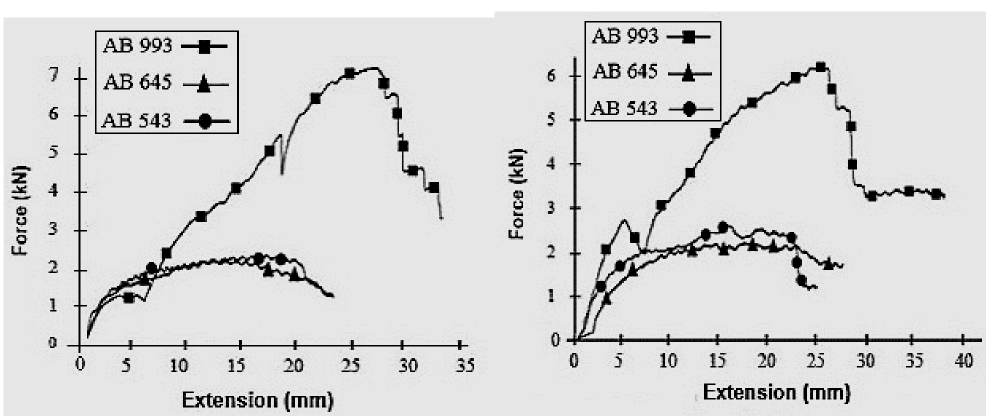


Figure 4: Definition of E_d and E_p for determination the equivalent viscous damping ratio for one cycle

The available potential energy (E_p), can be determined as $E_p = {}^1/_2\ F.V$, where ***F*** and ***V*** are the maximum force and maximum displacement attained in cycle, respectively.

3. RESULTS AND DICSCUSSIONS

Figure 5 presents the monotonic load-displacment curves of the joints manufactured by MDF and Part icleboard and different brackets. Figure 6 shows load-displacement curves of various connections under cyclic loading. Using these curves, the evaluated mechanical properties. The deformation of the joints made from brackets and wooden materials(MDF and particleboard) is shown in Figure 7.



(a) (b)

Figure 5: The load-displacement curves of joints made (a) particleboard and (b) MDF under monotonic loading

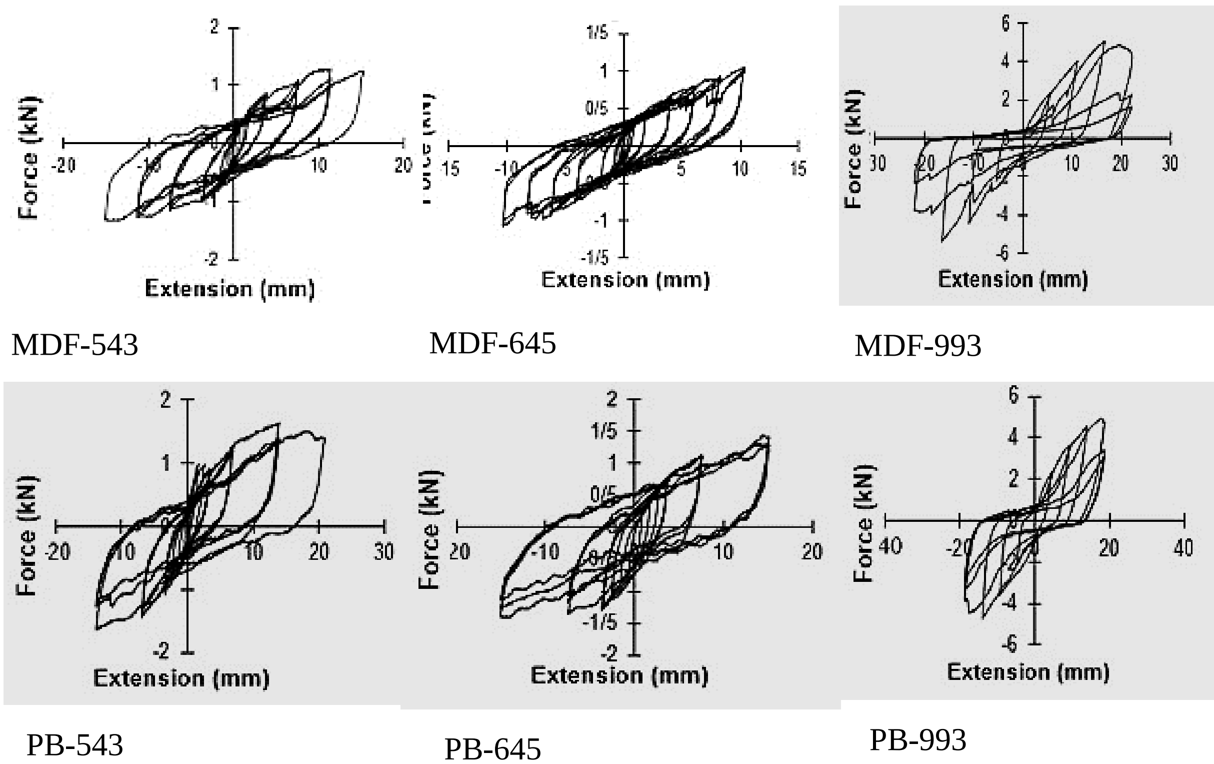


Figure 6: Results of cyclic tests for angle brackets(PB: particleboard. Numbers indicate the bracket type)

(a) (b)

Figure 7: Deformation of the brackets under cyclic loading in connection with MDF (a) and particleboard (b)

Table 1 shows the comparison of maximum load in monotonic and cyclic loading. In most cases, the maximum load of all connections in cyclic loading is about one third of monotonic loads. The strength reduction in cyclic loading versus static loading can be attributed to fatigue of the connections during cyclic loading.

Table 1: Comparison of the maximum load of connections during static and cyclic loading

	（M）	（C）
Connection	F_{max} （kN）	F_{max} （kN）
MDF-543	2.09	1.52
MDF-645	1.94	1.11
MDF-993	6.31	4.43
PB-543	2.28	1.51
PB-645	1.93	1.36
PB-993	5.57	4.9

(C): Cyclic, (M): Monotonic

Table 2 shows the data extracted from extention-force curves in cyclic loading. In all connections, the joints manufactured by AB 993 bracket exhibited the maximum displacement and load. The AB 993 bracket also exhibited the highest yield point displacement and yield point load; thus it can be concloude that this connection has a high load capacity in the elastic region; and the higher load is required to reach the plastic limit. The minimum yield point displacement and yield point load was related to the AB 543 bracket.

The maximum load of MDF-993 connection was 74.7% and 65.6% higher than MDF-645 and MDF-543 connections, respectively. Similar results have been observed for particleboard and the maximum load of PB-993 connection was 72.2% and 69.1% higher than PB-645 and PB-543 connections, respectively. Although the connections containing AB-645 bracket exhibited higher yield load than those containing AB 543 brackets, but they had lower maximum and ultimate load. This behaviour can be attributed to influence of wooden material on the connection strengths.

A comparison between connections manufactured by AB 543 and AB 645 shows that the AB 543 connections with 4 screws exhibited higher maximum load than AB 645 connections with 6 screws. This difference can be explained by higher bracket area to number of screw ratio. This ratio was than 12.5 and 10.0 for AB 543 and AB 645, respectively.

As shown in Table 2, the AB 543 has the highest initially and plastic stiffness in all experiments. The reason for the higher stiffness in AB 543 can be attributed to the shorter length of this bracket.

The reduction of strength in MDF-543 and MDF-645 connections during cyclic loading was lower than PB-543 and PB-645 connections. MDF-993 connection had higher impairment of strength than PB-993 connection. MDF and particleboard in connection with AB 543 and AB 645 brackets exhibited relatively good strength and the screw failure was not observed. In MDF-993 and PB-993 connections, screw failure was observed in all tests. Actually the broken screws cannot provide any strength and the strength suddenly and significantly decreases and lead to cutting of the screws (Figure 8). The strength reduction in MDF-993 connection was 43.7% more than PB-993 connection.

Particleboard and MDF in connection with AB 543 and AB 645 have the same ductility approximately, but in connection with AB 993 have lower ductility. AB 993 despite has high maximum load but has ductility less and this indicates that AB 993 in high loading protect its elastic range.

From Table 2, most of the connections have a viscous damping of less than 20%, which indicates that they have great potential to withstand against cyclic loading or earthquake. Also the results showed that dissipation of energy in the third cycle was always lower than the first cycle which indicates that the energy dissipation in the connections under cyclic loading decreases after several cycles

The connections manufactured by both wooden materials(MDF and particleboard) and AB993 bracket exhibited lower damping in first and third cycles than the other brackets.

Table 2: Mechanical properties of angle bracket connections according to EN 12512

Mechanical property	MDF-543	MDF-645	MDF-993	PB-543	PB-645	PB-993
K_{el} (kN/mm)	0.64	0.49	0.37	0.6	0.49	0.47
K_{pl} (kN/mm)	0.1	0.08	0.06	0.1	0.08	0.07
F_y (kN)	0.75	0.67	3.3	0.7	0.79	3.68
V_y (mm)	1.7	3.1	10.8	1.74	4.1	11.7
F_{max} (kN)	1.52	1.11	4.43	1.51	1.36	4.9
V_{max} (mm)	13.2	8.9	16.4	13.1	14	16.8
F_u (kN)	1.49	1.11	3.94	1.42	1.29	4.54
V_u (mm)	13.8	8.9	20	14.9	17.5	19.4
D	10.1	10.7	2.0	11.3	10.5	2.0
ΔF_{1-3} (%)	7.0	3.8	50.2	11.5	8.0	28.3
$\nu_{eq\ (1st)}$ (%)	21.1	19.2	16.9	19.7	21.9	15.5
$\nu_{eq\ (3st)}$ (%)	18.0	18.9	17.0	15.8	18.9	13.2

(a) (b)

Figure 8: Failure of screws in PB-993 (a) and MDF-993 (b)connections

4. CONCLUSION

In this paper, the effect of cyclic loading on metal fasteners in connection with different wooden materials has been evaluated by laboratory tests. Mechanical properties such as stiffness, ductility, impairment of strength and equivalent viscous damping were calculated. The overall results of this paper are as follows:

1. Overall evaluation of all tests showed that the bracket connections have very strong and that they have low dissipation and can be one of the most widely used connections in preventing the overturning the non-structural factors in the event of an earthquake.

2. In cyclic loading MDF-993 and PB-993 connections had the highest strength and MDF-645 and PB-645 connections the least strength. MDF-543 and PB-543 connections had the higher strength than MDF-645 and PB-645 connections. The maximum load in manufactured connection with MDF is very close to the particleboard.

3. AB 543 exhibited the highest initial and plastic stiffness among all of the brackets.

4. MDF-993 and PB-993 connections with the highest strength have the least ductility. MDF and particleboard have had the same ductility.

5. in all connections, he equivalent viscous damping decreased from the first cycle to the third cycle.

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ABSTRACT

This research study is a compilation of literature review that presents a general overview about the generation, handling and utilization of waste wood. The present scarcity in natural resources due to exploitation, besides the environmental problems created by industrialization in mass production methods has transformed the concept of waste into resource. In this aspect, waste wood is also considered as a promising resource, since it is generated in each process stage of the forest industry operations; initiated by harvesting logs from the forest, followed by the primary processing at the sawmills, then continuing with the use of sawn timber in secondary production facilities and even in the end at the disposal stage after use, if certain material quality requirements are met. The resource-based management perspective and the environmental concerns have led the waste wood to be handled with the sequence of reduce, reuse, recycle, recover and landfill from most favoured to least option, respectively. About recycling stage of the waste wood, the influence of mechanical innovations regarding machinery and equipment which have been used in the sorting and size reduction processes is a determinant factor to be highlighted, since contaminant removal is a key issue for many end use applications. In addition to hierarchical handling of waste wood, there has been also implementations towards cascading-use of waste wood in order to prolong its useful life and reduce the amount of residues that are disposed to landfills.

The study points out that handling waste wood is interdependent with solid waste management systems regarding the municipal and construction-demolition waste streams. Furthermore, the legal bindings are important to encourage industry and consumers to separate waste at site for manufacturers as much as it is viable, otherwise penalties should be imposed for unproper applications in order to prevent future occurrences.

Through the investigation of waste wood handling, it is found out that the utilization availability options of waste wood are primarily present in renewable energy sector, conventional wood-based panel industry and the innovative composite materials field. The intensive industrial implementations, scientific research studies, legal regulations and state sanctions are implemented by Germany, Finland, Sweden and United Kingdom in the European continent and United States of America and Canada in the American continent. The inspection about waste material handling in general reveals that this issue is just not related to industrial development, but also dependent on government regulations and social-cultural awareness of societies.

KEYWORDS: Waste Wood, Resource Management, Waste Management, Recycle, Reuse, Cascading-Use, Bioenergy Feedstock

1 INTRODUCTION

It is clear that the wood material derived from forests has been and is going to be one of the most important material resource for the needs and the deeds of mankind like fuel, construction, paper and furniture. Generation of waste is natural and in some cases inevitable throughout the process steps taken for the production of these commodities. In addition, it would also here be rightful to mention that the wood-based products can turn into waste items or materials at the end of their useful economic life time or utilization period.

This literature review study is an overview of the generation sources and utilization alternatives or possibilities for waste wood as a raw material resource. Through the literature survey, it is found out that the waste wood material generation is not solely dependent on the forest industry operations or processes. The handling methods carried out for wood and wood based products at the end of their useful economic life time are rather dependent on the municipal and solid waste management systems which also vary in a different way for each country.

The definition of waste in EU Waste Framework Directive (EU 2008) is ''any substance or object which the holder discards, intends or is required to discard. '' This definition can cover various type of materials where they emerge as a result or in between production processes or daily activities conducted by individuals or the society . Whereas the study of Dijkema et al. (2000) defines waste as'' an emerged quality of a substance'' under the following paradigm of ''a material or substance can be qualified as waste when it is not used to its full potential''. Moving on from the latter definition; the importance of utilization from waste and in this case waste wood has to be emphasized due to the environmental issues and economical benefits.

The issue of waste wood, within the content of this study is examined through 3 stages:

1.Generation of Waste Wood
2.Handling of Waste Wood
3.Utilization from Waste Wood.

2 GENERATION OF WASTE WOOD

There are three primary sources where generation of waste wood or wood fiber containing wastes occur.

1.Forest Industry Operations,
2.Municiapal Solid Waste (MSW) System,
3.Construction and Demolition (C&D) Waste System

2.1 Forest Industry Operations

The first stage where the generation of waste wood by means of residues starts is the harvesting operations in the forests. As described in FAO report (1993), approximately 60% of the harvested trees are left in the forest where these remains and non-commercial species are slashed, burned or merely felled and left to rot in order to make access easier for logging. Even though, these residues may appear to be an attractive fuel source; the cost of collection, handling and transportation of these materials have to be carefully examined. Another important issue that must be considered is the possibility of losing valuable soil nutrient created by the left leaves, bark and thinnings which are sources for forest soil regeneration. The classification of operational sources and types of wood residues presented in FAO report (1993) is shown in Table 1.

Table 1: The Classification of Sources and Types of Wood Residues, FAO report (1993)

Source	Type of Residue
Forest Operations	Branches, needles, leaves, stumps, roots, low grade and decayed wood, slashings and sawdust
Sawmilling	Bark, sawdust, trimmings, split wood, planer shavings, sander dust
Plywood Production	Bark, core, sawdust, Lilly pads, veneer clippings and waste, panel trim, sander dust
Particleboard Production	Bark, screening fines, panel trim, sawdust, sander dust

From the information provided in table 1, it can be inferred that the waste wood sources in terms of residues are first generated at the operations conducted in the forest and afterwards during the processes conducted at the production facilities. In accordance with the FAO (1993) report, the study of Parikka M.

(2004) also classifies the residues in two categories as the residues which are generated during the logging operations in the forest and the residues which are generated in the processing of timber, plywood, particleboard, pulpwood and etc.

2.2 Municipal Solid Waste (MSW)

The composition of municipal solid waste is usually a mixture of different types of wastes. As a matter of fact, the content of municipal solid is usually similar in different countries. However, there are differences in waste management systems regarding the regulations about collection, separation and disposal of these wastes. The study of Falk (1997) defines municipal solid waste according to the Environment Protection Agency (EPA) of United States of America, as the waste from residential, commercial, institutional, and industrial sources; including durable goods, non-durable goods, containers and packaging, food scrap, yard trimmings, and miscellaneous organic waste. On the other hand, municipal solid waste does not include; construction and demolition waste, automobile bodies, municipal sludges, combustion ash, and industrial process waste that may or may not be disposed of in municipal waste landfills or incinerators. The three categories of municipal solid waste that contain wood fibre are listed as paper and paperboard, yard trimmings, and wood. The content of the wood category contains such items as wood furniture and cabinets, pallets and containers, scrap lumber and panels that are not considered as construction and demolition debris, and waste wood from manufacturing facilities. The study of Falk (1997) also points out estimations depending on the regional and national studies which suggest that about 10% of the wood in the municipal solid waste was recycled and an additional 54% was potentially recoverable.

2.3 Construction and Demolition (C&D) Waste

The content of the construction and the demolition wastes are different. As it is explained in the study of Falk and McKeever (2004); construction waste originates from the construction, repair, and remodelling of residential and non-residential structures. It consists of fairly clean, contemporary building materials, which can be readily separated at the job site. On the other hand, demolition waste originates when buildings or other structures are demolished. Therefore, demolition waste is often contaminated with paints, fasteners, adhesives, wall covering materials, insulation, and dirt. Furthermore, some of these materials may no longer be in use or may presently be considered as hazardous, making recovery more difficult. On-site separation of demolition waste can be time-consuming and operation costs can be high.

2.4 Classification of Waste Wood and Handling Options

The handling of waste and in this aspect the waste wood, there occurs the necessity for the establishment of a methodological approach. In this respect, the EU Waste Framework Directive (EU 2008) sets the basic concepts and definitions related to waste management with a waste management hierarchy of prevention, preparing for re-use, recycling, recovery and disposal from most favoured to least options. Moving on from the waste management hierarchy, the supply chain of the waste wood resource is the other important factor which has to be examined in order to get an understanding of the waste wood handling issue.

The study of Garcia C. A. and Hora G. (2017) proposes that the waste wood supply chain (WWSC) includes three process: (1) waste wood collection (centralized or decentralized), (2) transportation (road, rail or water) and (3) sorting and processing (centralized or decentralized). In order to carry out the operations required in these three processes there occurs the necessity of economical feasibility supported by legislations.

Here-by, it also has to be emphasized that classification of waste wood is crucial in order to handle the waste wood material in the most suitable way. In this sense, the German Ordinance on the Management of Waste Wood (2002) is a useful guidance for the classification of waste wood.

The German ordinance answers the question of ''how to handle the waste wood as a material resource to be utilized?'' by dividing the waste wood into four categories, according to the pollutant types possessed. These four different categories are used to categorize the recycled waste wood based on the presence of preservatives or other chemical substances. In this ordinance, the quality requirements are established towards a decision making process either for energy recovery, re-use or recycling. The four categories of waste wood abstracted from the study of Garcia C. A. and Hora G. (2017) are presented in Table 2.

Table 2: Categories of Waste Wood from the study of Garcia C. A. and Hora G. (2017)

Category	Description	Applications
A I	Untreated or only mechanical treated wood	Chips and Shavings to produce wood-based materials, synthesis gas and activated carbon production (possible energy)
A II	Glued or painted wood (No halogen-organic compounds or preservatives)	Chips and Shavings to produce wood-based materials, synthesis gas and activated carbon production (possible energy)
A III	Wood containing halogen-organic compounds; no preservatives	It can be used as material if the varnishes and coatings are removed
A IV	Contaminated Wood, including halogenorganic compounds No PCB	Energy use in large combustion facilities
Polychlorinated biphenyls (PCB)	PCB treated wood	Non-hazardous disposal

2.5 Factors Affecting the Feasibility of Recycling the Waste Wood

About the handling issue of waste wood the study of Falk (1997) asks the question of ''How economical is it to recycle wood waste?'' The answer of this question is furthermore explained by the associated factors, such as the type of product to be produced from the waste, availability of a nearby resource, and costs of sorting and cleaning. In his study Falk (1997) puts forward that the most important fact is that the recycled resource has to be able to compete favourably in cost with alternative raw materials. Furthermore, in the same study, technical and economical obstacles to be tackled for the recycled wood waste to have an increasing role in the production of a variety of wood-based products are listed as; developing an infrastructure that can deliver a clean, consistent waste wood resource, and developing definitions and material standards that will help manufacturers and suppliers to make a more uniform and consistent trade by using this resource. The key issue of contaminant removal is also highlighted in the study of Falk (1997) as another factor which has to be paid attention in order to increase the ratio of input resource derived from waste wood by recycling. Since the other forms of wood, waste from Municipal Solid Waste and Construction and Demolition waste streams is often in a mixture form with other materials and demolition waste is particularly dirty and this causes sorting process to be costly. The study of Falk (1997) concludes that when progress is made in those mentioned areas, the potential of wood waste to become a viable alternative raw material will be realized.

2.6 The Cascading Use of Wood Material

The EU Commission (2016) report defines ''the cascading use of wood material is the efficient utilization of resources by using residues and recycled materials for material use to extend total biomass availability within a given system''. The same report furthermore emphasizes that the cascading use of wood takes place if, wood is processed into a product and this product is used at least once more time either for the recovery of the material or the energy purposes. Cascading is divided in two categories; first one is a single-stage cascade where the wood is processed into a product and this product is used once more for energy purposes. The second one is the multi-stage cascade where the wood is processed into a product and this product is used at least one more time in material form before disposal or recovery for energy purposes. The study of Thonemann and Schumann (2018) gives an application example for the cascade utilization of wood. In their study, stages of cascading utilization is established for production of solid wood beams out of a tree trunk for the construction and furniture industry. The stages of cascading and options for decision making are listed as follows: The by-products from sawmills (industrial waste wood) are used to produce wood-based-panels (e.g. particleboards) and chemical products (pulp and paper). To produce new panel products, solid wood, and wood-based panel products can also be recycled. Finally, burning of wood-based panels, paper products, and their corresponding by-products can generate energy. An example for energy generating would be the burning of wood pellets which are made of recycled material in a pellet stove to produce thermal or electrical energy. Additionally, burning is not the only alternative to the final usage. For example, combustion engines can use synthetic fuels made from wood chips. Lastly, recycling of wood ash after burning for fertilizing purposes would close the cycle and this leads to a cradle to- cradle system. The ideal cascade use of wood from the study of Thonemann and Schumann (2018) is shown in Figure 1.

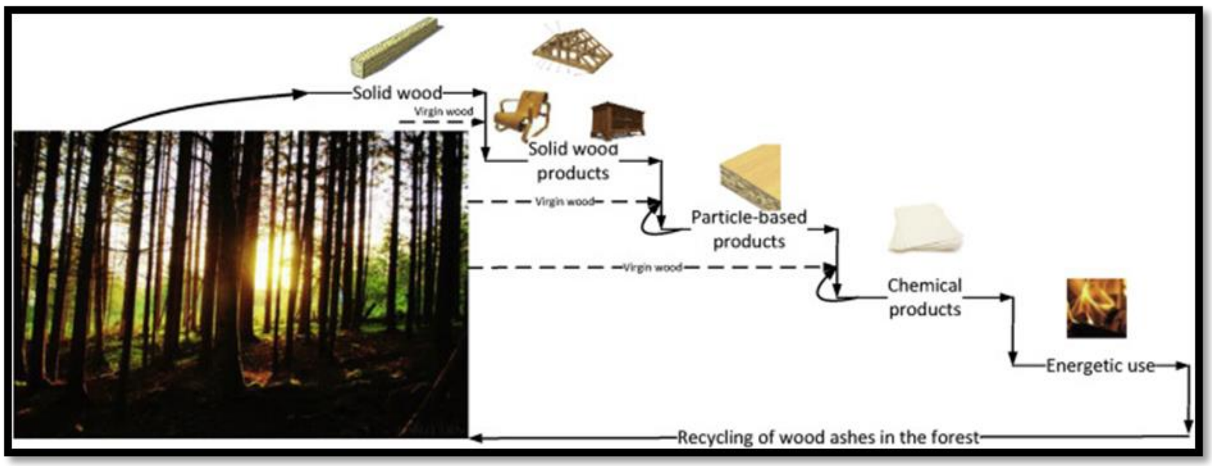

Figure1: Ideal Cascade Use of Wood Resource (Thonemann and Schumann (2018)

3 TRANSFORMATION FROM ORDINARY WASTE TO VALUABLE BIORESOURCE

The resource supply and management techniques in our present era seeks for solutions aiming towards the most economical way and more recently, the least environmentally harmless viable way. If one also adds the issue of sustainability in the latter two factors regarding resource management, there occurs the necessity to utilize from any material to its full potential. In this respect, waste wood has turned into a valuable bioresource both for the forest products industry and the energy sector.

Regarding the forest products industry, the study of Knauf (2015) reveals that the most important material use of waste wood is in the production of particleboard of the wood based panel industry. Other sectors than the particle board production industry have little importance or have a niche character like mulching, or are merely regional in significance like animal bedding practices in the United Kingdom. The study of Knauf (2015) presents that in 2012, six million tonnes of absolute dry waste wood mass was used in whole Europe for the production of particleboard. This amount of waste wood used in the production of particleboard means that approximately 33% of the raw material need of the European particleboard industry was supplied with the waste wood resource. On the other hand, the percentage of waste wood use for particleboard production shows variation for different countries. For example, where Sweden have 0% and Italy have 95% for the level of waste wood utilization for particleboard production. In the same study, a further example regarding the utilization level of waste wood is brought by means of the capability of producing particleboard from 100% of waste wood from Italy. As a conclusion, these cases show that it is technically possible to use considerably more waste wood as a material resource than it was used before.

In order to have an understanding for the current and future resource value of the waste wood, the energy sector also has to be examined. The limits of resources and increasing demand for supplying energy requires the necessity to utilize from renewable resources in a sustainable way. Moving on from this perspective, wood resource and its engineered products have great economic importance due to the fact that this type of resource can be used both as virgin material and also as waste material for energy generation purposes.

Regarding the utilization from waste wood for the energy issue, World Energy Council's Waste to Energy (2016) report provides data about the energy amount that can be provided by the biomass composed of wood residues. The report puts forward that the modern technology using biomass differs from traditional biomass in two key characteristics; first, the source of organic matter should be sustainable and second, the technology used to obtain the energy, should limit or mitigate the emissions of flue gases and be accountable for the ash residue management. Furthermore, the report points out a plus for the modern biomass technology as that the efficiency of conversion in heat level is higher which results in less use of fuel. The report also gives examples from the regions in Europe where modern biomass is largely used; Finland where approximately 60% of bioenergy is produced in the forest industry by using black liquor, bark, sawdust, and other industrial wood residues. Another example is given from Sweden, where approximately 40% of bioenergy utilization is in the forest industry by using residues such as bark, chips, black liquor and tall oil.

4 INTERCONNECTION BETWEEN HANDLING AND UTILIZATION FROM WASTE WOOD

Although, the utilization issue as a phrase can be comprehended as a separate part or stage for the waste wood subject, the utilization and handling issues are interconnected. The proper handling method or technique will result in the best available utilization solution.

The connection of waste wood handling and how to utilize from these materials from a resource management based approach is analysed in the study of Furubayashi and Nakata (2018) where a case study scenario is conducted aiming towards estimating the costs and CO2 emissions of wood biomass co-firing in the Tohoku region of Japan. In their study, sawmill residues, construction wastes, forest residues, thinning residues, and fruit-tree pruning residues are treated as raw materials and wood chips, pellets, torrefied pellets (known as black pellets) are regarded as bio-fuels. Afterwards, a woody biomass supply system is designed and it is comprised of four processes: collection, resource transportation, pre-processing, and fuel transportation. The result of their study considering the energy balance, CO2 reduction, and costs is that the chip production case is superior to the pellet or black-pellet production cases. Another important point from their study that has to be highlighted based on the energy quantity and costs is that the pre-processing plants should be distributed within each municipality, because the resource transportation has a greater effect on the other factors than the scale effect of the pre-processing facilities.

5 UTILIZATION EXAMPLES OF WASTE WOOD

The possibilities of efficient use of wood waste from forestry operations and wood based production industry are various. Through the literature survey, different utilization fields and end use applications cited will be presented in this part of the study.

The study of Daian and Ozarska (2009) from Australia points out that the recovered waste wood is utilized in various applications such as; mulch, fuel, salvaged (recycled) timber, animal bedding and recycling into particleboard. The study by Deac et. al. (2009) from Romania examines the energy potential of wood residual products (mainly sawdust) and proposes that this can be a potential thermal energy source for rural areas where this resource can reduce the costs for thermal energy generation for the households. Another application example is a case study made by Nyemba et. al. (2018) from Zimbabwe of Africa; their study mentions that timber processing and the manufacture of furniture processes generate a considerable amount of waste in the form of off-cuts, shavings and sawdust which pose challenges and are costly for the manufacturing firms in terms of safe extraction and disposal. Furthermore, the proposed solution in the study of Nyemba et. al. (2018) for these type of waste wood is to utilize from them with in-house fabricated briquetting machines by compacting the sawdust waste into briquettes that can be used as an alternative source of fuel. Furthermore, from the perspective of construction engineering and adding value to utilization attributes; the study of Çetiner and Shea (2018) examines a natural fibre material in the form of wood waste experimentally to assess its suitability for use as a thermal insulation material, without the addition of any binder, within a timber frame wall construction. In their study, the wood waste used is from primary production sources in the form of untreated material. According to their experimental results, the thermal conductivity values of wood waste with different densities are slightly higher than commonly used inorganic based insulation materials. Although comparable to other natural insulation materials in the market, the wood waste material studied in their experiment have the economic advantage of being a low-cost by-product.

6 CONCLUSIONS

-The classification of waste wood based on the presence of preservatives or other chemical substances enables a healthy decision making process for the most appropriate choice among energy recovery, re-use or recycling. Furthermore, contaminant removal and the required technology is a key issue for the waste wood to be handled as a resource for the subsequent utilization options.

-Recent developments in the wood based panel and composite materials technologies show that it is technically possible to use considerably more waste wood as a material resource than it was used before regarding the panel board production industries.

-Wood resource and its engineered products have great economic importance due to the fact that this type of resource can be used both as virgin material and also as waste material for energy generation purposes. Finland and Sweden present self-sustaining practices for energy supply mechanisms for the forest products industry.

-Even though it may be regarded as small scale applications, regional or local solutions for handling the waste wood and turning this resource into engineered fuel products like briquettes or pellets to generate thermal energy with in-house machines can be economically beneficial for rural communities.

-Handling waste wood is interdependent with solid waste management systems regarding the municipal and construction-demolition waste streams. Furthermore, the legal bindings are important to encourage industry and consumers to separate waste at site for manufacturers as much as it is viable, otherwise penalties should be imposed for unproper applications in order to prevent future occurrences.

-Waste generation, handling and utilization issues' analyse in general reveals that these issues are just not related to technological and industrial developments, but also rather interdependent on government regulations and social-cultural awareness of societies.

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Determination of the Optimum Feed Rate and Spindle Speed Depending on the Surface Roughness of Some Wood Species Processed with CNC Machine

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ABSTRACT

In modern furniture industry, CNC machines are widely used, especially when high quality of product and flexibility of manufacturing process are expected. Even though there are many advanced computer-aided manufacturing systems for furniture producers, it is difficult to set process parameters according to obtain desired material surface properties because wood is a natural polymeric material with a heterogeneous structure. Wood surface properties are affected both material and machining factors, such as wood species, anatomical characteristics, moisture content, grain direction, feed rate, spindle speed, cutting depth, and tool geometry. In this study, it was aimed to determine of the optimum feed rate and spindle speed depending on the surface roughness of some wood species processed with CNC machine. Spruce, chestnut, larch and iroko were used as wood species. Three spindle speed (10000, 14000 and 18000 rpm) and feed rate (5000, 7000 and 9000 mm/min) were determined for CNC processing. The surface roughness (Rz) of wood samples were determined according to DIN 4768 standard.

As a result of the study, the lowest surface roughness values were found in 10000 rpm spindle speed and 5000 mm/min feed rate for spruce and chestnut wood and 18000 rpm spindle speed and 7000 mm/min feed rate for larch and iroko wood. The highest values in the all of wood species were obtain from 10000 rpm spindle speed and 9000 mm/min feed rate.

KEYWORDS: CNC, Spindle Speed, Feed Rate, Surface Roughness

1 INTRODUCTION

Wood and wood based materials have been used as a construction material for years, mostly because of low cost, renewability, strength and low processing energy requirements. In recent years, the machining of wood products has acquired great importance, due to the short supply of wood and increasing environmental awareness among users and manufacturers (Sofuoglu, 2017).

Working with automatic mechanical equipment demands precise, accuracy, speed, consistency and flexibility. In this case it takes the help of embedded computer applications to do the job. One of the mechanical equipment combined with microcomputer that has been widely used is a CNC machine (Computer Numerical Controlled). CNC machines are used for mechanical work such as cutting, engraving, drilling and others. The computer technology used to control, parse and execute certain objects based on user command. In the manufacturing industry, the use of CNC machines greatly affects the increased production (Jayachandraiah et al., 2014; Ginting et al., 2017). CNC machines are used in various manufacturing applications such as steel machining, plastic cutting, etc. and are widely used in the woodworking industry. In the furniture industry, CNC machines perform drilling, milling, sanding and cutting operations (Koc et al., 2017). These machines provide high productivity increasing the efficiency up to 2.5 times and flexibility in production and integration to automation systems (Raja and Baskar, 2011).

The surface quality of solid wood and wood based panels is one of the most important properties characterizing the wood machining process and its conditions, manufacturing processes, such as finishing or adhesive strength properties. The surface roughness of wood can be affected by different factors, such as annual ring variation, wood density, cell structure, earlywood ratio and latewood ratio, and humidity (Zhong et al., 2013; Sofuoglu, 2017). CNC machining process is a significant stage as it affects surface coating performance such as adhesion strength of coating, minimization of waste and appearance of wood products (Cool and Hernandez, 2011; Tan et al., 2012; Ozdemir et al., 2015). Surface roughness is a crucial quality indicator of cutting and coating process (Koc et al., 2017). Nas et al. (2012) reported that the surface roughness had changed significantly depending on the parameters as a result of milling the material surfaces in CNC machinery. Wilkowski et al. (2011) utilized Taguchi method to investigate effective factors for CNC processing parameters of wood surface roughness of oak and ash. The cutting parameters such as feed rate and spindle speed were resulted as significant parameters on the surface roughness.

The main purposes of process monitoring and control are to optimize manufacturing speeds and to reduce production times. An effective process monitoring system should alert the operator and shut the machine down when critical conditions are about to be reached. In wood machining, the control process should manage key control variables such as feed rate or spindle speed, and adjust them to approach optimum conditions for the chosen machining objectives (Iskra ve Tanaka, 2005). In this study, it was aimed to determine of the optimum feed rate and spindle speed depending on the surface roughness of some wood species processed with CNC machine.

2 MATERIALS AND METHOD

In this study, spruce, chestnut, larch and iroko were used as wood species. Three spindle speed (10000, 14000 and 18000 rpm) and feed rate (5000, 7000 and 9000 mm/min) were determined for CNC processing. It is given description of test groups according to wood species in Table 1.

Table 28: Description of Test Groups

Wood Species	Spindle Speed (rpm)	Feed Rate (mm/min)	Wood Species	Spindle Speed (rpm)	Feed Rate (mm/min)
Spruce	10000	5000	Chestnut	10000	5000
		7000			7000
		9000			9000
	14000	5000		14000	5000
		7000			7000
		9000			9000
	18000	5000		18000	5000
		7000			7000
		9000			9000
Larch	10000	5000	Iroko	10000	5000
		7000			7000
		9000			9000
	14000	5000		14000	5000
		7000			7000
		9000			9000
	18000	5000		18000	5000
		7000			7000
		9000			9000

The wood samples were processed on Megatron 2128, 4 Axis CNC Milling Machine with 9 kW spindle power, a maximum spindle speed of 24.000 rpm. Working area of the machine is 2100x2800x150 (mm). 2 mm diameter conical knife were used for all of the groups. The CNC machine and processing of the wood samples are shown in Figure 1.

Figure 26: CNC milling machine and Processing of the wood samples

A fine stylus-type profilometer, Mitutoyo Surftest SJ-301 Surface Roughness Tester was used for the surface roughness test (Figure 2). This device consists of a main unit and a pickup. The pickup has a skid-type diamond stylus with a radius of 5 μm and a tip angle of 90°. Cut off length (kc) was 2,5 mm, and tracing length was 12,5 mm. Ten replicates of wood samples for each group were used for surface roughness measurement. The samples cut at the dimensions of 50×50×10 mm were used for each test group to evaluate their surface roughness. The Rz roughness parameter (mean of the 10-point height of irregularities) was used to evaluate surface roughness of the samples according to DIN 4768 (1990).

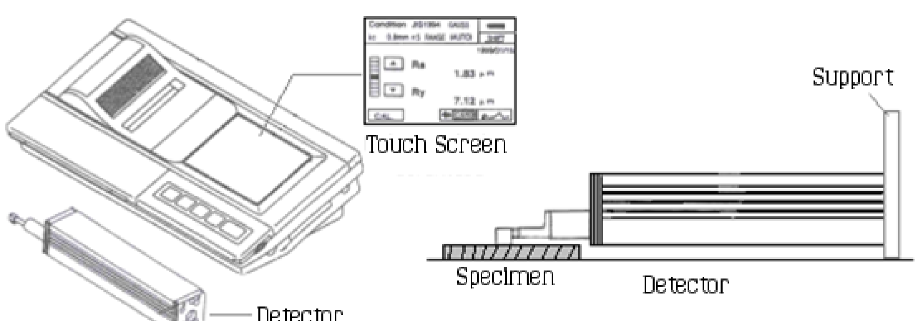

Figure 2: Mitutoyo Surfest SJ-301 surface roughness meter

3 RESULTS AND DISCUSSION

The surface roughness mean values (Rz) are given in Figure 3 according to wood species and CNC parameters. The groups that given the lowest roughness values are shown with red arrow.

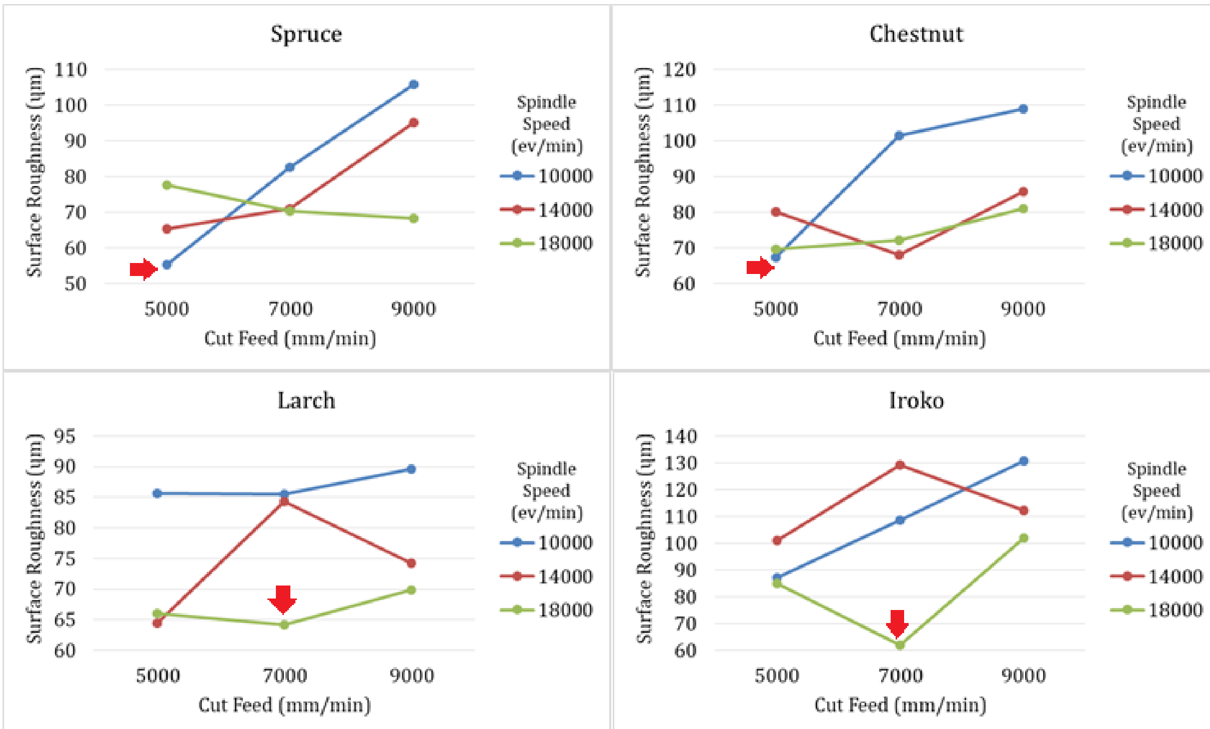

Figure 3: The change of surface roughness mean values according to wood species and CNC parameters

As can be seen that Figure 2, the lowest surface roughness values were found in 10000 rpm spindle speed and 5000 mm/min feed rate for spruce and chestnut wood. Many researchers reported that the effect of feed rate and spindle speed on surface roughness in wood and wood based materials machining, and the results demonstrated that the surface roughness decreases with increasing spindle speed and increases with the feed rate (Iskra and Tanaka, 2005; Sutcu, 2013; Sutcu and Karagoz, 2012). In this study, smoothest surfaces for spruce and chestnut were obtained from the lowest spindle speed and feed rate.

However, it was found in 18000 rpm spindle speed and 7000 mm/min feed rate for larch and iroko wood. Davim et al. (2009) studied CNC processing parameters of MDF such as spindle speed, cutting speed and feed rate. Higher spindle speed and higher feed rate performed smother surfaces where in the present study lower feed rate and higher spindle speed performed minimum surface roughness. Koc et al. (2017) determined that minimum surface roughness values of MDF, ayous and beech wood were found as spindle speed of 18,000 rpm and feed rate of 2 m/min in their study.

The highest values in the all of wood species were obtain from 10000 rpm spindle speed and 9000 mm/min feed rate. Sofuoglu (2017) found that the surface roughness, both Ra and Rz, increased with increasing feed rate, but decreased with increasing spindle speed.

4 CONCLUSIONS

CNC wood working machinery has been widely introduced in wood industries, especially in the furniture industry. CNC has been used for the grooving, milling, patterning of furniture material etc. This technology presents many advantages related to output, surface quality and provide greater improvements in productivity, and increase the quality of the machined part. In this study, the effect of various CNC machine parameters such as spindle speed and feed rate in the wood working processing were investigated on the quality of wood surface. The ranges of CNC parameters studied in this research are spindle speeds of 10000, 14000 and 18000 rpm and feed rates of 5000, 7000 and 9000 mm/min. As a result of the study, the lowest surface roughness values were found in 10000 rpm spindle speed and 5000 mm/min feed rate for spruce and chestnut wood and 18000 rpm spindle speed and 7000 mm/min feed rate for larch and iroko wood. The highest values in the all of wood species were obtain from 10000 rpm spindle speed and 9000 mm/min feed rate.

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Some Technological Properties of Oriental Beech (*Fagus Orientalis* Lipsky.) Wood Grown in Ayancık/Sinop Region in Turkey

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ABSTRACT

In this study, it was investigated some physical and mechanical properties of naturally grown Oriental beech (*Fagus orientalis* Lipsk.) in the Ayancık-Sinop in the Middle Black Sea Region of Turkey. The experiments were carried out on the test specimens obtained from randomly selected 5 samples trees taken from the region, according to the relevant TSE, ASTM and ISO standards. As a result, density values of air and oven dry, volume density value, compression strength parallel to the grain, static bending strength and modulus of elasticity, impact bending, tensile strength parallel to grain, tensile strength perpendicular to grain in tangential and radial direction, cleavage strength perpendicular to grain in tangential and radial direction, shear strength parallel to grain in tangential and radial direction, values of Brinell-hardness in transversal, tangential and radial sections were 0.693 gr/cm^3 and 0.666 gr/cm^3, 0.552 gr/cm^3, 619 kp/cm^2, 1182 kp/cm^2, 119256 kp/cm^2, 0.96 kpm/cm^2, 1407 kp/cm^2, 37.66 kp/cm^2 and 33.74 kp/cm^2, 109.68 kp/cm^2 and 72.78 kp/cm^2, 110.70 kp/cm^2 and 106.59 kp/cm^2, 5.42 kp/mm^2, 2.85 kp/mm^2 and 2.60 kp/mm^2 respectively. Somewhat higher values were obtained in this study by comparison with another research in the same region. This difference may be related to growth conditions of trees. In particular, it can be stated as the most important factor that the sample areas are at lower altitude.

KEYWORDS: Beech wood, physical properties, mechanical properties.

1 INTRODUCTION

The Oriental beech (*Fagus orientalis* Lipsk) is one of the most important commercial hardwood species in Turkey forestry. Although this species indigenously grows from Bulgaria to the Carcuasus, there are abundant forest areas of Oriental beech along the Black Sea region in Turkey. It grows high altitudes on mountains along the Black Sea coast, from Demirköy/Kırklareli to Hopa/Artvin. It can be seen in the Marmara region and some parts of Anatolia, and it established local forests in the Northeastern Mediterranean region of southern Turkey (Yaltırık, Anşin).

Turkey has about 22.3 million hectares forest area, about 28.6 percent of the country's land area. The beech wood has high economic importance and it covers a total of 1.899.929 ha, equal to 8.50 % of Turkey forests (Anonymous, 2009). The total wealth of forest trees Turkey 1,611,774,193 m^3, the total annual allowable cut the amount of 18,314,621 m^3. The Oriental beech, with 209.324.220 m^3 wood value and 1.743.052 m3 annual allowable cut is the primary raw material for the Turkish forest product industry (Anonymous, OGM, 2015).

The most evident property of beech, which can grow tall up to 30-40 meters and up to 1 meter diameter. It is used to produce furniture, parquet, package cases, poles, coal, and crossties when impregnated and fuel wood. Its wood is classified as a medium density hardwood. It is heavy, hard, strong, high in resistance to shock, and is most suitable for steam bending. Beech shrinks substantially and therefore requires careful drying. Usually –mostly- it is used for flooring, furniture, brushes, blocks, handles, veneer, woodenware, carpenters' work benches and toys (Bozkurt and Erdin, 1997). When treated with preservatives, beech wood is suitable for railway ties (Yaltırık, 1993).

Many studies were carried out relation with Beech species. Technological properties of Oriental beech grovn in Turkey (Berkel 1941, Gürsu 1960, Malkoçoğlu 1994, Malkoçoğlu at al. 2010, and Bektaş et al. 2002), in İran (Pojouh 1974, Sadegh at al, 2011), in Armenia (Arzumanjan and Mamikonjan 1961), in Bulgaria (Stoyanoff 1949), in Croatia (Govorcin et al. 2003) and in Greek (Skarvolis, et al, 2013) were investigated. Also, anatomical properties of oriental beech grown in Turkey were determined (Şanlı, 1978).

In this research, some technological properties of Oriental beech, indigenously grown in Ayancık/Sinop (Fig.1) north part of Turkey, were determined and these data were compared with other research results, available in the literature.

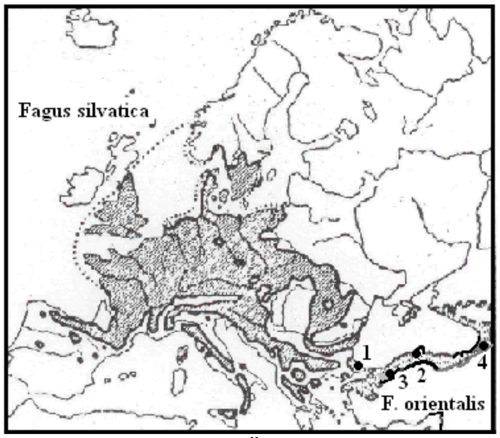

Figure1: The distribution of beech species (Anşin and Özkan 1993) and test areas (1. Demirköy/Kırklareli, 2. Ayancık/Sinop, 3. Düzce and 4. Borçka/Arvin).

2 MATERIALS AND METHODS

The trial trees were taken from Ayancık Forests located in the Black Sea Region, north part of Turkey. Tree samples were chosen randomly from experimental area (Kalıpsız, 1981). It is considered grown area conditions choosing of trees. General properties of samples trees and test area are determined according to TS 4176 (same ISO 4471), and they are showed Table 1.

Table 1: Properties of test areas and sample trees.

	Sample tree no	1	2	3	4	5
Test Trees	Age of Tree	240	199	186	121	139
	Diameter of tree $d_{1.30}$ (cm)	44	36	49	50	64
	Height of tree	26.30	30.10	33.00	31.00	37.15
	Dead branch (m)	15.00	16.70	14.80	19.00	20.50
Test Area	Altitude (m)	890	860	950	920	910
	Slope (%)	15	10	20	20	20
	Direction	N	N	S-E	N-W	N-E
	Bonitet	2	2	2	2	2

1.2 m long end-matched log sections were prepared from the whole tree, by cutting from heights of between 3 and 6 m from the base as mentioned in TS 4176 (same ISO 4471). Test specimens were prepared from these selected sections for the determination of technological properties.

2.1 Determination of Physical and Mechanical Properties of Tree Species

Boards with 3, 6 and 8 widths were cut from logs according to TS 2470 (same ISO 3129) and TS 53 (same ISO 3129). Boards were stored for air drying. After air-drying process small and clear specimens (Fig.

2) were cut from the boards according to Turkish standards to compression strength parallel to grain ($\sigma_{c//}$) (TS 2595 same ISO 3787), bending strength (MOR) (TS 2474 same ISO 3133), modulus of elasticity in bending (MOE) (TS 2478 same ISO 3349), impact bending (σ_w) (TS 2477 same ISO 3348), shear strength parallel to grain ($\sigma_{s//}$) (TS 3459 same ISO 3347), tensile strength parallel ($\sigma_{t//}$) and perpendicular to grain ($\sigma_{t\perp}$) (TS 2475, 2476 same ISO 3345, 3346), cleavage strength (σcl) (TS 7613 same ASTM D 143) and Brinell hardness values (cross section: H_{BC}, radial section: H_{BR}, tangential section: H_{BT}) (TS 2479 same ISO 3350). Then the specimens were conditioned at 20 ± 2°C with 65% relative humidity for a moisture content of about 12%. After the specimens acclimatization technological properties of Oriental beech wood were determined (Fig. 1).

The following equations have been used to determine the physical and mechanical properties, respectively. Densities of air and oven dry (D_{12} and D_0), compression ($\sigma_{c//}$) and tensile strentgh parallel ($\sigma_{t//}$) and perpendicular ($\sigma_{t\perp}$) to grain, tensile strength perpendicular to grain ($\sigma_{t\perp}$), and cleave strength parallel to grain ($\sigma_{cl//}$), bending strength(MOR)and modulus of elasticity in bending (MOE), impact bending (σ_w) and shear strength parallel to grain (σ_{sh}), and Brinell hardness values (H_B).

$D_{12} = W_{12}/V_{12}$ (gr/cm^3) and = W_0/V_0 (gr/cm^3) (1,2)
$\sigma_{c//}$, $\sigma_{t//\text{and}}$ $\sigma_{t\perp}$, $\sigma_{cl} = P_{max}/axb$ (kp/cm^2) (3)
MOR= $3.P_{max}.L/2.b.h^2$ (kp/cm^2), and MOE = $PxL_s^3/4xfxbxh^3$ (kp/cm^2) (4, 5)
$\sigma_w = W/bxh$ (kp/cm^2) and $\sigma_{sh//} = P_{max}/2xbxh$(kp/cm^2) (6, 7)
$H_B = 2xP_{max}/\pi xD(-D^2-d^2)$ kpf/mm^2 (8)

Where $W_{12}/_0$ is the air and oven dry weigh (gr), $V_{12}/_0$ is the air and oven dry volume, P_{max} is the max. load at the break point, a or b is the specimen cross-sectional dimension (mm), L is the is the length of span (mm), h is the thickness of the specimen, W is the energy absorbed by the specimen (kpm), F is the cross-sectional area of the specimen (cm^2), f is the bending value (mm), D is the Brinell sphere diameter (mm), d is the pore diameter on sample (mm).

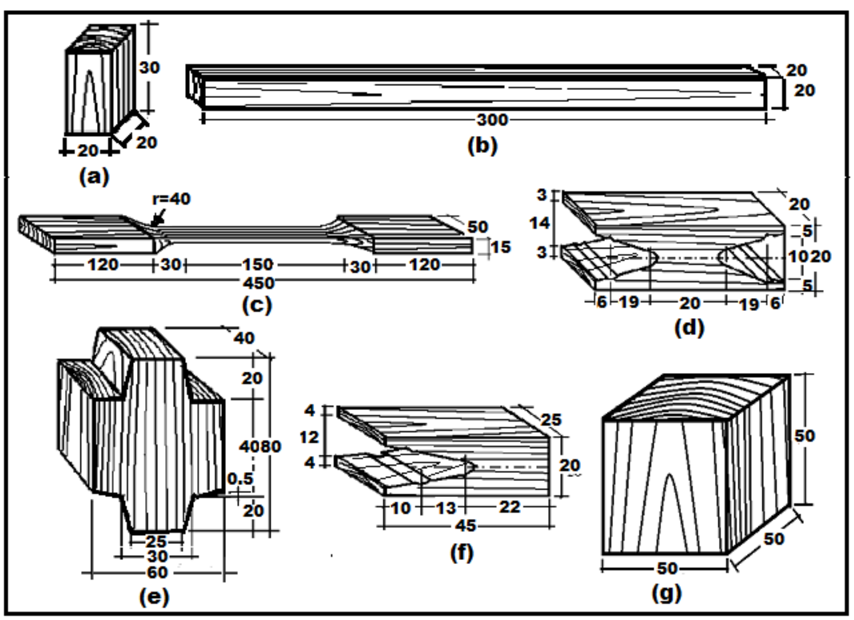

Figure 2. Experimental samples and dimensions (mm)*

*a. Density and strength parallel to grain; b. Bending strength, modulus of elasticity in bending (MOE) and impact bending; c. Tensile strength parallel to grain ($\sigma_{t//}$); d. Tensile strength perpendicular to grain ($\sigma_{t\perp}$); e. Shear strength parallel to grain ($\sigma_{s//}$), f. Cleavage strength (σcl) ; g. Brinell hardness values (cross section: HBC, radial section: HBR, tangential section: HBT).

Moisture contents (M) of specimens were measured according to TS 2471 (same ISO 3130) at the end of every experiment. Strength values of specimens moisture content deviated from 12 % were corrected by using the following equation:

$$\delta_{12} = \delta_m \times [1 + \alpha\,(M_2 - 12)] \qquad (9)$$

where δ_{12} = strength at 12 % moisture content (kp/cm²), δ_m = strength at moisture content deviated from 12 % (kp/cm²), α = constant value defining relationship between strength and moisture content (α = 0.05, 0.04, 0.02, 0.025, 0.03, 0.03, 0.015, 0.015, 0.04 and 0.025 for $\sigma_{c//}$, MOR, MOE, σ_w, $\sigma_{s//}$, $\sigma_{t//}$, $\sigma_{t\perp}$, $\sigma_{cl//}$, $H_{B//}$ and $H_{B\perp}$, respectively), M_2 = moisture content during test (%).

Static, specific and dynamic quality values (I_{st}, and I_d) of Oriental beech wood were determined by using following equations:

$$I_{st} = (\sigma c_{12} / D_{12}) \times 100 \text{ kpm} \qquad (10)$$

$$I_d = a / (D_{12})^2 \text{ kpm} \qquad (11)$$

Where σ_{c12} is the compression strength parallel to grain in 12 % moisture content (kp/cm²), D_{12} is the air-dry density (gr/cm³) and a is the impact work (Bozkurt and Göker, 1996).

3 RESULTS AND DISCUSSION

Descriptive statistics for some physical properties (g/cm³) are given in Table 2, and the strength and hardness of Oriental beech wood are given in Table 3. The results were compared with determined values for same kind and other some species and stated in Table 4.

Table 2: Some physical properties (gr/cm³) of Oriental beech wood.

Properties	No	$\bar{X}$	SD	CV (%)	Min.	Max.
D_{m12}	592	0.693	0.053	7.65	0.575	8.825
D_{m0}	592	0.666	0.058	8.71	0.512	0.824
D_b	523	0.553	0.039	7.05	0.448	0.675

D_{m12}: Air-dry density, D_{m0}: Oven-dry density, D_b: Density value in volume

Table 3: Some technological properties of Oriental beech wood in in Ayancık/Sinop

Properties		N	x̄	SD	CV (%)	Min.	Max.
Compr. strength parall. to grain ($\sigma c//$)		592	619	93.08	15.03	380	961
Bending strength (MOR)		69	1182	198.2	16.8	821	1711
Modulus elasticity in bending (MOE)		69	119256	4385.5	3.7	108654	139094
İmpact bending (σw)		65	0.95	0.43	45.8	0.22	2.37
Shear strength parallel to grain ($\sigma_{s//}$)	T*	19	111	12.62	11.40	90	138
	R**	39	107	14.85	13.93	81	136
Tensile strength parallel to grain ($\sigma_{t//}$)		57	1407	436.85	31.04	386	2434
Tensile strength perpendicular to grain ($\sigma_{t//}$)	T*	36	38	6,55	17,39	24	50
	R**	67	34	5,42	16.06	18	44
Cleave strength parallel to grain ($\sigma_{cl//}$)	T*	35	110	19,46	17.74	77,33	165,09
	R**	28	73	16,91	23.42	39,01	111,64
Brinell hardness values (kp/mm²)	H_{BCr***}	38	5.42	0.64	11.94	3.91	7.09
	H_{BTr**}	38	2.85	0.33	11.57	2.62	3,14
	H_{BRr*}	38	2.60	0.37	14.60	2.24	2.72

*Tangential direction, **Radial direction and ***Crosscut

Woods of trees have been classified based on the values relating to technological properties (Bozkurt and Erdin 1990). According to this classification; density values, compression strength, bending strength of Oriental beech are classified as “Medium”, although impact bending is classified as “Very high”.

Resistance and Brinell hardness values; tangential sections showed higher results than radial sections. This situation may be due to weak rays from core to periphery in beech wood.

Table 4: Comparison of ring width (RW) (mm), air-dry density (g/cm^3) and some mechanical properties of Oriental beech with same and other beech species.

Tree species	RW (mm)	D_{12}	$\sigma_{c//}$	MOR	σ_w	References
FO (Sinop/Turkey)	1.84	0.693	619	1182	0.93	(Malkoçoğlu, 1994)
FO (Black Sea Region)	1,58	0.669	572	1123	0.95	
FO (Artvin/Turkey)	1,15	0.610	501	1023	0.82	(Malkoçoğlu, 1994, 2010)
FO (Tokat/Turkey)	1.41	0.663	763	1052	-	(Gürsu,1960)
FO (Sinop/Turkey)	-	0.660	644	870	0.92	(Berkel, 1941)
FO (K Maraş/Turkey)	1,51	0.663	606	1204	0.85	(Bektaş aet al., 1999)
FO (Iran)	1,46	0.658	564	-	0.70	(Pojouh, 1974)
FO (İran)	-	0.635	685	1292	-	(Sadegh et al, 2011)
FO (Greek)	2.25	0.600	491	1072	0.70	(Skarvelis et al, 2013)
FS (Greek)	2.12	0.650	575	1049	0.81	
FS (Europen)	-	0.714	521	1105	0.85	(Stoyanoff et al. 1949)
FS (European)	1,64	-	648	-	0.94	(Horvat, 1969)
FS (European)	2,22	0.698	527	1102	0.98	(Cividini, 1969)
FG (USA)		0.730	503	1025	1.02	Wangaard, 1950)
FLu (Chinese)	-	0.714	526	1155	1.36	(Qıng, 1985)
FC (Japanese)	-	0.650	450	1000	1.20	(Anonymous, 1966)

FO: *F orientalis*, FS: *F sylvatica*, FG: *F grantifolia*, FL: *F longiopetiolata*,, FC:*F crenata*

In Table 4, Beech woods grown in region of Ayancık/Sinop mostly showed "Normal values" in comparison with some physical and mechanical properties of beech species in Turkey and other countries. Also, in the table it is seen that the physical and mechanical properties of beech species grown in the world are quite different. In the literature, variations in the technological properties in the same species are due to different factors, such as grown conditions, ecological factors. In particular, exposure, altitude, soil, and climate conditions can affect the technological properties of wood. (Kollman and Wilfred 1968, Panshin and De Zeeuw 1980). However, having diffused pores and homogeneous structure in beech wood is the most important advantage for various purposes such as machining, coating etc. (Berkel 1970, Kolmann and Wilfred 1968). In general, there is a small correlation among age, annual ring wide and density in diffuse porous wood (Panshin and De Zeeuw, 1980).

In evaluation of according to density classes of Beech species (Bozkurt and Erdin); it can be evaluated that the beech species grown in Turkey, Iran, Greece and Japan have normal density while the beech species grown in USA, Europe and China have higher density. However, it should be emphasized that the selection based on the evaluation of this tree species is made based on the height of the growing place. In this respect, as product construction elements, it may be advisable to use narrow annual ringed wood trees which grow in higher growth areas, which require less dimensional changes in wood products industry, especially in furniture industry.

Interestingly, the study by Malkocoglu (1994) showed close values on the technological features with a study carried out by Berkel (1941). However; the study by Malkoçoglu showed somewhat higher values even though the height of growing areas is lower compared to Berkel's study (Malkoçoğlu 860-950 m, Berkel 900-1100 m). This can be taken into consideration for the evaluation of wood species in the silviculture field and the forest products industry.

In Resistances and Brinell hardness values, tangential section showed higher results than the ones in radial sections. This may be due to the rush rays with weak structure which lay out from the core to periphery in the beech wood.

Medium density hardwoods, such as beech can be classified as low (I_s< 7), fair (7<I_s<8.5) and good (8.5<I_s) quality according to their static quality value (I_s). According to this, I_s is 8.9 kpm and *Fagus orientalis* has good quality wood. Furthermore, medium density hardwoods are also classified as low (I_d< 1), fair (1<I_d<2) and good (2<I_d) quality according to their dynamic quality value. Same way, according to this classification, dynamic quality value is 1.98 kpm and *Fagus orientalis* wood has good quality wood (Berkel, 1970 and Bozkurt and Erdin, 1997).

4 CONCLUSION

In this study, some physical and mechanical properties of Oriental beech trees of Ayancık/Sinop region were determined. The results were compared with the research results on beech wood in different regions. The test results proved that the Oriental beech trees grown in this region have elastic and good quality wood. In respect to wood properties, some differences were observed from other beech species. These differences may be explained by some regional conditions, that affects the growth characteristics and properties of the wood. In this case, normal density of the Oriental beech trees in Ayancık shows "Normal" mechanical properties due to the high altitude.

It is observed that the physical and mechanical properties of beech species that grow in the world are quite different. In particular, the wood densities of trees species in their use and evaluation for various purposes are an important indication. As known, higher density wood species show generally higher resistance and higher dimensional changes. According to these; furniture, joinery, wooden structures etc., in workpieces or constructions that require little work, it may be advisable to select wood with narrowed annual ring which grow in higher altitude areas.

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Drilling Bits and Operations Used in Drilling Machines in Furniture Industry

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ABSTRACT

Various manual, semi-automatic or fully automatic tools and machines which have different capacities are used for drilling operations in furniture, joinery, wooden and wood building industries. These show significant structural and functional changes based on traditional and advanced technologies. Especially in the last quarter of the 20th century, the use of CNC machines in the processing of wood and wood-based materials provided significant possibilities in production elasticity and capacity. These have high dimensional sensitivity and surface quality processing technology from the simplest to the most complex product geometries. Although CNC machines have advanced technologies, the interactions between cutting tools, machining conditions and materials have an important place in the machining of wood and wood-based materials for a good surface quality. Parameters of machining conditions are presented in a wide range with technical data, equations and graphics associated with surface quality for both traditional and modern machines. However, in practice, the machining conditions are usually based on the feed rate, rotation speed, grain direction, cutting width and material type according to cutter characteristics. In this study, it is focused on drilling bits and machines used in furniture industry. Problems and proposed solutions encountered with drilling operations were indicated.

KEYWORDS: Drilling machines, drilling bits, furniture industry, wooden materials.

1 INTRODUCTION

Drilling or boring is one of the oldest technologies of machining in all of the branches of production industry owing to the need for component assembly. It is an integral part of wood cutting technologies for creating holes in the furniture production industry besides milling, moulding and sanding,. It is the most common and frequent mechanical processing operations not only in the wood and wood-based industry, but also in the processing of metals, plastic materials, composites etc. (Çakmak and Malkoçoğlu, 2017; Ispas and Racaşan, 2013; Javorek et al. 2013). Boring represents the ideal technique for producing corner joints and joints for laminated wood panels (Hesselbach et al. 2007; Killman and Fink 1996).

To improve drilling quality and capability, it is necessary to understand the drilling process characteristics as a principle of chips creation, its orientation for removing from the zone of cutting, forces and their value and orientation during cutting, fracture mechanics during delamination of wood layers etc (Jovorek et al. 2013).

In this study, it is focused on drilling bits and machines used in furniture industry and problems and proposed solutions encountered with drilling operations.

2 FACTORS AFFECTING MACHINING CONDITIONS AND SURFACE QUALITY IN DRILLING OPERATIONS

Generally, it can be stated that drilling quality depends on the machining conditions (feed rate and spindle speed- rotations per minute (rpm), drilling depth, and cutting force), tool geometry (helix or rake angle, tool life, drill type and diameter) and materials (density, moisture content, grain orientation etc.) The structure and composition of the composite in particular have a strong influence on the tool wear as well (Malkoçoğlu, 2017; Gornik et al. 2013; Ispas and Racaşan, 2013; Javorek et al. 2013). Many researchers has been studied on spindle speed, feed rate, depth of cut (Podzievski and Gorski, 2012; Prakash and Palanikumar, 2011; Davim et al. 2008), tool geometry and different diameters of drills (Bakar et al. 2018; Ispas and Racasan, 2017;Valarmathi et al. 2013; Palanikumar et al. 2009; Prakash et al. 2009; Ispas et al. 2015), surface quality and tool wear (Gornik Bučar et al. 2013; Szymański and Pinkowski 2012; Podziewski and Górski 2012; Javorek et al. 2013; Gaintode et al. 2008) in drilling operations of wood and wood based materials. According to these studies; the most significant drilling parameters for the surface roughness are feed rate and spindle speed. Various machining conditions such as the cutter type, diameter, grain direction (along the grain and across the grain) and rpm are proposed with equations and graphs technically or by the cutter manufacturer's catalogues (Fig. 1). However; this data relating to processing parameters is in a wide range; the suitability of the production efficiency level depending on the material surface quality cannot be fully explained in the selection of these conditions. (Kaplan et al. 2018; Krimpenis et al., 2014; Anonymous-1).

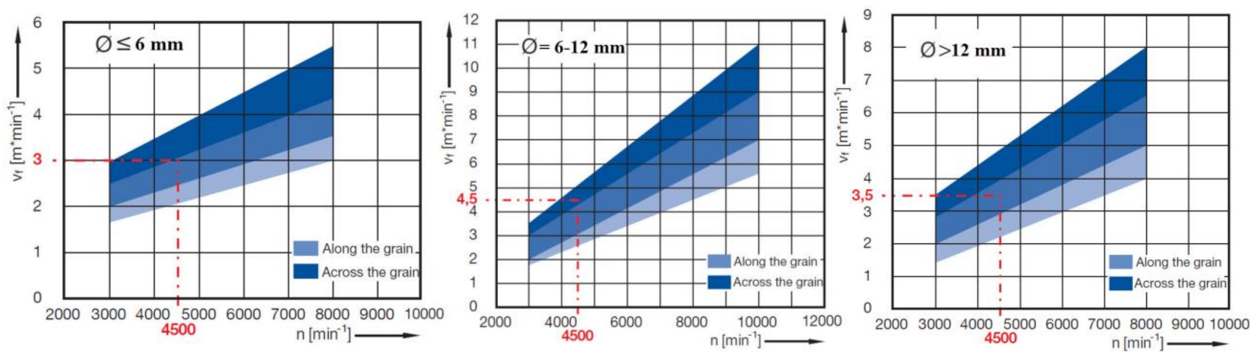

Figure 1: Suggested machining conditions for some multi-purpose drills (v_f: feed speed, n: rotations per minute-rpm: Correction factor for v_f: Hardwood=0.8, Laminated veneer lumber=1.2) (Anonymous-1)

It is observed in Figure 1 that the rpm and feed rate are directly proportional to diameter drills in the machining of softwood and decrease in along the grain direction with respect to across the grain direction. At the same time, the feed speed decreases as the drill diameter increases.

3 DRILLS AND DRILLING MACHINES IN FURNITURE INDUSTRY

Many different types of machines and tools are used in in drilling operations in the furniture industry. These show that structural and functional changes based on traditional and advanced technologies. In the processing of various materials, their functions must be well known for traditional or modern applications. Thus, it is possible to operate them conveniently according to general structure and parts of each machine and tools (Malkoçoğlu, 2017; Burdurlu and Baykan, 1998; İlhan et al. 1990).

3.1 Drilling Machines

Drilling operations based on plans which are made for each furniture part are performed by simple or advanced semi-automatic and fully automatic machines. These machines used in the furniture production have quite different structures. Two different drilling systems are used depending on the distance between drill centres in these machines. For this purpose, 22 mm for solid products and 32 mm for panel production are applied. Portable drilling, multi spindle, column, multiple hinge boring, semi-automatic, through feed, point to point machines, and CNC machining centres are widely used. The machines and some important features are summarized below:

Semi-automatic drilling machine has a low capacity, and its working area is limited. Only, it can be processed on one or two surfaces of the furniture parts or both in the same time. Several models in which a wide range of drill bits can be installed (Fig. 2) for this machine.

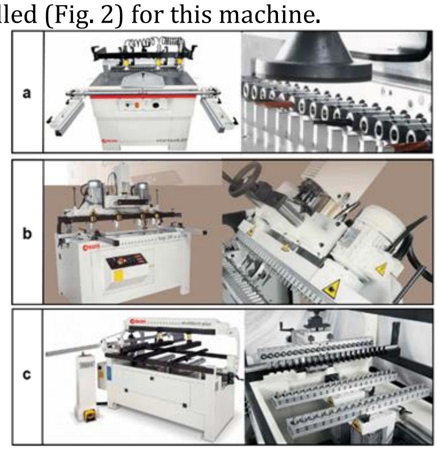

Figure 2: Some semi-automatic drilling machine types (Anonymous-2)

Through feed drilling machines provide configurability and a wider production ranges in comparison with semi-automatic drilling machines. It concentrates several machining operations in a single machine and can be equipped to suit requirements with upper vertical boring units and with horizontal units, to complete boring on 4 faces of the panel. These machines have a high productivity of up to 28 workpieces per minute, very fast set-up times (5-20 seconds), and 12 machining heads as many as 380 independent spindles (Fig 3).

Figure 3: Through feed drilling machine (Anonymous-2)

Point to point drilling machines are used in machining of wood, chipboard, MDF, plywood etc. Window and door parts which are hard to hold can be easily machined by means of independent vacuum pods. The biggest advantage of these machines is that they are compatible to edge banding. (Fig. 4).

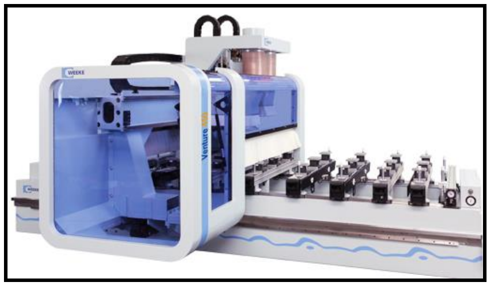

Figure 4: Point to point drilling machine (Anonymous-3)

Multi-spindle drilling machines constitute a popular group of woodworking machines used primarily in medium or small-sized furniture joinery shops. The design of drilling machines facilitates drilling operations in the vertical and horizontal position of the working assembly. Produced seats are most frequently used to mount dowels and doweled joints (Szymański and Pinkowski, 2012) (Fig. 5).

Figure 5: Multi spindle drilling machine

The operations in the column drilling machines (Fig 6-a) and portable drills (Fig 6-b) are adjusted manually. These are usually suitable for workshop type productions.

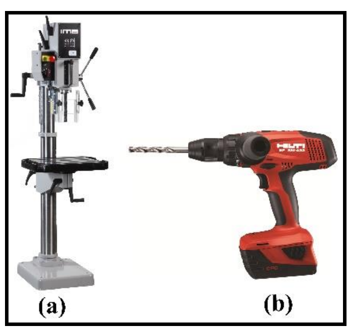

Figure 6: Column drilling machines and portable drill (Anonymous-4)

Single or multiple hinge boring machines are used for door production in various furniture products (Fig. 7).

Figure 7: Multiple hinge boring machine.

CNC machining centers are multifunction machines and widely used in furniture industry for various purposes as dimensioning, drilling, fitting, carving, grooving, sizing, edge bending and 3D machining (Fig. 8).

Figure 8: CNC machining center (Anonymous-2)

3.2 Drill Types and Characteristics

There are functionally significant effects of all parts forming the drill in machining of materials at high quality and capacities. For instance; drill point and eccentricity of drill body for machining tolerances; the chip gullet (number of flutes) for the optimal removal of the chips and the wearing of the tool and shank diameter, cutting edges, rake or helix angle, rpm and feed rates are directly related in terms of surface quality and capacity.

3.2.1 Drill Parts and Geometry

Drills are usually cutting tools used for routing, sizing or grooving besides drilling operations. They consist of main 4 parts (body, shank, flutes, point). Also, they have any other more characteristic as diameter, rake or helix angle, heel, land, spur etc. (Fig. 9).

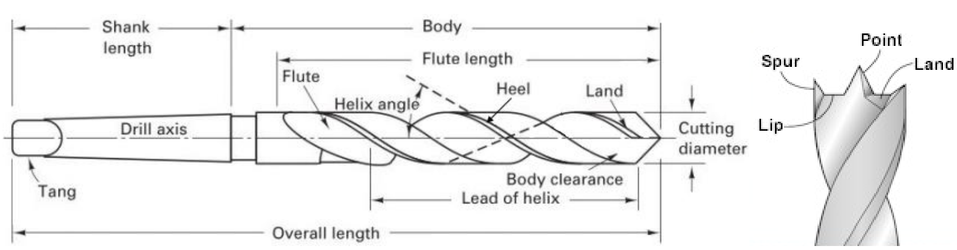

Figure 9: Basic drill geometry (Davis, 1989).

3.2.2 Drill Types

In terms of their functions, generally 6 different types drills are used in drilling operations in the furniture industry . These are dowel drilling, through hole drilling, hinge drilling, countersink, multi-purpose drilling and stepped drilling (Fig. 10).

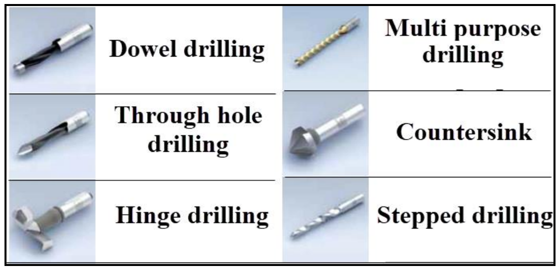

Figure 10: Drill types (Anonymous-1)

Dowel and through hole drills are used to drill tear-free dowel holes and blind holes in panels. There are two dowel drill designs (with and without heel) for both. Design without heel type is optimized dowel drill for machining panels in the furniture industry. There are minimum friction and feed forces as the flute with smaller diameter. And a loose countersink can be clamped on the shank. Design with heel type is used to drill holes in solid wood and for machines with insufficient guidance during drilling (Fig 11).

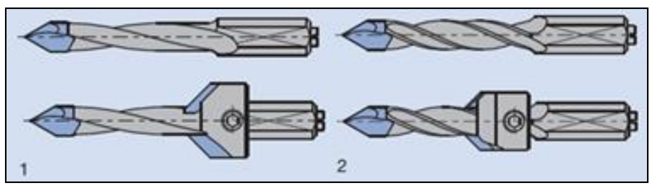

Figure 11: Through hole and dowel drilling designs (1. Design without heel, 2. Design with heel) (Anonymous-1)

Hinge drills that have usually 10 mm shank diameter are used to drill tear-free hinge holes. There are two types design: one with center point and one without center point. Design with center point is optimized for machining standard panels in the furniture industry. Short type is used to drill deep holes in thin panels (Fig 12).

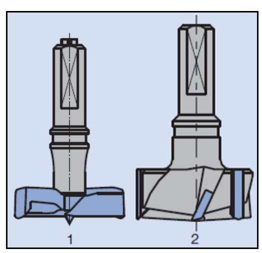

Figure 12: Hinge drilling designs (1. design with center point, 2. design without center point) (Anonymous-1).

Multi-purpose drills are used to drill holes for the furniture industry and in timber frame construction. There are three types drill, namely twist, levin and cylinder head. Twist drill is used to drill a hole deeper than possible with dowel drill and SP, HS, and HW cutting materials can be used. Levin type drill is used to drill a deep hole and has a spiral flute with a large chip gullet giving excellent chip clearance in cross section. Cylinder head drill is used to drill a tear-free hole in solid wood, for a blind hole, for a hinge hole and hole for a repair plugs (Fig 13).

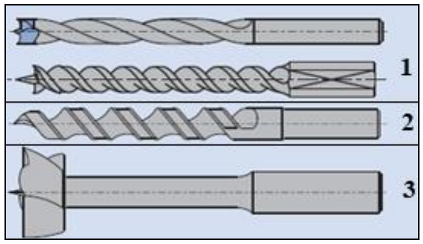

Figure 13: Multi-purpose drilling types (1. Twist drills, 2. Levin type drill, 3. Cylinder head drill) (Anonymous-1)

Countersink drill is used for a countersinking of hole. There are two drilling types as loose (for mounting on dowel drills) and single part countersink (for the additional countersinking of holes) (Fig 14).

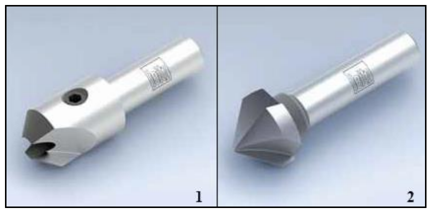

Figure 14: Countersink drilling types (1. Loose, 2. Single part) (Anonymous-1).

Step drill is used to drill a stepped hole. This drill type is characterized by two or more drilling operations. There are more than one type diameter cutters on single tool body. The hole diameter increases in each operation (Fig 15).

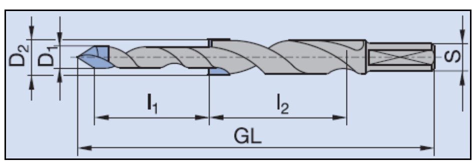

Figure 15: Stepped drilling type (Anonymous-1).

4 DRILL TYPES AND MACHINING CONDITIONS IN OPERATIONS OF VARIOUS MATERIALS IN DRILLING MACHINE

The structure, types and geometries of the drills depending on the intended use have an important place in the selection. Accordingly; the properties that should be considered based on the diameter of the drill types, cutting material, number of teeth, rpm and feed speed and machining materials are listed in Table 1.

Table 1: Drilling types, machines, machining conditions and materials (HW: Tungsten Carbide, HS: Highspeed Steel, DP: Polycrystalline Diamond, SP: Alloyed tool steel) (Anonymous-1; Anonymous-5-7).

Drill Types	Diameter (D)	Cutting Material - Number of teeth (Z)	RPM (r/min) X1000	Feed Rate (m/min)	Drilling machine types	Materials
1 Dowel drilling	3-25	HW - Z2	3-12	0,8-6,5	Point-to-point drilling machines, through feed drilling machines, CNC	Softwood/hardwood ,chipboard and fibre materials (MDF, HDF etc.), uncoated,
2	5-12	HW - Z2	3-9	0,7-2,5		

Through hole drilling	5-10	DP - Z1	4-9	0,8-2	machining centers, hinge boring machines, multi spindle units, column drilling machines[4], portable drills[4]	plastic coated, veneered etc., laminated veneer lumber (plywood, multiplex plywood etc.). elastomers[2], flame resistant particle[2] and solid resin glulam[2], fibre reinforced plastics[2], fire resistant particle[3], Plastics (thermoplastic, fibre reinforced etc.)[4], NF-metals (aluminum, copper etc.)[4], glued lumber[5], thermoplastic[6]
3 Hinge Drilling	15-40	HW-Z2, Z3	2,8-9	0,6-5		
	15-35	DP- Z2	2,8-7	0,6-2,5		
4 Countersink	15-20	HW	3-9			
5 Multi-purpose drilling	12-16	HW- Z1	3-7,5	0,5-2,5	With/without CNC routers control, machining centers, special cutting machines to machine frame parts, column drilling machines, drilling machines, multi spindle units, portable drills.	
	2-60	HW- Z2	1,2-9	0,25-4		
	5-12	HS- Z1	3-6	0,5-2,5		
	3-12	HS- Z2	1,5-4	0,8-2,8		
	45-40	SP- Z2	1-4	0,2-2,8		
6 Stepped Drilling	5,5-8,8	HW	3-6	0,8-2,8	Multi spindle units, CNC machining centers, portable drills.	

As indicated in Table 1, all types of drills can be used with softwood, hardwood, chipboard and fiber materials (MDF, HDF etc.), uncoated, plastic coated, veneered panels and laminated veneer lumbers (plywood, multiplex plywood etc.). Based on drilling machines; all drill types can be used with CNC machining centers and multi spindle units; point to point and through feed drilling machines can only be used with first 4 drill types. In addition, it is stated that the highest speed and feed rate are in dowel drilling operations and the lowest is in multi-purpose drilling operations. It can be stated that CNC drilling machines operate at higher speeds and feed rates than conventional machines.

In practice, there is usually no significant difference in rpm and feed speed. However, it can be stated that HW and DP based drills are used at higher speeds than HS and SP based drills in terms of cutting material type. Dowel, countersink and stepped drilling types are HW based with 2 cutters; through hole drilling types are HW and DP based with 1-2 cutters and multi-purpose drilling types are generally HW, HS and SP based with 2 cutters and have especially higher diameter.

5 PROBLEMS AND PROPOSED SOLUTIONS ENCOUNTERED WITH DRILLING OPERATIONS

The problems encountered with drilling operations and the proposed solutions can be summarized in 9 main sections (Table 2).

Table 2: Problems, causes and precautions in drilling operations (Anonymous-1; Anonymous-5-7).

Problem	Possible causes	Precautions
Drill wears quickly	• Feed rate per rotation too low	• Increase feed rate or reduce RPM (see charts on product pages).
High wear to spurs	• Tool remains stationary at the reversal point when drilling dowel holes • Abrasive workpiece material	• Reduce RPM or increase acceleration of the feed axis (when possible) or Change program. • Select drills with more wear resistant cutting-edge material (HW or DP).

Uneven edges (new drill)	• Feed rate per rotation too high as the bit enters or leaves the workpiece • Insufficient concentricity of drill • Insufficient centering on return stroke of the drill	• Reduce feed rate or increase RPM (see charts on product pages). Check concentric clamping of bit and chuck, Check spindle and chuck for deformation. • Check spindle and chuck for signs of wear. • Use drills with heel.
Chips and workpiece become hot	• Tool too long at the reversal point when drilling dowel holes	• Reduce RPM or increase acceleration of the feed axis (when possible). Change program.
Burn marks at the bore wall (new drill)	• Insufficient chip flow	• Clear gullet from time to time when drilling deep holes. Select drill type for high chip volumes (e.g. Levin type).
Bore too large	• Error in concentricity or the center point is not central	• Check boring bit clamping for con centricity. Check boring bit chuck and motor spindle for deformation and wear, Check the concentric running of the center point.
Unclean countersunk wood	• Chips jammed between flute and loose countersink	• Use one-piece stepped boring bit when machining solid wood.
Broken drill	• Wrong application parameters • Bore is full of chips • Non-uniform workpiece material • Premature loosening of workpiece clamping • Worn drilling spindle	• Reduce feed rate, increase RPM (see charts on product pages). • Clear gullet from time to time when boring deep holes. Select boring bit type for large chip quantities (e.g. Levin type). • Check workpiece for foreign objects, Reduce feed rate. • Adjust program. • Check spindle bearing. Repair if necessary.
Broken spurs	• High feed rate when drilling hard workpiece materials • Workpiece material not suitable for machining with spurs	• Reduce feed rate. • Grind off spur and chamfer cutting edge at change-over to the minor cutting edge.

6 RESULTS AND SUGGESTIONS

Different types of machines and drills are used in furniture, joinery and building industry for drilling operations. In these operations, it is generally imposed on from much the cutter company catalogs as well as theoretical information. But; in the proper machining of wood and wood-based materials which have heterogeneous structure, these factors must be considered:

- High carbon content drills (HW/DP) which are more durable in terms of tool wear should be preferred in machining with high rpm and feed rates.
- The optimal rpm and feed rates should be selected for drilling machines. It should be considered that high rpm and low feed rate affect wear adversely .
- Improper drill geometry negatively affects surface quality, capacity and tool wear. In particular, insufficiency of chip gullet increases the heating and hence wearing of the tool.
- Material moisture content is important in the machining process. Accordingly, lower feed rates should be usually preferred considering higher moisture content.

As a result; wood and wood-based materials should be efficiently machined based on surface quality, production capacity, and costs. In this respect, it can be recommended to continue the scientific researches on the optimization of the machining in the forest products industry such as furniture, woodwork and wood building areas and to make appropriate applications accordingly.

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Effect of Different Ratio Peracetic Acid Bleaching on Colour Changing of Spruce Wood and Beech Wood

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ABSTRACT

Final quality of finishing depends on various elements including application method of coating, characteristics of substrate such as porosity, chemical structure, and interaction between coating and the substrate. The purpose of this work is to determine some surface properties of peracetic acid bleached specimens of wood species with cellulosic varnish as a function of peracetic acid ratio. For this purpose, beech which hardwoods species and spruce which softwoods species were used and also cellulosic varnish were used and peracetic acid with there diferent raito (undiluted, 1/3 diluted and 1/6 diluted) was used. The color changing of the samples was determined. As a result, the highest colour changing was determined of bleached beech wood with peracetic acid diluted 1/3.

KEYWORDS: Spruce, Colour changing, Bleaching, Peracetic acid (undiluted, 1/3 diluted and 1/6 diluted)

1 INTRODUCTION

The color of furniture is as important as its shape, dimension, form, and balance. In interior decoration, carpets, curtains, etc. should be in harmony with wall, ceiling, and base coverings. The natural color of wood materials, in many cases, cannot meet these requirements. Therefore, to provide color compatibility, wood may be subjected to a bleaching process prior to surface finishing. Bleaching is a process in which some specific chemical solutions are applied to turn the color of wood lighter. In the furniture industry, this process is carried out on some tree woods (mahogany, oak, etc.) together with surface treatments. Bleaching and impregnation affect the wood structure and specifications such as hardness, color, and brightness to some extent. The hardness of the varnish layer is the most important parameter for the protection of wood against external factors (Edwin and Carter, 1983).

Each type of wood species has its own variation of color, texture and grain pattern. Some cuts of solid wood and flitches of veneer may be light eror darker than others. To obtain a uniform color for use in furniture, the choice is generally limited to a color equal to or darker than the natural color of the wood. The only way to avoid this darkening is to bleach the wood or use a bleaching toner on the wood before finishing (Gerard, 1983). There are two reasons for the discoloration of wood. The first is damage, drying of branches, disease etc. in alive trees (Shigo, 1973.). The second is oxidation, iron stains, fungi discoloration and chemical stains occurring on wood cut from trees. This kind of discoloration degrades the quality of wood material (Bauch, 1999). Bleaching is there moving of color pigments in the structure of wood using various bleaching chemicals and bleaching systems (Ejechi and Obuekwe, 1996). While there are many materials available, that we most common chemicals used as wood bleaching agents are sodium hydroxide and hydrogenperoxide (Edwin and Carter, 1983.)

Physical characteristics in particular appearance of the finished product is affected by not only the type of finish but also interaction between finish and the substrate. It is well known fact that species, wood density and roughness of the substrate are considered major parameters to have an effective finishing process. Wood being non-homogenous material also creates certain challenges for an ideal finished member. Sapwood and heartwood ratio within its anatomical structure would also be important element affecting interaction between the finishing material and the substrate. In certain species having extractives and other chemicals in the heartwood would create some barrier having good adherence of finish to the surface of wood substrate. Various studies investigated adhesion strength of different wood species coated using different types of finishing materials (Jaic and Zivanovic, 1995; Jaic et al., 1996; Zavarin, 1984; Ozdemir et al., 2009).

The main objective of the present research was to evaluate bleaching effect on the varnish properties of spruce wood and beech. Five different bleach chemicals which sodium hydroxide-hydrogen peroxide, oxalic acid, peracetic acid, peracedic acid diluted 1/3, ,peracedic acid diluted 1/6 and spruce wood (*Picea orientalis* L. (Link.)) were used. In this study, effect of heartwood, sapwood ratio and flat, edge grained cross section of colour changing on spruce wood and beech were determined it.

2 MATERIALS AND METHODS

2.1 Wood Species

The wood species, namely spruce (Picea orientalis L. Link) and beech (Fagus orientalis L) were used fort the experiments. A total of 300 defect free heartwood (flat and edge grained) and sapwood samples (flat and edge grained)with dimensions of 400 mm by 100 mm by 200 mm were prepared and conditioned in a climate room having a relative humidity of 65 % and a temperature of 20 °C until they reach to equilibrium moisture content of 12%. Conditioned specimens were sanded with 80-grit and 180-grit sand paper using a commercial sanding machine (Feed speed: 12 m/min, sanding pressure: 0.5 MPa).

2.2 Bleaching Chemicals

All specimens bleached with five different chemicalss, namely, sodium hydroxide-hydrogen peroxide, oxalic acid, peracetic acid, peracedic acid diluted 1/3, peracedic acid diluted 1/6.

2.3 Varhish Applying

In the next step both heartwood and sapwood specimens were coated with cellulosic based varnish using a pressurized spray gun at a spread rate of 120 g/m^2 and cured in the convection drying chamber.

2.4 Colour measurement

The CIELAB system is derived from CIE (International Commission on Illumination) Standard Colour Table by transforming the original X, Y and Z colorimetric coordinates (colour values) into three new reference values of L*, a* and b*. The objective of this transformation is a colour-space to aid in the numerical classification of colour differences. Each colour in the CIELAB colour-space (Fig. 1) has a unique location defined by its Cartesian coordinates with respect to the axes L*, a* and b*where L* is the degree of lightness, ranging from white (100) to black (0) along a grey scale, a* is the degree of redness and greenness, and b* is the degree of yellowness and blueness.

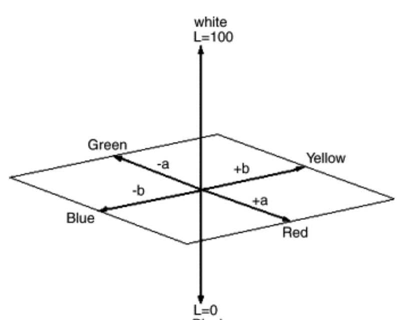

Figure 1: The CIE L*a*b* colour space

Colour measurements were conducted according to ISO 4287-2 standard. L*, a*and b* colour coordinates for each sample group were determined before and after high temperature drying, exposure to laboratory indoor conditions and preservative treatments. These colour space values were used to calculate the total colour change (ΔE*) as a function of treatments applied to veneers according to the following equations:

$$\Delta L^*=Lt^*-Li^* \quad (1)$$

$$\Delta a^*=at^*-ai^* \quad (2)$$

$$\Delta b^*=bt^*-bi^* \quad (3)$$

$$\Delta E^*=(\Delta L^*)2+(\Delta a^*)2+(\Delta b^*)2 \quad (4)$$

3 RESULTS AND DISCUSSION

It was given values of finishing colour changes in spruce and beech wood in Table 1 and 3.

Table 1: Finishing color changes in spruce wood

	SAPWOOD				HEARTWOOD			
	Edge grain	Edge grain*	Flat grain	Flat grain*	Edge grain	Edge grain*	Flat grain	Flat grain*
L	77.05	82.12	79.98	78.79	79.58	77.52	75.89	80.11
a	6.88	1.85	5.88	2.92	5.69	3.23	6.82	2.45
b	18.76	22.63	21.31	23.77	21.18	20.96	21.65	20.46
ΔE		**8.12**		**4.03**		**3.22**		**6.19**
L	78.73	78.50	80.76	79.51	83.74	81.35	81.36	78.98
a	6.50	7.42	4.95	6.65	4.06	6.31	5.07	6.89
b	19.97	20.60	17.92	19.79	20.92	21.86	19.75	20.23
ΔE		**1.14**		**2.82**		**3.41**		**3.03**
L	76.68	80.28	75.29	80.31	77.86	80.65	70.56	78.57
a	6.93	5.20	7.14	4.93	6.21	4.67	6.18	5.11
b	19.48	22.21	19.00	21.06	20.26	21.59	19.66	21.35
ΔE		**4.84**		**5.86**		**3.45**		**8.26**
L	78.03	82.29	77.94	81.62	73.65	79.57	75.69	80.96
a	5.91	4.28	6.25	4.30	7.55	4.98	6.63	4.62
b	17.96	22.13	18.63	21.25	22.21	23.62	20.99	21.59
ΔE		**6.18**		**4.92**		**6.61**		**5.67**
L	76.11	81.77	77.70	83.69	80.15	83.28	80.70	83.98
a	6.91	4.20	5.82	3.34	5.85	3.94	5.64	3.73
b	18.90	22.17	18.23	20.18	20.90	21.34	21.44	21.41
ΔE		**7.08**		**6.77**		**3.69**		**3.80**

Table 2: The color change (ΔE) values in the resulting spruce wood of the bleaching process

	SAPWOOD		HEARTWOOD		
	Edge grain	Flat grain	Edge grain	Flat grain	
2	8.12	4.03	3.22	6.19	**5.39**
3	1.14	2.82	3.41	3.03	**2.60**
4	4.84	5.86	3.45	8.26	**5.60**
5	6.18	4.92	6.61	5.67	**5.84**
6	7.08	6.77	3.69	3.80	**5.33**
	5.47	**4.88**	**4.08**	**5.39**	

1:Control, 2-sodium hydroxide-hydrogen peroxide,3-oxalic acid, 4-peracetic acid, 5-peracedic acid diluted 1/3, ,6-peracedic acid diluted 1/6

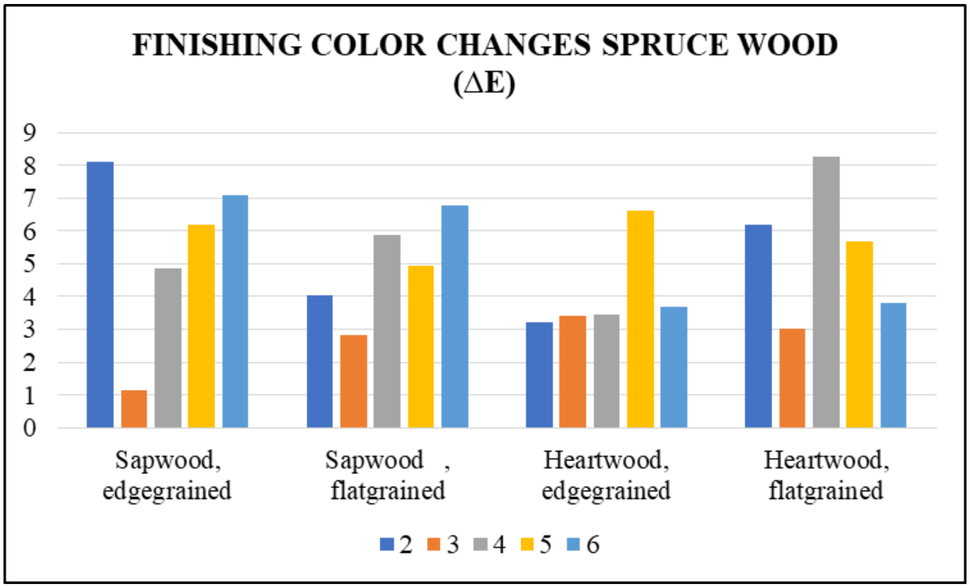

Figure 2: Color change in spruce wood (ΔE)

According to this, when the roots of radiant wood of radiant wood were subjected to the highest color change 2 (8,12) bleaching process results, it was followed by bleaching process 6, 5,4 and 3, respectively.

The highest color change of the sapwood of the sapwood was obtained by the bleaching process with the 6th line (6.77), followed by the bleaching process with 4, 5 and 2, respectively, and the bleaching process with the 3 line (2.82) was obtained.

In the core wood radial section, the highest color change was obtained in the bleaching process 5 (6.61), followed by the bleaching process 6,4,3 in the order, and the bleaching process in the 2 line (3.22) was obtained.

When the results of the bleaching process with the 4th line (8,26) were obtained, the bleaching process was 2,5,6 and 5, respectively, while the 3 line (3,03) bleaching process results were obtained.

Table 3: Finishing color changes in beech wood

		SAPWOOD				HEARTWOOD			
	Edge grain *	Flat grain	Flat grain*	Edge grain	Edge grain*	Flat grain	Flat grain*	63,89	78,36
	a	10,16	0,09	10,63	1,67	10,69	0,66	11,84	3,50
Edge grain	***b***	25,59	14,54	24,32	14,86	26,25	13,60	24,80	18,91
	ΔE		**23,25**		**19,02**		**23,49**		**17,71**
3.00	***L***	71,24	69,22	72,82	71,24	69,07	68,59	69,76	69,26
	a	11,09	13,44	10,13	11,86	11,67	13,06	11,27	12,31
	b	26,87	27,35	23,71	23,73	27,12	26,05	26,36	24,83
	ΔE		**3,14**		**2,34**		**1,82**		**1,92**
4.00	***L***	71,79	76,99	73,74	77,02	72,54	77,40	69,62	76,34
	a	10,59	7,71	9,03	6,97	10,15	7,35	11,53	8,05
	b	25,60	25,37	22,60	23,12	25,47	23,81	26,39	24,69
	ΔE		**5,95**		**3,91**		**5,85**		**7,76**
5.00	***L***	71,23	80,28	71,52	77,28	68,65	76,40	67,01	74,68
	a	10,73	6,51	9,77	6,83	11,60	7,79	11,86	8,44
	b	25,46	25,17	23,37	23,30	27,39	26,14	26,40	26,48
	ΔE		**9,99**		**6,47**		**8,73**		**8,4**
6.00	***L***	72,08	81,50	75,53	82,21	68,39	77,09	67,95	78,09
	a	9,94	5,87	7,76	4,93	11,55	7,21	11,16	7,08
	b	24,30	24,29	20,47	22,01	27,05	25,41	24,79	25,15
	ΔE		**10,26**		**7,42**		**9,86**		**10,94**

Table 4: The color change (ΔE) values in the resulting beech wood of the bleaching process

	SAPWOOD	SAPWOOD	HEARTWOOD	HEARTWOOD	
	Edge grain	Flat grain	Edge grain	Flat grain	
2	23,25	19,02	23,49	17,71	**20,87**
3	3,14	2,34	1,82	1,92	**2,31**
4	5,95	3,91	5,85	7,76	**5,87**
5	9,99	6,47	8,73	8,4	**8,40**
6	10,26	7,42	9,86	10,94	**9,62**
	10,52	**7,83**	**9,95**	**9,35**	

1:Control, 2-sodium hydroxide-hydrogen peroxide,3-oxalic acid, 4-peracetic acid, 5-peracedic acid diluted 1/3, ,6-peracedic acid diluted 1/6

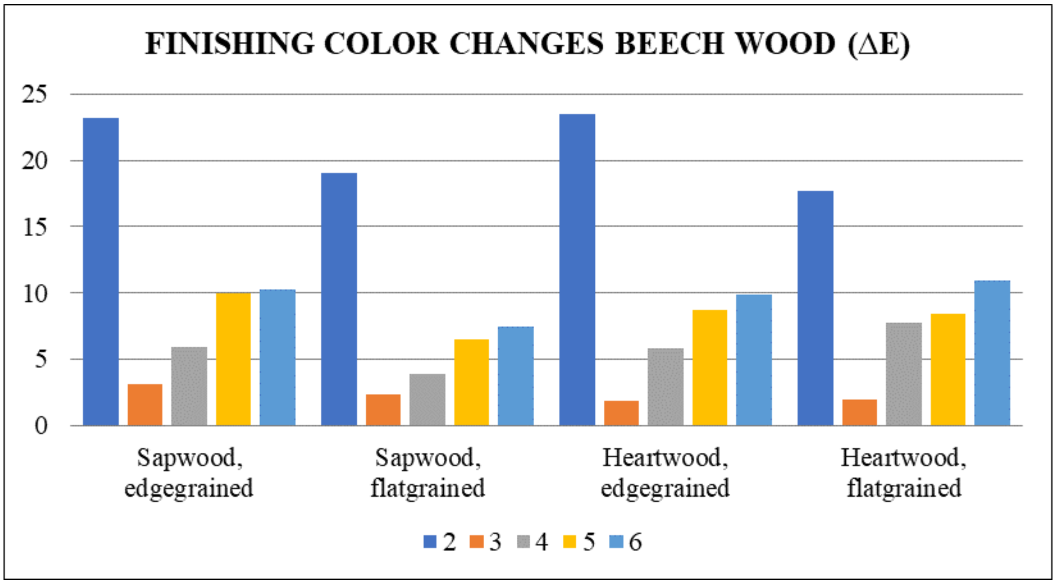

Figure 3: Color change in beech wood (ΔE)

According to this, when the roots of the sapwood of radiant wood were subjected to the highest color change 2 (23,25) bleaching process, bleaching process with 6,5,4 bleaching was observed respectively and bleaching process with 3 lines (19,02) was obtained.

The highest color change of the sapwood of the sapwood was obtained when bleaching process 2 (19.02) was obtained, while it was followed by bleaching process of 6,5,4 and 3, respectively.

In the core wood radial section, the highest color change 2 (23,49) bleaching results were obtained, followed by 6,5 and 4 bleaching, respectively, while the lowest 3 (1,82) bleaching results were obtained.

When the results of the bleaching process with the highest color change 2 (17,71) were obtained, it was found that the bleaching process with 6, 5 and 4 points was followed respectively, whereas the result with 3 lines (1.92) bleaching results was obtained.

4 CONCLUSION

The effect of bleaching chemıcals on the color changing of spruce wood and beech wood were evaluated. Bleaching chemicals increased on surface activation.

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Influence of Bleaching Chemicals on The Some Varnishing Properties of Coated Fir Wood

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Effect of Different Ratio Peracetic Acid Bleaching on Colour Changing of Spruce Wood and Beech Wood

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ABSTRACT

The paper presents the aim and objectives of a research project concerned with the effect of bleaching chemicals on surface adhesion strength and surface roughness in Fir wood. This purpose five different bleach chemicals which sodium hydroxide-hydrogen peroxide, oxalic acid, peracetic acid, peracedic acid diluted 1/3, ,peracedic acid diluted 1/6 and fire wood (Abies normanniana) were used. The project deal with effect of heartwood, sapwood ratio and flat, edge grained cross section surface roughness and adhesion strength on fir wood were determined. All specimens were varnished with cellulosic varnish. Surface roughness of coated samples were also measured using a stylus method. Adhesion strength was determined according to related standarts for bleaching and control samples. The results indicated that, all bleaching chemicals were increased the surface roughness. While the lowest adhesion strength was determined for the samples treated with oxalic acid bleaching, the highest adhesion strength was determined for the samples treated with perasetic acid bleaching.

KEYWORDS: Fir, Bleaching, Surface roughness, Adhesion strength

1 INTRODUCTION

Surface coating of wood is one of the most important parameters influencing properties of wood products in laminated applications. Final quality of coating depends on various elements including application of coating method, characteristics of substrate such as porosity, chemical structure, and interaction between coating and the substrate (Good, 1976; Richter et al., 1995, Kolmann and Cote1984).

To obtain a uniform color for use in furniture, the choice is generally limited to a color equal to or darker than the natural color of the wood. The only way to avoid this darkening is to bleach the wood or use a bleaching toner on the wood before finishing (Gerard, 1983). There are two reasons for the discoloration of wood. The first is damage, drying of branches, disease etc. in alive trees (Shigo, 1973). The second is oxidation, iron stains, fungi discoloration and chemical stains occurring on wood cut from trees. This kind of discoloration degrades the quality of wood material (Bauch, 1999). Bleaching is there moving of color pigments in the structure of wood using various bleaching chemicals and bleaching systems (Ejechi and Obuekwe, 1996). While there are many materials available, that we most common chemicals used as wood bleaching agents are sodium hydroxide and hydrogenperoxide (Edwin and Carter,1983.)

In another study moisture content of different wood species was determined as an important factor influencing overall adhesion strength of the finish (Ozdemir, T.; Hiziroglu, S.;Malkocoglu 2009). Zavarin found that porosity of wood can be considered as an important factor influencing adhesion strength of finished samples (Zavarin, 1984). Another past study evaluated surface characteristics of radial and tangential grain orientations of three different hardwood species and concluded that rougher surfaces required higher amount of finishing material and overall quality of finishing was influenced by the surface roughness of the substrate (Ozdemir and Hiziroglu, 2007).Adhesion strength of oak and beech specimens coatedpolyure than varnishes was studied by Jaicand Zivanovic. It was found that 10.3% moisture content of the samples resultedin the highest adhesion values for both species (Burdurlu et. al., 2006).Pull-off test set up is one of the most commonly used one to determine adherence quality between finish and substrate. Adhesion strength of cellulosic varnish coated wood species as function of their surface roughness was evaluated using a pull-off type equipment by Ozdemir and Hiziroglu (Ozdemir et al., 2009).

Currently there is very limited information on adhesion strength of wood species bleached with some chemicals as function of sapwood and heartwood ratio. Therefore, the objective of this work was to get an initial data on adhesion strength characteristics of such samples from a species, namely fir coated with cellulose varnish. Results from this work are expected to be used as quality control tool to finish these species with a better efficiency and effectively so that any furniture of cabinet members manufactured from these species can be used more efficiently during their service life.

The main objective of the current study was to evaluate bleaching effect on the varnish properties of fir wood. The aim was the examinate the effect of five different bleach chemicals which sodium hydroxide-hydrogen peroxide, oxalic acid, peracetic acid, peracedic acid diluted 1/3, peracedic acid diluted 1/6 and fir wood (*Abies normanniana*) were used. In this study, effect of heartwood, sapwood ratio and flat, edge grained cross section surface roughness and adhesion strength on fir wood were determined.

2 MATERIALS AND METHODS

The wood species, namely fir wood (*Abies normanniana*) were used fort the experiments. A total of 300 defect free heartwood (flat and edge grained) and sapwood samples (flat and edge grained)with dimensions of 400 mm by 100 mm by 200 mm were prepared and conditioned in a climate room having a relative humidity of 65 % and a temperature of 20 °C until they reach to equilibrium moisture content of 12%. Conditioned specimens were sanded with 80-grit and 180-grit sand paper using a commercial sanding machine (Feed speed: 12 m/min, sanding pressure: 0.5 MPa). A stylus type equipment, Mitutoyo SJ-301 profil meter was employed to measure surface roughness of the samples. Equipment has stylus with 0.5 µ radius and 90o contact angle running a speed of 0.5 mm/s. A total of 40 random measurements with a span of 15 mm were taken from the surface of each sample in radial and tangential direction across the grain orientation. Mean peak-to-valley height (Rz) which was used as an indicator for the surface quality of the samples (Wick et al., 1998; Vistosyte et al., 2012). After the first testing for surface roughness, all specimens bleached with five different chemicals, namely, sodium hydroxide-hydrogen peroxide, oxalic acid, peracetic acid, peracedic acid diluted 1/3, peracedic acid diluted 1/6. After the bleaching, all specimens tested same methods for surface roughness. In the next step both heartwood and sapwood specimens were coated with cellulosic based varnish using a pressurized spray gun at a spread rate of 120 g/m^2 and cured in the convection drying chamber.

Erichsen Adhesion-525 MC pull-off type tester was employed for adhesion strength evaluation of the specimens. Twenty five random measurements were taken from the surface of the samples by gluing steel head with 20 mm diameter using epoxy resin on the samples. A constant speed of 100 mm/min was applied the force to the surface layer by pulling the coating from the surface and adhesion strength value of the finishing was determined in N/mm^2 on the display of the pull-off testing unit. Finally variance analysis (ANOVA) and Duncan tests were used to analyse the experimental results.

3 RESULTS AND DISCUSSION

It was given results of percentage of surface roughness in Table 1.

Table 1: Results of percentage of surface roughness

		2	3	4	5	6
Sapwood	**Edge Grained**	94,692 (20,831)	57,45 (14,731)	58,140 (15,381)	48,494 (8,321)	70,616 (7,180)
	Flat Grained	36,543 (11,855)	58,782 (14,387)	54,843 (11,455)	65,611 (14,886)	95,025 (17,401)
Heartwood	**Edge Grained**	126,260 (22,336)	117,09 (24,613)	47,274 (16,125)	80,662 (22,007)	98,126 (21,936)
	Flat Grained	42,807 (7,725)	71,371 (19,640)	137,440 (33,721)	79,273 (19,326)	94,121 (22,375)

2-sodium hydroxide-hydrogen peroxide,3-oxalic acid, 4-peracetic acid, 5-peracedic acid diluted 1/3, ,6-peracedic acid diluted 1/6

The results of percentage of surface roughness presented in table 1. Statistical analysis (Table 1) showed that there was a significant effect between five different bleach chemicals [sodium hydroxide-hydrogen peroxide, oxalic acid, peracetic acid, peracedic acid diluted 1/3, peracedic acid diluted 1/6 on the fir wood. This study effect of heartwood, sapwood ratio and flat, edge grained cross section surface roughness on fir wood were determined (Figure 1). As it is expected that surface roughness is usually considered as intent physical property of wood and wood based products. According to table 1, fir wood edge grained sapwood which was pre-treated with2-sodium hydroxide-hydrogen peroxide the highest surface roughness value with 94.692. The fir wood flat grained sapwood which was pre-treated with-peracedic acid diluted 1/6 had the highest surface roughness value with 95.025. The fir wood edge grained heartwood which was pre-treated sodium hydroxide-hydrogen peroxide had the highest surface roughness value with 126.260. The spruce flat grained heartwood which was pre-treated with peracetic acid had the highest surface roughness value with 137.44.

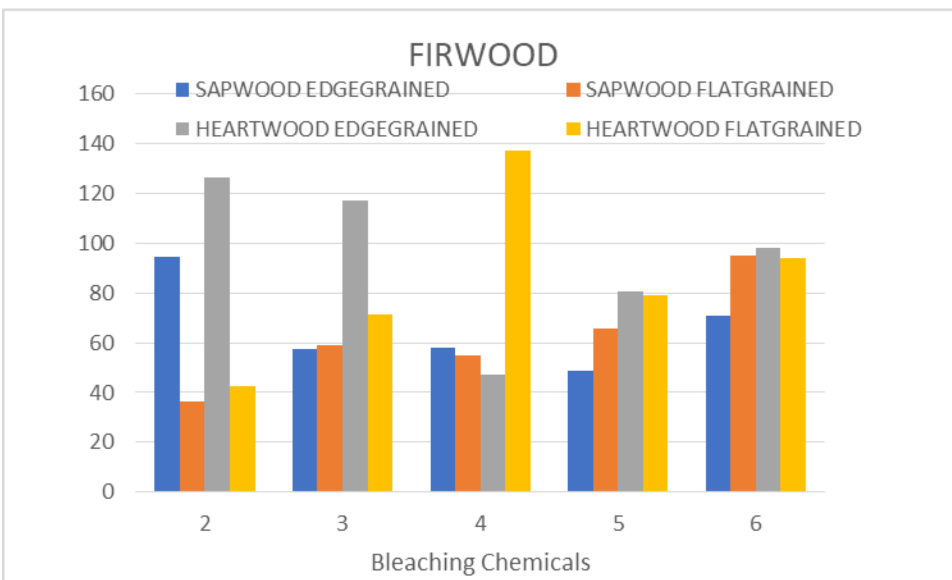

Figure 1: Results of percentage of surface roughness(%)

Table 2: Results of percentage of adhesion strength

SPRUCE				
Sapwood/Heartwood	Edgegrain/flatgrain	NO*	Average	Standart Devision
Sapwood	EdgeGrain	1	1,44	0,21
		2	1,6	0,09
		3	0,68	0,23
		4	1,71	0,09
		5	1,68	0,11
		6	1,65	0,14
		Toplam	1,46	0,39
	FlatGrain	1	1,62	0,12
		2	1,74	0,08
		3	0,75	0,12
		4	1,78	0,08
		5	1,78	0,12
		6	1,7	0,14
		Toplam	1,56	0,38
Heartwood	EdgeGrain	1	1,55	0,29
		2	1,67	0,19
		3	0,83	0,41
		4	1,71	0,12
		5	1,68	0,14
		6	1,66	0,11
		Toplam	1,52	0,38
	Flatgrain	1	1,57	0,24
		2	1,69	0,18
		3	0,77	0,34
		4	1,74	0,13
		5	1,7	0,15
		6	1,69	0,12
		Toplam	1,53	0,4
*1:Control, 2-sodium hydroxide-hydrogen peroxide,3-oxalic acid, 4-peracetic acid, 5-peracedic acid diluted 1/3, ,6-peracedic acid diluted 1/6				

According to the results of analysis to examine the effect of bleaching on the% roughening of the fir wood, the effects of the core and sapwood, radial and tangential sections, the highest surface roughness was obtained when the core and sapwood were compared in the fir wood, resulting in the bleaching of the tangential section 4 (137,440) . The lowest surface roughness was obtained as a result of the treatment of the raw wood tangential section 2 (36,543) bleaching agent.

The results of the analyses to examine the effects of radial and tangential sheeting on the% roughness of the fir wood in the fir wood were influenced by the tangential section of the living wood, while the tangential section of the wood panel was effective. If we examine the table in detail, that is to say in terms of bleaching operations, the fir wood has the highest surface roughness (94, 929) and the lowest surface roughness with 5 (48, 494) bleaching. The lowest surface roughness of the sapwood with the 6th line (95,025) bleaching was highest and the bleaching with 2 lines (36,543) was the lowest. In fir wood, the core wood radial cutting line 2 (126,260) has the highest bleaching and the 4th line (47,274) bleaching has the lowest surface roughness. In the fir wood, the core wood tangent sheathe 4 (137,440) bleaching was the highest and the second (42,807) bleaching the lowest surface roughness was obtained.

Table 3: Statistical analysis of the roughness and adhesion strength test results.

Surface Roughness					
Source	Sum of squares	df	Mean square	F value	Significance level
Effect of heartwood and sapwood (A)	19387,492	1	19387,492	57,034	***
Effect of flat and edge	1190,423	1	1190,423	3,502	NS
Effect of bleaching	5719,358	4	1429,840	4,206	**
AxB	199,836	1	199,836	0,588	NS
AxC	2512,802	4	628,201	1,848	NS
BxC	44155,634	4	11038,908	32,474	***
AxBxC	18906,677	4	4726,669	13,905	***
Error	33992,888	100	339,929		
Total	832587,092	120			
Adhesion Strength					
Source	Sum of squares	df	Mean square	F value	Significance level
Effect of heartwood and sapwood (A)	0,015	1	0,015	0,466	NS
Effect of flat and edge	0,224	1	0,224	6,806	*
Effect of bleaching	30,003	5	6,001	181,919	***
AxB	0,108	1	0,108	3,286	NS
AxC	0,049	5	0,01	0,3	NS
BxC	0,131	5	0,026	0,792	NS
AxBxC	0,073	5	0,015	1,442	NS
Error	7,125	216	0,033		NS
Total	594,538	240			NS

N.S: Non-significant *Significant at the α=0.05 level **Significant at the 0.01 level *** Significant at the α=0.001 level

Table 4: Duncan test results

Strength Properties	Factors	LS Mean	Homogenous Groups*
Percentage of Surface Roughness	Bleaching Chemicals		
	sodiumhydroxide-hydrogen	75,08	ab
	peroxide	76,17	ab
	oxalic acid	74,42	a
	peracetic acid	68,51	b
	peracedic acid diluted 1/3	89,47	a
	peracedic acid diluted 1/6		
	Grain		
	Edge grain	79,881	a
	Flat Grain	73,582	a
	Wood		
	Heartwood	89,442	a
	Sapwood	64,021	b
Adhesion Strength	Bleaching Chemicals		
	Control	1,55	b
	sodiumhydroxide-hydrogen	1,68	c
	peroxide	0,74	a
	oxalic acid	1,74	d
	peracetic acid	1,72	cd
	peracedic acid diluted 1/3	1,68	cd
	peracedic acid diluted 1/6		
	Grain		
	Edge grain	1,493	a
	Flat Grain	1,554	a
	Wood		
	Heartwood	1,531	a
	Sapwood	1.515	a

4 CONCLUSION

The effect of bleaching chemicals on the fir wood quality was evaluated. Bleaching chemicals increased on surface activation. Thus, the results indicated that, all bleaching chemicals were increased the surface roughness. The highest adhesion strength was determined for peracetic acid bleaching.

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The Low-Velocity Impact Behaviour of Wood Skinned Sandwich Composites with Different Core Configurations

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ABSTRACT

In this paper an experimental investigation on the low-velocity impact response of wood skinned hybrid sandwich composites was presented. Firstly, the impact damage analyses were made on different thermo-wood materials; ashwood, ıroko and pinewood at low speeds with different energy levels. And so the ashwood one was observed as the most suitable skin for sandwich design. Several alternative design configurations were developed by using rubber-cork and E-glass composite layers between the foam core and wood skin in order to improve the impact performance of conventional sandwich composites. Low-velocity impact (LVI) tests were performed using a drop weight test machine at different impact energies and destructive cross-sectioning was performed to examine the interior damage growth and penetration depth of the specimens. The impact performances of the specimens were evaluated in terms of energy absorption capacity, maximum contact force and penetration depth. The multi-core design concept significantly improved the energy absorption capacity with a reduced extent of impact induced damage. The proportion of recyclable materials in each configuration and the energy absorption levels per unit cost were also presented for the interest of product designers.

KEYWORDS: Wood skin, Sandwich structures, Impact behaviour

1 INTRODUCTION

Low carbon emissions and sustainable development are shared goals in the transportation vehicles, and one way to achieve them is to implement lightweight materials based on renewable materials. Thus, renewable materials like woods are emerging as a possible alternative to non-renewable materials (Bovea & Vidal, 2004; Matos & Simplicio, 2006). In practice, wood–based materials are widely used for meeting the requirements of marine applications in sandwich designs in particular for their sustainability, recyclability and esthetical appearance in addition to high stiffness and low weight characteristics(Zenkert, 1995). They are mainly used as components of the structural bulkheads and decks, partitions or elements for ceilings and floor structures for boat interior applications (Negro, Cremonini, Zanuttini, Properzi, & Pichelin, 2011).

Wood-based lightweight composites belong to the family of sandwich panels, comprise of two thin and stiff skins bonded to a thick, inner soft core(Cremonini, Negro, Properzi, & Zanuttini, 2008). However, sandwich structures are susceptible to various impact loads and may exposed to different impacts during their service life(Zenkert, 2009). It is generally accepted that low-velocity impacts (LVI) occur at velocities below 10 m/s, and may result in significant damage such as localized skin damage, core crushing and debonding between skin and core. So, these damages can reduce the strength of whole structure under quasi-static and dynamic loads (Abrate, 1997, 2005) . With the aim of increasing LVI damage tolerance, hybrid sandwich structure concepts have been developed by using intermediate layers strategically placed between the face sheets and the core material(Mamalis, Spentzas, Pantelelis, Manolakos, & Ioannidis, 2008). It was observed that introducing ductile intermediate layers beneath external skins in foam core sandwiches improved protection against core crushing under LVI loadings(Dvorak & Suvorov, 2006; Suvorov & Dvorak, 2005).On the other hand, using a stiffer composite sheet into a traditional single sandwich structure decreased the local effect of the impact energy and so it was spread in a wider area within the structure(Jedari Salami, Sadighi, Shakeri, & Moeinfar, 2013; Jiang & Shu, 2005). Experimental results indicated that an increased damage resistance may be obtained as a function of the mechanical properties of the intermediate layers and their location(Dvorak & Suvorov, 2006; Jedari Salami et al., 2013; Jiang & Shu, 2005; Suvorov & Dvorak, 2005).

Eco-friendly structures receive increasing attention due to their environmental benefits such as recyclability and sustainability. Despite their popularity, they have intrinsically lower mechanical properties which have to be complemented with synthetic materials to form stronger hybrid structures. Especially, wood materials are relatively brittle and have poor resistance to impact loads (Hildebrand, 1997; Sutherland, 2017). For instance, balsa wood cores perform well under static loading, but they fail catastrophically under impact loading due to the low fracture toughness along the grain direction(Daniel, Abot, Schubel, & Luo, 2012). With regard to plywood structures, at high impact energy levels, they are perforated with heavy loss of structural integrity, which can be undesirable in most applications(Susainathan, Eyma, De Luycker, Cantarel, & Castanie, 2018). Previous studies also revealed that the impact damage tolerance of such wood-based materials can be increased by using them in conjunction with composite materials in sandwich designs (Balıkoğlu, Demircioğlu, İnal, Arslan, & Ataş, 2018; Shin, Lee, & Cho, 2008; Susainathan et al., 2018).

Motivated by the current trend towards the natural-based composites, this study focused on a development of new multi-layered wood-skinned sandwich panels made of thermo-wood materials, namely, heat-treated wooden material which have been used as the skins with PVC foam core. By employing a compressible intermediate layer and a stiffer composite internal sheet, it was aimed to enhance the LVI performance of wood-skinned sandwich composites. The effects of rubber-cork layer thickness and foam core material on the impact resistance and damage mechanisms of the wood-skinned sandwich composites were characterised by energy absorption rates, contact forces and penetration depths. The characteristics of the impact damage mechanisms were analysed by the cross-sectional images of the impacted specimens. As a result, this experimental study focused on the LVI behaviour of environmentally friendly wood-skinned sandwich composites. The outcomes of this study may provide some useful information on how effectively improve the LVI damage resistance of commercial available PVC core wood marine sandwich panels.

2 EXPERIMENTAL STUDY

2.1 Materials and Manufacturing Method

Heat-treated (thermowood) material was chosen as skin for proposed sandwich concepts. Heat-treated wood (ThermoWood®) has been used in indoor and outdoor applications such as furniture, decking, cladding and flooring of the boats(Kol, 2010). The main benefits of this process are distinct enhancements in hygroscopicity, dimensional stability and biological durability(Handbook, 2003). In the first phase of this research, the mechanical performances of termowood ıroko, pinewood and ashwood were compared. The effective mechanical properties of the ashwood, ıroko and pinewood materials were measured according to the DIN standards and are given in Table 1. At least 5 samples were tested for both compressive and bending tests. The thermowood specimens with dimensions of 15 mm × 30 mm × 300 mm (thickness × width × span length) were tested under three-point bending according to DIN EN 310 standard (DIN, 1993). The dimensions of the compression test specimens were determined as 60 mm × 20 mm × 20 mm (parallel to grain direction) according to DIN EN 52185 standard (DIN, 1976). In addition, the penetration depths of the thermowood materials at low speed impact tests were compared and ashwood one was observed as the most suitable skin for sandwich design as observed in Figure 3. The wood skinned sandwich composite panels were manufactured by the hand lay-up technique. 5 mm thick heat-treated ashwood (Thermo Wood®) material with a density of 623 kg/m^3 was used as the face sheet material for all panels whereas low and high density PVC foams were used as core materials which were denoted as LPVC and HPVC, respectively. Table 2 summarizes the physical and mechanical properties of the PVC foams obtained from the manufacturer's datasheet (Web-1). Furthermore, rubber cork material was used as the intermediate layer between the ashwood skin and the foam core due to their good impact absorption capability, 100% recyclability and ease of maintenance (Castro, Silva, Devezas, Silva, & Gil, 2010; Gil, 2009; Knapic, Oliveira, Machado, & Pereira, 2016). The properties of the rubber-cork material are given in Table 3 (Web-2).

Several design combinations of sandwich structures were developed with different foam thicknesses and alternating foam type locations with respect to the impacted face in addition to rubber-cork sheets which were placed between the ashwood skins and the foam cores. Figure 1 (a) shows the baseline wood skinned single foam sandwich (SFS) design where only the 25 mm and 15 mm thick HPVC foams were sandwiched between the ashwood skins. The SFS specimens with rubber-cork intermediate layers under the ashwood skins were introduced as the second design as shown in Fig. 1 (b) and were referred to as SFSR specimens. In the third design, wood skinned multi-foam layered sandwich (abbreviated as MFSR) concepts were formed by introducing a 1 mm thick internal composite sheet between two PVC foam core layers; see Fig. 1 (c). The internal composite sheet was made of [0/90]s E-glass biaxial non-crimp fabric reinforcement with an areal density of 600 g/m^2 and vinyl ester resin matrix material (see Table 4). The in-plane mechanical properties of internal sheet were determined with coupon tests following the ISO and ASTM test standards (ASTM, 2012, 2016; ISO, 2012). The PVC foams together with the internal composite sheet were considered as a separate unit and produced by a wet layup process while these foam core units were joined to the ashwood skins and rubber-cork layers by using a polyurethane solvent-based one component adhesive. After a total curing time of 24 h, the sandwich panels were cut into 100 mm×100 mm square specimens for impact tests. The manufacturing matrix of eight different sandwich specimen designs is listed in Table 5.

Table 1: Properties of thermowood materials

Material	Trademark	Density (kg/m^3)	Compressive Strength, parallel to grain (MPa)	Flexural strength, longitudinal to grain direction (MPa)	Flexural Modulus (MPa)	Moisture content (%)
ASHWOOD	Novawood	623	71.5	92.9	15782	4-6
IROKO	Novawood	675	70	107	14887	4-6
PINEWOOD	Novawood	480	36.9	59.1	7425	4-6

Table 2: Properties of PVC foam cores (Web-1)

Code	Trademark	Density (kg/m^3)	Compressive Strength (MPa)	Compressive Modulus (MPa)	Tensile Strength (MPa)	Tensile Modulus (MPa)	Shear Strength (MPa)	Shear Modulus (MPa)	Color
LPVC	Airex C70.55	60	0,9	69	1,3	45	0,85	22	Yellow
HPVC	Airex C70.75	80	1,45	104	2	66	1,2	30	Green

Table 3: Properties of rubber-cork material (Web-2)

Material	Trademark	Density (kg/m^3)	Tensile Strength (MPa)	Compressibility (%)	Hardness
Rubber-cork	TeknoCork	100-110	0.52	25-40	75 Shore A

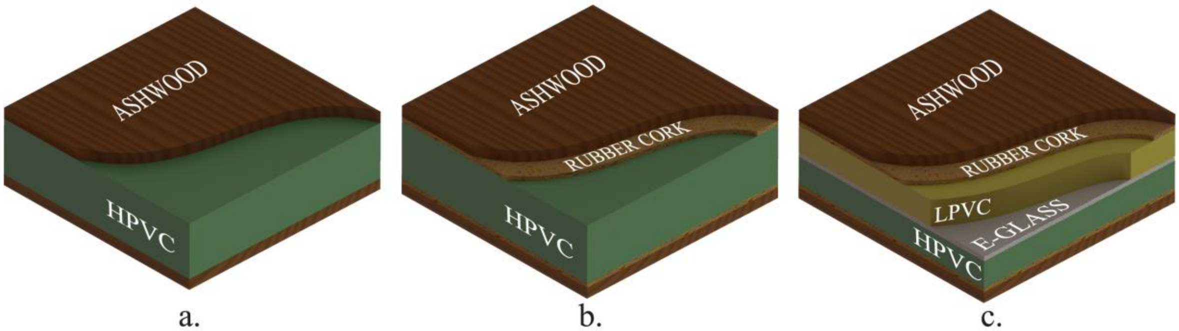

Figure 1: Schematic drawings of (a) wood skinned sandwich (SFS), (b) SF with rubber-cork intermediate layers (SFSR) and (c) multi-layered wood skinned sandwich (MFSR) design concepts

Table 4: In plane properties of E-glass/vinyl ester internal composite sheet

Material properties	Values
Moduli	
Longitudinal Young's modulus (GPa)	20.3
Transverse Young's modulus (GPa)	19.2
Poisson's ratio	0.16
In-plane shear modulus (GPa)	3.4
Strengths	
Longitudinal tensile strength (MPa)	312
Longitudinal compressive strength (MPa)	112
Laminate shear strength (MPa)	43.3

Table 5: Manufacturing matrix of specimens

Structure	Specimen Code	Skin	Intermediate Layer	CORE			Intermediate Layer	Skin	Thickness (mm)	Specimen weight (gr)	Recyclable content (Vol. %)	Cost (€/m²)
SFS	H25	AW	---	---	HPVC25	---	---	AW	35	73	28.6	137
	H15	AW	---	---	HPVC15	---	---	AW	25	67	40	86
SFSR	H25R2	AW	R2	---	HPVC25	---	R2	AW	39	94	35.9	141
	H15R2	AW	R2	---	HPVC15	---	R2	AW	29	88	48.3	90
	H15R5	AW	R5	---	HPVC15	---	R5	AW	35	127	57.1	95
MFSR	HHR2	AW	R2	HPVC12	E-GLASS	HPVC12	R2	AW	39	134	35.9	157
	LLR2	AW	R2	LPVC12	E-GLASS	LPVC12	R2	AW	39	126	35.9	143
	LHR2 HLR2	AW	R2	LPVC12	E-GLASS	HPVC12	R2	AW	39	130	35.9	150

Description

SFS: Single foam core sandwich design with ash wood skin, **SFSR:** Single foam core sandwich design with rubber-cork intermediate layer and ashwood skin
MFSR: Multi foam core sandwich design with E-glass sheet, rubber-cork intermediate layer and ashwood skin,
AW: Ashwood, **R2:** 2 mm Rubber Cork, **R5:** 5 mm Rubber Cork, **E-GLASS**: 600 gr/m² bi-axial fabric
HPVC25: 25 mm PVC 80kg/m³ AIREX C70.75 (Green), **HPVC15:** 15 mm PVC 80kg/m³ AIREX C70.75 (Green)
HPVC12: 12 mm PVC 80kg/m³ AIREX C70.75 (Green), **LPVC12:** 12 mm PVC 60kg/m³ AIREX C70.55 (Yellow)
Cost (€/m2): It includes the total cost of all layers except ashwood skins.

2.2 Drop Weight Test

To compare penetration depths of specimens, weight drop tests of sandwich panels were conducted with the release of 6 kg impactor from a height of 0.5, 0.75, 1.0 and 1.25 to create impact energies of 30 J, 45 J, 60 J and 75 J respectively. Weight drop tests were performed by a testing apparatus as defined by Nordtest test method (NT MECH 042). The hemispherical (HS) with a 12.7 mm diameter steel impactor was used. A schematic of the impact tower with impactor geometry is illustrated in Fig. 2. The sandwich specimens were subjected to low-velocity impact test by using Instron CEAST Fractovis Plus-7526 drop weight testing machine in order to obtain the impact response of the specimens and to reach quantitative conclusions, various parameters such as contact force, impactor displacement, and absorbed energy values. Impact load was applied by a hemispherical steel impactor of 12.7 mm tip diameter at the centre of the specimens, which were clamped by a pneumatic fixture with a 76.2 mm hole diameter. The test velocities for 15, 30, 45, and 75 J impact energy levels were 2.468, 3.49, 4.275, and 5.518 m/s, respectively. Three specimens were tested for each sandwich configuration and average values were calculated. As a result of the experiments in the impact tower, ashwood material showed better performance in terms of penetration resistance compared to other ones (see in Fig. 3).

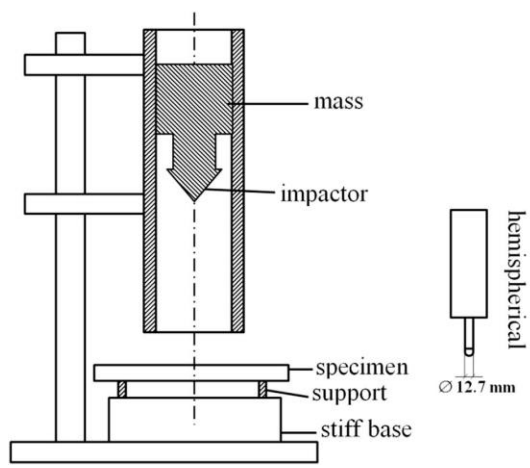

Figure 2: A schematic of the impact tower with a hemispherical impactor

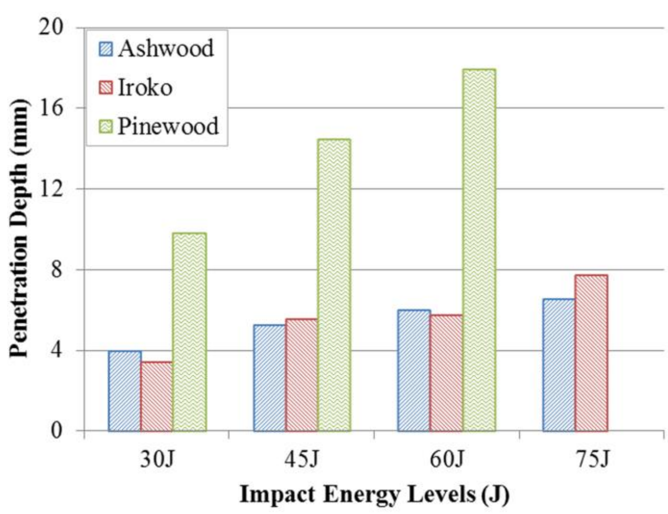

Figure 3: Penetration depths of ıroko, ashwood and pinewood thermowood materials

3 EXPERIMENTAL RESULTS AND DISCUSSION

Single Foam Core Sandwich Specimens (SFS): At 15 J of impact energy, the penetration depths were almost the same (Fig 4a). However, the penetration depth to specimen thickness ratio was 48% in H15 specimen due to the lower thickness of the HPVC foam core while it was 34.3% for H25 specimen (Fig 4b). As the impact energy was increased to 30 J, the partial perforation of the bottom ashwood skin of H25 and complete perforation of the H15 was observed as seen in Figure 5 a and b. H25 specimens were completely perforated at the impact energy of 45 J. This result can be explained as follows: by increasing the core thickness, the penetration case can occur at a wider energy range under LVI loadings. Also, it was observed that as the core thickness increased, specimens showed more elastic behaviour and so, maximum contact force value decreased while contact time and maximum deflection values increased. Comparing the samples H15 and H25 at 30 Joule energy level, the decrease in core thickness increased the maximum contact force as observed in Figure 4e.

Single foam core sandwich design with rubber-cork intermediate layer and ashwood skin (SFSR): At 15 J of impact energy, the rubber cork layer had an insignificant effect on the penetration depth. However, the deformation capability of the rubber cork layer prevented the impactor to reach the foam core, meaning a lesser damage to the core material as seen Figure 5 c-e. As illustrated in Fig. 4 b, the penetration depth to thickness ratio was also slightly reduced from 34.3% to 30.8% with the introduction of the rubber cork layers in H25-R2 specimen. This reduction was from 48% to 41.4% in H15-R2 specimen. A comparison between the H15-R2 and H15-R5 specimens shows that the penetration depth to thickness ratio was reduced from 41.4% to 34.3% due to thicker rubber cork. At 30 J of impact energy, the penetration depth of H25-R2 and H15-R2 specimens was decreased in comparison to H25 and H15 specimens, respectively (see Fig. 4a). Also, the penetration depth to thickness ratios were decreased about 20% compared to the SFS counterparts (see Fig. 4b). Compared H25-R2 with H25, this reduction was observed from 97.1% to 76.9%. H15-R2 specimen showed a penetration depth to thickness ratio of 75.9% while H15 was completely perforated at 30J energy level. H15-R5 specimens with the thicker rubber cork exhibited higher penetration depth in comparison to the H15-R2 specimens (see in Fig. 4a). All of the SFSR specimens were completely perforated at 45 J impact loading (see in Fig. 5 c, d, e).

Multi foam core sandwich design with E-glass internal sheet, rubber-cork intermediate layer and ashwood skin (MFSR): At 15 J of impact energy, the impactor perforated the ashwood skin in all four types of specimens with some differences. HH-R2 and HL-R2 type specimens, which have the HPVC at the impacted region, were subjected to core crushing while LL-R2 and LH-R2 specimens with the LPVC at the impacted region were suffered a significant core cracking. It can be said that the density of the foam material in the direction of impact at low energy levels affects the damage state (Fig.5 f-i). At the 15J energy level, HH-R2 and HL-R2 showed a penetration depth to thickness ratio of 30.8% while it was 35.9% for LL-R2 and LH-R2 specimens (see in Fig. 4 b.). In the case of 45 J of impact energy, the impactor contacts with the E-glass internal sheet and this interaction caused a fibre breakage and inter-laminar delamination in the E-glass sheet. Although the impactor did not get into contact with the lower core, it was crushed due to the load transferred through the internal sheet. At this energy level, the LL-R2 samples showed a 69.2% penetration depth to thickness value, while the others remained at the same level of 64.1% (see in Fig. 4b). For the impact energy of 75 J, all the ashwood skins, internal composite sheet and the core material were perforated. LL-R2 specimens experienced the lowest energy absorption because of the low density PVC core material. In contrast, HH-R2 comprising of the high density PVC resulted highest absorbed energy (see Fig. 4 c). Compared the absorbed energy values of HL-R2 and LH-R2, placing the higher density foam uppermost resulted in a slight increase in the perforation resistance (see in Fig 4 c). The cross-sectional views of the MFSR specimens revealed that using a high density PVC foam core created a more impact-resistant structure under LVI loading.

3.1 LVI responses of sandwich specimens

Figure 4 illustrates the impact responses of the sandwich specimens obtained from LVI tests. Considering the thickness differences of the specimens, penetration depths and penetration depth to total thickness ratio of the specimens are given in Fig. 4 (a-b). The energy absorption is normalised by the total weight of the sandwich specimens to take into account the additional layers and the different densities of the foam core materials. Figures 4 (c) and (d) summarise the absorbed energy and the specific energy absorption of the sandwich specimens for complete perforation case. The maximum contact forces of all the sandwich specimens subjected to different impact energies are summarised in Fig. 4 (e). The absorbed energy to cost ratio were calculated by dividing the absorbed energy to the unit areal cost of each configuration as seen in Fig. 4 (f).

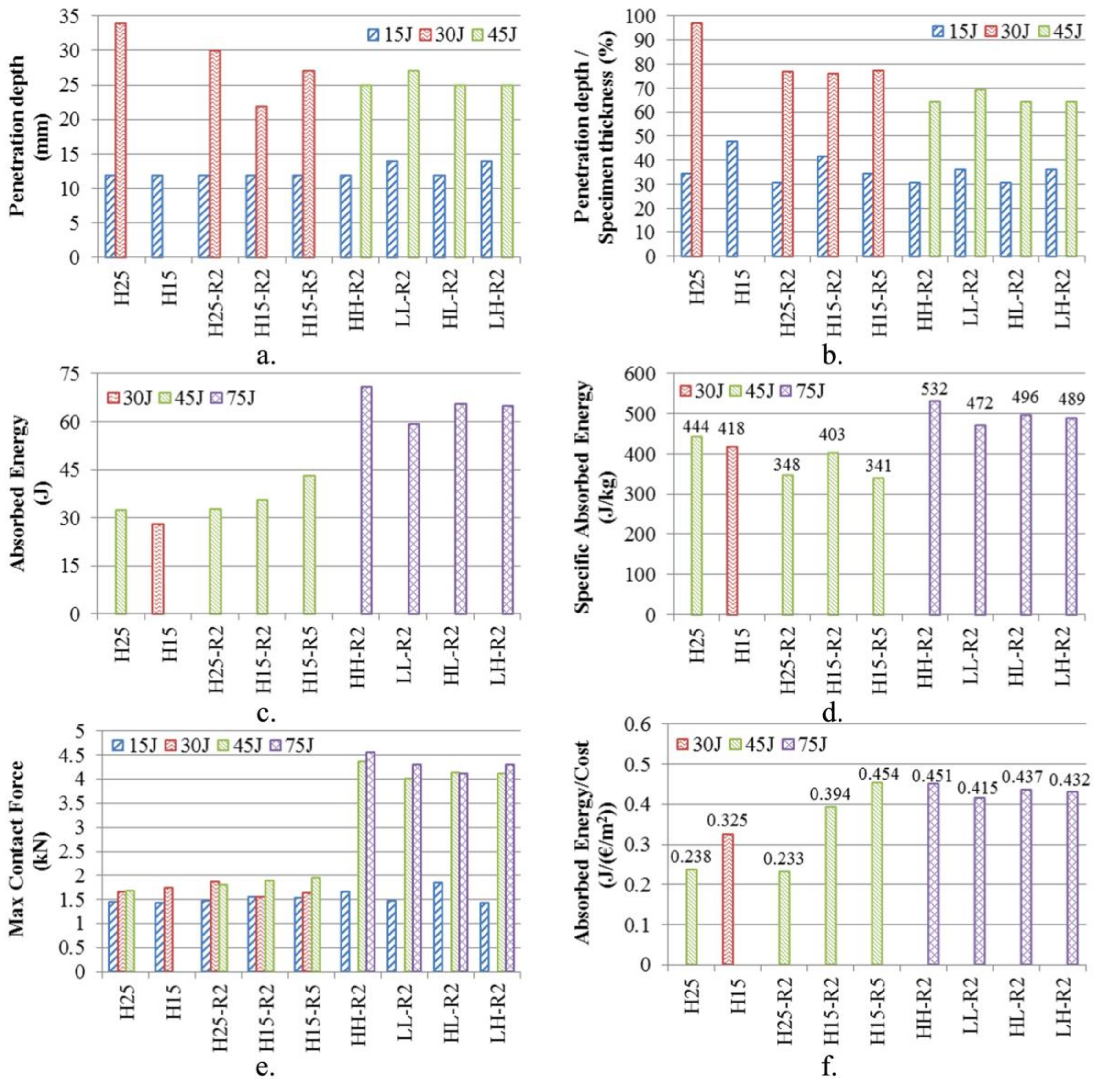

Figure 4: LVI test results; a) penetration depth, b) penetration depth/specimen thickness, c) absorbed energy, d) specific absorbed energy, e) maximum contact force and f) absorbed energy/cost

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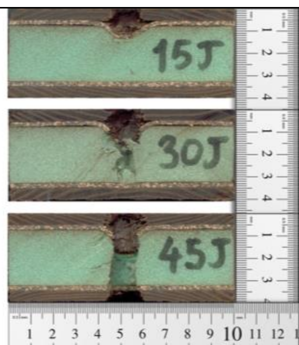
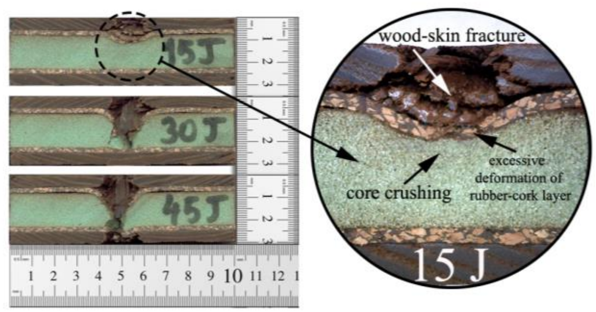
3.2 Destructive sectioning method

Single foam core sandwich design with ashwood skin (SFS)

a. Specimen H25 b. Specimen H15

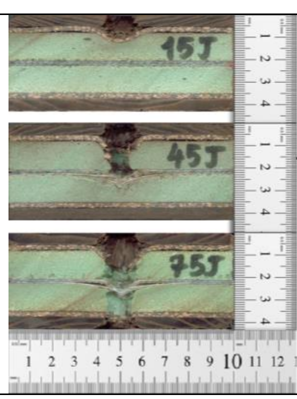
Single foam core sandwich design with rubber-cork intermediate layer and ashwood skin (SFSR)

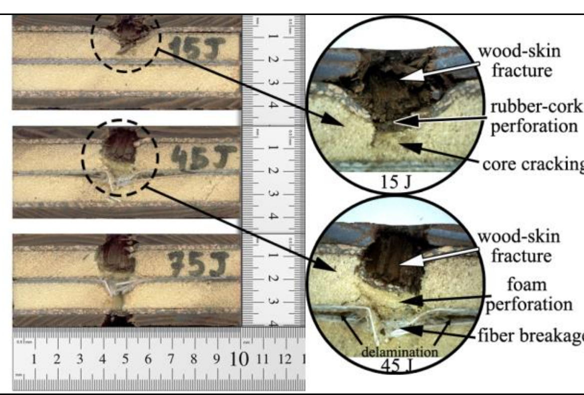




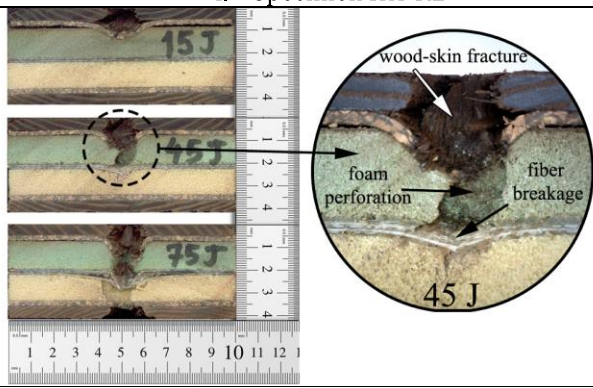
c. Specimen H25-R2 d. Specimen H15-R5 e. Specimen H15-R2

Multi foam core sandwich design with E-glass internal sheet, rubber-cork intermediate layer and ashwood skin (MFSR)

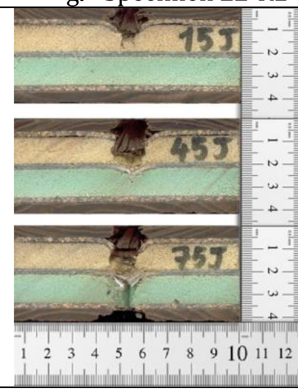




f. Specimen HH-R2



g. Specimen LL-R2



h. Specimen HL-R2

i. Specimen LH-R2

Figure 5: Cross-sectional damage views of the impacted sandwich specimens

4 CONCLUSIONS

In the present paper, innovative, eco-friendly and impact resistant sandwich structure designs were developed using recyclable and long-lasting thermowood and rubber-cork materials. Three different concepts were presented in order to evaluate their performance under low velocity impact loading. Cross-sectional images of the damaged specimens enabled visual inspection of interior damage patterns and penetration depth values. Fundamental findings are summarised below:

- In terms of penetration resistance, ashwood material has been found to be the most suitable for the skin material compared to pinewood and ıroko ones as a result of experiments in the impact tower.
- Introduction of the rubber cork intermediate layer resulted in reduced penetration depth for 30 J of impact energy by increasing the energy absorption. At low level of impact energy, the rubber cork prevented foam cracking, and the damage was therefore confined to the recyclable materials only. This is an advantage for the repair processes and to avoid the progressive cracking of the foam upon further loading cycles.
- Penetration depth was increased with increasing the rubber cork thickness due to the replacement of stiff foam core by a relatively flexible rubber cork material on the travel path of the impactor. However, the absorbed energy was increased about 10% while the specific absorbed energy decreased due to weight gain of the sandwich structure.
- From the economical perspective of view, with respect to the specific absorbed energy and absorbed energy/cost ratios, HH-R2 was found to be the best panel configuration among the proposed design alternatives (see Fig .4 f).
- The introduction of the rubber-cork material increased the recyclability rate of the sandwich structures up to 57%. In the MFSR configurations, the recyclability rate is 35.6%.
- The proposed wood skinned sandwich composite designs are easy to manufacture, repair and recycle in addition to their valuable esthetical appearance. These configurations may be utilised in floor applications such as decks and cabins, bulkhead panels as well as interior and exterior design applications.

5 ACKNOWLEDGEMENTS

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ABSTRACT

This paper presents the preliminary results of the ongoing research project aimed at the use of wood in the transition to a green economy in Slovakia. The main objective of the project is to propose and develop optimal models of wood use in the national context that would take into account the main principles of the green economy and their application in different sectors of wood production, processing and utilisation. In particular, the paper presents the results of the analysis of the production potential of wood and the prognosis of its development, with a specific attention paid to the possibilities of wood felling by tree species (coniferous and broadleaves) and the representation of the quality grades of wood assortments.

Based on the present state of wood utilisation in Slovakia, a proposal of the simplified basic model of wood material flows was developed covering the flows of the main raw wood material groups: roundwood, pulpwood, fuelwood and a separate flow of energy wood. The proposed wood flows cover the primary and secondary wood sources and their utilization while taking into account apparent domestic consumption. This basic model will serve as a reference basis for the comparison with other wood use options.

Variant models will be based on the proposed changes to the current state resulting from the analysis of and discussion on the factors affecting wood flows. As a part of the project, carbon monitoring and its quantification in harvested wood products is performed for the purposes of modelling and optimization of wood utilization.

KEYWORDS: wood flows, wood products, wood felling, wood assortments, carbon balance

1 INTRODUCTION

The main objective of the scientific project is to create an optimal model of wood utilization in Slovakia. This task required some preparatory and analytical work aimed mainly at the stipulation of main product categories, levels and methods of processing and use of wood, as well as the definition, analysis and quantification of the current material flows of wood.

To identify and quantify wood material and energy flows wood resource balance approach was applied. The main principles are: (i) resources are represented by domestic roundwood consumption and complemented by wood residues, recycled material, processed wood fuel and other woody biomass, and (ii) uses are represented by main processing sectors and energy users. Data were acquired from the official statistical sources in 2016-2017 and complemented by empirical data collected through questionnaires both on the side of resources and uses. As a result, a proposal of the simplified basic model of wood material flows was developed that will serve as a reference basis for the comparison with other wood use options.

In order to define driving factors and possible future development the identification and analysis of different external and internal factors affecting the use of wood in Slovakia, mainly in the field of wood production, wood processing and its use as well as supply chains, needed to be carried out. The extent of wood utilization in the different wood-processing industries varies depending mainly on these key factors:

Wood production:

- Available structure of roundwood assortments.
- Legal restrictions on producers of roundwood.
- Level of technical infrastructure in the forestry sector.
- Forestry and environmental state policy in the area of exploitation of forest resources.
- The impact of climate change on the structure of forest stands, especially tree species.

Wood processing and use:

- State policy on wood processing and use.
- Technical level of the wood-processing industries; support for research and innovation.
- Competitiveness of wood against fossil fuels and other renewable energy sources (RES).
- Restrictions on processors of raw wood, recycled wood and paper.

Supply chain:

- Accessibility and transparency of information on the production, purchase and distribution of wood from producers to processors and consumers.
- Quality of the market environment.

The mentioned analyses are based on the data originating from following sources of information, in particular on: (i) Summary information on forests obtained from data of the forest management plans (FMP); (ii) National Forest Inventory and Monitoring (NFIM) of the Slovak Republic (Šebeň, 2017), based on a mathematical and statistical methods of surveying the state and development of forests; the second cycle of NFIM was carried out in 2015-2016; (iii) Socio-economic and production information on forestry including wood-processing and pulp industry; (iv) Own research findings.

Another important project task is aimed at the development out of the proposal of variant models of wood utilization that will be based on the proposed changes to the current state resulting from the analysis of and discussion on the factors affecting wood flows with the aim to achieve (i) optimal value utilisation of available raw wood assortments structure, (ii) increased domestic level of wood consumption, (iii) increased cascade wood utilisation with the priority to use wood in long life cycles, (iv) generation of energy primarily from wood waste, residues or recycled products, and (v) improvement in the carbon balance of wood use through the changes in the portfolio of produced wood products. As a part of the project, carbon monitoring and its quantification in harvested wood products will be performed for the purposes of modelling and optimization of wood utilization. Existing approaches based on the Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories (IPCC, 2006, 2013) have been applied.

This paper provides some results of the analyses on the production potential of the Slovak forests and the prognosis of its development, with a particular attention paid to the production and felling of wood including tree species composition (coniferous, broadleaves) and a share of wood assortments according to quality grades.

2 RESULTS

2.1 Analyses of the production potential and its utilization in the Slovak forests

The area of forests growing on forest land in Slovakia is 1,923.4 thousand ha. In addition to forests on forest land there is about 288±39 thousand ha of forests on the non-forest land (agricultural, other) in Slovakia that were identified within the NFIM 2015-2016. The forest cover in Slovakia including forests on non-forest land is more than 45% (Moravčík et al., 2017a).

Total volume of growing stock in forests in Slovakia according to NFIM 2015-2016 was 628±24 mil. m^3, out of which 583±23 mill. m^3 were on forest land and remaining volume of 46±7 mill. m^3 on non-forest land. According to FMPs the volume of growing stock just on forest land was 480.25 mill. m^3 in 2017; it is about 100 mil. m^3 less than volume of growing stock according to NFIM 2015-2016 (583±23 mill. m^3). The reasons for these differences are well justified but it is not relevant for the content of this paper. The volume of growing stock has been increasing in the long term - during the last ten years has increased by 8.3% (Figure 1). The main reason for this increase is the current uneven age composition with over-normal share of forests older than 70 years (age classes: 8th and higher), (Figure 2). The present increasing trend is caused mainly by the development of growing stock of broadleaved tree species. The volume of coniferous growing stock has been decreasing since about 2010 (Figure 1). The development of growing stock by age classes is depicted in Figure 3 (Moravčík et al., 2017a).

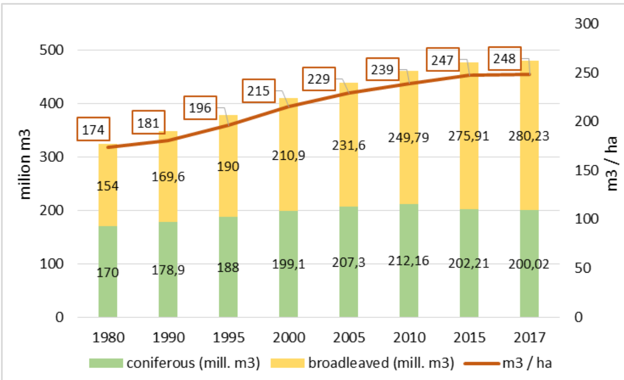


Figure 1: Total growing stock by main groups of tree species (coniferous, broadleaves) and per hectare

Figure 2: Proportion of age classes – actual and normal (ideal)

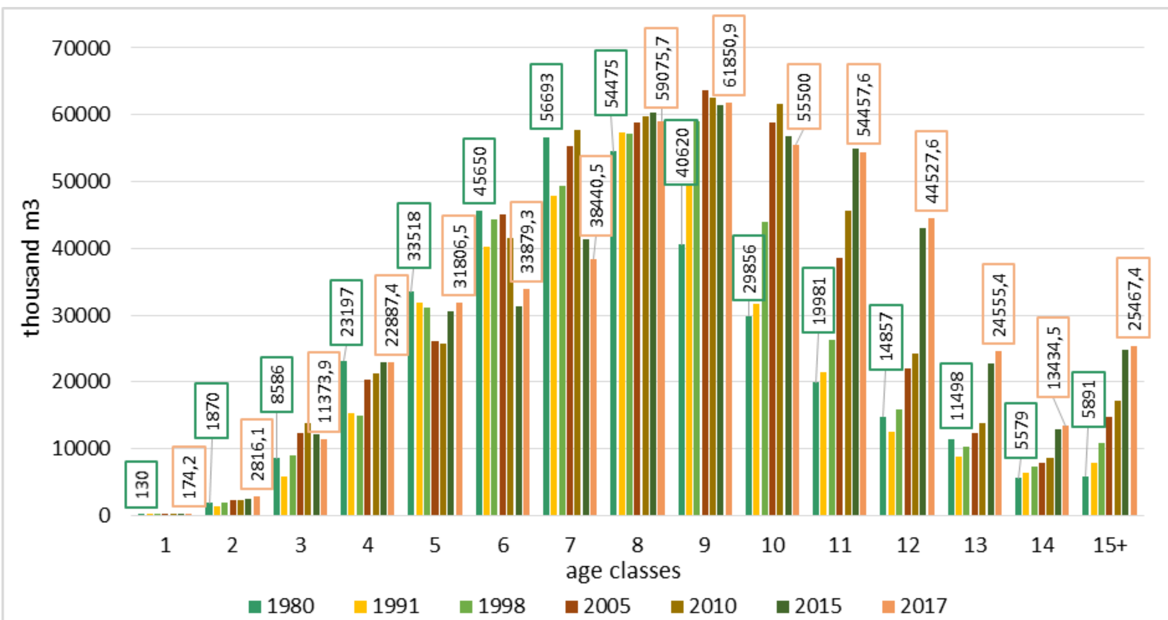


Figure 3: Development of growing stock by age classes since 1980

The distribution of volume of growing stock in Slovakian forests according to quality grades of wood assortments was derived from both information sources (FMP and NFIM) separately for both coniferous and broadleaved by the means of mathematical models of domestic assortment tables (Petráš, Nociar, 1990; Mecko et al., 1994; Petráš et al., 2007) as a function of the tree diameter (d1,3), height (h) and stem quality (A - high quality, B and C - below average) for the following tree species: beech, spruce, oak, hornbeam, pine, birch, fir, spruce. Other tree species have been assigned to the mentioned trees in view of their similarity.
Through this analysis the total growing stock in Slovakia was classified into these categories of quality grades: logs (grades: I, II, IIIA and IIIB), pulpwood (V. grade) and energy and fuelwood (VI. grade) and waste.

Table 1: Model distribution of <u>coniferous</u> growing stock by quality grades of wood assortments

<table>
<tr><td>Inventory</td><td>I</td><td>II</td><td>IIIA</td><td>IIIB</td><td>V</td><td>VI</td><td>waste</td></tr>
<tr><td rowspan="3">FMP (m³, %)</td><td>4 591 150</td><td>10 249 470</td><td>87 836 900</td><td>53 590 190</td><td>42 115 380</td><td>3 555 970</td><td>33 300</td></tr>
<tr><td rowspan="2">2,27</td><td rowspan="2">5,07</td><td>43,49</td><td>26,53</td><td rowspan="2">20,85</td><td rowspan="2">1,76</td><td rowspan="2">0,02</td></tr>
<tr><td colspan="2">Total III: 70,02</td></tr>
<tr><td rowspan="2">NFIM (%)</td><td rowspan="2">3,0±0,6</td><td rowspan="2">4,6±0,6</td><td>40,1 ±2,6</td><td>29,1 ±1,9</td><td rowspan="2">21,3 ±1,1</td><td rowspan="2">1,8 ±0,1</td><td rowspan="2">0,1 ±0,0</td></tr>
<tr><td colspan="2">Total III: 69,S2</td></tr>
</table>

Table 2: Model distribution of <u>broadleaved</u> growing stock by quality grades of wood assortments

<table>
<tr><td>Inventory</td><td>I</td><td>II</td><td>IIIA</td><td>IIIB</td><td>V</td><td>VI</td><td>waste</td></tr>
<tr><td rowspan="3">FMP (m³, %)</td><td>4 810 720</td><td>21 291 110</td><td>54 030 020</td><td>71 548 300</td><td>112 742 580</td><td>13 985 210</td><td>271 830</td></tr>
<tr><td rowspan="2">1,73</td><td rowspan="2">7,64</td><td>19,39</td><td>25,67</td><td rowspan="2">40,46</td><td rowspan="2">5,02</td><td rowspan="2">0,10</td></tr>
<tr><td colspan="2">Total III: 45,06</td></tr>
<tr><td rowspan="2">NFIM (%)</td><td rowspan="2">1,8 ±0,3</td><td rowspan="2">6,1 ±0,5</td><td>15,1 ±0,9</td><td>25,9 ± 1,4</td><td rowspan="2">43,5 ±1,6</td><td rowspan="2">7,3 ±0,9</td><td rowspan="2">0,2 ±0,0</td></tr>
<tr><td colspan="2">Total III: 41</td></tr>
</table>

Due to the current state and development of forests in Slovakia we can observe some important facts (Moravčík et al., 2017a):
1) gradual increase of planned felling (blue line in the Figure 4) mainly because of the current uneven age composition;
2) permanently higher volume of annual felling (red line) till 2010 as compared with the planned felling mainly because of high volume of incidental felling (grey line);
3) lower volume of actual felling as compared to the volume of total current increment (yellow line) (Figure 4).

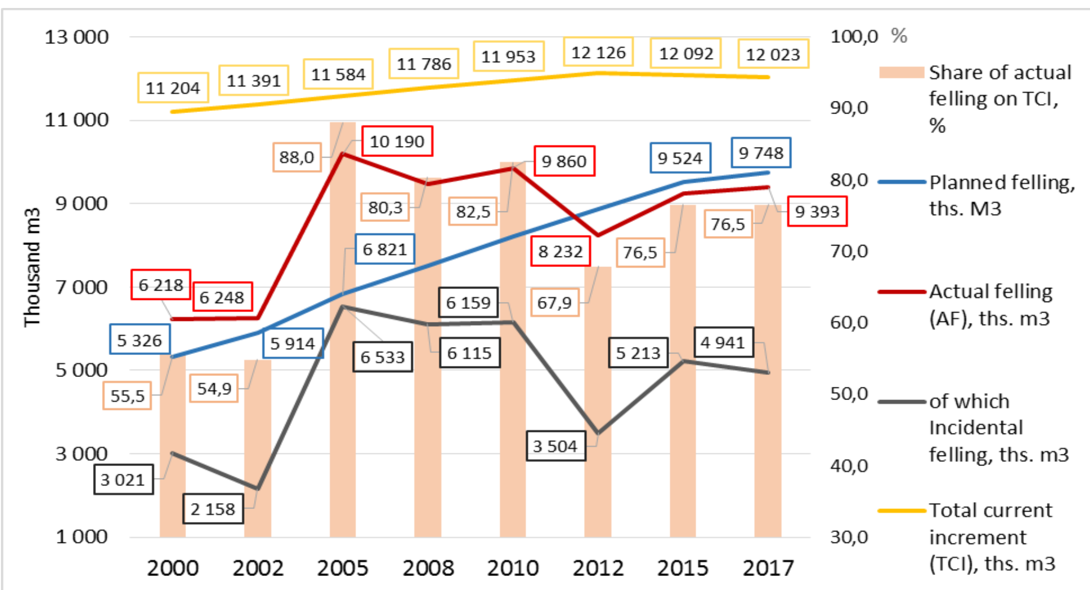


Figure 4: Trends in timber felling divided to „planned“, „actual“, of which „incidental“, compared to the „total current increment“ (TCI)

In order to determine the actual utilization of the available production potential we have compared the shares of model quality grades in forests in Slovakia (Table 1 and Table 2) with their real shares in wood supply; for balancing annual fluctuation we used the average of supplies in 2013-2017 (Figure 5). Based on this analysis we can state that the potential share of quality grades of assortments in their real production has not been achieved.

It follows from this comparison that there is a lower share of quality grades I, II and III in the real structure of both groups (coniferous and broadleaved tree species) and vice versa, a higher share of grades V and VI. The real share of qualitative grades I - III in coniferous trees is lower by 12.5% and in broadleaved ones by 14.6%. Through this comparison, we have obtained important basic information about the real inadequate utilization of raw wood assortments, given its available potential (Moravčík et al., 2017b).

Table 3: Comparison of the real and the model shares of quality grades

Indicator	I	II	III	V	VI
	Share of quality grades, %				
Real coniferous	0,06	0,11	64,51	28,84	6,48
Model coniferous	2,64	4,84	69,66	21,08	1,78
Difference: real – model	-2,58	-4,73	-5,15	7,76	4,7
Real broadleaved	0,09	0,54	36,55	55,29	7,53
Model broadleaved	1,77	6,89	43,11	42,05	6,18
Difference: real – model	-1,68	-6,35	-6,56	13,24	1,35

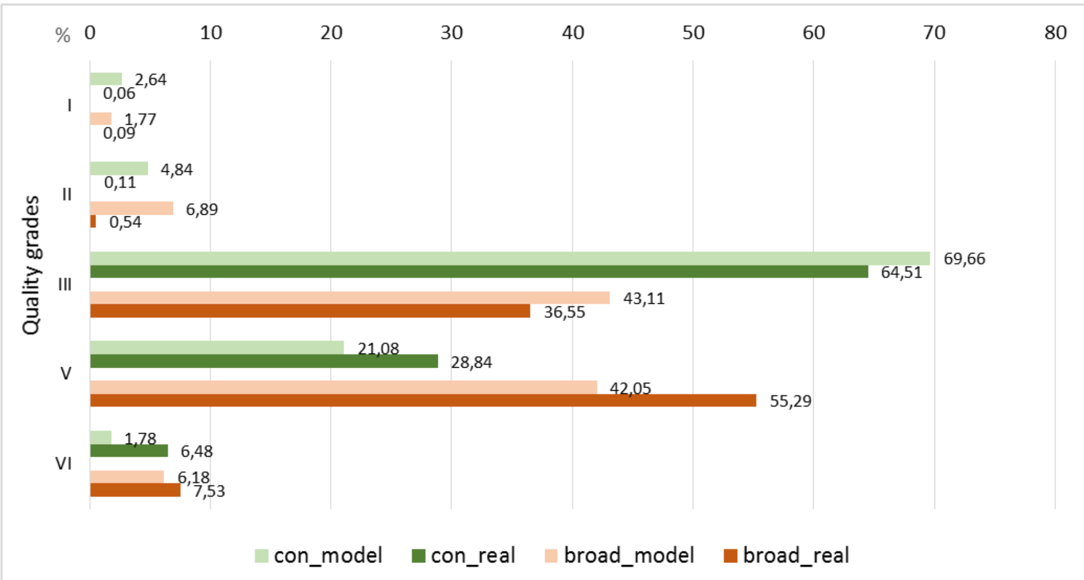


Figure 5: Comparison of the real and the model shares of quality grades

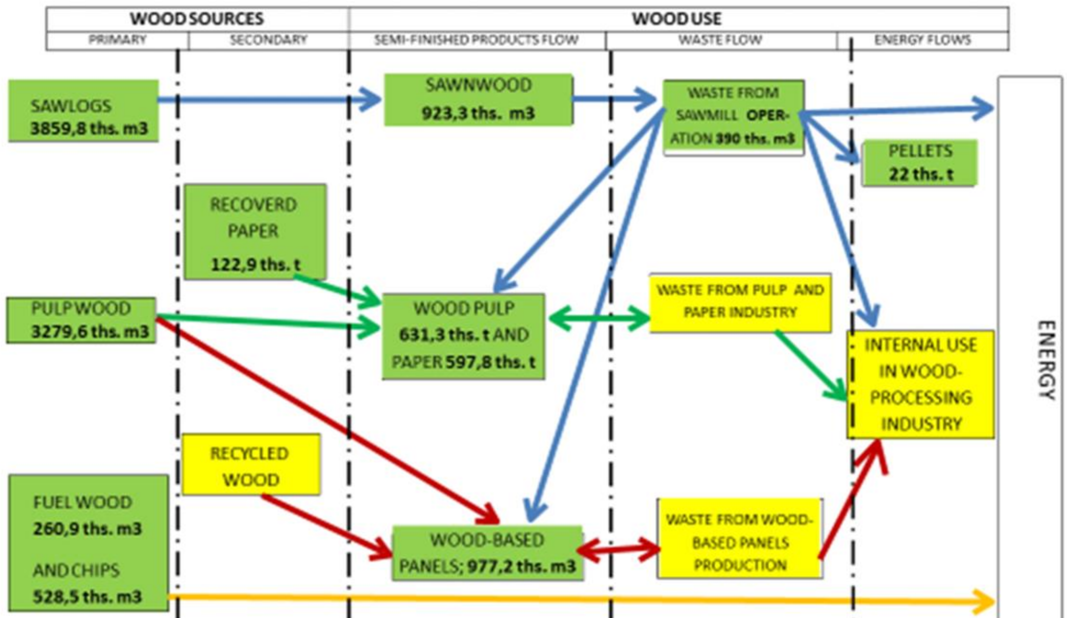
A lower share of real supplies of more valuable I. - III. quality grades assortments as compared to the available potential was reflected in the decrease of the total income generated by coniferous wood products by 34.6 mil. Eur and 42.6 mil. Eur in case of broadleaved wood products annually.

2.2 Formation of the optimal model(s) of sustainable wood utilization in Slovakia

Applying the mentioned analyses we have quantified the individual items of the simplified basic model of the actual wood use (Figure 6). As for the quantification there are still certain data missing (displayed by yellow colour) related mainly to the volumes of recycled wood, waste from pulp and paper industries, waste from wood-based panels industries and volume of woody material used in wood-processing industry for energy purposes. This basic model provides a reference basis for comparison with other wood use options.

The most important task of the next research will be to work out the proposal of optimal models of the sustainable wood utilization. They will be based on changes in wood utilization, as compared to basic (actual) reference model so as to ensure:

- Optimal value utilization of the available structure of raw wood assortments;
- Increase in domestic wood processing and consumption (export vs. domestic consumption);
- Application of cascade wood use principles; generation of energy primarily from wood waste, residues or recycled products;
- Improvement the carbon balance of the use of wood and sequestration of carbon in harvested wood products (HWP).



Sawmill Sector Wood Based Panel Sector Pulp and Paper Sector Energy Sector

Figure 6: Simplified basic model of wood flows in Slovakia

2.3 Estimation of carbon stocks and annual carbon stock changes in harvested wood products

In this research solution we have applied the „Stock change approach“ (Lim, B., Brown, S., Schlamadinger, B., 1999) within the carbon balance. This approach evaluates the annual change of the carbon stock in harvested wood products (HWP) within the domestic consumption, it is: production + import - export. Estimation of carbon stocks and annual carbon stock changes in HWP pool is calculated separately for each of the HWP fractions: „sawnwood“, „wood-based panels“ and „paper and paperboard“. For this purpose, the first-order decay (FOD), which is a flux data method, in combination with estimates of half-lives is applied (IPCC, 2006, 2013):

(A) $$C(i+1) = e^{-k}.C(i) + \left(\frac{1-e^{-k}}{k}\right).\,\mathrm{inflow}(i) \qquad \mathrm{s}\ C(1900)=0{,}0$$

(B) $$\Delta C(i) = C(i+1) - C(i)$$

Where:
i = year C(i) = the carbon stock in the particular Harvested Wood Product category at the beginning of year i, Gg C
k = decay constant of FOD for each HWP category (HWPj) given in units yr-1 (k = ln(2)/HL, where HL is half-life of the HWP pool in years.
Inflow (i) = the inflow to the particular HWP category (HWPj) during year i, Gg C yr-1 ΔC(i) = carbon stock change of the HWP category during year i, Gg C yr-1.

Harvested wood products carbon pool is defined as the wood products in service life within the particular country. The carbon pool includes products generated from the wood production in the country in forests, remaining forests and land converted to forests. The losses from the pool are to landfill and the atmosphere. Emissions from landfill are reported under the waste sector of the inventory.
For the assessment, the half-lives were applied according to respective IPCC guidelines 2013 for Kjoto Protocol: 35 years for sawnwood, 25 years for wood-based panels and 2 years for paper products. The

estimation approach applied for HWP accounting calculates delayed emissions on the basis of the annual stock change of semi-finished wood products using the first order decay function following above mentioned equation. The results of gains and losses of CO_2 from domestically produced and used HWP are provided in Figure 7.

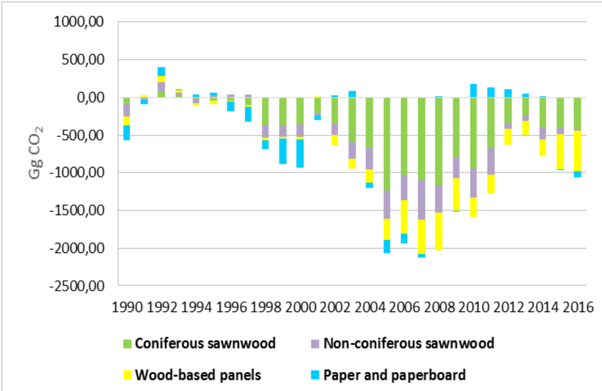


Figure 7a: The balance of CO_2 from domestically used harvested wood products till 2016

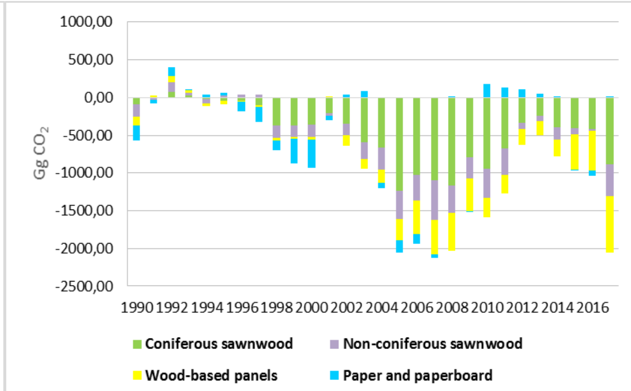


Figure 7b: The balance of CO_2 from domestically used harvested wood products with added the model year 2017

In the depicted figure the positive values represent the greenhouse gas emissions; the negative values represent the removals of carbon from the atmosphere. All values are expressed in Gg $CO_2.year^{-1}$. The listed method of carbon balance will be used in our project for the formation of models of wood utilization that would lead to the increasing carbon stocks in harvested wood products. On the figure 7b in 2017 we applied data resulting from model distribution of the growing stock by quality grades of wood assortments (Table 3, Figure 5). It follows from the figure that this had an immediate effect on the increasing volume of CO_2 stored in the harvested wood products. For the modelling we have elaborated a sophisticated and detailed programmatic solution.

3 CONCLUSION

Sustainable production and adequate financial appreciation of felled timber through the achievement of available assortment structure, so as to maximize profitability and marketability while increasing also social and environmental benefits, are very important goals of the forestry sector. Ensuring higher appreciation of felled timber can be achieved by increasing the production of more valuable assortments. Therefore, the paper aimed at the comparison of actual volume and value structure of supplies of raw wood assortments produced by forestry in Slovakia (option 0) with the possible available structure of assortments (variant 1). Variant 1 is based on the assumption that the forestry produces, supplies and markets to the processors the raw wood assortments in volume and quality structure corresponding to the current production potential in the forests. For this purpose, we have worked out a detailed analysis of the mentioned production potential from the viewpoint of the basic production indicators.

This option assumes also maximum wood utilization by the wood industry, with the waste that is generated being primarily used for further material production. The end-of-life products are recycled and ultimately used to produce energy. The above procedure is consistent with so-called "cascade" use of wood, which consists in the effective multiple utilization of biomass for different purposes before it reaches the end of its life cycle. The cascade use of wood directly prolongs the life cycle, and thus the storage of carbon in wood products, which is also related to the value utilization of biomass, it means the focusing on products with higher added value.

The final objective of this paper was to quantify the difference between the carbon volumes stored in wood products within the following variants: Option 0 which is characterized by the current conditions, range and ways of using wood and Variant 1 characterized by the optimal value utilization of the available raw wood assortments. Different ways of wood utilization have different CO_2 balances. Long-life wood products (lumber, veneers, wood panels, paper, paperboard) do not immediately oxidize. Carbon is released into the atmosphere only when the products become waste or fuel. For different wood products IPCC (2013) determines half-lives as follows: 35 years for sawnwood, 25 years for wood-based panels and 2 years for paper. In the case of energy use of fuel wood and charcoal, immediate oxidation occurs. There is no delay in release of carbon emissions into the atmosphere. In addition, construction timber (wood-based houses) is not only a long-term carbon storage but it also replaces conventional building materials from non-renewable source (bricks, steel, concrete, plastics) where their production produces significant emissions and other environmental pollution. It is therefore obvious that wood used for long-life products protects the atmosphere from disproportionate CO_2 growth for decades, so it is necessary and desirable to use wood for products with the longest possible life.

4 ACKNOWLEDGEMENTS

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The Effect of Nano-graphene Oxide on Physical and Mechanical Properties of Particleboard

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ABSTRACT

In this research, the physical and mechanical properties of 3-layered particleboard made of industrial wood chips and UF resin consumption of 10 wt% with four levels of grapheme nano oxide including 0, 0.25, 0.50 and 0.75 percent based on the dry weight of UF resin and tow pressing times including 4 and 5 minutes were studied. The results showed that by increasing the amount of graphene nano-oxide from 0 to 0.75 percent and pressing time duration up to 5 minutes, dimensional stability of the boards improved. It means that thickness swelling after 2 and 24 hours immersion in water decreased significantly. Also, the addition of graphene nano oxide to the boards has a significant effect on internal bonding. It means that increasing the amount of graphene nano-oxide has increased the adhesion of the boards to a significant level. On the other hand, the press time had a positive effect on internal bonding of the boards. Somehow, by increasing the amount of graphene nano-oxide and the increase in press time, the internal bonding of the boards increased significantly, and all boards had a higher adhesion than the European standard.

KEYWORDS: Graphene nano-oxide, Dimensional stability, mechanical properties, Internal bonding.

1 INTRODUCTION

Graphene is a single-layer material made up of carbon atoms, which is arranged in a two-dimensional honeycomb grid and due to its good electrical, thermal and mechanical characteristics which is resulted from its unique structure, it has become an ideal non-organic filler for the manufacture of composites that improves the electrical, thermal and mechanical properties of these types of products (Dreyer et al., 2010; Allen et al., 2010; Kuilla et al., 2010; Bose et al., 2010). In fact, the special properties of graphene have made a tremendous transformation in the composite industry, and due to its numerous uses in various industries, its production is expected to increase (Sambasivudu and Yashwant., 2012) and as one of the filler materials in the manufacture of composites is proposed (Potts et al., 2011). In this regard, research by (Hansma et al, 2007) has shown the success of graphene-based nano composites. Their research led to an optimization of the amount and composition of the adhesive with high durability nanostructures such as graphene, which eventually produced strong, low-density, and refractory composites. Also Ramanathan et al (2008) made an unprecedented change in the glass transition temperature (Tg) of nano composites using graphene. They stated that with the addition of graphene (up to 1% by weight) to polyacrylonite (PAN), the glass transition temperature of the composites increased to 40°C and when graphene adds only 0.5% by weight to Poly methyl meta-Cyril (PMMA), the glass transition temperature is increased to 30°C. They also reported that adding 1% of graphene to PMMA, an increase of 80% in elastic modulus and an increase of 80% in tensile strength was obtained. Studies done by Das et al (2009) on nano composites made of polyvinyl alcohol and reinforced with graphene showed that only by adding 0.6% graphene, a significant improvement in the elasticity modulus and the hardness of the composites were obtained. Yadav et al (2013) introduced graphene oxide as a nano filler for the preparation and production of biodegradable nano composites made of carboxyl methyl cellulose (CMC). Their research results showed that between graphene oxide (GO) and CMC, a strong adhesion is formed through the formation of hydrogen bonds. As a result, this connection led to improved mechanical properties. The composites have high mechanical strength and thermal stability. Due to the low thermal conductivity of wood, practically for adhesive and wood coagulation, it is spent a lot of time and energy in this section. Also, the components of particleboard including wood particles and usually urea formaldehyde adhesive and their chemical structure, are affected by environmental factors, which will change the dimensions. Therefore, in order to reduce these imperfections and improve the functional properties of particleboard and reduce energy consumption in the production line, there are various corrective methods, including the use of different nano materials. Therefore, considering the electrical and thermal properties of graphene nano-oxide, it is expected to reduce the press time of the desired particleboard production, and then, considering its appropriate resistance properties, in subsequent reactions as an appropriate treatment for other Chemical reactions to be used.

2 MATERIAL AND METHODS

2.1 Materials

In this research, coarse and soft industrial wood chip with a moisture content of 4% were provided from commercial particleboard plant in Golestan province, Iran for the production of laboratory boards and transferred to the laboratory. Coarse wood particles were used for the middle layer and soft wood particles for the surface layer of the particleboard. Urea formaldehyde resin from the Samed Glue Factory (in Mashhad, Iran), and Ammonium Chloride Hardener, manufactured by the German Mercury Corporation was prepared. Graphene nano-oxide powder was purchased from the leading Iranian powder company (API). It's specifications are given in table 1.

Table 1: Specified graphene nano-oxide powder

Color	The thickness of the graphene sheet	Dimensions of graphene sheets	The ratio of carbon to oxygen	The amount of impurities
Black	<3Nm	µm<44	8	<70ppm

2.3 Methods

After preparing the raw materials, to make anisotropic boards, the moisture content of the surface layer was 8% by water spray. Then, for each surface and middle layer separately, wood particles, Urea formaldehyde adhesive with a concentration of 50% and ammonium chloride as a catalyst of 2% dry weight of adhesive and graphene nano-oxide as a variable with 0%, 0.25% 0.5% and 0.75% were weighted. After that ammonium chloride and graphene nano-oxide appropriate for any treatment were added to urea formaldehyde resin for the surface layer and the middle layer separately by magnetic stirrer. Then the gluing of the wood particles of each layer was done by the adhesive machine. For the formation particle mat, a wooden mold with dimensions of 30 x 30 cm was used and the glued wood particles by laboratory scale were weighted and poured separately in to the mold for each layer of the board and after the mat formation, put ino to the laboratory press using a temperature of 160 °C and two press times of 4 and 5 minutes. The density of boards 0.7 gr/cm^3, the press pressure 30 kg/cm^2 and the thickness of the boards 16 mm were fixed for all of the boards. After pressing, in order to uniform moisture content of the boards and also to balance the internal stresses, the boards were kept for 10 days in climatic condition with a relative humidity of 65% and a temperature of 21 °C. After the desired time, the boards were cut for physical and mechanical tests. Flexural strength (MOR) and modulus of elasticity (MOE), internal bonding (IB) and thickness swelling after 2 and 24 hours of the boards were determined. All the data were statistically analyzed by using the analysis of variance (ANOVA) and Duncan's mean separation tests.

3 RESULTS AND DISCUSSION

3.1 Thickness Swelling

The results of analysis of variance show that the interaction effect of the amount of graphene nano-oxideand and the press time on the thickness swelling of the particleboard after 2 and 24 hours immersion in water has a significant difference at 95% confidence level. By increasing the amount of graphene nano-oxideand and time pressing, the thickness swelling of particleboard after 2 and 24 hours immersion in water is reduced Which that the lowest thickness swelling after 2 and 24 hours immersion in water related to boards made of 0.75% graphene nano-oxide, and 5 min press time. Also the highest thickness swelling after 2 and 24 hours immersion in water related to the control samples with 4 minutes press time (Figures 1 and 2). Rangavar and HusseiniFard (2015) studied the effect of adding copper nano particles on urea formaldehyde adhesive on the physical and mechanical properties of particleboard made from palm residues. Variable factors in this study included of copper nano particles in the amounts of 6 and 8% of dry weight of wood, press time of 5 and 6 minutes, and press temperatures of 150 and 160 °c. The results showed that the addition of copper nano particles to the urea formaldehyde adhesive improved significantly the physical and mechanical properties of the boards and reduced press time. The boards, which were made by mixing the amount of 6% copper nano particles based on the dry weight of wood chips with adhesive and press temperature of 160 °C, with a press time of 5 minutes, had mechanical properties above the standard EN 312-2.

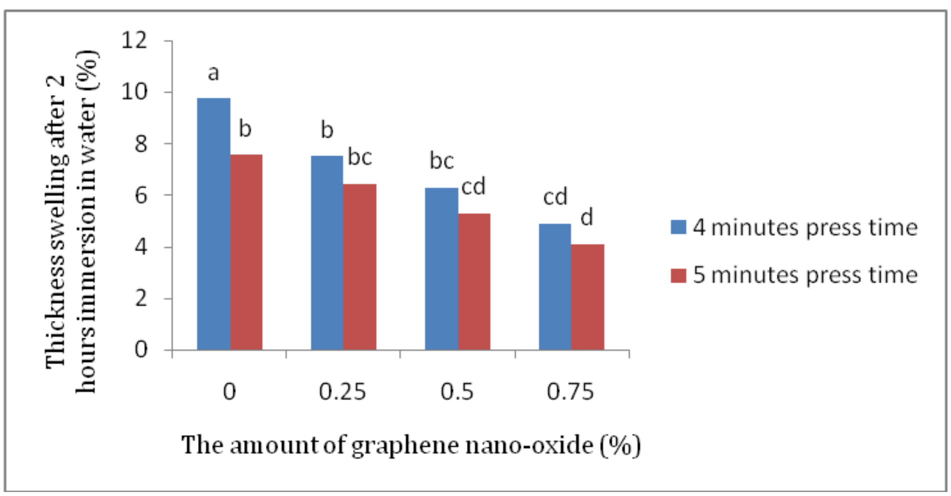

Figure 1: The interaction effect of the amount of graphene nano-oxide and press time on the thickness swelling after 2 hours immersion in water

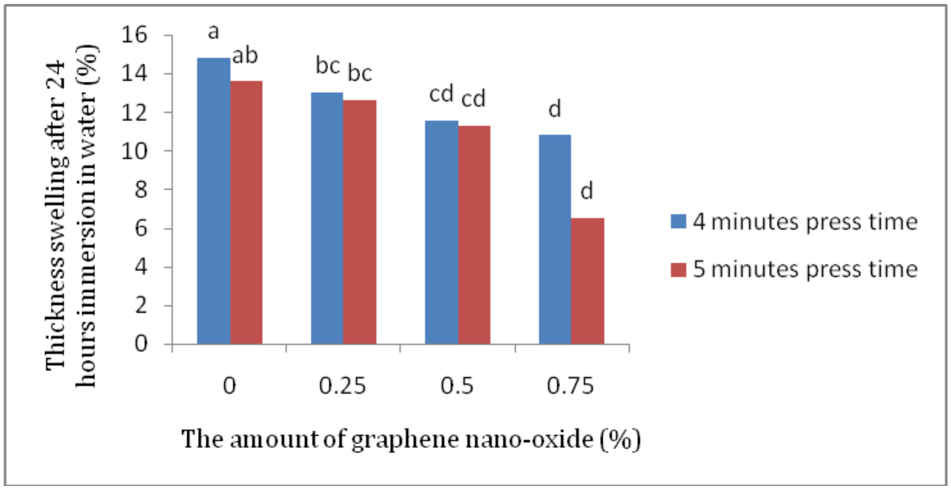

Figure 2: The interaction effect of the amount of graphene nano-oxide and press time on the thickness swelling after 24 hours immersion in water

3.2 Internal bonding

The results of variance analysis show that the interaction effect of the amount of graphene nano-oxide and press time on the internal bonding of particleboard is not significant at 95% confidence level. However, by increasing the amount of graphene nano-oxide and press time, the internal bonding ratio of the particleboard increases. The highest internal bonding related to the boards made of 0.75% graphene nano-oxide with 5 min press time and the lowest internal bonding related to the control boards made with 4 minutes press time (Figure 3). The insignificance of different levels of variables on internal adhesion can be considered as the possibility of using a shorter press time. That is, using these types of nano particles, can be made in a shorter time to produce boards with internal bonding higher than standard. Farajallahpour et al (2011) investigated the effect of different levels of silver nano particles on the heat conduction in the press cycles and physical and mechanical properties of particleboard. Heat transfer from the press surface to the middle layer of particles, during press time was recorded by thermocouples. The results showed that the presence of silver nano particles increase heat transfer to the core layer and as a result, improves internal bonding. But nano particles had negative effects on physical properties and increased WA and TS after 24 hour.

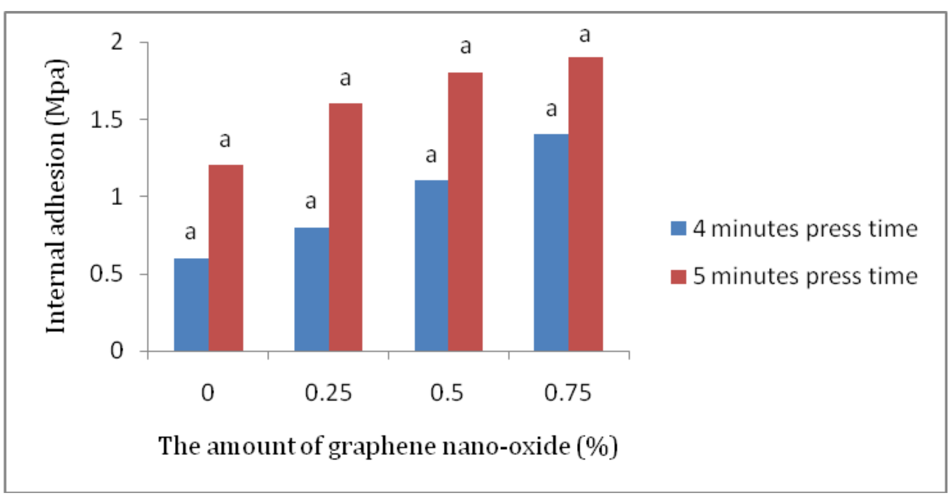

Figure 3: The interaction effect of the amount of graphene nano-oxide and press time on the internal bonding

4 CONCLUSION

The results of this study indicate that the amount of graphene nano-oxide and press time on the thickness swelling after 2and 24 hours immersion in water were significant. By increasing the amount of graphene nano-oxide along with increasing the press time reduced the thickness swelling after 2and 24 hours immersion in water. So that, the least amount of thickness swelling after 2 and 24 hours immersion in water (4.08% and 6.52% respectively) was related to the boards made with 0.75% graphene nano-oxide and the 5 minutes press time and the highest thickness swelling after 2 and 24 hours immersion in water (9.74% and 14.81% respectively) was related to the control boards made with 4 minutes of press time, which that by increasing the press time, from 0.25% of the graphene nano-oxide used without any negative effect on the physical properties of the board. On the other hand, the results of this study show that the amount of graphene nano-oxide and the press time on the internal bonding of the particleboard was not significant and all the internal bonding values of the boards were above the standard, so by using the optimum graphene nano-oxide with short press time were expected the desired internal bonding of particleboards. It means that in case of optimal use of bonding with the use of more pressing time (5 minutes), the mechanical properties of the boards increased in most cases. Finally, with the goal of optimally using graphene nano-oxide, the amount of graphene nano-oxide can be proposed up to 0.75% for the production of particleboard without the physical and mechanical properties of particleboards damaged. Also, in examining the interaction effect of variables, it was found that a shorter press time (4 minutes) can be used to produce boards without any damaging of mechanical properties.

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Investigation on Using Alkali sulfit-Anthraquinone (AS-AQ) Liquor Powder as Coupling Agent for Wheat Straw Flour-Polypropylene Composite

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ABSTRACT

In this research, the effect of the wood filler content and coupling agent (MAPP) on the physical and mechanical properties of Polypropylene composite reinforced with wheat straw flour from the annual harvesting of wheat straw, were studied. For this purpose, the wheat straw flour in three levels of 30%, 40%, 50% and four levels: 0%, 5%, 10%, 15% of alkali sulfite-anthraquinone liquor powder as compatible, were used. Then, the Physical and mechanical properties of samples, including thickness swelling after 2 and 24 hours of immersion in water, bending strength, bending modulus, tensile strength, tensile modulus, were measured. The results showed that by increasing wheat straw flour, the bending strength and tensile strength were decreased but the thickness swelling, bending modulus and tensile modulus were increased. It was also found that by alkali sulphite-anthraquinone liquor powder as compatible, thickness swelling, bending strength, bending modulus, tensile strength and tensile modulus were improved. The results revealed that at increased consumption of wheat straw flour and adding compatible leads to improve quality of the interface and significant changes especially dimensional stability and MOE, are achieved.

KEYWORDS: Alkali sulfite-anthraquinone liquor, polypropylene, wheat straw flour, coupling agent.

1 INTRODUCTION

Due to limitations of wooden resources, the growing demand for products with higher quality and longer life, the aspects of innovation of products and their environmental effects, wood-plastic composites can be introduced as advanced and expandable products. All materials that are a combination of cellulosic material or lignocellulosic and thermoplastic resins are called wood-plastic composites. These resins include polypropylene, polyethylene and polyvinyl chloride (Kazemi and Jalilvand, 2008). In recent years, the use of natural fibers as reinforcements or fillers in the manufacture of polymer composites has attracted many researchers and different sectors of the industry. These fibers in comparison with other rival boosters like fiber glass and mineral fillers have many advantages, such as lower density, higher strength and modulus, low erosion and ease of fiber surface modification and are also widely available. Also, these fibers are cheaper than synthetic fibers and can replace synthetic fibers in many applications where cost savings on product resistance properties are preferred (Saffarzadeh and Ebrahimi., 2000; Karimi et al., 2004; Tajvidi et al., 1998; Rahimi., 2000). In the meantime, wheat straw is a perennial agricultural product with an average annual production of 18 million tons in Iran. The main part of straw is used as animal feed, but it does not optimize the part that is more than the livestock feed needs. This material can be used as filler for the preparation of composites (Moradian et al., 2003; Rezaei et al., 2014). The fact that natural fibers can be renewable and degraded in nature will play a significant role in future use of these materials. And also the growing interest of consumers in purchasing environmentally friendly products has increased the need for industries to use natural materials (Kim and Pal., 2010). On the other hand, black liqueurs of pulp and paper mills are the most important source of lignin, So that about 50 million tons of lignin are produced annually in the world's pulp and paper mills (Wang et al., 2013). However more than 98% of black liquor produced in the pulp and paper industry consumes as fuel, and only 2% of black liquor containing lignin is used in other products, such as chemical materials (Vishtal and Kraslawski., 2008; Younesi et al., 2010). The economic value of converting per kg of liqueurs to fuel is $ 18.00, while the economic value of converting it to chemicals is $ 1.08 per kg (Saeed and Zhan, 2007). Since today the use of wood and lignocellulose materials is a major concern in the field of bio-refinement, finding new applications with a higher economic value for lignin derived from black liquor of pulp and paper mills has attracted the attention of researchers. So far, Various applications have been proposed for lignin, which can be used as a compatibilizer for wood-plastic composites, for the preparation of fuel, for the production of biocomposites and adhesives (Younesi et al., 2010; El Mansouri et al.,2011; , El Mansouri et al., 2007; Kleinert et al., 2009; Behrooz et al., 2009). Lignin contained in black liquor derived from the soda and kraft pulping process, due to alkali hydrolysis and the breakdown aryl ether bond in the process of eliminating lignin, lower molecular weight and greater amounts of functional groups such as aliphatic and phenolic hydroxyl groups, in comparison with other lignocellulosic raw material, have a higher reactivity potential (Behrooz et al., 2009). Gorjani and Omidvar (2006) study the mechanical properties of heavy polyethylene/wheat straw made with 15, 30 and 40% fine grain wheat flour (25 to 40 mesh) and coarse grains (Mesh 12 to 25) and 2% maleic anhydride. The results showed that increasing wheat straw up to 30%, increases tensile and flexural strength and up to 40% improved tensile modulus of elasticity of the composite, but does not have much effect on impact resistance. Tay et al. (2009) examined the use of palm paper pulp as reinforcement in polypropylene composites. This pulp was prepared with baking soda. Alkali treatment in this baking process increases the crystallization of fibers and makes fibers rresistant and firm. Mixing the pulp within the polymer matrix, resulting in an increase in the tensile and flexural properties, increasing the amount of sodium hydroxide in the baking liquid leads to higher apparent coefficient. Ten and Vermerris (2015) investigated recent developments in lignin-derived polymers and reported that lignin is a very suitable material for the production of advanced composites that has many economic and environmental benefits. Therefore, in this research, with the purpose of useful use from the black liquor of pulp and paper industry (AS-AQ) and increasing their value added, wood-plastic composites were made by wheat straw flour, produced annually as one of the agricultural waste, and black liquor powder as a waste material from the alkali-anthraquinone sulfite pulping process and polypropylene as polymer.

2 MATERIAL AND METHODS

In this study, wheat straw were obtained from the farms around Gonbad, Golestan province, Iran and then transferred to the laboratory of Gonbad Kavosu niversity. After crushing, using mechanical mills were converted to fine particles. In order to ensure uniformity and eliminate the effect of wheat straw size on composite properties, the particles transported from 40 mesh and remaining on 60 mesh were dried and immediately placed inside the nylon bags to prevent moisture penetration. Polypropylene brand Z30S from Arak Petrochemical Company with density of 0.9 gr/cm^3 and Melt Flow Index was 16gr/10 min and maleic anhydride grafted to polypropylene (MAPP) as a coupling agent was used. In order to make the desired composite, wheat straw flour and polypropylene polymer ratio of 30/70, 40/60 and 50/50, and maleic anhydride grafted polypropylene with a constant level of 5% was used (Table 1). Also, to evaluate the effect of the amount of liquor powder on the composite properties, liquor powder was used at four levels of 0, 5, 10 and 15% based on dry weight of wheat straw. The materials for each treatment were mixed with two spiral extruders located in Iran Polymer and Petrochemical Institute and samples related to physical and mechanical tests were prepared by injection molding method. Subsequently, test samples to reach moisture equilibrium with the environment were placed in a climatic condition for at least 48 hours. Thickness swelling after 2 and 24 hours immersion in water and mechanical properties including flexural strength and modulus, and tensile strength and modulus according to ASTMD790 and ASTMD638 standards were measured. All the data were statistically analyzed by using the analysis of variance (ANOVA) and Duncan's mean separation tests.

Table 1- the percentage of components made of composites

Row	Treatment code	Wheat straw (%) flour	Polypropylene (%)	Liqueur (%) powder	MAPP
1	**A_1B_1**	**30**	**65**	**0**	**5**
2	**A_1B_2**	**25**	**65**	**5**	**5**
3	**A_1B_3**	**20**	**65**	**10**	**5**
4	**A_1B_4**	**15**	**65**	**15**	**5**
5	**A_2B_1**	**40**	**55**	**0**	**5**
6	**A_2B_2**	**35**	**55**	**5**	**5**
7	**A_2B_3**	**30**	**55**	**10**	**5**
8	**A_2B_4**	**25**	**55**	**15**	**5**
9	**A_3B_1**	**50**	**45**	**0**	**5**
10	**A_3B_2**	**45**	**45**	**5**	**5**
11	**A_3B_3**	**40**	**45**	**10**	**5**
12	**A_3B_4**	**35**	**45**	**15**	**5**

3 RESULTS AND DISCUSSION

3.1 Thickness swelling after 2 and 24 hours immersion in water

The results of analysis of variance showed that the interaction effect of wheat straw and liqueur powder on thickness swelling of the wood-plastic composites after 2 and 24 hours immersion in water was not significant (Fig. 1 and 2). It is known that the least amount of thickness swelling after 2 and 24 hours is related to treatment of 30% wheat straw flour and 0% liquor powder. But treatments of 40 and 50% wheat straw flour and 15% liqueur powder and 50% wheat straw and 10% liquor powder show the highest thickness swelling after 2 and 24 hours. Adhikary et al. (2008) studied the dimensional stability and mechanical behaviour of wood-plastic composite materials based on recycled heavy polyethylene and concluded that the dimensional stability and mechanical properties of composite are improved by adding 3 to 5% by weight of compatibilizer. The microscopic structure analysis of the corrected composite fracture surface confirmed the improvement of molecular chain joints.

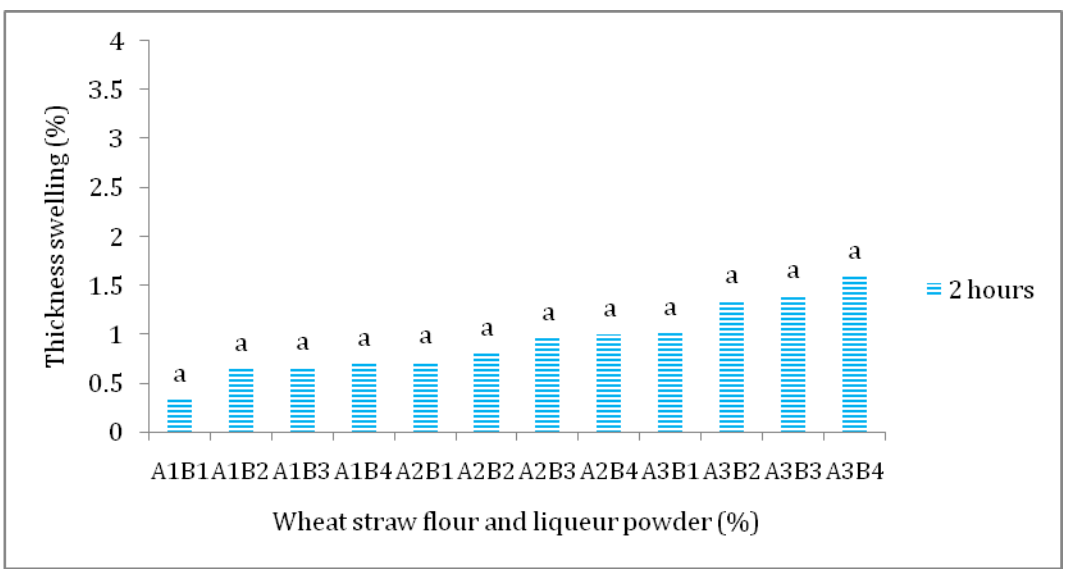

Figure 1. Interaction effect of wheat straw flour and black liqueur powder (AS-AQ) on thickness swelling after 2 hours immersion in water

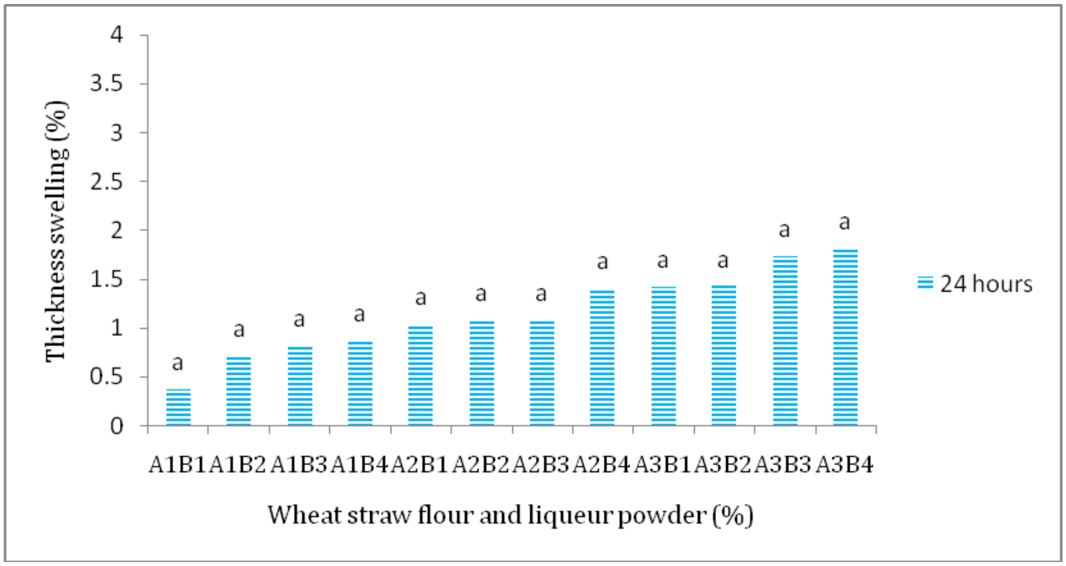

Figure 2. Interaction effect of wheat straw flour and black liqueur powder (AS-AQ) on thickness swelling after 24 hours immersion in water

3.2 Tensile and flexural strength

The results showed that the interaction effect of wheat straw flour and black liqueur powder on the flexural strength of wood-plastic composites is significant. As shown in Figure 3, the lowest flexural strength of wood-plastic composite is related to the use of 30% wheat straw and 5% black liqueur powder, and its highest value is the use of 50% wheat straw and 15% black liqueur powder. As a result, it can be concluded that even using 50% wheat straw flour, the amount of acceptable flexural strength was achieved. As a result, it is possible to produce composites that consume more wheat straw flour, which is a bio-degradable substance. Analysis of variance showed that the interaction effect of wheat straw flour and black liqueur powder on tensile strength of wood-plastic composites was not significant. As shown in Fig. 4, the lowest tensile strength of wood-plastic composites is related to the use of 50% wheat straw flour and 15% black liqueur powder and its highest value is the use of 30% wheat straw flour and 0% black liqueur powder. As a result, it can be deduced that even with 50% wheat straw flour, the amount of acceptable tensile strength was achieved. This means increasing the amount of black liquor powder (15%) has moderated the negative impact of rising wheat straw flour consumption. As a result, it is possible to produce products with higher consumption of wheat straw, which is a biological and destructive substance. The tensile strength decreases with increasing fiber and reducing the amount of black liquor powder. Xue et al. (2003) studied the mechanical properties of wood fiber / polypropylene composites and optimized the composition of these composites. The results showed that poplar fiber reinforced composites have better mechanical properties than pure polymers, and improve maleic anhydride bonded to polypropylene, the bond between the fibers and the material, as well as the tensile strength.

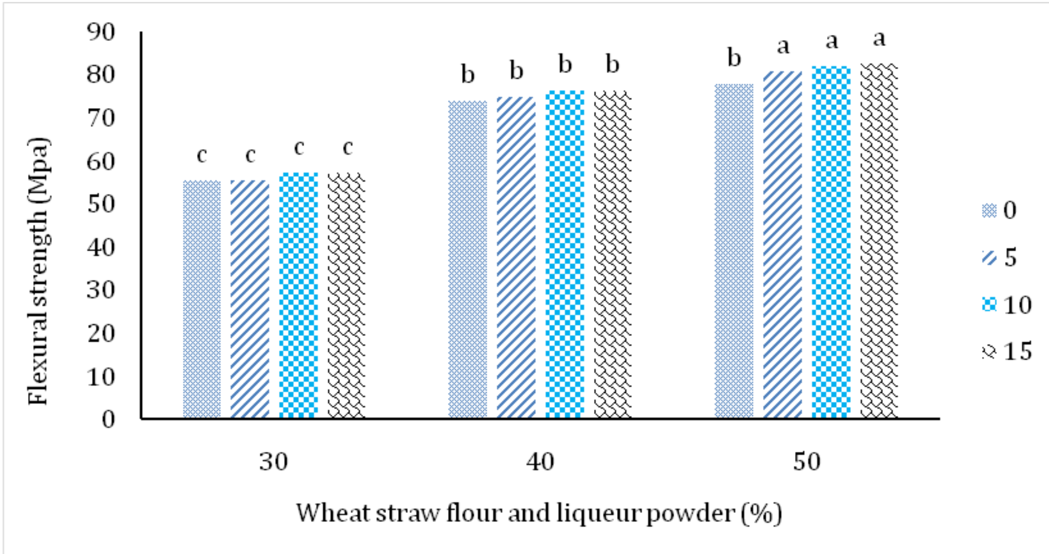

Figure 3: Interaction effect of wheat straw flour and black liqueur powder (AS-AQ) on flexural strength of the samples

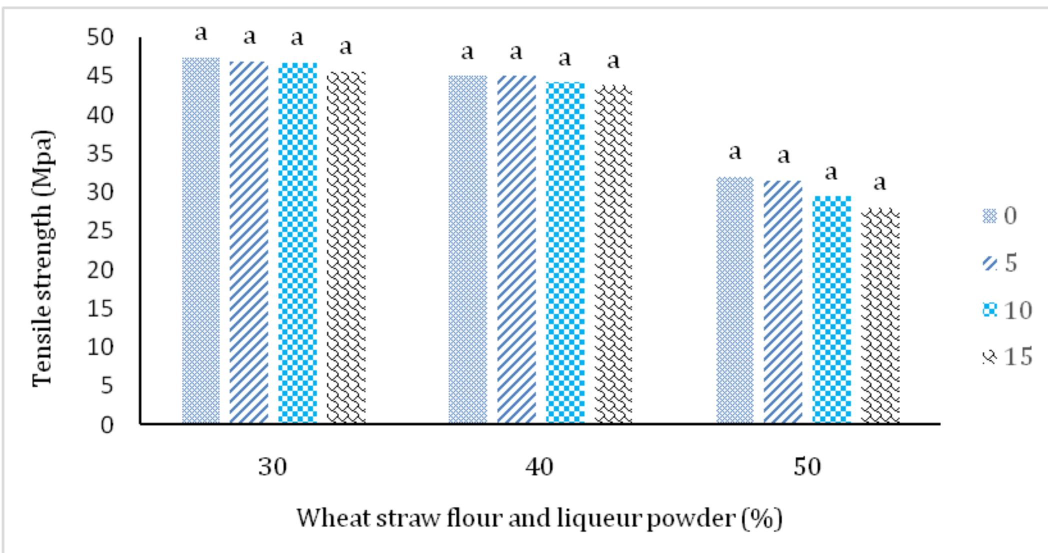

Figure 4: Interaction effect of wheat straw flour and liqueur powder (AS-AQ) on tensile strength of the samples

3.3 Tensile and flexural modulus

The results of variance analysis showed that the interaction effect of wheat straw flour and black liqueur powder on flexural modulus of wood-plastic composites is significant. As shown in Fig. 5, the lowest amount of flexural modulus is related to the use of 30% wheat straw flour without any black liquor powder and the highest amount was using 50% wheat straw flour and 10 and 15% black liqueur powder in a common group. Also the results showed that the interaction effect of wheat straw flour and black liqueur powder on tensile modulus of wood-plastic composite is not significant. As shown in Fig. 6, the least amount of tensile strength of wood-plastic composites is related to the use of 30% wheat straw flour without any black liquor powder and its highest value is the use of 50% wheat straw flour and 15% black liqueur powder. As a result, it can be deduced that even with the consumption of 30% wheat straw flour, an acceptable tensile modulus can be obtained. Buzarovska et al (2008) used the rice straw as filler in polypropylene composites. Rice straw improved mechanical properties. The flexural and tensile modulus increased with increasing filler in the composites.

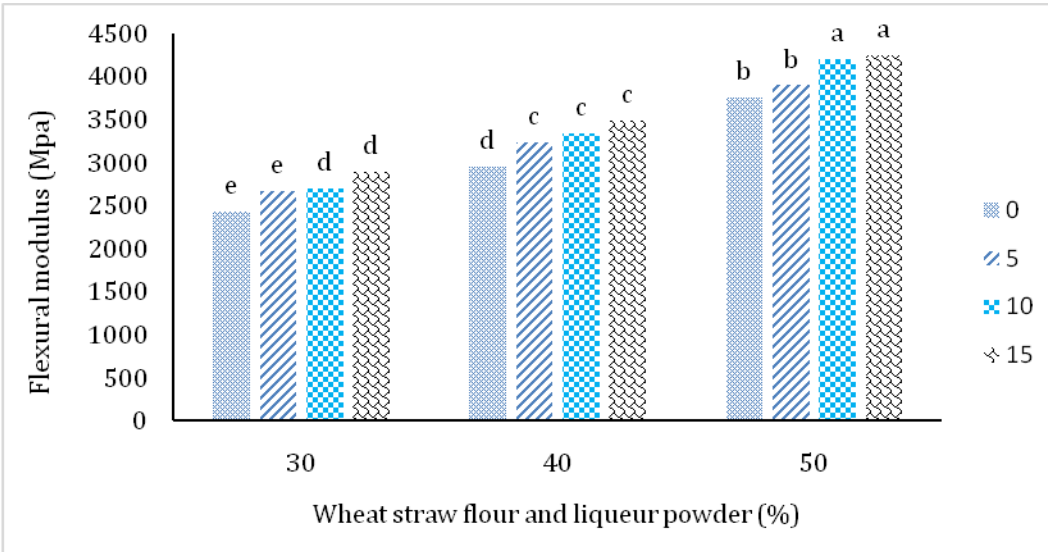

Figure 5: Interaction effect of wheat straw flour and black liqueur powder (AS-AQ) on flexural modulus of the samples

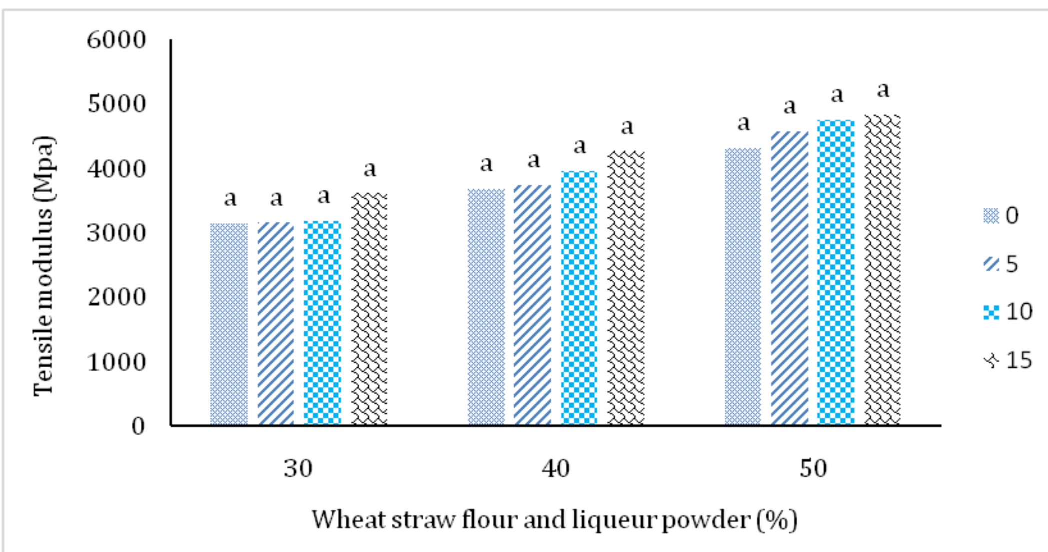

Figure 6: Interaction effect of wheat straw flour and black liqueur powder (AS-AQ) on tensile modulus of the samples

4 CONCLUSION

The results of this study show that thickness swelling of the wood-plastic composites after 2 and 24 hours immersion in water increased by increasing the amount of wheat straw flour. Increasing wheat straw flour in composites, due to the fact that lignocellulosic materials have a hydrophilic structure, the amount of water absorption and following that thickness swelling increases. The highest amount is related to the use of 50% wheat straw flour and 15% black liquor powder. In fact, polymers are hydrophobic due to non-polarity, and this is the opposite of the hydrophilic nature of cellulosic fibers. So adding cellulosic fillers to the polymer matrix can increase thickness swelling of the wood-plastic composites. On the other hand, the presence of water-soluble hydroxyl groups of cellulose chains cause formation new hydrogen bonding with water molecules, which results water absorption and thickness swelling of the wood-plastic composites. But according to the results, increasing the application of black liqueur powder did not significantly change the thickness swelling after 2 and 24 hours of the boards. Black liqueur powder causes chemical reactions between the lignocellulosic material and polymer and bonded with hydroxyl groups of lignocellulose materials and the formation of ester groups that in addition to deactivating the available hydroxyl groups of lignocellulosic fibers, the hydrophilic nature makes them hydrophobic. Therefore, although the use of 50 % wheat straw flour thickness swelling of the wood-plastic composite increases, but due to the insignificant combination of variable factors, it can be deduced that even with 50% wheat straw flour, the thickness swelling reached an acceptable level. Because of the combination of variable factors, increasing the percentage of black liquorice powder (15%) moderates the negative effect of increasing wheat straw flour on the thickness swelling. The results of this study show that with increasing wheat straw flour, the flexural strength of the composite increases significantly. With increasing wheat straw flour from 0% to 50% and 10% of black liquor powder, the flexural strength increased. The mechanical properties of the composites are highly dependent on the surface quality of the two substrates and the reinforcing material phase, because the transfer of stress from the polymeric material to the reinforcing phase is carried out by the region. Considering that matrix phase role maintaining the reinforcing phase and transferring power to it and the role of the reinforcing phase is to increase the matrix strength, hence, with increasing wheat straw flour, the tolerable stress of the composite material was reduced to some extent. The results of this study show that with increasing wheat straw flour, tensile strength decreases. The highest amount was related to the use of 30% wheat straw flour without any black liquor powder and the lowest was the use of 50% wheat straw flour and 15% black liquor powder .However, no significant difference was observed between treatments andall of them placed in the same group. The reason for this can be stated that, basically, in wood-plastic composites, plastic play the role of adhesive for bonding wood particles. This connection is a result of the plastic melt, causing the wood fibers to each other is connected, therefore, by increasing the percentage of fiber, the percentage of plastic decreases, and subsequently the amount of these connections will also decrease, and as a result, the tensile strength will be reduced. The flexural modulus increased significantly with the increase of wheat straw flour compared to polypropylene. The highest amount is due to the use of 50% wheat straw flour and 15% black liquor powder. The results also showed that the interaction of wheat straw flour and black liquor powder on the tensile modulus of wood-plastic composite is not significant. The highest amount is related to the use of 50% wheat straw flour and 15% black liquor powder. But all levels of using wheat straw flour and black liquor powder were in the same groups. By increasing the use of lignocellulosic filler in the composite structure, the tensile modulus has increased, which is obvious because wheat straw flour has a higher modulus of elasticity than polypropylene polymer. So this feature has been improved by decreasing the amount of polymer and increasing the amount of flour in the composite. Therefore, based on the results of this study, it can be concluded that due to the high level of wheat straw in Golestan province and and abundant production of wheat straw is burned as waste, the possibility of producing wood-plastic composite using this type of waste is recommended. Considering the application of this product and the importance of its mechanical or physical properties, it can be stated that wheat straw flour can be used up to 50%, because the use of 50% wheat straw flour in the manufacture of wood-plastic composite reduces the contribution of using polymers, which are not biodegradable chemical compounds. In addition of reducing environmental impacts, it also reduces costs and also increasing the amount of black liquor powder has led to improved mechanical properties.

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Investigation on Dimensional Stability of Particleboard Manufactured from Tobacco Stalk Wastes and Industrial Wood Particles

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ABSTRACT

In this study, the dimensional stability of particleboard manufactured by industrial wood particles and agricultural wastes including tobacco stalks was investigated. For this purpose, different ratios of tobacco stalk wastes and industrial wood particles were used including 0:100, 30:60 and 60:40. Also, UF resin was used as 12 wt% and 14 wt%. Then Thickness swelling within 2 and 24 hours immersion in water was measured. The results showed that increasing the amount of tobacco stalk particles increased the thickness swelling within 2 and 24 hours immersion in water, but all of the boards had optimum standard of EN. It means that increasing the amount of tobacco stalk particles even up to 60 percent had no negative effect on dimensional stability in accordance with EN standard. In addition, increasing the amount of UF resin had a positive effect on reducing thickness swelling and improved dimensional stability of the boards.

KEYWORDS: Dimensional stability, Tobacco stalk wastes, Urea formaldehyde resin.

1 INTRODUCTION

Nowsdays, due to the scarcity of resources and the growing demand for wood products, finding alternatives to the wood and paper industry and its related industries is inevitable. For this reason, lignocellulosic material obtained from agricultural wastes was considered as one of the alternative materials of forest resources in the manufacture of wood products, especially particleboard (Alvarez et al., 2011). The use of agricultural wastes as a renewable resource is one of the most important solutions that has been introduced in recent years and is not a new issue, and it seems inevitable to turn to the use of agricultural wastes. These points have led to a lot of research in recent years on the characteristics of wooden composite products, especially particleboard, from agricultural waste such as: wheat stems (Cheng et al., 2004; Sain and Panthapulakkal., 2006), wheat straw and tobacco stalk mixture (Jamlirad et al., 2017), rice straw (Zhang and Hu., 2014), tobacco (Acda and Cabangon, 2013), bagasse (Widyorini et al., 2005), rapeseed (Mazahari Mousavi et al. 2013), sunflower stems (Klìmek et al., 2016), kenaf (Kalaycıoglu and Nemli, 2006), bamboo (Sudin and Swamy, 2006), Coconut skin (Almedia et al., 2002), hazelnut (Cöpür et al., 2008) and cotton stem (Alma et al., 2005). Therefore, agricultural wastes is considered as an appropriate alternative because of their breadth, easy access, abundance, regeneration, high resistance, low density, environmental and economic issues (Sarki et al., 2011). *Nicotiana tobacom L.* is a non-woody plant belonging to *Nicotiana*, is one of the valuable agricultural products in Iran. After the leaves are harvested and transmitted to the cigarette industry, its stalk, which is 1 to 2 meters high and incorporated in the soil, can be like other similar herbaceous plants, such as hemp, jute, flax hemp (Flex), cannabis (Hampshire), and Rami (Agrupis et al. 2000; Olotuah, 2006), used as a raw material in the particleboard production. Waste tobacco stalk is a fibrous biomass consisting basically of cellulose, hemicelluloses and lignin (Shakhes et al., 2011). However, significant volume and presence of nicotine in waste tobacco stalks increasing solid waste disposal and pollution problems in many countries. Nicotine, 3-(1-methyl-2-pyrrolidinyl) pyridine, is one of the most highly toxic alkaloids from plants (Schmeltz., 1971). In Iran, tobacco is planted a lot annually and 20 percent of the country's total production is in Golestan province. Since these remains are only burnt which can cause a lot of environmental pollution. Therefore this present paper reports on the dimensional stability of particleboard manufactured by high volume of tobacco stalk and industrial wood particles and tow levels of UF resin in order to introduce the best mixture of them for particleboard production with standard limit.

2 MATERIAL AND METHODS

Right after tobacco harvest in Golestan Province, Iran, tobacco stalk residues collected from the farms used to produce particleboard. The residues were cleaned from impurities, cut in to chips and then screened to obtain appropriate particle size for particleboard production. Screened tobacco stalks were dried to 6-8% moisture content at 80 °C. Then they were immediately packaged in thick and impermeable nylon bags to prevent moisture exchange with ambient air. The industrial wood particles were provided by a commercial particleboard plant in Golestan province, Iran. The tobacco stalks mixed with industrial wood particles were used in three levels (0:100, 30:70, 60:40) (Table 2). The adhesive was urea formaldehyde resin which was produced by a local plant with characteristics given in Table 3. The UF resin was used in two levels of 12 wt% and 14 wt%. Ammonium chloride (NH_4Cl) was also added to the resin as a hardener for 2 wt% of UF resin. Then, a single layer of particleboard measuring 400 mm×400 mm×16 mm was produced at density of 0.7 g /cm^3. According to each treatment, tobacco stalk and industrial wood particles were placed in a drum blender and sprayed with urea formaldehyde and ammonium chloride to obtain a homogenized mixture. No wax was added to the mix in this research. Then the board production was performed by pressing the particle mat using a laboratory scale hydraulic hot press. Three panels were produced three times for each treatment. The produced particleboards conditioned at 21 °C and 65% relative humidity to reach moisture content of about 12% prior testing. After that, Dimensional stability of the boards (thickness swelling of the boards) according to EN 317 was determined.

3 RESULTS AND DISCUSSION

The results show that the amount of tobacco stalks particles and UF resin had no significant affects on thickness swelling of particleboards within 2 hours but affect the thickness swelling of composites within 24 hours at the 95% confidence level. As shown in Figures 1 and 2, at different levels of using tobacco stalk with 14% of the adhesive, the amount of thickness swelling of the boards within 2 and 24 hours immersion in water is at different levels. By increasing the amount of adhesive used up to 14%, the thickness swelling of the boards has decreased, That is, increasing the amount of adhesive used, although it improves the dimensional stability of the boards. However, variable factors do not have a significant effect on thickness swelling within 2 hours. Economically, 12% of the amount of adhesive used can be chosen as a suitable treatment, because with increasing the amount of adhesive, there is no statistically significant change in thickness swelling. All of the treatments have the maximum standard of thickness swelling within 24 hours immersion in water of P3 (Fig 2).

In this regard, according to the results of Papadopoulos et al (2004) research on the use of bamboo particles in the production of particleboard, it is also suggested that boards made from this lignocellulosic material with 10% adhesive can be used indoors, But to improve the features of the board that have an ANSI standard should have a glue consumption of 14%.

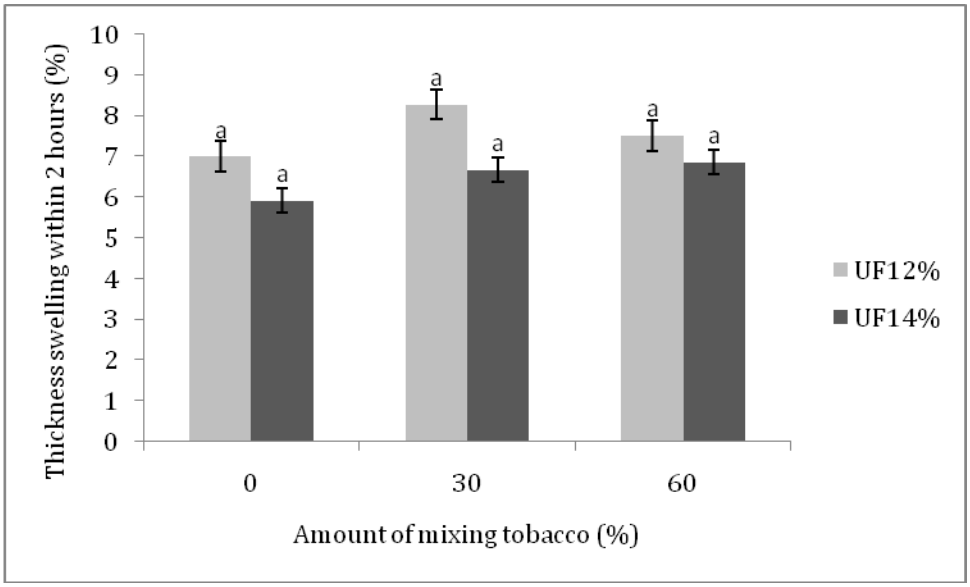

Figure 1: Comparison of thickness swelling (TS) of the composites within 2 hours as function of tobacco stalk and UF resin contents

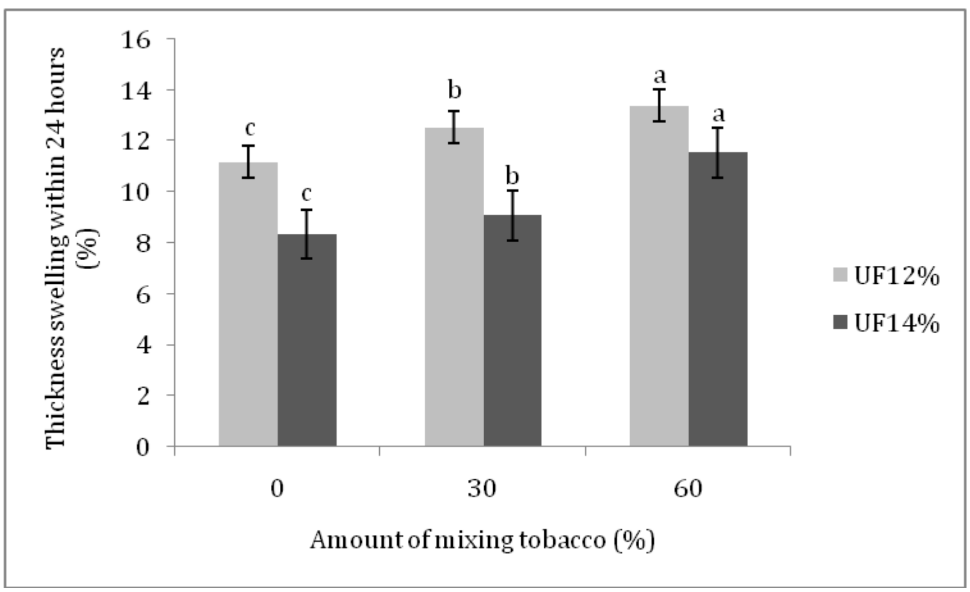

Figure 2: Comparison of thickness swelling (TS) of the composites within 24 hours as function of tobacco stalk and UF resin contents

4 CONCLUSION

In this research the particleboards from the combination of tobacco stalk particles and industrial wood particles using two levels of 12% and 14% UF resin consumption was produced. Then the dimensional stability of the boards was measured. The results showed that increasing the adhesive consumption of the boards from 12% up to 14% improves physical properties of the boards. The addition of a greater amount of adhesive to the wooden particles due to its increased use in the production of particleboard has led to boards having a better and more compact quality and better internal bonding which can reduce water absorption and subsequent thickness swelling of the boards. In addition according to the results revealed that with using 60% tobacco stalk particles and 40% of industrial wood particles and 12% and 14% UF resin consumption, thickness swelling of the boards within 24 hours immersion in water was better than the standard European (P3). The results showed that tobacco stalk particles can be used as a suitable and inexpensive raw material for particleboard production and is recommended for the production of boards with standard physical properties.

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ABSTRACT

Pine tree (*Pinus densiflora*) belongs to the family *Pinaceae* and are distributed in East-Asian countries, especially in Korea, northeast China and Japan. The tree has been used for oriental medicine, and also for health food and dietary supplements.

The wood and bark were collected and ground after drying, then immersed with 70 % aqueous ethanol for 3 days, respectively. After filtration, the extracts were fractionated with *n*-hexane, chloroform, ethyl acetate (EtOAc) and H_2O, then freeze dried after condensation.

Total flavonoid and polyphenol contents were investigated and glucose uptake activity, one of the antidiabetic tests, was also evaluated. Total flavonoid and polyphenol contents were higher in inner and outer bark than in wood. Glucose uptake activities on wood and bark were also similar to insulin used as the positive control in all of fractions.

EtOAc soluble fraction of bark were chromatographed on a Sephadex LH-20 column using MeOH, H_2O, various aqueous MeOH-H_2O and EtOH-hexane as eluting solvents. The isolated compounds were elucidated as

(+)-catechin (1), (-)-epicatechin (2), taxifolin (3), taxifolin-3'-*O*-*β*-D-(+)-glucose (4), quercetin (5) and quercitrin (6) by spectral and literature data, and also by comparison with the authentic samples.

Based on the above results, it can be suggested that the pine bark extractives can be a natural resource for manufacturing supplementary health products.

KEYWORDS: Pine tree (*Pinus densiflora*), column chromatography, flavonoid and polyphenol contents, glucose uptake activity, health products

1 INTRODUCTION

The World Health Organization (WHO) estimates that 80 % of the people in developing countries rely on the traditional medicines for their primary health care needs and that 85 % of the medicines are from the extracts of plants (Farnsworth et al., 1985). Plants constitute a rich source of bioactive chemicals and there are largely free from adverse effects and have excellent pharmacological actions (Kador et al., 1985a; 1985b). Therefore, recently there have been many studies to evaluate biological activities of various natural resources (Ko, 2011; Yang, 2011; Ko and Choi, 2015).

Pine tree (*Pinus densiflora*) belongs to the family *Pinaceae* and are distributed in East-Asian countries, such as Korea, northeast China and Japan. The tree is evergreen, 30 m high and 1.5 m in diameter, and the needles are 2 to 6 cm in length and 1 mm in width. The needles have been used to prepare the drinks in Asia (Kim, 2000).

The bark has been used as the remedies for bleeding, rheumatoid, bruise and scald, etc. in Korea.

However, there is a little report on the chemical constituents and biological investigation of pine tree. In this work, we investigated the chemical constituents of the extracts of pine tree, elucidated structures of the isolated compounds and evaluated some basic biological activities of the crude for future functional use

2 MATERIALS AND METHODS

2.1 Plant materials

Fresh xylem, inner bark and outer bark were collected at Gangwondo Forest Science Institute in September 2016, air dried for two weeks and then ground to fine particles to be extracted, respectively.

2.2 Sample preparation

The samples were ground after drying, then immersed with 70 % aqueous ethanol for 3 days, respectively. After filtration, the extracts were fractionated with *n*-hexane, chloroform, ethyl acetate (EtOAc) and H_2O, then freeze dried after condensation.

2.3 Biological activity

2.3.1 Total polyphenol content

Total polyphenol contents were measured using Folin-Ciocalteau's phenol reagent. Each sample (0.2 mL), distilled water (4.8 mL) and 0.5 mL of 50 % Folin-Ciocalteau's phenol (Sigma, St Louis, Missouri, USA) were mixed well and reacted for 3 minutes. 1 mL of 10% Na_2CO_3 was added After the reaction, the absorbance was measured at 700 nm using a UV / vis spectrophotometer. Total polyphenol contents were calculated by the calibration curve of gallic acid (Sigma, St Louis, Missouri, USA).

2.3.2 Total flavonoid content

Total flavonoid contents were measured by Moreno et al. 0.1 mL of 10 % aluminium nitrate, 0.1 mL of 1 M potassium acetate, and 4.3 mL of 80 % ethanol were mixed with 0.5 mL of each sample, and reacted at room temperature for 40 minutes. Then, the absorbance was measured at 415 nm using a UV / vis spectrophotometer. Total flavonoid contents were calculated by quercetin (Wako, Osaka, Japan) calibration curve.

2.3.3 Glucose uptake activity

The glucose uptake of HepG2 cells was measured by glucose uptake colorimetric assay kit. Cells were seeded at 1×10^5 cells / mL in 96-well plates, cultured for 24 hours, and then cultured for another 24 hours in a medium containing no FBS. The cultured cells were replaced with KRPH containing 2 % BSA. After 40 minutes, 1 μM insulin and sample (1 mg / mL) were treated and cultured for 20 minutes, followed by treatment with 10 mM 2-deoxyglucose for 20 minutes. Cells were treated with 8 μL of assay buffer and 2 μL of enzyme mix A, incubated at 37 °C for 1 hour, and then extracted with extraction buffer. After heating at 85 °C for 40 minutes, the mixture was cooled and neutralization buffer was added. After centrifugation at 500 rpm for 10 seconds, the supernatant was taken. 20 μL of glutathione reductase, 16 μL of DTNB [5-5'-dithiobis (2-nitrobenzoic acid)] and 2 μL of recycling mix were added to each well. And absorbance was measured at 412 nm using an ELISA microplate reader.

2.4 Chromatographic procedure and structure elucidation

A portion of bark EtOAc soluble fraction (6 g) was chromatographed on a Sephadex LH-20 column, successively eluting with MeOH-H2O (1:9 → 3:7 → 5:5 → 7:3 → 9:1, v/v) to afford 14 fractions.

^{1}H and ^{13}C NMR spectra, including 2D-NMR such as HSQC (Heteronuclear Single Quantum Coherence) and HMBC (Heteronuclear Multiple Bond Correlation), were recorded on a Bruker (USA) Avance DPX 700 MHz spectrometers using TMS (Tetramethylsilane) as an internal standard and chemical shift was given in δ (ppm).

Thin layer chromatography (TLC) was done on DC-Plastikfolien Cellulose F (Merck) plates and developed with TBAW (t-BuOH-HOAc-H2O (3:1:1, v/v/v)) and 6 % aqueous HOAc. The spot was detected by illuminating ultraviolet light (UV, 254 and 365 nm) and by spraying vanillin (Vanillin-EtOH-H_2SO_4 (15:250:2.5, w/v/v)), then heating.

2.4.1 Compound 1, (+)-catechin

Yellowish amorphous powder, R_f: 0.67 (TBAW) and 0.41 (6 % HOAc).

MALDI-TOF-MS: Calculated for $C_{15}H_{14}O_6$ 290, Found m/z 313 $[M+Na]^+$, 291 $[M+H]^+$.

^{1}H NMR (CD_3OD, δ): 2.50 (1H, *dd*, J = 8.1 and 16.1 Hz, H-4ax), 2.84 (1H, *dd*, J = 5.4 and 16.1 Hz, H-4eq), 3.98 (1H, *m*, H-3), 4.56 (1H, *d*, J = 4.5 Hz, H-2), 5.85 (1H, *d*, J = 2.3 Hz, H-6), 5.92 (1H, d, J = 1.9 Hz, H-8), 6.71 (1H, *d*, J = 1.9 Hz, H-6), 6.76 (1H, *dd*, J = 1.9 and 8.1 Hz, H-5), 6.97 (1H, *d*, J = 1.9 Hz, H-2).

^{13}C NMR (CD_3OD, ppm): 28.55 (C-4), 68.84 (C-3), 82.88 (C-2), 95.53 (C-8), 96.32 (C-6), 100.85 (C-10), 115.28 (C-2'), 116.12 (C-5'), 120.08 (C-6'), 132.24 (C-1'), 146.26 (C-3'), 146.28 (C-4'), 157.86 (C-7), 157.61 (C-5), 156.95 (C-9).

2.4.2 Compound 2, (-)-epicatechin

Brownish amorphous powder, R_f: 0.37 (TBAW) and 0.31 (6 % HOAc).

EI-MS: Calculated for $C_{15}H_{14}O_6$ 290, Found m/z 290 $[M]^+$.

^{1}H NMR (CD_3OD, δ): 2.73 (1H, *dd*, J = 2.8 and 16.8 Hz, H-4ax), 2.86 (1H, *dd*, J = 4.6 and 16.8 Hz, H-4eq), 4.17 (1H, *m*, H-3), 4.81 (1H, *s*, H-2), 5.92 (1H, *d*, J = 2.2 Hz, H-6), 5.94 (1H, *d*, J = 2.2Hz, H-8), 6.75 (1H, *d*, J = 8.2 Hz, H-5'), 6.79(1H, *dd*, J = 1.8, 8.2 Hz, H-6'), 6.97 (1H, *d*, J = 1.8 Hz, H-2').

^{13}C NMR (CD_3OD, ppm): 29.31 (C-4), 67.54 (C-3), 79.93 (C-2), 95.93 (C-8), 96.43 (C-6), 100.11 (C-10), 115.37 (C-2'), 115.93 (C-5'), 119.43 (C-6'), 132.33 (C-1'), 145.83 (C-4'), 145.99 (C-3'), 157.41 (C-9), 157.72 (C-5), 158.05 (C-7).

2.4.3 Compound 3, taxifolin

Brownish amorphous powder, R_f: 0.76 (TBAW) and 0.38 (6 % HOAc).

MALDI-TOF-MS: Calculated for $C_{15}H_{12}O_7$ 304, Found m/z 327 $[M+Na]^+$, 305 $[M+H]^+$.

^1H NMR (CD_3OD, δ): 4.51 (1H, *d*, *J* = 11.5 Hz, H-3), 4.91 (1H, *d*, *J* = 11.5 Hz, H-2), 5.88 (1H, *d*, *J* = 2.0 Hz, H-6), 5.92 (1H, *d*, *J* = 2.1 Hz, H-8), 6.80 (1H, *d*, *J* = 8.1 Hz, H-5'), 6.85 (1H, *dd*, *J* = 1.9 and 8.1 Hz, H-6'), 6.97 (1H, *d*, *J* = 1.9 Hz, H-2').

^{13}C NMR (CD_3OD, ppm): 73.87 (C-3), 85.32 (C-2), 96.61 (C-8), 97.63 (C-6), 102.12 (C-10), 116.20 (C-2'), 116.47 (C-5'), 121.30 (C-6'), 130.08 (C-1'), 145.49 (C-3'), 147.34 (C-4'), 164.72 (C-9), 165.44 (C-5), 168.88 (C-7), 198.69 (C-4).

2.4.4 Compound 4, taxifolin-3'-*O*-*β*-D-(+)-glucose

Brownish amorphous powder, R_f: 0.61 (TBAW) and 0.67 (6 % HOAc).

FAB-MS: Calculated for $C_{21}H_{22}O_{12}$ 467, Found m/z 466 $[M-H]^-$.

^1H NMR (CD_3OD, δ) : 3.26~3.51 (4H, *m*, H-2'', 3'', 4'', 5''), 3.73 (1H, *dd*, J = 5.61 and 5.46 Hz, H-6'' a), 3.87 (1H, *d*, J = 3.02 and 11.8 Hz, H-6'' b), 4.56 (1H, *d*, J = 11.63 Hz, H-1''), 4.81 (1H, *d*, J = 11.63 Hz, H-3), 4.97 (1H, *d*, J = 1.8 and 10.0 Hz, H-2), 5.89 (1H, *d*, J = 15.47 Hz, H-6), 5.90 (1H, *d*, J = 1.9 Hz, H-8), 6.78 (1H, *d*, J = 8.25 Hz, H-5'), 7.14 (1H, *d*, J = 8.28 Hz, H-6'), 6.96 (1H, *d*, J = 1.6 Hz, H-2').

^{13}C NMR (CD_3OD, ppm): 62.62 (C-6''), 71.27 (C-4''), 74.65 (C-2''), 77.20 (C-3), 77.63 (C-5''), 78.23 (C-3''), 83.59 (C-2), 96.36 (C-6), 97.36 (C-8), 102.56 (C-10), 102.60 (C-1''), 115.90 (C-2'), 116.22 (C-5'), 121.12 (C-6'), 129.01 (C-'0), 146.42 (C-4'), 147.37 (C-3'), 164.18 (C-9), 165.54 (C-5), 169.17 (C-7), 195.94 (C-4).

2.4.5 Compound 5, quercetin

Yellowish amorphous powder, R_f: 0.58 (TBAW) and 0.00 (6 % HOAc).

EI-MS: Calculated for $C_{15}H_{10}O_7$ 302, Found m/z 302 $[M]^+$.

^1H NMR (CD_3OD, δ): 6.27 (1H, *d*, *J* = 2.0 Hz, H-6), 6.53 (1H, *d*, *J* = 2.0 Hz, H-8), 7.00 (1H, *d*, *J* = 8.5 Hz, H-5'), 7.70 (1H, *dd*, *J* = 2.3 and 8.5 Hz, H-6'), 7.82 (1H, *d*, *J* = 2.3 Hz, H-2'),

^{13}C NMR (CD_3OD, ppm): 94.45 (C-8), 99.17 (C-6), 104.08 (C-10), 115.71 (C-2'), 116.18 (C-5'), 121.44 (C-6'), 123.71 (C-1'), 136.77 (C-3), 145.93 (C-3'), 147.02 (C-2), 148.43 (C-4'), 157.75 (C-9), 162.28 (C-5), 165.13 (C-7), 176.60 (C-4).

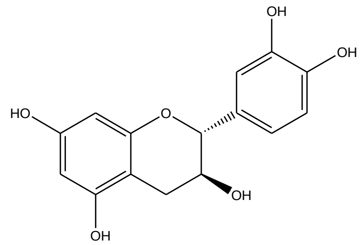
2.4.6 Compound 6, qercitrin

Yellowish amorphous powder, R_f: 0.63 (TBAW), 0.25 (6 % HOAc).

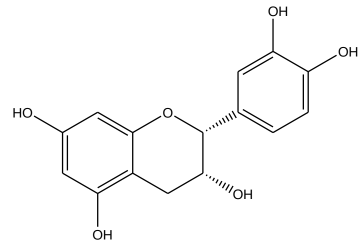
MALDI-TOF-MS: Calculated for $C_{21}H_{20}O_{11}$ 448, Found m/z 449 $[M+H]^+$.

^1H NMR (CD_3OD, δ): 0.95 (3H, *d*, *J* = 6.2 Hz, H-6''), 3.28 (1H, *m*, H-4''), 3.35 (1H, *m*, H-5''), 3.73 (1H, *dd*, *J* = 3.4 and 9.3 Hz, H-3''), 4.20 (1H, *d*, *J* = 3.31 Hz, H-2''), 5.35 (1H, *d*, *J* = 1.5 Hz, H-1''), 6.19 (1H, *d*, *J* = 2.1 Hz, H-6), 6.36 (1H, *d*, *J* = 2.1 Hz, H-8), 6.85 (1H, *d*, *J* = 8.8 Hz, H-5'), 7.25 (1H, *dd*, *J* = 8.3 and 2.2 Hz, H-6'), 7.31 (1H, *d*, *J* = 2.1 Hz, H-2').

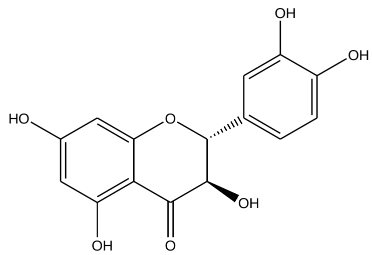
^{13}C NMR (CD_3OD, ppm): 18.06 (C-6''), 72.32 (C-5''), 72.44 (C-3''), 72.53 (C-2''), 73.67 (C-4''), 95.12 (C-8), 100.22 (C-6), 103.96 (C-1''), 106.31 (C-10), 116.78 (C-5'), 117.34 (C-2'), 123.27 (C-6'), 123.39 (C-1'), 136.65 (C-3), 146.83 (C-3'), 150.21 (C-4'), 158.94 (C-9), 159.72 (C-2), 163.64 (C-5), 166.29 (C-7), 180.07 (C-4).



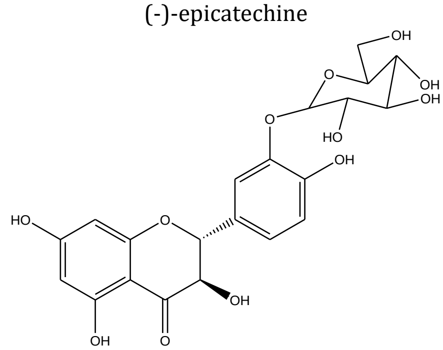
(+)-catechin



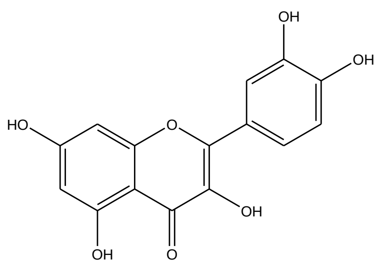
(-)-epicatechine



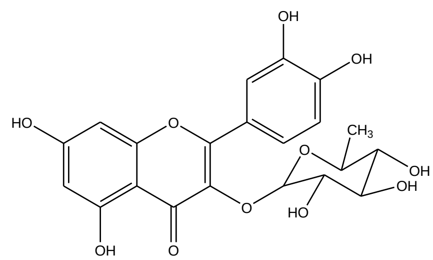
taxifolin



Taxifolin-3'-*O*-*β*-D-(+)-glucose



quercetin



quercitrin

Figure 1: Chemical structures of isolated compounds.

3 RESULTS AND DISCUSSION

3.1 Total polyphenol content

The total polyphenol contents were higher in inner and outer bark than in xylem. Also the contents were higher in the EtOAc soluble fractions compare to the other fractions as shown in Fig. 2.

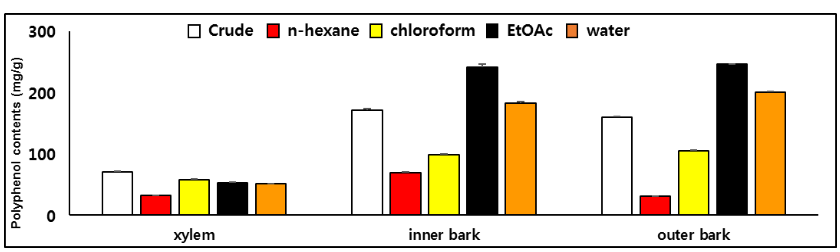


Figure 2: Total polyphenol contents of each fractions in the pine extracts.

3.2 Total flavonoid content

The total flavonoid contents were also similar results to the total polyphenol contents. In the xylem, the contents were low and high in the inner bark and outer bark. However, the higher flavonoids contents were in the water soluble fractions as shown in Fig. 3.

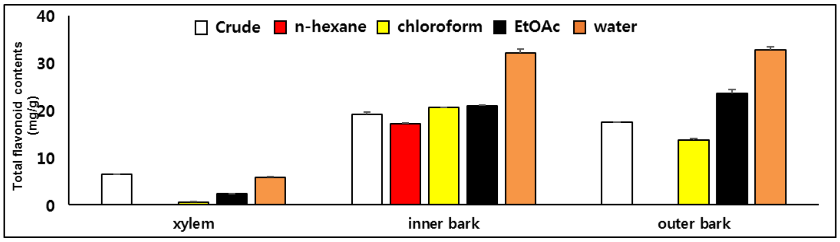


Figure 3: Total flavonoid contents of each fractions in the pine extracts.

3.3 Glucose uptake activity

In the previous study, the antidiabetic experiment using α-glucosidase had no α-glucosidase inhibitory activity in the pine extracts.

In this work, the glucose uptake activities of the extracts were done on each fractions, including crude extracts. All of the fractions indicated higher activities compare to the untreated control and the activities were close to 80% of commercial insulin as shown in Fig. 4. Therefore, the pine extracts may have a potential to be used for manufacturing a health product to control diabetes in the future.

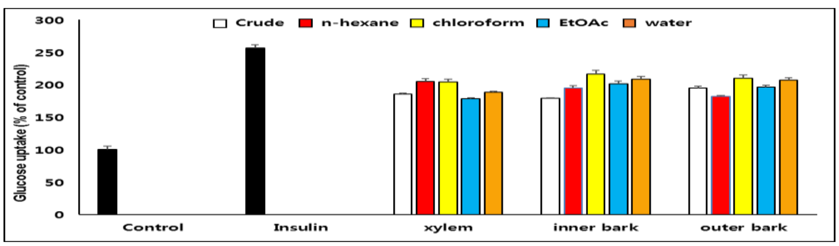


Figure 4. Glucose uptake activities of each fractions in the pine extracts.

3.4 Structure analysis

3.4.1 Compound 1

Compound 1 was obtained as a yellowish amorphous powder and on the basis of the above spectral evidence, it was identified as (+)-catechin (Foo et al., 1983).

3.4.2 Compound 2

Compound 2 was obtained as a brown amorphous powder and identified as (-)-epicatechin ((+)-(2R,3R)-5,7,3',4'-tetrahydroxyflavan-3-ol) on the basis of the above results and literature data (Agrawal, 1989),

3.4.3 Compound 3

Compound 3 was isolated as a brownish amorphous powder and elucidated as taxifolin, which was good agreement with the literature (Harbone and Mabry, 1982).

3.4.4 Compound 4

Compound 4 was isolated as a yellowish amorphous powder.

Accordingly, this compound was elucidated as taxifolin-3'-*O*-*β*-D-(+)-glucopyranose, which was also coincided by comparison of the literature data (Agrawal, 1989).

3.4.5 Compound 5

Compound 5 was obtained as a yellowish amorphous powder from EtOAc soluble fraction.

According to the spectral data, it was identified as quercetin (3,5,7,3',4'-pentahydroxyflavone) (Kwon et al., 2007; Luo et al., 2009).

3.4.6 Compound 6

Compound 6 was obtained as a yellowish amorphous powder from H2O soluble fraction.

On the basis of the spectral data and by comparison of the literature data (pyo et al., 2002; Lee et al., 2004), it was elucidated as quercetin-3-*O*-*α*-L-rhamnopyranose, quercitrin.

4 CONCLUSION

Pine tree xylem, inner bark and outer bark were collected and ground after drying, then immersed with 70 % aqueous ethanol for 3 days, respectively. After filtration, the extracts were fractionated with *n*-hexane, chloroform, ethyl acetate (EtOAc) and H_2O, then freeze dried after condensation.

Total flavonoid and polyphenol contents were investigated and glucose uptake activity, one of the antidiabetic tests, was also evaluated. Total flavonoid and polyphenol contents were higher in inner and outer bark compare to xylem extract. All fractions of the pine extracts had good potentials in glucose uptake activity and similar activities to insulin, a commercial control. Therefore, the pine extracts may have a big potential to be used for manufacturing a health product to control diabetes in the future. EtOAc soluble fraction of inner bark was chromatographed on a Sephadex LH-20 column using MeOH, H_2O, various aqueous MeOH-H_2O and EtOH-hexane as eluting solvents to separate the chemical constituents of the extracts. The isolated ones were (+)-catechin (1), (-)-epicatechin (2), taxifolin (3), taxifolin-3'-*O*-*β*-D-(+)-glucose (4), quercetin (5) and quercitrin (6). Of these isolated compounds, (-)-epicatechin (2), quercetin (5) and quercitrin (6) were reported, for the first time, in this work.

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Thermal Conductivity of Cross Laminated Timber (CLT) with A 45° Alternating Layer Configuration

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ABSTRACT

Cross-laminated timber (CLT) has increasingly become a viable alternative to other structural materials, mainly because of its excellent properties related to sustainability, energy efficiency, and speed of construction. This has resulted in the recent emergence of a significant number of CLT buildings constructed around the world. Cross-laminated timber panels consist of lumber boards stacked and glued in layers, which run perpendicular to each other, making them dimensionally stable with high in- and out-of-plane strength and stiffness. Thermal conductivity is used to estimate the ability of insulation of material. Thermal conductivity of wood material has varied according to wood species, direction of wood grain, specific gravity, moisture content, resin type, and addictive members used in manufacture of wood composite panels. The aim of this study is the comparison of two types of CLT panels consisting of boards either with grain direction aligned at 45˚ or at 90˚, in terms of their insulation properties. In the study, spruce (*Picea orientalis L.*) was used as a wood species, and was used polyurethane for CLT panels. Thermal conductivity of CLT panels was determined according to ASTM C 518 & ISO 8301. As a result of this study, it was indicated that thermal conductivity values for 90˚ layers were higher than the values for 45˚ layers.

KEYWORDS: Cross-laminated Timber, Grain Direction, Spruce, Thermal Conductivity

1 INTRODUCTION

In facing the global warming trend, there is a dire need for more effective measures to sustain comfortable temperatures in living environments. To sustain an indoor temperature that is independent of outdoor temperature fluctuations, materials need to be developed that have superior thermal insulation abilities (Kawasaki and Kawai 2006). Wood has been intensively used as residential construction material due to its natural beauty and great properties, such as high specific strength, thermal insulation, and ease of handling and processing (Kilic et al. 2006). For example, wood's low thermal conductivity and good strength make it of special interest for building construction, refrigeration, automobile applications, and cooperage, among others (Gu and Zink-Sharp 2005; Sahin Kol and Altun 2009; Aydin et al., 2015). Technological improvements in mass timber engineering have created a renewed sense of purpose and a more versatile use of wood as a building material. Combined with environmental issues, the importance of wood-based structures is becoming more evident compared with steel and concrete, which in turn will promote further advancements toward sustainable construction solutions (Fredriksson, 2003; Buck et al., 2016). Reducing energy consumption of buildings is required in order to counteract global warming induced by carbon dioxide, and thermal insulation of a building is an important part of this process. One of the development concepts used in the design of insulation materials is to aim to achieve a low thermal conductivity (k-value). An alternative development concept is to aim to use environmentally friendly products (Sekino, 2016).

Timber constructions have undergone a revival of popularity over the last years; this positive trend is associated to a combination of several factors. Firstly, wood-based structural products generate fewer pollutants compared to the mineral-based building materials (e.g. steel and concrete) because are obtained from sustainable and renewable resources. Secondly, timber structural elements are prefabricated off-site and transported to the building location, where they are quickly assembled. Finally, the high strength-to-weight ratio of wood is a great advantage for structures erected in seismic-prone areas, because it limits the total mass of the buildings (Izzi et al., 2018). Cross-laminated timber (CLT) is an innovative engineering wood panel product made from gluing layers of solid-sawn lumber at perpendicular angles. Owing to the excellent structural rigidity in both orthogonal directions, CLT becomes a preferred construction material for shear walls, floor diaphragms, and roof assemblies. CLT is normally made of Spruce-pine-fir (SPF) lumber or Douglas fir-Larch lumber (He et al., 2018). Cross-laminated timber (CLT) is an engineered wood product that is playing a major role in the worldwide push for wood buildings taller than the conventional limit of 5–6 stories for light-frame wood construction (Sullivan et al., 2018). It can also be combined with other mass timber produces such as glulam beams and columns (Bolvardi et al., 2018). The higher strength, stiffness, and solid wood volume of CLT, compared to conventional light frame construction, are the specific characteristics enabling the increased building heights of wood structures (Sullivan et al., 2018).

With the increasing adversity of climate changes from global warming, discussions within the international community for establishing an appropriate response policy have become more urgent (Seo et al., 2011). In facing the global warming trend, there is a dire need for more effective measures to sustain comfortable temperatures in living environments. To sustain an indoor temperature that is independent of outdoor temperature fluctuations, materials need to be developed that have superior thermal insulation abilities (Kawasaki and Kawai, 2006). Thermal conductivity is a very important parameter in determining heat transfer rate and is required for development of thermal insulation of materials (Sahin Kol and Altun, 2009). Several studies about thermal conductivity of composite materials showed that thermal conductivity was influenced thickness of composite materials, density, moisture content, temperature, material space ratio and flow direction of heat (Suleiman et al., 1999; Bader et al., 2007; Sonderegger and Niemz, 2009; Aydin et al., 2015).

The aim of this study is the comparison of two types of CLT panels consisting of boards either with grain direction aligned at 45˚ or at 90˚, in terms of their insulation properties. In the study, spruce (*Picea orientalis L*.) was used as a wood species, and was used polyurethane for CLT panels. Thermal conductivity of CLT panels was determined according to ASTM C 518 & ISO 8301.

2 MATERIAL AND METHODS

In this experimental study, 20 mm-thick lumber with the dimensions of 100 mm by 100 mm were obtained from Spruce (Picea orientalis L.) logs. The average moisture content was 12±3% as determined by the oven dry method according to EN 322 (1999). Afterwards, the lumber processed both edgewise and flatwise through a jointer, the dimensions of each individual board were 16 mm in thickness and 85 mm in width. Three-layer-CLT panels with 48 mm thick were manufactured by using Polyurethane (PUR) glue resin. The glue was applied at rate of 160 g/m^2 to the single surfaces of logs. After gluing, it was formed CLT panel drafts. The draft of CLT panels is shown in Figure 1. Two types of CLT panels were produced: transverse layers at 45° and the conventional 90° arrangement. Press pressure was 8 kg/cm^2 while pressing time and temperature were 40 min and 40°C, respectively. Two replicate panels were manufactured for each test groups. Test samples were conditioned to achieve equilibrium moisture content at 20 °C temperature and 65% relative humidity prior to testing.

Figure 1: Draft of cross laminated timber

The thermal conductivity of the cross laminated veneer were determined according to ASTM C 518 & ISO 8301 (2004). Sample size required is 300x300xpanel thickness mm. Two specimens were used for each group. The tests were made at laboratory of Forest Industry Engineering in KTU. The Lasercomp Fox-314 Heat Flow Meter shown in Figure 2 was used for the determination of thermal conductivity.

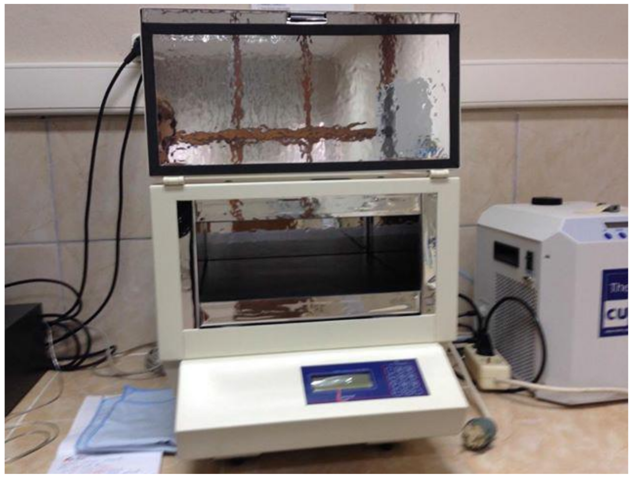

Figure 2: Lasercomp Fox-314 Heat Flow

3 RESULTS AND DISCUSSION

As a result of this study, it was indicated that thermal conductivity values for 90˚ layers were higher than the values for 45˚ layers. The thermal conductivity values in the 45° alternating CLT layers was found to be 0,1015 W/mK and in the 90° alternating CLT layers it was found to be 0,1032 W/mK. Wood is a hygroscopic, porous material. The unique structure of wood causes the anisotropic nature of wood in its mechanical and physical properties. Thermal conductivity of wood has been studied by many scientists (Festus et al., 2017). Several studies about thermal conductivity of composite materials showed that thermal conductivity was influenced thickness of composite materials, density, moisture content, temperature, material space ratio and flow direction of heat (Suleiman et al., 1999; Bader et al., 2007; Sonderegger and Niemz, 2009; Aydin et al., 2015). The thermal conductivity of wood varies in the three main directions of wood as they are usually referred to in the wood lumber industry – Longitudinal direction (parallel to the grain, along the length of a tree), Radial direction, (perpendicular to the grain, along the radius of the cross section) and Tangential direction (perpendicular to the gain, tangent to each growth ring) (Festus et al., 2017).

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Effecting of Some Quality Properties of Press Plates in Different Forms on Melamine Coated Particleboard Surfaces

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ABSTRACT

In this research, it was aimed to determine the effect of the press sheets (chipboard covered with melamine resin impregnated decor paper) with different forms on the surface properties (cigarette fire, water vapor, and resistance to hot pots). For this purpose, 8 mm thick test plates pressed with melamine resin décor papers were obtained by using press plates with four different surfaces (NTR, HGS, BUTE, STR). According to test results; mean values of resistance to cigarette fire (were prepared according to TS EN 14323) were NTR (4), BUTE (4,33), HGS and STR (4,66); mean values of water vapor resistance (were prepared according to TS EN 14323) were determined as NTR and BUTE (5), HGS and STR (4,66). Despite that, it has been found that the average values of press sheets with different forms give a similar result. Despite that, it has been found that press sheets with different forms give similar results (5) in the mean values of the resistance to hot containers (were prepared according to TS EN 438-2).

KEYWORDS: Particle board, Decor paper, Press sheet form, Surface properties

1 INTRODUCTION

The furniture has been produced in various forms for centuries although they are rarely designed considering their structural characteristics (Eckelman, 1966). Structural (engineering) design in furniture is important for designing furniture that will provide reliable service to the user. In order for a furniture system or furniture assembly to be structurally designed and analyzed in a manner that is appropriate to the engineering rules, some physical and mechanical properties of the materials to which they are primarily made need to be known (Kasal, 2004).

The advance knowledge of the behavior of the materials involved in furniture production against physical and mechanical effects provides technical, aesthetic and economic benefits to designers, manufacturers and users. Both in design and in scientific works based on this; the physical and mechanical properties of the material and the values of the resistances of the couplings are used (Efe, 1994).

Wood based boards are the most important developments in the forest products industry. From these products, chipboard and medium density fiberboards (MDF) are preferred due to the properties they have in many places of use (İstek et al., 2017).

The surfaces of wood based boards are coated with laminates, phenolic craft paper, polyvinyl acetate based decorative papers, paper, various resin impregnated papers, ammonium sulphomate impregnated papers, thin papers, foil, hot transfer films, lacquer paint, pattern printing and polyvinyl chloride based surface coating materials (Kalaycioğlu et al., 1996; Kara et al., 2014; Muğla et al., 2014).

The most commonly used impregnated decorative papers in the surface coating process are produced from alpha cellulose. Then, pattern printing, ink printing, print press, glue impregnation processes and is coated on the surface of the plate (Soner, 2009: Istek et al., 2010). In order to increase the strength of the impregnated decorative papers, the surfaces must be coated with varnishes. It is affecting the characteristics of the important such as scratches, abrasion and resistance to cigarette fire on the surface of the plate etc. depending on the varnish type and resin mixture ratios (Nemli, 2008).

Physical and mechanical performances of wooden based plates; coating material and wood quality(Sparkes et al., 1993; Hoag, 1993); in the structure of glue and decor paper used in lamination process(İstek et al., 2010); to the difference and mixture ratios of urea and melamine formaldehyde used in impregnation on decorative papers(Bardak et al., 2011); depending on surface coating process (Kılıç et al., 2009; İstek et al., 2012; Kara et al., 2014) that varies on them.

Performance of wood-plated panels on the surface is changeable of depending on the nature of the coating material. Performance of melamine formaldehyde impregnated decorative papers used to coat board surfaces is better than those applied to surface abrasion resistance, urea and melamine-urea formaldehyde impregnated (Bardak et al., 2011). Depending on the surface coating process, in wood-based panels, the dimensional stability increased while water uptake and swelling decreased and formaldehyde emission decreased significantly (İstek et al., 2012), The specific gravity of the laminate coated plates with varnish oak coating and finish foil, when thickened in water, hardness, bending and pressure resistance properties have positive effect on the uncoated plate (Akkılıç, 2004).

Futhormore, PVC, lamine and lacquer coatings have a positive impact on resistance to water vapor and staining, while PVC coated MDF sheets have higher resistance to abrasion resistance than laminar coated and lacquered boards, while cigarette fire resistance is higher on lacquered painted boards.

Strength resistance against water vapor and staining is also suitable for the quality values of the three surface coating materials(PVC, lamine and lacquer). The resistance properties of PVC coated plates to impact are higher than those of laminar and lacquer painted plates, while the resistance of lacquered painted plates to cracking is lower than those of PVC and laminar coated plates (Muğla, 2010).

Nowadays, it is seen that the surface coated chipboards are produced flat or patterned with direct printing technology. In this research, some physical and mechanical properties of the chipboards produced by coating their surfaces in different press patterns were compared. Thus, the effects of pattern and surface differences on the production of some physical and mechanical properties of chipboards are determined.

2. MATERIALS AND METHODS

2.1. Material

In this research, Kastamonu Integrated Wood Industry. Inc. Kastamonu Chipboard Plate Fabric uses 4 different form press sheet (NTR. HGS, BUTE, STR) and 8 mm thick chipboards (Parings -Lam) produced by coating opaque white decor paper impregnated with melamine resin.

2.2. Method

The test specimens were prepared according to TS EN 325-326. The standards used to determine the control criteria and manufacturer's instructions are given in Table 1.

Table 1: Standards and company instructions for setting control criteria

Control Criteria	Used Standard
Thickness (Kl)	TS EN 324-1
Density (YT)	TS EN 323
Scratch Resistance (ÇZD)	TS EN 438-2
Smoke Fire Durability(SAD)	TS EN 14323
Water Vapor Durability(SBD)	TS EN 14323
Resistance to Hot Containers(SKD)	TS EN 438-2
Resistance to Porosity on Surface(YPKD)	Surface Porosity Test Introduction
Crackling Resistance (ÇTD)	Chip Chopping Test Introduction

3. FINDINGS AND EVALUATION

Control criteria for the experiments, average values of some physical and mechanical properties of plates in different surface forms are given in Table 2.

Table 2: Mean values of physical and mechanical properties of plates.

Control Criteria	Standard Values	Unit	Sheet Surface Forms							
			NTR		HGS		BUTE		STR	
			X	v (%)	X	v (%)	X	v (%)	X	v (%)
Kl	± 0,3	mm	0,15	0,00	0,10	0,00	0,95	0,00	0,90	0,00
Y	±%6	kg/m³	27,3	0,05	33,0	0,49	15,3	0,03	24,0	0,69
ÇZD	Min 4. deg.	Newton	0,83	0,97	0,50	0,00	0,00	0,00	0,50	0,00
SAD	Min 3. deg.	Observation	0,00	0,00	0,67	2,37	0,33	3,32	0,67	2,37
SBD	Min 3. deg.	Observation	0,00	0,00	0,67	2,37	0,00	0,00	0,67	2,37
SKD	Min 4. deg.	Observation	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
YPKD	Ggrd	Observation	Positive		Positive		Positive		Positive	
ÇTD	Ggç	Observation	Positive		Positive		Positive		Positive	

X: Mean, v: Variation coefficient, Ggrd: No visible color change, Ggç: No visible crackling.

According to the results of the experiments, variance analysis results related to some physical and mechanical properties of chip-lam plates produced with 8 mm thickness with different surface properties are given in Table 3.

Table 3: Variance analysis of some physical and mechanical properties of chip-lam plates.

Variance Sources		Degree of Freedom	Sum of squares	Squares Average	F value	Severity Level $p < 0.05$
Thickness	Between Groups	3	0,13	0,04	--	--
	Inside Groups	8	0,00	0,00		
	Total	11	0,13			
Density	Between Groups	3	491,58	163,86	4,35	0,04
	Inside Groups	8	301,33	37,67		
	Total	11	792,92			
Scratch Resistance	Between Groups	3	6,56	2,19	105,00	0,00
	Inside Groups	8	0,17	0,02		
	Total	11	6,73			
Smoke Fire Durability	Between Groups	3	0,92	0,31	1,22	0,36
	Inside Groups	8	2,00	0,25		
	Total	11	2,92			
Water vapor resistance	Between Groups	3	0,33	0,11	0,67	0,60
	Inside Groups	8	1,33	0,17		
	Total	11	1,67			

According to Table 3, strength and scratch resistance of chip-lam plates pressed with different sheet forms were statistically significant ($p \leq 0.05$). In addition, the resistances to thickness, cigarette fire and water vapor were statistically insignificant ($p \leq 0.05$). Table 4 shows the homogeneity of density values of chip-lam plates pressed with different sheet forms.

Table 4: The homogeneity group of density values of Chip-Lam plates

Sheet Surface	Density(kg/m^3)	HG
HGS	733,00	A
NTR	727,33	AB
STR	724,00	AB
BUTE	715,33	B
LSD: 6,43		

According to Table 4, density values of chip-lam plates were highest in HGS surface patterned ones and lowest in BUTE surface patterned ones. The homogeneity of the scratch values of the chip-lam plates pressed with different sheet forms is given in Table 5.

Taple 5: The homogeneity group of scratch resistance values of chip-lam plates

Sheet Surface	Scratch Resistance (Newton)	HG
STR	5,50	A
BUTE	5,00	B
NTR	4,83	B
HGS	3,50	C
LSD: 0,40		

According to Table 5, scratch resistance value of chip-lam plates is highest in those with STR surface pattern and lowest in those with HGS surface pattern.

4. RESULTS AND DISCUSSION

As a result, it is thought that different press sheets design for aesthetic purposes. It concluded that created an appearance on following the press sheet in the form of HGS is very smooth and glossy on the surface of the plate; on the surface of the press sheet in NTR form, very little wave pattern and matte; the stamp sheet in the STR form has a dashed line pattern and matt; the press sheet in the BUTE form has a dotted pattern and a brilliant appearance on the surface of the plate.

According to the results of the study, differences in the strength and scratch resistance of the chip-lam plates pressed with different sheet forms (NTR, HGS, BUTE, STR) were determined. HGS surface specimens have a higher density value than STR surface specimens only, while resistance to scratches is determined to be lower than all other specimens. It was determined that the resistance values against scratches were higher than all other samples when the density value of the STR surface samples was at the intersection of the density values of the HGS and BUTE surface samples. The resistance to scratching of HGS surfaced samples may be lower than all other samples, since it allows the visual inspection to be more pronounced on glossy surface layers. The resistance to scratching of STR surface samples can be higher than all other samples, which can be the effect of matte surfaces. In addition to this, it is thought that depending on the form of the press sheet, the cut line patterned surface causes the visual perception error.

Different patterns formed on the surfaces of Chip-Lam plates by pressing with different sheet forms will provide aesthetics in the furniture and if the selection according to usage areas is made, it can be said that the economic life of the equipment will increase. In the following studies, it may be useful for the sector to do some physical and mechanical experiments for different surfaces of such sheets.

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