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PROCEEDINGS OF

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(ORENKO 2020)

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September 23-26, 2020

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PREFACE

This proceedings book contains selected papers of the ORENKO 2020 – International Forest Products Congress held on September 23-26, 2020. The congress, organized by the Forest Industry Engineering Department at Karadeniz Technical University, has received abstracts from different countries including Malaysia, Iran, Portugal Canada, Slovenia, Serbia, Bulgaria, Bangladesh and Turkey. After an initial review of the submitted abstracts, the 60 abstracts were accepted for oral and poster presentation.

Although given the positive trends related to COVID-19 and easing of restrictions in some countries and regions, there are still some restrictions for domestic and international flights and people are still advised to stay away from crowded places and take necessary measures i.e., using face mask, physical distance and hygiene. Our first priority is always the health and safety of attendees of the congress. Therefore, The ORENKO 2020 Organization Committee has decided to hold the ORENKO 2020 online. Our goal is trying our best to generate an atmosphere where the participants can share their expertise, experience, and resources virtually via webcam and microphone with others.

The purpose of this online congress is to provide an up-to-date discussion in the field of forest products in general. ORENKO 2020 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.

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 2020 is a credit to a large group of people, and everyone should be proud of outcome.

ORENKO 2020 Congress Secretariat

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ORAL PRESENTATIONS

POTENTIAL USAGE AREAS OF IIOT IN FOREST PRODUCTS INDUSTRY

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Abstract

The increasing usage of wood materials in the industry necessitates correct, effective and sustainable use of existing raw material resources. In this context, the concept of Industry 4.0, which includes smart production systems, smart objects, and smart management models, stands out. Industry 4.0 is defined by the concept where human, machinery, robotic control equipment, products and all related objects can communicate with each other; thus lines are arranged, and eventually they work as a networked system. IoT (Internet of Things) is defined as the communication of all elements/objects within the industry 4.0 system. In the light of current developments, the use of technology in the routine life activities of people is expanding. The most striking example of this is the progress in the telecommunication sector like smartphones. The aim here is not only to ensure verbal communication between people, but also the communication between objects, and objects with people. This creates the system referred as IoT. IIoT (Industrial Internet of Things), also called industrial internet, is the use of IoT in industry/manufacturing. This means that the whole supply chain works in interrelation. In this paper, the definition of IIoT concept and its potential in the forest products industry are examined.

Keywords: IIoT, internet of things, industry 4.0, forest products industry

1. IIoT Concept

The Industrial Internet of Things or IIoT is defined as countless devices, machines, computers and people connected by programming tools and data analytics for reflexive business results. IIoT or Industry 4.0 as it is called in the market, utilizes the power of smart machines and constant analytics to make use of the data that vehicles have accumulated in industrial conditions for a long time. Two of the main reasons why IIoT has such an impact on the industry is that smart machines are better at capturing and analyzing data in real time than humans and better at delivering important information such as business decisions from that data accurately and quickly.

Especially with machine-to-machine (M2M) communication, big data, and machine learning, IIoT enables businesses to be more efficient and reliable in their processes. Achieving this effect with connected sensors and actuators, IIoT helps businesses save time and money by contributing to early detection of inefficiencies and problems in businesses and supporting the effort to turn complex data into meaningful-usable information. The most potential usage areas of IIoT are quality control, sustainable applications, supply chain traceability and stages, such as preventive maintenance, advanced field service, energy management and asset tracking.

2. How Does IIOT Work?

The IIoT ecosystem, a network of smart devices connected to build systems that monitor, collect, exchange and analyze data, consists of:

- Smart objects: Objects that can detect, transmit and store information about themselves
- All kinds of data communication infrastructure
- Analytical systems and applications that produce meaningful business information by processing raw data
- People

Edge devices and basic functioning of smart objects; involves transmitting information directly to the data communication infrastructure and converting it into actionable information about how a particular machine part works in this infrastructure. This data would then be able to be utilized to enhance operational cycles, such as preventive maintenance and business processes.

Typical IIoT frameworks require information to be shared over various devices and over numerous networks, from edge gadgets (such as sensors, remote devices, and computers) to the cloud (central computing systems). Huge data volumes can easily overwhelm a network, particularly a network spanning remote operations. In addition, strict security requirements make the system more demanding. To manage increased data volume, performance requirements, security risk and security certificates, interconnected systems require new approaches (Canavan, L., 2020).

Managing the flow of data in IIoT systems is vital to ensuring that IIoT applications work as designed. Unlike a database which manages past data at rest, the data bus manages data in motion. Bus system makes operations and integration logic easier. Software components communicate through shared and filtered data, rather than trading messages. Applications straightforwardly read and write the value of these privately stored data objects.

3. IIoT and IoT Difference

The IoT (Internet of Things) and IIoT (Industrial Internet of Things) are almost the same thing but have very little difference in terms of the scope of their operation (Jeffrey Lee, 2017). IIoT focuses on improving network among devices, saving time, efficiency optimization and other potential advantages, while IoT can be utilized for industrial, manufacturing and agricultural tasks. It plays a significant role in the daily effect of businesses and their security.

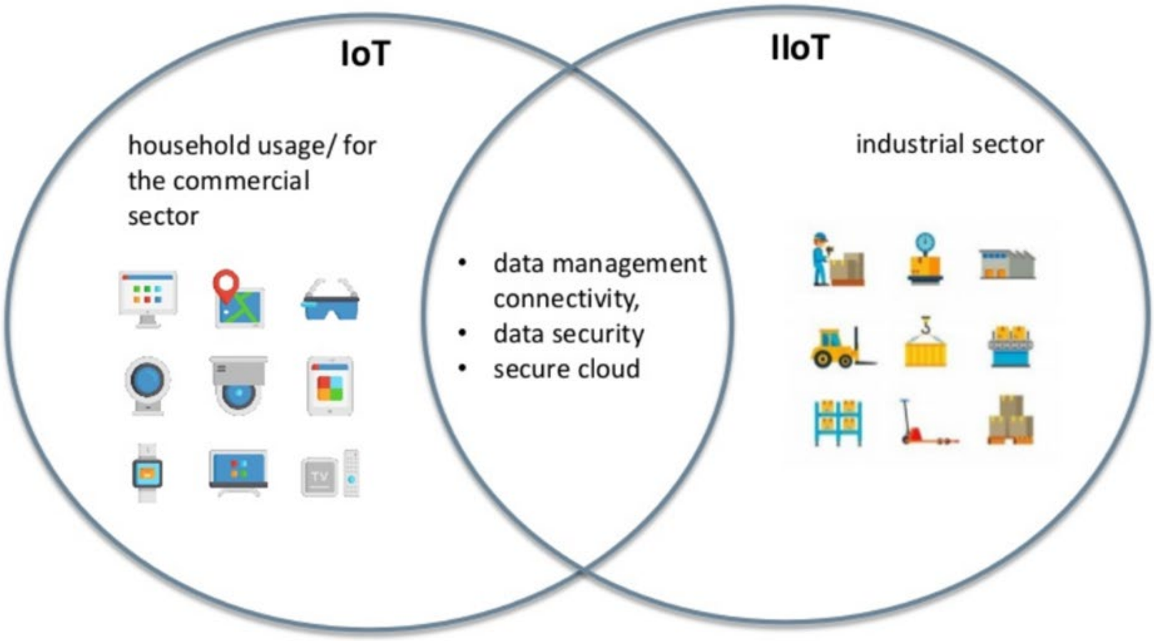

Figure 1. Areas covered by IoT and IIoT. (2019)

The expression "IoT" includes all elements of IIoT as well as consumer use cases such as smart home technologies and wearable gadgets. The focus of IoT it is the "consumer perspective". So, IIoT is a subcategory of IoT. More clearly, IIoT is the use of IoT technologies in the manufacturing and industrial sector. Industrial internet in manufacturing includes machine learning, big data, sensor data usage, automation and machine-to-machine communication technologies. Especially in production, the IIoT eco-system has great potential to create quality control, sustainable and green practices, supply chain management and overall efficiency (KUMAR & IYER, 2019). The basic idea behind IIoT is that smart machines are superior to people at catching and transmitting information precisely. Briefly, IIoT is about making machines more effective and simpler to follow.

4. Industry 4.0

The expression “Industry 4.0” represents the fourth industry revolution. It is perceived as a higher degree of organization and command over supply chains. To be more precise, industry 4.0 is based on the technological concepts of cyber-physical systems and Internet of Things (IoT). Fourth industry revolution happened to guarantee the accessibility of current data progressively by combining all components engaged with the value chain.

Today, from furniture to wood industry every sector and company are operating different. Yet, a common problem is faced. It is the need to access information across processes, products and people simultaneously. Here, Industry 4.0 does not just play the role of investing in technologies and improving tools for manufacturing efficiency—it is about to bring a new concept to the how whole business or company operates and grows (Ocak et al. 2018; Tuncel et al. 2017; Tuncel et al. 2018a; Tuncel et al. 2018b; Tuncel et al. 2019).

5. Use Cases for Industrial IoT

accomplishing goals by saving time, increase profitability and empower organizations to jump in front of competitors. IIoT is already demonstrating its welfare and flexibility with live deployments in various businesses. Here are the most common IIoT use cases.

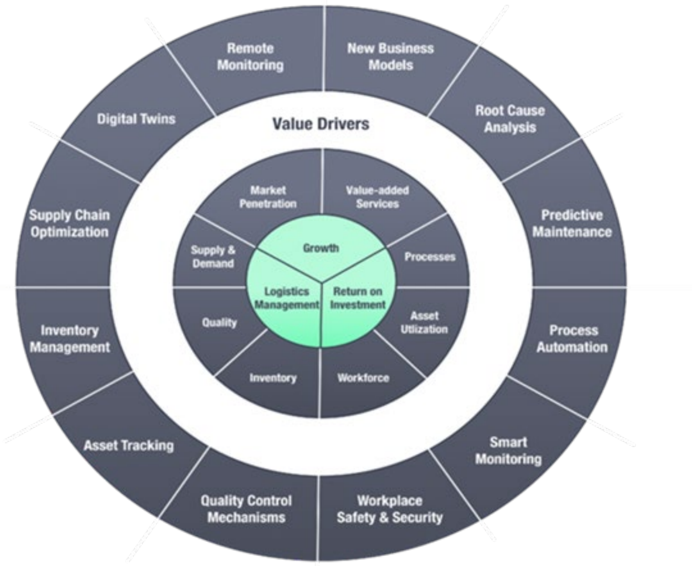

Figure 2. Industrial IoT Use Cases (Doyle, 2020)

Predictive Maintenance: These technologies track all the activities of hardware and increase granular perceivability over all tasks. Producers utilize this review to decrease the chances of system disappointment and hardware degradation. With the utilization of sensors, cameras and data analytics, directors of businesses can know when an equipment will fail before it does.

Smart Metering: Smart meters have gotten a great deal of prominence over the world as of late. Enterprises are recognizing the advantages of smart meters. A smart meter is an internet-capable gadget used for measuring energy, water or natural gas consumption of a building or home (Silicon Labs, 2018). Smart meters additionally give power utilization perceivability right to the meter, so utilities can streamline energy dissemination and make a move to move request loads.

Simultaneous Asset Tracking: In recent studies it is discovered that an expected $1.9 trillion of monetary worth could be planned by the utilization of IoT gadgets and asset tracking solutions in supply chain and logistics area (Top 5 Industrial IoT Use Cases. 2020). Industrial IoT empowered asset tracking is playing out a more extensive part in the advanced economy than at any other time. The majority of the organizations that have their properties distributed over immense geological areas need to confront a large group of issues that influence their profitability, operational expense, and staffing in addition to other things. The purpose of simultaneous asset tracking is to allow an organization to locate and monitor important assets, ensure quality issues, prevent theft, and maintain stock levels.

Fleet Management: For organizations that depend on transportation as a major aspect of their business, fleet management encourages them to eliminate or limit the dangers related with vehicle venture, improving effectiveness and profitability while reducing generally transportation and staff costs. Shipping services are the best examples of this. They use real-time traffic feeds and efficiency algorithms to convey more packages more efficiently, with less mileage.

5.1. Potential of IIoT Use in Forest Products

Focusing on the provision of inter-machine communication in production facilities, machine learning and the best use of big data, IIoT enables the wide use of IoT in sectoral applications and enables the business to work more efficiently and securely. In fact, IIoT is beyond the work of machines and physical objects connected with IoT over the internet. It refers to the data flow between the software, information technologies, CNC and PLC controls, operational technologies and the networking of all processes. In addition to these, end-to-end data flow and traceability of the supply chain, the monitoring and control of the sub-breakdown of production, logistics and operational functions, and the ability to provide remote access as well as smart sensors bring great ease of use.

The effects of instantaneous data from sensors and other sources on decision processes will be a factor in the enterprise's ability to make accurate and healthy analyzes with the least amount of time, and therefore to work more efficiently. In a manufacturing enterprise, the ability to make cost control by analyzing the financial data coming from the internet or the network as well as the data coming from the machines and looms instantly, the correct determination of the capacity of the enterprise with all the data on production planning and the most optimum use of the capacity thanks to this accumulated data. Knowing the stops in advance will minimize the lost times and contribute positively to the profitability of the business. In addition, instant tracking of financial fluctuations will be used as an important resource in creating future scenarios.

All of the cost analyzes currently made in many sectors are made with foresight, not in line with net measurements. This creates negative differences compared to the actual cost. Therefore, there is a possibility of loss of business here. By seeing exactly these problems, Tuncel and Candan (2017) is able to calculate the real cost instantly by analyzing all the data obtained from the field and within the enterprise in his study (GE-547285), which was developed for "Smart Cost Analysis" (2017) and whose patent procedures were initiated in the same year. This is one of the concrete results that will be achieved with IIoT. This and similar applications will be very easily applicable not only in the forest products industry but also in all sectors. This study will be used not only in costing but also in many areas such as maintenance planning, line optimizations, and workforce optimizations.

We believe that the technological predisposition of the forest products industry will provide rapid transition in adapting IoT and IIoT applications to businesses. The important thing is for the systematic infrastructure to be designed correctly on an enterprise basis, which will facilitate this transition.

The forest products industry is the 4th largest industry in the economy of Turkey. Under this main roof; furniture industry, wood-based composites industry (plywood, particleboard, MDF, OSB, LVL, sandwich panel, CLT, GLULAM etc.), paper products industry, parquet industry (solid wood parquet, laminate flooring, laminated parquet), joinery industry (door and window production), solid wood industry, wooden packaging industry (pallets, crates etc.), wooden craft industry, wood-based stationery industries (pencil, etc.) take part.

Especially in recent years, due to the widespread use of the Internet, the increase in information technologies, the diversification and complication of production and customer demands, all these sub-sectors have come to the point of using IoT and IIoT technologies. All investments to be made in this regard are not expected to be arbitrary, but to become a necessity for the business to compete in the near future. This investment should not be perceived as equipment and machinery. Since all personnel (engineers, industrial designers, technicians, etc.) working in the factory will be involved in this process, technological investment should be made in human resources.

6. IIoT Challenges

Organizations are profiting by embracing the Industrial Internet of Things (IIoT) advancements. They get better insight, more reliable, dynamic, more efficient, and improved operating. However, those prizes accompany some challenges. In the end, the system is getting more complex and these devices deal with sensitive systems. Below are primary industrial IoT challenges:

- Data Storage&Management: Data storage is a significant challenge for organizations. The information which was put away in past are now utilized for estimations. It is obligatory for organizations to embrace an appropriate arrangement for a safe storage of information before running IIoT in full mode.
- Sensors and actuators coordinated with modern gadgets create an great amount of detected data streams with high speed. The detected data is stored in heterogeneous IIoT gadgets. Handling, transmission, accessibility, and capacity of detected data is a difficult errand and require enormous work. To cup with these difficulties, proficient data management models are required (Khan et al., 2020).
- Security on IIoT: There had been various instances of digital attacks before and the effective adoption of IIoT based frameworks by the business clients is influenced by the trust on IIoT systems. IIoT is in its early stages and the greater part of the ongoing researches indicates security and protection as a significant challenge faced by the organizations.
- Actuators and Sensors: General requirements from all edge devices. For example energy consumption, latency, security, stability from the viewpoint of the industrial user (Gubbia, J., Buyyab, R., Marusic, S., Palaniswami, M., 2013). Pertinence of detected data, particularly that originating from outside the processing plant is vital if it is to be utilized inside an atomatic industrial control.
- Economy: A need for an economic case that will obviously demonstrate advantages of presenting new IIoT improvements on sensors and actuators is really important. Moreover, deciding on viable models for paying for the provision to detected data. More examination is additionally needed to help financial appraisals that show up in the commercial area.

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GAS EMISSIONS FROM THE COMBUSTION OF THE PARTICLE BOARDS PRODUCED WITH PEANUT HUSK ADDITIVE

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Abstract

This study is conducted to determine the amount of CO and NO gas emissions generating from the combustion of the particleboards produced with peanut husk additive. For this purpose, wood chips consist of red pine (*Pinus brutia Ten*.), Oriental beech (*Fagus orientalis L.)* and Silver poplar (*Populus alba L*.) mixed with peanut husk in 100% (B1), 75% (B2), 50% (B3) and 25% (B4) proportions in order to produce 4 different types of boards. We used 3 different kinds of glue for each type in board production such as 100% UF (G1), 95% UF+5% MF (G2) and 95% UF+5% FF (G3). Finally, total of 12 boards were produced. The analysis of the gases performed according to ASTM-E 160-50 principles.

As a conclusion, it was determined that peanut husk additive ratio are effective on CO and NO gas emissions. The emission of CO gas was found higher in the combustion of B1 type boards. CO gas amount values decreased significantly as the peanut husk ratio diminished in the parameters of board production. Glue form has also effect on the amount of gas emission resulting from the combustion of particleboards. CO emissions were less in the boards produced with (G1) glue while NO gas emission was found higher produced with (G2) glue.

Keywords: Gas emissions, combustion, peanut husk, CO, NO, particleboard

1. Introduction

Due to the growing interest in fire safety, architects, construction companies emphasize the fire performance of building materials and how to ensure the most effective fire safety. Wood and wood-based materials are mainly organic materials containing carbon and hydrogen and consist of compounds classified as flammable substances (Göker and Ayrılmış, 2003). In countries where the use of wood materials for construction is high, it is desirable that such materials would be particularly resistant to burning. Under conditions where the combustion condition occurs, the change in wood material can develop in a very short time while material quickly differ from its original structure. Especially despite the technological developments in recent years, there may be loss of life and property in the face of fires. The ignition of the material and the toxic gases that emerge can cause death. However, the important issue here is that whether wooden material can show a healthy performance in such extraordinary conditions. In case of fire risk, a smoke layer is formed depending on type of materials. This smoke layer can cause poisoning. 75% of the casualties in fires are caused by smoke poisoning and suffocation. Considering this, it is imperative to provide smoke control for the materials, primarily to prevent loss of life (Kars, 199). Wood combustion starts with moisture loss and followed by hemicellulose, cellulose and lignin degradation (Browne, 1963). Wood is a flammable material. In order to burn itself, the temperature It must be increased to 275 °C (Le Van and Winandy, 1990). In the combustion of biomass, the transformation of the moisture is seen n the first phase where the temperature is less than 126 °C, the release of CO and light hydrocarbons (CH4 etc.) is seen in the second phase (126 °C-426 °C), CO2 occurring and H2O formation take place in the third phase (426 °C - 676 °C) (Kozinski and Zheng, 1998). At temperatures below 426 °C and above 876 °C, smoke formation with a short-term yellow-blue flame is observed (Kozinski and Saade, 1998). CO and NO flue gas emissions values of the pellet samples produced from pine shavings were determined as 761 and 107 ppm, respectively. The addition of 9% zeolite binding agent to the pellet samples decreased these values to 309 and 22 ppm (Tüplek, 2011).

Fidan Et. al. studied combustion characteristics of impregnated cedar. The result showed that the CO content was the highest during combustion without flame for the winter samples (28,907 ppm) while the NO content was the highest without flame combustion for the spring samples (76.15 ppm) (Fidan et. Al, 2016) In the study investigating the combustion properties of impregnated spruce wood, it is found that CO amount was the highest (19,866 ppm) in Tanalith-E treated specimens and lowest (15,841 ppm) in Wolmanith-CB treated specimens (Yaşar et. Al,2017). A study was carried out to determine the carbon dioxide amount in the combustion of European oak wood (Quercus petreae liebl.) bleached and varnished. According to the results the amount of CO_2 in the flame source side (ppm) is the highest in the varnish level as (3.469) and the lowest as (1.236) (Atar et. Al, 2017).

2. Materials and Methods

Total of 12 different types of particle boards were produced with a mixture of Peanut shell (Arachis hypogaea) and wood chips consist of Red pine (Pinus brutia Ten.), Oriental beech (Fagus orientalis L.) and Silver poplar (Populus alba L.). As binders; urea formaldehyde, melamine formaldehyde and phenol formaldehyde were used with different ratios. Boards were produced on the basis of 0.650 g/cm^3 density with 18 mm thickness and 500x500 mm^2 size. Laying process was made to perform three-layer particle board. Production parameters are given in Table 1.

Table 1. Boards production parameters

Board type	No	Peanut husk ratio (%)	Wood chips ratio (%)	Glue content (%)	Density (g/cm^3)	Thickness (mm)	Size (mm)
B1	1	100	0	%100UF (G1)	0,650	18	500x500
	2	100	0	%95UF+%5MF (G2)	0,650	18	500x500
	3	100	0	%95UF+%5FF (G3)	0,650	18	500x500
B2	4	75	25	%100 UF (G1)	0,650	18	500x500
	5	75	25	%95UF+%5MF G2)	0,650	18	500x500
	6	75	25	%95UF+%5FF (G3)	0,650	18	500x500
B3	7	50	50	%100 UF (G1)	0,650	18	500x500
	8	50	50	%95UF+%5MF (G2)	0,650	18	500x500
	9	50	50	%95UF+%5FF (G3)	0,650	18	500x500
B4	10	25	75	%100 UF (G1)	0,650	18	500x500
	11	25	75	%95UF+%5MF (G2)	0,650	18	500x500
	12	25	75	%95UF+%5FF (G3)	0,650	18	500x500

Laying process is shown in Pictures 1-3.

Picture 1. Bottom surface layer (Thin chipping)

Picture 2. Middle layer (Coarse chipping)

Picture 3. Top surface layer (Thin chipping)

Gas emission analysis was performed according to ASTM E 160-50 (Table 2). Before performing the test samples were conditioned at a temperature of 20 ± 2 0C and a relative humidity of 65 ± 5% until they reached constant weight prior to impregnate and they were weighed up to a precision of 0.01 g. Test specimens are given in Table 2.

Table 2. Test specimens

Test	Standart	Sample dimension (mm)	Sample number
Gas analysis	ASTM E 160-50	76 x 76 x 13	864

Each sample group was weighed prior to combustion and were stacked on a gauze tripod. Samples of 12 types of boards were stacked in 12 levels so as to form a tetragonal prism and were burned in the test. The source of flame was centered directly below the stack and was burned for 3 min. to maintain combustion with flame (FS), then the source was extinguished to maintain combustion without flame (WFS) and the glow (TS) stages. Analyses of gases (CO and NO) have been performed with the sigma flue gas analyzer placed in the flue. The visuals of the experiment are given in Picture 4 and Picture 5.

Picture 4. Preparation of samples

Picture 5. Performing the test

3. Results

In this study, it was aimed to determine the effect of peanut shell additive rate, glue content on gas emissions during the combustion of the boards. In the research of this effect, peanut shell additive rate with glue form were taken into account as independent variables while gas emission values were dependent variable. Multiple analysis of variance (Anova) was applied to the data with the MSTAT-C statistical evaluation program. When the difference between groups was found significant, mean values was compared with the Duncan test. Thus the ranking of the importance between the factors is determined by dividing them into homogeneity groups according to the critical value of the smallest important difference (LSD).

Measured NO gas values according to combustion type, board type and glue content are given in Table 3.

Table 3. NO gas values.

Boards	Glue variety	Combustion type	N	X_{mean}	$X_{min.}$	$X_{max.}$	$S_{d.}$	Boards	Glue variety	Combustion type	N	X_{mean}	$X_{min.}$	$X_{max.}$	$S_{d.}$
B1	G1	FS	5	7.376	2.579	12.173	0.765	B3	G1	FS	5	6.234	1.437	11.031	1.93380
		WFS	5	21.742	16.945	26.539	1.917			WFS	5	20.150	15.353	24.947	4.58476
		GS	5	69.102	64.305	73.899	5.664			GS	5	69.406	64.609	74.203	10.226
	G2	FS	5	9.438	4.641	14.235	0.631		G2	FS	5	9.190	4.393	13.987	0.399
		WFS	5	30.970	26.173	35.767	2.358			WFS	5	29.604	24.807	34.400	0.438
		GS	5	96.024	91.227	100.821	1.239			GS	5	93.130	88.333	97.927	7.775
	G3	FS	5	7.152	2.355	11.949	0.766		G3	FS	5	6.269	1.472	11.065	1.935
		WFS	5	20.052	15.255	24.849	3.025			WFS	5	20.088	15.291	24.885	5.331
		GS	5	73.006	68.209	77.803	10.437			GS	5	69.366	64.569	74.163	13.227
B2	G1	FS	5	6.924	2.127	11.721	1.027	B4	G1	FS	5	6.004	1.207	10.801	2.319
		WFS	5	21.752	16.955	26.549	1.917			WFS	5	19.198	14.402	23.995	5.344
		GS	5	70.004	65.207	74.801	3.250			GS	5	66.783	61.986	71.580	6.270
	G2	FS	5	9.170	4.373	13.967	0.399		G2	FS	5	8.576	3.779	13.373	1.820
		WFS	5	31.816	27.019	36.612	3.336			WFS	5	27.628	22.831	32.425	5.997
		GS	5	90.062	85.265	94.859	6.570			GS	5	97.112	92.315	101.909	10.048
	G3	FS	5	7.378	2.581	12.175	0.6129		G3	FS	5	5.794	0.997	10.591	1.490
		WFS	5	18.132	13.335	22.929	2.777			WFS	5	19.670	14.873	24.467	2.361
		GS	5	72.944	68.147	77.741	11.432			GS	5	74.626	69.829	79.423	8.393

B1: Boards with 100% peanut husk add. **B2**: Boards with 75% peanut husk add. **B3**: Boards with 50% peanut husk add. **B4**: Boards with 25% peanut husk add.
G1: 100% Urea formaldehyde **G2**: 95% Urea formaldehyde+5%Melamine formaldehyde **G3**: 95% Urea formaldehyde+5%Phenol formaldehyde **FS**: Flame stage **WFS**: Without flame stage **GS**: Glowing stage

According to results NO content (ppm) in flame stage was found highest at B1+G2 (9.438) and lowest at B4+G3 (5.794). In without flame stage highest value was found at B2+G2 (31.816), the lowest was found at B2+G3 (18.132). And for the glowing stage, the lowest value was found at B4+G1 (66.783) while the highest was at B4+G2 (97.112).

Multiple variance analysis results regarding the effect of the board type and glue content on the NO gas amount are shown in Table 4.

Table 4. Variance analysis of NO gas emissions

S	D.V	Sum of squares	D_F	Mean of squares	F	α<0.05
B_t	NO	41.525	3	13.842	0.470	**0.004**
G_f	NO	5711.656	2	2855.828	96.980	**0.000**
C_s	NO	166556.951	2	83278.476	2828.032	**0.000**
B_t*G_f	NO	55.122	6	9.187	0.312	0.930
C_s*G_f	NO	3143.939	4	785.985	26.691	**0.000**
B_t*C_s	NO	68.506	6	11.418	0.388	0.886
B_t*G_f*C_s	NO	191.633	12	15.969	0.542	0.884
Error	NO	4240.441	144	29.448		
Corrected Total	NO	180009.772	179			
Total	NO	419038.707	180			
*Statistically significant; **B_t**: Board type; **G_F**: Glue form; **S**: Source; **C_S**: Combustion stage; **D.V**: Dependent variable						

Board type, glue form and their binary interactions on NO emissions were found statistically significant (α=0.05). The Duncan test was used to determine which groups differed in significant outcomes. NO gas amount related to homogeneity groups of board type and glue form are given in table 5.

Table 5. Duncan mean separation test for NO emissions according to board types

	Gas	B1	B2	B3	B4
Flame stage	¹NO	7.9887^A	7.8241^A	7.2309^B	6.7914^C
¹LSD= ± 0,2134 (ppm)					
Without flame stage	²NO	24.2547^A	23.8998^A	23.2804^A	22.1656^A
²LSD= ± 5,758 (ppm)					
Glowing stage	³NO	79.3773^A	77.6700^A	77.3008^A	79.5070^A
³LSD= ± 22,134 (ppm)					

Amount of NO amount varied according to the type of combustion. It is found that peanut husk additive ratio is effective only in flame stage. This relationship was not found in other stages of combustion. Least NO amount was seen in B4 type plates during the flame stage and without flame stage. B1 type boards have generally been the type of board in which the amount of gas seen high. Duncan mean separation test for glue form is given Table 6.

Table 6. Duncan mean separation test for NO emissions according to glue forms

	GAS	G1	G2	G3
Flame stage	[1]NO	6.6346^{B}	9.0935^{A}	6.6481^{B}
[1]LSD = ± 2.127 (ppm)				
Without flame stage	[2]NO	20.7106^{B}	30.0343^{A}	19.4854^{B}
[2]LSD = ± 7.775 (ppm)				
Glowing stage	[3]NO	68.8238^{B}	94.0820^{A}	72.4856^{B}
[3]LSD = ± 17.596 (ppm)				

It is determined that use of melamine formaldehyde had an effect on the amount of NO while urea formaldehyde or urea +phenol formaldehyde has none. A considerable increase was observed in the boards produced using melamine formaldehyde.

Measured CO gas values according to combustion stage, board type and glue form are given in Table 7.

Table 7. CO gas values.

Boards	Glue variety	Combustion type	N	X_{mean}	$X_{min.}$	$X_{max.}$	$S_{d.}$	Boards	Glue variety	Combustion type	N	X_{mean}	$X_{min.}$	$X_{max.}$	$S_{d.}$
B1	G1	FS	5	658.482	625.037	691.927	18.657	B3	G1	FS	5	590.101	556.586	623.467	6.123
		WFS	5	1529.292	1495.847	1562.735	21.168			WFS	5	1244.541	1210.564	1277.028	24.135
		GS	5	1078.862	1045.417	1112.306	49.021			GS	5	948.265	914.738	981.638	20.351
	G2	FS	5	692.902	659.457	726.344	10.098		G2	FS	5	607.667	574.142	641.035	5.176
		WFS	5	1594.201	1560.755	1627.642	26.224			WFS	5	1323.432	1289.964	1356.841	14.943
		GS	5	1279.805	1246.358	1313.247	32.174			GS	5	1011.228	977.755	1044.632	40.158
	G3	FS	5	696.818	663.373	730.265	8.268		G3	FS	5	610.029	576.568	643.495	6.892
		WFS	5	1596.205	1562.755	1629.644	27.896			WFS	5	1322.454	1288.984	1355.635	18.311
		GS	5	1285.800	1252.354	1319.243	146.590			GS	5	1013.257	979.764	1046.964	27.307
B2	G1	FS	5	580.604	547.155	614.049	48.685	B4	G1	FS	5	557.869	524.369	591.128	21.076
		WFS	5	1391.003	1357.555	1424.448	76.134			WFS	5	1150.264	1116.764	1183.635	26.252
		GS	5	1069.408	1035.955	1102.846	16.742			GS	5	748.286	714.764	781.851	21.253
	G2	FS	5	656.810	623.355	690.244	36.506		G2	FS	5	599.865	566.334	633.238	23.847
		WFS	5	1561.804	1528.354	1595.243	27.197			WFS	5	1255.056	1221.564	1288.562	16.537
		GS	5	1142.411	1108.957	1175.844	52.846			GS	5	791.667	758.195	825.044	13.538
	G3	FS	5	667.863	634.358	701.245	25.635		G3	FS	5	597.202	563.755	630.695	17.512
		WFS	5	1578.425	1544.956	1611.846	23.617			WFS	5	1252.834	1219.355	1286.264	14.342
		GS	5	1141.884	1108.355	1175.244	44.296			GS	5	790.667	757.169	824.044	23.222

B1: Boards with 100% peanut husk add. **B2**: Boards with 75% peanut husk add. **B3**: Boards with 50% peanut husk add. **B4**: Boards with 25% peanut husk add. **G1**: 100% Urea formaldehyde **G2**: 95% Urea formaldehyde+5%Melamine formaldehyde **G3**: 95% Urea formaldehyde+5%Phenol formaldehyde **FS**: Flame stage **WFS**: Without flame stage **GS**: Glowing stage

According to results; CO content (ppm) in flame stage was highest at B1+G3 (696.518) and lowest at B4+G1 (557.869). In without flame stage, highest value was found at B1+G3 (1596.205) and the lowest was found at B4+G1 (1150.264). And for the glowing stage lowest value was found at B4+G1 (748.286) while the highest was found at B1+G3 (1285.800).

Multiple variance analysis results regarding the effect of the board type and glue content on the NO gas amount are shown in Table 8.

Table 8. Variance analysis of CO gas emissions

S	D.V	Sum of squares	D_F	Mean of squares	F	α<0.05
B_t	CO	2340315,785	3	780105,262	544,928	**0,000**
G_t	CO	271826,448	2	135913,224	94,940	**0,000**
C_t	CO	17958254,950	2	8979127,475	6272,198	**0,000**
B_t*G_f	CO	24741,009	6	4123,502	2,880	0,011
C_t*G_f	CO	29719,349	4	7429,837	5,190	**0,001**
B_t*C_t	CO	637050,451	6	106175,075	74,167	**0,000**
B_t*G_f*C_t	CO	62302,769	12	5191,897	3,627	**0,000**
Error	CO	206146,937	144	1431,576		
Corrected Total	CO	21530357,698	179			
Total	CO	207738543,974	180			
*Statistically significant; **B_t**: Board type; **G_F**: Glue form; **S**: Source; **C_S**: Combustion stage; **D.V**: Dependent variable						

Except for binary interactions of combustion stage and glue form, all sources have been found statistically significant (α=0.05). The Duncan test was used to determine which groups differed in significant outcomes. CO gas amount related to homogeneity groups of board type and glue form are given in table 9.

Table 9. Duncan mean separation test for CO emissions according to board types

	Gas	B1	B2	B3	B4
Flame stage	[1]CO	682.734^{A}	635.0667^{B}	602.533^{C}	584.933^{D}
[1]LSD= ± 14.764 (ppm)					
Without flame stage	[2]CO	1573.2307^{A}	1510.4000^{B}	1296.6000^{C}	1219.3333^{D}
[2]LSD= ± 52.962 (ppm)					
Glowing stage	[3]CO	1214.8207^{A}	1117.8667^{B}	990.8667^{C}	776.8000^{D}
[3]LSD= ± 86.335 (ppm)					

CO gas emissions place in separate homogeneity groups according to the peanut husk additive ratio. For all combustion stages highest amount of CO gas was observed in B1 boards while least values were found in B4 type boards.

Table 10. Duncan mean separation test for CO emissions according to glue form

	GAS	G1	G2	G3
Flame stage	[1]CO	596.720^B	639.275^A	642.954^A
[1]LSD = ± 35.774 (ppm)				
Without flame stage	[2]CO	1328.6230^B	1433.6000^A	1437.4500^A
[2]LSD = ± 57.639 (ppm)				
Glowing stage	[3]CO	961.1655^B	1056.2500^A	1057.8500^A
[3]LSD = ± 48.962 (ppm)				

According to the glue form, CO level was seen less in the boards produced with urea formaldehyde. These boards placed in a separate homogeneity group.

4. Conclusion

The emission of CO gas was found higher in the combustion of B1 type boards. CO gas amount values decreased significantly as the peanut husk ratio diminished in the parameters of board production. The amount of CO gas emission was measured at the maximum level in all (B1) boards produced with 100% peanuts husk additive. According to peanut husk ratio, when peanut content decrease, CO gas amount decrease by 5,44%, 16,08% and 25,12% respectively. It has been determined that glue form has an effect on the amount of CO resulting from the combustion of particleboards. CO amount were less in the boards produced with G1 (100% Urea formaldehyde). This can be explained by the fact that the carbon content of G1 is lower than G2 (95% Urea formaldehyde + 5% Melamine formaldehyde) and G3 (95% Urea formaldehyde + 5% Phenol formaldehyde). Using G1 glue form (100% Urea formaldehyde) resulted in an 8,02% decrease in CO gas amounts.

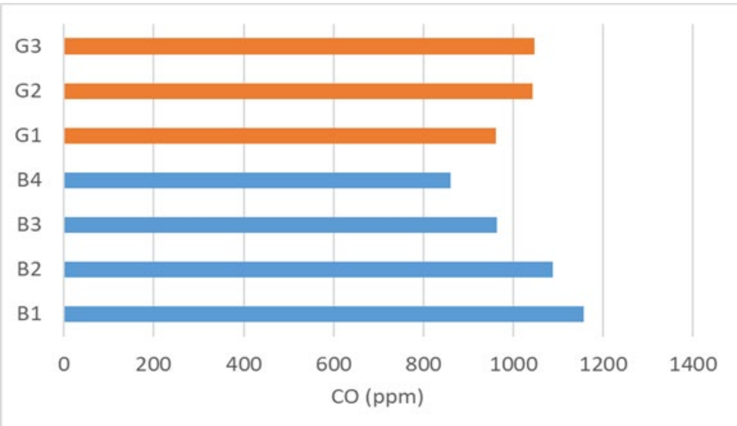

Figure 1. Average CO gas amounts according to board type and glue form

We have found no relationship between NO gas amount and peanuts husk ratio except for the flame stage. In Flame stage, when peanut husk ratio diminished, the amount of NO gas decreased. The minimum amount of NO gas was found in B4 type boards (boards with 25% peanut husk add.) with 6.791 (ppm) in flame stage. NO gas emission was higher in boards produced with G2 glue form (95% Urea formaldehyde + 5% Melamine formaldehyde). This could be related to the presence of nitrogen in the structure of melamine. During combustion nitrogen (N) could react with oxygen (O) to form NO gas.

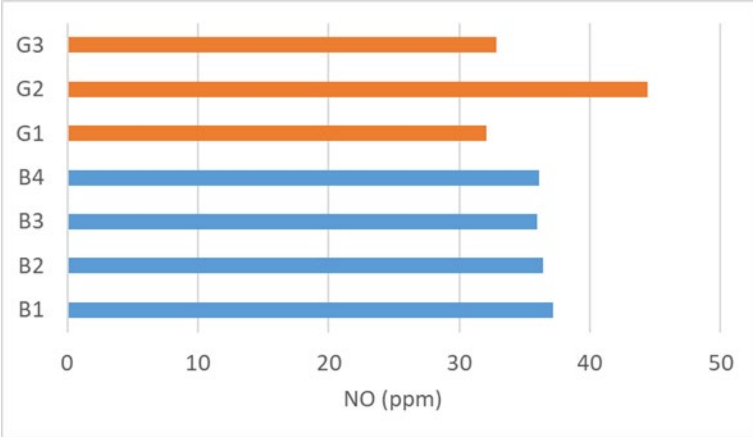

Figure 2. Average NO gas amounts according to board type and glue form

Highest CO emissions were detected in B1 type boards for all combustion stages. While the level of CO gas amount (ppm) in B1 type plates is in the range of 600-800, values varied between 1500-2000 during the without flame stage and glowing stage. CO emissions were lowest in B4+G1 boards and highest in B1+G3 boards for all combustion stages. Using G2 glue form resulted in an 25,14% increase in NO gas amounts.

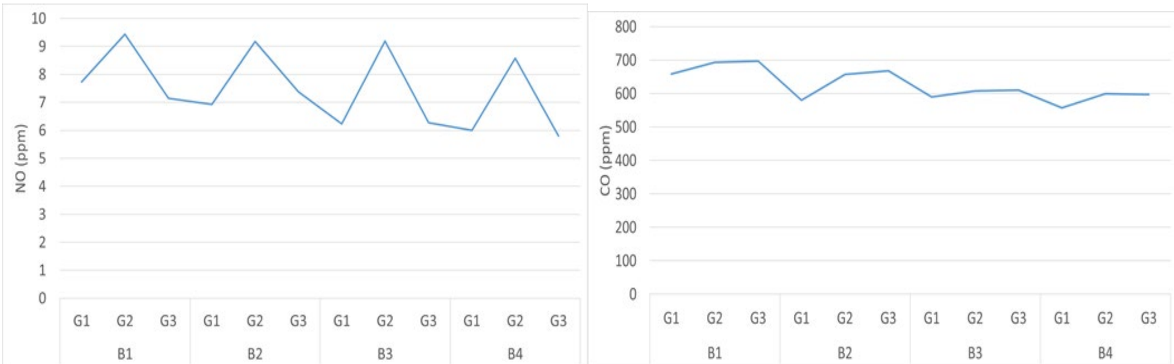

Figure 3. Values of CO and NO gases during the flame stage.

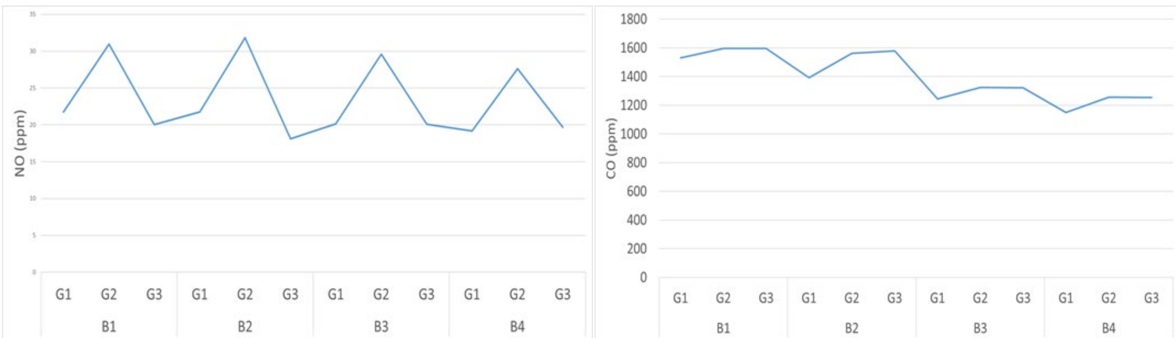

Figure 4. Values of CO and NO gases during the without flame stage

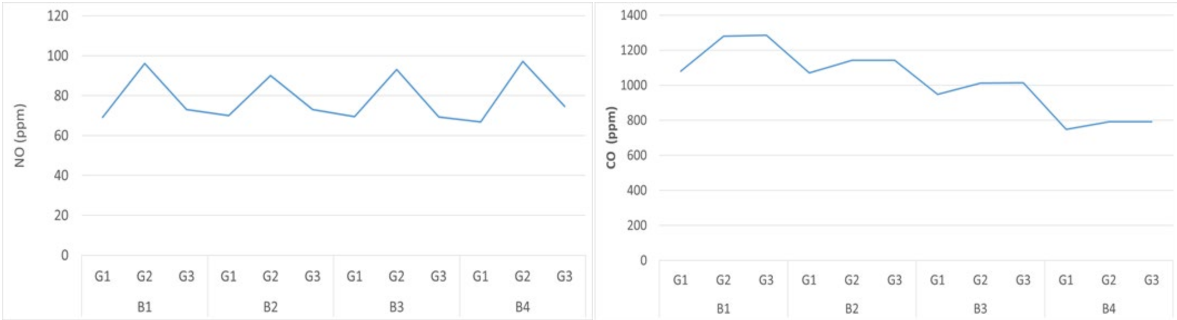

Figure 5. Values of CO and NO gases during the glowing stage

When NO emissions are examined, the highest values were found in boards produced with G2 glue form for all combustion stages. According to the results; in flame stage the highest NO value (ppm) was determined in B1+G2 board (9.438) and lowest in B4+G3 board (5.794). In without flame stage, B2+G2 board's value (31.816) was found lowest and B2+G3 board's value (31.816) was found highest. And for the glowing stage, B4+G2 board's value (97.112) was found highest while B4+G1 board's value (66.783) was found lowest.

In the event of a fire, toxic gases such as CO and NO are released during the combustion. These gases can be fatal when they reach significant amounts due to their effect on the respiratory tract. In fact, most of the casualties in fires are caused by poisoning and suffocation. Considering this, ensuring smoke control in materials is essential to prevent loss of lives. Thus it is important that what the materials are made of.

In this context, it may be appropriate using boards which showed dense smoke with fire retardants.

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INCREASING THE OUTDOOR DURABILITY OF UREA FORMALDEHYDE PARTICLE BOARD WITH NEW GENERATION WATER-BORNE ACRYLIC COATINGS

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Abstract

In general, urea formaldehyde glue has a low moisture resistance ratio and therefore, particle boards produced with urea formaldehyde are suitable for use in closed areas. However, the moisture resistance of melamine formaldehyde glue is relatively higher than that of urea formaldehyde glue. Particle board products produced with melamine formaldehyde may be used in semi-open outdoor conditions and indoor structures, except for common usage areas, where there may be hot-cold water leaks, moisture deposits or steam, such as bathrooms, showers, sinks, cellars or kitchen sinks.

In this study, it was aimed to increase the resistance of urea formaldehyde particle board to semi-open outdoor conditions (temperature and humidity) by applying water-borne acrylic coatings. The outdoor durability of urea formaldehyde particle boards (test panels) prepared with two different water-borne acrylic coating formulations was compared to urea formaldehyde and melamine formaldehyde particle boards (control panels). For the test and control samples, an artificial weathering test was applied for 12 days (288 h). After the weathering test, some mechanical (flexural strength, modulus of elasticity, tensile strength) and physical (surface roughness, water absorption, moisture and density) of the test and control samples were determined.

After the outdoor test, the change in the mechanical and physical properties of the test samples were found close to the control in the melamine formaldehyde particle boards. However, it was determined that the semi-open outdoor durability of the test samples was quite higher than the urea formaldehyde particle boards without coating applied. The results of this study showed that, in semi-open outdoor conditions, urea formaldehyde particle boards may be preferred instead of melamine formaldehyde particle boards.

Keywords: Urea formaldehyde, melamine formaldehyde, particle board, acrylic varnish, outdoor durability, mechanical properties, physical properties

1. Introduction

Particle board is a very popular engineered wood-based panel produced from wood particles and a synthetic resin. It is designed for a wide range of substrate applications including furniture, kitchen worktops, interior signs, sliding doors, home constructions, flooring, shelving and cabinets, office drivers, counters, walls and ceilings, tables and other industrial products (Baharoğlu et al. 2014). The demand for particle board composites has recently increased throughout the world. This increase may be attributed to the economic advantage of low-cost wood and other lignocelluloses fibrous materials (Nemli et al. 2009).

Urea formaldehyde (UF) resin is prevalently used in manufacturing of particle board because of its low price, short compression time and high reactivity. However, the main disadvantage of UF resin is lack of resistance to water. For this reason, many researchers have focused on developing new chemicals for solving this problem such as melamine addition to UF, paraffin and polyethylene glycol usage and coating of particle board surfaces with decorative papers (Nemli et al. 2005, Girods et al. 2008).

In recent years, the use of particle board as a structural building material has been increasing. For this reason, the durability of particle board in semi-open outdoor conditions becomes important. The best way to evaluate the durability of particle board in semi-open outdoor conditions is to determine the changes in its physical and mechanical properties during practical use (Geimer et al. 1973). For this purpose, "short-term accelerated aging tests" regarding the durability of materials against semi-open outdoor conditions are applied, and the performance of the materials are estimated from this information (Kajita et al. 1991). Disadvantages such as increased surface roughness, increased thickness and loss of mechanical resistance have been determined in particle boards exposed to semi-open outdoor conditions. Particle boards are widely used as a substrate for thin coatings such as resin-impregnated papers and vinyl films for aesthetic and strength purposes. The surface roughness of particle board plays an important role in coating properties, because any surface irregularities can be visible through thin coatings, which reduces the final quality of the board. Raw material properties and production parameters affect the surface roughness of particle board panels (Nemli et al. 2007). Additionally, wettability is defined as the state of a surface that determines how quickly a liquid will wet the surface or whether it will be sprayed on the surface. Wettability is crucial for good adhesion between the particle board and the coating. Liquid surface coatings or adhesives have to wet, flow and penetrate the cellular structure of wood to maintain close contact between the composite surface molecules and the coating. Dimensional changes of wood-based panels in humid conditions are the main disadvantage of using board as a building material (Sahin and Arslan 2011). Moisture absorption causes a decrease in the strength of the particle board and destruction between the wood and adhesive bonds. There is extensive research to improve the dimensional stability of particle boards. Some of this are liquid surface coatings that are widely used to improve the dimensional stability and water repellency of boards due to their low cost and ease of use (Barnes and Lyon 1978, Kalaycıoğlu and Nemli 2006, Nemli and Aydın 2007).

The moisture resistance of melamine formaldehyde glue is relatively higher than that of urea formaldehyde glue. Particle board panels produced with melamine formaldehyde may be used in semi-open outdoor conditions and indoor structures, except for common usage areas, where there may be hot-cold water leaks, moisture deposits or steam (Park et al. 2009, Young No and Kim 2007, Sun et al. 2011). The objective of this study is to increase the resistance of urea formaldehyde particle board to semi-open outdoor conditions (temperature and humidity) by applying water-borne acrylic coatings.

2. Materials and Methods

2.1. Manufacturing of The Particle Board Panels

Industrial wood particles (mixture of *Pinus brutia* Ten., *Populus canadensis* moench, *Fagus orientalis* Lipsky, *Quercus cerris* L. var. Cerris) obtained from a commercial particle board factory were used as raw material for particle board manufacturing. The particle boards were produced under commercial conditions at Starwood Forest Product Company, Bursa, Turkey. The wood particles were processed into particle board furnish by passing through a chipper and flaker. The wood particles were dried to 1% moisture content based on the oven dry weight of them. A screening machine with meshes of 1 mm and 0.25 mm aperture and a pneumatic system were used to obtain core- and surface-layer particles.

Ammonium sulfate was added into the adhesive by about 1% based on the solid amount of the adhesive as a hardener, with solid contents of 10% and 25% for the surface and core layers, respectively. As a hydrophobic substance, 1% paraffin emulsion with a solid content of 32%, based on oven dry particle weight for the core and surface layers, was used. Three-layered boards were compressed under a 220 °C press temperature, a 55-s press time and 3.0 N/mm^2 pressure and produced in dimensions of 280 x 210 x 0.8 cm. Duplicate panels were made for each group. After compression, the particle boards were conditioned at a temperature of 20 °C and 65% relative humidity.

2.2. Coating Systems

The commercial water-based impregnation product, containing the active ingredients of 1.20% propiconazole and 0.30% iodopropynyl butylcarbamate, was used as a primer for 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/m² using a brush. Tinuvin 5333 DW as UV absorber was used in this study. Commercially produced finishing, containing acrylic resins and three copolymer dispersion, was used as the topcoat for the specimens. A small amount of defoamer and 2,2,4-trimethyl-1,3-pentandiolemonoisobutyrate, a coalescing agent was added in the topcoat formulation to reduce the effect of other additives on the photostabilization performance. The characteristic features of the wood coating materials that were used in the study are given in Table 1. These formulation products were supplied from the BASF Company for the wood coatings (Table 2). Three layers of topcoats were also applied to each sample at a spread rate of 100 g/m² by a 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.

Table 1: Acrylic resin types for wood coating systems.

Products	Description	Physical	Active content (%)
Acronal Eco	Pure acrylic	liquid	50
Joncryl 8226	Acrylic emulsions	liquid	42
Tinuvin 5333 DW	UV Absorber	liquid	40

Table 2: The formulations of wood coating systems.

Formulation	X	AX	Y	AY
Acronal Eco 6270	73.7	50	-	23.7
Joncryl 8226	-	23.7	73.7	50
Tinuvin 5333 DW	6.0	6.0	6.0	6.0
Film-forming agents	0.67	0.67	0.67	0.67
Defoamers	1.0	1.0	1.0	1.0
Dispersing agent	0.6	0.6	0.6	0.6
Rheology modifier	1.3	1.3	1.3	1.3
Distilled water	16.73	16.73	16.73	16.73

The viscosity of the four different coatings applied in this study was determined by using DIN cup/4mm/20 0C (ASTM D 1438, 1971).

Table 3: The physical characteristics of the four different coatings

Coating Systems	Solid Content (%)	PH	Viscosity
X	39	8.2	80
AX	30	8.3	65
Y	44	8.5	120
AY	35	8.4	75

2.3. 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, and the temperature in the chamber was approximately 60 °C (ASTM G 154-12a). The weathering experiment was carried out in cycles of UV-light irradiation for 4h followed by a condensation temperature of 50 °C for 4h in an accelerated weathering test cycle chamber over 12 days (288 h). Eight replicate samples for each coating system were prepared for each artificial weathering test condition.

2.4. Surface Roughness Test

A Mitutoya SurfTest SJ-301 instrument was employed for the surface roughness measurements. The R_a and R_b roughness parameters were measured to evaluate the surface roughness of the surfaces of the unweathered and weathered coated particle board and uncoated particle board samples according to DIN 4768. R_a is the arithmetic mean of the absolute values of the profile departures within the reference length, and R_z 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.

2.5. Physical and Mechanical Tests

The panels were kept in a conditioned room with a relative humidity of 65% and a temperature of 20 °C until they reached an equilibrium moisture content. They were then cut into test samples based on the EN standards (EN 310, 1993; EN 319, 1993; EN 317, 1993). The modulus of elasticity (MOE) and modulus of rupture (MOR) from static bending, internal bond strength (IB) and thickness swelling (TS) after 24 h immersion of the samples were determined. Ten samples were cut from the test panels to measure their physical and mechanical properties. The mechanical tests were performed with a Universal Introns testing machine.

3. Results

3.1. Change in Mechanical and Physical Properties

Some of the mechanical and physical properties of the test and control panels before and after the artificial weathering test are given in Table 4. This table generally shows that coating application increased the outdoor durability of the UF control panels.

Table 4: Mechanical and physical properties of experimental panels.

	BEFORE WEATHERING						
	Density (g/cm³)	MC (%)	MOR (N/mm²)	MOE (N/mm²)	IB (N/mm²)	Thickness swelling (%) 2 h	Thickness swelling (%) 24 h
AX	4.90±0.77	6.65±0.74	13.8±1.69	1916±457	0.66±0.01	1.38±0.02	10.42±2.98
X	4.99±0.81	6.69±0.66	14.6±1.77	2316±434	0.72 ± 0.03	3.11±0.87	13.38±3.07
AY	5.06±0.89	6.54±0.47	13.9±1.72	1865±260	0.70 ± 0.02	3.62±0.79	13.01±3.12
Y	4.93±0.68	6.98±0.79	13.1±1.13	2109±478	0.64± 0.02	1.29±0.08	10.41±1.98
UF	5.00±0.92	7.18±1.11	13.8±1.22	2361±441	0.59 ± 0.01	11.5±3.89	20.58±4.05
MF	5.05±0.84	7.09±1.01	20.8±2.50	3393±593	1.77 ± 0.02	2.09±1.02	8.63±2.24
	AFTER WEATHERING						
	Density (g/cm³)	MC (%)	MOR (N/mm²)	MOE (N/mm²)	IB (N/mm²)	Thickness swelling (%) 2 h	Thickness swelling (%) 24 h
AX	4.29±0.64	6.45±1.24	11.8±1.10	1499±170	0.59±0.02	5.85±1.52	18.51±3.94
X	4.41±0.75	6.32±1.21	12.9±1.12	1844±324	0.64±0.08	14.69±3.21	21.65±5.73
AY	4.32±0.89	6.54±0.78	13.3±1.22	1764±256	0.59±0.04	6.61±2.14	16.75±3.94
Y	4.43±0.75	5.86±0.86	12.3±2.81	1731±221	0.59±0.06	9.12±2.59	18.66±4.56
UF	4.14±0.79	6.94±0.98	7.80±1.89	1256±150	0.24±0.02	13.35±2.85	29.1±8.38
MF	4.47±0.76	7.11±1.18	16.8±2.32	2296±495	1.43±0.09	2.96±0.83	9.13±3.58

As seen in Figure 1, the coating application provided a very high protection of the UF control panel against the weathering conditions. After the artificial weathering test, the lowest decrease in the mechanical properties was found in the UF control panels applied coating, and mechanical strength loss was determined in the AX variation close to the control MF panel. After the weathering test, the highest loss of mechanical strength was in the UF control panel.

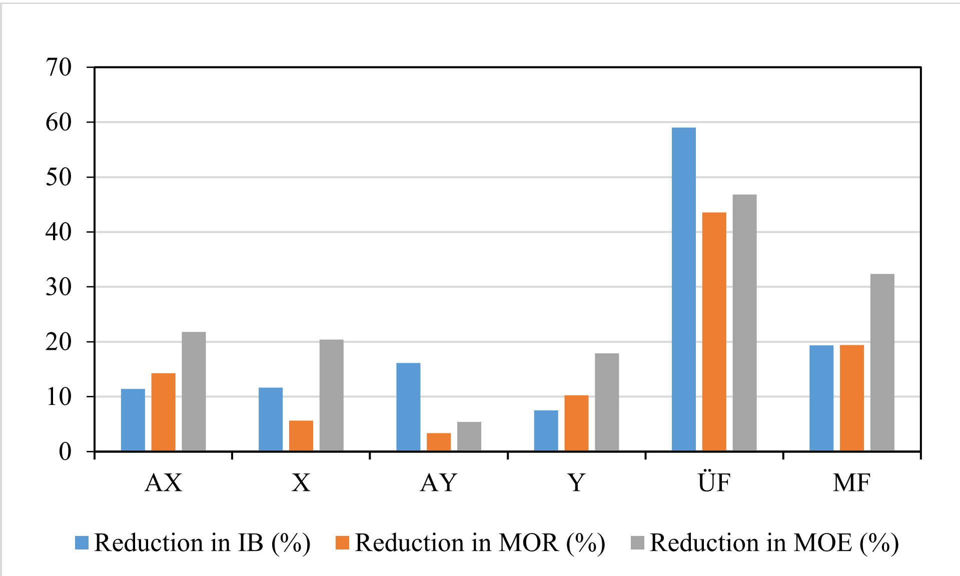

Figure 1. Changes in mechanical strengths of experimental panels after weathering

After the artificial weathering test, the best thickness swelling results for 2 and 24 hours were determined in the MF control panel and the coating applied AY variations as the test panels. After the weathering test, it was understood that the 2- and 24-hour thickness swelling results were the highest in the UF control panel, and the coating application provided significant protection in the thickness swelling results.

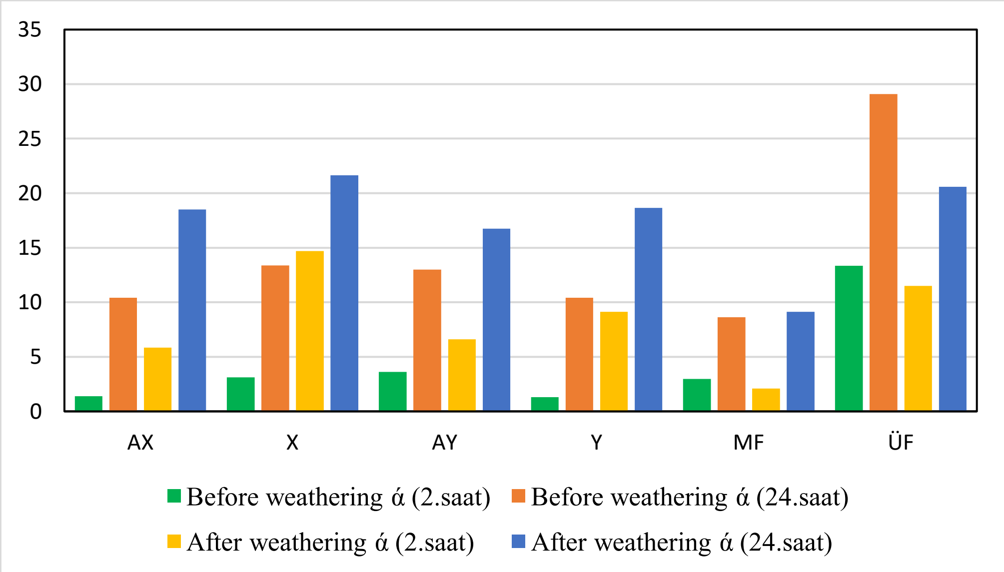

Figure 2. Changes in thickness swelling of experimental panels after weathering

3.2. Change in Surface Roughness Parameters

Table 5 shows the surface roughness index values and Ra and Rz roughness parameters before and after the artificial weathering test of the control and test panels. After the weathering test, the lowest change index of the Ra roughness parameter was in the Y variation, and the index values of the AX variation and MF control panels were also determined to be close to each other. The index values of the AY and X variations were also found to be close. After the weathering test, the change index in the Rz roughness parameter was the lowest in the AY variation, and the change index in the Y and AX variations was also close. After the weathering test, the highest Rz change index values were found in the UF and MF control panels.

Table 5: Changes in surface roughness parameters of experimental panels after weathering

Coating	***Before weathering***			***After weathering***			***Change rate***	
Code	***Ra***	***Rz***		***Ra***	***Rz***		***RI_a***	***RI_z***
AX	*1.46±0.21*	*15.4±1.74*		*1.73±0.19*	*18.4±2.08*		*0.19±0.12*	*0.18±0.11*
AY	*0.65±0.12*	*4.82±0.79*		*0.71±0.18*	*6.1±1.01*		*0.29±0.10*	*0.09±0.09*
X	*0.52±0.04*	*5.27±0.41*		*0.72±0.12*	*6.39±1.27*		*0.22±0.18*	*0.38±0.17*
Y	*1.73±0.28*	*16.7±2.47*		*1.96±0.25*	*19.4±1.99*		*0.17±0.07*	*0.13±0.08*
MF	*3.27±0.44*	*33.95±2.66*		*4.62±0.75*	*40.52±4.46*		*0.19±0.14*	*0.41±0.21*
UF	*3.68±0.76*	*34.82±5.25*		*6.07±0.87*	*45.04±4.27*		*0.31±0.15*	*0.64±0.24*

4. Discussion

The single most important factor contributing to the weather conditions of particle boards is the change in moisture content. It appears that UV radiation and chemical changes do not have a significant effect on the effect of weather conditions. Continuous changes in moisture content create shrinkage and swelling stresses in the glue line between adjacent particles in the particle board content, as well as in the particles themselves. It is absorption and desorption of liquid water that causes excessive thick swelling of the sheet, surface roughness and deterioration. Thickness swelling occurs due to the normal swelling of wood particles and their swelling due to release of the compressible set (Kajita et al. 1991).

Based on the EN standards, 11.5, 13 and 1600 N/mm^2 are the minimum requirements for the modulus of rupture and modulus of elasticity of particle board panels for general uses and furniture manufacturing, respectively (EN 312-2 1996, EN 312-3 1996). In comparison to the MF control panels, the X, AY and Y test panels met the minimum modulus of rupture requirement of the EN standards for general uses after the artificial weathering test. Additionally, the AX test panel satisfied the modulus of rupture requirement for furniture manufacturing applications. The results showed that the X, AY and Y test panels complied with the modulus of elasticity for interior fitments (including furniture). Moreover, with the exception of the UF control panel, the other panels were found to comply with the internal bond strength value for general uses, which is 0.24 N/mm^2 as stated in the EN 312-2 (1996) standard. According to the test results, the AX, AY, X and Y panels had the required level of internal bond strength for interior fitments that is 0.35 N/mm^2 according to the EN312-3 (1996) standard. Figs. 1 and 2 show the changes in the mechanical strengths of the experimental panels after weathering. Based on the EN 317 standard (1993), particle board should have a maximum thickness swelling value of 8% (for 2-h immersion). The mean thickness swelling of the specimens ranged from 5.85 to 14.69% for 2-h immersion. The X test and UF control panels did not satisfy the thickness-swelling requirement for general uses. This was because the X and Y coating systems separated from the UF chipboard surface during the 2-hour immersion process. However, the thickness swelling values of the AX and AY wafers (5.85% and 6.61% for 2-hour immersion) were very close to the required thickness swelling level of panels for general use. Fig.2 illustrates the artificial weathering test effects on the thickness swelling values (for 2- and 24-hour immersion) of the test and control particle boards.

From the observations given in Table 4, it is seen that, after the weathering test, the UF control panels swelled by 13.35-29.1% of their original thickness while standing, and this process was irreversible. This increase in volume was clearly reflected in the strength properties of the boards. The tear modulus decreased by 40-45% due to the weathering test. While the density was 5.00 g/cm^3 in the UF control panels before weathering exposure, the higher internal bond strength and rupture modulus values of the panels whose density decreased to 4.14 g/cm^3 after weathering exposure also decreased. The positive effect of panel density on mechanical properties was mentioned in a similar study. However, the increase in the board's density resulted in poor thickness swelling properties, similarly to the results of a previous study. Acrylic coating application significantly improved the rupture modulus and thickness swelling values in the weathering conditions. This was due to the reduction in the moisture absorption of the sheet surface in the weathering conditions with coating application. Thus, the amount of decrease in the internal bond strength values of the test plates applied with coating when exposed to weathering conditions was much lower than the UF control panel and close to the MF control panel (Kalaycıoglu and Nemli 2007).

In fact, a coating film can delay and prevent excessive moisture ingress into the panel at best, but it cannot stop it. Before coating, the gaps between the particles are closed, and the effectiveness of the paints increases if the surface is smoothed. A normal acrylic coating has a limited external life of about two years in particle boards. Therefore, a regular maintenance coat is required to extend the service life of such structures. While smooth surfaces are preferred in the end-use applications of chipboard panels, the thickness of the panels should also be on acceptable levels. Surface roughness and bursting of wood particles have also been serious problems due to the weathering conditions of particle boards. This allows rainwater to stay on the surface of the board for a long time, thus increasing the risk of more water penetrating the board. These defects can only be eliminated by using microchips on the surface and making the surface of the card waterproof. Although particle boards have large dimensions, their applications in buildings require many joints (Kajita et al. 1991, Şahin and Arslan 2011).

5. Conclusion

In this study, the durability of UF panels in semi-open outdoor conditions was improved with 4 different waterborne acrylic coating systems. After exposure to the artificial weathering test, the percentage of decrease in the physical and mechanical properties of the UF control panels applied the waterborne acrylic coatings was close to that of the MF control panels. The coating systems applied in the study positively affected the durability of the UF control panel in semi-open weathering conditions. Additionally, the fact that waterborne acrylic coatings are renewable preservatives may make a significant contribution to the particle board industry. In semi-open outdoor conditions, the durability time of the UF control panel was increased with the application of the waterborne acrylic coating system, and it reached a durability level close to that of the MF control panel. It is recommended that this study is evaluated in the industry by performing a cost analysis of application of waterborne acrylic coating on the surface in UF particle board and MF particle board production.

6. Acknowledgments

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PRODUCTION OF *PLEUROTUS OSTREATUS, PLEUROTUS CITRINOPILEATUS* AND *PLEUROTUS DJAMOR* IN DIFFERENT CONTENTS AND SOME PHYSICAL ANALYSIS

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Abstract

In this study, some physical analysis of oyster mushroom (*P. ostreatus*), yellow oyster mushroom (*P. citrinopileatus*) and pink oyster mushroom (*P. djamor*) were investigated. Waste sawdusts of beech, alder, chestnut and walnut wood were used as substrate. After sterilization of sawdusts, 3% mycelium and 1% calcitic lime were added to the sawdusts and placed in the nylon bags. There was only one type of sawdust in each nylon bags. The temperature of the cultivation room was 15±2 °C, the humidity was 80 - 90%, and ventilation was made at certain intervals. In the study, *P. citrinopileatus* was the fastest micellization mushroom type at the beech sawdust substrate, Mycelium development was the slowest in the *P. djamor* type at the chestnut sawdust substrate. Cultivated in chestnut sawdust substrate, the *P. djamor* is generally considered to be the lowest width-length measure mushroom. For *P. ostreatus* cultivated in beech sawdust compost, the mushroom produced can have the highest width-length dimensions. The lowest yield was 19.77% in the *P. djamor* at the chestnut sawdust substrate. The highest yield was *P. citrinopileatus* species cultivated in beech substrate with 31.02%. Following this, *P. ostreatus* cultivated in beech sawdust substrate was very close with 30.99% yield. The lowest biological activity rate was 38.22% at the *P. djamor* which cultivated in chestnut sawdust substrate. The highest biological activity rate was *P. citrinopileatus* cultivated in beech sawdust substrate with 70.93%.

Keywords: P. ostreatus, P. citrinopileatus, P. djamor, Physical analysis, Wooden substrate, Micellization, Mushroom quality and yield, Biological activity.

1. Introduction

As known that *Pleurotus* species fall into the category of non-wood forest products. Although there are about 40 species, 3 important species have been studied in this study (Jose and Janardhanan 2001). Oyster mushrooms are formed by decomposing lignocellulosic composts thanks to their enzymes (Zadrazil, 1978). Due to its easy breeding techniques and wide adaptability, *P. ostreatus* has an important role in recycling organic waste (Das and Mukherjee, 2007). Besides, they do not require environmental control and can be cultivated simply and cheaply (Josiane et al., 2018).

Oyster mushroom that is grown by imitating natural conditions has an important situation in the country's economy (Josiane et al., 2018). Increasing population and diversifying agro-industrial wastes reach large volumes and cause environmental problems as well as commercial exploitation. These wastes are sometimes left in the field, and sometimes they are desired to be eliminated by burning. However, incinerated wastes return to the atmosphere as carbon dioxide, which causes the release of greenhouse gases that cause global warming.

Pleurotus mushroom comes into play at this point and turns the waste, which is a problem for disposal, into three main outputs, making it beneficial to the environment and living beings. Firstly, useful compost is created by using lignocellulosic waste. As the second output; a value-added product with very high nutritional value is obtained from composts. As the third output; composed composts after mushroom production are used as animal feed or fertilizer. The composts content can be prepared depend to region. The variety of agricultural or forest waste in its content creates differences in the oyster taste, nutritional value, scent and texture of the oyster. Today, oysters are produced from many different composts and these oysters are compared in terms of their nutritional values (Yıldız et al., 2017a; Yılmaz et al., 2016; Yılmaz et al., 2017).

The main aim of the study is to investigate the usage possibilities of wood production wastes in oyster production. It is also to put forth how which type of waste effects mycelium growth and oyster quality and compare with each other.

2. Materials and Methods

The project was carried out in the laboratories of the Eastern Black Sea Forestry Research Institute and in the laboratories of the Karadeniz Technical University, Faculty of Forestry, Department of Forest Industry Engineering, Forest Biology and Wood Protection Technology Department.

2.1. Materials

For the preparation of compost, the waste parts of the furniture production woods were used in. Waste wood types were turned into sawdust which are consist of alder, walnut, beech, and chestnut wastes and used. Micelles, chemicals and auxiliary elements required were provided from commercial companies.

2.1.1. Compost Content and Preparation

Wood wastes that were turned into sawdust were sterilized in autoclave at 121 °C and under high pressure for 30 minutes in order to eliminate harmful organisms. After this process, they were allowed to cool. The prepared composts were then filled in 1 kg for each of 29 x 45 cm polypropylene bags. 4 bags were prepared for each varition (Yıldız et al., 2002). Mycelium inoculation was carried out in a sterile cabinet with the help of a sterile spatula by inoculating 3% mycelium to the upper part of the bags. 1% calcitic lime was added to the bags to regulate the Ph balance. The remaining 96% was wood sawdust (Şanlı, 2014). Only one type of wood sawdust was used in each bag. Combination variations with different wood species have not been investigated. The reason composts are of one type is to compare the impact and performance of wood on oysters.

2.1.2. Inoculation and Harvesting

Mycelium inoculation was carried out in the micelle development room where containing 25 ± 2 °C and 70-80% humidity also suitable light and ventilation. After the mycelium development is completed, 5 cm wide cuts are made on both side surfaces of the bags to encourage oyster formation. Oysters are mostly harvested by cutting them from the surface with a knife when they reach the same size.

2.2. Methods

2.2.1. Measurement and Analysis

2.2.1.1. Mycelium Growth Rate: The time elapsed from grafting until the mycelium grown around the bag was daily evaluated.

2.2.1.2. Mushroom Quality Analysis: Cap length, cap width, stipe length and stipe width values were measured on the mushrooms.

2.2.1.3. Total Yield and Biological Efficiency Rate: Oysters yield was calculated as total fresh weight of mushrooms obtained from 4 flushes in the harvest period (Royse, 1985). Biological efficiencies were defined as the percentage ratio of the fresh weight of harvested oysters over the dry weight of substrates (Chang et al., 1981).

3. Result

3.1. Mycelium Growing Time

P. ostreatus (white oyster mushroom), *P. citrinopileatus* (yellow oyster mushroom), and *P. djamor* (pink oyster mushroom) were cultivated on four different wooden sawdusts which are alder, walnut, beech, and chestnut. Mycelium Growing Time (day) is presented in Table 1.

Table 1. Mycelium Growing Time (day) of Cultivated Oysters

Substrates	Oyster Mushroom (X* ± SD**)		
	White Oyster	**Yellow Oyster**	**Pink Oyster**
Alder	18 ± 0.82^{a}	16 ± 0.82^{a}	20,3 ± 0.96^{a}
Walnut	18 ± 0.82^{a}	15,5 ± 0.58^{b}	20,3 ± 0.96^{a}
Beech	16,5 ± 1,29^{a}	13 ± 0,82^{b}	20 ± 0,82^{a}
Chestnut	19,8 ± 1,26^{b}	18,3 ± 0,5^{c}	21,3 ± 0,96^{a}

[a] Means having the same superscript letter(s) are not significantly different (p>0.05) by Duncan's multiple range test. X*: Average, S.D.**: Standard Deviation

3.2. Mushroom Quality Properties

Mushroom Quality Properties (cap length, cap width, stipe length, stipe width of oysters) of *Pleurotus* types of the current study are presented in Table 2.

Table 2. Mushroom Quality Properties of Cultivated Oysters

Substrates	Mushroom type	Cap Length		Cap Width		Stipe Length		Stipe Width	
		X	S.D.	X	S.D.	X	S.D.	X	S.D.
Alder	White	2.20[a]	0.38	8.07[b]	1.36	2.63[a]	0.23	0.49[a]	0.09
	Yellow	2.46 [a]	0.56	6.23[a]	2.16	2.67[a]	0.26	0.45[a]	0.19
	Pink	2.44[ab]	0.53	5.67[a]	1.77	2.67[a]	0.18	0.42[ab]	0.09
Walnut	White	2.16[a]	0.70	6.63[a]	1.36	2.63[a]	0.15	0.52[a]	0.11
	Yellow	2.36 [a]	0.51	6.06[a]	1.87	2.71[a]	0.27	0.46[a]	0.12
	Pink	2.57[ab]	0.44	5.66[a]	1.71	2.66[a]	0.17	0.48[b]	0.10
Beech	White	2.30[a]	0.78	8.70[b]	1.08	2.61[a]	0.16	0.50[a]	0.16
	Yellow	2.71 [a]	0.72	7.07[a]	1.40	2.61[a]	0.20	0.40[a]	0.11
	Pink	2.83[b]	0.71	6.94[a]	1.58	2.73[a]	0.29	0.38[ab]	0.10
Chestnut	White	2.13[a]	0.61	6.49[a]	1.24	2.57[a]	0.18	0.45[a]	0.08
	Yellow	2.16 [a]	0.42	5.83[a]	1.08	2.63[a]	0.18	0.41[a]	0.10
	Pink	2.07[a]	0.29	5.33[a]	0.62	2.56[a]	0.10	0.35[a]	0.04

[a] Means having the same superscript letter(s) are not significantly different ($p>0.05$) by Duncan's multiple range test.

3.3. Total Yield

Total yield (%) of *Pleurotus* types of the current study are presented in Table 3.

Table 3. Total Yield (%) of Cultivated Oyster Mushroom

Substrates	Oyster Mushroom (X ± SD)		
	White Oyster	**Yellow Oyster**	**Pink Oyster**
Alder	25,04 ± 1,68[a]	25,15 ± 3,74[ab]	22,73 ± 1,26[b]
Walnut	22,04 ± 4,19[a]	28,29 ± 2,29[bc]	21,44 ± 1,9[ab]
Beech	30,99 ± 3,88[b]	31,02 ± 3,55[c]	28,81 ± 2,34[c]
Chestnut	21,74 ± 1,07[a]	21,42 ± 1,09[a]	19,77 ± 1,07[a]

[a] Means having the same superscript letter(s) are not significantly different ($p>0.05$) by Duncan's multiple range test.

3.4. Biological Efficiency

Biological efficiency (%) of *Pleurotus* types of the current study are presented in Table 4.

Table 4. Biological efficiency (%) of Cultivated Oyster Mushroom

Substrates	Oyster Mushroom (X ± SD)		
	White Oyster	**Yellow Oyster**	**Pink Oyster**
Alder	53,75 ± 2,29[b]	58,72 ± 5,39[b]	49,45 ± 3,42[c]
Walnut	54,65 ± 8,38[b]	62,04 ± 4,07[b]	44,75 ± 2,31[b]
Beech	61,16 ± 5,32[b]	70,93 ± 7,04[c]	66,57 ± 1,93[d]
Chestnut	42,50 ± 2,16[a]	41,60 ± 2,32[a]	38,22 ± 2,16[a]

[a] Means having the same superscript letter(s) are not significantly different ($p>0.05$) by Duncan's multiple range test.

4. Discussion

4.1. Mycelium Growing Time

In the study, considering the time it takes for the mycelium to spread out to the bag, it was determined that *P. citrinopileatus* growing in beech sawdust completes the earliest mycelium development within 13 ± 0,82 days while *P. djamor* mushroom grown in chestnut sawdust was completed its development with 21,3 ± 0,96 days (Table 1). Küçükomuzlu and Pekşen (2005) reported that Pleurotus spp. produced from straw and bran compost have obtained the fastest mycelium development with 39.50 days. In another study, the mycelium development period for P. ostreatus was reported as between 28-36 days (Upadyay and Vijay, 1991). In another study, three types of Pleurotus; P. sajor-caju, P. platypus and P. citrinopileatus mushrooms were grown on a variety of agricultural wastes, such as rice straw, corn stalk, sugar cane pulp, coconut fiber and mixtures of these wastes. The beginning of primordium was observed 22-27th days (Ragunathan et al., 1996). Ragunathanand and Swaminathan (2003), in their similar study, cultivated three species of Pleurotus; P. sajor-caju, P. platypus and P. citrinopileatus, on different agricultural wastes (cotton stalk, coconut fiber, sorghum stems and mixtures of these wastes). Primordium beginning was observed between 21 and 30 days. The results of the cultivation of P. djamor, P. ostreatus, and P. pulmonarius species on coffee waste and wheat straw are scrutinized. Primordium growing time was given as 11-12 days in the wheat straw substrate for P. djamor at the earliest and 16-32 days for P. pulmonarius mushroom at the latest. The same values varied between 13 and 31 days in coffee waste (Salmones et al., 2005). In another study, according to the growing substrate and mushroom species, the mycelium growing time is specified between 2-8 weeks by Oei (1991). In a study, mycelium growth rates of substrates inoculated with five different Pleurotus species were compared after 30 days. The lowest rate of development was observed in P. djamor mushroom (Kalyoncu and Kalmış, 2007). The study was accordance with literature. Indeed, the shorter mycelium growing time was determined in this study compared to the literature. It can be explaned with the amount of substrates and type. In the study, the most suitable sawdust for oyster production was the sawdust obtained from beech wood. Chestnut wood sawdust were the substrate where the minimum mycelium development was obtained. Chestnut tree's natural strength and being antifungal can be associated with this result. In another study, it is stated that chestnut sawdusts pasteurization liquid, which is especially rich in tannins, obtained significant resistance against C. puteana in scotch pine sapwood (Yıldız et al., 2017b).

4.2. Mushroom Quality Properties

As seen Table 2, considering the cap length values, the shortest cap length was found in P. djamor mushroom growing in chestnut sawdust compost; the longest cap length was obtained from P. djamor mushroom grown in beech sawdust compost. Considering the cap width values, the shortest cap width in P. djamor mushroom cultivated in chestnut sawdust compost; the largest cap width value was obtained in P. ostreatus mushroom growing in beech sawdust compost. Considering the stipe length values, the shortest stipe length was in P. djamor mushroom grown in chestnut sawdust compost; the longest stipe length value was obtained in P. djamor mushroom growing in beech sawdust compost. Considering the stipe width values, the shortest stipe width in P. djamor mushroom growing in chestnut sawdust compost; the largest stipe width value was obtained in P. ostreatus mushroom growing in walnut sawdust compost. P. djamor (pink oyster) grown on chestnut sawdust stands out with the lowest quality in general. P. ostreatus (white oyster) grown in beech sawdust compost is the best quality mushroom among the produced mushrooms. In a study, P. citrinopileatus has the largest cap (10,02 cm) and the longest stipe (5,42 cm) among P. sajor-caju, P. florida, P. eous, P. citrinopileatus, P. fossulatus, P. flabellatus, P. platypus, P. ostreatus, H. ulmarius mushroom species. P. ostreatus took the second place in terms of cap size (9,26 cm) and stipe length (3,20 cm) at the same study. Moreover, P. ostreatus (1,73 cm) and P. citrinopileatus (1,47 cm) had the thickest stipe in the reference study. P. citrinopileatus was the most spore producing species among the others (Rout et al., 2018).

4.3. Total Yield

According to the results of the study, the lowest yield was P. djamor mushroom grown in chestnut wood sawdust with 19.77%. The highest yield was P. citrinopileatus grown in beech sawdust with 31.02%. Following that, total yield of P. ostreatus mushroom grown in beech sawdust was very close to P. citrinopileatus with 30.99% (Table 3). Pleurotus spp, is one of the fungi that causes white rot in wood. Beech is one of the most suitable trees for producing mushroom, which is not resistant to fungal rot. In a study, beech, oak, pine, fir and hornbeam trees were selected to investigate rot fungi in the wood. The tree species most exposed to rot in the study was beech (Sertkaya et al., 2017). In another study, P. ostreatus gave the highest yield at the first measurement compared to other fungal species (Zhai and Han, 2018). In another study, pleurotus species were grown on cotton stipes. Yield was maximum in P. citrinopileatus mushrooms (Ragunathanand and Swaminathan, 2003). When the study is compared with the literature, it is seen that the results are in accordance with the literature. Considering the mushrooms and yield results in the study, the results of P. ostreatus and P. citrinopileatus show similarity with other studies.

4.4. Biological Efficiency

According to the results of the study, the lowest biological efficiency rate was found in P. djamor mushroom growing in chestnut wood sawdust with 38.22%. The highest biological activity rate was found in P. citrinopileatus mushroom growing in beech wood sawdust with 70.93% (Table 4). In a study, three species of Pleurotus, P. sajor-caju, P. platypus, and P. citrinopileatus mushrooms were grown on various agricultural wastes such as rice straw, corn stalk, sugar cane pulp, coconut fiber and a mixture of these wastes. Biological activity varied between 25.18% and 38.63% (Ragunathan et al., 1996). In another study, three species of Pleurotus, P. sajor-caju, P. platypus and P. citrinopileatus were grown on different agricultural wastes (cotton stalk, coconut fiber, sorghum stems and mixtures of these wastes). Biological activity ranged from 26.11% to 41.42% (Ragunathanand and Swaminathan, 2003). In a different study, oyster mushroom that produced from coffee waste and wheat straw have been studied. Salmones et al. (2005), found the biological efficiency rate between 30.5 and 80.5%. Industrial paper waste was investigated in the production of P. citrinopileatus mushrooms. Biological efficiency ranged from 3.3% to 94.5% (Kulshreshtha et al., 2013). As seen in the studies, the biological efficiency rate varies between a wide scale depending on the type of mushroom to be produced and the growing substrate. Therefore, it is seen that the results of this study also support the literature studies.

5. Conclusion

As a result of the study, physical and quality analyses of the Oyster mushrooms species produced in the different composts and under the specified conditions were carried out. When oyster mushrooms want to be consumed as food, the cap part is generally consumed. It is known that the stipe part is not consumed much in general. Considering the size of the cap, the white oyster growing in beech compost can be recommended.

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METAL AND RADIONUCLIDE ACCUMULATION OF SOME CULTIVATED MUSHROOMS

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Abstract

Heavy metals and radionuclides of human origin and naturally occurring in nature are accumulated in plants, animals and fungi. In particular, some fungal species have a high capacity to absorb radionuclides. In this study, some metals (^{27}Al, ^{52}Cr, ^{55}Mn, ^{56}Fe, ^{59}Co, ^{60}Ni, ^{63}Cu, ^{66}Zn, ^{75}As, ^{111}Cd, ^{204}Hg, ^{206}Pb) and radionuclides (^{232}Th, ^{238}U, ^{40}K, ^{137}Cs) of culture mushrooms such as *Pleurotus eryingii, Pleurotus citrinopileatus* (cultivated on alder and walnut tree sawdust, separately) and *Pleurotus djamor* (cultivated on beech and walnut tree sawdust, separately) were investigated. Metal accumulations were determined using Inductively Coupled Plasma – Mass Spectrometer (ICP-MS). Radioactivity measurements were performed by using High Purity Germanium (HPGe) detectors. Among the studied mushrooms, *Pleurotus citrinopileatus* has drawn attention with highest ^{52}Cr, ^{55}Mn, ^{60}Ni, ^{63}Cu, ^{66}Zn, ^{204}Hg, ^{206}Pb content. Among the radionuclides ^{232}Th, ^{238}U content were not determined in any mushroom species. ^{137}Cs was not detected in any mushrooms except *Pleurotus citrinopileatus* cultivated on alder tree sawdust (15 ± 3 Bq/kg.). The highest ^{40}K radionuclide content was determined in *Pleurotus eryingii* mushroom cultivated on alder tree sawdust with 947 ± 32 Bq/kg. It was concluded that the metal and radionuclide content of mushrooms were affected by mushroom type and cultivation conditions.

Keywords: Cultivated mushrooms, metal content, *Pleurotus*, radionuclide content

1. Introduction

The medicinal properties of both wild mushrooms and cultivated mushrooms have been intensively studied in recent years (Mizuno 2002; Patel et al. 2012; Chaturvedi et al. 2018; Phan et al. 2019; Shomali et al. 2019; Sevindik, 2020). With the increasing awareness of people about mushrooms, consumption of mushrooms has also increased (Hess et al. 2017). Moreover, mushroom cultivation has been both a source of income and a nutritious food for people (Grimm and Wösten 2018). *Pleurotus* species have become more attractive as they can be grown more easily among the other cultivated mushrooms (Sánchez 2010). In addition, some types of *Pleurotus* have very beautiful colors (*Pleurotus citrinopileatus*-yellow, *Pleurotus djamor*-pink) and these mushrooms are also used for visual purposes, especially in restaurants.

Mushrooms cannot produce metal ions themselves but it is known that the edible mushroom species in nature or cultivated mushrooms can accumulate heavy metals and radionuclides (Ban-nai et al. 1994; Chatterjee et al. 2017; Kalač and Svoboda, 2000). Mushrooms directly or indirectly intake the nutrients and metal ions from the environment -soil or substrate- and thanks to their absorption properties, they store them in high concentrations (Michelot et al. 1998; Širić et al. 2016). For this reason, it is important to determine whether metal ions, which have a detrimental effect on human health, are present in fungi taken directly as food. In this way, it can be determined whether there is heavy metal contamination in the growing area of mushroom.

Pleurotus species can be cultivated on many different lignocellulosic environments (Shah et al. 2004; Das and Mukherjee, 2007) and the nutritional content of these mushrooms is affected by their subsrates (Chang et al. 1981; Ahmed et al. 2009; Oyetayo and Ariyo 2013). In the literature it was reported that the chemical configuration of substrates could affect the mushrooms' nutritional elements, yield and the level of various toxic (Swulski et al. 2018). This study was made for highlight the required that substrates used for cultivation of mushroom species contain the lowest possible toxic levels to provide the safety of consumers. For that purpose, some metals (^{27}Al, ^{52}Cr, ^{55}Mn, ^{56}Fe, ^{59}Co, ^{60}Ni, ^{63}Cu, ^{66}Zn, ^{75}As, ^{111}Cd, ^{204}Hg, ^{206}Pb) and some radionuclides (^{232}Th, ^{238}U, ^{40}K, ^{137}Cs) of cultivation mushrooms such as *Pleurotus eryingii, Pleurotus citrinopileatus* (cultivated on alder and walnut tree sawdust, separately) and *Pleurotus djamor* (cultivated on beech and walnut tree sawdust, separately) were investigated.

2. Materials and Methods

2.1. Mushroom

In this study, some culture mushrooms such as *Pleurotus eryingii, Pleurotus citrinopileatus* (cultivated on alder and walnut tree sawdust, separately) and *Pleurotus djamor* (cultivated on beech and walnut tree sawdust, separately) were investigated in terms of metal and radionuclide accumulations (Table 1, Table 2 and Table 3). *P. eryingii*, *P. citrinopileatus* and *P. djamor* myceliums were obtained from a commercial firm located in Istanbul. Alder, walnut and beech sawdust was supplied from workshop of Forest Industry Engineering, Karadeniz Technical University, Trabzon. All mushrooms were cultivated as detailed in our previous studies (Yıldız et al. 2017). The mushroom names were coded from 1 to 6. The mushroom species and the substrate types on which they were cultivated were shown in Table 1 and Figure 1.

Table 1. The mushroom and substrate types

Mushroom codes	Mushroom types	Substrate types
1	*Pleurotus eryingii*	Alder tree sawdust
2	*Pleurotus eryingii*	Walnut tree sawdust
3	*Pleurotus citrinopileatus*	Alder tree sawdust
4	*Pleurotus citrinopileatus*	Walnut tree sawdust
5	*Pleurotus djamor*	Beech tree sawdust
6	*Pleurotus djamor*	Walnut tree sawdust

All the mushroom samples were sliced and dried on a drying machine at 40 °C until they were completely dehydrated. Then mushroom samples were crushed for passing a 40-

mm mesh sieve. For radioactivity measurements, mushroom powders were put in a plastic cylindrical container of uniform size (50 mm in height, 60 mm in diameter) and sealed for a period of 4 weeks in order to allow for radon and its short-lived progenies to reach secular radioactive equilibrium prior to gamma spectroscopy (Turhan et al. 2007).

2.2. Metal accumulation

Metal accumulations of mushrooms were determined using Inductively Coupled Plasma – Mass Spectrometer (ICP-MS). One dissolution and three measurements were performed. Internal standard masses were continuously measured simultaneously with the samples during measurement: Li (6 no gas), Sc (45 Helium), Ge (72 Helium), Rh (105no gas), Rh (105 helium) Rh (103 no gas), In115 (no gas), Tb (159 no gas), Lu (175), Bi (209).

The microwave procedure was as follows: Weights not exceeding 0.5 g but close to that value were weighed (up to 0.5g) into the 50 ml heat and pressure resistant teflon containers. 8 ml of suprapur purity 65% HNO_3 and 2 ml of suprapur purity 30% H_2O_2 were added.

Microwave programming: Maximum 1000W energy and 45 bar pressure limit values are set. A temperature of 200 °C was reached from room temperature within 15 minutes. It remained at a constant temperature of 200 °C for 15 minutes. Then the heating process has ended. It was left to come to room temperature for half an hour.

Samples dissolved in microwave were transferred from teflon cups to 50 ml polyethylene falcon tubes. Up to 50ml of ultra-pure water was added. Dilution factor for each sample was determined. For example, dilution factor for 0.4167g sample weighed: Final volume / weight of sample = 50ml / 0.4167g = 119.99. During the analysis, the calibration values and results of the elements were measured as ppb = µg/kg. Measurements were made in accordance with the standards of EPA 200.8, EPA 6020 for mushroom samples.

Pleurotus eryingii cultivated on walnut tree sawdust

Pleurotus eryingii cultivated on alder tree sawdust

Pleurotus citrinopileatus cultivated on walnut tree sawdust

Pleurotus citrinopileatus cultivated on alder tree sawdust

 *Pleurotus djamor* cultivated on beech tree sawdust	 *Pleurotus djamor* cultivated on walnut tree sawdust

Figure 1. The mushroom species and the substrate types on which they were cultivated

2.3. Radioactivity measurements

Radioactivity measurements were performed by using a HPGe computer-controlled detector having the resolution of 1.9 keV for the 1332 keV energy line of 60Co with conventional electronics and 15% relative efficiency (Canberra, GC1519 model) and Genie 2000 as the software. The detector was shielded with a 10 cm thick lead layer to reduce the background due to the cosmic rays and the radiation nearby the system (Cevik et al. 2009).

Decay corrections were performed according to the sampling date. The energy calibration and absolute efficiency calibration of the spectrometer were carried out using calibration sources which contained ^{133}Ba, ^{57}Co, ^{22}Na, ^{137}Cs, ^{54}Mn, and ^{60}Co peaks for the energy range between 80 and 1400 keV (calibration sources supplied by Isotope Products Laboratories) (Cevik et al. 2008). The reference material of the International Atomic Energy Agency (IAEA-375) and the Gamma Acquisition & Analysis program were used to calibrate the efficiency of the gamma detector.

The gamma-ray lines of 295.2 keV from ^{214}Pb, 352.0 keV from ^{214}Pb and 609.4 keV from ^{214}Bi were used to evaluate the ^{238}U activity concentration, while 583.1 keV gamma-ray from ^{208}Tl, 238.6 keV from ^{212}Pb and 911. keV from ^{228}Ac were used to determine to the ^{232}Th activity concentration. The activity concentrations of ^{40}K and ^{137}Cs were determined by using their 1460 keV and 661 keV gamma-ray lines, respectively. After the samples and gamma spectroscopy system (with energy and yield calibrations) were prepared for measurement, the radioactivity analysis of each sample was performed for 80.000 seconds. At the end of this period, the spectra of the radioactive isotopes from the samples were calculated. The specific activity of each sample was then calculated utilizing the following Equation 1 (Changizi et al. 2012).

$$A = \frac{C_{net}}{\varepsilon * I_{\gamma} * t * m} \tag{1}$$

where; C_{net} was the net area of the total absorption line, AA was the activity of the isotope in Bq/kg, I_{γ} was the absolute intensity of the transition, t was the sample measurement time, ε was the full energy peak efficiency and m was the mass of the sample.

The minimum detectable activity (MDA) of the present measurement system was calculated as follows Equation 2 (Currie 1968)

$$MDA = \frac{\sigma\sqrt{B}}{\varepsilon * P * t * w} \tag{2}$$

where; MDA is in Bq/kg, σ was the statistical coverage factor equal to 1.645 (confidence level 95%), B was the background for the region of interest of a certain radionuclide, P was the absolute transition of gamma decay, ε was the full energy peak efficiency, t was the counting time in seconds and w was weight of the dried sample in kg.

2.3.1. Effective dose

A possible risk of radioactivity for human being that consume the mushrooms is expressed by the effective dose (E) given in µSv/y. The average annual effective dose equivalent that an individual receives due to the radionuclides ingestion from contaminated mushrooms was calculated using the following Equation 3 (International Atomic Energy Agency, 2001)

$$E = C * H * DF \qquad (3)$$

where; E was annual effective dose from consumption of nuclide in foodstuff (µSv/y), C was the concentration of radionuclide in foodstuff (Bq/kg), H was the consumption rate for foodstuff p (kg/y) and DF was the dose coefficient for ingestion of radionuclide (µSv/Bq). The values of this conversion factor for adults were: 0.28, 0.23, 1.3×10^{-2} and 6.2×10^{-3} µSv/Bq for ^{238}U, ^{232}Th, ^{137}Cs and ^{40}K, respectively. In this study, the average annual consumption of mushrooms by adult Turkish people was taken as 0.360 kg.

3. Results

3.1. Metal accumulation

Metal accumulation of studied mushrooms was presented in Table 2.

Table 2. Metal accumulation of studied mushrooms

Metal contents (µg/kg)	Mushroom codes					
	1	2	3	4	5	6
Al	**47880,6**	32582,9	11480,3	12742,8	15511,6	17577,8
Cr	166,55	919,76	96,37	137,07	93,95	**1360,56**
Mn	8245,91	10571,9	8420,46	15067,4	13539,3	**59275,2**
Fe	49978,5	**232626**	41661,6	105689	122635	120888
Co	38,94	112,45	<0,00	6,29	6,65	**467,74**
Ni	225,79	853,76	522,88	**3027,39**	723,72	1359,45
Cu	5639,74	9410,69	9908,61	15359,2	6037,01	**31122,7**
Zn	34084,7	54583,7	81163,4	**115226**	105905	70250,6
As	37,83	152,39	2,43	27,06	15,59	**228,3**
Cd	175,96	43,5	269,78	284,07	421,49	**1786,33**
Hg	<0,00	10,46	6,03	8,5	9,09	**85,69**
Pb	<0,00	91,57	24,79	53,03	38,03	**760,34**

3.2. Radionuclide accumulation

Radionuclide accumulation of studied mushrooms was presented in Table 3.

Table 3. Radionuclide accumulation of studied mushrooms

Mushroom codes	Radionuclides (Bq/kg)			
	^{238}U	^{232}Th	^{137}Cs	^{40}K
1	ND*	ND	ND	**947 ± 32**
2	ND	ND	ND	350 ± 13
3	ND	ND	**15 ± 3**	367 ± 14
4	ND	ND	ND	495 ± 18
5	ND	ND	ND	306 ± 12
6	ND	ND	ND	455 ± 17

*ND: Not detected

3.3. Effective dose

Effective dose values of studied mushrooms were presented in Figure 2.

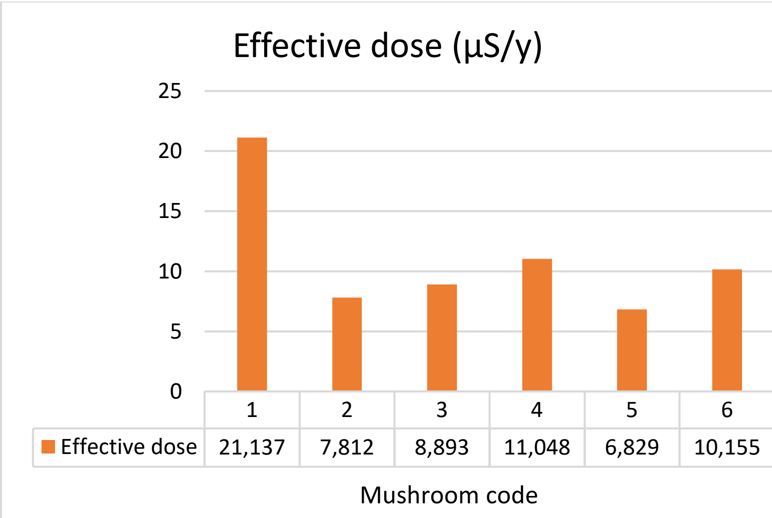

Figure 2. Effective dose values of studied mushrooms

4. Discussion

Aluminum (Al) is one of the most abundant metals in the earth's crust with a concentration of 80 g/kg (Müller et al. 1997). In this study, Al content of studied mushrooms were ranged between 11480,3 and 47880,6 µg/kg and the highest Al content was determined in *P. eryingii* mushroom cultivated on alder tree sawdust. It was reported that Al contents of some wild mushrooms in Poland were 25,9-6,0 mg/kg (Mleczek et al. 2013). Our Al results were found very lower than that of reported data for wild mushrooms.

Chromium (Cr) essential for human metabolism in low concentrations because it is enzyme activators, but it can be toxic as its concentration increase (Garcia et al. 2013). In the literature, Cr content of 25 higher mushroom species were reported in the range of 0,05 and 4,51 mg/kg (Vetter, 1997). In this study, the highest Cr content was determined in *P. djamor* cultivated on walnut tree sawdust with 1360,56 µg/kg.

Manganese (Mn) is an essential element for the activity of a group of enzymes called phosphotranferases (Knap et al. 2007). Researchers have been reported that Mn contents of wild edible and cultivated mushrooms were 4.8-65.4 mg/kg (Akyüz and Kirbağ 2010). In this study, Mn content of studied mushrooms were ranged between 8420,46 and 59275,2 µg/kg and the highest Mn content was determined in *P. djamor* mushroom cultivated on walnut tree sawdust with 1360,56 µg/kg.

Iron (Fe) is an integral part of many proteins and enzymes that maintains various physiological functions (Jomova and Valko, 2011). It has been reported that Fe content of 15 mushrooms were 467–3,280 mg/kg and also the tolerable daily intake (PTDI) for iron is 48 mg for an average adult (60 kg body weight) (Kula et al. 2011). In this study, the highest Fe content was determined in *P. eryingii mushroom* cultivated on walnut tree sawdust with 232626 μg/kg.

Cobalt (Co) can be either toxic or essential for living organisms depending on its concentration level. Borovička and Řanda (2007) have reported that Co content of macro-fungi is relatively low (mostly below 0.6 ppm), rarely in units of ppm. In this study, the highest and lowest Co content was determined in *P. djamor* cultivated on walnut tree sawdust (467,74 μg/kg) and *P. citrinopileatus* cultivated on alder tree sawdust, respectively (<0,00 μg/kg).

Nickel (Ni) is a nutritionally essential trace metal for at least several animal species, micro-organisms and plants, and therefore either deficiency or toxicity symptoms can occur when, respectively, too little or too much Ni is taken up (Cempel and Nikel, 2006). In a previous study, Ni content of 25 higher mushroom species were reported in the range of 0,81 and 9,9 mg/kg and and the Ni content was noted under the toxicological limits (20mg/kg) (Vetter 1997). In this study, the highest Ni content was determined in *P. citrinopileatus* mushroom cultivated on walnut tree sawdust with 3027,39 μg/kg.

Copper (Cu) is an essential element and adverse effects can potentially be associated with both very low and very high intakes (toxic levels) (Georgopoulos et al. 2006; Mleczek et al. 2013). It was determined the Cu content of 6 wild mushrooms in Poland in the range of 8,20- 26.33 mg/kg. In this study, Cu content of the studied mushrooms were ranged between 5639,74 and 31122,7 μg/kg.

Zinc (Zn) is a masculine element that balances copper in the body, and is essential for male reproductive activity (Duruibe et al. 2007). PTDI for Zn is 60 mg for an average adult (60 kg body weight) (Kula et al. 2011). The Zn content of 6 wild mushrooms have been reported as 31.92-88.71 mg/kg (Mleczek et al., 2013). In this study, Zn content of cultivated mushrooms were determined in the range of 34084,7-115226 μg/kg.

Arsenic (As) is a toxic element and one of the most notorious compounds (Falandysz and Rizal 2016). It has been reported that As content of 37 common edible mushroom taxa was 0,0-146,9 mg/kg (Vetter 2004). In this study, the highest As content (228,3 μg/kg) was 100 times higher than the lowest As content (2,43 μg/kg).

Cadmium (Cd) is toxic at extremely low levels and in this study Cd content of mushrooms were determined in the range of 43,5-1786,33 μg/kg. In a previous study, ten times higher cadmium concentrations were determined in cultivated *P. ostreatus* than in *A. bisporus* (Haldimann et al. 1995).

Mercury (Hg) is highly toxic for microorganisms, animals, and humans (Boening 2000). It has been reported that Hg content of 6 wild mushrooms were 0.9-1.71 mg/kg (Mleczek et al. 2013). In this study, Hg content of studied mushrooms were ranged between 0,00 and 85,69 μg/kg and the highest Hg content was determined in *P. djamor* cultivated on walnut tree sawdust.

Lead (Pb) is the most significant toxin of the heavy metals. Its inorganic forms are absorbed through ingestion by food and water, and inhalation (Ferner 2001). In a previous study, the Pb content of 15 higher mushrooms have been described as 0.69-9.15 mg/kg (Kula et al. 2011). The highest Pb content was determined in *P. djamor* cultivated on walnut tree sawdust with 760,34 μg/kg.

Uranium (^{238}U), thorium (^{232}Th) and potassium (^{40}K) are primordial radionuclides, while cesium (^{137}Cs) is anthropogenic radionuclide which are available in diverse environments such oceans, rivers, streams, soils, rocks, vegetable, animals and human body (Hu et al. 2010). In this study, uranium and thorium was not detected in any studied mushrooms. In our previous study, uranium and thorium content of cultivated mushrooms were determined 14,6-26,6 and

2,1-9,2 Bq/kg, respectively (Gürgen et al. 2019). Cesium radionuclide was detected in only *P. citrinopileatus* mushroom cultivated on alder tree sawdust. In a previous study, cesium (^{137}Cs) content of 27 wild mushrooms were described as 2,5- 2763 Bq/kg (Kirchner and Daillant 1998). Potassium content of studied mushrooms were ranged between 306-947 Bq/kg and the highest potassium content was determined in *P. eryingii* cultivated on alder tree sawdust. It has been reported that the average concentrations of ^{40}K of 6 wild mushrooms varied from 254.17 to 416.07 Bq/kg (Faweya et al. 2015).

Effective dose values were ranged between 6,829 and 21,137 µS/y. *P. eryingii* cultivated on alder tree sawdust and *P. djamor* cultivated on beech tree sawdust reached the highest and the lowest effective dose values, respectively. All effective doses were found below the world average value (290 µSv/y) (International Atomic Energy Agency 2014).

5. Conclusion

Important findings of this study can be sorted as below;

- In this study, among the studied mushrooms, *P. djamor* cultivated on walnut tree sawdust had drawn attention with highest Cr, Mn, Co, Cu, As, Cd, Hg and Pb contents. But there is no risk for human life because very low accumulation of metals.
- *P. citrinopileatus* cultivated on alder tree sawdust had drawn attention with Cs (Cesium) content.
- All effective doses were found below the world average value (290 µS/y).
- It was concluded that the metal and radionuclide content of mushrooms were affected by mushroom type and cultivation conditions.

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UTILIZATION OF UREA POWDERS WITH DIFFERENT SIZES AS A FORMALDEHYDE-SCAVENGER IN THE PARTICLEBOARD MANUFACTURING

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Abstract

In this study, the effects of different size and rate of urea powder usage in particleboard manufacturing on the formaldehyde emission of the boards were investigated. Two different sizes (Large, Small) and five different rates of urea powder (1, 2, 3, 4 and 5%) were used for particleboard manufacturing. Urea formaldehyde (1.35 moles) adhesive was used for production of three layered particleboards. Formaldehyde contents were determined by perforator method according to EN 120. Furthermore, mechanical and physical properties including bending strength, modulus of elasticity, internal bond strength, surface stability, thickness swelling and water absorption of the samples were determined according to EN 310, EN 319 and EN 317 standards, respectively. Formaldehyde emission values were decreased with the mixing of the urea powder with chips prior to gluing and the produced boards had E0 grade in terms of formaldehyde emission. The size and rate of the urea powder were statistically effective on the mechanical and physical properties of the produced boards. In addition, all of the boards produced with small size urea powders satisfied the required standards for mechanical, physical and formaldehyde emission properties, except groups produced with 5% small size urea powder. It should be noted that slight decrease of mechanical and physical properties were observed with the loading of urea powder. As a result, it was determined that using of the small size urea powder provided better results than large size.

Keywords: Formaldehyde emission, carcinogenic substance, perforator method, particleboard, urea formaldehyde adhesive, urea powder.

1. Introduction

Due to the rapid growth of the world population, demand in the furniture industry has increased. With this increase, the need for raw materials has also raised. Particleboard and MDF are the most used wood-based boards in the furniture industry. Turkey has an important place in Europe and the World for the wood-based panel sector and this is a fast-developing sector in Turkey. Formaldehyde-based adhesives such as urea-formaldehyde (UF) and melamine-formaldehyde (MF) resins are the most commonly used adhesives in the manufacturing of these wood-based boards. Using the formaldehyde-based resins causes some disadvantages for these kinds of boards. The main and also the most important disadvantage of wood panels produced with formaldehyde-based resins is their formaldehyde emission which is identified as "probably carcinogenic to humans" (Group 2A) by International Agency for Research on Cancer (IARC) in 1995 (IARC 1995). In addition, the definition was changed from Group 2A- "probably carcinogenic to humans" to Group 1- "carcinogenic to humans"-"formaldehyde is carcinogenic to humans" by IARC (IARC 2006). One of the main issues of panel manufacturers is solving this problem. Researchers have been performed many studies on this area.

The most common method is the use of resin with a lower mole ratio for reducing formaldehyde emission values. However, using lower mole ratio adhesive decreases the formaldehyde emission values at the expense of strength values of the particleboards. Usage of hardeners, fillers, and additives prepared in proper formulations in order to scavenge free formaldehyde after hardening helps to improve formaldehyde emission properties (Şahin et al. 2011). Some researchers aimed to reduce the formaldehyde emission values by using tannins in urea-formaldehyde resin (Beer, 1994, Çolak et al., 2009). The use of tannins in urea formaldehyde resin has helped to reduce the formaldehyde emission values of the particleboards. Besides, the addition of melamine in the second or third stage of urea-formaldehyde adhesive manufacturing is another way to decline formaldehyde emission. The reduction of free formaldehyde in the panels with melamine powder is a known fact, but the rising of melamine powder usage caused to increasing of resin cost (Pizzi, 1994). In addition, one of the other methods is using formaldehyde-scavenger chemicals in the mat during the manufacturing of the particleboards or the resin for the decrease formaldehyde emission values. Chemicals most commonly used as formaldehyde-scavengers are amine-based ones. Boran et al. (2011) also added amine compounds in UF resin and produced medium-density particleboards. It was determined that formaldehyde emission from medium-density particleboard panels decreased by adding urea, propyl amine, methylamine, ethylamine, and cyclopentyl amine solution. Furthermore, Atar et al. (2014) used a water solution of urea powder (10 wt%) as a formaldehyde scavenger in UF resin. It was reported that usage of 1 wt% of the solution based on the solid weight of the UF resin decreased the formaldehyde emission values but slight decrease in mechanical and physical properties was also observed. In the literature, studies on the comprehensive usage of urea powder as a formaldehyde-scavenger are quite shallow, except in resin manufacturing.

In this study, utilization of urea powders with different sizes and different rates as a formaldehyde-scavenger in the particleboard manufacturing was investigated. For this purpose, three-layer particleboards were manufactured with two different sizes (Large, Small) and five different rates of urea powder (1, 2, 3, 4, and 5%). Formaldehyde content (by Perforator method), mechanical and physical properties of the samples were determined according to EN 120, TS EN 310, TS EN 319, TS EN 311, and TS EN 317 standards, respectively.

2. Materials and Methods

Urea formaldehyde (UF) resin with a molar ratio of 1.35 (with 62% solid content) was used as an adhesive for manufacturing of three-layer particleboards. Coarse and fine chips consisting of a mixture of red pine and poplar wood supplied from Kastamonu Integrated particleboard facilities (Tarsus/Turkey) were used. Commercial urea obtained from Comzest Trading Fzc, which is used in manufacturing of adhesive for particleboard and MDF production, was used as urea powder. Ammonium chloride supplied from Akça Chemical

Substances, Transportation, Trade Industry Incorporated Company was used as a hardener for UF resin. Aqueous solution of Ammonium chloride (with 25% solid content) was prepared as a hardener.

2.1. Classification of Urea Powder

Urea powders were screened with automatic vibrating sieve machine and passed from 0.2 mm sieve was used as small size urea powder. Urea powders in sizes between 1mm and 0.2mm sieve were used as large sized urea powder. (Included stayed on 1mm and 0.2mm sieve).

2.2. Manufacturing of Particleboards

Fine particles were utilized in surface layers (SL) while coarse ones in core layer (CL). Eleven different particleboard groups with three layers (two surface layers and one core layer) were manufactured. The experimental design of the study was presented in Table 1. The core layer was accounted for 67% of the total board weight. Surface layers were contained 33% of the total board weight.

Table 1. Experimental Desing

ID	Urea Fromaldehyde Resin (%)*	Urea Powder Size	Urea Powder Amount (%)**	Amonium Chloride (%) ***
Control	10	-	-	10
S1	10	Small	1	10
S2	10	Small	2	10
S3	10	Small	3	10
S4	10	Small	4	10
S5	10	Small	5	10
L1	10	Large	1	10
L2	10	Large	2	10
L3	10	Large	3	10
L4	10	Large	4	10
L5	10	Large	5	10

*Same rate of Resin was used in both layers.
**Based on Dry Resin amount
***Ammonium Chloride with 25% solids content was used based on the liquid amount of adhesive.

Depending on the Experimental design given from Table 1, first particles and urea powders were dry-mixed in a high-intensity mixer. Then, UF resin which has hardener added into the high-intensity mixer to produce a homogeneous blend. The blends were laid into frame of 500mm x 500mm. A hot press was used for forming of particleboards (90-120 Bar). The target thickness was 19mm. Pressing time and temperature were 210s and 205 °C, respectively. After pressing, particleboards were conditioned at a temperature of 20 °C and 65% relative humidity. The conditioned boards were cut from four edges and grinded thickness range of 0.50 – 1.00 mm. Then test samples were cut according to TS EN standards.

2.3. Testing of Manufactured Boards

Testing of the samples was conducted in a climate-controlled testing laboratory. Densities were measured by air-dried density method according to the TS EN 323 standard. Bending strength, modulus of elasticity, internal bond strength, surface soundness, screw withdrawal strength, thickness swelling and water absorption of the samples were determined according to TS EN 310, TS EN 319, TS EN 311 and TS EN 317 standards, respectively. Mechanical properties testing were performed on Zwick Z010 (10KN).

2.4. Analysis of Data

Design-Expert® Version 7.0.3 statistical software program was used for statistical analysis. The effectiveness of urea powder rate and size as a formaldehyde-scavenger in particleboard manufacturing was evaluated.

3. Results and Discussion

Moisture Content after the Pressing (Table 2.) and Means of Density (Table 3.) were given in the tables below.

Table 2. Moisture Content after the Pressing

Grup	Number of Samples	Mean of Moisture Content (%)
Control Board	3	6,20
Small	18	6,00
Large	18	6,52

The average moisture content of the produced particleboards after pressing varies between 6.00% and 6.52%. The highest average moisture content (6.52%) was observed from groups where the large size urea powders were used. In addition to that, the lowest average moisture content (6.00%) was observed from groups which contained small size urea powders. However, small size contained groups shows closed average moisture content with control groups (6.20%).

Table 3. Means of Density

ID	Number of Samples	Mean Density (kg/m^3)
Control Board	8	687,60
Small	40	697,85
Large	40	679,26

When the Table 3 examined, it is observed that the average density values of the produced particleboards were close to each other. The close results to the targeted board density values were obtained. Interaction graph of Density values was also shown in Figure 1. If we handled Figure 1, it is seen that board densities were slightly decreasing with the amount of urea powder increases. However, the effect of urea powder size (P = 0.2728) and urea powder amount (P = 0.0625) on this change was not found to be statistically significant.

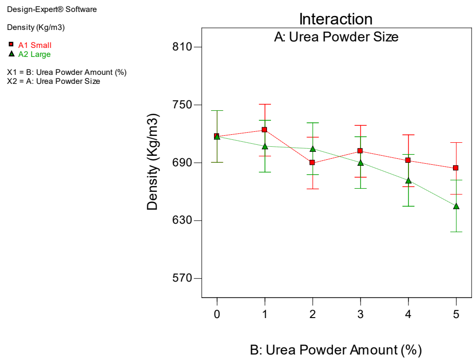

Figure 1. Interaction graphs of Density.

As can see from the interaction graph given in Figure 2, when the first adding of urea powder Formaldehyde Content (FC) was sharply declined. Decreasing on FCs were continued with the loading of urea powder. However, after first loading, every 1% added was not as effective on the FC as the first addition. The maximum allowable formaldehyde content for E0, E1, and E2 class particleboard is 2, 8, 30 mg/100g dry particleboard sample according to EN 312, respectively. The control group boards (10.59 mg/100g) in the E2 Formaldehyde emission class were upgraded to E0 class by using 5% small urea powder (1.6 mg/100g). Similar results were reported in previous studies (Costa et al., 2013, Atar et al., 2014). Large urea powder groups showed parallel results with small one. It has been determined that the size of the urea powder has a slight effect on formaldehyde emission values.

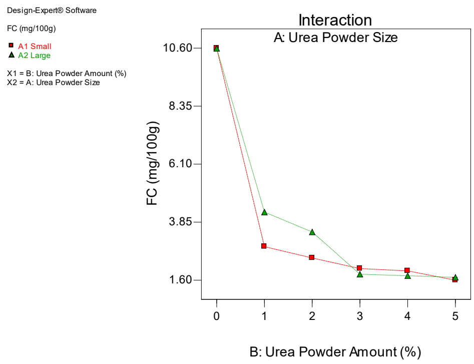

Figure 2. The influence of urea powder size and rate on the formaldehyde content.

Based on results, both urea powder size and amount had significant effect on IB strength values (P<0,0001). Interaction graphs of internal bond strength were shown in Figure 3. With the adding of urea powder IB values were reduced. This was well consistent with the previous studies (Costa et al., 2013, Atar et al., 2014). Small size urea powder group were provided better IB properties than the large ones. The all board produced with small size urea powder groups satisfied standard requirements (P2 class particleboard: furniture boards for the interior application) for IB properties (0.35 MPa), except 5%. For the 1% and %2 large size groups satisfied the standards but others groups not. In the groups where 3% and more large size urea powder was used, much lower IB values observed compared to those using 1% and 2%.

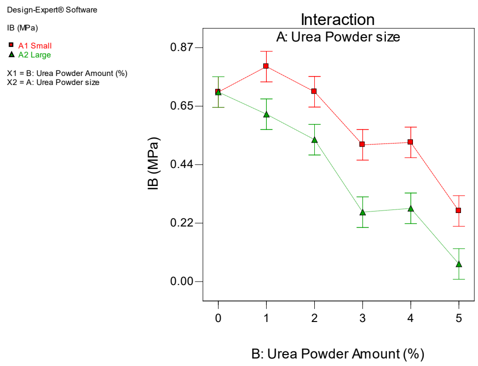

Figure 3. Interaction graphs of internal bond strength.

The interaction graphs of bending strength and modulus of elasticity were given in Figure 4. It was determined that the urea powder size had a statistically significant effect on the bending strength (P = 0.0013). Larger urea powder sizes decreased the bending strength values. Better results were obtained from boards produced using small size urea powder than large size urea powder boards. It was observed that the amount of urea powder has also statistically affected the bending strength values (P <0.0001). A decrease in bending strength was observed with the increase in the amount of urea powder. But all the manufactured boards were provided standard requirements (11 MPa) for P2 class boards in the standard, except large size with 5% using.

In the MOE properties, parallel results were observed with bending strength properties. As the size and amount of urea increased, the MOE tended to decline. Besides the results, the size and amount of urea were significantly effective on the MOE (P <0.0001). As with bending strength, all the produced boards were provided standard requirements (1600 MPa) for P2 class boards in the standard, except large size with 5% using. In addition, in that group, a modulus of elasticity (1567.99 MPa) close to the standard was obtained.

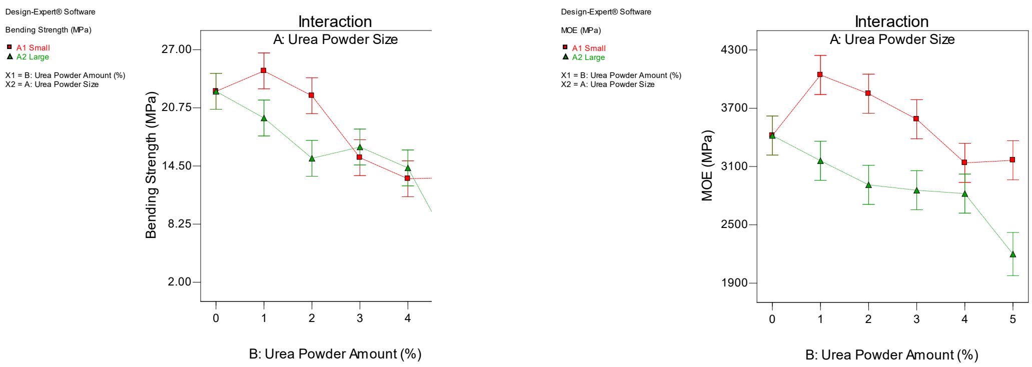

Figure 4. The effects of urea powder size and rate on the bending properties.

Size of the urea powder has a statistically significant effect on the surface strength feature (P <0.0001). Small size Urea powder groups provided better surface strength values than large sizes. The amount of urea powder has a significant effect on surface strength values (P = 0.0002). All the produced board groups showed higher results than the standard value (≥0.8 MPa) required for P2 class particleboards.

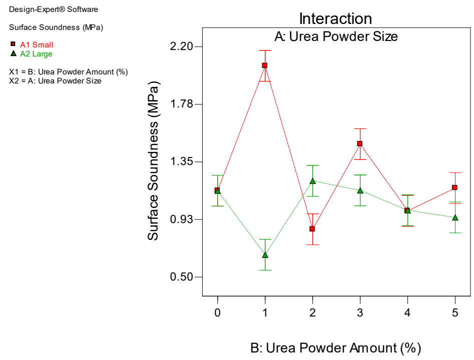

Figure 5. Interaction graphs of the surface soundness.

The maximum force was determined in the SWS test. Similar to the MOE values, all the produced boards reached the standard requirements for SWS, except for samples having 5% large size urea (min. 450 MPa). Urea powder size (P=0.0014) and amount (P<0.0001) had significant effect on SWS properties. Better results were obtained in groups where small size urea powder was used compared to the large size urea powder ones. SWS values were decreased with the increase of the urea powder amount.

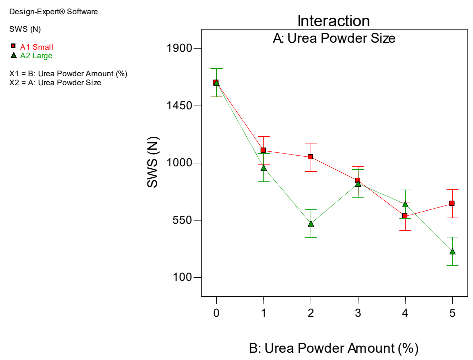

Figure 6. Interaction graphs of screw withdrawal strength.

Thickness swelling (TS) and water absorption (WA) tests were carried out as physical properties of the produced boards. As a result of the test, the interaction graphs of TS and WA were given in Figure 7. Amount (P<0,0001) and size (P=0,0006) of the urea powder were significantly effective on TS properties. TS properties were getting worst with the rising of urea powder amount. As it is mentioned previously, with the increase of the urea powder amount, the quality of adhesion in the core layer was reduced leading to lower IB values. Lack of good adhesion may ease the water penetration into the boards during TS test and may cause an increase in thickness swelling values. The water absorption interaction graph was also presented in Figure 7. Some changes were observed in the WA values for both groups. It was determined that urea powder size had no statistical effect on these changes (P = 0.8682), but the amount of urea powder had a statistically significant effect on the WA feature (P <0.0001). While none of groups were satisfied the standard for TS (Max. 15%), all groups provided standard requirements for WA (Max. 80%), except small size urea powder with 5% (86.21%).

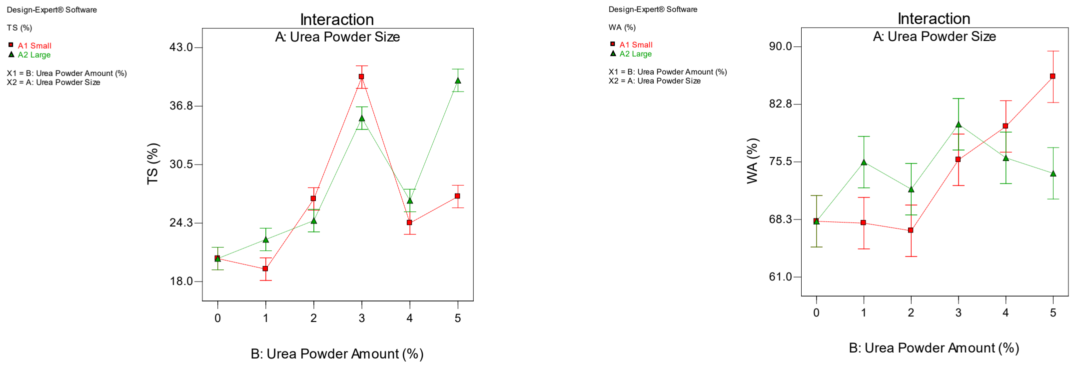

Figure 7. Interaction graphs of thickness swelling and water absorption (at 24h).

Moreover, all the data and standard requirement were summarized in Table 4. While values matched standards were painted in green, not matched values were painted in red.

Table 4. Summary of Study

ID	FC	IB	BS	MOE	SS	SWS	WA	TS
Control	10.59 E2	0,70 (0,06)	13,34 (0,32)	3418,96 (460,09)	1,14 (0,03)	1064,67 (177,94)	68,02 (6,02)	20,46 (1,26)
S1	2.90 CARB2	0,80 (0,06)	14,01 (0,12)	4042,04 (141,96)	1,12 (0,14)	1097,67 (130,70)	67,79 (2,79)	19,33 (0,88)
S2	2.46 CARB2	0,71 (0,10)	13,82 (0,78)	3849,33 (353,78)	0,85 (0,03)	1045,33 (290,29)	66,83 (4,16)	26,83 (1,71)
S3	2.05 CARB2	0,51 (0,10)	13,11 (0,04)	3586,31 (32,70)	1,48 (0,21)	860,00 (94,50)	75,76 (4,07)	39,86 (82,32)
S4	1.96 E0	0,52 (0,10)	13,29 (0,27)	3137,68 (158,47)	0,99 (0,25)	581,67 (15,57)	79,96 (5,12)	24,26 (1,26)
S5	1.60 E0	0,26 (0,00)	13,58 (0,11)	3163,91 (40,04)	1,16 (0,20)	680,00 (55,07)	86,21 (1,31)	27,09 (1,23)
L1	4.24 E1	0,62 (0,08)	13,89 (0,09)	3159,23 (15,18)	1,20 (0,06)	964,33 (171,10)	75,47 (5,32)	22,50 (1,11)
L2	3.47 CARB2	0,53 (0,06)	13,23 (0,01)	2911,46 (35,50)	1,21 (0,15)	524,67 (4,51)	72,06 (0,70)	24,52 (1,18)
L3	1.83 E0	0,26 (0,01)	13,92 (0,09)	2855,90 (11,00)	1,14 (0,05)	838,33 (25,70)	80,24 (1,49)	35,47 (1,37)
L4	1.77 E0	0,27 (0,05)	13,38 (0,27)	2821,21 (197,12)	0,99 (0,08)	676,67 (56,59)	76,01 (1,62)	26,66 (0,60)
L5	6.19 E1	0,07 (0,00)	13,31 (0,20)	1567,99 (115)	0,94 (0,11)	306,00 (8,54)	74,06 (1,34)	39,50 (2,09)
Standard Value	E1 ≤ 8.00*	≥ 0.35	≥ 11	Min. 1600	≥ 0.80	≥ 450	Max. 80	Max. 15

*According to the EN 120 perforator method which stays in EN 13986 standard for European Countries, E1 limit for wood based boards such as particleboard and MDF.

From Table 4, it was clearly seen that the size and amount of urea powder usage have a significant effect on the board's properties. About the formaldehyde content, E0 and E1 class particleboard produced with different size urea powders. All the produced groups satisfied the E1 class particleboards standard, except for control group. In addition, some groups having small size (S4 and S5) and large size (L3 and L4) urea powders provided E0 class particleboards. All boards produced with small size urea powder were satisfied standard requirements for all mechanical properties, except for S5 group. The boards produced with large size urea powder up to 4% were fulfilled the standard requirements for mechanical properties, except IB properties. L1 and L2 groups provided much higher IB values than the standard values. These two groups were also satisfied the all other mechanical properties required by standards. To mention on physical properties, while none of groups were satisfied the standard for TS, all groups provided standard requirements for WA, except small size urea powder with 5%. L3 group boards showed the maximum WA value of 80%. It should be noted that there was no paraffin or equivalent products was used in this study.

These physical property results might be improved by appropriate addition of water repellent chemicals.

4. Conclusion

As results of the study, different size and amount of urea powder were successfully utilized as a formaldehyde-scavenger in the manufacturing of particleboards with UF resin and the following conclusions were reached;

1. The best results were obtained by using 5% of small size urea powders for Formaldehyde content,
2. With the presence of a small amount of urea powder in the formulation, Formaldehyde emission was sharply declined. Further, the increase in urea powder amount provided moderate improvement not as effective as the first addition,
3. Both the amount and the size of urea powders had significant effect on panel properties,
4. The physical properties of the some of the produced samples were not satisfied the standard requirements. Using of some water repellent chemicals might help to overcome that problem.

As a result of the studies, it has been observed that urea powder can be used as a formaldehyde-scavenger. Reducing the formaldehyde emission, which is dangerous for human health, is one of the main goals of every manufacturer. It is thought that this study can be guide for wood-based board manufacturer. It should be investigated whether the studies are suitable for mass production by working more and cost studies should be done.

5. Acknowledgments

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INFLUENCE OF THERMAL MODIFICATION OF ASH WOOD *(Fraxinus excelsior* L.*)* AND MACHINING PARAMETERS IN CNC FACE MILLING ON SURFACE ROUGHNESS USING RESPONSE SURFACE METHODOLOGY (RSM)

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Abstract

The objective of this research was to analyse the effect of thermal modification of ash wood *(Fraxinus excelsior* L.*)* at moderate temperature of 160°C and three processing parameters: spindle speed, feed rate and depth of cut in CNC face milling operation on surface quality, expressed by arithmetic surface roughness parameter (Ra).

In order to determine material properties, moisture content (MC), density, swelling, anti-swelling efficiency (ASE) and contact angle for both untreated and thermo-treated ash wood have been measured.

Highly effective, incomplete 3^3 Box-Behnken factorial design was made, with three levels of cutting speed: 8.000, 12.000, and 16.000rpm; three levels of feed rate: 1.000, 1.500 and 2.000 mm/min; and three levels of depth of cut: 2, 4, and 6 mm. According to the above design matrix, all groups of 50x50x30mm samples have been machined with two machining strategies: *raster* and *offset*. Surface roughness parameter Ra was measured per each run. Response - surface analysis (RSM) was applied to the parameter Ra for all sets of samples. The 3-D response surface plots, polynomial equations and ANOVA tables have been obtained per each observed input variable, for both machining strategies (*raster* and *offset*).

The results indicated that the thermal modification of ash wood at 160 °C improved it`s physical properties: decreased MC, improved wood density, improved ASE and increased wood hydrophobicity.

Polynomial equations and ANOVA tables showed different behaviour of untreated and treated ash wood regarding changing of machining parameters in experimental space. O*ffset* processing strategy, gave better results in the quality of wood surface, than *raster* processing strategy for all types of samples. Thermal modification of ash wood at 160°C improved surface quality after machining for both processing strategies.

Keywords: ash wood, thermo-wood, surface roughness, response surface methodology (RSM), design of experiment (DOE), CNC face milling

1. Introduction

The effects of thermal modification on wood are well known since sixties. Some effects of thermal treatments, on equilibrium moisture content (EMC), and on change of thickness swelling (TS) of different wood species were stated by Kamdem *et al*. (2002), Akyildiz and Ates (2008), Cao *et al*. (2010), Tjeerdsma *et al*. (1998) and Yildiz (2002), Lovrić et al. (2017).

Temperature greater than 180°C causes significant changes in chemical properties in wood (Tjeerdsma et al. 1998, Kotilainen 2000). High temperatures reduce hemicelluloses (Rousset et al. 2004).

Another much more significant change in physical properties due to high temperatures is greater dimensional stability, i.e. lower hygroscopicity of the wood (Tjeerdsma et al. 1998, Kotilainen 2000, Yildiz 2002, Rousset et al. 2004).

Boonstra et al. (2006) indicate that during thermal modification at temperatures up to 200 °C in hard wood species such as ash wood *(Fraxinus excelsior* L.) there is a collapse of the trachea and deformation of wood fibers (libriforms) located in their immediate vicinity. Damage to cell walls administratively on the direction of wood fibers occurs in the form of transverse cracks and this leads to a decrease in bending.

According to Herrera et al. (2016) thermal modification causes a significant decrease in the hemicelluloses content in the cell walls of ash wood and increases the content of lignin and extractives, which is expressed at temperatures higher than 200 °C.

The quality of the treated surface is most often determined by the surface roughness parameter Ra, which is widely recognized and the most widespread in international frameworks. Surface roughness parameter Ra analysis was carried out as research conducted by Supadarattanawong & Rodkwan (2006), Rawangwong et al. (2011), Karagoz et al. (2011), Sofuoglu (2015) and Hazır & Hüseyin Koç (2016).

But thermal modification of wood on lower temperatures also can improve it`s machinability regarding power consumption and surface quality. The surface roughness depends on many parameters of processing such as feed rate, grit number of sanding belt during sanding (Palija et al., 2018), spindle speed, the depth of cut, feed rate, the angle of processing and the type and material from which the tool was made during milling (Karagoz et al. 2011).

Karagoz et al. (2011) examined the influence of thermal modification of wood on surface roughness, during processing on the CNC machine. The samples are 50x50x150 mm in size, of four wood species: white pine wood (*Pinus sylvestris* L.), Oriental beech *(Fagus orientalis* Lipsky.), Turkish dishes (*Abies bornmülleriana Mattf.*) and Canadian poplar (*Populus canadensis)*. Thermal modification was performed at temperatures of 120, 160 and 200°C.

Ender Hazır and Hüseyin Koç (2016) investigated optimization process by combined approach of central composite face-centered (CCFC) experimental design and response surface methodology (RSM). The second order mathematical models in terms of machining parameters were developed for surface roughness using response surface methodology.

Ender Hazır and Hüseyin Koç (2016) in the second research used three steps Taguchi technique to find "best" combination of inputs in CNC milling of Beech pine (*Fagus orientalis* Lisky) regarding surface roughness parameter Ra.

Sufuoglu (2015) used an artificial neural network (ANN) modeling approach to predict and controlof surface roughness (Ra and Rz).

The MAIN OBJECTIVE of this research was to analyze the effect of thermal modification of ash wood *(Fraxinus excelsior* L.*)* at moderate temperature of 160°C and three processing parameters: spindle speed, feed rate and depth of cut in CNC face milling operation (with two machining strategies: *raster* and *offset*) on surface quality, expressed by arithmetic surface roughness parameter (Ra).

The SECOND OBJECTIVE was to determine material properties, analyzing moisture content (MC), density, swelling, anti-swelling-efficiency (ASE) and contact angle for both untreated and thermo-treated ash wood.

2. Materials and Methods

The research material in the form of 32mm thick tangential planks of dried ash wood (*Fraxinus Excelsior* L.), and 32mm thick tangential planks, thermally modified at temperatures of 160°C has been taken from industrial production. From these planks 30 control samples of the untreated ash wood and 30 samples of thermally modified ash wood has been made. (Figure 1).

2.1. Material Properties

Material physical properties such as MC, density and swelling has been determined by standard methods as described Zdravković et al. (2010), Islam et al. (2012), Zdravković et al. (2013).

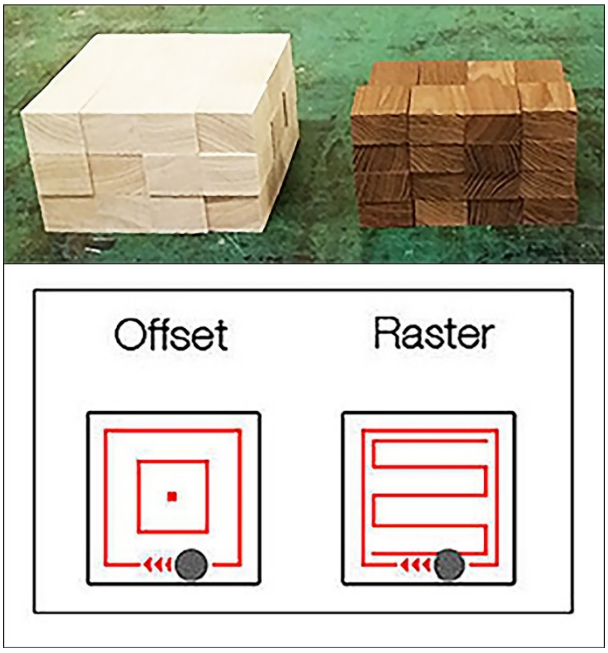

Figure 1. Untreated and thermo-treated ash wood samples for machining in two strategies: *offset* and *raster*

Contact angle (θ) has been measured and expressed by usual method (Zdravković et al. 2010, Islam et al. 2012) from digital photos (Figure 2). The measurement was performed three times, for each droplet position, on two types of samples and was presented as a mean.

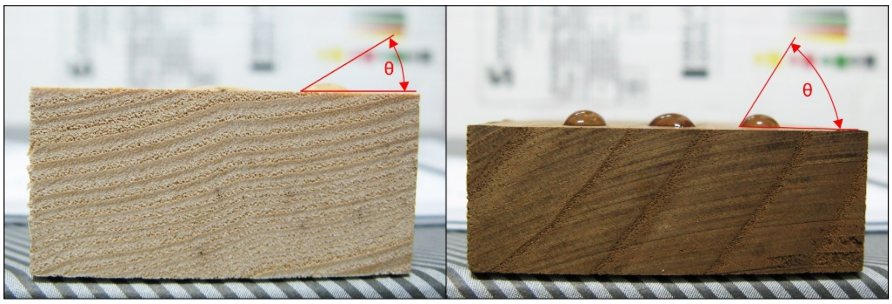

Figure 2. Contact angle measurement (θ) on untreated and thermo-treated ash wood samples

Anti-swelling-efficiency (ASE) is measure of effectiveness of wood treatment. The samples were oven-dried and after stabilization in the conditioning chamber, the specimens were soaked in a water bath at temperature of 20±1°C for each type of sample for 7 days.

Anti-swelling-efficiency (ASE) has been calculated as follows:

$$ASE(\%) = \frac{S_r - S_t}{S_t} \cdot 100[\%] \qquad (1)$$

$$S(\%) = \frac{V_2 - V_1}{V_1} \cdot 100[\%] \qquad (2)$$

where
S_r – volumetric swelling coefficient of untreated samples
S_t - volumetric swelling coefficient of treated samples
V_1 – volume of wood before soaking (cm^3)
V_2 - volume of wood after soaking (cm^3)

2.2. Experimental Design (ED)

Incomplete 3^3 Box-Behnken factorial design was made, which requires 15 runs for the analysis, unlike 27 runs for full factorial design. Box-Behnken factorial design is widely accepted in industrial experimentation (Box, Behnken 1960; Myers, R. H., Montgomery, D. C., 1995; Zdravković 1999; Dong-Hee Lee, Kwang-Jae Kim 2011; Ender Hazır and Hüseyin Koç 2016).

The values of three experimental variables were chosen carefully to cover the feasible range of each variable, as follows:

- 1.000, 1.500 and 2.000 mm/min for feed rate
- 8.000, 12.000, and 16.000 rpm for spindle speed
- 2, 4, and 6 mm for depth of cut.

After computer analysis by software *Statgraphics Centurion XVI* (*StatPoint Technologies, Inc.*), ANOVA tables, second order polynomial equations and 3-D response surface plots have been obtained.
The general form of the second order polynomial equation is:

$$y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \beta_{11} x_{1i}^2 + \beta_{22} x_{2i}^2 + \beta_{33}^2 x_{3i} + \beta_{12} x_{1i} x_{2i} + \beta_{13} x_{1i} x_{3i} + \beta_{23} x_{2i} x_{3i} + r_i \qquad (3)$$

Yi -response for the i[th] run
β_0 -constant
β_1 -linear influence of the first factor
β_2 -linear influence of the second factor
β_3 -linear influence of the third factor
β_{11} - second order parameter to estimate curvature for the first factor
β_{22} - second order parameter to estimate curvature for the second factor
β_{33} - second order parameter to estimate curvature for the third factor
β_{12},β_{13},β_{23} - parameters of interaction
x_1 – feed rate (m/min)
x_2 – spindle speed (rpm)

x_3 – depth of cut (mm)
r_i - residual error

The ANOVA table partitions the variability in observed sets of data into separate pieces for each of the effects. It then tests the statistical significance of each effect by comparing the mean square against an estimate of the experimental error. Polynomial equations which have been fitted to the data are displayed at the bottom of ANOVA tables below. Values of the variables are specified in their original units.

2.3. CNC Face Milling Operation

According to the computer-generated experimental design matrix, all groups of 50x50x30mm samples have been machined on CNC machine *(BDARK 2120 PRO, Turkey)* in face milling operation, with two machining strategies - *offset* and *raster* (Figure 3). The CNC machine was programmed by software Autodesk ArtCAM 2018 (Autodesk, Inc. USA).

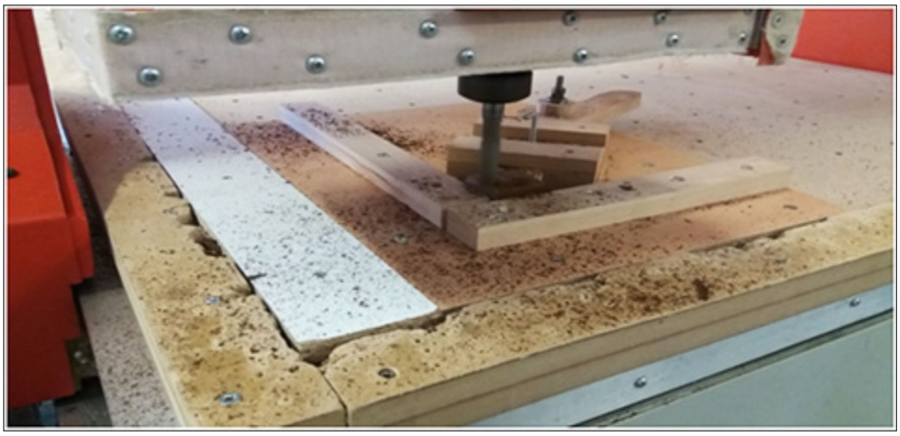

Figure 3. CNC machine *(BDARK 2120 PRO, Turkey)* in face milling operation

2.4. Measurements of Arithmetic Surface Roughness Parameter (Ra)

The average arithmetic surface roughness parameter (Ra) was measured on 4 reference lengths of (2.5mm), per each sample, in the latewood zone. The measurement was carried out by stylus contact tester (model TimeSurf TR200, manufacturer Beijing TIME High Technology Ltd.), in accordance with ISO 4287:1997 protocol (Figure 4). The diameter of the diamond stylus tip was 2 µm, and the stylus was pressed on the surface by the force of 4 mN.

Figure 4. Stylus contact tester *(TR200 TIME, China)* for measurement of parameter R

3. Results

3.1. Physical properties: MC, ratio βt/βr, ASE, contact angle (θ)

Control (untreated) samples of ash wood had an average MC of 7.58%, while thermally modified samples at a temperature of 160°C had an average MC of 4.42%.

Thermally modified samples at a temperature of 160°C had an average tangential swelling of 3.54%, while the average tangential swelling in the control samples was 6.90%.

Thermally modified samples at a temperature of 160°C had an average radial swelling of 4.51%, while average radial swelling in the control samples was 5.68%.

Wood anisotropy, expressed through the ratio of tangential and radial swelling βt/βr, is a very important indicator of the impact of physical properties on the quality of the surface processed wood. This βt/βr swelling ratio of wood over water and βt/βr swelling ratio of wood in the water is shown in table 1.

It can be noted that the ratio in tangential and radial direction in control(untreated) samples of ash wood is highest and it is 1.61%, while in thermally modified samples at temperature of 160 ° C, this ratio is 1.44% what idicates that thermal modificatione make wood more stabile.

Anti Swelling Efficinecy parameter (ASE) was as expected (28.19%), considering relatively low temperature of thermal treatment of 160°C.

Table 1. Tangential - radial swelling ratio βt/βr

Type of samples	**Tangential - radial swelling ratio βt/βr**	
	Swelling over water (7 days)	**Swelling in water (7 days)**
Untreated	1.61	1.84
Thermo-treated at 160°C	1.44	1.51
Anti-Swelling Efficiency parameter (ASE)		28.19%

Table 2 shows the value of the contact angle of the water droplet, whose change was tracked from the starting zero position, (0s) to a total of 20 seconds. The contact angle value was measured every 10 seconds. The decline of the contact angle over time (and the increase in its cosines) is faster in the control (untreated) samples of the ash wood.

Table 2. Wettability of ash wood-contact angle θ

Type of samples	Contact angle θ (°)		
	0 s	**10 s**	**20 s**
No treated	33.98	13.43	5.78
Treated at 160 °C	61.79	53.93	46.31

3.2. Arithmetic Surface Roughness Parameter (Ra)

ANOVA tables and second order polynomial equations showed different behaviour of untreated and treated ash wood regarding changing of machining parameters in experimental space. The main indicator of machined surface quality was arithmetic surface roughness parameter (Ra) expressed by polynomial equations and response surface graphs. Response surface graphs has been shown in the function of feed rate and spindle speed, with depth of cut fixed at 4mm in every observed case.

The ANOVA table partitions the variability in sets of data into separate pieces for each of the effects.

The accuracy of the fitted model was tested by R-Squared statistic who indicates in which percent the fitted model explains the variability in the process.

The Durbin-Watson (DW) statistic tests the residuals to determine if there is any significant correlation based on the order in which they occur in the data file. Since in all observed cases the P-value was greater than 0.05, there were no indication of serial autocorrelation in the residuals.

Table 3. ANOVA table for surface roughness parameter Ra and polynomial equation (untreated. *raster*)

Variable	Sum of Squares	Degrees of freedom	Variance ratio	F value	P – value
A: feed rate	0.071442	1	0.071442	0.34	0.5859
B: spindle speed	0.0117811	1	0.0117811	0.06	0.8226
C: depth of cut	1.88277	1	1.88277	8.93	0.0305
AA	0.520039	1	0.520039	2.47	0.1772
AB	0.400689	1	0.400689	1.90	0.2266
AC	0.0484	1	0.0484	0.23	0.6522
BB	0.0344134	1	0.0344134	0.16	0.7030
BC	0.0995403	1	0.0995403	0.47	0.5227
CC	0.462596	1	0.462596	2.19	0.1987
Residual error	1.05475	5	0.21095		
Total (corrected)	4.66747	14			
Ra (untreated. *raster*) = $9.05771 - 0.0070315\times A - 0.000312906\times B + 1.0221\times C + 0.00000150117\times A^2 + 1.5825E\text{-}7\times A\times B + 0.00011\times A\times C + 6.03386E\text{-}9\times B^2 - 0.0000197188\times B\times C - 0.0884896\times C^2$					

$R^2=0.774$

The R-Squared statistic indicates that the model as fitted explains 77.402% of the variability in (untreated. *raster*).

Analysis showed the highest influence of factor C (depth of cut) on arithmetic surface roughness parameter Ra, followed by A^2 (feed rate-squared) and C^2 (depth of cut-squared) and interactions AB (feed rate x spindle speed).

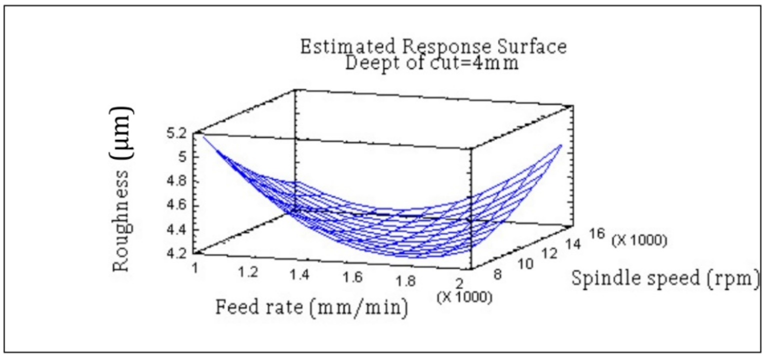

Figure 5. Surface roughness Ra response surface graph for untreated wood and raster processing strategy

Table 4. ANOVA table for surface roughness parameter Ra and polynomial equation (T160 °C. *raster*)

Variable	Sum of Squares	Degrees of freedom	Variance ratio	F value	P – value
A: feed rate	0.00418612	1	0.00418612	0.02	0.8945
B: spindle speed	0.0489845	1	0.0489845	0.23	0.6534
C: depth of cut	0.15429	1	0.15429	0.72	0.4358
AA	0.34498	1	0.34498	1.60	0.2613
AB	0.00416025	1	0.00416025	0.02	0.8948
AC	0.116281	1	0.116281	0.54	0.4953
BB	0.159616	1	0.159616	0.74	0.4285
BC	0.00038025	1	0.00038025	0.00	0.9681
CC	0.000310256	1	0.000310256	0.00	0.9712
Residual error	1.07602	5	0.215205		
Total (corrected)	1.87842	14			
Ra (T160 °C. *raster*) = 7.81071 – 0.00411075 ×A – 0.00026325×B–0.190021×C + 0.00000122267×A^2–1.6125E-8× A×B +0.0001705×A×C + 1.29948E-8×B^2–0.00000121875×B×C +0.00229167×C^2					

R^2=0.4272

The R-Squared statistic indicates that the model as fitted explains 42.716% of the variability in (T160 °C. *raster*).

The factor A^2 (feed-rate squared) showed the highest influence on arithmetic surface roughness parameter Ra, while other factors were unsignificant.

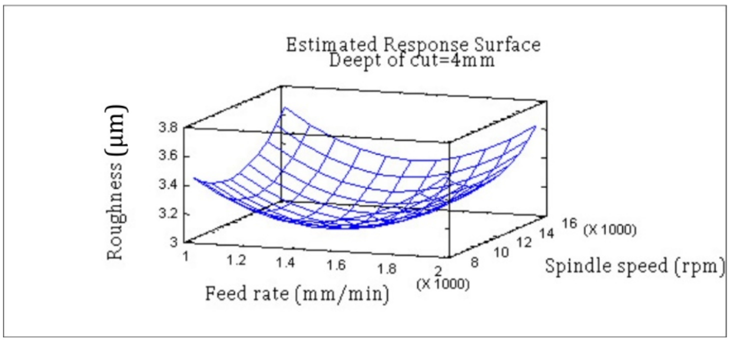

Figure 6. Surface roughness Ra response surface graph for treated wood at 160°C and raster processing strategy

Table 5. ANOVA table for surface roughness parameter Ra and polynomial equation (untreated. *offset*)

Variable	Sum of Squares	Degrees of freedom	Variance ratio	F value	P – value
A: feed rate	0.166176	1	0.166176	0.59	0.4765
B: spindle speed	0.5	1	0.5	1.78	0.2396
C: depth of cut	0.0294031	1	0.0294031	0.10	0.7594
AA	0.0711254	1	0.0711254	0.25	0.6362
AB	0.000064	1	0.000064	0.00	0.9885
AC	0.0135722	1	0.0135722	0.05	0.8347
BB	0.144084	1	0.144084	0.51	0.5059
BC	0.042436	1	0.042436	0.15	0.7135
CC	0.549308	1	0.549308	1.96	0.2208
Residual error	1.40422	5	0.280844		
Total (corrected)	2.98345	14			
Ra (untreated. *offset*) $= 4.20571 - 0.00163425\times A - 0.000288312\times B + 0.559854\times C + 5.55167E\text{-}7\times A^2 + 2.E\text{-}9\times A\times B + 0.00005825\times A\times C + 1.23463E\text{-}8\times B^2 + 0.000012875\times B\times C - 0.0964271\times C^2$					

R^2=0.529

The R-Squared statistic indicates that the model as fitted explains 52.933% of the variability in (untreated. *offset*).

Factors C^2 (depth of cut-squared) and B (spindle speed) showed the highest influence on arithmetic surface roughness parameter Ra, while other factors were unsignificant.

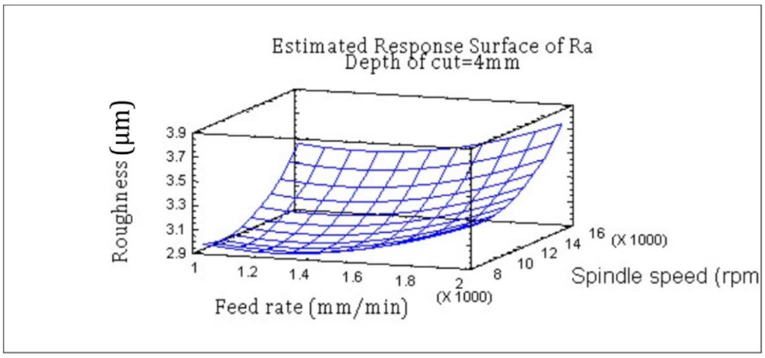

Figure 7. Surface roughness Ra response surface graph for untreated wood and offset processing strategy

Table 6. ANOVA table for surface roughness parameter Ra and polynomial equation (T160°C. *offset*)

Variable	Sum of Squares	Degrees of freedom	Variance ratio	F value	P – value
A: feed rate	0.111628	1	0.111628	2.05	0.2112
B: spindle speed	0.905185	1	0.905185	16.66	0.0095
C: depth of cut	0.326432	1	0.326432	6.01	0.0578
AA	1.02564	1	1.02564	0.00	0.9990
AB	0.047961	1	0.047961	0.88	0.3906
AC	0.00801025	1	0.00801025	0.15	0.7168
BB	0.0195866	1	0.0195866	0.36	0.5744
BC	0.00042025	1	0.00042025	0.01	0.9333
CC	0.000400641	1	0.000400641	0.01	0.9349
Residual error	0.271625	5	0.0543251		
Total (corrected)	1.69188	14			
Ra (T160°C. *offset*) = 1.81558 + 0.00071225× A + 0.000112406×B +0.0284167×C + 6.66667E-10× A^2– 5.475E-8× A ×B +0.00004475× A ×C– 4.55208E-9×B^2–0.00000128125×B×C + 0.00260417×C^2					

R^2=0.83945

The R-Squared statistic indicates that the model as fitted explains 83.945% of the variability in (T160°C. *offset*).

The highest influence on arithmetic surface roughness parameter Ra, indicated factor B (spindle speed), followed by C (depth of cut) and factor A (feed rate), while other factors were unsignificant.

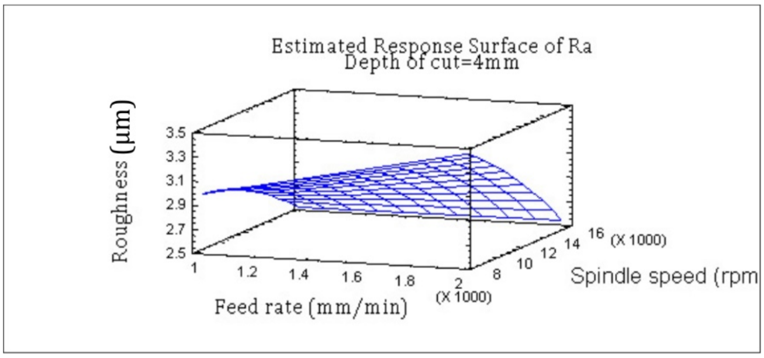

Figure 6. Surface roughness Ra response surface graph for treated wood at 160°C and offset processing strategy

4. Discussion

Analysis of tangential - radial swelling ratio βt/βr proved that thermal modification of ash wood at 160°C improved it`s physical properties: decreased MC, improved ASE and increased wood hydrophobicity. Anti-Swelling-Efficiency parameter (ASE) was as expected (28.19%), considering relatively low temperature of thermal treatment of 160°C. Other authors have found much more significant change in physical properties due to higher temperatures. Dimensional stability was greater, i.e. lower hygroscopicity of the wood (Tjeerdsma et al. 1998, Kotilainen 2000, Yildiz 2002, Rousset et al. 2004). But thermal modification of ash wood at 160°C is good balance between it`s physical properties imrovement and surface quality after CNC face milling.

Karagoz et al. (2011) examined the influence of thermal modification of wood on surface roughness, during processing on the CNC machine. They found that the values for the parameter Ra were higher in the radial than in the tangential direction, while the overall results suggest that the Ra was lower with the thermal modification temperature rising.

Analyses showed that *offset* processing strategy, gave better results in the quality of wood surface, than *raster* processing strategy for all types of samples. Uddin et al. (2007) found the same results by exploring the 2D trajectory of the work tool movement during CNC milling operation. They found that the spiral (*offset*) processing strategy obtained better quality of the treated surface compared to raster processing strategy.

Sofuoglu (2015) found the similar results: smallest values for the surface roughness parameters Ra and Rz were obtained at spindle speed of 16000 rpm. The parameter Rz was smaller in *offset* processing strategy, while Ra parameter values were approximate. The most optimal processing was *offset strategy,* with spindle speed of 16000 rpm and feed rate of 1000 mm/min.

5. Conclusion

- Average MC of no-treated ash wood was 7.58% while average MC of thermally treated ash wood at 160 °C was 4.42%.
- Anisotropy of thermally treated ash wood at 160°C was stabilized what was indicated by βt/βr ratio: on samples over water it was lowered from 1.61 to 1.44 and on samples submerged into water it was lowered from 1.84 to 1.51. It means that swelling in tangential and radial direction was more uniform, and wood has become more stable.
- The decrease of contact angle was faster over time (spilling), with control (untreated) samples.
- Anti-Swelling-Efficiency parameter (ASE) was as expected (28.19%), considering relatively low temperature of thermal treatment of 160°C.
- Polynomial equations and ANOVA tables showed different behavior of untreated and treated ash wood regarding changing of machining parameters in experimental space.
- *Offset* processing strategy, gave better results in the quality of wood surface, than *raster* processing strategy for all types of samples. Thermal modification of ash wood at 160°C improved surface quality after machining for both processing strategies.

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INVESTIGATION OF THE EFFECT OF BUILDING MATERIAL SELECTION AND DESIGN STYLE ON KILN THERMAL PROPERTIES IN SOLAR KILNS

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Abstract

Natural and technical drying methods are generally applied in timber drying. Although energy is not used in natural drying, the drying time is long and timber cannot be dried until the desired humidity for interior spaces. Despite the fact that timber can be dried up to the degree of humidity desired in technical drying, drying costs are high. In the timber industry, 70% of the energy is spent during the drying phase. Depending on the tree type and timber thickness, the energy spent varies between 600-1000 kWh for 1 m^3 of timber. In recent years, the drying of timber with solar energy is being studied as an alternative drying method in order to reduce energy costs in drying. For this purpose, various types of solar energy timber drying ovens are designed and drying trials are carried out. In most of these studies, it was concluded that solar furnaces can be used economically if fuel prices increase and solar collectors costs can be reduced. In these studies, the effects of wall building materials on the temperature regime have not been evaluated. In terms of drying quality, drying temperatures appropriate for the characteristics of the dried timber should be applied. During the sunbathing period, the temperature rises first, it drops again after reaching the maximum value between 12:00 and 14:00. The specific heat and heat conduction coefficients of the wall materials also have important effects on the change of the oven temperature. The negative effects of intense energy consumption on costs and environmental pollution in timber drying have strengthened the tendency to benefit from solar energy in recent years. Although drying of timber in flat collector solar ovens takes more time than conventional drying, energy costs are low and there are no negative environmental effects.

In this study, the selection of building materials and design type to be used in the design of solar furnaces are evaluated in terms of thermal properties. Materials with different thermal capacities create different thermal features in different designs. Therefore, it is possible to control the course of the temperature distribution throughout the solar timber drying ovens by choosing different building materials and design types.

Keywords: Solar kilns, timber drying, drying economy, furnace design

1. Introduction

Natural and technical drying methods are generally used in drying timber. Although energy is not consumed in natural drying, the drying period is long and timber cannot be dried to the desired result humidity for interiors. Although the timber can be dried to the desired result humidity level in technical drying, drying costs are high. 60-70% of the energy in the timber industry is spent during the drying phase. The energy consumed depending on the tree type and timber thickness varies between 600-1000 kWh per 1 m^3 of timber (Comstock, 1978).

In recent years, drying timber with solar energy has been studied as an alternative drying method in order to reduce energy costs in drying. For this purpose, various types of solar-powered timber drying furnaces are designed and drying trials are carried out. In most of these studies, it has been concluded that solar furnaces can be used economically if the fuel prices increase and the costs of solar collectors can be reduced. In these studies, little coverage has been given to the effects of wall building materials on the temperature regime (Read et al., 1978; Gaugh, 1977; Bois, 1977; Yang, 1980; Chen, 1981; Little, 1984; Örs and Üçüncü, 1992).

In terms of drying quality, drying temperatures suitable for the properties of the dried timber should be applied. In solar furnaces, the temperature varies according to solar energy values and shows significant differences throughout the day. During the sunbathing period, the temperature first rises and decreases again after reaching the maximum value between 12:00 - 14:00. The width of the hourly temperature change interval negatively affects the drying time and quality. In Figure 1, possible hourly variations in temperature during the day are shown for a solar furnace. The temperature of the furnace, which decreases to the lowest level at night, reaches its maximum value between 13:00 and 14:00 during the day due to the effect of solar radiation, and this temperature difference between this temperature difference negatively affects the drying.

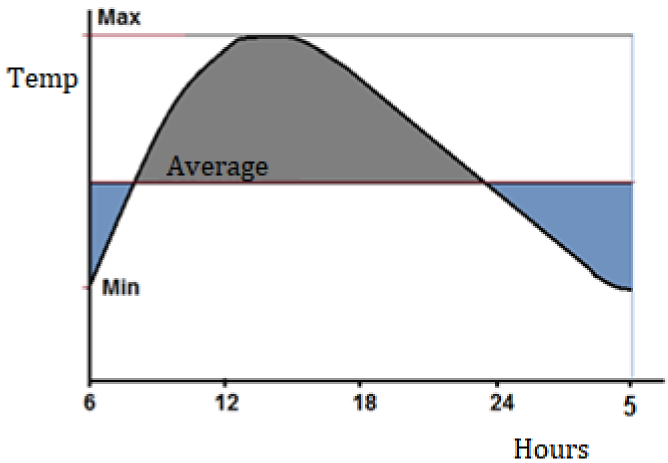


Figure 1. Hourly change graph of temperature in solar furnace

The specific heat and heat conduction coefficients of the wall materials also have an important effect on the change of furnace temperature. Therefore, by choosing the wall building materials to be used, a more homogeneous distribution of the oven temperature can be achieved. Greenhouse type solar furnaces have been considered in this study and these furnaces can be designed up to 10 m^3 capacity. In the study, the effects of the wall designs of the greenhouse type solar furnace with a lumber capacity of 10 m^3 and a collector area of 60 m^2 on the temperature regime were examined.

2. Materials and Methods

2.1. Material

The collector area of the examined greenhouse type solar furnace is 60 m^2 and its timber capacity is 10 m^3. 34.5 m^2 of the solar collector designed in the position of the roof of the oven has a 30° and 25.5 m^2 slope of 60° (Üçüncü, 1995).

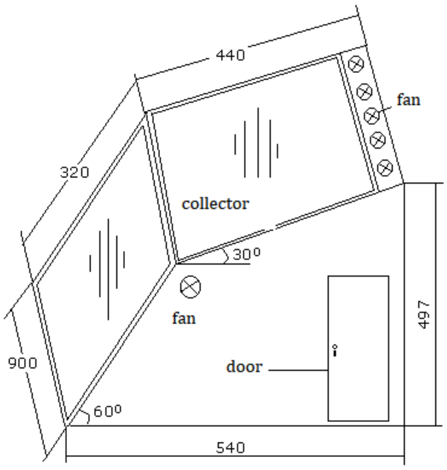
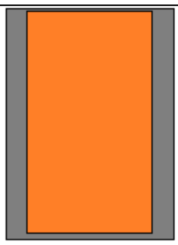
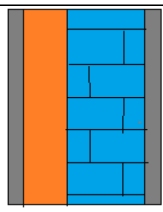


Figure 2. Solar furnace

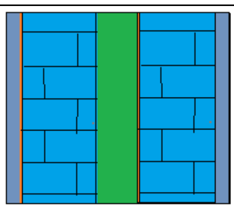
In order to examine the effects of wall designs and materials on temperature regime, 4 types of walls were designed (Figure 3).



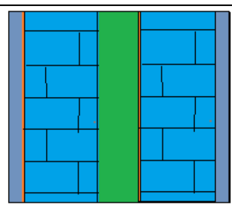
A type wall:
1. 2 cm cemented particle board
2. 5 cm glass wool
3. 2 cm cemented particle board



B type wall:
1. 2 cm cemented particle board
2. 8,5 cm brick
3. 5 cm glass wool
4. 2 cm cemented particle board



C type wall:
1. 2 cm cemented particle board
2. 8,5 cm brick
3. 5 cm glass wool
4. 8,5 cm brick
5. 2 cm cemented particle board



D type wall:
1. 2 cm interior plaster
2. 8,5 cm brick
3. 5 cm glass wool
4. 8,5 cm brick
5. 2 cm interior plaster

Figure 3. Wall design and building materials

2.2. Method

The furnace temperature was calculated using the thermal equilibrium equation (Dağsöz, 1977).

$$Qg = Qd + Qk \quad (1)$$

Here, Qg is the useful solar radiation (W) entering the furnace, Qd is the energy stored in the furnace walls (W), Qk is the heat lost from the furnace (W).

Useful solar radiation entering the oven

$$Qg = \eta \, Ac \, Ie \tag{2}$$

Here, η is collector efficiency, Ac collector field and Ie is the instantaneous solar radiation incident on the collector surface. Hourly solar radiation values coming to the collector surface are calculated from Trabzon's average irradiance values for many years and given in Table 1 (Kılıç and Öztürk, 1983). The value of 45% was taken as a basis for collector efficiency (Üçüncü, 1991).

Stored heat

$$Qd = \sum mCp \, (t_i - t_{i-1}) \tag{3}$$

Lost heat

$$Qk = K \, Ad \, (t_i - t_o) \tag{4}$$

Table 1. Hourly solar radiation coming to the collector surface in Trabzon and monthly average values of outdoor temperature, Ie (W/m²).

Months	Hours																							Total	Tempreture
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5		(°C)
january	0	8	112	232	310	344	344	310	232	112	8	0	0	0	0	0	0	0	0	0	0	0	0	0	2012	7,4
February	0	58	191	315	397	436	436	397	315	191	58	0	0	0	0	0	0	0	0	0	0	0	0	0	2794	7,3
March	21	116	234	336	407	437	437	407	336	234	116	21	0	0	0	0	0	0	0	0	0	0	0	0	3102	8,3
April	69	177	298	400	463	493	493	463	400	298	177	69	0	0	0	0	0	0	0	0	0	0	0	0	3800	11,4
May	102	216	334	424	487	517	517	487	424	334	216	102	0	0	0	0	0	0	0	0	0	0	0	0	4160	15,8
June	119	242	335	447	506	539	539	506	447	335	242	119	0	0	0	0	0	0	0	0	0	0	0	0	4376	20,0
July	100	213	320	401	457	482	482	457	401	320	213	100	0	0	0	0	0	0	0	0	0	0	0	0	3946	22,6
August	77	179	287	370	430	454	454	430	370	287	179	77	0	0	0	0	0	0	0	0	0	0	0	0	3594	23,1
September	36	135	249	345	406	441	441	406	345	249	135	36	0	0	0	0	0	0	0	0	0	0	0	0	3224	20,0
October	0	79	212	324	401	436	436	401	324	212	79	0	0	0	0	0	0	0	0	0	0	0	0	0	2904	16,5
November	0	19	151	273	362	396	396	362	273	151	19	0	0	0	0	0	0	0	0	0	0	0	0	0	2402	13,2
December	0	3	90	211	288	322	322	288	211	90	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1828	9,7
Average	52	138	251	353	421	452	452	421	353	251	138	52	0	0	0	0	0	0	0	0	0	0	0	0	3334	16,1

Here, m wall mass (kg), specific heat of Cp wall material (Wh / kg°C), ΣmCp sum of thermal capacities of furnace walls (WH/°C), furnace temperature at ti i (°C), t_{i-1} initial furnace temperature (°C), to outdoor temperature (°C), K is the total heat transfer coefficient of the furnace (W/m²°C), Ad is the furnace wall area (m²). Based on the equations given, the following equation is obtained for the oven temperature.

$$t_i = \frac{\eta \, Ac \, Ie + \sum mCpt_{i-1} + KAdt_o}{\sum mCp + KAd} \tag{5}$$

In the calculation of the total heat transfer coefficient, the heat transfer coefficient of the wall and the heat losses resulting from air renewal are taken into account. The furnace volume is approximately 150 m³ and the rate of air regeneration in the furnace has been taken as 4, considering the required moist air requirement for drying. Equations and equation coefficients regarding the possible temperatures that will occur in the furnace according to the designed walls are given below.

For wall type A:

$$t_i = 0{,}0250\, Ie + 0{,}7868\, t_{i-1} + 0{,}2132\, t_o \tag{6}$$

For wall type B:

$$t_i = 0{,}0175\, Ie + 0{,}8366\, t_{i-1} + 0{,}1634\, t_o \tag{7}$$

For type C wall:

$$t_i = 0{,}0118\, Ie + 0{,}9026\, t_{i-1} + 0{,}0974\, t_o \tag{8}$$

For wall type D:

$$t_i = 0{,}0153\, Ie + 0{,}8740\, t_{i-1} + 0{,}1260\, t_o \tag{9}$$

3. Findings

The temperature in solar furnaces varies significantly throughout the day due to reasons such as the constant change of solar energy during the day, the variation in terms of the seasons, and none at night. With these features, drying in solar ovens can be considered within the concept of batch drying. Although intermittent drying does not have a direct harmful effect on drying quality, the continuous and sudden change in temperature may affect the drying quality as well as increase the drying time. Wall materials also have a significant effect on the furnace temperature in solar furnaces. In order to examine the effect of wall materials on temperature, the annual average hourly temperature distribution, standard deviation, maximum, minimum and change interval values for four types of furnace walls designed in Trabzon climatic conditions are given in Table 2.

Table 2. Furnace temperature values according to wall types

Wall type	Hours																								t1	S1	MAX	MİN	CI
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5					
A	16	18	24	30	37	43	48	51	52	50	45	40	35	30	27	24	22	21	19	18	18	17	16	16	30	13	52	16	36
B	15	17	21	26	31	36	40	43	45	44	41	38	34	31	28	26	24	22	21	20	19	18	18	17	28	11	45	15	29
C	15	16	19	23	27	31	34	37	39	39	38	37	35	33	31	29	28	27	25	24	23	23	22	21	28	9	39	15	24
D	15	17	20	25	30	35	39	42	44	44	42	39	36	33	31	29	27	26	24	23	22	21	20	20	29	11	45	15	29

In Table 3, the monthly average furnace temperature and standard deviation values for four types of furnace walls. Here, t1 and S1 are solar furnace temperature (°C) and standard deviation with wall type A, t2 and S2 solar furnace temperature and standard deviation with wall type B, t3 and S3 solar furnace temperature and standard deviation with wall type C, t4 and S4 D-type wall furnace temperature and standard deviation.

Table 3. Monthly average temperature and standard deviation values of furnace types

Months	A		B		C		D	
	t1	S1	t1	S1	t1	S1	t1	S1
january	17,1	9,2	16,0	6,9	16,0	5,2	16,8	6,5
February	20,8	12,1	19,3	9,2	19,2	6,9	20,3	8,5
March	23,2	12,7	21,6	9,6	21,5	7,2	22,7	9,0
April	29,7	14,8	27,7	11,2	27,6	8,4	29,1	10,5
May	35,8	15,7	33,6	12,0	33,5	9,0	35,2	11,2
June	41,1	16,4	38,7	12,5	38,6	9,3	40,4	11,6
July	41,6	14,8	39,5	11,3	39,4	8,4	41,1	10,5
August	40,4	13,8	38,5	10,5	38,4	7,8	40,0	9,8
September	35,5	12,9	33,8	9,8	33,7	7,3	35,1	9,2
October	30,5	12,4	28,9	9,4	28,9	7,0	30,1	8,8
November	24,8	10,8	23,5	8,2	23,5	6,1	24,5	7,6
December	18,5	8,5	17,5	6,4	17,5	4,8	18,3	6,0
Average	29,9	12,8	28,2	9,7	28,2	7,3	29,5	9,1

Average oven temperature has the highest value in A type oven and the lowest in C type oven. In A type oven, the highest value of the average oven temperature during the day (24 hours) occurred in July with 41.6 °C, and the lowest value occurred in January with 17.1 °C. The same values in B, C and D type furnaces, respectively; 39.5; 39.4; 40.1 °C and 16.0; 16.0; It became 16.8 °C. Standard deviation also increases in high temperature average values. The largest standard deviation was observed in A type furnace with 12.8 °C, the smallest standard deviation was observed in C type furnace with 7.3 °C.

In Figure 4, the temperature changes of solar furnaces with wall types A, B, C and D are shown by months depending on time. In Figure 5, hourly temperature distribution for wall types is shown. In solar furnaces, the maximum temperature for any type of wall material is generally reached between 14:00 and 15:00 hours. In the solar oven for all wall types, the temperature of the oven does not fall to the ambient temperature the next day, when the solar radiation starts. In the furnace with a wall with a high thermal capacity, the difference between the final temperature and the ambient temperature is greater.

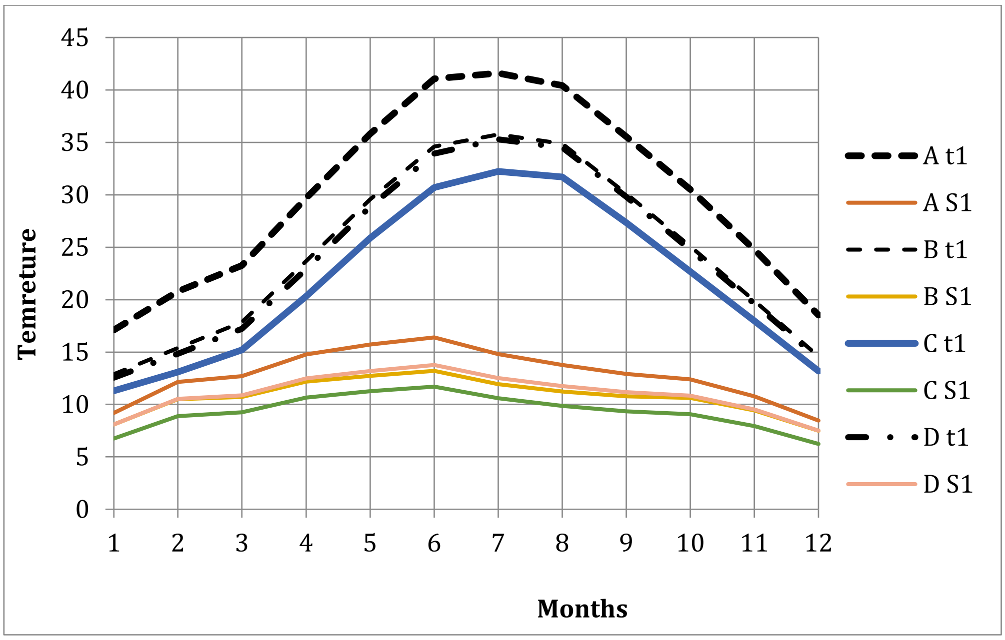


Figure 4. Monthly average temperatures

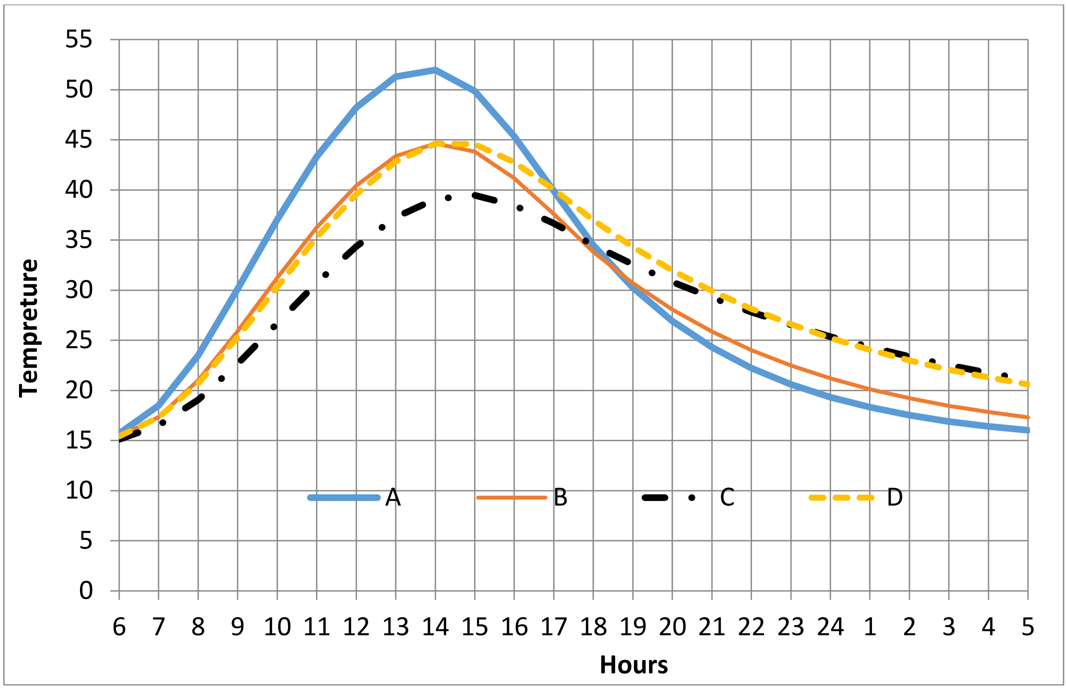


Figure 5. Hourly temperature distribution according to wall types

5. Discussion and Conclusion

Since materials with high thermal capacity will store large amounts of heat, the furnace temperature decreases in furnaces built of these materials. However, despite the low temperatures that occur in the oven during the sunbathing period, the temperature drop is less after the sunbathing ends and at night. In furnaces built of materials with low thermal capacity, the temperature of the furnace, which is higher during the sunbathing period, is greater at night. Accordingly, although the average temperature is lower in furnaces built with materials with high thermal capacity, the variation interval and standard deviation are also small, so they may have more positive effects on the drying quality. This type of furnace has more suitable features in terms of ensuring homogeneous and high quality drying.

In solar systems where high temperatures are desired during the sunshine period, the selection of low thermal capacity building materials can be recommended. However, it would be beneficial to use materials with higher thermal capacity in solar ovens where activity is desired throughout the day. According to theoretical calculations, it is seen that more stable temperature values will be formed in solar furnaces to be built from C and D type walls.

In terms of heat loss in solar furnaces, since the heat losses caused by air renewal are more effective than the thermal conductivity of wall materials, the thermal insulation thickness of 5 cm is taken as a basis instead of the 8 cm thermal insulation thickness recommended in the literature. For the same reason, it is possible to use polyurethane or styrofoam for thermal insulation.

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A SCALE DEVELOPMENT STUDY TO EXAMINE THE APPLICATION OF TOTAL QUALITY MANAGEMENT

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Abstract

The total quality management approach is a management style in which the human factor stands out, continuous development and improvement is adopted, group work is emphasized in the enterprise, and quality responsibility spreads to all of the employees. The goal of total quality management is to provide continuous and excellent service to the customer with well-trained and motivated employees.

Within the scope of this study, some features (customer orientation, management leadership, full participation, systematic process analysis and human understanding first) of total quality management activities implemented in forest products industry are examined. For this purpose, 377 engineers and foremen working in 14 large-scale companies with ISO 9001 Quality Management System Certificate were reached through a survey method. The questionnaire used consists of two parts. In the first part, some demographic features of the employees were evaluated with 13 questions. In the second part of the survey, the management system applied in the enterprises was researched with 50 questions. The survey data were evaluated with the Structural Equation Model (SEM) prepared in SPSS and AMOS statistical package programs and the results were revealed.

As a result, a statistically acceptable scale has been put forward for researchers who want to examine the total quality management studies in the forest products industry.

Keywords: Total Quality Management, Scale Development, Forest Products İndustry, Quality Management System

1. Introduction

The unique elements, technologies, production and management processes of the socio-cultural and economic structure, which differ completely from the past, are also changing today, when the environmental conditions change rapidly and the world takes the globalization process. Organizations need to establish an effective quality system and management in order to survive in increasingly difficult competition conditions. Today it is the "Total Quality Management" (TQM) model that can provide these (Kaptan, 2007).

TQM is the integration of all functions and processes of an organization to be successful in continuously improving the quality of its goods and services. The goal is customer satisfaction. TQM understanding not only increases the quality but also increases the efficiency of the organization. Employee satisfaction is also taken into consideration in production and service activities that are carried out by considering customer satisfaction (Swift, 1998).

TQM is the art of achieving perfection. It is an effective method to achieve the ideal. Total quality management is the set of principles and philosophy that represent developing organizations. It is quantitative methods and human resources application that improve all processes within the organization. To deliver more than current and future customer expectations. TQM is a discipline carried out with inferential management techniques, existing development efforts and technical tools (Besterfield,1999).

The basic elements of total quality management, in which the human factor comes to the fore, aims at continuous development and improvement, group work is emphasized in the enterprise, and quality responsibility is in all business employees, are the issues that businesses that adopt the total quality management approach should know. Within the scope of this study, the characteristics of total quality management activities applied in the forest products industry (customer focus, management leadership, full participation, systematic process analysis and human understanding first) are examined and a scale that can be used by researchers who will work in this field is presented.

2. Materials and Methods

Within the scope of this study, the characteristics of total quality management activities (customer focus, management leadership, full participation, systematic process analysis and human understanding first) applied in the forest products industry were examined. For this purpose, 377 engineers and foremen working in 14 large-scale companies holding ISO 9001 Quality Management System Certificate were reached by survey method. In the study, a questionnaire form prepared by compiling from the survey studies applied on TQM and performance was used (Eroğlu, 2003; Serin, 2004; Yağar, 2007; İnce, 2007; Aydın, 2007). The questionnaire used consists of two parts. In the first part, some demographic characteristics of the employees were evaluated with 13 questions. In the second part of the questionnaire, the management system applied in businesses was investigated with 50 questions.

The obtained data were checked with reliability and validity analysis. Although there are many models used in reliability analysis, the Cronbach alpha coefficient was used in this study. This coefficient takes values between 0 and 1 (Kalaycı, 2009). In our study, values with α coefficient of 0.80 and above were accepted. In our study, factor analyzes were conducted to measure the construct validity. At this stage, KMO (Kaiser-Meyer-Olkin) and Bartlett tests were applied to determine the suitability of the data for factor analysis.

After determining the suitability of the data for factor analysis, factor analysis was started. Within the scope of the analysis, the principal component factor extraction method and the varimax vertical rotation method were preferred. One of the conditions in the implementation of structural equation models is that each scale should consist of a single dimension and at least 3 variables belonging to that scale should be included in the analysis (Eroğlu, 2003). Within the scope of the study, in order to increase the reliability of the SEM, a limitation has been introduced to be 70% and above explanatory factor analysis. After these stages, the model prepared was transferred to the AMOS (Analytic Moment of Structure) 16.0 package program, analyzes were performed and the results were presented.

3. Results and Discussions

3.1. General Information of Participants

Some general information about the employees who participated in our survey is given in Table 1.

Table 1. General information about the participants

Age	Frequency	Percentage
20-24	19	5,0
25-29	77	20,4
30-34	85	22,5
35-39	50	13,3
40-44	22	5,8
45-49	18	4,8
>50	3	0,8
Unanswered	103	27,3

Gender	Frequency	Percentage
Male	301	79,8
Female	42	11,1
Unanswered	34	9,0

Marital status	Frequency	Percentage
married	200	53,1
Single	98	26,0
Other	4	1,1
Unanswered	75	19,9

Position in business	Frequency	Percentage
Engineer	183	48,5
Foreman	152	40,3
Unanswered	42	11,1

Working time in the position (years)	Frequency	Percentage
0-5	154	40,9
6-10	92	24,4
11-20	61	16,2
<21	13	3,4
Unanswered	57	15,1

Total working time (years)	Frequency	Percentage
0-5	173	45,9
6-10	101	26,8
11-20	56	14,9
>21	15	4,0
Unanswered	32	8,5

As seen in Table 1, 42.9% of the employees surveyed are between the ages of 25-35, 79.8% are male, 53.1% are married. 48.5% of the participants are engineers and 40.3% are foremen. 40.9% of them have been working in this position for a maximum of 5 years. It was determined that the maximum working time (45.9%) was 5 years.

3.2. Compliance with normal distribution

Kurtosis values were used to examine the data distribution. The purpose of kurtosis measures is to reveal how the variables are distributed around the mean. If the kurtosis value of the variable is between -3 and +3, it indicates that the values of the variables come from a typical normal distribution (Kalaycı, 2009). For this purpose, kurtosis values of each variable are given in Table 2.

Table 2. Kurtosis values of the variables

Variables	Kurtosis	Variables	Kurtosis	Variables	Kurtosis
co1	0,907	huf1	-0,477	fp7	-1,286
co2	1,374	huf2	0,306	fp8	0,939
co3	0,502	huf3	-0,432	fp9	0,842
co4	0,583	huf4	0,189	fp10	-0,147
co5	0,963	huf5	-0,459	fp11	-0,845
co6	0,206	huf6	-,0615	fp12	0,535
co7	0,359	huf7	0,117	fp13	0,762
co8	0,013	huf8	-0,505	spa1	1,134
co9	-0,508	huf9	-0,180	spa2	0,390
co10	-0,010	fp1	0,173	spa3	0,390
co11	0,694	fp2	0,634	spa4	0,448
co12	0,071	fp3	0,390	spa5	0,596
co13	-0,024	fp4	0,211	spa6	0,442
co14	0,920	fp5	1,312	spa7	0,365
co15	0,421	fp6	1,013		

As seen in Table 2 kurtosis values of all variables are within the specified limits (-3 / +3). For this reason, it was accepted that the data had a normal distribution and the analysis continued.

3.3. Reliability and Validity Analysis

At this stage, the scales were analyzed for reliability and validity, and after obtaining appropriate values, they were subjected to factor analysis. The α coefficient for each scale and the results of factor analysis reduced to a single scale are given in the table.

Table 3. α coefficient for each scale and the results of factor analysis

Scales	Crocbach α	Variables	Explained Variance (%)
Customer orientation	91,7	co4, co6, co7	73,372
Human understanding first	84,4	huf6, huf8, huf9	73,662
Full participation	87,5	fp1, fp2, fp3	74,402
Systematic process analysis	85,7	spa2, spa4, spa5, spa6	70,735
Management leadership	89,3	ml1, ml2, ml3, ml4	72,953

3.4. Results of the Measurement Model

After the reliability and validity analysis of the scales, the results of the measurement model were examined. The measurement model is shown in Figure 1.

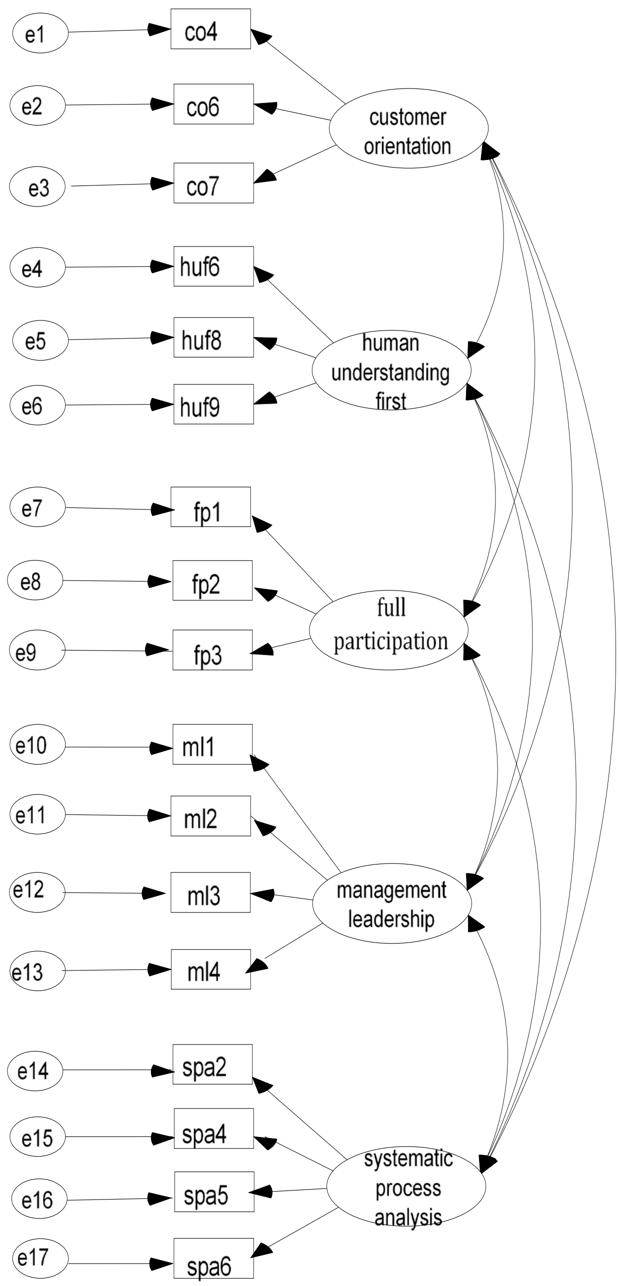

Figure 1. Measurement model

The goodness of fit indexes of the measurement model shown in Figure 1 are shown in Table 4.

Table 4. The goodness of fit indexes of the measurement model

Fit indexes	Measurement model	Adjusted measurement model
Chi-Square statistic	242,326	212,083
Degrees of freedom	109	107
Chi-Square / Degrees of freedom	2,223	1,982
GFI	0,929	0,938
AGFI	0,901	0,911
CFI	0,964	0,972
RMR	0,034	0,033
RMSEA	0,057	0,050
NFI	0,937	0,945
IFI	0,964	0,972

As seen in Table 4, the "Chi-square / degree of freedom" of the goodness of fit indices of the measurement model was above the acceptable limit of 2, therefore a modification was applied to the model. Since the corrected measurement model obtained indexes of goodness of fit are within the limits mentioned earlier, it is accepted that the measurement model is supported by the data.

By applying Confirmatory Factor Analysis (CFA) to the improved measurement model, it was revealed to what extent latent variables could be explained by the observed variables. In addition, variance estimates and reliability of the factors calculated in order to determine the validity and reliability of the measurement model are given in Table 5.

Table 5. CFA results for the improved measurement model

Latent Variable	Observed Variable	Factor Load	Standard Error	t-value	Explained Variance	Reliability
Customer focus	cf4	0,730	0,060	13,746	0,60	0,82
	cf6	0,800	0,072	14,877		
	cf7	0,794	-	-		
Human understanding first	huf6	0,714	0,070	13,780	0,61	0,82
	huf8	0,813	0,071	15,513		
	huf9	0,813	-	-		
Full participation	fp1	0,737	-	-	0,62	0,83
	fp2	0,795	0,071	14,934		
	fp3	0,820	0,075	15,398		
Systematic process analysis	spa2	0,741	0,053	15,604	0,59	0,85
	spa4	0,713	0,059	14,584		
	spa5	0,782	0,056	16,525		
	spa6	0,841	-	-		
Management leadership	ml1	0,820	-	-	0,63	0,90
	ml2	0,889	0,052	20,008		
	ml3	0,744	0,055	16,694		
	ml4	0,684	0,058	14,144		

Table 5 shows the factor loadings, standard errors, t values, explained variances and reliability levels of the variables in the measurement model. Considering the factor loads of the variables, it is seen that they change between 0.684 and 0.889. Therefore, except for ml4, all other factor loads have values above the critical value of 0.70. In addition, the t values of these predictions were found to be significant at the 0.05 significance level. Therefore, the validity of the measurement model was provided.

In the measurement model, two types of reliability measures were used, namely the explained variance of the factors and the reliability coefficients of the factors. The explained variance estimates of the factors show the total variance value explained by each factor in the relevant observed variables. As seen in Table 5 the explained variance values of the found factors are above the lower limit (50%). Reliability coefficients of the factors, another reliability criterion, indicate the internal reliability of the factors. Reliability coefficients of the factors have taken values above the lower limit of 0.70. Therefore, it can be stated that the measurement model is reliable.

5. Conclusion

In this study, it is aimed to develop a scale to be used to examine the applications of total quality management in enterprises. The questionnaire form prepared for this purpose was applied in the forest products sector. After the necessary statistical analysis, a scale applicable at sectoral level has been established. Scale developments can be made on different sample groups to examine total quality management practices.

6. Acknowledgments

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MULTICRITERIA EVALUATION OF STRUCTURAL COMPOSITE LUMBER PRODUCTS

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Abstract

In this study, laminated veneer lumber, parallel strand lumber, and laminated strand lumber were evaluated via multicriteria decision-making methods. Within the model, nine evaluation criteria were defined: moisture content, density, bending strength, modulus of elasticity, compression strength parallel to grain, dynamic bending strength, tensile strength parallel to surface, tensile strength perpendicular to surface, and screw holding capacity. The weights of the criteria were computed using the fuzzy analytic hierarchy process (FAHP). The evaluation based on distance from an average solution (EDAS) and the technique for order preference by similarity to an ideal solution (TOPSIS) were employed to determine the ranking of the alternatives. After the borda count method was used, an integrated ranking was obtained. According to the results, the first three important subcriteria were density, bending strength, and modulus of elasticity. Furthermore, laminated veneer lumber was determined as the best alternative. Consequently, this study can present a road map to evaluate wooden materials.

Keywords: Structural composite lumber, Multicriteria decision-making, FAHP, EDAS, TOPSIS

1. Introduction

Structural composite lumber (SCL) is a family of engineered wood products. It includes laminated veneer lumber (LVL), parallel strand lumber (PSL), laminated strand lumber (LSL), and oriented strand lumber (OSL) (Bayatkashkoli and Faegh, 2014). LVL is manufactured from wood veneers that are rotary peeled, dried, and laminated together with parallelly oriented grains under heat and pressure with an adhesive (Çolak et al., 2007). PSL is manufactured by adhesively bonding long, thin, and narrow strands of wood under high pressure (Arwade et al., 2010). LSL consists of oriented wood flakes that are glued and compressed to form panels up to 90 mm thick (Moses et al., 2003). OSL is similar to LSL. The SCL products are commonly used for rafters, headers, beams, joists, studs, and columns (APA, 2016). The advantages of SCL are high strength, flexibility, high stiffness, and excellent preservative treatability (Yazdani et al., 2004).

A large number of experimental studies have been conducted to evaluate the various properties of the SCL products (Moses et al., 2003; Yazdani et al., 2004; Çolak et al., 2007; Arwade et al., 2010; Ahmad and Kamke, 2011; Bayatkashkoli and Faegh, 2014; Bal, 2016; Çolak et al., 2019). In light of the experimental studies, it can be said that there are many factors that must be carefully evaluated. Therefore, it is important to use methods providing supportive and logical results in the evaluation process. Multicriteria decision-making (MCDM) methods can be used to evaluate decision elements. The fuzzy analytic hierarchy process

(FAHP), the evaluation based on distance from an average solution (EDAS), and the technique for order preference by similarity to an ideal solution (TOPSIS) have been widely used to deal with decision-making problems and obtain quite reliable results (Chauhan and Singh, 2016; Karakuş et al., 2017; Ecer, 2018). Therefore, in this study, these methods are used to evaluate the SCL products.

The MCDM methods have been efficiently applied to the various fields of wood science. Smith et al. (1995) employed the AHP method to analyze factors affecting the adoption of timber as a bridge material. Azizi (2008) selected the best wood supply alternative by employing the analytic network process (ANP) and the BOCR approach. Lipuščček et al. (2010) employed the AHP method to classify wood products in terms of their impact on the environment. Azizi and Modarres (2011) selected the best construction panel by using the AHP and ANP methods. Azizi et al. (2012) used the AHP method to select the best medium density fiberboard (MDF) product. Kuzman and Grošelj (2012) compared different construction types by utilizing the AHP method. Sarfi et al. (2013) used the AHP method to analyze factors influencing the markets of particleboard and MDF. Karakuş et al. (2017) employed the TOPSIS method, the multiple attribute utility theory, and the compromise programing to predict the optimum properties of some nanocomposites. Singer and Özşahin (2018, 2020a, 2020b) prioritized some factors influencing the surface roughness of wood and wood-based materials in sawing, planing, and CNC machining. Özşahin et al. (2019) employed AHP and MOORA to select the best softwood species for construction.

Consequently, the literature review has demonstrated that there are many attempts on the use of MCDM methods for solving various decision-making problems in wood science. However, the literature has a gap in evaluating the SCL products by MCDM methods. Therefore, the objective of this study is to evaluate LVL, PSL, and LSL by the MCDM analysis. In order to determine the priorities of the alternatives, an evaluation model containing FAHP, EDAS, and TOPSIS is proposed.

2. Materials and Methods

2.1. Sample Preparation

The experimental data used in this study were obtained from the literature (Sizüçen, 2008; Özçifçi et al., 2010). The experimental process could be briefly explained as follows. Poplar (*Populus tremula* L.) veneers with the thickness of 3 mm were used to produce LVLs. Poplar (*Populus tremula* L.) strands were used to produce PSLs and LSLs. The size of strands in PSLs was 3 mm thick by 20 mm wide by 600 mm long. The size of strands in LSLs was 1.2 mm thick by 20 mm wide by 300 mm long. The veneers and strands were conditioned at a temperature of 55±2 °C and a relative humidity of 6±1% until they reached an average moisture content of 3%. Phenol formaldehyde was chosen as the adhesive. It has density, viscosity, and pH value of 1.195-1.205 kg/m^3, 250-500 MPa s, and 10.5-13, respectively. The materials were pressed for 7 minutes at a temperature of 180±3 °C and a pressure of 30 kg/cm^2 (ASTM D 5456, 1996). After pressing, the samples were conditioned at a temperature of 20±2 °C and a relative humidity of 65±5% (TS 642/ISO 554, 1997). The moisture content and density values of the samples were determined according to TS 2471 (1976) and TS 2472 (1976). The bending strength and modulus of elasticity tests were carried out according to the procedure of TS EN 310 (1999). The compression strength parallel to grain, dynamic bending strength, screw withdrawal, and tensile strength tests were carried out according to TS 2595 (1977), TS 2477 (1976), ASTM D 1761 (2000), and ASTM D 1037-06a (2006), respectively.

2.2. Fuzzy Sets and Fuzzy Numbers

The fuzzy set theory was developed by Zadeh (1965) in order to represent the uncertainty, vagueness, and ambiguity of judgments (Chauhan and Singh, 2016). In the classical set theory, an element belongs or does not belong to a set. The element of a fuzzy set naturally belongs to the set with a membership value from the interval [0,1] (Kahraman and Kaya, 2010). The most commonly utilized fuzzy numbers are triangular and trapezoidal fuzzy numbers. In this study, triangular fuzzy numbers (TFNs) will be employed owing to their ease of use. The following equation is the membership function of a TFN denoted as (l, m, u):

$$\mu_{\widetilde{M}}(x) = \begin{cases} 0, & x < l \text{ or } x > u \\ (x-l)/(m-l), & l \le x \le m \\ (u-x)/(u-m), & m \le x \le u \end{cases} \quad (1)$$

l, m, and u indicate the lower value, the mid-value, and the upper value, respectively. The main arithmetic operations for two TFNs are as follows:

$$\widetilde{M}_1 \oplus \widetilde{M}_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \quad (2)$$

$$\widetilde{M}_1 \otimes \widetilde{M}_2 = (l_1 l_2, m_1 m_2, u_1 u_2) \quad (3)$$

$$\widetilde{M}_1^{-1} = (1/u_1, 1/m_1, 1/l_1) \quad (4)$$

2.3. The FAHP Method

AHP is a useful method to solve complex MCDM problems (Saaty, 1980). In the AHP method, the elements of the same level are compared in pairs with respect to an element located at the higher level. However, AHP is based on crisp judgments. In reality, it is very hard to acquire precise data owing to uncertainties on the judgments of decision-makers. Each decision-maker prefers natural language expressions rather than crisp numbers (Heo et al., 2010). Therefore, FAHP will be used to obtain the weights of the criteria. The steps of the FAHP method used in this study can be summarized as follows (Chang, 1996; Somsuk and Laosirihongthong, 2014):

Step 1: The value of fuzzy synthetic extent with respect to the ith object is computed.

$$S_i = \sum_{j=1}^{m} M_{g_i}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} \right]^{-1} \quad (5)$$

Step 2: The degree of possibility of $S_i = (l_i, m_i, u_i) \ge S_j = (l_j, m_j, u_j)$ is calculated using the following equation:

$$V(S_i \ge S_j) = \begin{cases} 1, & m_i \ge m_j \\ 0, & l_j \ge u_i \\ \frac{l_j - u_i}{(m_i - u_i) - (m_j - l_j)}, & \text{otherwise} \end{cases} \quad (6)$$

where $i = 1,2,\ldots,n$, $j = 1,2,\ldots m$, and $i \ne j$.

Step 3: The degree of possibility of S_i over all the other fuzzy numbers is calculated.

$$V(S_i \ge S_j | j = 1,2,\ldots m;\ i \ne j) = \min V(S_i \ge S_j | j = 1,2,\ldots m;\ i \ne j \quad (7)$$

Step 4: Compute the weight vector of a fuzzy matrix. Assume that $w_i^{'} = \min V(S_i \ge S_j | j = 1,2,\ldots m;\ i \ne j)$.

$$w_i = \frac{w_i^{'}}{\sum_{i=1}^{n} w_i^{'}} \quad (8)$$

Here, w_i is a non-fuzzy value. The evaluation scale used in this study is given in Table 1.

Table 1. The evaluation scale

Linguistic scale	Triangular fuzzy scale
Equal	(1,1,2)
Moderate	(2,3,4)
Strong	(4,5,6)
Very strong	(6,7,8)
Extremely preferred	(8,9,10)

2.4. The EDAS Method

EDAS is a MCDM method that uses distances from average solutions (*AV*). The evaluation of alternatives is carried out according to the higher values of the positive distance from the average (*PDA*) and the lower values of the negative distance from the average (*NDA*). The EDAS procedure consists of the following steps (Keshavarz Ghorabaee et al., 2015):

Step 1: The decision matrix D of n alternatives and m criteria is formed.

$$D = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \quad (9)$$

Step 2: AV values are calculated.

$$AV_j = \frac{\sum_{i=1}^{n} x_{ij}}{n} \quad (10)$$

Step 3: The values of PDA and NDA are computed.

$$PDA_{ij} = \begin{cases} \dfrac{\max(0,(x_{ij} - AV_j))}{AV_j}, if\ j \in B \\ \dfrac{\max(0,(AV_j - x_{ij}))}{AV_j}, if\ j \in NB \end{cases} \quad (11)$$

$$NDA_{ij} = \begin{cases} \dfrac{\max(0,(AV_j - x_{ij}))}{AV_j}, if\ j \in B \\ \dfrac{\max(0,(x_{ij} - AV_j))}{AV_j}, if\ j \in NB \end{cases} \quad (12)$$

B and NB are associated with benefit criteria and non-benefit criteria, respectively.

Step 4: The weighted sums of PDA and NDA are calculated with Equations (13) and (14).

$$SP_i = \sum_{j=1}^{m} (w_j PDA_{ij}) \quad (13)$$

$$SN_i = \sum_{j=1}^{m} (w_j NDA_{ij}) \quad (14)$$

Here, w_j is the weight of the jth criterion.

Step 5: The normalized values of SP and SN are determined as follows:

$$NSP_i = \frac{SP_i}{\max_i(SP_i)} \quad (15)$$

$$NSN_i = 1 - \frac{SN_i}{\max_i(SN_i)} \quad (16)$$

Step 6: The appraisal score (*AS*) is calculated.

$$AS_i = \frac{NSP_i + NSN_i}{2}, \quad 0 \leq AS_i \leq 1 \quad (17)$$

2.5. The TOPSIS Method

TOPSIS is a MCDM method that obtains a solution which is closest to the positive ideal solution (*PIS*) and farthest from the negative ideal solution (*NIS*). The TOPSIS procedure consists of the following steps (Hwang and Yoon, 1981):

Step 1: The decision matrix is formed (see Equation (9)).

Step 2: The normalized decision matrix is obtained.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \quad i = 1,2,\ldots,n; \; j = 1,2,\ldots,m \quad (18)$$

Step 3: The weighted normalized decision matrix is obtained according to Equation (19).

$$V_{ij} = w_j r_{ij} \quad (19)$$

Step 4: *PIS* and *NIS* are determined using Equations (20) and (21), respectively.

$$A^* = \{v_1^*, v_2^*, \ldots v_n^*\} = \{(\max v_{ij} | j \in B), (\min v_{ij} | j \in NB)\} \quad (20)$$

$$A^- = \{v_1^-, v_2^-, \ldots v_n^-\} = \{(\min v_{ij} | j \in B), (\max v_{ij} | j \in NB)\} \quad (21)$$

Step 5: Calculate the distance of alternatives from *PIS* and *NIS*.

$$d_i^* = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^*)^2} \quad (22)$$

$$d_i^- = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^-)^2} \quad (23)$$

Step 6: The relative closeness to the ideal solution (C_i) is computed.

$$C_i = \frac{d_i^-}{d_i^* + d_i^-} \quad (24)$$

2.6. The Borda Count Method

The borda count method can be employed to incorporate different ranking results. An alternative gets *m* votes for the first-ranked criterion, *m*-1 votes for the second-ranked criterion, and 1 vote for the last-ranked criterion. The alternative with the largest sum of scores is the winner (Laukkanen et al., 2005).

2.7. Application

In the present study, a MCDM model is proposed to evaluate LVL, PSL, and LSL. This model consists of the following main phases: (1) prioritization of the criteria by FAHP, (2) prioritization of the alternatives by EDAS and TOPSIS, and (3) determination of the final ranking of the alternatives by Borda. The evaluation model is shown in Figure 1.

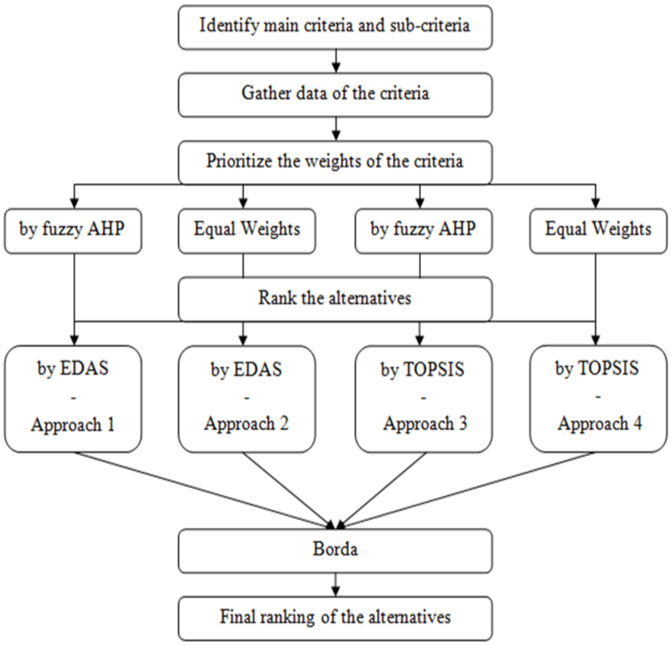

Figure 1. The evaluation model used in the study

In order to evaluate the alternatives, two main criteria are defined as physical properties (PP) and mechanical properties (MP). The subcriteria of physical properties are moisture content (PP1) and density (PP2). The subcriteria of mechanical properties are bending strength (MP1), modulus of elasticity (MP2), compression strength parallel to grain (MP3), dynamic bending strength (MP4), tensile strength parallel to surface (MP5), tensile strength perpendicular to surface (MP6), and screw holding capacity (MP7). The hierarchical structure of the problem is portrayed in Figure 2.

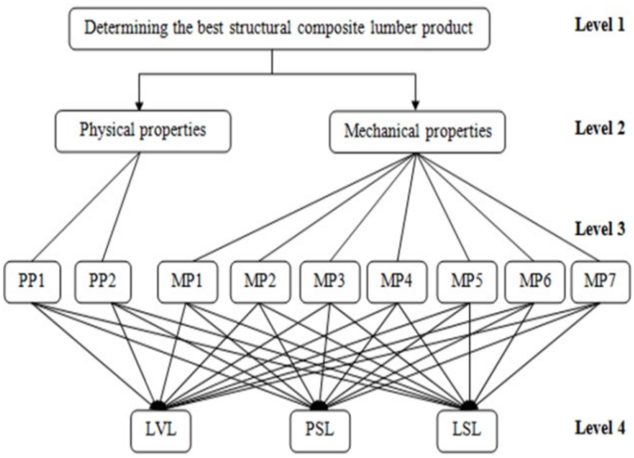

Figure 2. The decision hierarchy

A decision-making team consisting of five experts who have experience with the research topic is constructed to evaluate each criterion. The experts use the linguistic terms (see Table 1) to compare the criteria. The linguistic terms are then converted to TFNs. The geometric means of the fuzzy values are computed to obtain the overall results of each evaluation matrix.

3. Results and Discussion

The importance of each criterion is determined using FAHP. The comparison matrices can be seen from Tables 2-4.

Table 2. The comparison matrix of the main criteria

Criterion	PP	MP
PP	(1.000, 1.000, 1.000)	(0.608, 0.750, 0.944)
MP	(1.059, 1.332, 1.644)	(1.000, 1.000, 1.000)

Table 3. The comparison matrix of the subcriteria within physical properties

Criterion	PP1	PP2
PP1	(1.000, 1.000, 1.000)	(0.758, 0.903, 1.217)
PP2	(0.822, 1.108, 1.320)	(1.000, 1.000, 1.000)

Table 4. The comparison matrix of the subcriteria within mechanical properties

Criterion	MP1	MP2	MP3	MP4	MP5	MP6	MP7
MP1	(1.000, 1.000, 1.000)	(1.084, 1.185, 2.000)	(1.149, 1.380, 2.169)	(1.084, 1. 380, 1.741)	(0.871, 1.035, 1.431)	(0.871, 1.035, 1.431)	(1.320, 1.719, 2.491)
MP2	(0.500, 0.844, 0.922)	(1.000, 1.000, 1.000)	(1.246, 1.476, 2.297)	(0.922, 1.246, 1.644)	(1.059, 1.246, 1.888)	(1.059, 1.246, 1.888)	(1.320, 1.719, 2.491)
MP3	(0.461, 0.725, 0.871)	(0.435, 0.678, 0.803)	(1.000, 1.000, 1.000)	(0.803, 0.966, 1.320)	(0.699, 0.903, 1.320)	(0.699, 0.903, 1.320)	(1.000, 1.380, 1.888)
MP4	(0.574, 0.725, 0.922)	(0.608, 0.803, 1.084)	(0.758, 1.035, 1.246)	(1.000, 1.000, 1.000)	(0.944, 1.185, 1.741)	(0.944, 1.185, 1.741)	(1.084, 1.476, 2.000)
MP5	(0.699, 0.966, 1.149)	(0.530, 0.803, 0.944)	(0.758, 1.108, 1.431)	(0.574, 0.844, 1.059)	(1.000, 1.000, 1.000)	(1.000, 1.000, 2.000)	(1.431, 1.933, 2.433)
MP6	(0.699, 0.966, 1.149)	(0.530, 0.803, 0.944)	(0.758, 1.108, 1.431)	(0.574, 0.844, 1.059)	(0.500, 1.000, 1.000)	(1.000, 1.000, 1.000)	(1.431, 1.933, 2.433)
MP7	(0.401, 0.582, 0.758)	(0.401, 0.582, 0.758)	(0.530, 0.725, 1.000)	(0.500, 0.678, 0.922)	(0.411, 0.517, 0.699)	(0.411, 0.517, 0.699)	(1.000, 1.000, 1.000)

The weights are presented in Table 5. As seen in Table 5, mechanical properties (0.734) are more important than physical properties (0.266). The most significant subcriterion is density (0.147). Other important subcriteria are ranked as follows: bending strength (0.132), modulus of elasticity (0.132), moisture content (0.119), tensile strength parallel to surface (0.114), and tensile strength perpendicular to surface (0.112). The lowest priority value belongs to screw holding capacity (0.040). It is followed by compression strength parallel to grain (0.093).

Table 5. Summary of the weights

Main criterion	Local weight	Subcriterion	Local weight	Global weight
Physical properties	0.266	Moisture content	0.448	0.119
		Density	0.552	0.147
Mechanical properties	0.734	Bending strength	0.180	0.132
		Modulus of elasticity	0.180	0.132
		Compression strength parallel to grain	0.127	0.093
		Dynamic bending strength	0.151	0.111
		Tensile strength parallel to surface	0.156	0.114
		Tensile strength perpendicular to surface	0.152	0.112
		Screw holding capacity	0.054	0.040

The decision matrix is given in Table 6. The physical and mechanical properties of the alternatives are evaluated by EDAS and TOPSIS. The results are presented in Tables 7 and 8. According to the results obtained by using the FAHP-EDAS approach, the best SCL product is LVL with an *AS* of 0.693. PSL with an *AS* of 0.597 is positioned at the second rank, while LSL with an *AS* of 0.491 is placed at the third rank. According to the results of the equal weighted EDAS analysis, the *AS*s of LVL, PSL, and LSL are 0.776, 0.474 and 0.328, respectively. These values show that the best SCL product is LVL.

Table 6. The decision matrix

	PP1 (%)	PP2 (g/cm^3)	MP1 (N/mm^2)	MP2 (N/mm^2)	MP3 (N/mm^2)	MP4 (kgm/cm^2)	MP5 (N/mm^2)	MP6 (N/mm^2)	MP7 (N/mm^2)
LVL	8.13	0.40	64.51	7907.20	49.87	0.46	25.97	805.01	6.10
PSL	8.00	0.44	60.23	7864.55	43.85	0.50	25.88	796.66	5.46
LSL	8.34	0.50	61.83	8022.48	41.91	0.40	26.04	775.88	5.89

Table 7. The EDAS results

	FAHP-EDAS						Equal weighted EDAS					
	SP_i	NSP_i	SN_i	NSN_i	AS	Ranking	SP_i	NSP_i	SN_i	NSN_i	AS	Ranking
LVL	0.020	1.000	0.016	0.385	0.693	1	0.025	1.000	0.012	0.552	0.776	1
PSL	0.014	0.705	0.013	0.490	0.597	2	0.014	0.571	0.017	0.377	0.474	2
LSL	0.020	0.982	0.026	0.000	0.491	3	0.016	0.656	0.027	0.000	0.328	3

Table 8. The TOPSIS results

	FAHP-TOPSIS				Equal weighted TOPSIS			
	d_i^+	d_i^-	C_i	Ranking	d_i^+	d_i^-	C_i	Ranking
LVL	0.020	0.014	0.419	3	0.015	0.017	0.518	1
PSL	0.015	0.016	0.528	1	0.015	0.016	0.517	2
LSL	0.018	0.019	0.520	2	0.019	0.015	0.448	3

When the results of the FAHP-TOPSIS analysis are examined, it is seen that PSL (0.528) is the best alternative. According to the results of the equal weighted TOPSIS analysis, the ranking of the SCL products in descending order with respective weights is LVL (0.518) > PSL (0.517) > LSL (0.448). Borda is employed due to different ranking results. Consequently, the ranking of the alternatives is as follows: {LVL – PSL – LSL}. In light of the results, it can be said that LVL is the best SCL product.

In Sizüçen's work, the experimental results of LVL, PSL, and LSL are reported. However, the ranking of them is not reported. This shortcoming is eliminated by the MCDM analysis.

4. Conclusion

The objective of this study is to evaluate LVL, PSL, and LSL by taking into account their physical and mechanical properties. In order to achieve the objective, an evaluation model containing FAHP, EDAS, and TOPSIS is proposed. FAHP is used to obtain the weights of the criteria. The weights are used in EDAS and TOPSIS to determine the ranking of the alternatives. Borda is employed to incorporate the ranking results. According to the results, the first three important subcriteria are density, bending strength, and modulus of elasticity. Moreover, it can be said that LVL possesses better properties when compared with PSL and LSL. Consequently, the evaluation model proposed in this study can provide beneficial insights for researchers in terms of the evaluation of wooden materials.

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LOCATION SELECTION FOR THE FURNITURE INDUSTRY BY USING A GOAL PROGRAMMING MODEL

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Abstract

The location of a facility plays a significant role in minimizing costs and maximizing the utilization of resources. Therefore, in this study, a goal programming model was proposed to determine an appropriate location for the furniture industry. Seven provinces in the Western Black Sea Region of Turkey were considered as candidate places. The objectives of this study were identified as follows: proximity to raw materials, the number of qualified people, proximity to markets, population, and distances to other provinces in the region. The proposed model was solved using an optimization tool. The results demonstrated that Karabük was the best choice. Consequently, the model proposed in this study can be used as a guideline for furniture firms.

Keywords: Goal programming, Facility location problem, Furniture industry, Western Black Sea Region, Turkey

1. Introduction

The furniture industry is a labor-intensive and dynamic sector. It includes the manufacturing of furniture parts and their assembly with appropriate finishing operations. Wood, medium density fiberboard, plywood, hardboard, and oriented strand board are some basic materials used in the furniture industry (Gordić et al., 2014). One of the countries that have abundant raw materials for furniture production is Turkey. The emergence of the furniture industry in Turkey dates back to the nineteenth century. The Turkish furniture industry has developed along with rapid globalization. The country's furniture industry is mainly divided into wooden furniture (massive and veneered), metal furniture, and others. The number of companies engaged in furniture production is 33,924 and the number of employees in the sector is 151,904 (Web-1). The furniture sector has a share of ~10% of the Turkish manufacturing industry (Karademir and Koc, 2020).

One of the most important problems faced by furniture manufacturing companies is location selection. Facility location selection is the determination of the best geographic location for a facility. The decision-making process includes the identification, analysis, evaluation, and selection among options (Ertuğrul and Karakaşoğlu, 2008). Location selection is a vital strategic decision owing to its important effects on the economic operation of plants and the sustainable development of regions (Govindan et al., 2016; Johansson and Olhager, 2018). Wrong selection results in inadequate qualified work forces, unavailability of raw materials, increased operating expenses or disastrous effects due to political and societal interferences (Mousavi et al., 2013). Hence, it is important to develop location strategies for business units such as factories, distribution centers, and stores.

Facility location problems have been studied for many years. Many different decision-making methods have been used to solve these problems. Safari et al. (2012) employed a fuzzy extension of the TOPSIS method for facility location selection. Cebi and Kahraman (2013) selected an appropriate wind energy plant location by employing the Choquet integral. Ozgen and Gulsun (2014) solved the capacitated multi-facility location problem by using the probabilistic linear programming approach and the fuzzy analytic hierarchy process (AHP). Chadawada et al. (2015) utilized the AHP-QFD approach to select the best facility location. Güler et al. (2016) used the goal programming (GP) approach to determine the optimal location of a feed factory. Mahmud et al. (2016) determined the most appropriate location of a mango supplying business by employing the AHP method and the analytic network process (ANP). Bolturk and Kahraman (2018) proposed the interval-valued intuitionistic fuzzy combinative distance-based assessment for wave energy facility location selection. Kheybari et al. (2019) used the best-worst method to determine the optimal location of a bioethanol facility. Yücenur et al. (2020) employed the step-wise weight assessment ratio analysis and the complex proportional assessment to select the best location for a biogas facility. Seker and Aydin (2020) evaluated different locations for hydrogen production plants by using the Entropy-TOPSIS approach extended with interval-valued Pythagorean fuzzy sets.

There are also some studies seeking solutions to such problems in the field of wood science. Azizi and Modarres (2007) used the ANP method to evaluate different locations for plywood and veneer plants. Imren et al. (2016) determined the optimal location of a furniture company by employing the AHP method. Azizi and Ramezanzadeh (2016) employed the AHP method to select the best location for the particleboard industry. Üçüncü et al. (2017) selected the best location for the furniture industry by employing the TOPSIS method. Azizi (2017) used the TOPSIS method for the location selection of solar wood drying units. Yeşilkaya (2018) utilized AHP, TOPSIS, and PROMETHEE to determine the optimal location of a paper factory.

In the present study, the GP approach is employed for the location selection problem of a furniture manufacturing company in Turkey. Hence, this study contributes to the existing literature by introducing the use of the GP approach on determining the most appropriate location for the furniture industry. The study will help the furniture industry in improving the effectiveness of decision-making processes on the identification of the best facility location.

2. Materials and Methods

2.1. Study Area and Data Collection

This paper focuses on the determination of the most appropriate facility location for the Turkish furniture industry. The Western Black Sea Region of Turkey is selected as the study area. The region consists of the following provinces: Kastamonu, Düzce, Bolu, Zonguldak, Bartın, Karabük, and Sinop. Figure 1 shows the study area.

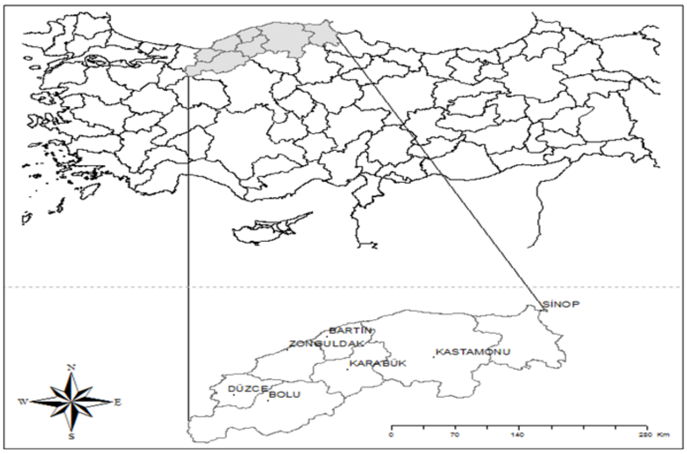

Figure 1. The study area

Within the model, five evaluation criteria are defined as proximity to raw materials, the number of qualified individuals, proximity to markets, population, and distances to the provinces in the region. To analyze the alternatives and to solve the location selection problem, data are required for possible facility locations. The data of this study are obtained from the General Directorate of Turkish Highways (Web-2), the Turkish Statistical Institute (Web-3), and Google Maps (Web-4). Figure 2 illustrates the criteria used in this study.

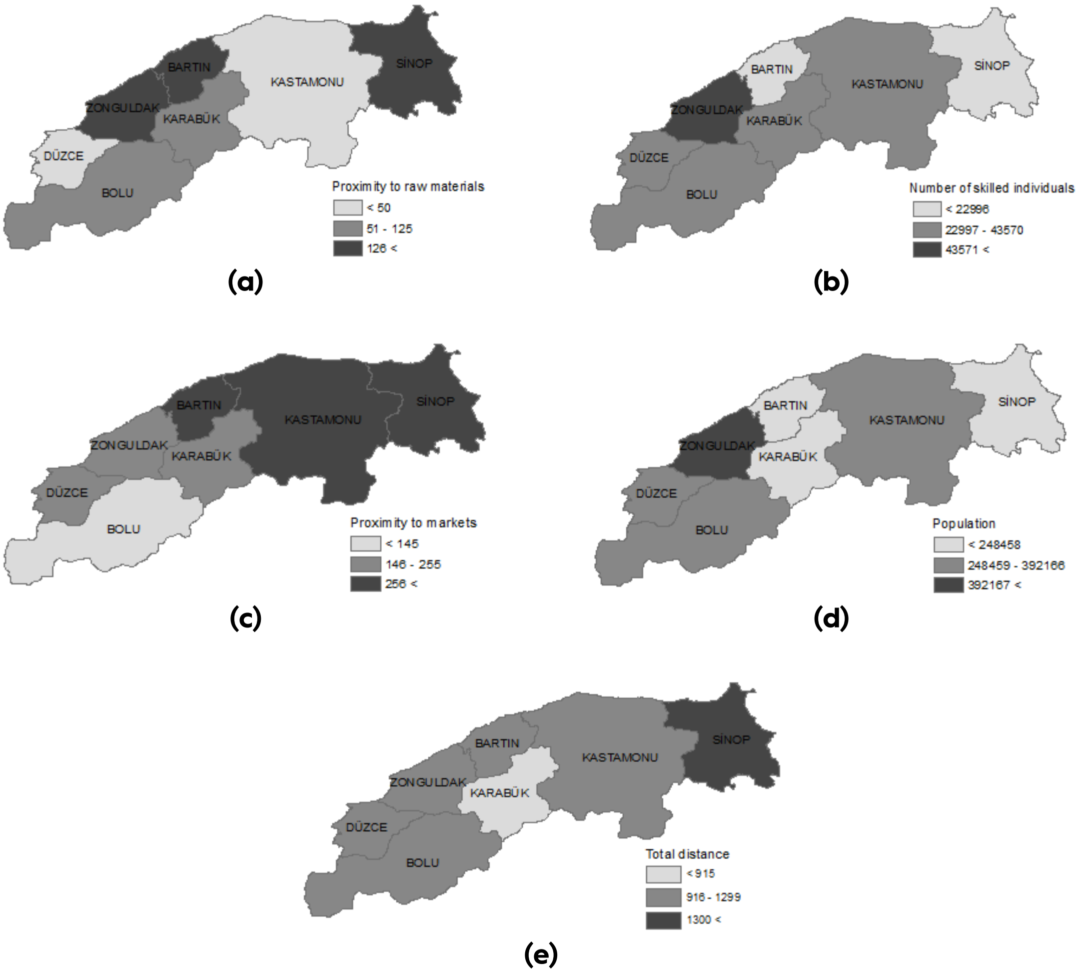

Figure 2. The criteria used in this study: (a) proximity to raw materials, (b) the number of qualified individuals, (c) proximity to markets, (d) population, and (e) distances to the provinces in the region

2.2. Goal Programming

GP is an important class of multicriteria decision models. The GP approach can be employed to obtain satisfying solutions for multiple and contradictory objectives (Gür and Eren, 2018; Ruben et al., 2020). GP attempts to minimize deviations from goals and determines a point that satisfies these goals. The achievement function is the key element of a GP model. This function represents the mathematical expression of unwanted deviation variables (Diaz-Balteiro et al., 2013). The mathematical structure of a GP model is as follows (Özcan et al., 2017):

$$\text{Min } Z = \sum_{i=1}^{m} (d_i^+ + d_i^-) \tag{1}$$

$$\sum_{j=1}^{n} a_{ij}x_j - d_i^+ + d_i^- = b_i, \qquad i = 1, \dots, m,\ j = 1, \dots, n \tag{2}$$

$$d_i^+, d_i^-, x_j \geq 0 \tag{3}$$

where x_j is the decision variable, a_{ij} is the coefficient of the decision variable, b_i is the aspiration level, and d_i^+ and d_i^- are positive and negative deviations, respectively.

According to Rifai (1996), the key steps of the GP structure can be explained as follows: identification of goals, conversion of these goals into constraints, examination of each goal to determine correct deviation variables, and establishing a hierarchy of importance among goals. Once the above-mentioned steps are completed, the decision-making problem can be quantified as a GP model. Table 1 shows the general structure of this model (Karagül, 2018).

Table 1. The general structure of a GP model

Goal	Acceptable situation	Deviation variable to be minimized
$a_{ij}x_j \leq b_i$	Underachievement	d_i^+
$a_{ij}x_j \geq b_i$	Overachievement	d_i^-
$a_{ij}x_j = b_i$	Exactly achievement	$d_i^+ + d_i^-$

3. Application

The GP approach attempts to minimize the total deviation of targets. This approach considers all of the targets simultaneously by establishing an achievement function that minimizes deviations from targets (Choudhary and Shankar, 2014). Therefore, this study employs a GP model to determine the most appropriate facility location for furniture production. The study area is the Western Black Sea Region of Turkey. Kastamonu, Düzce, Bolu, Zonguldak, Bartın, Karabük, and Sinop are considered as candidate locations (see Figure 1). The criteria determined to evaluate the alternative locations are proximity to raw materials, the number of qualified individuals, proximity to markets, population, and distances to the provinces in the region. The proposed approach applied to the location selection problem of the furniture industry is displayed in Figure 3.

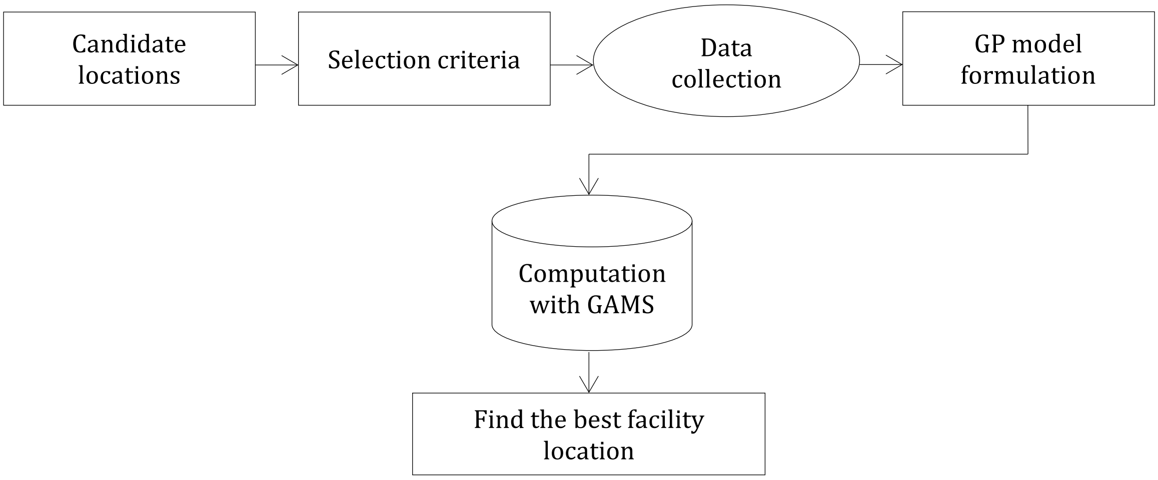

Figure 3. The procedure for location selection

Several objectives are defined to establish the mathematical model. The objectives involved in this study are as follows:

Goal 1: Minimizing the distance between the facility and the source of raw materials

Goal 2: Minimizing the distance between the facility and the market

Goal 3: Minimizing the distance of the facility to the provinces in the region

Goal 4: Minimizing the distance between the facility and the skilled-labor abundant locations

Goal 5: Minimizing the distance between the facility and the densely populated places

Once the objectives of the study are defined, the mathematical model is formulated. The mathematical formulation of the proposed GP model and the notations employed in this model are presented below.

Notations

i, j : provinces

k: goals

$$x_i = \begin{cases} 1 & \text{if there is a facility at location } i \\ 0 & \text{otherwise} \end{cases}$$

d_{ij}: Distance between facility location i and province j

r_i: The distance of facility location i to the source of raw materials

m_i: The distance of facility location i to the market

u_i: The distance of facility location i to the provinces

b_j: The number of qualified individuals in province j

h_j: The population of province j

P_k: Priority level

d_k^+: Positive deviation variable for the kth goal

d_k^-: Negative deviation variable for the kth goal

Mathematical Model

$$\text{Min } Z = \sum_{k=1}^{5} P_k d_k^+ \quad (4)$$

$$\sum_{i=1}^{7} r_i x_i + d_1^- - d_1^+ = 0 \quad (5)$$

$$\sum_{i=1}^{7} m_i x_i + d_2^- - d_2^+ = 0 \tag{6}$$

$$\sum_{i=1}^{7} u_i x_i + d_3^- - d_3^+ = 0 \tag{7}$$

$$\sum_{j=1}^{7} b_j \sum_{i=1}^{7} d_{ij} x_i + d_4^- - d_4^+ = 0 \tag{8}$$

$$\sum_{j=1}^{7} h_j \sum_{i=1}^{7} d_{ij} x_i + d_5^- - d_5^+ = 0 \tag{9}$$

$$\sum_{i=1}^{7} x_i = 1 \tag{10}$$

$$d_k^+, d_k^- \geq 0 \;\; k = 1, \dots, 5 \tag{11}$$

$$x_i \in \{0,1\} \;\; i = 1, \dots, 7 \tag{12}$$

Equation (4) is the objective function of the GP model. The aim of the GP model is to minimize the sum of the positive deviations. Constraint (5) attempts to minimize the distance between the facility and the source of raw materials. Constraint (6) tries to minimize the distance between the facility and the market. Constraint (7) ensures a low distance between the facility and the provinces in the region. Constraint (8) attempts to minimize the distance of the facility location to the skilled-labor abundant locations. Constraint (9) tries to minimize the distance between the facility and the densely populated places. Constraint (10) indicates that the facility will be located in only one location. Lastly, constraints (11) and (12) ensure the non-negativity and binary restrictions on the decision variables.

The GP model described above is used to determine the best facility location. The codes required to solve the facility location selection problem are written in GAMS. The results of the analysis are summarized in Table 2. From Table 2, it is possible to see that the solutions obtained by the GP model are $x_6 = 1$ and $x_1 = x_2 = x_3 = x_4 = x_5 = x_7 = 0$. The results indicate that Karabük is the best place for building a furniture manufacturing plant.

Table 2. The results of the GP model

Variable	Level	Marginal
x_1	0	4.7423E+8
x_2	0	4.2018E+8
x_3	0	4.0485E+8
x_4	0	3.4066E+8
x_5	0	3.9870E+8
x_6	1	3.3145E+8
x_7	0	8.5451E+8

The demand for furniture products has increased in parallel with the increase in human population. Furniture manufacturing companies should choose the most suitable location to meet their customers' expectations at minimum costs and to support their long-term competitive structures. In order to select the best location, decision-makers should apply an appropriate method. The contribution of this paper is the presentation of an effective approach for solving the location selection problem of furniture manufacturing companies. With the help of GP, decision-makers could get an alternative ranking list in solving the problem.

4. Conclusion

Selection of the most appropriate location for the furniture industry is an important phase in the construction process because the results of this decision can have long-term effects on various factors such as profitability, accessibility, and sustainability. Developing a location selection model is needed for decision-makers to avoid undesired negative results. In this study, a GP model is proposed to determine an appropriate location for the Turkish furniture industry. Kastamonu, Düzce, Bolu, Zonguldak, Bartın, Karabük, and Sinop are evaluated using the following criteria: proximity to raw materials, the number of qualified individuals, proximity to markets, population, and distances to the provinces in the region. The proposed model is solved via an optimization tool. Based on the results of this study, it can be said that Karabük is the most appropriate location. Consequently, the proposed GP model can present a road map for decision-makers to make a dispassionate and objective location selection. In further research, this model can be combined with different decision-making methods to have an integrated decision support system that may assist decision-makers for the evaluation of candidate locations.

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DECAY RESISTANCE OF WEATHERED BEECH WOOD

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Abstract

Wood is susceptible to photo-degradation in outdoor applications, and deformations occur on its surface such as micro or macro cracks, color changes etc. Especially, cracks make wood material more vulnerable to biotic attacks. In this study, decay resistance of natural and accelerated weathered beech samples was investigated by a brown *(Coniophora puteana)* and white rot *(Coriolus versicolor)* fungi attacks. For this purpose, beech samples exposed to natural weathering (NW) for 393 days, and accelerated weathering (AW) for 1512h, and then subjected to decay test in malt extract agar medium for 2 and 4 weeks. After 2 weeks of decay testing, weight loss of samples by *C. versicolor* was found to be 24.30% for controls, 13.29% for AW samples and 24.38% for NW samples. In the case of *C. puteana*, it was found as 21.15%, 21.49% and 30.61% for controls, AW samples and NW samples, respectively. Weight loss of samples by *C. versicolor* was found to be 61.82% for controls, 30.72% for AW samples and 37.62% for NW samples, after 4 weeks of decay testing. The weight loss by 4 weeks exposure of *C. puteana* was found to be 21.43%, 28.44% and 37.67% for controls, AW samples and NW samples, respectively. Natural weathering caused more weight loss than accelerated weathering test for both fungi species.

Keywords: White rot, brown rot, natural weathering, accelerating weathering, beech.

1. Introduction

During outdoor exposure, wood may undergo serious changes of its physical and structural properties due to the combined effect of sunlight (UV), oxygen, moisture, atmospheric pollutants and microorganisms. The combination of oxygen and UV rapidly causes the oxidation of lignin and hemicellulose, and depolymerisation of cellulose. Most of the reaction products are water soluble, so they are easily removed from the wood surface by rain, resulting in weight loss, roughness and color changes (Xie et al., 2005; George et al., 2005; Evans, 2008; Lionetto et al., 2012). Weathering studies of wood can be both performed in laboratory and real outdoor conditions. Laboratory weathering test also known as artificial weathering test includes ultraviolet light and moisture cycles, and this procedure is generally accepted as a simulation of outdoor conditions. However, in reality there are many other degradation factors in outdoor such as colonization of microorganisms, aerosols, mechanical effects of wind, human, etc. Therefore, both experiments in laboratories and outdoor exposure tests in ground and above ground situations are essential for service life assessment of wood (Metsa-Kortelainen et al., 2017; Brischke and Meyer-Veltrup, 2015; Tomak et al., 2018).

In outdoors, wood undergoes biological decay by white, brown and soft rot fungi. Basidiomycetes are responsible for most of wood decay (Bari et al., 2015). During exposure to fungal attack, significant changes occur in wood chemical composition, resulting in significant weight loss, mechanical strength loss and aesthetical defects. Weathering tests prior to decay tests can accelerate wood degradations, and can help the simulating of outdoor degradations in shorter time. The combination of the weathering tests and decay tests may become a new strategy to test wood preservatives in future. Studies on decay test of wood and/or wood based composites after weathering tests showed that weathering affected decay process. Catto et al. (2016) investigated the effect of natural weathering and decay test by *Trametes villosa*, *Trametes versicolor*, *Pycnoporus sanguineus* and *Fuscoporia ferrea*. The results showed that natural weathering accelerated fungal degradation by influencing fungal growth. Decay resistance of weathered albizzia and sugi wood samples was studied by Sudiyanni et al. (1996). They found that weathered samples had higher weight loss than control samples. In another study, oak wood was naturally and artificially aged, and then, were inoculated with brown and white rot fungi. In that study, brown-rot caused greater change in weight-loss in naturally aged samples than white-rot did (Chow and Bajwa, 1998). Reinprecht and Grznárik (2015) reported that the artificial ageing decreased the the decay resistance of the modified or the modified and painted pine sapwood. Decay test of weathered beech samples showed that samples had darker color than that of controls due to the weight loss after *C. puteana* attack (Reinprecht and Hulla, 2015).

In this study, decay resistance of natural and accelerated weathered beech samples was investigated by a brown *(Coniophora puteana)* and white rot *(Coriolus versicolor)* fungi. Samples were exposed to natural weathering (NW) for 393 days, and accelerated weathering (AW) for 1512h, and then were subjected to decay test in malt extract agar medium for 2 and 4 weeks. Weight loss of samples was compared with un-weathered samples (control).

2. Materials and Methods

2.1. Materials

Beech samples were obtained from Sulekler Forest Industry, Bursa, Turkey. Samples with dimensions of 2 mm (radial) x 75 mm (tangential) x 150 mm (longitudinal) were prepared for artificial and natural weathering tests. After weathering tests, the samples were cut into 2 mm (radial) × 5 mm (tangential) × 30 mm (longitudinal) for the decay test. Samples without any visible defects such as cracks, strain and knots were selected prior the experiments, and then oven-dried. Malt extract agar sourced from Merck (Darmstadt, Germany).

2.2. Method

2.2.1. Artificial weathering

Artificial weathering was carried out in the Atlas UV Test machine (Illinois, USA) according to ASTM G154 (2016) standard. The weathering cycle consisting of a continuous UV (340 nm, 0.89 W/m^2) for 8 h at 60 °C followed by a condensation for 4 h at 50 °C was applied for 1512 h.

2.2.2. Natural weathering

Samples were exposed to outdoor conditions in south at an angle of 45° to the horizontal in Bursa Technical University campus with an altitude of 162 m in Bursa, Turkey for the period from November 2018 to November 2019 according to ASTM G7 (2013) and EN 927-3 (2003) standards.

2.2.3. Decay test

The decay test was performed according to EN 113 (1997) principles, with some changes in sample size and kolle flasks. 6 replicates were used for each group. Malt extract agar solution of 4.8% concentration, and the samples were sterilized in an autoclave (Tomy SX700, Japan) at a pressure of about 0.1 MPa at 120 °C for 25 min. Fungi cultures of the brown rot fungus *Coniophora puteana* (Schumach.) P. Karst. (Mad-515) and white rot fungus, *Coriolus versicolor* (Linnaeus) Quelet (1030) were inoculated to sterile malt extract agar medium in the petri dishes. Samples were incubated at 20 °C and 70% RH for 2 and 4 weeks. After the test, oven dry weights of samples were determined. The weight loss was calculated by the following equation:

Weight loss (%) = (Mint-Mend/ Mint) × 100

Where,

M is the weight of the samples and the subscripts "int" and "end" refer to the oven-dry weight at 103 °C before and after the decay test, respectively.

3. Results and Discussions

The weight loss of the samples is illustrated in Fig. 1 for *C. versicolor*, and Fig. 2 for *C. puteana* attack. The weight loss of control samples showed that the decay test was valid, and the test conditions were suitable for growth of the fungi. Test fungi showed suitable growth and colonization of the mycelium on all samples.

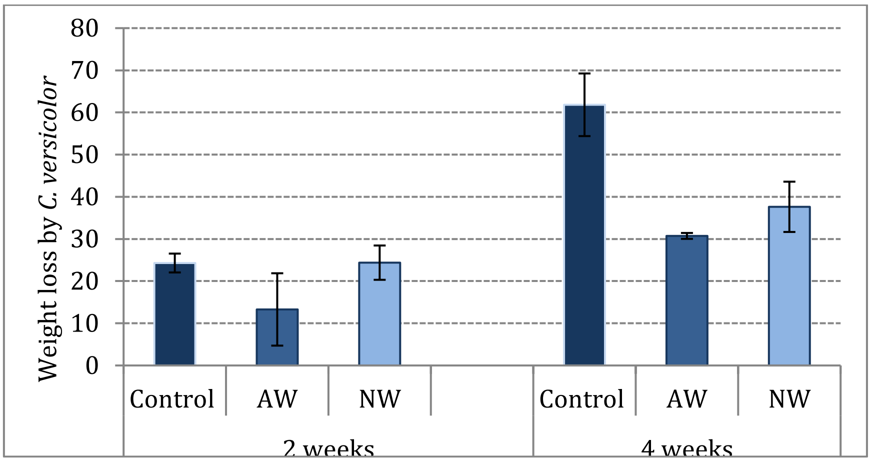

Fig. 1. Weight loss of samples caused by *C. versicolor* attack

After 2 weeks, natural weathering and control samples degraded almost similarly around 24% by *C. versicolor* attack. Fungal degradation was found to be less in the artificial weathering samples (13.29%) than in the others. This may be explained by the rapid degradation of the chemical components of wood due to artificial degradation. Samples thickness was around 2mm, and this could accelerate the photo-degradation. At the end of the 4 weeks, the weight loss of beech samples was 61.82, 30.72 and 37.62% for control, artificial weathering and natural weathering samples, respectively (Fig. 1). Panek et al. (2014) stated that beech sample of artificial weathering exhibited less weight loss than the untreated control samples. At the end of the test, natural weathering samples did not lose as much weight as control samples. It may be concluded that the chemical components in the control samples are higher than the weathering samples, and thus may create a more suitable medium for fungi growth.

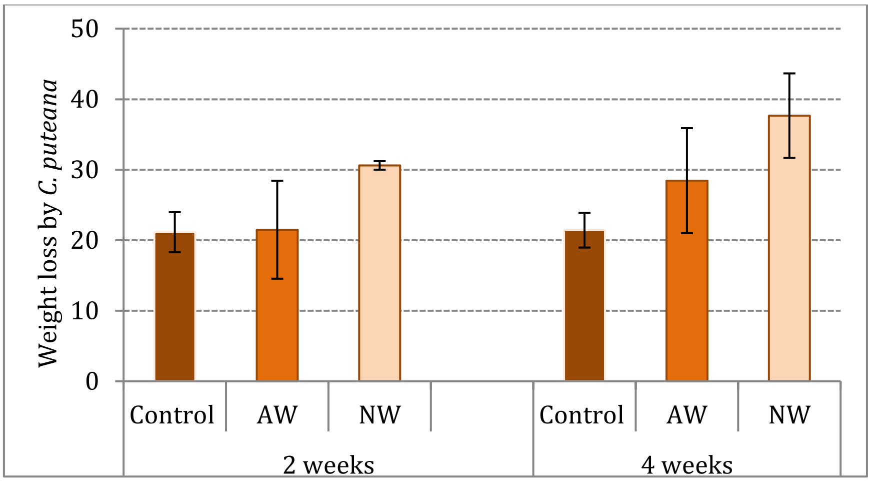

Fig. 2. Weight loss of samples caused by *C. puteana* attack

Artificial weathering and control samples degraded almost similarly after 2 weeks of *C. puteana* exposure. At the end of the 4 weeks, the weight loss of beech samples was 21.43, 28.44 and 37.67% for control, artificial weathering and natural weathering samples, respectively. Natural weathering samples degraded more than artificial weathering and control samples. Cracks and voids in the natural weathered samples could cause an entrance for fungi mycelium, an increase in the moisture uptake during the decay test, and therefore an increase in weight loss.

In Fig. 1, control samples showed higher weight loss than weathered samples however in Fig. 2, weathered samples had higher weight loss than controls. The decay mechanism of *C. versicolor* and *C. puteana* might be the main reason for this finding.

4. Conclusion

In the study, effect of natural and artificial weathering on decay resistance of beech samples was investigated. The results showed that fungi species and weathering types affected the decay resistance of samples. 4 weeks of exposure to *C. versicolor* caused more weight loss than *C. puteana* for all samples. In all cases natural weathering samples exhibited less decay resistance than artificial weathering samples.

5. Acknowledgments

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WATER ABSORPTION, ANTI-SHRINK EFFICIENCY AND DECAY RESISTANCE OF TREATED WOOD BY SILICA BASED SOLUTIONS

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Abstract

In this study, the effect of two different silica (SiO_2) based solutions on water absorption, anti-shrink efficiency and decay resistance of Scots pine wood was studied. Sol-gel process was used in order to prepare SiO_2 based solutions. One of the SiO_2 based solutions (Sol-gel 1) was prepared by using tetraethoxysilane (TEOS), ethanol and de-ionized water (TEOS:H_2O=1:1/2). The same precursors was used for preparing the other solution (Sol-gel 2) but with a different molar ratio of TEOS:H_2O=1:4. Scots pine wood samples were first vacuum impregnated with the solutions and then cured. The level of water absorption and anti-shrink efficiency were determined with cyclical wetting tests, total of 14 days. Samples were exposed to brown rot fungus, *Coniophora puteana* attack according to EN 113 standard to determine the best SiO_2 based solution for sufficient decay resistance. Leached samples were also suspected to decay test in order to evaluate any loss in effectiveness in decay resistance due to possibility of silica leaching. Both solutions had similar weight percent gains in wood, around 25%. SiO_2 treated samples decreased water absorption of wood as 20% in comparison with un-treated controls. Anti-shrink efficiency of wood was found as 26% for Sol-gel 1 solution and 35% for Sol-gel 2 solution at the end of the test. Decay resistance of treated samples was in the range of 63-91% in comparison with controls. Sol-gel 2 solution were found efficacious in suppressing *Coniophora puteana* attack when no leaching prior the decay test was used, however, Sol-gel 1 solution seemed to be ineffective against fungus attack that exhibited more than 3% weight loss. Leached samples had higher weight loss than un-leached samples. The remained silica inside leached wood supposed to be not sufficient enough to prevent brown rot fungus attack on wood. Results clearly showed Sol-gel 2 solution had better water absorption and anti-shrink efficiency rates, and decay resistance than Sol-gel 1 solution.

Keywords: Scots pine, sol-gel, decay resistance, anti-shrink efficiency, water absorption.

1. Introduction

Wood has been used as an environmentally friendly material in indoor and outdoor applications. However, wood has disadvantages such as biodegradability, dimensional instability, flammability and photo-degradation. To overcome those disadvantages, appropriate preservation methods are needed. Due to increasing environmental concerns, new methods and chemicals are still searching to be an alternative to traditional ones.

One of the strategies of the recent studies is to protect wood with using inorganic silicon compounds. Actually, silanes are known as modifying agents in the plastic, textile, construction and paper industries. They are used for hydrophobization of ceramics, scratch resistant surfaces, soil proofing and anti-graffiti coatings, or as an adhesion promoter between organic and inorganic materials (Donath et al., 2004). Wood treated with tetraalkoxysilanes showed improved dimensional stability, durability and fire resistance to a certain degree (Mai and Militz, 2004). In addition, wood treatment with tetraethoxysilane and alkyltriethoxysilanes provide strong hydrophobicity and partial fungal resistance (Donath et al., 2004; Mai and Militz, 2004; Gholamiyan et al., 2015). Donath et al. (2004) compared performance properties of wood samples impregnated with three different sol-gel precursors, namely: TEOS, methyl triethoxysilane, and propyl triethoxysilane. They observed that wood properties – such as cell wall bulking, anti-swelling efficiency, moisture uptake, and durability – improved significantly in wood samples treated with the monomeric sol-gel precursors compared to those samples that were treated with oligomeric sol-gel particles. Sebe et al. (2004) showed that n-propyl-trimethoxysilane reacted by alcoholysis with hydroxyl groups present in the wood substrate. This study showed that despite the sensitivity of the C-O-Si bond to hydrolysis, a significant amount of silane remained in the wood even after 14 days in water. Tanno et al. (1998) investigated the application of sol-gel formulations to wood to increase its dimensional stability and resistance to termites and fire, and also developed a sol-gel system that increases the fungal resistance of wood. In that study, the sol-gel system consists of tetraethoxysilane (TEOS) precursor mixed with small amounts of 2-heptadecafluorooctyl trimethoxysilane and 3- (trimethoxysilyl) -propyl- (carboxymethyl) - desylmethyl ammonium hydroxide. In the study of Saka and Tanno (1996), TEOS as a silane component was compared with methyltrimethoxysilane (MTMOS). The weight percent gain (WPG) of wood treated with MTMOS and TEOS was similar, but MTMOS resulted in a higher volume although the concentration in the impregnation solution was lower.

In this study, the effect of two different silica (SiO_2) based solutions on water absorption, anti-shrink efficiency and decay resistance against *C. puteana* attacks of Scots pine was investigated.

2. Materials and Methods

2.1. Materials

Wood samples from sapwood of Scots pine (*Pinus sylvestris* L.) with dimensions of 15 mm (radial) x 5 mm (tangential) x 30 mm (longitudinal) were prepared for the study. Samples without any visible defects such as cracks, strain and knots were selected for the experiments, and then oven-dried prior the treatments. Tetraethoxysilane (TEOS) and ethanol were sourced from Sigma Aldrich (St. Louis, MO, USA). Two SiO_2 based solutions were prepared. One of the SiO_2 based solutions (Sol-gel 1) was prepared by using TEOS, ethanol and de-ionized water ($TEOS:H_2O=1:1/2$). The same precursors was used for preparing the other solution (Sol-gel 2) but with a different molar ratio of $TEOS:H_2O=1:4$.

2.2. Method

The samples were first vacuum impregnated with solutions at 700 mmHg for 45 min, and were then immersed in the solutions for 60 min at atmospheric pressure. The samples were cured at 100°C for 24h. Weight percent gain of the samples (WPG, %) was calculated on the basis of the oven dry weight of samples before and after impregnation. Then, samples were conditioned at 20°C and 65% RH for 2 weeks.

Six replicates of treated and untreated wood samples were placed into beakers filled with deionised water. After defined times (24h, 48h, 72h, 96h, 120h, 144h, 168h and 336h), the samples were removed from the water, dabbed of with tissue and weighed. The dimensions of the samples were measured. This procedure continued for a total of 14 days. Relative water uptake (WA, %) (Eq. 1) and anti-shrink efficiency (ASE, %) (Eq. 2) were determined.

$WA = [(W2- W1) / W1] \times 100$ (1)
$ASE = [(Su- S) / Su] \times 100$ (2)
Where,
W2 = wet weight of wood samples after wetting with water
W1 = initial dry weight
Su = volumetric swelling of untreated wood
S = volumetric swelling of treated wood

Decay test was performed according to principles of EN 113 (1997) both for leached (L) and unleached (UL) samples with 6 replicates for each group. Water immersed samples were used as leached samples. Brown rot fungus, *Coniophora puteana* (Schumach.) P. Karst. (Mad-515) was used in the test. Malt extract agar of 4.8% concentration and samples were sterilized in an autoclave at pressure of about 0.1 MPa at 120°C for 25 minutes. Fungi cultures were inoculated to sterile malt extract agar medium in the petri dishes. After incubation period of inoculated petri dishes, one impregnated and one control samples were placed on the growing mycelium in each petri dish. The petri dishes were then incubated at 20ºC and 70% RH for 8 weeks. After the test, all wood samples were removed from the petri dishes and cleaned from the surface mycelium. Then, they were dried at a temperature of 103±2°C, weighed, and the weight loss (WL, %) was calculated on the basis of oven dry weight before the test. Decay resistance of impregnated samples defined as a percentage change was calculated based on the weight loss of control samples.

3. Results and Discussion

3.1. Weight gain (WPG), water absorption rate (WA) and anti-shrink efficacy (ASE)

Weight percent gain of samples was found to be 25.02 (±1.99) and 26.29 (±2.53)% for sol-gel 1 and sol-gel 2, respectively. Both solutions had similar weight percent gains in wood.

The average values of water absorption and anti-shrink efficiency of samples are shown in Figs. 1 and 2. Water absorption of the control samples increased from 69.48% to 155.04% during immersion in water. All treated samples had lower water absorption than that of the controls after 14 days. Impregnated samples had water absorption rate from 93.11 to 124.65%. At the end of the water immersion test, treated samples decreased water absorption of wood as 20% in comparison with controls. In the beginning periods of the test, up to 120h, treated samples absorbed more water than controls. A continuous increase was observed on absorbed water by controls while a slight increase on WA values was observed with treated samples along with water immersion periods. A remarkable difference on WA was not observed between two solutions. Donath et al. (2006) found that water repellence of samples treated with three types of silanes strongly diminished after a longer submersion time (24 h). It was reported that the reduction in hydrophobicity after longer submersion time was not caused by removal of silanes during submersion. This was explained by continued condensation of unreacted silanol groups in the aqueous functional silanes during the wetting-drying cycles.

Anti-shrink efficiency of Sol-gel 1 was found to be 32.12% for 24h and 25.90% for 336h. In the case of Sol-gel 2, it was found as 40.56 and 35.04% for 24h and 336h, respectively. The ASE values decreased during 72h but then they tend to increase slightly until the end of the test. The reduction of ASE from beginning to end of the test was 19% for Sol-gel 1 and 14% for Sol-gel 2. This could be due to Si–O–C-bonds are susceptible to hydrolysis (Brinker and Scherer 1990). Sol-gel 2 exhibited better dimensional stability than Sol-gel 1. Sol-gel 2 might penetrate and polymerize in the wood better than Sol-gel 1 since it was prepared with less molar ratio of TEOS to H_2O (1:4). High rate of un-reacted silanol groups might presence on wood impregnated with Sol- gel 1.

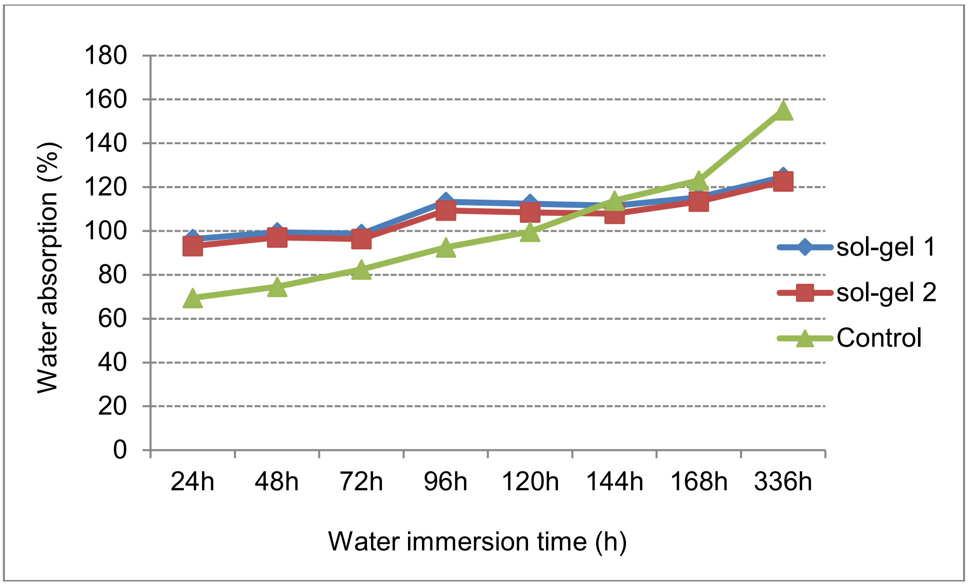

Fig. 1. Water absorption of samples during 14 days of water immersion

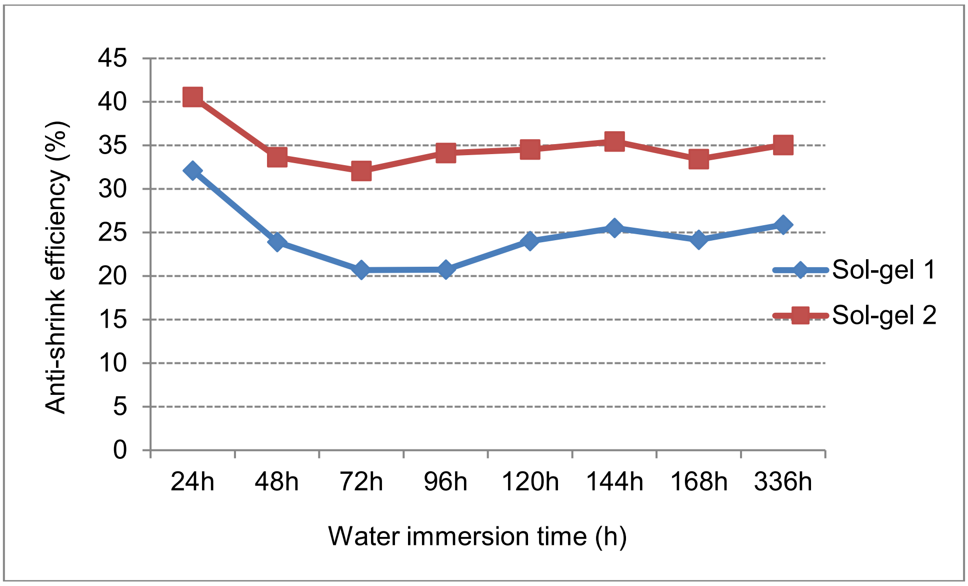

Fig. 2. Anti-shrink efficiency of samples during 14 days of water immersion

3.2. Decay resistance of samples

Fig. 3 summarizes the average values and standard deviations of the weight loss caused by *C. puteana* attack. The control samples were severely degraded by the fungus. The weight loss of the control samples was found to be greater than 25%. All treated samples exhibited better decay resistance than controls. Weight loss of samples treated with Sol-gel 1 was higher than required a maximum weight loss (3%) for a candidate wood preservative according to EN 113 (1997). Anti-fungal effect could not be proven, the slightly improved decay resistance was achieved by water repellency. Sol-gel 2 was found efficacious in suppressing *C. puteana* attacks when no leaching prior the decay test was used, however, it seemed to be ineffective after leaching. This probably related with hydrolysis and condensation reaction of silanes. This finding is also compatible with ASE results. SEM images can help to understand the protection mechanism of Sol-gel 2 and are needed for further studies.

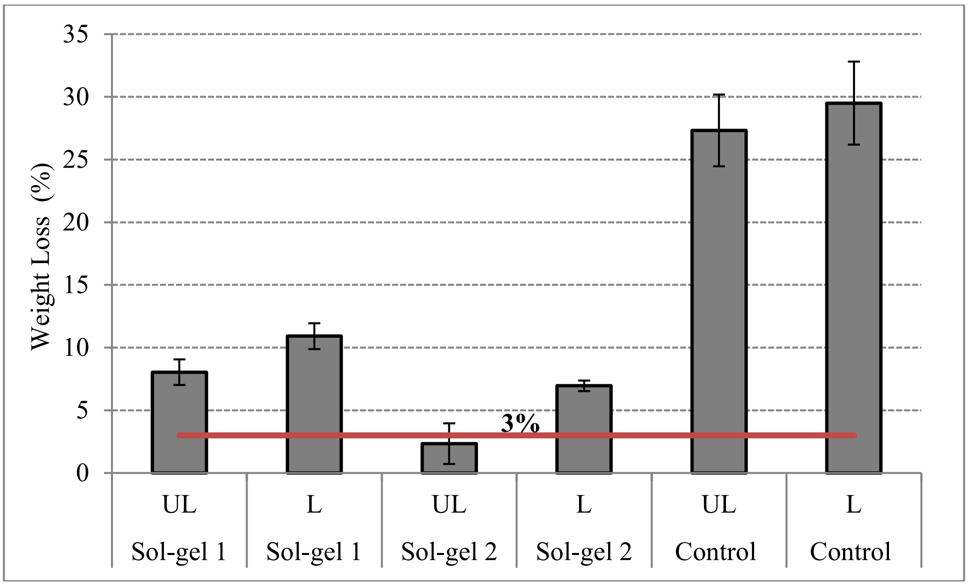

Fig. 3. Weight loss of decayed samples by *C. puteana*

4. Conclusions

In this study, two different silica based solutions were evaluated in order to investigate their water absorption and anti-shrink efficiency rate, and decay resistance against *C. puteana* attacks. Results showed that solutions increase water repellency and dimensional stability of wood. However the efficiency tends to decrease after longer water immersion periods, probably related with hydrolysis of silanes. Sol-gel 2 gives a promising result on preventing attack of *C. puteana*. However after leaching, sufficient decay resistance was not obtained with Sol-gel 2. As a consequently, the performance of the solutions are far poorer than that of the commercially available formulations in outdoors. However, impregnated wood can be used for interior purposes (Hazard class 1) and for internal humid conditions and protected external use (Hazard class 2).

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PREDICTION OF RETENTION LEVEL AND MECHANICAL STRENGTH OF PLYWOOD TREATED WITH FIRE RETARDANT CHEMICALS BY ARTIFICIAL NEURAL NETWORKS

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Abstract

The treatment with fire retardant chemicals is the most effective process to protect wood and wood based products from fire is. Therefore, use of fire retardant chemicals has been increased. However, the fire retardant chemicals have an effect on other physical, mechanical and some technological properties of the materials treated with them. In this study, firstly, the retention level prediction model was developed with the artificial neural network (ANN) to examine the effects of wood species and concentration aqueous solution on the retention levels of veneers. Then, the effects of wood species, concentration aqueous solution and retention level on the mechanical properties of plywood were investigated with the mechanical strength prediction model developed with ANN. The prediction models with the best performance were determined by statistical and graphical comparisons. It has been observed that ANN models yielded very satisfactory results with acceptable deviations. As a result, the findings of this study could be employed effectively into the forest products industry to reduce time, energy and cost for empirical investigations.

Keywords: Artificial Neural Network**,** fire retardant, plywood, concentration, retention level, mechanical properties

1. Introduction

Wood and wood based panels have long used a material in the construction industry because they have a great durability, high strength and versatility (Stevens et al., 2006). Plywood, being a wood based product, one of the most important building and furniture materials (Fateh et al., 2013). Plywood has some advantages when compared to solid wood and other wood panels. Physical properties of plywood are better than other wood panels. Bending strength and screw holding capacity of plywood is very high, and it is resistant to deformation disorders such as distortion or twisting. Since plywood has a homogeneous structure, its shrinkage and expansion are much less than solid wood. There are some unfavorable characteristics of the plywood similar to wood and other wood-based composite panels. It can be combusted easily, and this is one of the undesired characteristics of plywood (Ozkaya et al., 2007).

The flammability and combustibility properties of such a solid material can be reduced recommended several treatments (Fateh et al., 2013). The treatment with fire retardant chemicals is the most effective process to protect wood and wood based products from fire is. Therefore, use of fire retardant chemicals has been increased. It has also risen due to awareness of environmental protection and consumer safety, requirement standards to flame retardants have been raised accordingly. Moreover, capability and properties of fire retardant chemicals such as being harmless to human, animals, and plants and less release of smoke and toxic gases when burned are important parameters for consumer to select a fire retardant chemical. It was also shown the fire retardant chemicals have an effect on other physical, mechanical and some technological properties of the materials treated with them. Inorganic based fire retardant chemicals are extensively used in forest industry because they have both good thermal stability, less release of smoke, corrosive toxic gases and less strength loss (He et al., 2014; Yao et al., 2012).

Determination of the optimum concentration of aqueous solution and retention level without further loss of mechanical strength is also very important from industrial view point. For this aim, a lot of concentration 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).

In this study, firstly, the retention level prediction model was developed with the artificial neural network (ANN) to examine the effects of wood species and concentration aqueous solution on the retention levels of veneers. Then, the effects of wood species, concentration aqueous solution and retention level on the mechanical properties of plywood were investigated with the mechanical strength prediction model developed with ANN.

2. Materials and Methods

2.1. Data Collection

In this experimental study, 2 mm-thick rotary cut veneers with the dimensions of 500 mm by 500 mm were obtained from poplar (*Populus deltoides*), alder (*Alnus glutinosa* subsp. *barbata*) and Scots pine (*Pinus sylvestris* L.) logs. While the alder and poplar veneers were manufactured from freshly cut logs, Scots pine logs were steamed for 12 h before veneer production. The horizontal opening between knife and nosebar was 85% of the veneer thickness, and the vertical opening was 0.5 mm in rotary cutting process. The veneers were then dried to 6–8% moisture content with a veneer dryer. After drying, veneer sheets were treated with some fire retardant chemicals. For this aim, 5, 7 and 10% aqueous solutions of zinc borate, monoammonium phosphate (MAP) and ammonium sulphate were used. The veneers were subjected to re-drying process at 110°C after they immersed in the fire retardant solutions for 20 min. The retention level for each treatment solution was calculated with the following equation.

$$R = \frac{G \times C}{V} \times 10 \ \text{kg/m}^3 \qquad (1)$$

Where
R = Retention level (kg/m^3)
G = treatment solution absorbed by the sample
C = preservative or preservative solution in 100 g treatment solution.
V = volume of sample in cm^3

Three-ply-plywood panels with 6 mm thick were manufactured by using urea formaldehyde resin. The veneer sheets were conditioned to approximately 5-7% moisture content in an acclimatization chamber before gluing. The glue mixture was applied at a rate of 160 g/m^2 to the single surface of veneer by using a four-roller glue spreader. Hot press pressure was 12 kg/cm^2 for alder and 8 kg/cm^2 for scots pine and poplar panels while hot pressing time and temperature were 6 min and 110°C, respectively. Two replicate panels were manufactured for each test groups.

The bonding strength of plywood panels was determined according to EN 314-1 (1998) with a universal testing machine. Samples manufactured with UF resin were tested after immersion in water at 20°C for 24h. The bending strength and modulus of elasticity of plywood panels was determined according to EN 310 (1993) with a universal testing machine.

2.2. Artificial Neural Network (ANN) Analysis

In this study, the retention level and mechanical strength values of plywood were modelled by ANN approach using the data obtained from the literature. First, the change in retention level was modelled depending on the wood species and concentration of aqueous solution. Then, modelling of the change in mechanical strength values based on wood species, concentration of aqueous solution and retention level values was carried out. The proposed ANN models was designed by software developed using the MATLAB Neural Network Toolbox. The data were obtained from the experimental study. In order to examine the effects of related variables on retention level and mechanical strength values; the experimental data were randomly and homogeneously grouped as training and test data, different data sets were created and used to train ANNs. Among these data, 18 samples were selected for ANN training process, while the remaining 9 samples were used to verify the generalization capability of ANN. The data sets used in the training and prediction models are shown in Table 1 and Table 2. The retention level and mechanical strength values results obtained experimentally also presented in Table 1 and Table 2, respectively.

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. 2, the mean absolute percentage error (MAPE) ratio, calculated with Eq. 3 and coefficient of determination (R^2) with Eq. 4 was chosen as the prediction models.

$$\mathrm{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(t_i - td_i\right)^2} \quad (2)$$

$$\mathrm{MAPE} = \frac{1}{N}\left(\sum_{i=1}^{N}\left[\left|\frac{t_i - td_i}{t_i}\right|\right]\right)\times 100 \quad (3)$$

$$\mathrm{R}^2 = 1 - \frac{\sum_{i=1}^{N}(t_i - td_i)^2}{\sum_{i=1}^{N}(t_i - \bar{t})^2} \quad (4)$$

In Equations 2, 3 and 4, t_i is the actual output values, td_i is the neural network predicted values, and N is the number of objects.

Table 1. Training and testing data set and retention level prediction models results

Training Data					
Wood Species	Fire Retardant Chemicals	Concentration Aqueous Solution (%)	Retention Level (kg/m^3)		
			Actual	Predicted	Error (%)
Poplar	Zinc Borate	5	17.118	17.113	0.028
Poplar	Zinc Borate	10	30.243	30.269	-0.084
Poplar	MAP	5	11.233	11.298	-0.580
Poplar	MAP	7	14.219	14.041	1.254
Poplar	Ammonium Sulphate	7	11.594	11.514	0.693
Poplar	Ammonium Sulphate	10	14.660	14.833	-1.183
Alder	Zinc Borate	7	20.107	20.270	-0.809
Alder	Zinc Borate	10	29.053	28.967	0.294
Alder	MAP	5	10.233	10.238	-0.047
Alder	MAP	10	18.601	18.565	0.194
Alder	Ammonium Sulphate	5	9.781	9.520	2.664
Alder	Ammonium Sulphate	7	11.350	11.559	-1.844
Scots pine	Zinc Borate	5	13.800	13.824	-0.175
Scots pine	Zinc Borate	7	19.915	19.907	0.040
Scots pine	MAP	7	18.033	17.655	2.097
Scots pine	MAP	10	23.402	23.979	-2.467
Scots pine	Ammonium Sulphate	5	11.578	11.811	-2.010
Scots pine	Ammonium Sulphate	10	24.993	24.548	1.779
		MAPE	**1.014**		
		RMSE	**0.230**		
Testing Data					
Wood Species	Fire Retardant Chemicals	Concentration Aqueous Solution (%)	Retention Level (kg/m^3)		
			Actual	Predicted	Error (%)
Poplar	Zinc Borate	7	20.854	21.648	-3.805
Poplar	MAP	10	19.514	19.553	-0.200
Poplar	Ammonium Sulphate	5	9.705	9.248	4.707
Alder	Zinc Borate	5	16.324	15.980	2.110
Alder	MAP	7	14.595	13.661	6.401
Alder	Ammonium Sulphate	10	15.254	15.741	-3.192
Scots pine	Zinc Borate	10	26.420	25.938	1.825
Scots pine	MAP	5	12.689	13.656	-7.618
Scots pine	Ammonium Sulphate	7	17.553	17.397	0.886
		MAPE	**3.416**		
		RMSE	**0.602**		

Table 2. Training and testing data set and mechanical strength prediction models results

Wood Species	Fire Retardant Chemicals	C. Aqueous Solution (%)	Retention Level (kg/m^3)	Bonding Strength (N/mm^2)			Bending Strength (N/mm^2)			Modulus of Elasticity (N/mm^2)		
Training Data												
				Actual	Predicted	Error (%)	Actual	Predicted	Error (%)	Actual	Predicted	Error (%)
Poplar	Zinc Borate	5	17.118	1.421	1.425	-0.253	70.870	71.035	-0.233	4891.00	4881.46	0.195
Poplar	Zinc Borate	10	30.243	1.235	1.243	-0.637	60.710	58.914	2.958	4368.00	4367.45	0.013
Poplar	MAP	5	11.233	1.270	1.283	-1.011	71.840	71.984	-0.201	4969.00	5014.80	-0.922
Poplar	MAP	7	14.219	1.231	1.232	-0.078	71.310	69.919	1.950	4948.00	4890.57	1.161
Poplar	A. Sulphate	7	11.594	1.186	1.192	-0.542	61.670	61.877	-0.336	4596.00	4601.34	-0.116
Poplar	A. Sulphate	10	14.660	1.170	1.180	-0.816	60.180	61.988	-3.004	4584.00	4601.07	-0.372
Alder	Zinc Borate	7	20.107	1.882	1.890	-0.418	87.500	89.667	-2.476	7585.00	7736.28	-1.994
Alder	Zinc Borate	10	29.053	1.871	1.875	-0.213	87.880	87.302	0.657	7577.00	7550.38	0.351
Alder	MAP	5	10.233	2.158	2.171	-0.598	96.040	94.782	1.310	7897.00	7812.04	1.076
Alder	MAP	10	18.601	1.593	1.621	-1.766	94.500	93.358	1.209	7744.00	7727.46	0.214
Alder	A. Sulphate	5	9.781	1.909	1.903	0.290	92.120	90.815	1.416	7748.00	7694.74	0.687
Alder	A. Sulphate	7	11.350	1.798	1.802	-0.206	91.710	93.882	-2.368	7678.00	7708.33	-0.395
Scots pine	Zinc Borate	5	13.800	1.070	1.076	-0.556	64.860	63.995	1.334	4840.00	4840.23	-0.005
Scots pine	Zinc Borate	7	19.915	1.032	1.031	0.106	63.680	62.573	1.739	4820.00	4820.08	-0.002
Scots pine	MAP	7	18.033	0.798	0.807	-1.183	64.300	63.440	1.337	4757.00	4757.15	-0.003
Scots pine	MAP	10	23.402	0.793	0.781	1.474	56.760	58.804	-3.602	3956.00	3956.26	-0.007
Scots pine	A. Sulphate	5	11.578	0.876	0.880	-0.428	61.630	63.441	-2.938	4856.00	4856.19	-0.004
Scots pine	A. Sulphate	10	24.993	0.734	0.741	-0.893	59.470	58.776	1.166	4716.00	4716.33	-0.007
			MAPE	**0.637**			**1.680**			**0.418**		
			RMSE	**0.010**			**1.364**			**47.522**		
Testing Data												
Wood Species	Fire Retardant Chemicals	C. Aqueous Solution (%)	Retention Level (kg/m^3)	Bonding Strength (N/mm^2)			Bending Strength (N/mm^2)			Modulus of Elasticity (N/mm^2)		
				Actual	Predicted	Error (%)	Actual	Predicted	Error (%)	Actual	Predicted	Error (%)
Poplar	Zinc Borate	7	20.854	1.370	1.341	2.105	64.040	65.975	-3.022	4516.00	4661.80	-3.228
Poplar	MAP	10	19.514	1.168	1.197	-2.479	67.980	66.898	1.592	4703.00	4603.33	2.119
Poplar	A. Sulphate	5	9.705	1.256	1.207	3.872	66.150	63.965	3.303	4610.00	4582.56	0.595
Alder	Zinc Borate	5	16.324	1.956	2.111	-7.930	95.680	92.758	3.054	7819.00	7782.16	0.471
Alder	MAP	7	14.595	1.779	1.757	1.227	95.120	93.448	1.758	7864.00	7753.48	1.405
Alder	A. Sulphate	10	15.254	1.675	1.630	2.703	90.790	92.471	-1.852	7594.00	7683.04	-1.172
Scots pine	Zinc Borate	10	26.420	0.962	0.952	1.068	58.230	58.832	-1.034	4267.00	4312.14	-1.058
Scots pine	MAP	5	12.689	0.833	0.863	-3.574	64.960	63.694	1.949	4654.00	4823.35	-3.639
Scots pine	A. Sulphate	7	17.553	0.759	0.768	-1.193	62.480	63.331	-1.362	4857.00	4894.73	-0.777
			MAPE	**2.906**			**2.103**			**1.607**		
			RMSE	**0.059**			**1.717**			**97.516**		

Figure 1 shows the ANN models containing one input layer, one or two 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 retention level, bonding strength, bending strength and modulus of elasticity. First, the wood species and concentration of aqueous solution were used as the input variables, while the retention level values were used as the output variable in the ANN models. The processing element numbers (neurons) of the two hidden layers were 3-3 (first layer-second layer) for the models in Figure 1. Then, the wood species, concentration of aqueous solution and retention level were used as the input variables, while the bonding strength, bending strength and modulus of elasticity were used as the output variable in the ANN models. The processing element numbers (neurons) of the two hidden layers were 3-3 (first layer-second layer), 3 and 2-3 (first layer-second layer) for the models in Figure 1.

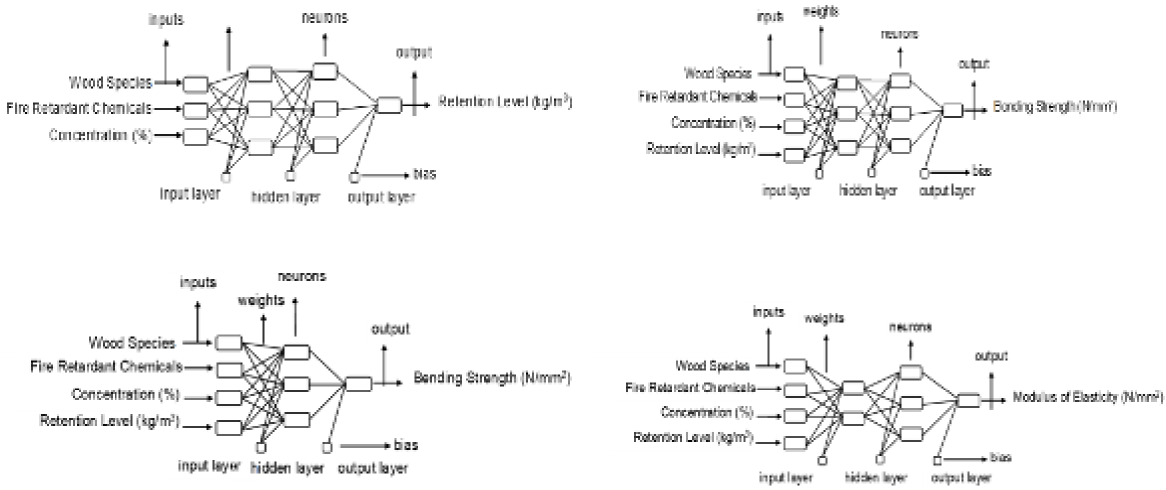

Figure 1. The ANN architecture selected as the prediction models

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. 5 was used as the performance function.

$$\mathrm{MSE} = \frac{1}{N}\sum_{i=1}^{N}\left(t_i - td_i\right)^2 \tag{5}$$

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. 6.

$$\mathrm{X}_{\mathrm{norm}} = 2 \times \frac{\mathrm{X} - \mathrm{X}_{\mathrm{min}}}{\mathrm{X}_{\mathrm{max}} - \mathrm{X}_{\mathrm{min}}} - 1 \tag{6}$$

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

ANN models were trained and tested with the data obtained from the experimental results of Demir et al. (2016). Change of retention level depending on the wood species and concentration were modelled with obtained network parameters. The amount of error variation depending on iteration of the selected ANN was shown in Figure 2. In addition, changes of bonding strength, bending strength and modulus of elasticity depending on the wood species, concentration and retention level were modelled with obtained network parameters. The amount of error variation depending on iteration of the selected ANN was shown in Figure 2. The best training performance was 0.00049989 in the 154th iteration for retention level, 0.00019427 in the 14th iteration for bonding strength, 0.004826 in the 19th iteration for bending strength, 0.00058161 in the 500th iteration for modulus of elasticity.

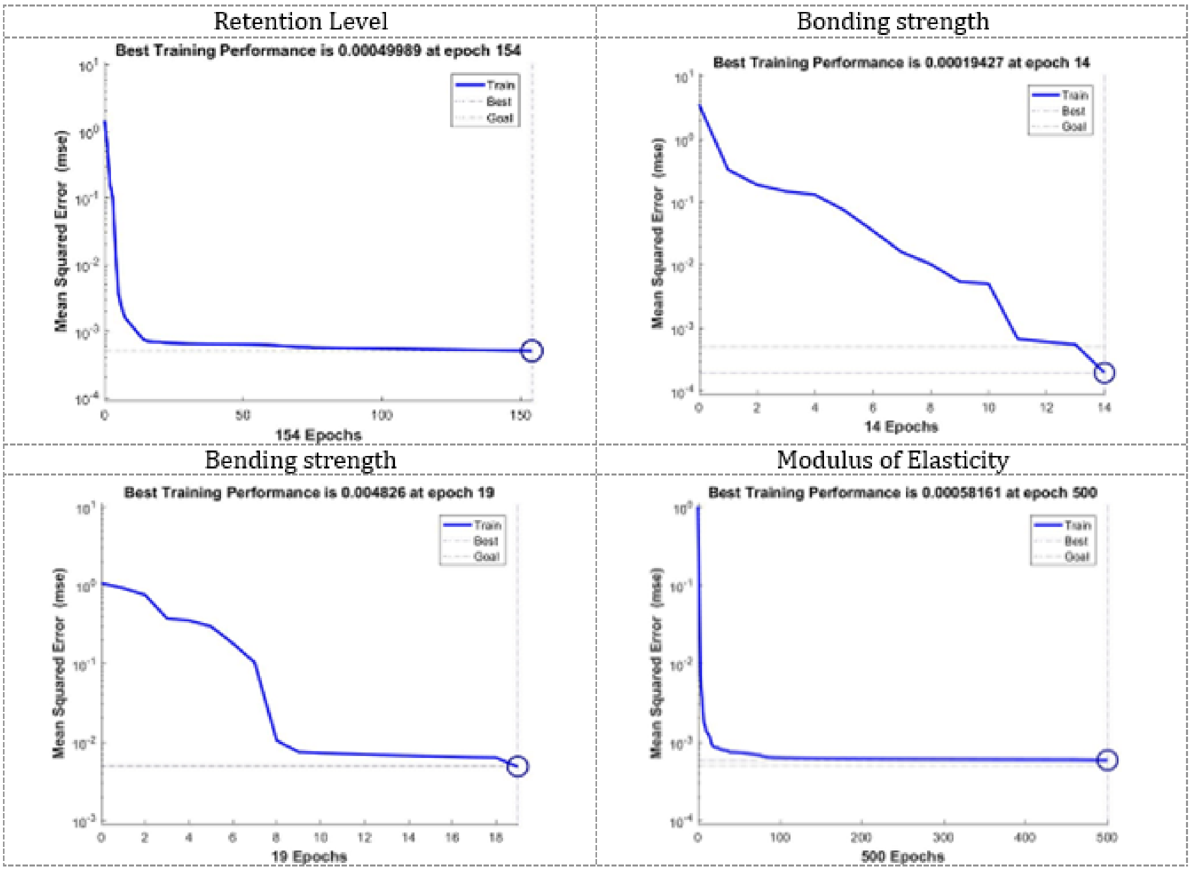

Figure 2. A plot of error variation depending on iteration of the ANNs

Figure 3 and 4 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 5.

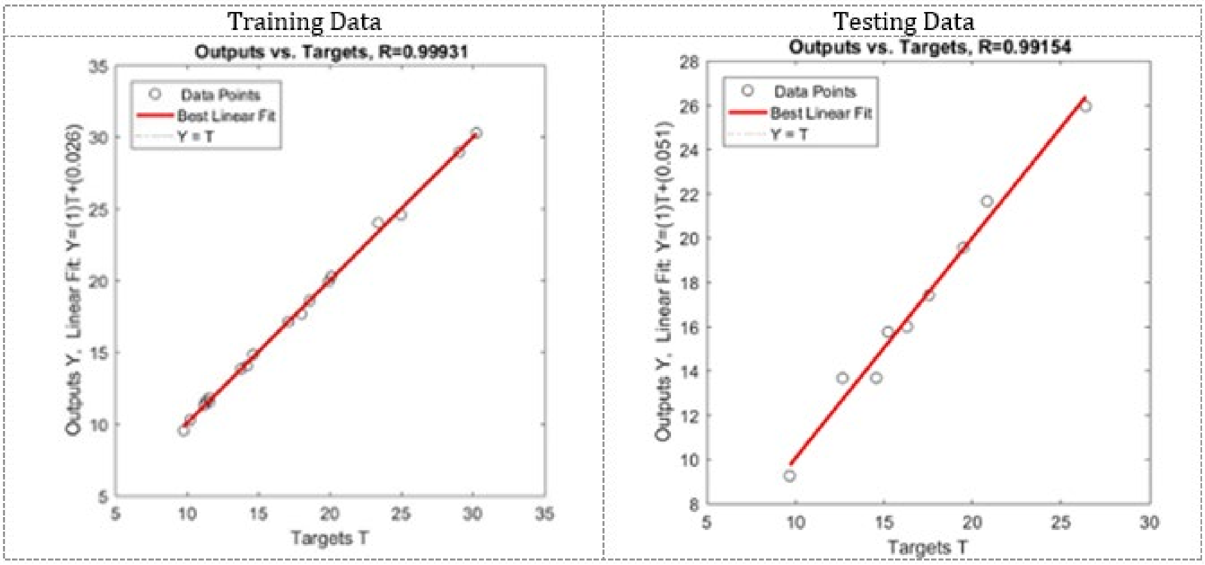

Figure 3. The relationship between experimental results of retention level and ANN predicted results

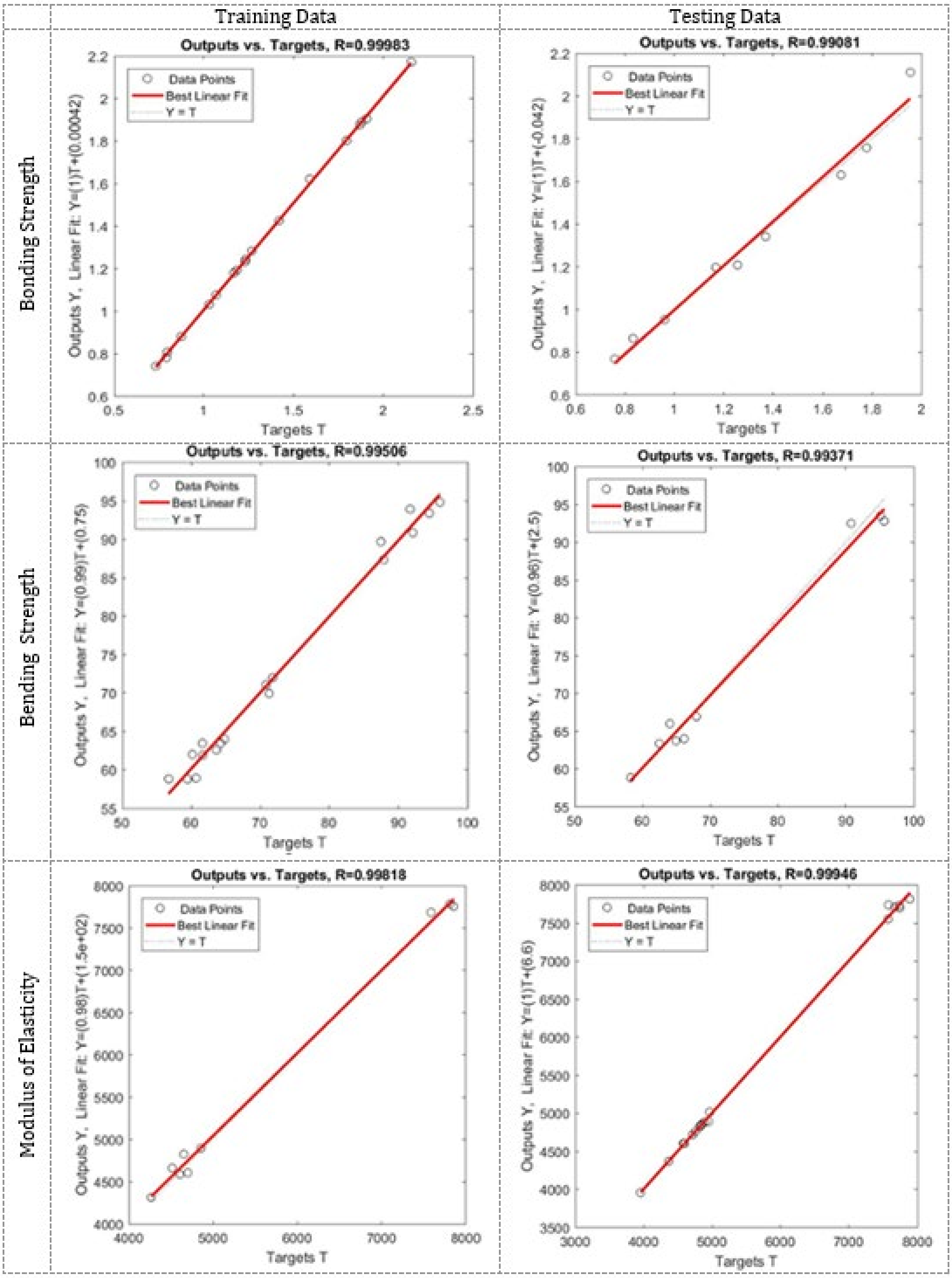

Figure 4. The relationship between experimental results of mechanical strength and ANN predicted results

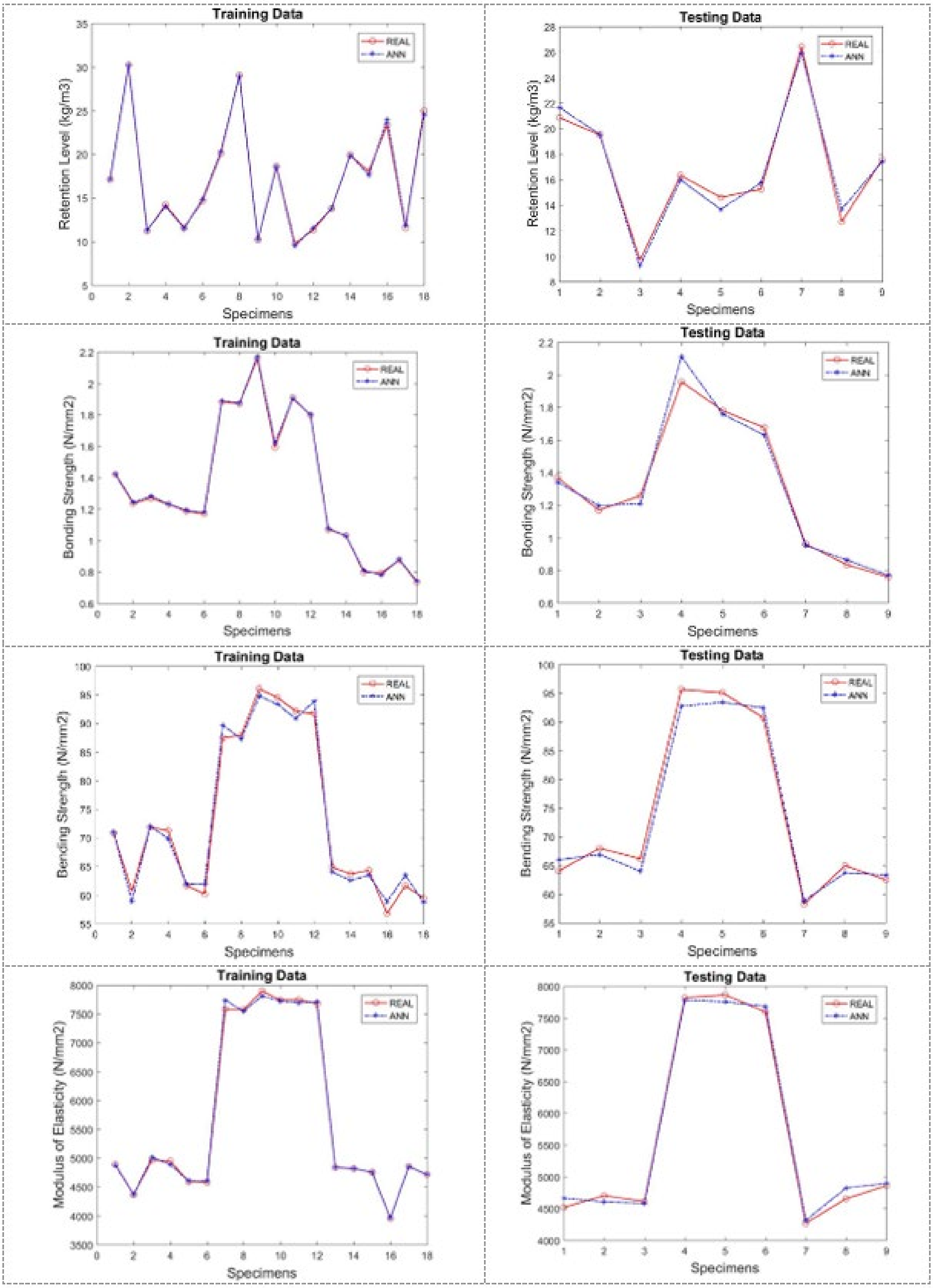

Figure 5. The comparison of the real and calculated values

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 (training and testing) are shown in Figure 3 (retention level, training R = 0.99931; testing R = 0.99154) and

Figure 4 (bonding strength, training R = 0.99983; testing R = 0.99081, bending strength, training R = 0.99506; testing R = 0.99371, modulus of elasticity, training R = 0.99818; testing R = 0.99946). 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 retention level, bonding strength, bending strength and modulus of elasticity values are plotted in Figure 5. 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 retention level, bonding strength, bending strength and modulus of elasticity were 1.014, 0.637, 1.680 and 0.418 % for training and 3.416, 2.906, 2.103 and 1.607 %for testing, respectively. These levels of error are satisfactory for the retention level, bonding strength, bending strength and modulus of elasticity. As seen from the results, the ANN approach has a sufficient accuracy rate for the prediction of retention level, bonding strength, bending strength and modulus of elasticity values of plywood.

The intermediate values not obtained from the experimental study for retention level, bonding strength, bending strength and modulus of elasticity were predicted from the designed ANN modelling. The retention level, bonding strength, bending strength and modulus of elasticity values predicted by the ANN models for different concentration of aqueous solution are shown in Figure 6, 7, 8 and 9.

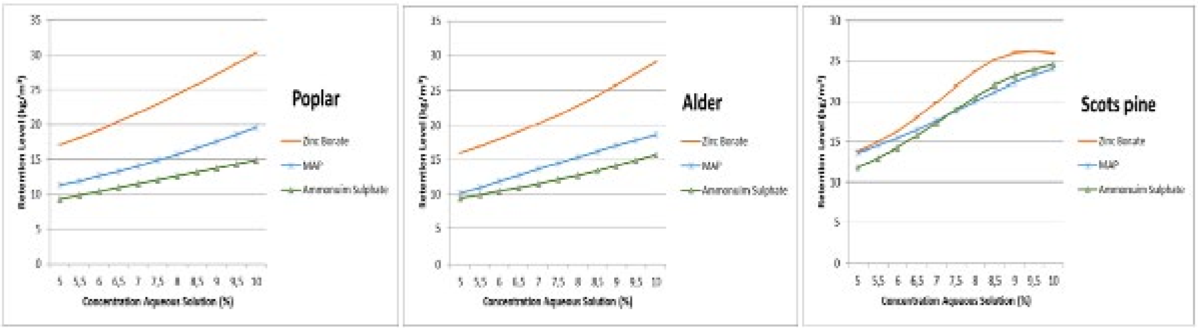

Figure 6. The change of retention level with increasing concentration of aqueous solution

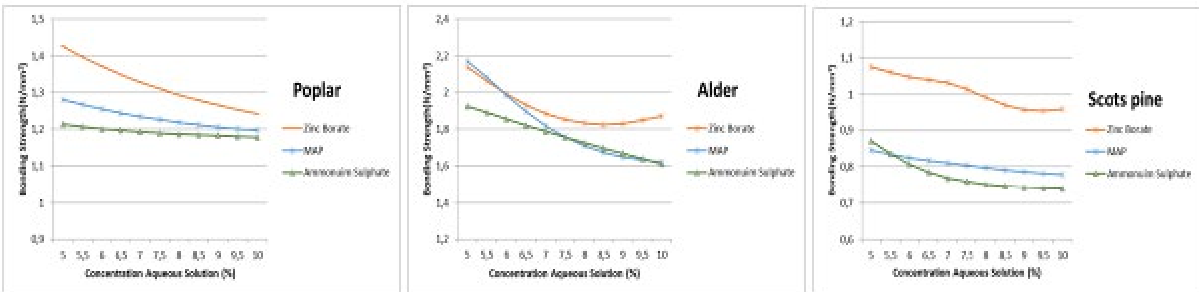

Figure 7. The change of bonding strength with increasing concentration of aqueous solution

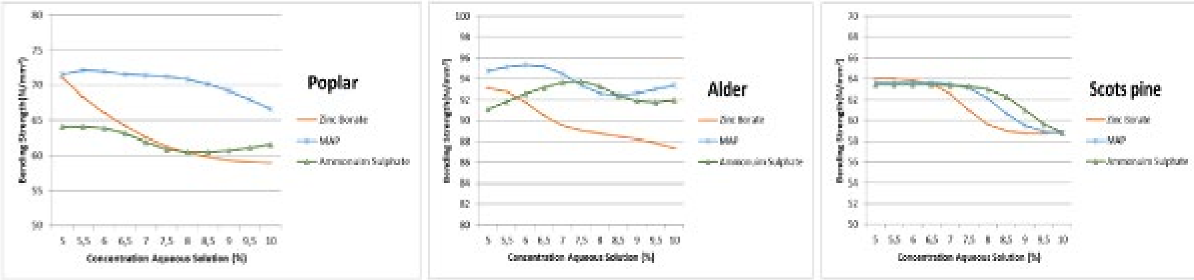

Figure 8. The change of bending strength with increasing concentration of aqueous solution

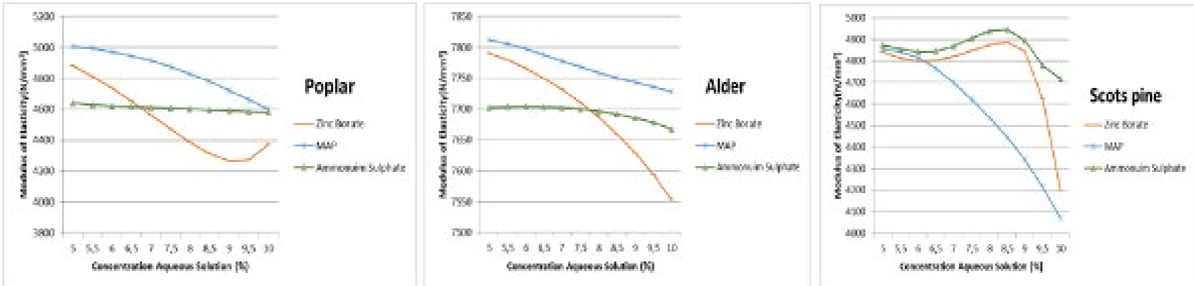

Figure 9. The change of modulus of elasticity with increasing concentration of aqueous solution

The retention level increased with increasing concentration aqueous solution according to Figure 6. Among the fire retardant chemicals, zinc borate caused more increase in retention levels than the other chemicals for all of wood species. In the first model, the retention levels estimated depending on the concentration values and in the second model the mechanical strength values were estimated. As can be seen Figures 7-9, generally, the mechanical properties of the panels can be adversely influenced by increased concentrations of fire retardants. In literature, it was stated that the reasons for the reduction in mechanical strength of fire-retardant plywood could be related to the acidity of fire retardant could influence the strength of the veneers; The poor compatibility between fire retardant and UF adhesive and the fast curing rate of the UF adhesive, accelerated by fire retardant, could, theoretically, prevent a direct and effective contact between the veneer and the UF adhesive, and hence affect the penetration of UF adhesive into the veneer (Cheng and Wang, 2011). The second drying process performed after the impregnation may also contributed to decrease in shear strength. Aydin (2004) indicated that the impregnation material layer in the form of crystal remaining on the veneer surface after drying affected adversely wettability with glue and so the mechanical strength values decreased. Among the fire retardant chemicals, zinc borate generally caused less decrease in bonding strength than the other chemicals for all of wood species. MAP generally caused less decrease in bending strength and modulus of elasticity than the other chemicals for all of wood species. However, the less decrease for modulus of elasticity values of Scots pine panels was obtain from ammonium sulphate.

The different changes of mechanical properties were determined according to concentration of fire retardants in the ANN models. For example, while the bending strength values of alder plywood treated with ammonium sulphate showed a slight increase up to 7.5% concentration, there was a slight increase in bending resistance up to 6% concentration in the treatment process with MAP. It is seen that the bending strength values of scots pine plywood remain almost constant up to 8% in the treatment process with ammonium sulphate, 7.5% in the treatment with MAP and 6.5% in the treatment with zinc borate (Figure 8). The modulus of elasticity of plywood treated with ammonium sulphate remained almost constant at all concentration values for poplar, up to 8% for alder and 8.5% for scots pine. Similar results to ammonium sulphate were obtained in the treatment process with zinc borate in scots pine plywood (Figure 9).

At ANN design, some experimental results were used for training and some others were used for testing (Table 1 and 2). On the other hand, some data values for the poplar samples treated at 7% concentration of aqueous solution with zinc borate was not available in training set. However, the strength values for this concentration and fire retardant chemical 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. Conclusion

In this study, ANN models were developed to model the effects of wood species and concentration values of aqueous solutions variables on the retention level and the effects of wood species, concentration values of aqueous solutions and retention level variables on mechanical strength values. As a results of the study, the retention level increased with increasing concentration aqueous solution. In generally, mechanical properties of the panels can be adversely influenced by increased concentrations of fire retardants. The different changes of mechanical properties were determined according to concentration of fire retardants in the ANN models. MAPE for retention level, bonding strength, bending strength and modulus of elasticity were 1.014, 0.637, 1.680 and 0.418 % for training and 3.416, 2.906, 2.103 and 1.607 %for testing, respectively. RMSE for retention level, bonding strength, bending strength and modulus of elasticity were 0.230, 0.010, 1.364 and 47.52 for training and 0.602, 0.059, 1.717 and 97.516 for testing, respectively. It can be concluded from this study that the ANN method is reasonable for the modelling (the optimization) of retention level, bonding strength, bending strength and modulus of elasticity at various concentration without needing the experimental study again and again.

5. Acknowledgments

In this study, the experimental results obtained from the study of Demir et al. (2016) were used. Therefore, the authors acknowledge Dr. Aydin Demir, Dr. Ismail Aydin, and Dr. Semra Colak for enabling data to be used.

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THE EFFECTS OF WOOD SPECIES, NAIL SIZE, GRAIN DIRECTION AND LAYER NUMBERS ON LATERAL NAIL STRENGTH OF STRUCTURAL PLYWOOD PANELS

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Abstract

In the use of solid wood and wood-based composite materials in wooden structures, metal elements such as nails, screws and bolts are used as fasteners. The strength of the connection points depends on many factors. In this study, it was aimed to determine effects of wood species, nail size, grain direction and layer numbers on lateral nail strength of structural plywood panels. Scots pine, black pine and spruce were used as wood species for structural plywood production. Five and seven-ply plywood panels, 10 mm and 14 mm thick, were manufactured by using phenol formaldehyde glue resin. Lateral nail strength test was performed according to ASTM D1761. The specimens were oriented so that the load was applied parallel and perpendicular to the grain of the main axis of plywood panel during the test. Also, nail size was chosen as 6d and 8d for test. As a result of the study, it was seen that the Scots pine plywood gave the highest lateral nail strength values among other wood species. Lateral nail strength values of seven-ply plywood was found higher than five-ply plywood. Lateral nail strength value of the samples using 8d nails was found to be higher than those using 6d nails. Also, it was determined the lateral nail strength values in perpendicular to grain were higher than those in parallel to grain.

Keywords: Lateral nail strength, structural plywood, nail size, grain direction, layer numbers

1. Introduction

Solid wood and wood-based composite boards are used in constructing buildings because they have some excellent advantages, such as easy process ability, low price, good aesthetic appearance, and light weight (Bal, 2017). Plywood, one of the most common wood based panels, has many usage areas varied from furniture (indoor) to construction (outdoor) and superior advantages compared to solid wood (Bal and Bektas, 2014).

Plywood-sheathed shear walls are widely used as bearing elements against horizontal loads such as seismic forces and wind forces (Nagasse et al., 2018). 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; Demir et al., 2019). To achieve the highest performance of a shear wall, it should have not only a high load-bearing capacity, but also a high ductility or ultimate deformation. Besides, the performance of a shear wall is affected by the joints between the plywood and timber (Nagasse et al., 2018).

The strength and stability of any structure depend heavily on the fastenings that hold its parts together. One prime advantage of wood as a structural material is the ease with which wood structural parts can be joined together with a wide variety of fastenings-nails, spikes, screws, bolts, lag screws, drift pins, staples, and metal connectors of various types (Rammer, 2010). When walls are covered with structural wood boards, fasteners represent the most important part of strength of the structure (McCormick, 2005). As plywood attached with nails in the frame, the lateral nail strength test are carried out in order to investigate nail performance on strength and stiffness of wood-frame (Bott, 2005; Demirkir and Colakoglu, 2015).

Lateral nail strength is affected on many factors such as fastener specification, wood properties, connection types and load application conditions. In this study, it was aimed to determine effects of wood species, nail size, grain direction and layer numbers on lateral nail strength of structural plywood panels.

2. Materials and Methods

Scots pine (*Pinus slyvestris*), black pine (*Pinus nigra*) 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.

Density of plywood panels manufactured in industrial plant were determined according to EN 323 (1993) before the lateral nail strength test. Twenty samples were used for the evaluation of plywood density. The density results of plywood panels are given Table 1.

Table 1. Test results of density of plywood panels

Wood Species	Layer Numbers	Density (g/cm^3)
Scots pine	5	0.585
	7	0.663
Spruce	5	0.510
	7	0.487
Black pine	5	0.566
	7	0.613

The lateral nail strength test was performed according to ASTM D1761 (2006). Lateral nail connection specimens were made with nails driven flush at a distance of 51 mm from the edge of the sheathing material. The nail size was chosen as 6d (63 mm × 2.5 mm) and 8d (76 mm × 2.8 mm). The nails were driven pneumatically to connect the framing member and the sheathing material. Spruce timber was used as the primary member. The size of sheathing member was 250mm × 76mm. All wooden materials were conditioned at 20°C and 65% relative humidity prior to testing. The specimens were oriented so that the load was applied parallel and perpendicular to the grain of the main axis of plywood panel during the test. The step by step show of the prepared examples is given in Figure 1.

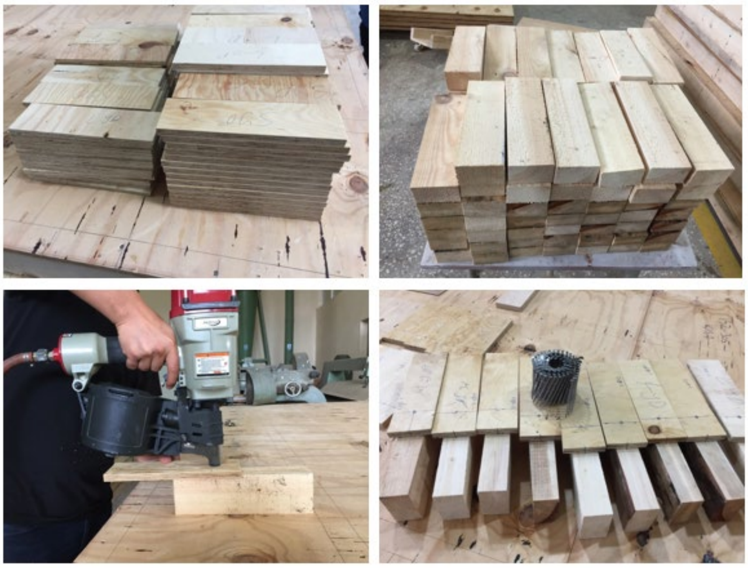

Figure 1. Preparation of specimens for lateral nail strength test

The specimen move was limited to one direction. The loading was set to a loading rate of 12.7 in a minute. A 22.4 kN load cell, attached to a 10 kN universal testing machine, was used to measure the applied load. The test was carried out at Forest Industry Engineering Department Laboratory in Trabzon, Turkey. For each group of test, 4 replications were performed. Figure 2 shows the test setup for the lateral nail strength and the changes that occur as a result of the test.

Figure 2. Lateral nail strength test setup and changes at the end of the test

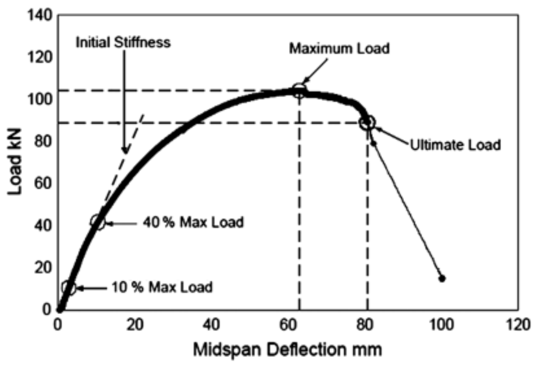

Figure 3. Analysis of a load-displacement curve (Pirvu 2008).

The following properties were calculated from this test, as illustrated in Figure 3:

• Initial stiffness, by selecting the points closest to 10% and 40% of the maximum load and fitting a straight line to the intervening points;

• Ultimate load, as 80% of the maximum load;

• Displacement at ultimate load; was identified based on the calculated ultimate load.

3. Results and Discussion

It was showed in Table 2 that lateral nail strength test results of plywood specimens according to wood species, layer numbers, nail size and grain direction.

Table 2. Results of Lateral nail strength of plywood panels

Wood Species	Layer Numbers	Nail Size	Grain Direction	Lateral Nail Strength (kN)	
				X	S
Scots pine	5	8d	Parallel	2.08	0.01
			Perpendicular	2.12	0.06
		6d	Parallel	1.64	0.09
			Perpendicular	1.69	0.12
	7	8d	Parallel	2.85	0.03
			Perpendicular	2.96	0.03
		6d	Parallel	1.65	0.03
			Perpendicular	1.86	0.02
Spruce	5	8d	Parallel	1.29	0.12
			Perpendicular	1.56	0.07
		6d	Parallel	1.20	0.04
			Perpendicular	1.24	0.10
	7	8d	Parallel	2.25	0.02
			Perpendicular	2.32	0.04
		6d	Parallel	1.70	0.06
			Perpendicular	1.72	0.03
Black pine	5	8d	Parallel	1.57	0.06
			Perpendicular	1.86	0.05
		6d	Parallel	1.33	0.01
			Perpendicular	1.42	0.06
	7	8d	Parallel	2.03	0.05
			Perpendicular	2.10	0.03
		6d	Parallel	1.78	0.04
			Perpendicular	1.82	0.04

X: Arithmetic mean values S: Standard Deviation

In order to determine the effect of wood species, layer numbers, nail size and grain direction on the lateral nail strength values of plywood panels, multiple variance analysis was performed and Student-Newman-Keuls test results used to compare the mean values of variance sources were given in Table 3.

Table 3. Student-Newman-Keuls test results of the samples (p<0.05).

Variance Sources	N	Lateral Nail Strength (kN)
Wood Species		
Scots pine	32	2,18 c
Black pine	32	1,74 b
Spruce	32	1,66 a
Layer Numbers		
5	48	1,58 a
7	48	2,09 b
Grain Direction		
Perpendicular	48	1,89 b
Parallel	48	1,78 a
Nail Size		
6d	48	1,59 a
8d	48	2,08 b

* Different letters indicate the statistically significant difference

As can be seen Table 2, scots pine plywood gave the highest lateral nail strength values among other wood species. The mechanical properties of plywood produced from the veneers of high-density wood are higher (Bal and Bektas, 2013). In Table 1, it is seen that scots pine plywood gave the highest density values among other wood species. It is stated in a study by Nanami et al. (2000) that there is a linear relationship between plywood density and lateral nail strength. Nanami et al. (2000) determined that the nail resistance (1.71 kN) of plywood panels with 9 mm thick and density of 0.63 g/cm^3 was higher than the resistance (1.36 kN) of same thickness panels with density of 0.59 g/cm^3. The primary impact on the density of the plywood is wood specie (Demirkır, 2012). 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). Similarly, laminated materials obtained from wood species with high density have high nail or screw holding resistance (Erdil et al., 2002). Former studies also showed that lateral nail strength is affected by wood species (Wu, 1999; Stieda, 1990).

The lateral nail strength values of seven-ply plywood was found higher than five-ply plywood. The reason for this can be shown that the density of seven-ply plywood is higher than that of five-ply plywood (Table 1). In previous studies, it was determined that there is a linear relationship between density and lateral s nail strength (Winistorfer and Soltis, 1994).

Lateral nail strength value of the samples using 8d nails was found to be higher than those using 6d nails. The value given by APA for 6d straight nails is 180 lbf (0.80 kN) and the limit value given for 8d straight nails is 220 lbf (0.98 kN) (APA, 2007). Considering these limit values, the values obtained in this study are generally higher. These high values are due to the density of the materials used (Bal et al., 2016). Also, it was determined the lateral nail strength values in perpendicular to grain were higher than those in parallel to grain. It is stated in the literature that the lateral nail strength of perpendicular to the grain is higher than the lateral nail strength of parallel to the grain (Demirkır, 2012; Hunt and Bryant, 1990; Nanami et al., 2000).

For the lateral nail strength, the displacement at maximum load, stiffness, ultimate load and displacement values at the ultimate load using graphs showing the relationship between displacements under the effect of applied load, while determining the maximum load are given in Table 4.

Table 4. Results of displacement at maximum load, stiffness, ultimate load and displacement values at the ultimate load according to the lateral nail strength

Wood Species	Layer Numbers	Nail Size	Grain Direction	Displacement at maximum load (mm)	Stiffness (kN/mm)	Ultimate load (kN)	Displacement at ultimate load (mm)
Scots pine	5	8d	Parallel	16.27	0.72	1.66	23.67
			Perpendicular	11.9	0.76	1.7	19.62
		6d	Parallel	16.48	0.76	1.31	25.31
			Perpendicular	14.15	0.69	1.35	20.65
	7	8d	Parallel	16.58	0.83	2.28	24.14
			Perpendicular	16.95	1.15	2.36	23.55
		6d	Parallel	17.15	0.6	1.32	19.04
			Perpendicular	16.21	0.66	1.49	21.84
Spruce	5	8d	Parallel	14.54	0.47	1.03	21.62
			Perpendicular	17.39	0.55	1.25	24.55
		6d	Parallel	12.76	0.35	0.96	20.7
			Perpendicular	14.7	0.41	0.99	22.76
	7	8d	Parallel	16.27	0.6	1.8	22.37
			Perpendicular	11.91	1.08	1.85	19.62
		6d	Parallel	17.48	0.79	1.36	23.98
			Perpendicular	13.18	0.59	1.37	21.99
Black pine	5	8d	Parallel	15.5	0.89	1.26	24.44
			Perpendicular	20.2	0.7	1.49	29.83
		6d	Parallel	14.56	0.63	1.06	24.13
			Perpendicular	14.78	0.54	1.14	22.17
	7	8d	Parallel	18.39	0.48	1.62	25.43
			Perpendicular	15.6	0.67	1.68	28.51
		6d	Parallel	14.72	0.57	1.42	29.88
			Perpendicular	17.23	0.8	1.46	28.77

Stiffness is one of the most important parameters for structural panels. If the panels used for sheathing material in a shear wall which have higher stiffness, they will be more resistant to earthquake loads. As shown in Table 4, stiffness values in perpendicular to grain of plywood panels are generally higher than those of parallel to grain of the panels for all wood species. Moreover, 8d nails and 7-ply plywood panels gave the highest stiffness values among the groups. In literature, the results of some studies on the effect of grain direction on stiffness supported these findings (Winistorfer and Soltis, 1994; Demirkir and Colakoglu, 2015), while Pirvu (2008), determined that there was no effect of grain direction on stiffness of panels. Some of the groups gave similar results. Besides the stiffness, higher max load and higher displacement at ultimate load are desired for resisting to lateral loads such as earthquakes. It can be concluded from the study that the plywood panels manufactured from scots pine and black pine are more convenient for structural aims, since they have higher stiffness, max load and displacement at ultimate load (Table 4). Displacement quantities at ultimate load of all groups exceed the value (15.6 mm) described in ISO 16670 (2003). In Ekwueme and Hart (2000), the maximum load and stiffness values of 8d common nails in 9.5-mm plywood were determined to be 1.22 kN and 1.59 kN=mm, respectively.

The results also exceed the standards in the National Design Specifications for Wood Construction (NDS) (National Forest Products Association, 2012) and ISO 16670 (2003), and met the values described in American Plywood Association (APA) standards L350G and L350A (2001, 2007).

4. Conclusion

The effects of wood species, nail size, grain direction and layer numbers on lateral nail strength of structural plywood panels was investigated in this study. The highest lateral nail strength values were obtained in scots pine plywood among the all groups. The seven-ply plywood panels gave higher strength values than five-ply plywood panels. 8d nails resulted in increased lateral nail strength according to 6d nails. The strength values of perpendicular to grain were higher than those of parallel to grain. Stiffness and displacement values at the ultimate load of plywood have been determined to be suitable according to the literature and standards and it has been proved that domestic resources can be especially resistant to earthquake risk.

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AN ASSESSMENT OF CARBON FOOTPRINT IN MDF MANUFACTURING: A CASE STUDY OF WOOD BASED PANEL PRODUCTION IN TURKEY

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Abstract

Nowadays, carbon footprint (CF) is became an important topic closely related to the ecological production of goods and services. Energy use and subsequent emissions of greenhouse gases (GHGs) in all human facilities affect the world's climate in the form of Global Warming in recent decades. The dominant greenhouse gas arising from human activities is carbon dioxide (CO_2). Carbon footprint is CO_2 and other GHGs that are released per unit product for a specific period. The main purpose of this study is the determination of most important critic processes about that contribute to the CF problem during medium-density production with Pareto analysis method. Medium-density fiberboard is a kind of composite panel product which is typically containing of cellulosic fibers with the combination of synthetic resins and additives becoming under heat and pressure. For this purpose, a wood-based panel company is selected to examine CF for its each process. As a conclusion this study makes an important contribution to the panel based industry to see the emission problems with the help of Pareto analysis and help to perform an environmental oriented production for the future. Moreover, two scenarios are built up to decrease of total carbon footprint in the selected plant. So, the analysis results are supported with two scenarios. Also, this study shall provide a general view and perception for the importance of the carbon footprint in the wood panel based industrial sector.

Keywords: Carbon footprint, Medium-density fibreboard (MDF), Pareto analysis, Scenarios.

1. Introduction

Turkish wood-based panel industry is one of the most important industries for the country. Turkey is among the worlds' largest board producers in the world following China and Germany (Yıldırım, Candan and Korkut, 2014). Because of the high capacity of industry, energy supply and consumption become a significant topic for the industry. Besides, wood supply has a big problem for the industry from past through today (Mahapatra and Mitchell, 1997; Ok, 2005, Ilter and Ok, 2007; Daşdemir, 2018). The industry runs out of substantial amounts of energy in the forms of natural gas, biomass, and diesel fuel. So, greenhouse gas (GHG) emissions are released in atmosphere. Thus, increasing energy efficiency and developing pollution reduction methods in this sector will be important for decreasing GHG emissions in coming decades. The most important agreement of concerning global warming and climate change is known as Kyoto Protocol and six greenhouse gases are defined as CO, CO_2, CH_4, N_2O, PFCs(per fluorocarbons), and HFCs (hydro fluorocarbons) which cause strongly global warming and it has been thought those gases are released by human activities. (IPCC, 2006 ; IPCC, 2007 ; WBCSD/WRI, 2007 ; ECCM, 2008). The dominant GHG is carbon dioxide that partly derives from diesel fuel burning (Post, 2006; ETAP, 2007; Steinfeld and Wassenaar, 2007; Da Schio and Fagerlund, 2013).

Carbon footprint concept was originated from the terminology of ecological footprint which was proposed by Wackernagel and Rees in 1996 (Wackernagel and Rees, 1996; Wackernagel et al., 1999; Ercin and Hoekstra, 2012). Carbon footprint is the total amount of CO_2 and other GHGs that occur over the full life cycle of a process or facility and it has been described units of tones or kg equivalent (Brenton et al., 2008; Matthewset al, 2008; IEA, 2012; Radua et al., 2013). Some researchers explain it as a measure of amounts of CO_2 emitted from the combustion of fossil fuels (Patel, 2006; Post, 2006 ; Carbon Trust, 2007 ;Grubb and Ellis, 2007; Wiedmann and Minx, 2007). The footprint is divided into two groups as primary (direct) and secondary (indirect) (Energetics, 2007; Goodier, 2010; Atabey, 2013; Uribe et al, 2019).

There are many researches about carbon footprint and pareto analysis method in wood industries throughout the world. But there are only a few researches in our country even it is one of the most important developed industry in Turkey. Gustavson and Sathre (2005) is presented a method for calculating the net carbon dioxide emission in the construction of wooden frames. This method is applied in Switzerland and Finland. So, emissions are calculated according to consuming types of fuel in each process. As a result, amounts of greenhouse gas emission are reduced in this research. Garcia and Freire (2013) calculated the carbon footprint of particleboard produced in Portugal. It was objected the effect of different methods in the particleboard carbon footprint (CF) calculation in applying four different CF measurement methods. Those methods are ISO-TS14067, the GHG Protocol Product Standard, PAS 2050, and Climate Declaration. Two several of research (Wilson, 2010) made and life cycle inventories are presented for as raw material usage, air, water and solid emission for 1 m^3 particle board and medium density fiberboard panel production. So, environmental performances are analysed and evaluated for the productions. Moroşanu et al. (2011) studied on identifying and evaluating of defects on oak veneer for four regions. The researchers were used the Pareto analysis method for developing the quality of the studied products. Pareto analysis was also used in order to determine the important carbon footprint problem(s) each of process in this research. Lippke et al (2012) investigated different uses of wood to see their efficiency by means of carbon and energy impacts to displace fossil energy. The researchers found out when waste wood was consumed as a biofuel instead of fossil fuels and so the emissions were decreased.

In this study, it is aimed to calculate CO_2 emissions for each process in a MDF industry in a plant scale of the largest producer in Marmara region, in Turkey. The plant named as XYZ plant afterwards in this study. This study was prepared by the data of XYZ company which belong to the year of 2015. The amount of annual production of MDF is 389561 m^3/year in 2015. The study is also aimed to make some suggestions to decrease the emissions for the future. So, two scenarios were produced and suggested. Carbon footprint values are calculated as statistically with Tier 1 method (IPCC, 2007) during the MDF production, and Pareto anaysis method is applied for determine the footprint' problem.

2. Materials and Methods

2.1. Medium-density fiberboard

XYZ is a plant operating in forest products industry and it produces particle board, medium density fiberboard (MDF), and parquet as products and it is also one of the largest plant due to its capacity in this field in Marmara region. Work flow in concerning with MDF manufacturing is shown in Fig. 1. The MDF production follow the processes such as chipping, screening, evaporation, refiner, gluing, drying, laying, pressing, sizing, climatization, and sandpapering. MDF is described as a wood based panel product manufactured from raw fibers of wood, wood chips, and small amount of other materials such as glues, binders and additives.

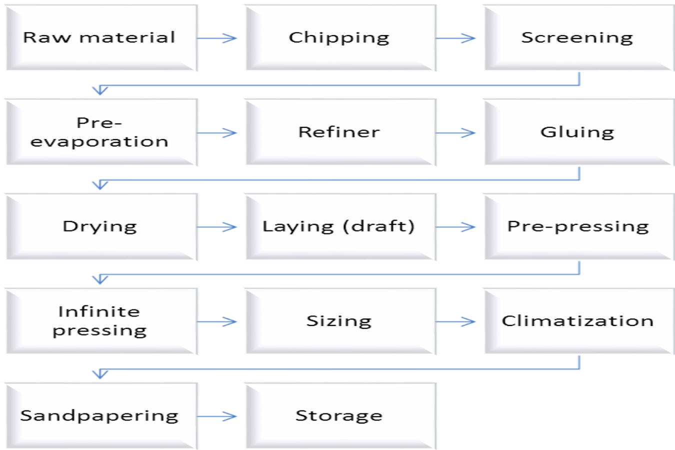

Figure 1. Flow chart for medium-density fiberboard panel production in XYZ plant(Erdil, 2018).

In these processes, energy is consumed in the forms of natural gas, biomass, and diesel fuel. Considering all the contributing factors, carbon footprints values are calculated using the Tier 1 method according to IPCC 2006 Guidelines (IPCC, 2006). To produce 389561 m^3 of medium-density fiberboard in 2015, it was used 10275 tons of wood chips, 10972 tons of emery powder, 8995 tons of edge trimming, and 7964 tons of fiber (dry) in boiler. On the other hand, the plant used 43277505 m^3 (460472653 kWh) natural gas energy, 141971971 kWh biomass energy, and 29365 liters (315673,7 kWh) of diesel fuel for annual production in 2015. The study is carried out in the XYZ plant considering the improvements of all of the energy flow processes comprises of following steps:

1-Design a study plan
2-Calculate of carbon footprint for each process
3-Practising of Pareto analysis steps
4-Drawing the Pareto diagram
5-Designate major emission problem(s) according to 80/20 law by the help of Pareto diagram
6-Make suggestions for the major emission problem(s)

2.2. Energy balance

In this plant, natural gas, biomass (dust, wood chips, fiber, trimmer, etc.) and diesel fuel are consuming as the main (directly) inputs for obtaining energy. While natural gas and biomass are consuming in MDF production process, diesel fuel is used by transportation equipment (volvo, escalator and forklift) which are using in the field. Those inputs are primary and direct energy sources for MDF production in process.

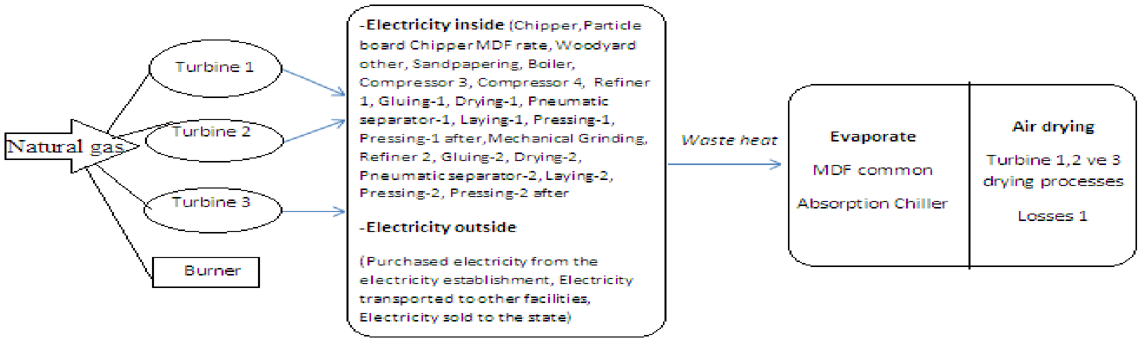

Figure 2. Energy balance flow chart 1 in medium density fiberboard (Erdil, 2018).

Natural gas is consuming in Turbine 1, 2, 3 and burner. As a result of the use of natural gas, electricity energy is producing and waste heat releases. The waste heat is recovered in evaporation, and air drying units as energy sources as seen in Fig.2. Those sources are called as indirectly energy sources. Even though the company produces its own electricity in the plant, in some cases the factory buys electricity from the electricity suppliers.

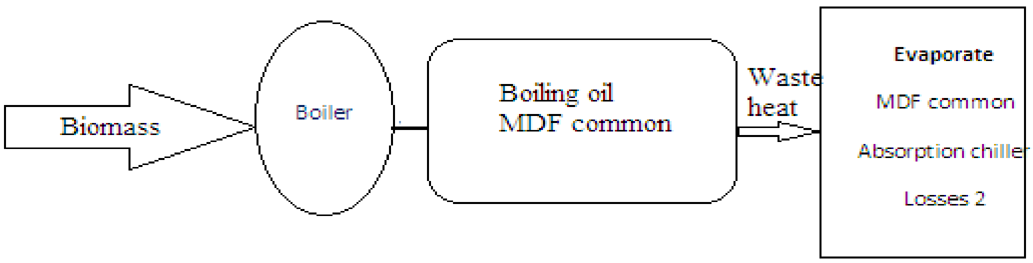

Figure 3. Energy balance flow chart 2 in medium density fiberboard (Erdil, 2018).

According to Fig. 3, biomass sources vary from wood dust, wood chips, bark, emery powder, etc. It is generally composed of process wastes. As a result of the process, waste heat is also released. The waste heat is recovered in evaporate as energy sources. Those sources are called as indirectly energy sources (Erdil, 2018).

2.3. Calculation of Carbon Footprint (CF)

Carbon footprints (CF) were calculated for each process according to the inputs' emission factors and then Tier 1 method was applied (IPCC, 2006 ; IPCC, 2007). Due to the simplicity in application and suitability to the data available, Tier-1 method was used in this study. Process based data related to energy and fuel consumption consumed for emission calculations through the equation given below (Pekin, 2006; Atabey, 2013; Turanlı, 2015). Before carbon footprint calculation, it must be known fuel consumption and emission factor. Emission factor can be researched in literature (Defra, 2010; Lelyveld and Woods, 2010 ; Cefic, 2010; Web-1,Web-2). Emission is calculated according to the equation 1 is given in below and CF is calculated according to equation 2 (IPCC, 2006; Erdil, 2017; Erdil,Yılgör and Güngör, 2017; Keskin, Erdil, and Sennaroğlu, 2017; Erdil, 2018).

Emission = Energy consumption x Emission factor x Oxidation factor (1)
(Oxidation factor is taken as 1)

CF = Emissions (kg CO_2e)/ Amounts of annual production (m^3) (2)

2.4. Pareto Analysis

Vilfredo Pareto was an Italian economist who lived in 19th century and evaluated economic problems by applying mathematics and developed a method which was maintained as his name and it was assisted to define and classify the problems according to the significance of the percentage values. It is a way of assisting causes of problems to derive an effective solution. This method uses due to 80/20 law in general. As a result of this method diagrams are obtained which is useful tool in defining the important problems. Pareto diagrams asist to build a relationship in between the problems and the reasons (Gitlow et al., 2005; Erdil, 2017; Erdil,2018). Pareto diagrams are the graphical tool used in Pareto analysis (Cravener et al.,1993; Leavengood and Reeb, 2002). Pareto analysis is a method which is used to distinguish causes from less significant ones.

Pareto analysis follows the procedures in below (Akın, 1996; Akın and Oztürk, 2005; Erdil, 2017; Erdil, Keskin and Sennaroğlu, 2017; Erdil, Yılgör and Güngör, 2017; Erdil, 2018):

1. Problems should be determined and then classified
2. Data are classified according to the problem. Total values which are in different categories and their percentages are determined.
3. A bar chart was drawn. In this bar graph, while the y-axis establishes the totals and percentages, the x-axis presents the classified groups.
4. Pareto diagrams are carried out to notice the biggest problem from beginning of the upper right-hand corner of the first bar.

2.5. Building up scenarios for decreasing of carbon footprint

After calculation and exhibition of carbon and energy footprints' of the MDF plant, there were built up two different scenarios for decreasing carbon footprint. According to scenario 1, biomass usage was suggested instead of natural gas in turbines (1, 2 and 3) as a fuel. On the other hand, according to scenario 2, solar panel establishment seems to help to decrease carbon footprint instead of usage an electricity.

3. Results

In this study, CF values were calculated for each process by means of primary and secondary energy sources. Furthermore, Pareto analysis was applied to define carbon footprint' problem in the plant. Moreover, two scenarios are built up to decrease of total carbon footprint in the plant.

3.1. Carbon footprints

The distribution of carbon footprints determined for the processes used in the plant as primary and secondary sources are presented in Figure 4. As can be seen, CF of Turbine 3 the highest value at 88,08 kg-CO_2e/m^3MDF of all other processes as primary in Figure 4-a. CF of MDF common (it's a general classification for the plant) which has the highest value at 44,91 kg-CO_2e/m^3MDF of all other processes as secondary sources in Figure 4-b.

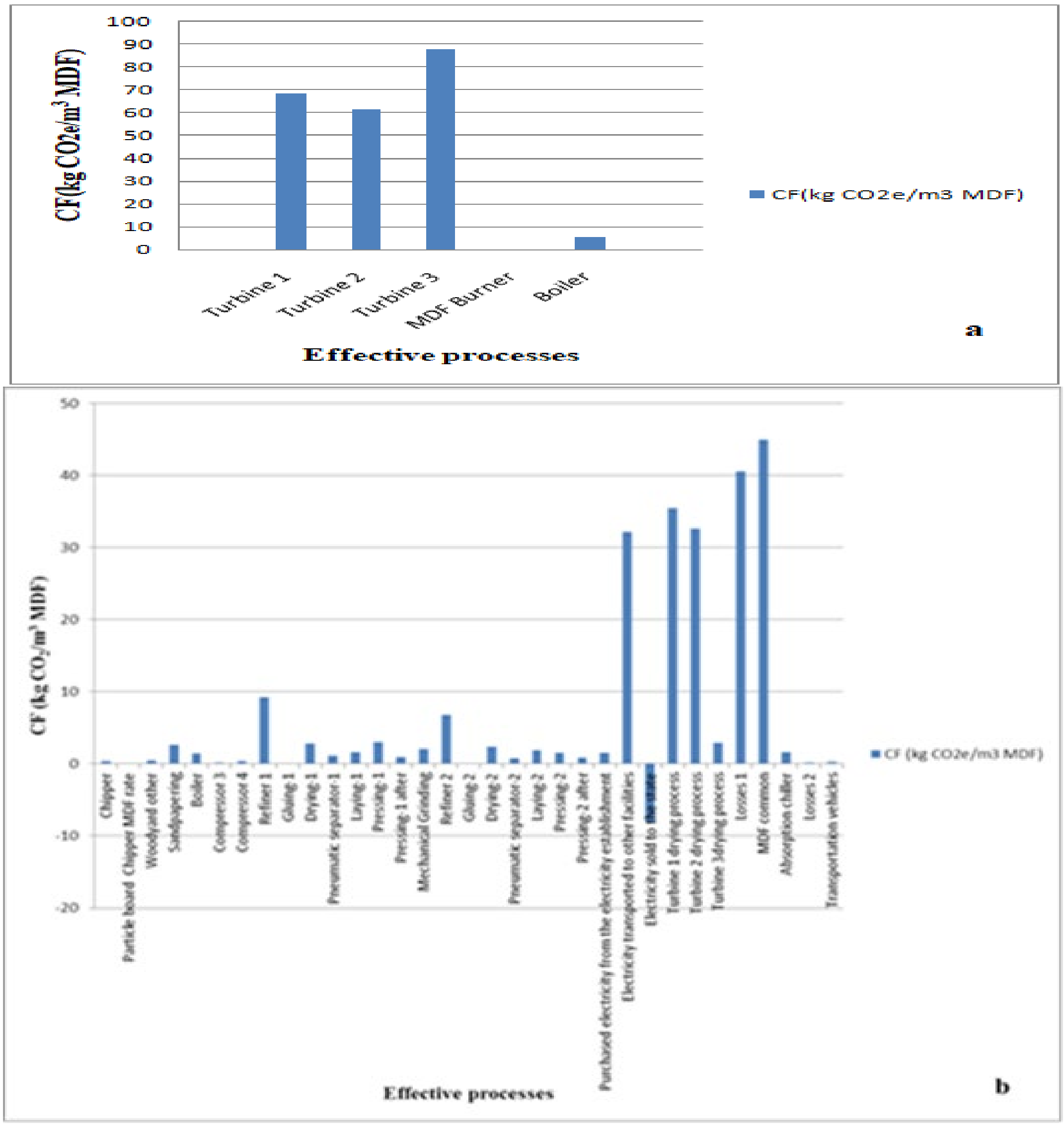

Figure 4. CF for each effective process (a-Primary and their' carbon footprints b-Secondary and their' carbon footprints).

3.2. Application of Pareto analysis

In this study, CF values were calculated for each process by means of primary and secondary energy sources with Tier 1 method. After then, Pareto analysis procedures are applied for drawn Pareto diagram. Pareto chart was drawn to define the problems which were revealed by the help of 80/20 law. For this aim, firstly, calculated CF values of every process' sources were enumerated as presented in Table 1.

Table 1. CF data according to effective processes in MDF production.

Serial number	Effective processes	CF (kg $CO_{2\,e}$ /m^3 MDF)
1	Turbine 1	68,47
2	Turbine 2	61,69
3	Turbine 3	88,08
4	MDF Burner	0,43
5	Boiler (consumed)	5,47
6	Chipper	0,35
7	PB Chipping MDF rate	0,05
8	Woodyard other	0,45
9	Sandpapering	2,59
10	Boiler (produced)	1,43
11	Compressor 3	0,2
12	Compressor 4	0,34
13	Refiner 1	9,21
14	Glueing-1	0,05
15	Drying-1	2,79
16	Pneumatic separator-1	1,13
17	Laying-1	1,62
18	Pressing-1	3,01
19	Pressing-1 after	0,96
20	Mechanical Grinding	2,03
21	Refiner 2	6,8
22	Glueing-2	0,03
23	Drying-2	2,38
24	Pneumatic separator-2	0,78
25	Laying-2	1,89
26	Pressing-2	1,45
27	Pressing-2 after	0,87
28	Purchased electricity from the electricity establishment	1,52
29	Electricity transported to other facilities	32,08
30	Turbine 1 drying process	35,45
31	Turbine 2 drying process	32,55
32	Turbine 3 drying process	2,93
33	Losses 1	40,54
34	MDF common	44,91
35	Absorption chiller	1,59
36	Losses 2	0,15
37	Transporation vehicles	0,22

Table 2. CF datas in ranked from high to low, calculated percent and cumulative percent of CF in medium-density fiberboard production.

Serial number	Effective processes	CF (kg $CO_{2\,e}/m^3$ MDF)	Percent (%)	Cumulative percent (%)
3	Turbine 3	88,08	19,29506	19,30
1	Turbine 1	68,47	14,99923	34,29
2	Turbine 2	61,69	13,51399	47,81
34	MDF common	44,91	9,838113	57,65
33	Losses 1	40,54	8,880808	66,53
30	Turbine 1 drying process	35,45	7,765778	74,29
31	Turbine 2 drying process	32,55	7,130496	81,42
29	Electricity transported to other facilities	32,08	7,027536	88,45
13	Refiner 1	9,21	2,017569	90,47
21	Refiner 2	6,8	1,489627	91,96
5	Boiler (consumed)	5,47	1,198274	93,16
18	Pressing-1	3,01	0,659379	93,82
32	Turbine 3 drying process	2,93	0,641854	94,46
15	Drying-1	2,79	0,611185	95,07
9	Sandpapering	2,59	0,567373	95,64
23	Drying-2	2,38	0,52137	96,16
20	Mechanical Grinding	2,03	0,444698	96,60
25	Laying-2	1,89	0,414029	97,02
17	Laying-1	1,62	0,354882	97,37
35	Absorption chiller	1,59	0,34831	97,72
28	Purchased electricity from the electricity establishment	1,52	0,332976	98,05
26	Pressing-2	1,45	0,317641	98,37
10	Boiler (produced)	1,43	0,31326	98,68
16	Pneumatic separator-1	1,13	0,247541	98,93
19	Pressing-1 after	0,96	0,2103	99,14
27	Pressing-2 after	0,87	0,190585	99,33
24	Pneumatic separator-2	0,78	0,170869	99,50
8	Woodyard other	0,45	0,098578	99,60
4	MDF Burner	0,43	0,094197	99,70
6	Chipping	0,35	0,076672	99,77
12	Compressor 4	0,34	0,074481	99,85
37	Transporation vehicles	0,22	0,048194	99,89
11	Compressor 3	0,2	0,043813	99,94
36	Losses 2	0,15	0,032859	99,97
7	PB Chipping MDF rate	0,05	0,010953	99,98
14	Glueing-1	0,05	0,010953	99,99
22	Glueing-2	0,03	0,006572	100,00
TOTAL		456,49		

Then enumerated values were ranked from high to low and the total amount of CF was found as shown in Table 2. Besides seen in Table 2, percentage and cumulative percentage were calculated for every sources' of values were took place.

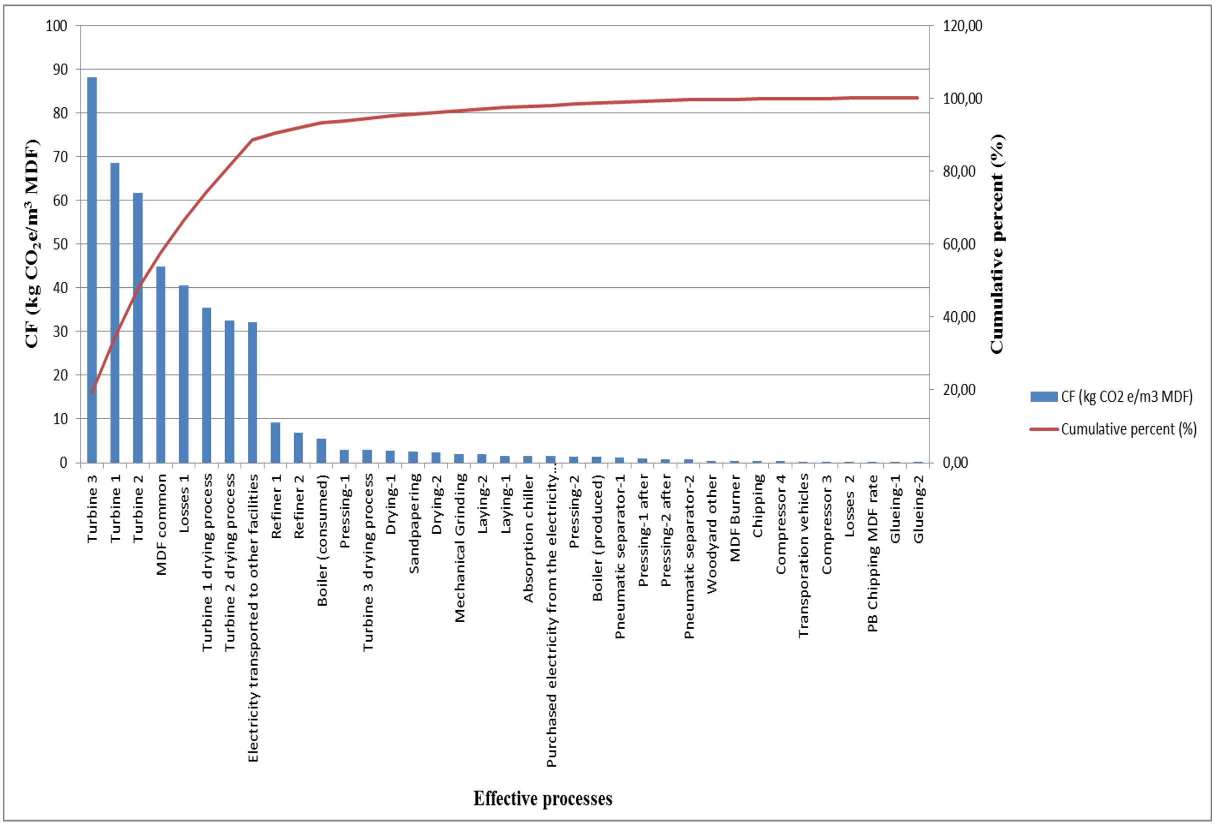

Figure 4. Application of Pareto analysis according to relationships between effective processes and carbon footprint values.

Pareto chart was drawn with 3 axes. While y axes in the left side shows CF values, y axes in the right side shows cumulative percent and x axes defines the sources in Fig.4.

3.3. Evaluation of scenarios to decrease of CF

As seen in Table 3, plant's total carbon footprint was calculated as 24,04 kg-CO_2e/m^3-MDF taking into consideration of all the processes for production according to scenario 1. The plant's total carbon footprint, taking into account of all the processes for production was calculated as 158, 34 kgCO_2e/m^3-MDF according to scenario 2.

Table 3. Carbon footprints according to scenarios.

INPUT/ OUTPUT	Effective processes	CF(kg CO2e/m3 MDF)	
		Scenario 1	**Scenario 2**
Primary	Turbine 1	5,55	-
	Turbine 2	5,002	-
	Turbine 3	7,14	-
	MDF Burner	0,43	-
	Boiler	5,47	-
PrimaryTotal		**23,82**	**-**
Secondary	Chipper	-	0
	Particle board Chipper MDF rate	-	0
	Woodyard other	-	0
	Sandpapering	-	0
	Boiler	-	0
	Compressor 3	-	0
	Compressor 4	-	0
	Refiner 1	-	0
	Gluing-1	-	0
	Drying-1	-	0
	Pneumatic separator-1	-	0
	Laying-1	-	0
	Pressing-1	-	0
	Pressing-1 after	-	0
	Mechanical Grinding	-	0
	Refiner 2	-	0
	Gluing-2	-	0
	Drying-2	-	0
	Pneumatic separator-2	-	0
	Laying-2	-	0
	Pressing-2	-	0
	Pressing-2 after	-	0
	Purchased electricity from the electricity establishment	-	0
	Electricity transported to other facilities	-	0
	Electricity sold to the state	-	0
	Turbine 1 drying process	-	35,45
	Turbine 2 drying process	-	32,55
	Turbine 3drying process	-	2,93
	Losses 1	-	40,54
	MDF common	-	44,91
	Absorption chiller	-	1,59
	Losses 2	-	0,15
Secondary Total		**-**	**158,12**
Primary and Secondary	Transportation vehicles	**0,22**	**0,22**
Total		**24,04**	**158,34**

4. Discussion

Gorener and Toker (2013) by using Pareto Analysis method; calculated the firm engaged in forest products industry which is specialized on medium-density fiber production. They purposed to define and classify failure modes and then make offers due to their importance degree by Pareto analysis. They also researched the occurrence of waste process by applying Pareto analysis. Bergman et al. (2014) investigated the carbon effects of wood products. This research determines how carbon emissions savings when wood products are consumed in constructing buildings in place of non-wood sources. Çetin et al (2014) are used pareto analysis method on the scope and extent of extra work caused by management and workers' issues in Turkish furniture industry. In our research, according to the Pareto diagram, it was clearly seen that Turbine 3, Turbine 1, Turbine 2, MDF common, Losses 1, and Turbine 1 drying processes are the first six effective processes constituting 74 % of the total problem sources (Fig. 4). While these six effective processes cause 74% of total problem, there is no problem of in remain which is composed of 26% of 37 effective processes.

Dodoo and Gustavson (2013) developed numbers of scenarios about the effect of wooden frame design on the life cycle of primary energy use in buildings. So, comparisons are made on the energy use and effects of carbon footprint for traditional and thermal insulated houses with those scenarios (usage of electric resistance heaters, heat pumps, cogeneration based heaters, and biomass based energy source heaters). Scenarios are created to decrease of carbon footprint values. Carbon footprint value is reduced 89 % by the use of biomass instead of natural gas energy according to scenario 1. According to scenario 2, solar panels are used instead of electricity energy so the carbon footprint value is reduced 1,41 % in this case. The objective of this research is to present and define factors that decrease of efficiency through issues of management, production processes, supervision of workers and aspects of the products themselves, therefore helping enterprises acquire necessary measures. This research was based on occurring cause effect diagram and evaluate the Pareto diagram to see the reasons which cause the highest emission problem(s).

5. Conclusion

In this study, it was demonstrated that the total amount of 6 effective processes which take place in sequences of 37 effective processes in the process correspond to 74 % of total amount of the processes with Pareto diagram by the help of 80/20 law. So primarily some improvements can be proposed for these 6 processes which are called Turbine 3, Turbine 1, Turbine 2, MDF common, Losses 1, and Turbine 1 drying process. It can be suggested that these processes may use biomass energy instead of natural gas as an energy source. Additionally, other renewables such as sun panels can be used as an energy source. Some best available techniques (BAT) can also be recommended. These techniques are explained below (Federal Environment Agency, 2011; BAT, 2014; Erdil, 2017; Erdil, 2018):

-Staff must be trained to develop environmental awareness periodically.

-Environmental management system must be applied for control of procedures and carry out responsibilities by personnel.

-Equipments' maintenance should be supplied regularly.

It is clear that, CF value is exhibited a very serious decline according to scenario 1 as a result of calculations mentioned in above. However, it seems that the biomass waste are not enough for obtaining energy as suggested in scenario 1. In case of being preferred scenario 1, biomass waste should be purchased out to carry out of this scenario. Also, it needs to be investigated in terms of cost and availability. On the other hand, installation cost of solar panels must be questioned for replacing the place of consumption of the electricity energy according to scenario 2. Furthermore, if the biomass wastes can be achieved to convert with high added-value products and high calorific products in MDF industry, which provide largely sustainable resources from forests, it will be achieved an environmentally friendly production.

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EVALUATION PRODUCT DEVELOPMENT, PRODUCT DESIGN FOR THE FURNITURE-WOOD INDUSTRY VIA QUALITY FUNCTION DEPLOYMENT AND PARETO ANALYSIS

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Abstract

Product design and development are often discussed from a strategic perspective by industry experts. A common view is that product development is necessary, and companies are advised to focus their efforts on it. In this study, the product development processes of companies in this industry are examined. The literature and concepts of product development, user friendly design, the state of innovation research in the furniture-wood industry and implementations of these concepts in the system, marketing strategy for the industry are presented in order to support the objective of this study. One purpose of this research is also to define the fundamental concepts and properties of the span of activities leading to products that are new to the firm, product development process and its key success factors but not necessarily new to the market perception, to present the literature of the resource-based view of the firm and the organizational capabilities approach approaching and to discover the principles towards the framework for furniture-wood industry. The study shares common ground with several of the perspectives described above.

This study aims to further the knowledge about product development in the furniture-wood industry and to provide insights that can help management, make their business' product development process more effective. According to this objective, the research is to demonstrate a general overview and assessment of product design-development in terms of management, quality management, and furniture products with the customer and market-business requirements via Quality Function Deployment (QFD) and Pareto Analysis (PA) for the wood-furniture industry.

Keywords: Wood-Furniture Industry, Pareto Analysis (PA), Product Development, Product Design, Quality Function Deployment (QFD)

1. Introduction

Resource limitations, production process uncertainty, the vulnerabilities of the wood material, and systemic limitations of supply chains to certain market segments were identified by product Development managers in the qualitative study as obstacles to product development. Research on forest product development can be classified according to the specific fields of interest: organizational innovation (what are the determinants of organizational innovation?); development of innovative goods (how can a good new product be better developed?); and Innovation structures (what is the right way to promote innovation in the composition and engagement of actors and institutions?). The numerous product, process and business processes advancement categories have been recognized by previous studies on advancement in the forest products industry. Researchers have given the highest importance to process creativity of these styles. For instance, the outsourcing techniques of the joinery and furniture sector have caused a demand for personalized blanks. Sector and consumer trends have contributed to process technology requirements (Hovgaard and Hansen, 2004; Hansen et al., 2006).

Initial public offering increases productivity by increasing the shelf life of a company and enabling cost savings for production and manufacture. Faster product production contributes to better efficiency according with the cite models built by consultant firms and other recent scientific studies (Robinson and Fornelli 1985; Griffin, 1997).

The increasing intensity encountered in the forest industry is rising as the availability of timber tightens and the global market sharps. However, a 'fresh' trend in innovative and environmentally sustainable building and refurbishment practices carries with it a tremendous possibility for the sector to expand its market shares by increasing value (Brege et al., 2004). Throughout the value chain of the building industry, the players have traditionally tried to optimize their own profit, without recognizing the impact of the value chain as a whole on the productivity (Nord, 2005). Previously, however, the emphasis on teamwork and the maximization of overall interest has been expanded. The concept is that new building practices and lean development strategies (e.g., modular architecture, off-site system manufacturing, and just-in-time delivery) would improve the productivity of all the value chain actors. Wood-based building technologies have numerous benefits in the manufacturing of off-site parts (e.g., light weight, which enables the transport of prefabricated modules) and are energy-efficient in both development and service (Sardén, 2005; Björnfot, 2006).

The latest developments in the retail market have included a broad variety of goods, dynamic pricing, product quality and user-friendliness. As a result, manufacturers of wood components are confronted with requests for vast quantities and a broad variety of ready-to-use items in packaging options tailored for the market. We are also expected to comply specifically with just-in-time delivery to retailers and fulfillment centers (Henningsson, 2005). Industries also shifted downstream in the furniture and joinery industry, contracting their wood processing operations and focussing on manufacturing, developing and selling device solutions. The resultant demands on the manufacturers of wood goods provide just-in-time production of specific blanks and parts, as well as technological and marketing assistance (Fransson, 2005). Ultimately, cost limitations, manufacturing method complexities, wood content vulnerabilities, and supply chains logistical deficiencies to certain consumer segments were described as obstacles to product growth by research and development representatives in the qualitative report.

2. Developments in the forest products industry - Marketing strategy

Marketing has highlighted the value of customers' position as collaborators in manufacturing processes. Customers are not a silent group and operating together more effectively in building meaning and meeting their specific desires is a ladder which often increases mutual happiness (Vargo et al., 2007; Abdolmaleki and Ahmadian, 2016). The opinions of management on product creation, as stated in the literature, revealed that product production in their businesses are carried out intentionally in a more unstructured, trial-and-error manner than suggested in the literature (Cooper and Kleinschmidt, 2004). Managers' views often offer proof of a personal association between creativity in the company, method and business model. This is compatible with some research (Schilling, 2008) but in contrast with an earlier forest industry innovation analysis (Hovgaard and Hansen, 2004), which defines such kinds of innovation as more or less distinct methods. Great consumer products do not market directly, so do not release classify themselves like an afterthought to be dealt with late in the process. A well organized human and correctly guided deployment is a finely balanced product marketing strategy, conducted with excellence. The delivery needs to be right resourced both in terms of individuals and funds (March and Simon, 1958; Hultink and Atuahene-Gima, 2000; Salomo et al., 2007).

Market costs of forest goods indicate a declining pattern, as demonstrated, for instance, by the actual value of sawn wood shipped from Finland, which plummeted 15 per cent from 1997 to 2004 (Finnish Forest Research Institute, 2005). Although, the belief in forest as an environmentally friendly resource has never been higher (Gustavsson et al., 2006; Upton et al., 2008). According to Hansen et al. (2014), forest strategic marketing work can be classified according to the key fields of interest: corporate creativity (what are the characteristics of innovation capability throughout companies?); new product creation (how could a competitive new product be better formed?); and process innovations (what is the structure of, and connection with, a new design?). Original forest product market innovation work has identified the different commodity, method and company advancement types of structures (Hovgaard and Hansen, 2004). Scientists have paid the most systems to perform creativity of such styles (Hansen et al., 2014). Sirmon et al. (2007) offer a paradigm explaining the mechanism through which organizations successfully build and optimize their capital and capacity resources by resources development. The model of this study demonstrates the mechanism by which resources are pooled and incorporated into capacity development, and explains how additional capabilities and capacities are created or gained, partially as a function of business sector impact.

Garcia and Calantone (2002) define the scale of creativity as the degree of product innovativeness for product inventions. They say that product innovation is a measurement of the possible misalignment that a product (method or service) in the marketing and/or technical cycle may produce. From a macro viewpoint, innovativeness is the potential of a technological product to establish a paradigm change within an industry's science and technology and/or business structure. Innovativeness is the potential of a new product to impact the current marketing strategies, technical capital, expertise, experience, strengths, or policy of the business from a micro viewpoint. Another (common and commonly agreed definition of product innovation according to Trott, 2005) is that proposed by Booz et al. (1982): 'New-to-the-world goods' establish a different demand and typically require a major technical change. The classification 'New Product Lines to the Business' encompasses goods new to the Business that enable the Company to join for the first time in existing markets. Additions to current product lines involve items of the same sort as established goods of the business but with one or more substantial variations. The hanges and modifications of current products segment involve improvements in the efficiency or functionality of established products, which comprise the bulk of all new product development. Drucker (2002) argued that innovation factors are contained in operational demands, business and consumer developments, emerging technology, unintended progress or loss, incongruities, population trends and paradigm adjustments. Throughout the Scandinavian forest industry several of those drivers are noticeable. Improvements in technology and business have contributed to new procedure demands, e.g. the restructuring practices of the joinery and furniture sector have created demand for design blanks. Changes in legislation and attitudes surrounding forest in multi-storey structures have contributed to growing interest in forest as a material for construction, therefore generating a need for wood-based device solutions for the construction sector (Nord, 2005).

Manufacturing process is also restricted, although in developed economies, trading is confined to manufacturers and customers. There are few vendors and the segment's main performance drivers are product growth, and building a reputable reputation of a trustworthy solution. Inventory control (e.g., at builders merchants) is an example of a complementary business on the path to maturity during the late growth process. Incrementally, a phase of supply problem is substituted by consumer expansion. The consistency of the company model increases and standardizes around those mainstream consumer structures have come a long way. Pressing costs is essential to product growth.

Industry analysts also address product creation from a technical viewpoint. A popular opinion is that new creation is required, so it is prudent that businesses concentrate their energies on it. There is also often guidance about what kinds of goods can be produced. Nevertheless, no matter what kind of growth initiative, conventional approaches, hierarchical processes and systems are obstacles to such progress in the forest industry (Nord, 2005). Studies on creativity in the forest industry based largely on process improvement (Hansen et al., 2014), and academics provided minimal guidance about how to successfully handle product production and resolve certain obstacles.

The key research issue is: What is the structure and engagement of actors and organizations that best promotes innovation? Studies into innovation processes are also the result of guidance about how to implement sectoral, national or global (innovation) policies. The Forest Development studies, a joint attempt to identify and incorporate the R&D (Research and Development) strategy for the forest business focused on by European forest owners' organizations (CEPF), the forest industry (CEIBois), and the paper industry (CEPI), are modern illustration of industrial collaboration that departs from the viewpoint of sectoral production schemes (www.forestplatform.org).

3. The Wood-furniture of Turkey

In Turkey, furniture is manufactured both in factories and in industrial-scale production units. Furniture production among a large number of small workshops is extremely decentralized. In manufacturing hand crafted and handmade furniture, these tiny workshops play a significant role. Workshops are versatile institutions in design that have ample resources that labor force to extend their manufacturing line and produce massive orders. By using advanced mass-production processes, large-scale wood furniture companies manufacture regular versions. Furniture-wood production in Turkey is concentrated primarily in Istanbul, Ankara, Bursa, Kayseri, Izmir and Adana. The most significant furniture production divisions are the center of Istanbul and Bolu-Düzce area, which is popular for its production of wood products. The wood industry is expanding rapidly in Bursa-İnegöl region, the third most important region of furniture production, which is accompanied by forest areas. The wood furniture industry in İnegöl region is limited but has tremendous potential to develop itself. Another significant furniture sector is Kayseri, which has a large manufacturing capacity for sofa beds, sofa beds and seven of Turkey's twenty-two largest producers' products (Furniture Industry in Turkey Report, 2010; Mobilya İmalatı Sanayi, 2015).

The wood industry is expanding rapidly in the Bursa-İnegöl zone, the third most important area of furniture production, which is surrounded by forest areas. The furniture industry in İnegöl area is limited but has tremendous potential to develop itself. Another significant furniture sector is Kayseri, which has a large manufacturing capacity for sofa beds, sofa beds and seven of Turkey's twenty-two largest producers. It also has furniture production districts named "Karabağlar and Kısıkköy" which supply furniture to the Aegean Region. As with so many consumer goods, furniture production is susceptible to change in design. Since the production of wood furniture is an important aspect of marketing, Turkish manufacturers are actively pursuing customer trends in international markets and are developing new designs and creating model modifications and enhancements. Turkish furniture makers and exporters are mindful that industry dynamics and customer behaviour play an important role in the production and design of new products (Furniture Industry in Turkey Report, 2010; Mobilya İmalatı Sanayi, 2015).

4. Materials and Methods

4.1. Quality Function Deployment

Quality Function Deployment (QFD) is a recognized strategy that works successfully in the manufacture and operation of high quality (Mazur, 2008; Sivasamy et al., 2015). Lam and Dai (2015) also claimed that QFD is well recognized for being a system that offers customers' expression in a comfortable way. QFD is regarded as an influencing device for companies to identify their customer requests, expand market share and enhance customer satisfaction strategies (Yeh et al., 2013). According to Khorshidi et al. (2016), QFD will help the creation of an important factor for the performance of product or service.

QFD is a methodology used in more effective product creation and Consistency Feature delivery improving consistency in many ways (Shen et al., 2000). The QFD approach identifies customer requirements in detailed, complex companies and helps them to resolve severe market strategies. QFD is a tailored quality control system (Kaulio, 1998) aimed at increasing consumer loyalty. Vinodh and Chintha (2011) stressed the point that QFD is not used to fix the issues, but is rather helpful in determining what needs to be done to improve consumer penetration. The QFD aims at helping the company to identify the customer; to meet with and prioritize client needs; to integrate demand for quality maximization; to prepare a holistic management system for user satisfaction; and to develop products/services approaches and practices that offer the greatest strategic advantage (Garver, 2012). A variety of QFD productive ventures in the private corporations, including the business system such as instruction (Koksal and Egitman 1998; Lam and Zhao 1998), difficult archives and database systems (Chin et al., 2001), public sector (Gerst, 2004), e-banking (Gonzalez et al., 2004). QFD is a frequently used, cross - organizational group systemic construction analyzed to determine and analyze significant issues related to customer satisfaction delivery, operational activities, policy and procedures (Gonzalez et al., 2004). QFD is a foundational solution to the development or enhancement of good quality and durable goods and facilities, property, qualities and accountability.

Deployment method for consistency feature: Quality Function Deployment (QFD) is a visual connective process that provides communities with the complete development programme focused on requirements of customers. It offers the means to provide consumers with realistic technological specifications at any step of a development cycle of customer/operation development. The usage of QFD can be checked well to minimize the development period by 50% and development costs by 30% (Clausing and Pugh, 199; Mukherjee, 2014).

Four steps of the activity of the QFD:
(i) The planning of products: quality house.
(ii) Product architecture and construction: emerging materials.
(iii) Preparing of the procedure.
(iv) Operating monitoring (illustrations of quality management).

A graph-matrix displays every phase of the QFD system cycle. QFD map is a graph that determines the "whats," the "hows," the interactions between "whats (consumer requirements)" and the parameters to determine which of the "HOWs (technical characteristics)" would reach the highest and most significant customer loyalty (Zare Mehrjerdi, 2011; Chahal and Thareja, 2012; Mukherjee, 2014).

As can be shown in figure 1, the house of quality (HoQ) comprises six steps:

1- Identify consumer specifications (WHATs) and decide certain weights for the left-hand wall of the house;

2- Link the quality of the company or the delivery of service to the right-hand wall;

3- Convert the client requirements into features and service design criteria (HOWs) just below the roof;

4- Decide the relation-core between WHATs and HOWs in the simple deployment matrix or in the modeling process decided to name;

5- Determine the relationship between the various attributes of the material and service architecture for the roof matrix and

6- Plan and develop the target utility conditions for the house's bottom floor, which are of utmost significance to each product / service design's structures and specifications.

The QFD illustrations supply the community of goals on topics that are of utmost interest to the customer and how they should be theoretically achieved.

To sum up, through benchmarking of technological, conceptual and consumer, the rating of the opponent's products and services may be performed. The QFD model is a multi - function system that can be extended throughout the whole partnership. This is an approach for engineering to restart clear, fundamental data in a functional form-document. This defines the customer's personality and general major shareholders for the context of selling and utilizes it to recognize and exploit potential possibilities (Clausing and Pugh, 1991; Chin et al., 2001).

4.2. Data and Methodology

In this part of the study, Quality Function Deployment (QFD) was implemented in this component of the analysis to obtain assessment of product design in terms of management, creativity, product-making quality control with the consumer and market-business expectation for the furniture industry. QFD was evaluated in the wood- furniture industry of Turkey. In this application, customer requirements, customer significance level and technical characteristics were determined and scored with the experts and employee of all production industrial sectors (TUSIAD-Turkish Industrialists and Business People Association). Besides, a questionnaire was prepared for learning the opinions, perspectives of customers about the sustainability of the lifecycle (design) of wood-furniture products. This step of the study was very important to gather data and also to assist in the implementation of the research.

The research was focused on a quantitative perception by means of a questionnaire-based survey determining the evaluation of the sustainability of the lifecycle (design) of or the furniture industry with companies-firms in Turkey currently enrolled in the program. This survey was e-mailed to approximately a total of 76 companies of Furniture production Industry in Turkey with the help of the Turkish Industrialists' and Businessmen's Association (TUSIAD) and Turkey Exporters Assembly (TIM). The results of this questionnaire were assessed on the framework of environment-oriented production such as green production. The sample size was 55, returning the survey from the textile companies in Turkey, with a 72% rate of response.

4.3. Quality Function Deployment Application

Customer requirements in the term of the lifecycle –furniture design of furniture products include some criteria. These are environmentally Eco-Friendly Design/Production-multi-storey construction (Green Production), Timely Delivery/Providing Service, Economic-User Friendly, fashion-Modular Design, Quality Production/drivers of product development, Long Life Production/Service (Customer Oriented).

The Technical characteristics include groupings identified according to the questionnaire on the environment which is focused on quality of product and sustainability of lifecycle of the textile product. These characteristics which were determined according to the survey questions and answers are shown in Table 1.

Some standards provide consumer expectations for quality-based products and customer loyalty, depending on the company's distribution structure. The technical features include quality control questionnaire defined, user-friendly interface based on product quality, efficiency, safety, reality and sustainability of incorporation of the enterprise's development network. These features are seen in Table 1 and Table 2 and were calculated due to the questionnaire and responses to questions.

Table 1. Technical Characteristics-Requirements (TCs-TRs)

Criteria			
s1	Regular machine checks-wide range of ready-to-use products	s10	Onsite Quality Studies-Green Manufacturing (Zero Error, Seeing the poor quality)
s2	Control plan at specific frequency	s11	Identify important points competitive pricing, Durable products
s3	Solving Technical Problems Presentation of the product / service to the customer	s12	Machines, Hand Tools and Auxiliary Apparatus innovation over improvements of thread
s4	Workers should work carefully	s13	Cutting Workshop Standing Work hidden engine of economy
s5	Machine-Equipments Maintenance systematics	s14	Psychosocial Factors-consumer-adapted packaging solutions
s6	Production Performance Evaluation wide product range	s15	Ergonomics & Manual handling & Handling of loads the more advertisement-Modular Design, Unique Design
s7	Technical Competences, Product Satisfaction	s16	Measures for chemicals-weaknesses of the wood material
s8	Brand, Fashion Trends	s17	Emergency Procedures-elimination structural shortcomings of supply chains
s9	Kaizen work (Improvements, Teamwork)	s18	Providing the necessary training and information

Table 2. Quality Function Deployment Table –Matrix for Furniture Industry

Customer Requirements (What)	Importance of customer**/ Technical characteristics (How)	Technical Criteria of Wood-Furniture Production																		General Total
		s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12	s13	s14	s15	s16	s17	s18	
Eco-Friendly Design / Production-multi-storey construction , Green production	4	3	9	3	9	9	3	9	0	0	9	3	9	9	3	9	3	3	3	
Timely Delivery / Providing Service	4	3	9	9	9	9	1	9	3	3	0	9	9	9	9	9	9	9	9	
Economic-User Friendly, Modular Design,Fashion Design	4	3	3	3	3	9	3	3	1	1	1	9	9	9	9	9	3	9	9	
Quality Production / drivers of product development	5	1	0	3	9	9	3	0	0	0	1	1	9	9	9	3	3	9	9	
Long Life Production / Service (Customer Oriented)	5	3	0	3	9	9	9	9	9	9	3	3	9	9	9	9	9	9	9	
Absolute Net Weight (AW)		56	84	90	174	198	88	129	61	61	60	104	198	198	174	168	120	174	174	2311
Customer Requirement Net Weight (CNW)		2,42	3,63	3,89	7,53	8,57	3,81	5,58	2,64	2,64	2,60	4,50	8,57	8,57	7,53	7,27	5,19	7,53	7,53	100,00
Rank		18	14	12	4	1	13	9	15	15	17	11	1	1	4	8	10	4	4	18

Note : Strenght of relationships (Yılmaz, 2009): Importance of customer **1-5 (1-Not important;2-Less important;3-not decide;4- important;5-Very important), Technical characteristics* (0-Not correlated;9-Very strong correlate;3-Middle correlate;1-Weak correlate)

For evaluated product categories from the furniture-wood industry, the QFD team focuses on the relationship (improvement ratio) between customer needs compares favourably to technical product specifications. The aim of this study is to decide how values variations of some quality characteristics influence the values of the other parameters for sustainability (Hows). Such research has a significant impact on the consistency and environmentally sustainable qualities of car components in the creation of the latest equipment, since the influence of intervention feedback on all business is shown. The outcome of this evaluation is reported in the matrix of correlations. The effects of the appraisal are reported in the framework of associations the make up the standard house without the roof. The QFD implementation analyzes the degree of satisfaction of customers with the quality attributes of customer demands (whats), associated with customer specifications, for analysed furniture sectors ' products with technical specifications of all furniture products. Importance weights (IW) – consumer requires degrees vary from 1 to 5 (5 – very important, 1 – not important), and the degree of connection intensity between consumer demands and technological demands of the applications are vary from 0 to 9 (9 – really strong correlation, 0 – not correlated).

For the first column, the metric and calculation knowledge are only clarified in respect to the requirement for consistency functions in the automotive industry, as seen below. Equations (1) and (2), similar to the similarity values of the QFD Framework Table (Table 2), are used for the scoring and comparisons of the other columns.

The numerical values in relationship matrix structures are an essential and simple technique for the measurement of weights. Equation (1) is the absolute weight (AW) of the j th functional criterion.

Absolute weight (AW): the calculation of IW weight and IR ratios brings one total weight of the consumer wants. The easiest way to measure the weight of the functional criterion is to assign symbol numbers in the reference matrix (Equation 1).

The following equation (1) shows the total weight of the functional specifications characteristic:

In the following Equation (1) and (2) (Yılmaz, 2009; Talebi, 2014; Mukherjee, 2014) we can show the level of importance of the corresponding features:

$$AW_j = \sum_{i=1}^{n} IR_{ij} \text{ x } IW_i \quad (1)$$

AW: Row absolute weight vector for degree of technical complexity of specific criteria-Absolute weight

Wherever;

IW: Importance Weight - importance weight of customer's requirement in respect with IRij

IR : Improvement Ratio - weight appointed to the relationship matrix, weight dedicated to the relationship matrix by row i and column j (i = 1,.2...,m m = 18 ; j = 1, 2, ...,n n = 5)

m = number of technical requirements

n = number of customer requirements.

Absolute importance weight (AW) is reported in the results matrix for each one of the specified quality features-criteria and higher absolute weight values represent the greater importance of the technical descriptor to represent VoC (Voice of Customer).

Consumer Need Weight (CNW-the relative importance): The AW value for each functional condition splits the total AW and then measures the percentage ratio to produce a weighted consumer required weight (Formula 2).

$$CNW_j = \frac{AW_j}{\sum AW_j} \text{ x } 100 \quad (2)$$

CNW in the first column = (The first total absolute weight in the first column/General Total of the Absolute weight) x 100

In addition, for each standard characteristic-criterion the relative weight (CNW) is determined in part as a share of the overall relative value of all property-criteria. From this knowledge, the QFD committee must decide which of the product characteristics-specifications would lead to greater consumer service in compliance with the requirements presented, and which will therefore need growth. For the measurement of CNW, the scoring-weighting and estimates in the other columns have been carried out, continue only as above formula (2).

Table 3. The groups of the priority order for the Technical Requirements (Depending on the sorting (Rank) CNW -percentage value)

The priority number-importance (Rank)	CNW-percentage value	Technical Requirements
1 (1)	8,57	s5; s12; s13
2 (4)	7,53	s4; s14; s17;s18
3 (8)	7,27	s15
4 (9)	5,58	s7
5 (10)	5,19	s16
6 (11)	4,5	s11
7 (12)	3,89	s3
8 (13)	3,81	s6
9 (14)	3,63	s2
10 (16)	2,64	s8;s9
11 (17)	2,6	s10
12 (18)	2,42	s1

The CNW-percentage values (Table 3) are the values found by calculating in Table 2. These values (CNW) are listed in Table 3 from high to low value in the application of quality function distribution in terms of meeting the occupational health and work safety and customer needs of the firm operating in the textile industry. With this ranking, suggestions were made for the technical characteristic results of high value. First, three (s5; s12; s13) technical characteristics, which gave the weight of customer needs with a percentage of 8.57%, secondly, four (s4; s14; s17; s18) technical characteristics, which gave the weight of customer needs, third suggestions were made for the development and improvement of one (s15) technical characteristics (CNW-technical characteristics which are listed in Table 3), which give the customer requirement weight (CNW) with a percentage of 7.27% in the priority ranking. It continues as shown in the Table 3.

5. Pareto Analysis Application

The Pareto analysis (PA) is adopted in a simple method to identify the root cause and/or problem solving; therefore the first component addresses the largest amount of issues. This is focused on the premise that as little as 20 percent of the problems will affect 80 percent of the issues.

Additionally, literature work shows that there is no doubt that the Technical Requirements (TCs-TRs) are the real modification of consumer needs and requests, however the actual TCs-TRs priority level. TRs are not appropriate, and can be further managed to improve. Regardless of the general trigger one TR may have precedence over the other TR. It can also be calculated that higher statistical importance of some TRs will do a stronger role than all the other TRs that might architect an implementation of the 80/20 theory of Pareto (Sankar and Prabhu, 2001).

Absolute weight (AW) values may be grouped into a Pareto diagram from the quality function deployment matrix (Table 1) to demonstrate the functional aspects are most critical in the fulfillment of consumer requirements.

A major risk threshold metric has been defined as a Pareto (PA) measurement of 80%, with an emphasis upon risk factors that may arise in the development and adjustment of quality-oriented engineering work and which has the gradation due to the magnitude of the quality parameters and the estimation of the related relative metric percent (Sankar and Prabhu, 2001). It is one of these types of studies which involve team preparation and analysis. Of the value of activity research to a related commitment that encourages assessments against possible errors to achieve a high-risk standard measured at the middle of the Average Weight (AW) table.

A similar chart may be developed by categorizing the data range into categories (also known as categories, bins or classifications). The Pareto chart's left-hand vertical axis is labelled 'absolute weight' (AW-the number of numbers for

Every classification), the correct vertical axis of the pareto chart is the total AW number, and the horizontal axis of the pareto chart is labelled with the specific criteria section names. Data points are numbered. Evaluation by residing within each group and constructing a Pareto diagram but unlike a bar diagram, the Pareto diagram is arranged in descending frequency severity and customers describe the groups (Sander, 1987; Figure 1).

Table 4. The Cumulative Values of CNW of the Technical Requirements for Pareto Analysis

Technical Requirements	AW	Percent (%)	Cumulative percent
s13	198	8,57	8,57
s12	198	8,57	17,14
s5	198	8,57	25,70
s18	174	7,53	33,23
s17	174	7,53	40,76
s14	174	7,53	48,29
s4	174	7,53	55,82
s15	168	7,27	63,09
s7	129	5,58	68,67
s16	120	5,19	73,86
s11	104	4,50	78,36
s3	90	3,89	82,26
s6	88	3,81	86,07
s2	84	3,63	89,70
s10	61	2,64	92,34
s9	61	2,64	94,98
s8	60	2,60	97,58
s1	56	2,42	100,00

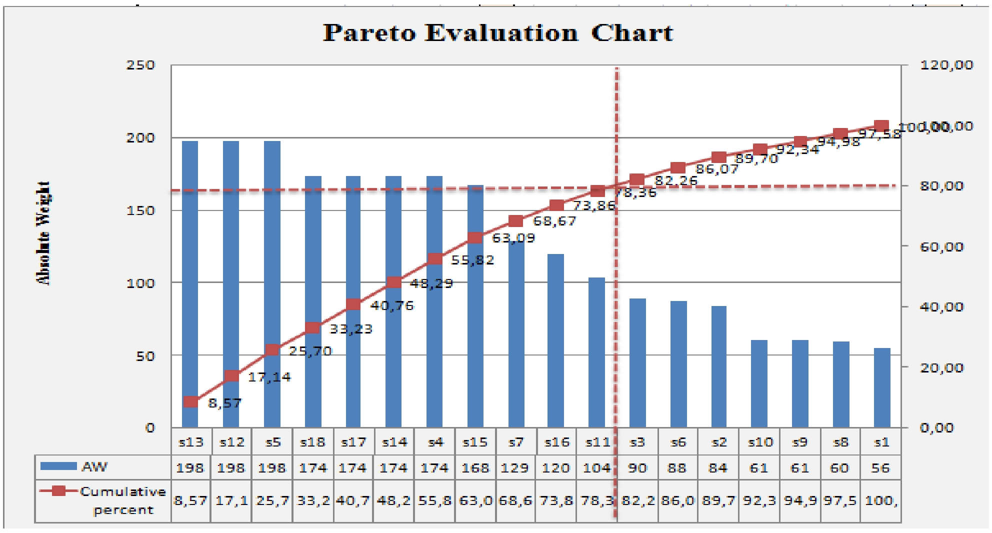

Figure 1. Pareto Analysis for the Prioritization of Technical Requirements

It is focused on the Pareto theory (also known as the 80/20 rule), which suggests that only a limited number of factors decide the bulk of the issues or outcomes of each case. The table 4 helps classify the vitally few participants who are accountable for most consistency problems. The chart is a kind of histogram that orders any data obtained by frequency of occurrence, and displays, for example, how many quality defects a specific category of defined cause has produced. A Pareto chart is used to display failures in the processing of beneficiary data for the initiative. The study defined eighteen items-categories of problems and calculated the amount of occurrence among the overall number of errors for each group. Figure 1 displays the corresponding map, where the bars reflect every failure type. The chart shows how 80% of errors could be reduced by improving data collection in 11 items-categories.

Correspondingly, in order to assess the value of technologies while developing, producing and refining the furniture products of the world furniture-wood industry in Turkey based on the significance of quality-oriented engineering studies, the TR for the longevity of the lifecycle of products following organized specifications is defined as an initial destination. PA findings lead to specific recommendations-solutions for systems and criteria that give rise to problems or issues with the proportion 80/20.

6. Discussion and Conclusions

According to the QFD, the resulting Pareto analysis (PA) review led to process guidelines, which identified difficulties or concerns with the 80/20 ratio. Pareto analysis theory advocates the determination of the top 20 percent of the causes that the needs to be addressed to resolve 80 percent of the challenges (Sankar and Prabhu, 2001); these methods are utilized with the most important forms of loss, in addition to address the original demand and customer service conditions. This challenge can be found in both industrial and utility industries. Failure Modes and Effect Analysis and Multi-Criteria Decision Making approaches can use together for this topic with every area of analysis that can be combined into the criteria of technology and the user.

It builds on the Pareto principle, which implies that only a small range of variables influence the majority of the problems or results of each event. The pareto chart is a form of histogram that points out any data collected by frequency of occurrence and shows, for example, how many quality defects a certain category of specified cause has produced. The Pareto diagram is used to demonstrate deficiencies in the collection of the beneficiary data for the project. The research established 18 issues-categories of problems and estimated the amount of instances between the total numbers of defects within each category. Figure 1 shows the related map, where the bars represent each type of failure. The graph illustrates how 80 percent of errors could be minimized by optimizing the processing of data in 11 categories.

Accordingly the TR for the durability of the product lifecycle following structured requirements is identified as its initial objective to assess the value of innovations during the growth, production and refining of furniture products in the global furniture-wood industry in Turkey based on the importance of quality-oriented technology studies. The results of the PA lead to clear recommendations-solutions for processes and requirements that give rise to challenges or concerns with an 80/20 ratio.

7. Conclusions

Pareto Analysis (PA) and Quality Function Deployment (QFD) classification have been widely employed in the literature and such approaches are also used to identify the most significant-threatening faults, remove or mitigate the most important forms of failures. Those are control analytical methods that can be used to assess which form of truth required to be assisted for improved improvement according to the measured and defined attributes. It can be known as the House of Quality had the opportunity to demonstrate durability of the technical facets of furniture product lifecycle by customer service demands, quality assurance and setting the stage for further real-life changes. A working group of leaders would develop a business plan to improve and raise efficiency by focusing on the benefits and disadvantages demonstrated by the equation of contact between the services of the customer and the associated property.

In this situation, these two methods were merged and employed together to test different requirements, boost quality of customer service and voice of customer (Customer loyalty with VoC-Voice of Customer). QFD is a systematic method for creating a new commodity or promoting sustainability, allowing the company to assess whether client preferences are adequately converted into their needs. Accordingly, achieving or beating consumer standards means more than maintaining or increasing service performance. Producers that do this, that rely on creativity and imagination to stay competitive, and who fulfill the expectations of their customers, will be able to compete in the global business climate. The software helps with identifying and categorizing the requirements for quality assessments to determine the lifecycle and longevity of furniture items.

The findings of the PA and QFD lead to simple recommendations-solutions for procedures and criteria that give rise to 80/20 problems or concerns. In the event of consideration of some recommendations to strengthen these criteria for the outcomes of applicable methodologies, a part of the important recommendations in this scope of study is explained as below;

-All specifications for the various stages of the life cycle should be determined in the design process. Maintenance and cleaning are the most important things which can be subject to particular criteria.

-The company helps a product to gain notice, among other items, by advertising it as a distinct furniture product. This is the fundamental aspect that shows the consistency and longevity of a furniture piece.

If the buyers are pleased with the advertised product, these consumers are converted into loyal consumers of the brand. Depending on the marketing strategy, the company allows the customer to buy new goods. The life-cycle of the product increases as the quality-durability of the product increases.

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STRUCTURAL PERFORMANCE ANALYSIS OF CROSS LAMINATED TIMBER (CLT) PRODUCED FROM PINE AND SPRUCE GROWN IN TURKEY

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Abstract

Wooden buildings with many advantages such as being lightness, durability, earthquake resistant, healthy, insulating, and esthetic are suitable for all kinds places especially earthquake zones. 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. This is a study on determining the properties of CLT panels manufactured from wood species grown in Turkey and investigating of the structural behaviour and seismic resistant performance of them. Lumbers of 100 mm (width) x 50 mm (thickness) x 2400 mm (length) used in CLT manufacturing were obtained from eastern spruce (Picea orientalis L.) and scots pine (Pinus slyvestris) logs. Two replicate three-layered CLT panels of 2400 mm × 2400 mm × 150 mm in size were manufactured for each group. Density of the CLT panels was determined according to EN 323. The seismic resistant performance of the CLT shear walls was determined according to ASTM E 72 standard. CLT panels manufactured from scots pine gave higher seismic performance than those of CLT panels manufactured from spruce. The maximum load capacity of the walls increased with increasing the density values of the CLT panels.

Keywords: CLT (Cross Laminated Timber), structural behaviour performance, artificial neural network, scots pine, spruce

1. Introduction

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). Engineered wood products, such as glued-laminated timber (glulam) beams and cross-laminated timber (CLT) panels, involve adhesive bonding and/or mechanical metallic fastening of timber to make large structural sections and building components (e.g. beams, columns, panels, walls, roofs) for construction applications. Furthermore, these engineered wood products are alternatives to common structural materials such as steel and concrete, and are consumed in large volumes worldwide (Sotayo et al., 2020).

CLT is a solid wood board made of timber a structural composite sheets with an orthogonal (90°) staggered assembly and is pressed by structural adhesives (FPInnovations, 2011). The use of Cross Laminated Timber (CLT) as a construction product has quickly grown in the last 15 years (Christovasilisa et al., 2020). The annual global volume production of CLT has seen exponential increases from production of 50,000 m^3 in the year 2000, to 625,000 m^3 in 2014 and an expected 3,000,000 m^3 by 2025 (Dugmore et al., 2019). In recent years, Cross Laminated Timber (CLT) has been widely used for different types of buildings such as offices, commercial buildings, public buildings and multi-story residential complexes (Hashemi and Quenneville, 2020).

The cross lamination provides good dimensional stability to the product, makes prefabrication of long and wide panels possible, and provides higher splitting resistance in connection systems (Gagnon and Pirvu, 2011). Cross laminated timber provides an alternative to concrete and steel, with efficient structural properties and excellent environmental attributes. It is a viable option for multistory buildings and large-scale structures because of its light weight relative to concrete, high strength and stiffness relative to light-frame wood, and its ease of assembly attributed to a high degree of prefabrication (Hossain et al., 2016). Given that these panels are also the main lateral load-resisting elements, the seismic performance of the system considerably depends on their lateral strength and stiffness. Thus, extensive research on the seismic behavior of these structures has been initiated by many research groups around the world to investigate the feasibility of adopting timber panelized structures in very seismically active areas (Hashemi et al., 2020).

CLT passed a major milestone in North America in 2012 with the publishing of ANSI/APA PRG 320, a recently updated standard that defined product manufacturing and design specifications for producers and users (ANSI/APA, 2019). According to J. Elling of the APA - The Engineered Wood Association, Tacoma, WA. (personal communication, August 2019), there are currently six CLT manufacturers scattered around the U.S.; D.R. Johnson, Freres Lumber Co., Inc., International Beams, Katerra, SmartLam, Sterling Solutions, and Vaagen Timbers. (Scouse et al., 2020).

The adoption of cross-laminated timber in Central Europe, starting in Austria, has generated interest in using local resources to create CLT panels elsewhere in Europe (Sikora et al., 2016; Aicher et al., 2016), Asia (Okabe et al., 2014; Lu et al., 2018; Song and Hong, 2018), Australia and New Zealand (Iqbaì, 2015), North America (Mohamadzadeh and Hindman, 2015; Kramer et al., 2014; He et al., 2018; Crovella et al., 2019), and South America (Baño, 2016). Currently, three main softwoods species including Spruce-Pine-Fir, Southern-Pine-Fir and Douglas fir-Larch are used as the main raw materials for commercial production of CLT panels (FPInnovations, 2013., ANSI/APA, 2017). However, due to lack of softwoods species in some countries, many attempts have been focused on using local hardwood species to produce CLT panels (Srivaro et al., 2020) Also, CLT panels are made from different timber species that depend on local resources such as Kiri, Katsura, Sugi, Hinoki, Buna spruce pine (Europe and Canada) and Radiata pine (Australia and New Zealand) (Navaratnam et al., 2020).

When the literature analysis is examined, it was shown that every species from different locations used in CLT manufacturing gave different mechanical performance. Research has shown that lack of edge gluing and gaps can have an influence on the mechanical response of CLT (Gardner et al., 2020).

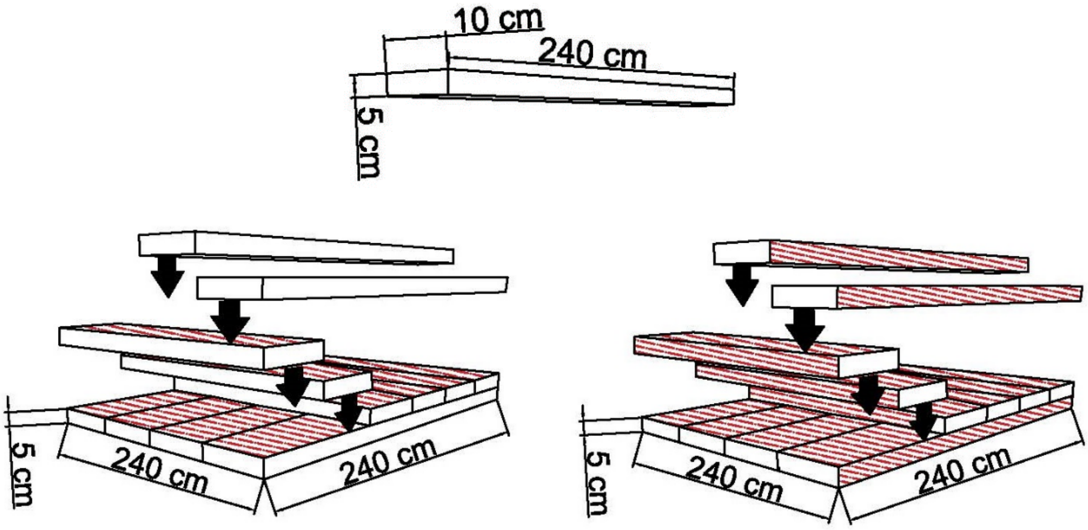
In this study the seismic performance of cross laminated timber produced from wood species grown in Turkey were investigated. Also, the current paper investigated the effect of gluing methods on the technological properties of CLT panels.

2. Materials and Methods

2.1. Wood Materials and Manufacturing of CLT

In this experimental study, lumbers of 100 mm (width) x 50 mm (thickness) x 2400 mm (length) were obtained from eastern spruce (Picea orientalis L.) and scots pine (Pinusslyvestris) logs. The lumbers were oven-dried in a lumber dryer until to reach 8±3% equilibrium moisture content. All sides of the lumbers were planned to reach to the desired thicknesses and widths before manufacturing.

Polyurethane adhesive which has high resistance to water and temperature was used for CLT manufacturing (KLEIBERIT PUR Adhesive 506.0). It is D4 according to DIN/EN 204. Two different methods were applied in CLT panels manufacturing. In one, the adhesive was only applied to the top surfaces of the lumbers. The narrow edges of them were not glued (non-edge-gluing). In other method, the adhesive was applied to both of upper surfaces and the narrow edges of lumbers (edge-gluing). Adhesive applying processes on CLT panels are shown in Figure 1 for both methods. The adhesive was applied at a rate of 160 g/m^2 by using a roller glue spreader.



a b

Figure 1. a) Non-edge gluing, b) Edge gluing (The shaded area shows the surfaces where gluing is applied)

Hydraulic cold press which can apply vertical clamping pressure and side clamping pressure as shown in Fig. 2 was used for pressing of CLT panels. The panels were pressed under a vertical clamping pressure (0.8 N/mm^2) and side clamping pressure (0,276 - 0,550 N/mm^2) for 40 min at ambient temperature.

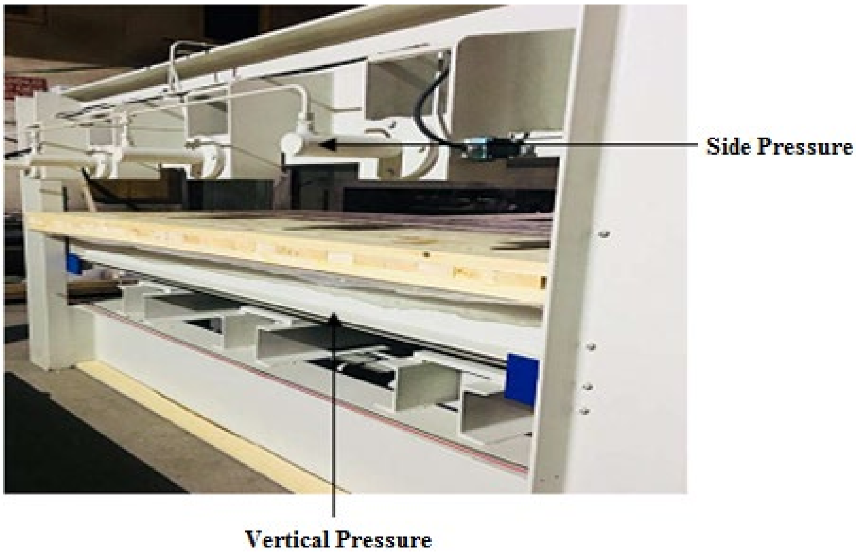
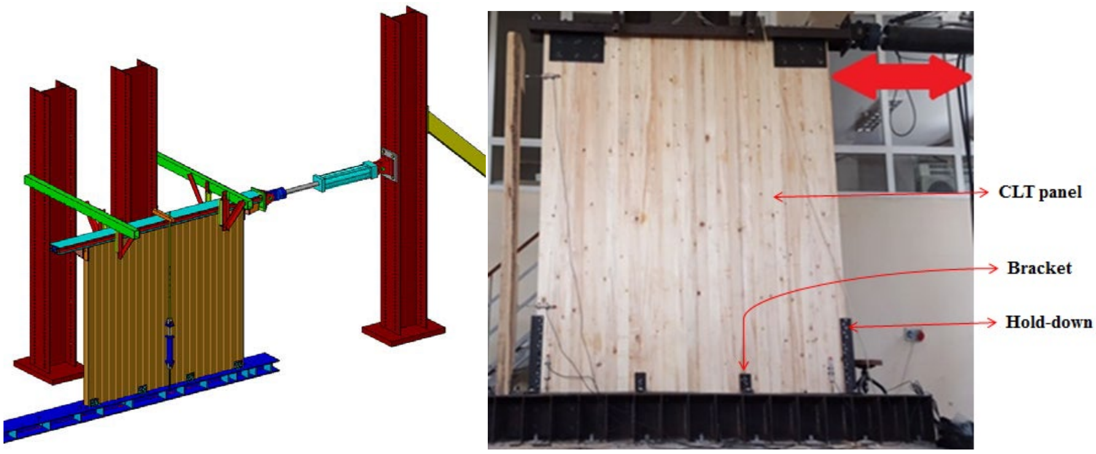


Figure 2. Hydraulic cold press

In this study, two replicate three-layered CLT panels of 2400 mm × 2400 mm × 150 mm in size were manufactured for each group. Then the panels were conditioned at 65 ± 5% RH and 20 ± 2°C for 2 weeks prior to technological testing.

2.2. Testing Procedures

The seismic resistant performance of the CLT shear walls was determined according to ASTM E 72 standard. Maximum load capacity and maximum displacement were also detected for each group. A sketch of the test set-up with a specimen ready for testing is shown in Fig. 3a (Popovski and Karacabeyli, 2012). CLT wall during the testing is shown in Fig. 3b. CLT shear walls in platform-type construction consist of two parts: connections and CLT panels (Fig. 3b) (Shahnewaz et al., 2019).



a b

Figure 3. a) Sketch of the test setup used for CLT walls b) CLT wall during test

The CLT wall analyses were carried out according to the ASTM E72 (2014) standard for displacements under loads of 354 kg, 712 kg and 1071 kg. After the shear wall was loaded as specified to 354 kg, 712 kg and 1071 kg load it again to failure or until the total displacement of the panel becomes 100 mm. The load was then loaded up to the maximum load that the shear wall could carry and the displacements at maximum load were determined.

Density of CLT panels were determined according to EN 323 (1993).

3. Results and Discussion

The density of the panels was determined in accordance with relevant standard. The obtained values are given in Table 1.

Table 1. Density of CLT panels

Density (gr/cm³)	Scots pine		Spruce	
	Non-edge gluing	Edge gluing	Non-edge gluing	Edge gluing
X	0,471	0,456	0,467	0,443
S	0,0137	0,0214	0,0313	0,0140

X: Arithmetic mean values, S: Standard deviation

According to Table 1, the density of CLT panels manufactured from scots pine logs is the higher than spruce.

The CLT wall groups were tested according to ASTM E 72 (2014) and some calculations were made for the seismic performance of the walls in the current study.

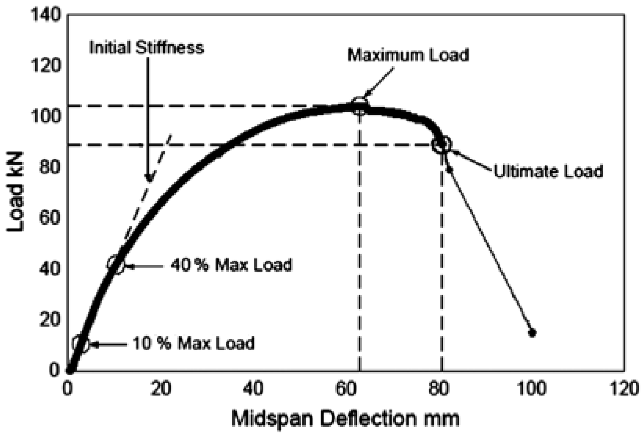


Figure 4. Analysis of a load-displacement curve (Pirvu 2008).

The following properties were calculated from this test, as illustrated in Figure 4:

• Initial stiffness, by selecting the points closest to 10% and 40% of the maximum load and fitting a straight line to the intervening points;

• Ultimate load, as 80% of the maximum load;

• Displacement at ultimate load; was identified based on the calculated ultimate load.

Fig. 5 shows the response of the CLT walls tested under loading. Higher maximum load displacements at maximum load were obtained from scots pine (non-edge gluing) CLT walls. Spruce CLT wall groups were higher maximum load displacements values at maximum load than those of scots pine CLT wall groups.

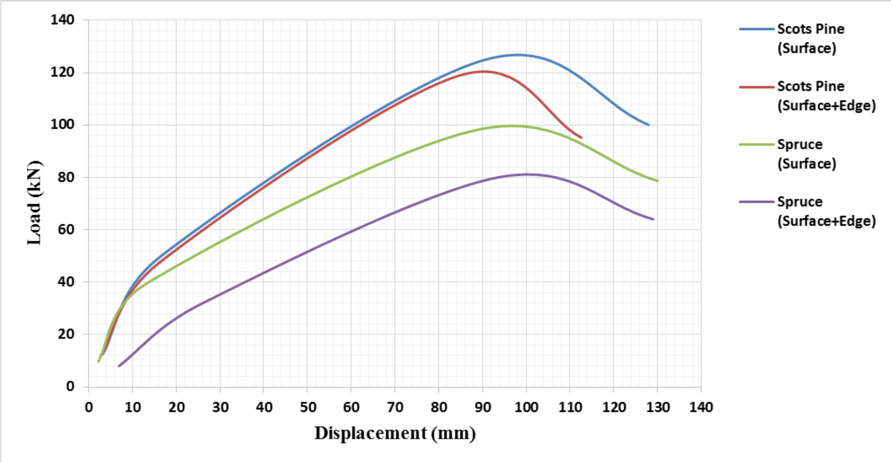


Figure 5. Load-displacement relationship for the test groups

Table 2. Results of seismic resistant performance test

Wood Species	Gluing Method	Maximum Load (kN)	Maximum displacement (mm)	Stiffness (kN/mm)	Ultimate load (kN)	Displacement at ultimate load (mm)
Scots pine	Non-edge gluing	125.09	90.94	2.81	100.07	127.96
	Edge gluing	119.02	84,95	2.65	95.21	112.57
Spruce	Non-edge gluing	98.35	89.33	2.72	78.68	130.4
	Edge gluing	80.09	93.78	1.25	64.07	128.99

As shown in Fig. 6, the main damages were found in the connecting elements at the end of the tests. It is similar to the literature. Previous researches indicated that CLT shear wall failure was mostly localized at the connections in a combination of sliding and rocking behavior (Shahnewaz et al. 2018; Gavric et al. 2015).

Figure 6. Failure modes of CLT shear walls

Stiffness is one of the most important parameters for structural panels. If the panels used for sheathing material in a shear wall which have higher stiffness, they will be more resistant to earthquake loads (Demirkir and Colakoglu 2015). As shown in Table 2, CLT panels manufactured with scots pine (non-edge-gluing) showed the highest stiffness, whereas CLT panels manufactured with spruce (edge-gluing) showed the lowest stiffness value. In addition to stiffness, ductility which is defined as the ability to deform structures especially with the effect of the load, is also an important factor. The displacement values at ultimate load can be compared in determining the ductility properties of the walls. According to Table 2, CLT panels manufactured with spruce (non-edge-gluing) showed the highest displacement value at ultimate load, whereas CLT panels manufactured with scots pine (edge-gluing) showed the lowest value. Gavric et al. (2015) were examined cyclic behavior of CLT wall systems and they found initial and plastic stiffness values between 0.47-0.96 kN/mm, 2.82-5.77 kN/mm, respectively. In this study, the stiffness values were found in between 1.25 and 2.81 kN/mm. Since CLT panels are rigid in comparison to their connections, the stiffness of CLT systems mostly depends on the connections (Shahnewaz et al. 2018).

When the effect of wood species on the maximum load carried by the walls is examined, the CLT walls manufactured from scots pine gave higher results than CLT walls manufactured from spruce (Table 3). The reason of this, scots pine has the highest density values (Table 1). It was stated that the lateral load resistance of a timber frame system depends on the rigidity of the timber, the sheathing material and the connecting elements used on the shear wall (Li et al. 2007). The highest displacement value at ultimate load was obtained from the CLT shear walls manufactured from spruce. As can be seen from Table 2, the maximum load values and displacement value at ultimate load of non-edge-gluing CLT panels were higher than those of the edge-gluing CLT panels. The lateral resistance of shear walls is generally influenced by 4 factors which are stiffness, bending strength, resistance at break and ductility (Demirkir et al. 2019).

The current version of ANSI/APA PRG 320 (2018), the performance standard for CLT in North America, has no provisions for gaps in CLT, and it is the authors' understanding that the committee that oversees PRG-320 is now considering a limitation on gaps. Under the European standard (2015), gaps as large as 6 mm are acceptable between adjacent laminations within a layer. Since edge gluing is not required under either standard, it is not uncommon for small gaps to occur between edge joints during the manufacturing process (Gardner et al., 2020).

4. Conclusion

The effects of production factors (wood species, gluing method) of CLT panels manufactured from wood species grown in Turkey on seismic performance of the panels were investigated in this study. CLT panels manufactured from scots pine gave higher maximum load (kN) and ultimate load (kN) values than those of CLT panels manufactured from spruce. Generally, CLT panels manufactured from non-edge-gluing of lumbers gave higher seismic performance than those of CLT panels manufactured from edge gluing of lumbers. Therefore, it can be concluded that there is no need to glue the side surfaces which cause loss of labor, time and cost. It is thought that the results presented in this study can provide a basis for the use of CLT panels from wood species grown in Turkey, resulting to widespread of CLT panel whole Turkey.

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INVESTIGATION OF HIGH STRENGTH COREBOARD PRODUCTION POSSIBILITIES

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Abstract

Some problems may arise from raw materials in packaging paper production factories used as waste paper raw materials. As waste paper fibers that are not primary fibers are recycled many times, the fibers can shortened and cut. This situation causes a decrease in the strength properties of the produced paper. The aim of this study is to improve the strength properties of coreboards produced from waste papers using commercial cationic starches (Cargill (Charge120), Roquette (Hi-Cat c643a), ADM (Meribond 166)). Coreboards with 450 (gr/m^2) grammages were produced by using certain proportions of cationic starch. Tensile and burst strength tests were carried out on the obtained coreboards, and the effect of cationic starches and dosage amounts on the strength was investigated. Based on the obtained results, it was observed that the coreboards produced using Hi-Cat cationic starch gave the best strength values. It was found that 40 kg/ton paper of Hi-Cat cationic starch gave the best values in cationic starch dosages such as 20-40-50 kg/ton paper. The breaking lengths (cross and machine directions) and burst strength of these coreboards were found to be 1.9 km, 3.9 km and 8.0 kg/cm^2, respectively.

Keywords: Coreboard, cationic starch, waste paper, strength

1. Introduction

In addition to fiber raw materials and fillers, different chemicals are also used extensively in paper production. These materials are used to improve the properties of the paper, such as coating the paper, adjusting its interaction with liquids, providing durability in wet and dry environments and colouring (Brander and Thorn, 1997). They are also used to increase the efficiency of the operating conditions of the paper mill such as drainage, retention, pitch prevention and foam extinguishing and to ensure effective operation. Polymeric materials are widely used in paper production with different mechanisms in many applications (Ondaral, 2007).

The importance of using waste paper as a raw material in the paper industry has increased significantly in the last decade (Bajpai, 2014). It is possible in today's paper production technologies to collect waste paper and to use paper and board products as raw materials by recycling them after use. Thus, environmental pollution caused by the disposal of used paper and cutting more trees can be prevented (Usta, 2004).

In addition to all the mechanisms that cause the interaction between the two fibers, the interaction between the fibers in sheet formation and during drying is very important for the strength of the paper (Ondaral, 2012). The fiber surfaces, which swell too much during the web formation and drying, will be pushed together with the capillary forces created between the fibers during the removal of water. This capillary force will deform the outer surfaces of the fibers and an internal bonding will take place between the fibers forming the paper as in the schematic representation given in Figure 1 (Ondaral, 2012).

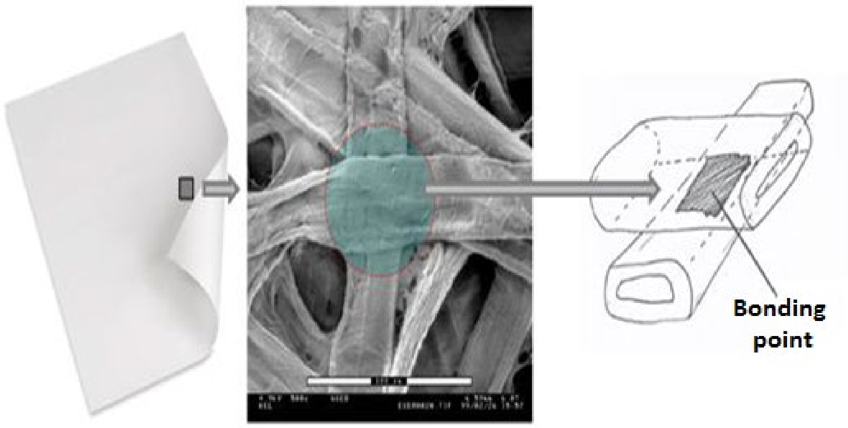

Figure 1. Schematic representation of inter-fiber bonding

The strength of this bonding point depends on the molecular bonding area in the bonding region, intermolecular forces, mechanical coupling between opposing surfaces, and the possible presence of covalent bonds (Ondaral, 2012).

Some problems may arise from the raw material in the packaging paper production factories used as recycled waste paper raw material. Since waste paper fibers that are not primary fibers are recycled many times, the fibers can be shortened and cut (Casey, 1980). This situation causes a decrease in the strength values of the produced paper. In order to minimize these strength losses, some chemicals and additives are used during paper production. The most commonly used substance among these is starch (Casey, 1981).

Starch is a basic substance used in various stages of paper production (bleached, unbleached, coating, uncoated, mechanical or chemical, printing paper or wrapping paper) It is used as glue are used corrugated cardboard as binder for bonding, glomeration and reaction matter. It is used during the production and after surface treatments to improve the properties of the paper. It is also used as glue in corrugated cardboard production (Bajpai, 2014). Starch and other additives improve the properties of paper and paperboard. It is used in papermaking processes, for coating purposes or for bonding. It strengthens the packaging products or improves the surface smoothness, gloss and opacity of the paper for better printability (CEPI, 2003).

While some of the coreboard cardboard, one of the paper industry product groups, is produced in our country, its value-added types are imported. According to Turkey Statistical Institute (TUIK) data, 12.7 thousand tonnes of coreboard were imported in 2018. Kahramanmaraş Paper Mill (KMK) aims to meet the national and domestic production needs that can be substituted for imported products needed in our country with sustainable R&D studies.

The aim of this study is to produce coreboard that has high Scott Bond value. While there are similar results of the study in the world, it is a new product group with added value for our country. It is aimed to develop an innovative product that is outside of standard production. The main goal of the study is to produce another product group in the paper and board category with added value.

2. Materials and Methods

The pulp samples used in this study were taken from the KMK pulp preparation unit that is produced under operating conditions. The pulp samples used in all laboratory studies were obtained from the same unit. For this reason, the produced papers have exactly the same pulp properties. The freeness level of the pulps was determined on the Schopper Riegler device according to the ISO 5267-1 standard. In addition, the properties of the pulp such as conductivity, dry matter, pH and anionic charges were investigated.

In the study, 3 different types of modified starch, known under the trade names Charge 120 / HICAT c643a / Meribond 166, whose use as dry strength enhancer was supported in literature studies were used. Starches were referred to as C (Charge120), H (Hi-Cat c643a), M (Meribond 166) as seen in Table 1 below.

Table 1. Modified starch properties

Code	Commercial Name	pH	Cationicity (DS)
C	Charge120	6-7	0,60-0,65
H	Hi-Cat c643a	6-7	0,65-0,68
M	Meribond 166	6-7	0,40-0,45

450 g/m^2 coreboards were produced with using 20 kg/ton starch. In addition, base (control) papers were produced under the same conditions. Then, the strength properties of all coreboards were determined.

During the coreboards production, 0.2% silica and 0.05% CPAM as anionic contaminant cleaner were added and the dry starch matter ratio was adjusted to be 3% in starch cooking. Then, the starch solution was added to the pulp suspension in the amount to be applied 0.02 kg of starch to 1 kg of dry paper and it was prepared for papermaking by mixing at 250 rpm at constant speed for 30 minutes.

This section should provide sufficient details of the experiment, simulation, statistical test or analysis carried out to generate the results such that the method can be repeated by another researcher and the results reproduced. The cationicity requirement of the prepared dough and its pH balance were adjusted. Coreboards were produced in Rapid Köthen paper machine from prepared starch-added and starch-free base pulps. The breaking length and burst indices of the coreboards were determined according to TAPPI T494 and TAPPI T403 standards. Ten test papers were produced from the pulps obtained from each experiment and arithmetic means of the data were used for evaluation of the study.

3. Results

The properties of the pulp, white water and retention in wet-end during paper production were given in Table 2 below.

Table 2. Pulp, white water and retention properties in coreboard production with using different starches

Starch Type	Pulp				White Water		Total Retention (%)	Filler Retention (%)
	Dry matter (%)	°SR	pH	Filler (%)	Dry matter (%)	Filler (%)		
Base	1.10	42	7	15.4	0.19	53.6	85.7	68.3
C	1.10	42	7	15.0	0.12	66.7	89.4	75.4
H	1.10	42	7	14.9	0.11	58.4	92.9	83.6
M	1.10	42	7	14.2	0.14	57.2	89.4	81.2

Total and filler retention rates increased with the use of cationic starch in the pulp slurry. The highest retention rate was obtained with the use of H starch. With the addition of H starch to the system in coreboard production, the total retention rate increased by approximately 8.4%. Using H starch gave the best filler retention rate compared to the other starches and it increased the filler retention about 22.4% in coreboard production. Due to the increase in retention, there were also decreases in the amount of dry matter and filler in white water.

Some strength properties of the coreboards produced with using different starch types were given in Table 3.

Table 3. The strength properties coreboards produced with using different cationic starches

Starch Types	Breaking Length (km)		Burst Index (kg/cm²)
	Machine Direction (MD)	Cross Direction (CD)	
Base	3.87	1.83	5.7
C	3.91	1.85	6.6
H	4.28	1.92	7.0
M	4.19	1.89	6.8

The use of cationic starch has improved the strength properties of the coreboards. As can be seen in Table 3, it was observed that the H cationic starch provided higher strength properties compared to other starches as a result of the values obtained in the samples produced with C, H and M cationic starches. With using H starch in production, breaking lengths (MD and CD) and burst index values of the coreboards with 450 grammages increased about 10.6%, 4.9 and 22.8%, respectively.

When the strength properties of coreboards made using different starches are examined, the best properties were obtained by using H cationic starch. For this reason, H starch was used in different dosages and the effect of starch dosage on the coreboards strength properties was investigated. 20-40-50 kg/ton paper dosages of H cationic starch were used in coreboard production and properties of pulp, white water and retention in wet-end were given in Table 4 below.

Table 4. Pulp, white water and retention properties in coreboard production with using different H cationic starch dosages

Dosages (kg/ton paper)	Pulp				White Water		Total Retention (%)	Filler Retention (%)
	Dry matter (%)	°SR	pH	Filler (%)	Dry matter (%)	Filler (%)		
0	1.22	44	7.10	23.0	0.12	50.3	87.3	74.1
20	1.23	43	7.05	23.4	0.11	53.3	88.7	76.4
40	1.28	44	7.10	22.8	0.12	56.7	90.4	78.1
50	1.19	43	7.03	23.1	0.10	57.4	91.1	80.6

According to Table 4, the dosage increases in the use of H cationic starch increased the retention rates. The highest retention rate was obtained with the use of 50 kg/ton paper of H cationic starch, and compared to the production of non-starch paper, it increased the total and filler retentions by 4.4% and 8.8%, respectively.

The breaking length and burst index values of the 450 gr/m^2 coreboards with using cationic starch in different dosages were presented in Table 5.

Table 5. The strength properties coreboards produced with using different cationic starches

Dosages (kg/ton paper)	Breaking Length (km)		Burst Index (kg/cm²)
	Machine Direction	Cross Direction	
0	3.17	1.71	6.7
20	3.36	1.77	7.3
40	3.89	1.90	8.0
50	3.60	1.82	7.7

According to Table 5 above, as the cationic starch usage dosage increased, the breaking length and burst index values of the coreboards improved. However, the strength properties began to decrease in dosage increases after 40 kg/ton paper. With using 40 kg/ton paper H starch in coreboard production gave the best results in strength properties. The breaking lengths (MD and CD) and burst index of the coreboards increased about 22.7%, 11.1% and 19.4%, respectively.

4. Discussion

The attachment of cationic starch to cellulose is explained by the ionic interaction between the cationic groups and the acidic groups of the cellulose. However, hydrogen bonding to a lesser extent also plays a role in starch adsorption (Ondaral, 2012). In pulp systems obtained from waste paper, impurities such as ink residues, starch - glue residues in the waste paper increase the anionic load of the system and reduce the bonding ability of cellulose. For this reason, it is important to adjust the system water.

Corn and potato-based KNs have been used for 20-30 years as a cationic bonding chemical for increasing the physical and especially strength values of papers in acidic or alkaline paper production and for bonding in alkaline paper production. When these substances are used at a dosage of 3-15 kg / ton depending on the application, their contribution to adhesion is quite high (Doiron, 1998). As the system circulation water is used under operating conditions, the cationic requirement may be higher. The formation conditions of the dough used here are important. In works with fresh water, while an average of 10 kg / ton KN can affect the strength as well as helping to hold, up to 40 kg / ton KN consumption can be reached under operating conditions. And it has been seen that the highest efficiency occurs at b dosage amounts.

Marton stated in a study that cationic starch selected to enhance a set of mechanical properties of cationic starch in paper is a well known dry strength agent, especially for improving interfiber bonding. (Marton and Marton, 1976). This study showed that the dosage amount is important. Overdosed KN ensures that the dough suspension reaches cationic saturation and acts as a filler. The addition of KN may have an adverse effect in suspensions whose anionic balance cannot be established.

5. Conclusion

It has been determined that the coreboards obtained from pulp-cationic starch suspension provide improvements in strength values compared to base papers. As a result of the study, it was determined that the strength values increased in the internal bonding and improvements in the tensile and bursting strength values. At the same time, when the pulp and white water properties are controlled, the change in the amount of dry matter and ash into white water can give an idea about the cohesion of cationic starch on the paper. When the effects of cationic starches on pulp and white water properties and coreboard strengths were examined, the best results were obtained with the use of Roquette (Hi-Cat c643a) cationic starch compared with Cargill (Charge120) and ADM (Meribond 166) cationic starches.

6. Acknowledgments

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EFFECTS OF SANDING AND VARIOUS SURFACE SMOOTHING PROCESSES ON SURFACE ROUGHNESS AND VARNISH ADHESION OF BEECH, OAK AND PINE MASSIVE PARQUETS

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Abstract

The objective of this study was to determine effects of sanding and various surface smoothing processes on surface roughness and varnish adhesion of beech, oak and pine massive parquets. First of all, the parquet samples were classified into four groups. Fifteen parquet samples were used for each group. Parquet samples in first group were processed on thickness machine, samples in second group were processed on plane machine, and samples in third group were sanded with 60 grit sandpaper while the parquets in fourth group were sanded with 180 grit sandpaper, parallel to grain direction. The surface roughness of the samples were determined according to DIN 4768. After surface roughness measurements, parquet samples were coated with cellulosic varnish by using a spray gun at a spread rate on 120 g/m^2. The adhesion of strength of the parquet samples were determined according to ASTM D 4541. According to the study results, the highest surface roughness values were obtained in oak, and there was no statistical difference between beech and pine. The adhesion strength values of beech parquets were higher than pine and oak parquets. Processing of sanding with lower grit sandpaper resulted in increased surface roughness while improved adhesion strength characteristics between the coating and the substrate.

Keywords: Surface roughness, adhesion strength, parquet, sanding, varnish

1. Introduction

The primary function of any wood finish (paint, varnish, wax, stain, oil, etc.) is to protect the wood surface, help maintain a certain appearance, and provide a cleanable surface (Williams, 2010). Finishing of wood material is one of the most important processes influencing overall quality of the final product. Physical characteristics in particular appearance of the finished product are affected by not only the type of finish but also the interaction between finish and the substrate. It is a well-known fact that species, wood density, and roughness of the substrate are considered major parameters to have an effective finishing process (Ozdemir et al., 2015).

Wood coatings prolong service life by safeguarding the substrate from, in particular, outdoor conditions like UV light, high and/or changing humidity, mechanical damage, chemicals, living organisms like fungi, termites, etc. Coatings can also further improve aesthetics by providing colour or gloss (Nikolic et al., 2015). Successful wood coating involves several stages including preparation of surfaces. Surface preparation is the most important factor in developing a successful coating system. The purpose of surface preparation is to remove all contaminants that can interfere with adhesion. Sanding or mechanical cleaning is then required to remove loose or deteriorated surface on wood to obtain the proper surface profile. The process of abrasive sanding is also essential in the manufacture of value-added wooden furniture, which demands quality surface finish (Ratnasingam et al., 2002).

Improperly prepared surfaces can lead to premature finish failure and poor performance (Carlson et al., 1991). Some mechanical pre-treatments such as sanding and planning can also be applied to get a fresh surface which eliminates bonding problems and improves glue bonding of wood (Aydin, 2004). Careful sanding to provide a smooth surface is essential for a good finish because any irregularities or roughness in the surface will be accentuated by the finish (Williams, 2010).

The wood surface texture can significantly affect the finishing requirements. New saw-textured surfaces may contain loose wood particles or protruding wood fibers. Loose wood material not removed prior to finishing or protruding fibers that are not thoroughly coated may lift. Therefore, it is essential that all foreign matter or loose material is removed prior to finishing (Carlson et al., 1991). The phenomenon of 'grain-raising' presents a major operational problem for high-quality wood finishing and will require sanding operations. Sanding can be considered as the last operation in the manufacturing process of the uncoated product. It is carried out to remove the first wood layers, producing a smooth and uniform surface and also eliminating blemishes due to previous operations such as gluing (Bulian and Graystone, 2009).

The objective of this work was to determine effects of sanding and various surface smoothing processes on surface roughness and varnish adhesion of beech, oak and pine massive parquets.

2. Materials and Methods

Beech, pine and oak massive parquets with the dimensions of 30 cm x 5 cm x 1.8 cm were obtained from a commercial parquet plant located in Karadeniz Region in Turkey. First of all, parquet samples manufactured from beech, pine and oak wood were classified into four groups. Fifteen parquet samples were used for each group. Parquet samples in first group were processed on thickness machine, samples in second group were processed on plane machine, and samples in third group were sanded with 60 grit sandpaper while the parquets in fourth group were sanded with 180 grit sandpaper, parallel to grain direction.

Surface roughness values of parquets were determined after planning and sanding processes. Mitutoyo Surftest SJ-301 was employed for surface roughness measurements. Cut-off length was 2,5 mm, sampling length was 12,5 mm and detector tip radius was 5 μm in the surface roughness measurements. Fifteen measurements were taken from all parquet samples across the grain orientation. Three roughness parameters, average roughness (Ra), mean peak-to-valley height (Rz), and maximum roughness (Rmax) were used to evaluate surface roughness of the samples according to DIN 4768 (1990). Samples were conditioned to an equilibrium moisture content before the surface roughness measurements so that the moisture content could not alter the results of measurements.

After surface roughness measurements, parquet samples were coated with cellulosic varnish by using a spray gun at a spread rate on 120 g/m^2. The coating was applied to surface as 2 bases and 1 top layer. The mixture of cellulosic varnish for each layer had 100 parts varnish and 50 parts thinner by volume. Viscosity of varnish for the application was determined as 98,74 mpa.s (cup Ø = 4 mm).

Once parquet samples were dried in ambient temperature after coating process, dry film thickness of each samples were measured by using Erichsen P.I.G 445 measuring device at an accuracy of 1µm, according to ASTM D 4138 (1971). Average dry film thickness of cellulosic varnish was measured as 80 µm.

Pull-off test was used to evaluate adhesion of strength of the parquet samples according to ASTM D 4541 (1978). Fifteen replicate measurements with a contact area of 20 mm circles were taken from each side of the samples. Erichsen-525 MC Adhesion tester with a head glued to the surface of the samples was employed for the tests. The equipment runs at a constant speed and applies tension force to the surface layer by pulling the coating from the surface. Adhesion strength value of the coating is limiting value of the tension force applied which is registered on the display of the equipment in N/mm^2.

3. Results and Discussion

It was showed in Table 1 that surface roughness test results of parquet samples after processing on thickness and plane machines and sanding.

Table 1. Surface roughness measurement results of parquet samples after processing on thickness and plane machines and sanding (values in parenthesis are standard deviations)

	Beech (µm)			Pine (µm)			Oak (µm)		
	Ra	**Rmax**	**Rz**	**Ra**	**Rmax**	**Rz**	**Ra**	**Rmax**	**Rz**
Processed on Thickness Machine	5.60 (1.02)	48,35 (9,01)	41,86 (8,16)	5,85 (0,81)	45,31 (10,66)	39,23 (5,74)	10,08 (1,30)	95,99 (10,35)	84,15 (6,80)
Processed on Plane Machine	4.85 (1.10)	44.68 (8.55)	38.04 (5.71)	5.23 (1.44)	43.97 (14.07)	35.46 (8.01)	9.52 (2.32)	101.38 (16.34)	80.49 (6.68)
Sanded with 60 Grit	6.81 (1.24)	53.71 (7.09)	45.69 (4.96)	6.73 (0.99)	56.80 (9.60)	50.57 (8.33)	11.36 (2.42)	120.46 (21.54)	93.83 (8.77)
Sanded with 180 Grit	3.69 (1.63)	37.28 (10.73)	30.38 (8.57)	3.97 (1.40)	41.52 (9.49)	32.47 (5.18)	5.66 (1.28)	75.27 (11.96)	61.76 (6.00)

In order to determine the effect of various surface treatments on the surface roughness values of beech, pine and oak massive parquet, multiple variance analysis was performed and the results are given in Table 2. Student-Newman-Keuls test results used to compare the mean values of variance sources were given in Table 3.

Table 2. Statistical analysis of the surface roughness test results

Source of Variation	**Sum of Squares**	**Degrees of Freedom**	**Mean Squares**	**F-value**	**Sig. level**
A: Wood Species	66734.5	2	33367.3	673.46	***
B: Surface Processing	11062.8	3	3687.6	74.43	***
Interaction: AB	1807.4	6	301.234	6.08	***
Error	8323.76	168	49.5462		
Total	87928.5	179			

Table 3. Student-Newman-Keuls test results of the samples (p<0.05).

Variance of Sources	N	Surface Roughness Rz (μm)	Homogenous Group*
Effect of Wood Species			
Beech	60	38.99	a
Pine	60	39.45	a
Oak	60	80.06	b
Effects of Surface Processing			
Processing on thickness machine	45	55.08	b
Processing on plane machine	45	51.33	b
Sanding with 60 grit sandpaper	45	63.37	c
Sanding with 180 grit sandpaper	45	41.54	a

* Different letters indicate the statistically significant difference

According to the results of analysis of variance; both wood species and applied surface processing and their interaction with each other on the surface roughness values of parquets are significant with a probability of 0.1% error (Table 2).

Among the three wood species tested in Table 3, oak parquets gave the highest surface roughness mean values (Rz) due to the most porous anatomical structure having the roughest surface (Salca and Hiziroglu, 2014). Normally diffuse porous woods with small pores tend to be the most evenly textured compared to the wood species such as oak, which has very large and open pores. Therefore, species with a finer texture (smooth and glassy) such as beech has a smoother surface roughness compared to species with a coarse texture (soft and rough) such as oak (Thoma et al., 2015). According to this statistical evaluation, the differences in surface roughness values for beech and pine were found not to be significant at 95% confidence level.

The smoothest samples were obtained after sanding with 180 grit sandpaper for all three parquet wood species while the highest surface roughness values were measured on parquets sanded with 60 grit sandpaper. Sanding operation could reduce the inhomogeneity of wood surfaces and make the wood surfaces more uniform. Therefore, sanding improved the surface roughness and application of higher grit of sanding reduced the surface roughness (Sulaiman et al., 2009). Hiziroglu et al. (2014) sanded surface of oak, pine and nyatoh samples on 80, 180 and 240 grit sandpaper applying. As a result of the study, they found that 180 grit sandpaper gave the lowest surface roughness values among their groups. Sogutlu et al. (2016) obtained same results from the oak, pine and cherry wood samples sanded on 80, 120 and 180 grit sandpaper. As a result of the study, they found that 180 grit sandpaper gave the lowest surface roughness values among their groups.

Pull-off strength adhesion test results of parquet samples after processing on thickness and plane machines and sanding were presented in Figure 1.

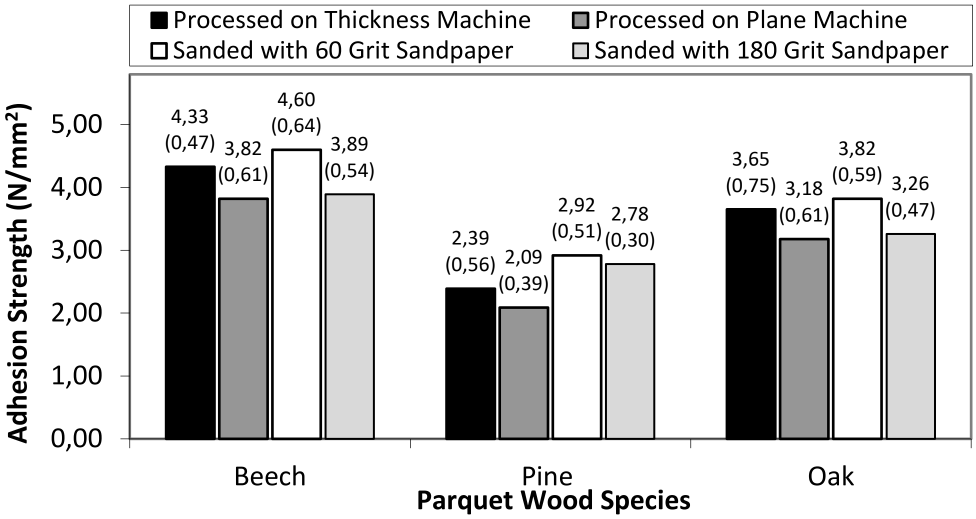

Figure 1. Pull-off strength adhesion test results of parquet samples after planning and sanding (Values in parenthesis are standard deviations)

In order to determine the effect of various surface treatments on the adhesion strength values of beech, pine and oak massive parquet, multiple variance analysis was performed and the results are given in Table 4.

Table 4. Statistical analysis of the adhesion strength test results

Source of Variation	**Sum of Squares**	**Degreess of Freedom**	**Mean Squares**	**F-value**	**Sig. level**
A: Wood Species	82.097	2	41.049	136.737	***
B: Surface Processing	11.756	3	3.919	13.053	***
Interaction: AB	3.956	6	0.659	2.196	*
Error	50.434	168	0.300		
Total	2237.961	180			

According to the results of analysis of variance; both wood species and applied surface processing and their interaction with each other on the adhesion strength values of parquets are significant with a probability of 0.1% error (Table 4).

Student-Newman-Keuls test results used to compare the mean values of variance sources were given in Table 5.

Table 5: Student-Newman-Keuls test results of the samples ($p<0.05$).

Variance of Sources	**N**	**Adhesion Strength (N/mm^2)**	**Homogenous Group***
Effect of Wood Species			
Beech	60	4.20	c
Pine	60	2.55	a
Oak	60	3.48	b
Effects of Surface Processing			
Processing on thickness machine	45	3.46	b
Processing on plane machine	45	3.08	a
Sanding with 60 grit sandpaper	45	3.78	c
Sanding with 180 grit sandpaper	45	3.31	b

* Different letters indicate the statistically significant difference

According to Figure 1 and the statistical evaluation (Table 5), adhesion strength values of beech parquets with cellulosic varnish were found higher than those of oak and pine parquets. The smooth surface quality of beech may be responsible for this finding. In the previous studies, adhesion strength of beech was also found to be better than that of oak (Jaic et al., 1996; Ozdemir and Hiziroglu, 2009). The adhesion strength of varnish on wood surfaces has been reported to be higher in wood from angiosperm trees compared to gymnosperms (Sonmez et al., 2009). The properties of the wood surface, its texture, anatomy and species all affect surface coating performance (Frihart, 2005).

The highest adhesion strength values were obtained for the groups sanded with 60 grit sandpaper while the lowest adhesion strength values were obtained for planed groups without sanding. Because, the surface roughness of the groups sanded with 60 grit sandpaper were higher than the other groups. It has been reported that increased surface roughness leads to increased varnish layer adhesion strength resistance due to a mechanical and chemical bond between the wood sample and varnish liquid when applied to its surface. Such chemical adhesion occurs as the varnish liquid fills gaps on the wood surface and solidifies (Sogutlu et al., 2016). Similarly, the adhesion strength increased with increasing the area for the mechanical interlocking between coating and wood substrate (Vitosyte et al., 2012).

4. Conclusion

The effects of the sanding and various surface smoothing processes on surface roughness and varnish adhesion of beech, oak and pine massive parquets was investigated in this study. The highest surface roughness values were obtained in oak, and there was no statistical difference between beech and pine. The adhesion strength values of beech parquets were higher than pine and oak parquets. Processing of sanding with lower grit sandpaper resulted in increased surface roughness while improved adhesion strength characteristics between the coating and the substrate. Therefore, it is recommended from this study that where high varnish adhesion strength is required, the wood surface should be sanded with low number grit sandpaper. The data obtained from this study will have potential to determine better finishing application for oak, pine and beech parquets.

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BRICS COUNTRIES AND TURKEY'S COMPETITION COMPARATIVE ANALYSIS OF THE FURNITURE INDUSTRY SECTOR

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Abstract

Economic problems driven by global crises have led to an increase in the power of developing countries against the economies of developed countries and created global economic unions. The economic union (BRIC), which was established by Brazil, Russia, India and China, which are considered to be the four biggest economies of the 21st century together with the United States, and represented by 5 countries with the inclusion of South Africa in 2011 and named as BRICS countries It has taken a leading position for developing economies.

Our country in the evaluations made at the level of the foreign trade balance, which has a positive position BRICS Under the subgroup of the furniture sector (Brazil, Russia, India, China and South Africa) countries in the face of how competition works include the 2010-2019 year performed to determine whether to position Turkey and the BRICS countries The levels of competition and specialization were calculated with the help of the Revealed Comparative Advantages Approach. Study results are seen in the presence of intense competition among all subgroups level in Turkey and China.

Keywords: BRICS, Furniture Sector, Turkey, Competition Comparative Analysis

1. Introduction

BRIC (Brazil, Russia, and India and China), which was first introduced into the literature in 2001 by the chief economist of Goldman Sachs, Jim O'Neill, was later named BRICS after South Africa was included in these countries. Jim O'Neill argued that BRICS countries will have a growing share in the world economy with their rich underground resources, geographic structures and population sizes and have the power to direct the economies. (Goldman Sachs, 2001) The remarkable increase in the economic growth of these countries, their high domestic consumption capacity, production organizations and openness to cooperation show that they are in a structure that can direct the world economy. It shows that the global economic power can pass from countries considered as G7 (Canada, France, Germany, Italy, Japan, England and USA) to BRICS countries. (Hult, 2009; Cook, 2019) Especially the problems in the unipolar world system centered in America and the searches made against the economic hegemony of Western countries have made the BRICS countries look positively as an alternative block structure where Asian countries are dominant. (Dilek et al., 2018). The cheap labor and low production costs of the BRICS countries provided a high level of foreign capital and thus the increase in foreign trade volume and created values above the world average in the economic growth of the countries.

Our country's active role in regional and global issues in recent years is known as an effort to become one of the rising global powers. BRICS countries will now be considered in the near future of the European economy, Turkey is willing to take part. Turkey to take part in the BRICS find alternative opportunities and achievements will be possible to achieve, especially in terms of regional economic power (Dilek et al., 2018). The success it has achieved in the economic transformation in recent years shows that it can be at the forefront of membership to BRICS and that it is in a highly competitive position in this field. (Battal and Akan, 2019) Determining the position of our country's production power against the BRICS countries, which are the rising economic power, and the level of competitiveness, will make it possible for us to be prepared for a possible BRICS membership. For this reason, in our study, it is aimed to determine the competitive position of the furniture sector, which has an important position in the foreign trade structuring of our country and has a foreign trade surplus in recent years, against BRICS countries across its sub-product groups. In line with this approach help of Revealed Comparative Advantage competitive analysis of the furniture sector in Turkey and the BRICS countries it was carried out between the years 2010-2019.

1.1. Furniture Industry in the World and in Turkey

Furniture, which is used for different purposes in all areas of life, is one of the rare sectors in our country that has not had a foreign trade deficit since 2001. The furniture industry sector, which appears in the field of production with micro, small and medium-sized enterprises, has gained a structure that has increased its strength in our country in recent years with the participation of large-scale enterprises in the production area with different product mixes. (Furniture Working Group Report, 2015) Especially, the furniture industry, which is in an active position in the field of foreign trade with EU member countries, realizes one third of its exports to EU countries and more than half of its imports from these countries. The export value of our country's furniture industry, whose development depends on its ability to export, has reached 3 billion 415 million dollars in 2019. This figure has increased by 27.1% compared to 2018. The value of our furniture imports in 2019 was 554 million, and it decreased by 6.6% compared to 2018. Exports worldwide are at the level of 197.3 billion dollars in 2019. The two major countries of world exports are China (32.8%) and Germany (6.9%). Turkey's share in world exports was 1.6%. When the world furniture import is taken into consideration, it is seen that a level of 190.4 billion dollars was realized in 2019. USA and Germany take the first place in import. (Furniture Sector Report, 2020).

The protection of the furniture industry's competitiveness is extremely important for Turkey. For this reason, in order for the furniture industry to maintain its competitive power, it is necessary to determine the production areas where it is strong.

1.2. BRIC Countries and Turkey's Foreign Trade in Furniture

Considering the recent economic developments, it is seen that the global crisis experienced in 2008 caused the actors that shaped the world economy to change. The failure of America and the European Union to manage the 2008 economic crisis well paved the way for developing economies and new unions. Thus, it has enabled new and powerful actors to enter the world economy. One of the most important of these actors is the BRICS countries formed by China, Brazil, India, Russia and South Africa. The most important features of the countries included in the BRICS are their foreign exchange reserves, which are an important force in global wars and crises. In the world foreign exchange reserves ranking, China (It has 30% of the world foreign exchange reserves.), Brazil, Russia and India are among the top 10. (Dam and Şanlı, 2019) Turkey After 2002, unlike the BRICS countries are in a position to constantly open the current account balance. The current account deficit problem as a result of failing to meet the import of export problems in Turkey's economic strength and development constitute. The most accurate and future-oriented activity for the current account deficit is to increase our production power. Therefore, the position of the economic union is planning to take place in Turkey should be evaluated correctly.

Determining the position of the production and competitiveness of the furniture sector, which has not had a foreign trade deficit since 2001, against BRICS countries and having a sustainable competitive advantage with the necessary support are among the vital economic issues. Foreign trade figures for the furniture industry are shown in Table 1. (Trade Map, 2020).

Table 1. Furniture Industry Sector in Foreign Trade-Turkey (1,000 dollars)

Years	Export	Imports	Current Account Balance
2010	1.786.405	1.080.935	705.470
2011	2.110.174	1.389.296	720.878
2012	2.420.661	1.204.663	1.215.998
2013	2.830.674	1.492.689	1.337.985
2014	2.970.948	1.588.941	1.382.007
2015	2.753.604	1.376.358	1.377.246
2016	2.174.499	1.007.001	1.167.498
2017	2.573.426	946.851	1.626.575
2018	3.130.599	843.291	2.287.308
2019	3.489.375	731.084	2.758.291

The positive increase in the current account balance between 2010 and 2019 is around 300%. The increasing trend of exports and the decrease in imports over the years show the effectiveness of the production and market power of the furniture industry. Foreign trade figures at the level of BRICS countries are shown in the tables below (Table 2, Table 3, Table 4).

Table2. Furniture Industry Sector in Foreign Trade-Brazil and Russia (1,000 dollars)

	Brazil			Russia		
Years	Export	Imports	Current Account Balance	Export	Imports	Current Account Balance
2010	882.664	726.722	155.942	293.153	2.820.120	-2.526.967
2011	911.741	885.440	26.301	263.830	3.791.879	-3.528.049
2012	1.063.782	1.079.418	-15.636	449.308	4.498.725	-4.049.417
2013	792.008	1.308.746	-516.738	467.997	4.672.473	-4.204.476
2014	894.397	1.220.045	-325.648	464.012	4.281.271	-3.817.259
2015	697.797	1.036.822	-339.025	377.304	2.290.253	-1.912.949
2016	677.508	871.352	-193.844	409.657	1.994.667	-1.585.010
2017	714.780	897.215	-182.435	494.237	2.703.111	-2.208.874
2018	770.926	995.890	-224.964	567.506	2.872.185	-2.304.679
2019	759.868	993.427	-233.559	666.336	2.896.580	-2.230.244

Examining the data in Table 2, it is seen that Brazil's furniture foreign trade figures are not high. Brazil has a foreign trade deficit after 2012. In addition, there is a decrease in export values and an increase in imports. It has a high foreign trade volume in Russia's Furniture industry. However, the high current account deficit is related to the increase in imports despite the increase in exports.

Table3. Furniture Industry Sector in Foreign Trade-India and South Africa (1,000 dollars)

	India			South Africa		
Years	Export	Imports	Current Account Balance	Export	Imports	Current Account Balance
2010	706.825	795.969	-89.144	839.937	666.473	173.464
2011	901.082	1.042.900	-141.818	766.383	759.633	6.750
2012	1.010.204	1.048.619	-38.415	638.414	821.657	-183.243
2013	1.193.880	1.147.716	46.164	564.107	809.478	-245.371
2014	1.204.430	1.232.627	-28.197	528.968	764.099	-235.131
2015	1.276.529	1.479.862	-203.333	457.380	781.312	-323.932
2016	1.353.830	1.462.388	-108.558	381.979	693.224	-311.245
2017	1.440.219	1.744.253	-304.034	397.402	710.006	-312.604
2018	1.661.015	1.849.116	-188.101	418.238	782.151	-363.913
2019	1.841.819	1.700.966	140.853	362.594	747.528	-384.934

When the data in Table 3 are examined, it is seen that India has a positive foreign trade balance in 2013 and 2019, but does not have a foreign trade deficit that can be considered significant. As in the Brazilian example, South Africa, which had a foreign trade deficit in 2012 and after, and had a growing deficit with each passing year, experienced a significant decrease in export level between 2010-2019.

Table 4. Furniture Industry Sector in Foreign Trade-China (1,000 dollars)

Years	Export	Imports	Current Account Balance
2010	50.584.033	3.060.824	47.523.209
2011	59.336.352	2.780.539	56.555.813
2012	77.886.189	2.872.045	75.014.144
2013	86.414.580	3.063.736	83.350.844
2014	93.374.119	3.373.789	90.000.330
2015	98.734.456	3.233.847	95.500.609
2016	89.500.006	3.235.812	86.264.194
2017	89.816.691	3.699.547	86.117.144
2018	96.416.994	3.971.384	92.445.610
2019	99.499.771	3.527.753	95.972.018

China, which is the rising economic power of recent years, is a considerable economic power in the furniture industry. When the data in Table 4 are examined, it is noteworthy that the doubling increases in the export volume especially within the scope of 2010-2019. The fact that imports remained at the same levels within this period indicates that the raw materials and semi-finished products required for production have reached a position that can be met from within the country. The foreign trade surplus formed in parallel with the increase in exports supports the country's leading position in the world economy.

2. Materials and Methods

2.1. Materials

Furniture industry it is one of the most important production branches of the forestry industry sector and adds positive values to the foreign trade volume of our country. It is aimed to determine the competitive position of our furniture industry against BRICS countries. In the study covering the years of 2010-2019, the competitive position of furniture products traded in six different subgroups according to the international foreign trade classification was determined by the analysis. Foreign trade figures used for the study were obtained from the Trade Map website. Furniture industry subgroups according to the international definition are shown in Table 5.

Table 5. Furniture Industry Subgroups

Product Code	**Product Label**
9401	Seats, whether or not convertible into beds, and parts thereof, n.e.s. (excluding medical,
9402	Medical, surgical, dental or veterinary furniture, e.g. operating tables, examination tables, . . .
9403	Furniture and parts thereof, n.e.s. (excluding seats and medical, surgical, dental or veterinary ..
9404	Mattress supports (excluding spring interiors for seats); articles of bedding and similar furnishing, . . .
9405	Lamps and lighting fittings, incl. searchlights and spotlights, and parts thereof, n.e.s; illuminated . . .
9406	Prefabricated buildings, whether or not complete or already assembled

2.2. Method

There are many methods developed in the historical process in order to measure international competitiveness. These methods, which are used in accordance with the purpose, primarily benefit from foreign trade data in order to measure the competitiveness of companies, industry and countries. In our study; Revealed Comparative Advantage (RCA), which was created by Liesner (1958) to measure competitiveness and later developed by Balassa (1965) and widely used until today, was used. (Akyüz ve Diğ., 2019) The index developed by Liesner (1958), which aims to measure the competitiveness by using export data and compares the exports of the country in any sector or product group with the exports of other countries or product groups, was developed by Balassa (1965) due to some deficiencies.

A value less than 1 that will be obtained as a result of the index with the formulation and definitions below indicates that the country does not have competitive power in terms of comparative advantages explained at the relevant goods level, that is, it has a disadvantage and a value greater than 1 is specialized in that product group, that is, it has revealed comparative advantage (Balassa, 1965; Kum, 1999; Altay and Gürpınar, 2008; Şahinli, 2014).

The Balassa index was formulated as follows:

$RCA_{ij}= (x_{ij} / X_j)/ (x_{iw} / X_w)$ where; (1)

RCA_{ij}; revealed comparative advantage index for the i_{th} goods of the j_{th} country.

x_{ij} : j_{th} country's i_{th} exported goods

X_j : j_{th} country's total exports

x_{iw} : i_{th} goods of the global exports

X_W : total global exports

3. Results and Discussion

The calculations made using the Revealed Comparative Advantages Index developed by Ballassa at the furniture sub-product group level are shown in the tables below.

3.1. Seats, whether or not convertible into beds, and parts thereof, n.e.s. (excluding medical)

The results obtained as a result of the calculations made at the level of years are shown in Table 6.

Table 6. Seats, whether or not convertible into beds, and parts thereof, n.e.s. (excluding medical)

Years	Brazil	Russia	Indian	China	South Africa	Turkey
2010	0,264	0,023	0,028	2,785	1,728	1,399
2011	0,261	0,017	0,049	2,801	1,151	1,464
2012	0,227	0,028	0,081	3,129	0,884	1,246
2013	0,199	0,030	0,097	2,886	0,723	1,351
2014	0,145	0,026	0,101	2,649	0,560	1,315
2015	0,144	0,028	0,110	2,469	0,437	1,234
2016	0,142	0,034	0,115	2,373	0,371	1,255
2017	0,118	0,043	0,128	2,402	0,316	1,259
2018	0,108	0,035	0,140	2,476	0,316	1,355
2019	0,106	0,043	0,148	2,461	0,245	1,435
Average	**0,171**	**0,030**	**0,099**	**2,643**	**0,673**	**1,331**

The results of the calculations Turkey has increased over the years, the competitiveness of products in the 9401 group. The competitive value, which was 1.399 in 2010, reached its highest level in 2011. Turkey was ranked second after China with competitive value of 1.435 in 2019. The high competitive advantage achieved by China in all years in this product group is clearly seen. Although China achieved the highest value in 2012, it experienced a decrease in its competitive advantage over the years examined. The obtained results indicate that Turkey can increase their competitiveness through access to the leading position in this product group. It is clearly seen that other BRICS member countries are in a non-competitive structure in the 9401 coded product group. The success of South Africa in this field in 2010 and 2011 decreased significantly in the following years and its competitive power decreased to insignificant levels.

3.2. Medical, surgical, dental or veterinary furniture, e.g. operating tables, examination tables.

The analyzes made and the results obtained in the 9402 coded product group are shown in Table 7.

Table 7. Medical, surgical, dental or veterinary furniture, e.g. operating tables, examination tables

Years	Brazil	Russia	Indian	China	South Africa	Turkey
2010	0,576	0,008	0,212	1,134	0,387	0,992
2011	0,426	0,015	0,319	1,226	0,269	1,095
2012	0,426	0,022	0,283	1,371	0,392	1,118
2013	0,355	0,025	0,276	1,416	0,334	1,813
2014	0,188	0,002	0,011	0,077	0,014	0,074
2015	0,313	0,042	0,305	1,527	0,268	0,942
2016	0,233	0,035	0,396	1,391	0,355	1,073
2017	0,177	0,044	0,309	1,452	0,287	1,175
2018	0,151	0,026	0,293	1,497	0,228	1,309
2019	0,145	0,039	0,259	1,704	0,337	1,387
Average	**0,299**	**0,025**	**0,266**	**1,279**	**0,287**	**1,097**

When Table 7 is worth examining Turkey's border with that level in 2010 (0.992 <1) in the competition, showing a significant improvement in 2019 have reached a level superior position (1.387> 1). Turkey has achieved significant growth in 2013. It decreased in the following years, but a position was obtained that resulted in an increase within the scope of the years examined. China is a country that can rival Turkey. It can be clearly seen that other countries are far from competition at this sub-product group level. Turkey has significantly reduced over the years, the competition that exists between disadvantage with China.

3.3. Furniture and parts thereof, n.e.s. (excluding seats and medical, surgical, dental or veterinary.

Analysis results are shown in Table 8.

Table 8. Furniture and parts thereof, n.e.s.(excluding seats and medical, surgical, dental or veterinary

Years	Brazil	Russia	Indian	China	South Africa	Turkey
2010	0,672	0,079	0,367	2,659	0,499	1,532
2011	0,510	0,079	0,034	2,754	0,369	1,657
2012	0,506	0,096	0,378	3,139	0,348	1,738
2013	0,475	0,092	0,359	2,970	0,328	1,984
2014	0,467	0,104	0,384	2,759	0,362	2,100
2015	0,489	0,108	0,440	2,609	0,350	1,916
2016	0,508	0,139	0,493	2,540	0,303	1,833
2017	0,499	0,151	0,472	2,499	0,279	1,769
2018	0,525	0,146	0,518	2,448	0,265	1,926
2019	0,532	0,172	0,569	2,316	0,284	2,075
Average	**0,518**	**0,116**	**0,401**	**2,669**	**0,338**	**1,853**

Turkey has a competitive advantage in this product group in all years. Turkey has reached the highest competitive position in 2014. In this product group, as in other sub-product group it is Turkey's only rival of China. The decline shows that China's competitiveness in the years Turkey has showed a significant increase in this period. Turkey is in a position to be a leader in this product group.

3.4. Lamps and lighting fittings, incl. searchlights and spotlights, and parts thereof, n.e.s; illuminated.

This product group among the three countries (China, India and Turkey) is experiencing a competitive battle. Although China has become an important role in Turkey and India are important competitiveness. The competitiveness of Turkey between 2010-2019 years has experienced an increase in the level of 27.3%. India, on the other hand, completed this period with an increase of 19%. It may also be a contest between China and Turkey in terms of competition.

Table 9. Lamps and lighting fittings, incl. searchlights and spotlights, and parts thereof, n.e.s; illuminated

Years	Brazil	Russia	Indian	China	South Africa	Turkey
2010	0,147	0,024	1,297	4,765	0,833	1,124
2011	0,139	0,021	1,172	4,802	0,778	1,038
2012	0,107	0,042	1,265	4,733	0,775	0,922
2013	0,117	0,054	1,299	4,392	0,794	1,009
2014	0,128	0,050	1,320	4,069	0,771	1,013
2015	0,133	0,060	1,529	3,828	0,719	1,002
2016	0,138	0,067	1,593	3,915	0,700	0,990
2017	0,140	0,058	1,496	4,014	0,612	1,153
2018	0,123	0,050	1,536	4,009	0,631	1,245
2019	0,129	0,062	1,546	3,822	0,534	1,431
Average	**0,130**	**0,048**	**1,405**	**4,234**	**0,714**	**1,092**

3.5. Lamps and lighting fittings, incl. searchlights and spotlights, and parts thereof, n.e.s; illuminated.

Lamps and lighting fittings, incl. searchlights and spotlights, and parts thereof, n.e.s; illuminated . . analysis results are shown in Table 10.

In this product group, the competitive advantage that continues to increase within the years obtained and examined by China is clearly seen. China has the sole say in this product group.

Table 10. Lamps and lighting fittings, incl. searchlights and spotlights, and parts thereof, n.e.s; illuminated

Years	Brazil	Russia	Indian	China	South Africa	Turkey
2010	0,062	0,085	0,220	3,768	0,406	1,073
2011	0,063	0,028	0,244	3,919	0,374	1,037
2012	0,054	0,054	0,238	4,541	0,302	0,771
2013	0,043	0,057	0,176	4,651	0,272	0,811
2014	0,040	0,059	0,155	4,577	0,268	0,688
2015	0,033	0,057	0,168	4,613	0,236	0,506
2016	0,033	0,079	0,182	4,590	0,227	0,554
2017	0,028	0,078	0,180	4,402	0,210	0,510
2018	0,025	0,072	0,169	4,379	0,254	0,493
2019	0,028	0,076	0,177	4,428	0,193	0,446
Average	**0,040**	**0,064**	**0,190**	**4,386**	**0,274**	**0,688**

In this product group, the competitive advantage that continues to increase within the years obtained and examined by China is clearly seen. China has the sole say in this product group.

3.6. Prefabricated buildings, whether or not complete or already assembled.

The results of the study are shown in Table 11.

Table 11. Prefabricated buildings, whether or not complete or already assembled

Years	Brazil	Russia	Indian	China	South Africa	Turkey
2010	0,272	0,314	0,185	1,604	1,493	2,996
2011	0,823	0,142	0,182	1,645	1,394	3,302
2012	2,448	0,410	0,216	1,621	1,405	3,682
2013	0,357	0,341	0,193	1,377	0,981	3,567
2014	1,502	0,304	0,261	1,471	1,065	3,106
2015	0,642	0,439	0,399	1,292	1,048	3,462
2016	0,477	0,556	0,286	1,331	0,792	2,317
2017	0,377	0,413	0,255	1,420	1,112	2,280
2018	0,258	0,385	0,331	1,289	1,065	2,628
2019	0,277	0,560	0,420	1,424	0,865	2,549
Average	**0,743**	**0,386**	**0,272**	**1,447**	**1,122**	**2,988**

Turkey has an important competitive advantage. China and South Africa is well positioned to rival Turkey. Brazil's success in 2012 and 2014 did not continue in the following years, and fell behind in terms of competition in this field. In the case of the protection of the competitive advantages possessed prefabricated sub-group of products in the world market in Turkey to have a say in the next year will be an expected situation.

4. Conclusion

In this study, the BRICS countries and Turkey in the lower level of the furniture industry product groups are intended to determine the competitive position. The analysis results are presented in a clear manner in which they have important competitive advantages of China and Turkey.

Seats, whether or not convertible into beds, and parts thereof, n.e.s. (Excluding medical,. In the sub group, this has continued competitive advantage against other countries, China and Turkey. China has the competitive advantage that between the years 2010-2019 showed a -11.6% decrease in the level of Turkey has increased the level of 2.5%.

Medical, surgical, dental or veterinary furniture, e.g. operating tables, examination tables, (9402) in the product group Turkey has achieved significant competitive advantage with changes in the level provided in 2019, while 40% are in a position to compete on the border in 2010. Within the same years, China maintained its first place with an increase of 50%.

Another product group showed a significant increase in Turkey Furniture and parts thereof, n.e.s. (excluding seats and medical, surgical, dental or veterinary. (9403) product group. Representing an increase of approximately 35% for Turkey in 2019 and 2075 has increased the level of competition events. Over the same period, China has shown a -13% reduction in its competitiveness.

Mattress supports (excluding spring interiors for seats); articles of bedding and similar furnishing,. China, which is the absolute competitive ruler in the (9404) product group, has experienced a -20% decrease in competitive advantage over the years. India, which ranks second in this product group, has increased by 19% in its competitive position between 2010-2019. Turkey is ranked third with a competitive advantage in the show with the increase in the level of 27.3% next year showed it would be more effective in a competitive position.

Lamps and lighting fittings, incl. searchlights and spotlights, and parts thereof, n.e.s; China, which is the only dominant position in the illuminated (9405) product group, is unrivaled in the market. The competitive advantage of having Turkey in 2010 and 2011 showed significant reductions in recent years.

Turkey, China and South Africa Prefabricated buildings to have a competitive advantage, whether or not complete or already assembled (9406), Turkey ranks first in the product line. Unlike other product groups, Turkey is situated in front of the Chinese in this product group. Turkey within the scope of review of the year - a 15% level has maintained its first place although it has shown a decrease. In this product group, China decreased by -11% and South Africa by -42%.

Turkey has a significant competitive advantage over the BRICS countries in the furniture industry. Turkey is seen clearly that China is the only competitor in this field. It is imperative in today's world of the effective and efficient use of resources, with significant gains in power sector of the furniture industry which Turkey has achieved and can have an influence on world markets.

China's manpower, raw material resources and international investments are seen as the main reasons for being in the first place. In this area which has a strong information technology infrastructure and the economy by strengthening Turkey's encouragement and support, and the development will provide significant advantages.

Turkey should use the furniture industry as the locomotive of development and stability and should make the necessary investments in this area.

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A STUDY ON THE EFFECT OF STARCH TEMPERATURE CHANGES ON PACKAGING PAPER PRODUCTION IN SIZE PRESS MACHINE

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Abstract

In this study, effect of temperature on the use of starch in packaging paper production and to find optimum use of starch, the properties of starch such as dry matter amount, viscosity and pH value were evaluated by continuously measuring. Fluting (90 gr/m^2), NSSC (120 gr/m^2) and Test liner (110 gr/m^2) paper types using waste paper as raw material were selected as the most common production types and their strength values were measured. All production conditions were kept constant and measurements were made by changing the starch temperature in the size press equipment. Starch obtained from natural corn was used in the size press. According to obtained data, it was measured that as a result of the increase in starch temperature from 70 °C to 75 °C, strength values such as burst, CMT and SCT increased by 6% in all paper types. When the temperature was increased to 80 °C, it was determined that there was an 18% increase compared to 70 °C. In addition, porosity values of the papers decreased by 7-10% with increasing temperature. At temperatures above 80 °C, it occurred defects in the paper and problems with sticking to the felts in the machine became difficult to control.

Keywords: Starch, temperature, packaging paper, strength

1. Introduction

In paper and board production, waste paper efficiency and quality is a very important issue, especially in paper machines that produce using 100% waste paper. In general, it is one of the most important and major factors affecting the quality and cost of the produced paper. Since there is no packaging paper production using 100% cellulose in Turkey, the papers consist of waste papers that are recycled in the same process. In each paper and board recycling cycle, the fibers in the paper and board are shortened and weakened (Edinger, 2004). This creates a strength problem in the paper production. Some auxiliary substances are used in the production of paper and board to alleviate such problems. Among these, the most commonly used material is starch (Özden and Sönmez, 2019). The place where starch is used in paper production is 'Size Press' equipment, this equipment is composed of 2 coated cylinders and hydraulically presses on paper to increase the penetration of starch into paper (Smook, 1994; Knowpap, 2013).

Starch must also go through some processes in order to be used in the production and to reach size press equipment (Özden and Sönmez, 2019). The starch preparation tank is first filled with cold water and starch is poured into the tank filled with water according to the dry matter amount of the starch mixture to be made. By injecting steam into the tank, the starch mixture is brought to a temperature of 95 °C at a suitable mixing speed and cooked for 10 minutes, so that the starch molecules absorb the water and come to a gel form. Then, while the mixing process continues at this temperature, it is rested for 10 minutes and at the end of this process, the starch solution is sent to the stock tank. The stock tank is double-walled and there are steam pipes between the two walls, so that the starch solution is kept warm. The starch solution is sent from the stock tank to the second stock tank under the press equipment, which is the end-use place, during this process, the starch temperature decreases due to the intermediate distance. Here, the starch temperature varies between 65-70 °C. Such a decrease in the temperature of the starch solution at the end-use area negatively affects the starch viscosity and indirectly its penetration into the paper, which has a negative effect on the strength values of the final product (Zijderveld and Stoutjesdijk, 1976; Andersen, 1997). In addition, if the starch mixture is not at the desired high temperature, the problem of sticking to the cylinder surface arises because the starch called 'picking' in the drying cylinder where the paper is first contacted after the press equipment where the starch is applied cannot penetrate well into the paper (Maurer, 2001).

Today, as a result of the decreasing waste paper quality and increasingly need for stronger paper, paper mills prefer to use starch as the most economical and efficient way to produce strength paper. Literature studies have shown that in order for starch to have a better effect on paper, the starch temperature must be kept at the highest possible level and used at that temperature. In this study, it was aimed to determine the process equipment required to increase the temperature of starch at the size press and apply it stably on paper and to determine the effects of starch temperature on the final paper produced. In addition to the temperature, in order to find an optimum use value, the starch properties such as dry matter amount, viscosity, and pH value were continuously measured and evaluated.

2. Materials and Methods

This study was carried out in Kahramanmaraş Paper Mill under the coordination of R&D unit. The modifications within the scope of the study were carried out in two stages. In line with the plans made according to the purpose of the study, the current situation was determined first and then a redesign was made in the conventional size press machine (Fig. 1) for the desired purpose. With the completion of these studies, trials have been carried out.

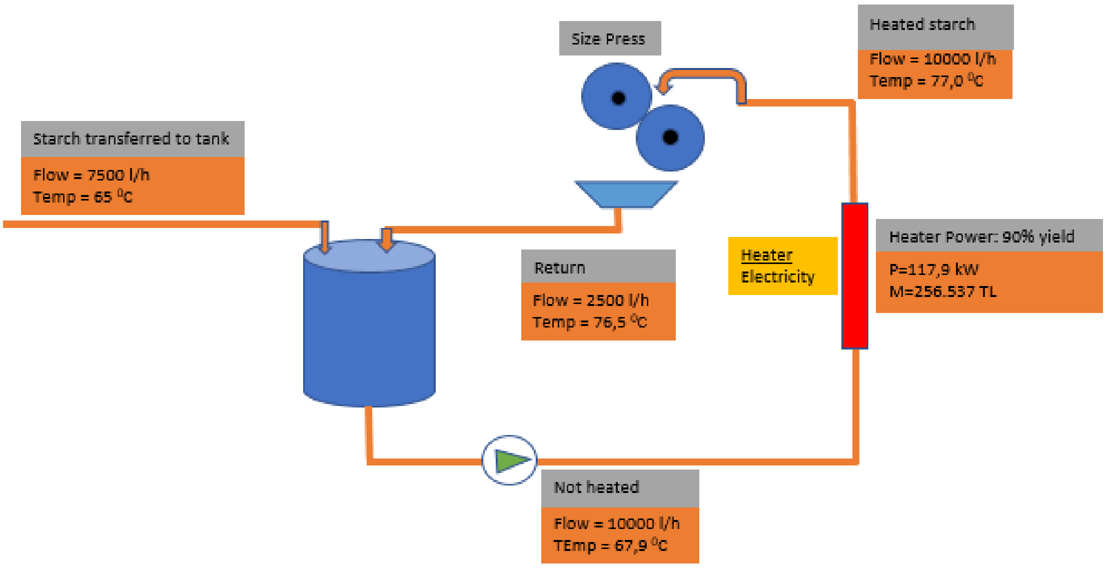

Figure 2. Conventional starch application workflow at size press

In the study, three different packaging papers were produced: Fluting (90 g/m^2), (NSSC 120 g/m^2) and Test liner (110 g/m^2). During the production, waste papers, fennopol 351, fennopol 326, silica (fennosil 2180), CK Floc 640 (Polydadmac), cationic starch (Hi-Cat 643A), natural starch, nopcomaster ENA 475, papertreat PD and chlorine dioxide were used. The changes in viscosity properties by heating starch to 60-70-75-80 °C temperatures were also investigated. At temperatures above 80 °C, it occurred defects in the paper and problems with sticking to the felts in the machine became difficult to control. The penetration of starch into paper was also calculated.

Some physical and strength properties of the packaging papers were determined and tests and standards were given in Table 1.

Table 6. Some physical and strength tests and standards applied to the packaging papers

Tests	Standards
Burst Strength (kPa)	TS EN ISO 2758
CMT (Corrugated Medium Test)	TS EN ISO 7263
CCT (Concora Corrugated Test)	TS 12735
SCT (Short Span Compressive Test)	TS ISO 9895
RCT (Ring Crush Test)	TS 12734
Scott Bond (Internal Bond Test)	TAPPI 569
Porosity	TS ISO 5636-5
Filler Content	TS 1683
COBB (Water Absorbency Test)	TS EN ISO 535

Ten test papers were produced from the pulps obtained from each experiment and arithmetic means of the data were used for evaluation of the study.

3. Results and Discussion

The properties of the starch such as dry matter, consumption and viscosity at different temperatures were given in Table 2 below.

Table 7. Some properties of the starch at different temperatures

Paper Type	Starch Properties	Temperature (°C)			
		60	70	75	80
Fluting	Dry Matter (%)	10.5	10.5	10.5	10.5
	Starch Consumption (gr/m^2)	3.6	3.68	3.7	3.74
	Viscosity (Pa.s)	82	74	71	66
NSSC	Dry Matter (%)	9.0	9.0	9.0	9.0
	Starch Consumption (gr/m^2)	6.1	6.21	6.25	6.29
	Viscosity (Pa.s)	78	74	71	63
Test Liner	Dry Matter (%)	7.5	7.5	7.5	7.5
	Starch Consumption (gr/m^2)	5.01	5.14	5.21	5.25
	Viscosity (Pa.s)	76	70	68	65

Dry matters of the starches used in fluting, NSSC, and test liner papers were keep constant as 10.5%, 9.0%, and 7.5%, respectively. Generally, starch consumption rates increased with the increase temperature of the starch at size press in production of all paper types. Moreover, viscosity values decreased due to the increases in starch temperature.

The physical and strength properties of the fluting papers with 90 (gr/m^2) grammages were present in Table 3.

Table 8. Some physical and strength properties of the fluting papers produced with using starch at different temperatures

Starch Temperatures (°C)	60	70	75	80
Burst Strength (kPa)	1.72	1.75	1.81	1.93
CMT (N)	150	162	178	186
CCT (kN/m)	1.20	1.29	1.35	1.43
SCT (kN/m)	1.21	1.29	1.32	1.42
Porosity (s)	43	42	40	37
Filler Content (%)	14.5	14.6	14.5	14.4

In Table 3, it can be observed that with the increase in starch temperature at size press, the properties of the fluting papers have improved. With the increase of starch temperature from 60 °C to 80 °C, burst strength, CMT, CCT and SCT values increased by 12.2%, 24%, 19.2% and 17.4%, respectively. Besides, he surface properties of the fluting papers have been positively affected by the application of starch at high temperatures at the size press. The porosity of the fluting papers decreased to 37 s by increasing the applied starch temperature to 80 °C at size press.

The physical and strength properties of the NSSC papers with 120 (gr/m^2) grammages were present in Table 4.

Table 9. Some physical and strength properties of the NSSC papers produced with using starch at different temperatures

Starch Temperatures (°C)	60	70	75	80
Burst Strength (kPa)	2.36	2.40	2.61	2.80
CMT (N)	290	295	307	332
CCT(kN/m)	2.01	2.01	2.11	2.29
SCT(kN/m)	1.85	1.87	1.90	1.99
Porosity (s)	36	34	34	33
Filler Content (%)	16.4	16.5	16.4	16.5
$COBB_{60}$ (gr/m^2)	35	35	36	34

According to Table 4, NSSC paper properties were enhanced with increasing starch temperature at size press. However, the use of starch at different temperatures had no significant effect on the COBB values of NSSC papers. With the increase of the starch temperature at the size press from 60 °C to 80 °C, the burst strength, CMT, CCT and SCT values of the NSSC papers increased by 18.6%, 14.5%, 13.9% and 7.6%, respectively, while the porosity values decreased by 8.3%.

In Table 5, physical and strength properties of test liner papers with 120 (gr/m^2) grammages produced by applying starch at different temperatures were given.

Table 10. Some physical and strength properties of the test liner papers produced with using starch at different temperatures

	60	70	75	80
Burst Strength (kPa)	2.30	2.30	2.60	2.80
RCT (kN/m)	0.78	0.80	0.81	0.83
SCT(kN/m)	1.79	1.80	1.83	1.90
Scott Bond(J/m^2)	556	563	581	506
Porosity	46	44	41	37
Filler Content (%)	15.5	15.4	15.5	15.4
$COBB_{60}$ (gr/m^2)	32	31	31	32

In the table, it is seen that the properties of the test liner paper except Scott Bond and COBB values increased in parallel with the increase in starch temperature. The Scott Bond value of the test liner decreased approximately 5% when the temperature of the applied starch was 80 °C. However, when the temperature of the applied starch was 75 °C, the Scott Bond value of the test liner increased by approximately 4.5% compared to 60 °C. As with the COBB values of NSSC papers, it was determined that starch application at different temperatures did not have a significant effect on COBB values of the test liner papers. With increasing starch temperature at size press from 60 °C to 80 °C, burst strength, RCT and SCT values of the test liner papers were increased about 21.7%, 6.4% and 6.1%, respectively. Porosity values of the test liner papers decreased from 46 to 37 by increasing starch temperature at the size press.

4. Discussion

In Table 2, it is seen that starch consumption increases and viscosity decreases depending on the temperature increase. Adhesion of starch applied at high temperature increases within the paper (Hedenqvist, 2002). Thus, an increase is observed in the rate of starch adhering to the paper surface at size press. Viscosity of starch solution has an important role in paper production in order to obtain smooth and strength paper (Clerck, 1991). The temperature applied in the preparation of the starch solution directly affects the viscosity (Harvey and Welling, 1976; Choudhury and Patel, 1992). High viscosity starch solutions cause problems at size press applications. It causes the formation of a sticky line between the starch application roller and the rapidly moving paper surface. In this case, which is called as "size pick up", the paper is in a sense separating from the size press, causing problems (adhesion), stresses and sometimes ruptures occur in the paper (Andersen, 1997). As a result, the high starch temperature applied at the size press section can provide the solution of the above mentioned problems.

In the production of packaging paper, as the temperature of the starch applied in the press increased, the physical and strength properties improved. The purpose of using starch in paper production is to improve the strength properties of the paper (Zijderveld and Stoutjesdijk, 1976). Therefore, the adhesion of starch to the surface of the paper has also increased the strength values of the paper (Maurer, 2001). In Table 2, it can be seen that as the application temperature of the starch applied to paper increased, the adhesion rate increased. One of the factors affecting burst strength is fiber length and the other is internal bonding (Clark, 1978; Eroğlu, 2003). Since starch applied at high temperature penetrates better into paper, an increase in burst strength is achieved. The attachment of cationic starch to cellulose is explained by the ionic interaction that occurs between the cationic groups and the acidic groups of the cellulose. However, hydrogen bonding to a lesser extent also plays a role in starch adsorption (Ondaral, S., 2012).

Other properties of the packaging papers such as CMT, CCT, SCT and RCT were also higher with high temperature starch application as well as burst strength. One of the most important properties affected by the application of starch to paper at size press is porosity, i.e. surface roughness (Maurer, 2009). When the tables given above are examined, the increases in the starch application temperature decreased the porosity values of the produced packaging papers. One of the problems encountered during the separation of the paper from the size press after the starch is applied to the paper is the picking. In this case, one of the solutions can be applied, such as lowering the machine speed, lowering the viscosity (diluting the starch) or heating the starch solution (Andersen, 1997).

5. Conclusion

It has been observed that some physical and strength properties of the packaging papers were improved with using starch at 80 °C. It was also determine that the high temperature of the starch solution applied on the paper eliminates the problems such as degradation, picking and rupture that at the size press occur. Increases in the temperature of the starch solution applied provide both more starch penetration into the paper and ease of application. It is possible to produce high strength paper by increasing the starch temperature applied at the size press without using any extra chemicals and raw materials. As a result of this study, application of the starch solution at 80 °C in the size press section gives optimum results.

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THE EFFECT OF LEACHING CONDUCTED IN NATURAL AND LABORATORY CONDITIONS ON SOME PHYSICAL AND MECHANICAL PROPERTIES OF ANATOLIAN CHESTNUT (*Castanea sativa* Mill.) WOOD

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Abstract

It is a classic procedure that has been applied in our country for a long time to leave the chestnut wood under the effect of rain water for a while before it is used. In this study, the effect of leaching process conducted under outdoor and laboratory conditions in Anatolian chestnut (*Castanea sativa* Mill.) wood on some physical properties of the wood was investigated. The effect of leaching process on oven-dried density, water uptake and water repellency properties, swelling and anti-swelling efficiency properties, and compression strength parallel to the grain were determined on the wood samples taken from two different locations in Eastern Black Sea Region. The results showed that leaching process resulted in an increasing of water uptake and swelling ratios of wood, but no effect on oven-dried density values. While the leaching process conducted in laboratory condition decreased compression strength, the conducted in natural condition increased it.

Keywords: Chestnut Wood, Leaching, Water Uptake, Swelling, Compression Strength

1. Introduction

The Anatolian chestnut (*Castanea sativa* Mill.) is an important hardwood species which is widespread in southern Europe and Turkey. While a total of 2.25 million hectares forests dominated by chestnut in Europe; it covers an area of 262.045 hectares in Turkey (Conadera et al. 2004; OGM, 2013). Chestnut shows a spread starting from Georgia border to the Balkans along the Black sea side (Fig.1). According to General Directorate of Forestry data, 74% of the total chestnut areas are located in the East and West Black Sea Region in Turkey. Besides the pure chestnut stand of forest areas in Turkey where it has made a mixed stand with other forest trees is located also quite large (OGM, 2013). Chestnut wood is very useful in terms of durability and decorative features. It has long fibers and bends easily. For that reason it is evaluated in bending furniture production. It is used in window joinery, exterior cladding, indoor and outdoor furniture, as a fence pile, parquet production, playgrounds, home and office decoration. Chestnut wood is also used as a building material and in the construction of sleepers. It is sold in the market as logs, timber, posts and poles (Ay and Şahin, 2002).

It is a classic procedure that has been applied in our country for a long time to leave the chestnut wood under the effect of rain water for a while before it is used. It is stated that this procedure can be applied for different reasons. Some manufacturers state that leaching chestnut timber under the influence of rain is done to facilitate and accelerate the drying process. It is thought that drying of chestnut wood takes longer time and being done under more difficult conditions if it is not leached. Some other manufacturers consider that extractives in chestnut wood cause the wood to darken or blacken during use if the leaching process is not carried out. Without leaching process timber bleeds a very concentrated black liquid when it comes into contact with water in the area of use. In addition, it is claimed that the leaching process controls the movement of chestnut wood. However, the removing of the extractives such as tannin can decrease the natural durability of chestnut wood. Therefore, it is a scientific necessity to investigate the effect of this leaching process on wood properties in detail.

Several studies has been conducted showing the influence of natural seasoning and/or leaching processes on the mechanical, physical and chemical composition properties of oak and chestnut wood. These studies are mainly concerned barrel making and effects of natural seasoning practise on it (De Simon et al. 1996; De Simon et al. 1999; Doussot et al. 2000; Cadahia et al. 2001a; Cadahia et al. 2001b; Diaz-Plaza et al. 2002; Cadahia et al., 2003; Aloui et al. 2004; Spillman et al., 2004; Canas et al., 2006). However, there is scarcely any research the effects of leaching process on the physical, mechanical, biological and chemical properties of chestnut wood.

Chestnut tree growing in the Eastern Black Sea can be divided into two main characters for regional differences. The first is the chestnut tree that grows between Artvin-Borcka region in which is east part of Eastern Black Sea Region. Its wood is soft and dark in color. The second is the chestnut tree that grows in the west from Sürmene until Ordu-Thursday. Its wood is hard, mechanically more resistant and light colored. For this reason, the research has been conducted on chestnut wood samples obtained from these two different growing regions. The aim of this study to obtain comparative data for some physical and mechanical properties between wood samples that exposed to natural/laboratory leaching and those that did not for two different growing region.

2. Materials and Methods

Two different geographies were chosen, namely Artvin-Borcka region and Ordu-Persembe region, in the selection of the wood specimen. Equivalent in terms of age, elevation and aspect from both regions; three test sample (for leached wood specimens) and three control sample (for non-leached specimens) were determined. From these test trees, test lumbers were cut in accordance with the principles of TS 2470, and the lumbers were exposured to leaching process in rain water for 2 years under natural conditions. From the control trees, the wood specimens which were used for laboratory leaching process and non-leached control specimens were obtained. The lumbers has been obtained from the roots of the trees at a distance of 130-230 cm. The places where the sample trees were taken and the general characteristics of the tree were determined according to the principles of TS 4176.

Wood test and control specimens were prepared in accordance with the measure determined in the standard of each test. The first 10 annual rings were omitted from the outer part of the timber towards the core, and the next 10 cm section was used for specimen supply. In order to minimize the differences that may arise from the structure of the wood, successive specimens containing the same annual rings were taken. TS 53 principles were followed in the preparation of the specimens. All specimens taken were conditioned at 20 °C and 65% relative humidity and become air-dried. In the experiments, four specimens taken from the test lumber leached under natural conditions and sixteen specimens taken from the control lumber not leached were used. For all experiments, four of the non-leached specimens were exposure to leaching process for 2 days, four for 6 days, and four for 14 days in accordance with the principles of TS 6193 EN 84 in laboratory conditions. Four specimens were not exposured to any leaching process and were used as control samples. Experimental design of the study and the numbers of test and control specimens are given in Table 1.

Table 1. Experimental design of the study and the numbers of test and control specimens

Test	Specimen dimension (mm) (L*T*R*)	Leaching Condition	Artvin/Borçka Region	Ordu/Perşembe Region	General Total
Density, water uptake and swelling	15*30*30	Natural leaching	12	12	24
		Control	16	16	32
		Leaching for 2 days	16	16	32
		Leaching for 6 days	16	16	32
		Leaching for 14 days	16	16	32
		Total	76	76	152
Compression strength	30*20*20	Natural leaching	12	12	24
		Control	16	16	32
		Leaching for 2 days	16	16	32
		Leaching for 6 days	16	16	32
		Leaching for 14 days	16	16	32
		Total	76	76	152

L*T*R*: Longitidunal*Tangential*Radial

The specimens of same dimension were used in the oven-dried density, water uptake and water repellency, swelling and anti-swelling efficiancy tests. As specified in TS 2472, the oven-dried density of the specimens was calculated by the equation given below:

$$\delta o = M_o / V_o \quad (g/cm^3) \tag{1}$$

Where,

δo : Oven-dried density (g/cm^3); M_o :Oven-dried weight (g); V_o : Oven-dried volume (cm^3)

Considering TS-2471 and TS-4043 principles ;the water uptake (WA) and water repellent efficiency (WRE) were calculated after each water replacement according to equations given below:

$$WA = [(W_2 - W_1) / W_1] \times 100 \tag{2}$$

$$WRE = [(WA_c - WA_t) / WA_c] \times 100 \tag{3}$$

Where,

W_2 = wet weight of the wood samples after wetting with water, W_1 = initial oven-dried weight,

WA_c=Water uptake values of untreated controls, WA_t= Water uptake values of treated samples.

In the expansion amount and anti-expansion activity test, the samples and measurement periods used in the water uptake rate and water repellency test were used. According to TS-4083 principles, the swelling ratio (SW) and anti-swelling efficiency (ASE) of the specimens in tangential direction were calculated according to equation below:

$$SWR = [(SW_2 - SW_1) / SW_1] \times 100 \quad (4)$$

$$ASE = [(SW_c - SW_t) / SW_c] \times 100 \quad (5)$$

Where,

SW_2 = wet tangential dimension of the wood samples after wetting with water, W_1 = initial oven-dried tangential dimension.

SW_c=Swelling values of unleached controls, WA_t= Swelling values of leached samples.

To determine the influences of natural and laboratory leaching process on strength properties, compression strength test was applied at the end of the all variations. The compression strength (CS) parallel to grain was calculated from the following formula:

$$CS = P / a \times b \ (kg/cm^2) \quad (6)$$

Where,

P: the force applied on wood specimen (kg), a: the width of the sample (cm), and b: the height of the sample (cm).

3. Results and Discussion

3.1. Density

Table 2 gives the oven-dried density values of test and control specimens leached in different combinations. The average oven-dried density of the non-leached chestnut samples was found to be 0.45 g/cm³ for Borçka and 0.47 g/cm³ for Perşembe specimens. Similar results are reported by several authors. In a previous study, the oven-dried density of chestnut was found to be 0.542 g / cm³ (Berkel, 1943). In another studies, the same value was determined as 0.517 g / cm³ (Yazıcı, 1998); 0.51 g / cm³ by (Ay and Şahin, 2002) and as 0.45 g / cm³ (Çetin and Gündüz, 2016). Koukos (1997) also reported that overall basic density was 0,486 gr/cm³ at breast height.

Table 2. Oven-dried density values

Sample Region	Leaching Position	Oven-dried density (g/cm³)			
		Mean	SD*	Min.	Max.
Artvin/Borçka	Natural leaching	0,457	0,014	0,442	0,484
	Control (Non-leaching)	0,447	0,045	0,371	0,526
	Laboratory leaching				
	2 days	0,449	0,039	0,390	0,497
	6 days	0,449	0,039	0,377	0,521
	14 days	0,434	0,045	0,370	0,495
Ordu/Perşembe	Natural leaching	0,518	0,041	0,476	0,603
	Control (Non-leaching)	0,469	0,049	0,406	0,568
	Laboratory leaching				
	2 days	0,465	0,047	0,404	0,539
	6 days	0,465	0,047	0,402	0,544
	14 days	0,451	0,049	0,392	0,559

SD*: Standard deviation

According to the results of simple analysis of variance (ANOVA) (significance level <0.05); leaching process had not effect on the oven-dried density. On the other hand, in the specimens taken from the Ordu/Perşembe region, especially those leached under natural conditions, the oven-dried density is somewhat higher than the other sample groups. Although there was no statistically significant density change, a slight linear mass loss has been occurred in the samples at the end of the leaching process in the laboratory (Fig.1). The mass loss in the Ordu/Perşembe samples is higher in the first stages of leaching compared to the Artvin/Borçka samples, and the mass loss rate decreases afterwards. This means that the chestnut tree, which grows in the Perşembe region, is leached easily and quickly in the first stage. After 14 days of leaching, an average of 4.68% mass loss has been occurred (Fig.1). In a study conducted on different imported trees, mass loss was found to be 2.85% for Doussie, 2.59% for Sapelli and 4.45% for Iroko after leaching (Arslan, 2017).

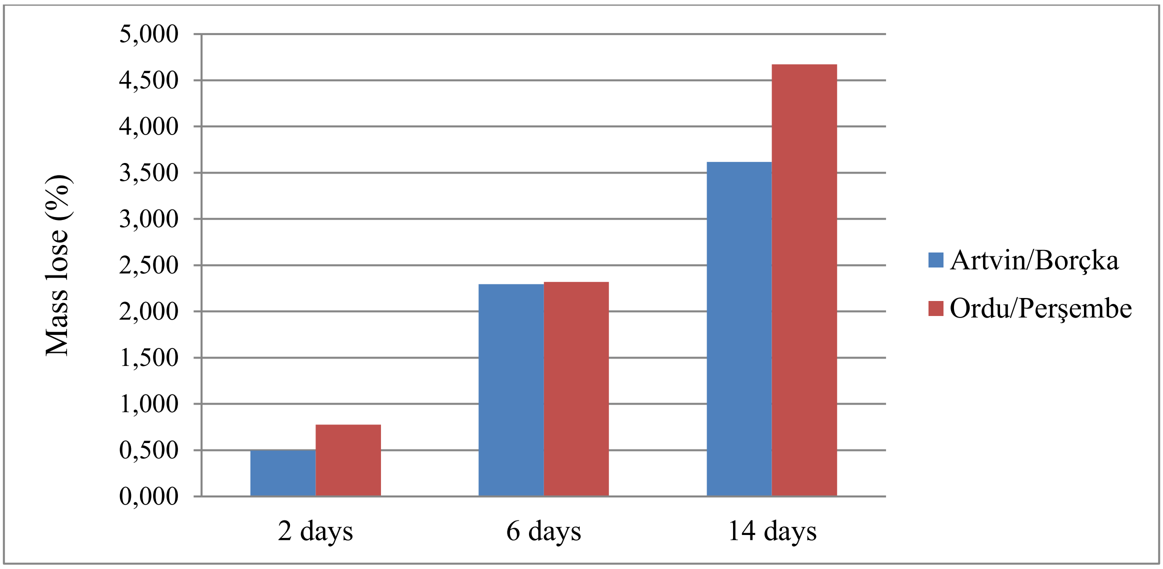

Figure 1. Mass lose after laboratory leaching.

3.2. Water Uptake and Water Repellency

Water uptake and water repellent efficiency values of all the variations are shown in Table 3. Water uptake durations actually have been carried out as 30 minutes, 1-2-4-6 hours, 1-2-4-6-8-10-12-14 days. However, only values of 30 minutes, 6 hours, 4 days and 14 days variations are given in the table. According to the results of ANOVA, significant statistical differences were found in terms of water uptake rates for both regions. The homogenity group of the variations are also shown in the table. The maximum amount of water absorbed by control specimens was 134.7% and 132.1% for Borçka and Perşembe regions, respectively. Ay and Şahin (2002) reported that the maximum amount of water that chestnut wood can absorb was 156.54%. The same value was determined as 147.4% in another study (Çetin and Gündüz, 2016). These kind of differences in the results can be attributed to different growing areas of the wood samples. In the specimens leached under natural conditions, the water uptake rate is lower than the control samples. This decrease is more pronounced in the specimens of Perşembe region (Fig 2). According to this graph, the natural leaching process reduced the water uptake rate, this decrease was 9% in the Perşembe samples. In the samples leached in the laboratory environment, the rate of water uptake has increased (Fig 2). The reasons for this situation can be explained by leaching out relatively more extractive ingredients in laboratory conditions compared to natural leaching. Aa a similar effect has been reported that extracted wood flours sorbed water faster than un-extracted wood flour (Kim et. al. 2009). Similar to our findings, it has been shown that no detectable influence of aging on short term water uptake into chestnut wood (Thaler et al. 2014).

Table 3. Water uptake, water repellent efficiency and homogenity group values of all the variations

Region	Water uptake Period	Water uptake (WA, %)					Water repellent efficiency (WRE, %)				
		Leaching position					Leaching position				
		C*	NL*	2 d*	6 d*	14 d*	C*	NL*	2 d*	6 d*	14 d*
Artvin /Borçka	30 minutes	12	13	16	16	11	-	-6	-20	-31	10
	6 hours	35	31	44	43	35	-	16	-14	-19	3
	4 days	104	101	105	102	96	-	4	2	2	8
	2 weeks	135	134	135	137	138	-	1	0	-3	-3
	HG**	i	j	j	k	k	-	d	c	d	E
Ordu/Perşembe	30 minutes	13	13	17	13	9	-	-4	-19	-15	25
	6 hours	34	30	44	42	38	-	12	-15	-26	-13
	4 days	102	90	106	105	99	-	12	0	-2	3
	2 weeks	132	121	136	141	137	-	9	0	-6	-4
	HG**		i	j	m	k	-	b	d	d	D

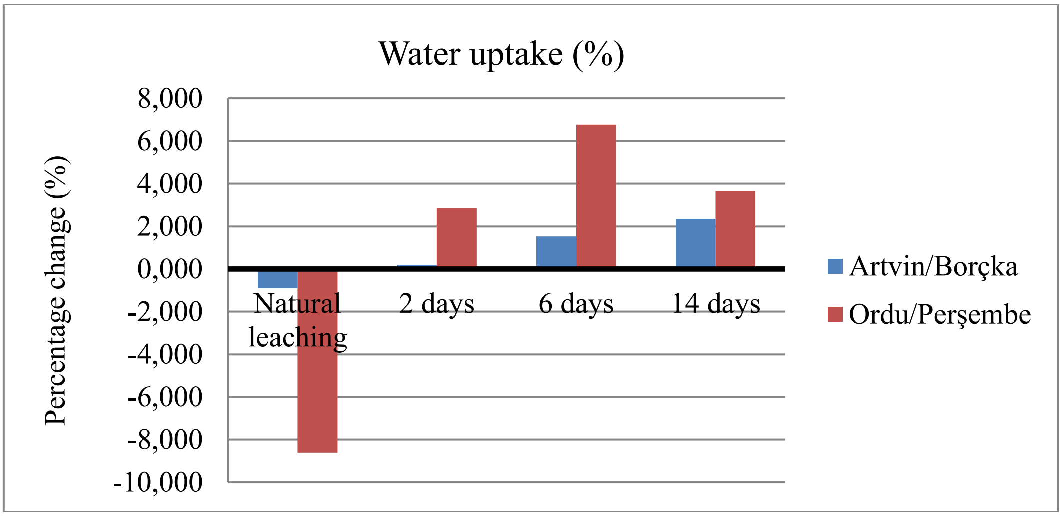

Figure 2. Percentage change in water uptake after leaching process.

Depending on the water uptake rates, there are statistical differences between the variations for water repellent efficiency values also. Water repellency effect increased in natural leaching conditions, but decreased in the 2 and 6-day periods of the leaching in laboratory condition (Fig. 3). It can be stated that the water-repellent effect appears more prominently in natural leaching and long-term laboratory leaching processes. These findings reveal a consistency in itself in that the water-repellent effect increases if the leaching done completely.

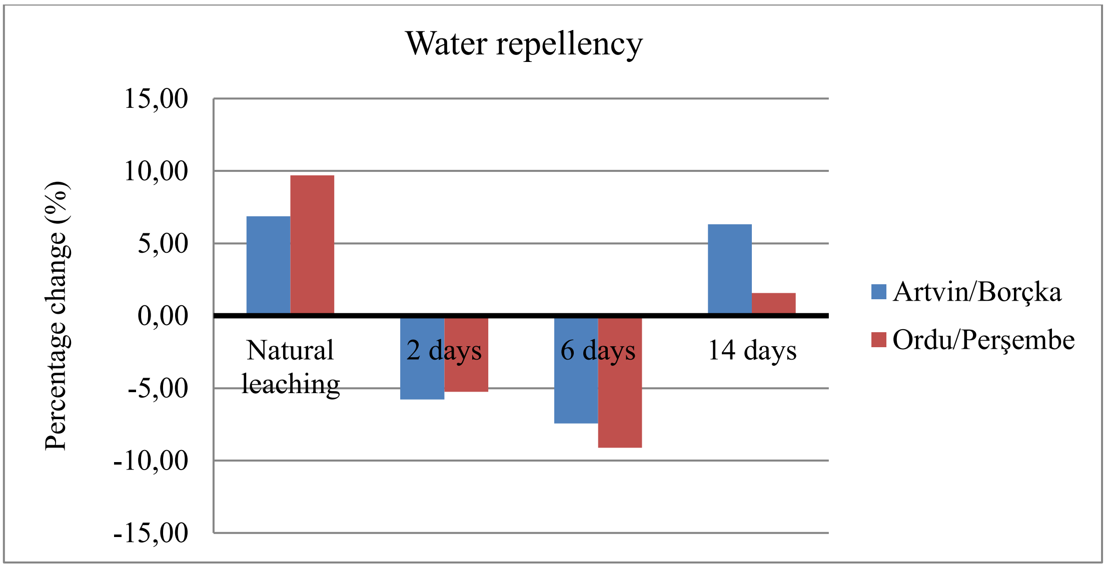

Figure 3. Percentage change in water repellency after leaching process.

3.3. Volumetric Swelling and Anti-Swelling Efficiency

Swelling and anti-swelling efficiency values of all the variations are shown in Table 4. Swelling durations actually have been carried out as 30 minutes, 1-2-4-6 hours, 1-2-4-6-8-10-12-14 days. However, only values of 30 minutes, 6 hours, 4 days and 14 days variations are given in the table. According to the results of ANOVA, significant statistical differences were found in terms of volumetric swelling rates for both regions. The homogenity group of the variations are also shown in the table. According to the findings, the volumetric swelling values in the unleached control samples were 11% and 9,5% for the Perşembe and Borçka regions, respectively. Those values are in good agreement with the results reported for chestnut wood by several authors. Berkel (1943) determined that the volumetric swelling of chestnut wood was 10.64%. The same value was found to be 10.2% in another study (Oral, 2006). Similarly, volumetric shrinkage of chestnut wood grown in Maçka/Trabzon region has been determined as 11,45% (Ay and Şahin, 2002).

The percentage change occurring in the volumetric swelling of the test specimens is given as a graphic in Fig. 4, assuming zero (0) for the control specimen. Fig.4 clearly shows that the change in the volumetric swelling after leaching tends generally in increase except for natural leached specimens of Perşembe region. Again assuming zero (0) for the control samples, percentage change in the anti-swelling efficiency is given graphically in Fig. 5. When all the processes were evaluated together, the leaching process generally decreased the anti-swelling efficiency value. In Artvin/Borcka specimens, the decrease is more evident. This means that Borcka samples become more prone to movement after leaching.

Table 4. Swelling, anti-swelling efficiency and homogenity group values of all the variations.

Region	Swelling Period	Swelling (SW, %)					Anti-swelling efficiency (ASE, %)				
		Leaching position					Leaching position				
		C*	NL*	2 d*	6 d*	14 d*	C*	NL*	2 d*	6 d*	14 d*
Artvin /Borçka	30 minutes	1,2	1,9	1,3	1,2	1,3	-	-4,8	-2,8	-0,2	-12,0
	6 hours	6,3	6,1	6,9	7,2	6,6	-	2,3	-4,8	-14,1	-11,3
	4 days	9,5	9,8	9,6	9,8	9,7	-	-2,2	1,2	-3,8	-7,7
	2 weeks	9,6	10,0	9,9	10,0	9,9	-	-4,8	0	-4,9	-9,2
	HG**	g	f	g	g	g	-	b	b	b	b
Ordu/Perşembe	30 minutes	1,7	2,0	1,5	1,6	1,3	-	-18,4	13,1	1,2	25,8
	6 hours	7,0	6,2	7,8	7,8	7,5	-	11,4	-8,6	-14,2	-8,7
	4 days	10,6	10,3	10,5	10,6	10,5	-	3,0	-4,9	-0,9	-0,1
	2 weeks	10,8	10,4	10,7	10,9	10,8	-	3,6	-5,2	-1,0	-0,3
	HG**	f	f	g	f	g	-	b	b	d	C

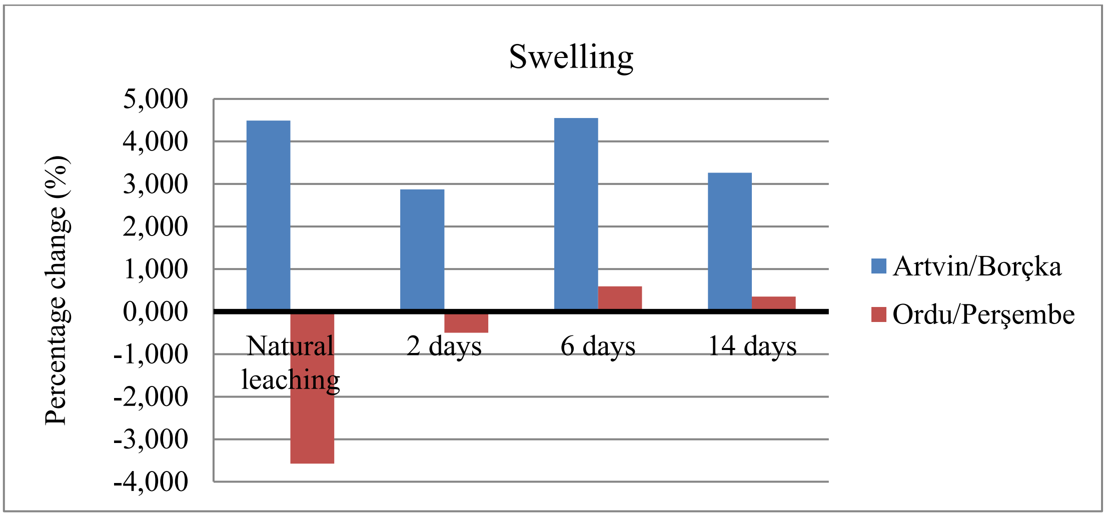

Figure 4. Percentage change in volumetric swelling after leaching process.

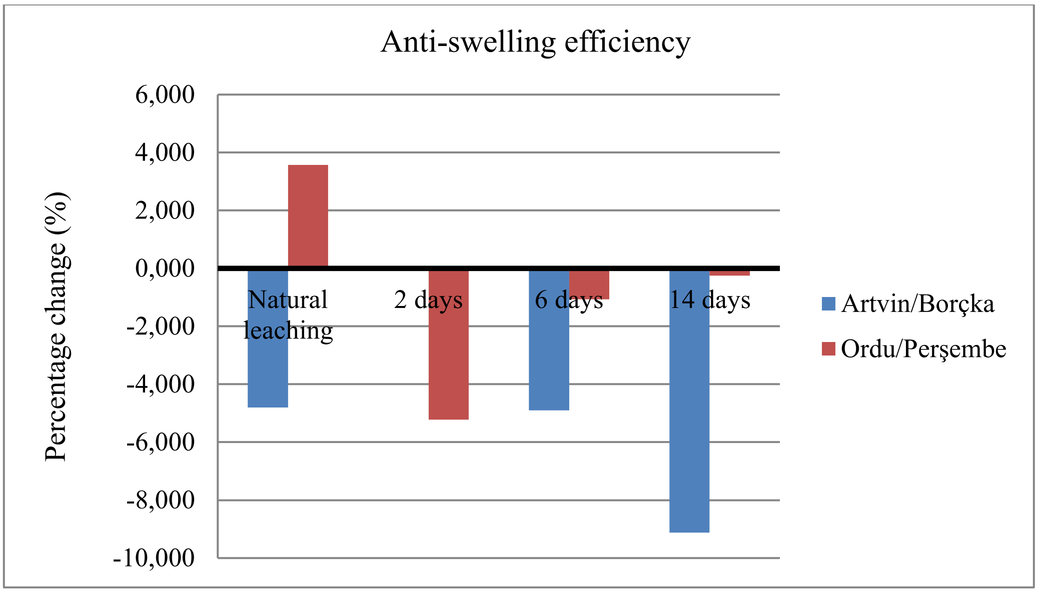

Figure 5. Percentage change in anti-swelling efficiency after leaching process

Some similar results have been reported by several authors for evaluating effectf of extractive matarials on wood swelling properties. In a study evaluating the effect of extractive substances on moisture sorption and shrinkage of tropical woods, it was found that shrinkage of wood had increased (from 18 to 34 %) when extractives were removed (Choong and Achmadi, 1991). In another study, it is reported that maximum wood swelling increased after removal of extractives (Mantanis et al, 1995). Chavenetidou et al. (2020) point out that removal of water soluble extracts resulted in an increase in radial and tangential shrinkage. Şahin (2010) also showed that ethanol-benzene extracted chestnut wood samples have relatively higher swelling rate in all directionns than un-extracted samples. In the present study, although the amount of volumetric swelling seemed close to each other in the test and control samples, it was determined that percentahe change in volumetric swelling and anti-swelling efficiency increased after the leaching process.

3.4. Compression Strength

The compression strength (CS) parallel to grain values parallel to the fibers for each region are given in Table 5. The CS values of un-leached specimens were 442,199 kp/cm² and 527,366 kp/cm² for Borcka and Thursday regions, respectively. The same strength value was found to be 459.82 kp/cm² by Yazıcı (1998). In another study, it was found to be 581,913 kp/cm² (Ay and Şahin, 2002). In this respect, the our findings are parallel to the literature. The CS value of the Perşembe region specimens was higher from Borçka region specimens as to be 20% and 10% for un-leached and leached variations, respectively. The percentage change of CS in the test specimens after leaching process are presented in Fig. 6.

Table 5. The compression strength parallel to grain of all the variations

Leaching position	Compression strength (kp/cm²)						
	Artvin/Borçka			Strength Difference Between Regions (%)	Ordu/Perşembe		
	Mean	SD*	Percentage change (%)		Percentage change (%)	Mean	SD*
Natural leaching	507,794	71,394	14,834	10,729	6,620	562,276	54,418
Control (Non-leaching)	442,199	48,831	0,000	19,260	0,000	527,366	63,120
Laboratory leaching							
2 days	401,162	42,968	-9,280	23,890	-5,758	497,001	63,224
6 days	399,980	43,632	-9,547	15,529	-12,377	462,092	69,371
14 days	385,467	49,217	-12,829	9,022	-20,313	420,244	71,549

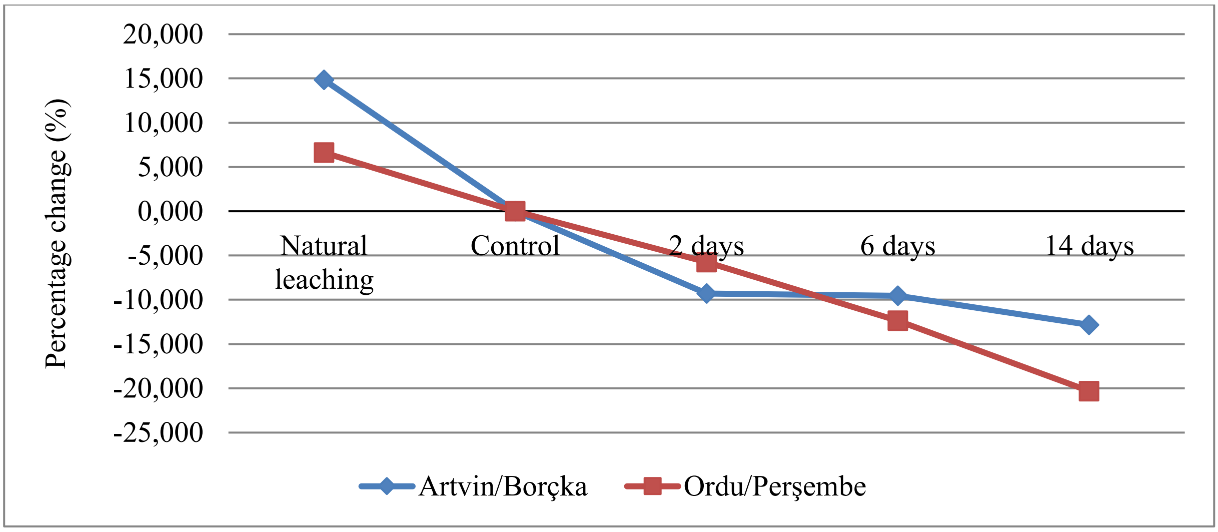

Figure 6. The percentage change of CS in the test specimens after leaching process

Leaching in the laboratory environment reduced the CS values of the samples. This decrease is directly proportional to the leaching duration and more in the Perşembe samples. In Borçka samples, the loss of resistance is higher in the first phase of leaching. However, the samples leached under natural conditions appear more resistant than the control samples for both regions (Fig. 6). Although this is an unexpected result; the fact that the samples washed under natural conditions, the fiber saturation point falls below the humidity again under the washing conditions that last for months, then reaches high humidity levels again and thus, the physical contraction and expansion many times explains the improvement in the mechanical resistance properties.

4. Conclusion

In this study, changes in some physical and mechanical properties of Anatolian Chestnut (Castanea sativa Mill.) that exposed to natural and laboratory leaching process were investigated for two different growing regions in Eastern Black Sea coastal area. The conclusions reached according to findings are listed below:

-The oven-dried density of Ordu/Perşembe wood is higher than Artvin/Borçka wood. Leaching process reduced the weight of the wood; however, did not created a significant change between groups in terms of oven-dried density.

- There is no significant difference between the two region samples in terms of non-leached samples for water uptake rate. Ordu/Perşembe wood is more affected by the leaching process in terms of water uptake and water repellency. The leaching process performed under natural and laboratory conditions have opposite results in terms of water uptake and water repellency. Especially in the Ordu/Perşembe samples, natural leaching decreased the water uptake rate significantly, but the laboratory leaching increased it.

- Ordu/Perşembe wood not leached has swelled slightly more than Artvin/Borçka wood. The natural leaching process increased the anti-swelling efficiency values in Ordu/Perşembe wood and decreased it in Artvin/Borçka wood. Artvin/Borçka wood was more affected by the leaching process in terms of swelling amount and anti-swelling effectiveness. In general, the leaching process increased the swelling amount of the wood and decreased the anti-swelling efficiency value.

- The CS value of the Perşembe region specimens was higher from Borçka region specimens as to be 20% and 10% for un-leached and leached variations, respectively. While the leaching process in the laboratory conditions decreased the compression strength of wood, natural leaching process increased it. In terms of strength, Artvin/Borçka samples was affected more by leaching.

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THE EFFECTS OF POLYSTYRENE SPECIES AND FIBER DIRECTION ON THERMAL CONDUCTIVITY OF PLYWOOD

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Abstract

Thermal conductivity of wood material is superior to other building materials because of its porous structure. 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, specific gravity, moisture content, resin type, and addictive members used in manufacture of wood composite panels. The aim of study was to determine the effect of polystyrene species and fiber direction on thermal conductivity of plywood panels. In the study, two different wood types (black pine and spruce), two different fiber directions (parallel and perpendicular to the plywood fiber direction), two different types of insulator (expanded polystyrene and extrude polystyrene) and phenol formaldehyde glue were used as the adhesive type. Thermal conductivity of panels was determined according to ASTM C 518 & ISO 8301. As a result of the study, the lowest thermal conductivity values were obtained in the perpendicular fiber direction of the spruce plywood using extrude polystyrene as insulation material. The use of extrude polystyrene as an insulation material in plywood has given lower thermal conductivity values than expanded polystyrene.

Keywords: Thermal conductivity, Polystyrene, Fiber direction, Black pine, Spruce

1. Introduction

In order to prevent the rapid depletion of energy resources in the world, all countries, especially developed countries, have developed methods of controlling their energy needs and using energy effectively. Efficient use of energy can be achieved with thermal insulation. In particular, it contains the building elements that separate the interior environment of the building from the external environment. (Uysal et al., 2011). Due to the porous nature of wooden materials, their thermal conductivity is very good compared to other building materials. Thermal Conductivity is an important parameter in determining the heat transfer rate (Ozdemir et al., 2013; Gu and Zink-Sharp, 2005). Thermal conductivity is used to determine the insulating ability of materials. The thermal conductivity of wood varies according to the wood type, fiber direction, glue type and additives used in the production of wood composite materials (Demirkır, 2014).

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).

The aim of study was to determine the effect of polystyrene species and fiber direction on thermal conductivity of plywood panels.

2. Materials and Methods

2.1. Wood Material and Manufacturing of Plywood

Black pine (Pinus nigra) 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. Method

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.

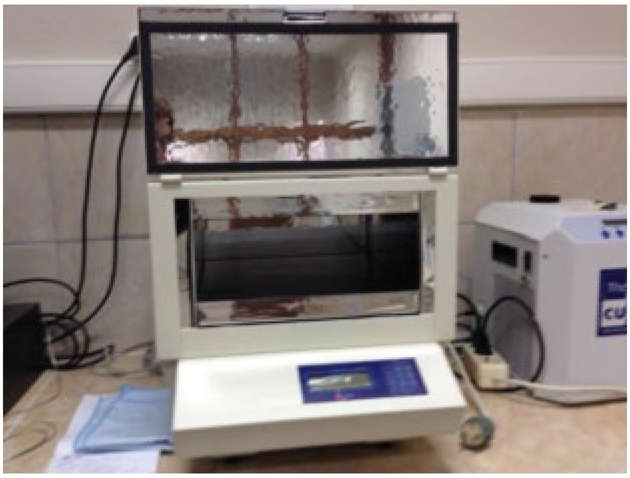

Figure 1. Lasercomp Fox-314 heat flow meter

3. Results and Discussion

The thermal conductivity coefficient values of the plywood-insulation material combinations used within the scope of the study are given in Figure 2 according to the type of wood, fiber direction and insulation materials.

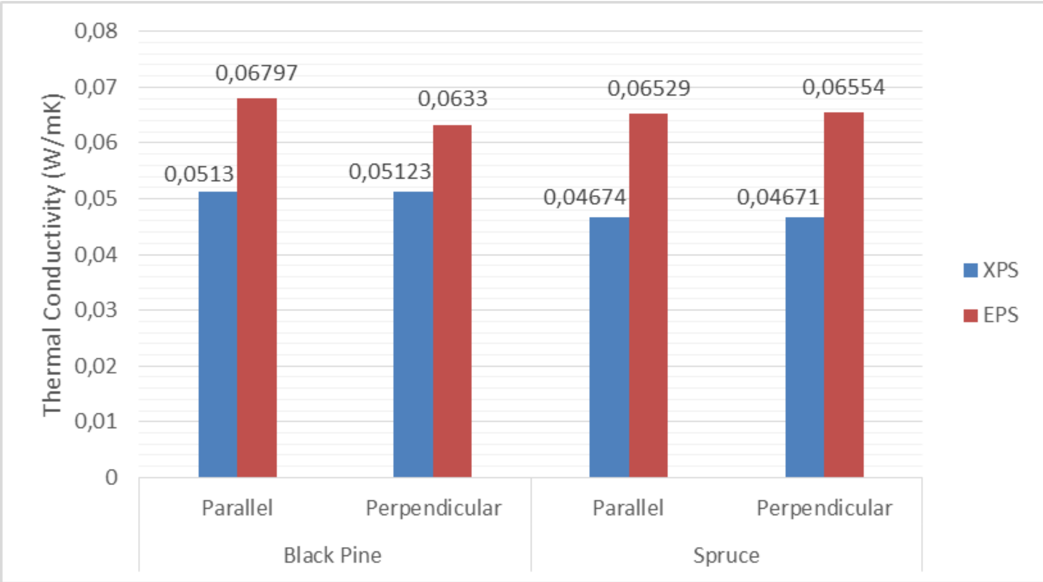

Figure 2. Thermal conductivity coefficients according to combination groups

When Figure 2 is examined, it is seen that the insulating material type and the wood type and fiber direction of the plywood change the thermal conductivity of the groups formed. When the tree type is examined, it has been determined that covering the curtain walls with spruce plywood shows a better insulation feature than the covering with larch. As the reason why larch gives higher thermal conductivity values, it can be shown that its density is higher than spruce plywood. In a study, pine species with different specific weights were examined and it was found that the heat conduction coefficient increased with the increase in density value (Krüger and Adriazola, 2010). The reason for the increase in the heat conduction coefficient due to the increase in density of wood is shown to be less air-filled cell spaces (Suleiman et al., 1999). The greater the air gap in the wood, the lower the thermal conductivity of the wood material (Şahin Kol et al., 2008). Thermal conductivity value of wood material; It is also stated in the literature that it changes in direct proportion depending on the specific weight of the material, the amount of moisture, the amount of extractive material and the amount of temperature (Rice and Shepart, 2004; Aytaşkın, 2009; Sonderegger and Niemz, 2009; Demir, 2014). In addition, the thermal conductivity of the wood material varies depending on the tree type, fiber directions in the same tree and the anatomical structure of the tree (Demir, 2014).

When the effect of the type of insulation materials used in thermal conductivity measurements was examined, it was seen that XPS boards showed a more insulating property. It is a desired result that XPS plates, which are resistant to fire, transmit heat more difficultly and thus minimize the risk of fire. Uygunoğlu et al. (2015) determining the behavior of XPS and EPS types during fire, it was found that XPS boards are more resistant than other EPS types. In a study by Dikici and Kocagül (2019), thermal conductivity coefficients of EPS and XPS boards were compared and it was stated that the values of XPS boards were lower. It is known that the thermal conductivity coefficient of XPS plates used in the study within the scope of the thesis is 0.033 W / mK, and that of EPS plates is 0.039 W / mK. It is recommended to use materials with low thermal conductivity coefficient values in studies where it is desired to improve the thermal insulation of buildings.

4. Conclusion

Today, it is a known fact that energy costs increase with the highest energy consumption in the building sector. For our country aiming to join the European Union, offering different solutions to energy efficiency is one of the most important issues. When the structures are examined, it is seen that heat losses occur from all directions. In a four-storey building, approximately 60% of the average heat losses are from the walls, 25% from the roofs, and 15% from the floors. It is important to carry out studies on the diversity of insulation materials, which are the main issues of heat loss in building walls, and to determine the most suitable one.

In this study, determining the type of materials that will add insulation feature to the wall and some factors belonging to the plywood used in coating the curtain walls were among the main goals. Accordingly, in the thermal conductivity coefficient measurements made within the scope of the study, it was seen that XPS boards could be more successful in the insulation properties of shear walls. Although EPS boards are preferred over XPS boards due to their cheaper price, it is thought that this difference in fees can be ignored when energy costs are considered.

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SITUATION OF FOREST CARBON PROJECTS IN CARBON MARKETS

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Abstract

It has been recognized that human activities increase the density of greenhouse gases in the atmosphere, these increases raise the natural greenhouse effect, increase the average temperature in the earth, and that natural ecological systems and humanity will be exposed to harmful effects, and that climate change is the common problem of mankind. For this reason, there has been a need for an intergovernmental global effort to address the climate change problem. Global cooperation activities are being carried out within the framework of United Nations Framework Convention on Climate Change, Kyoto Protocol and Paris Agreements to stabilize the increasing greenhouse gas emissions in the atmosphere. Forests that play a key role in combating climate change are among the most important issues discussed during the climate change negotiations. There are two important pillars of the forestry sector in climate change. One is mitigation and the other is adaptation. Issues related to forestry interviewed in the scope of mitigation are Land use , land use change and forestry (LULUCF) and REDD +. The mechanism for mitigation is carbon markets. The rate of forestry projects in carbon markets is low. Turkey is traded on the voluntary carbon market is achieving very low income according to the mandatory carbon market. However, the carbon credits that are traded are provided by the renewable energy sector. These credits are in Turkey need to combat climate change in forestry activities both actively involved in the negotiations for the benefit of the mechanisms created in this context and should maintain this attitude. Turkey must make changes in the organizational and technical infrastructure besides negotiations.

Keywords: Climate change, Kyoto protocol, Carbon credit, Forestry

1. Introduction

Climate change is a complex problem that, although qualitatively environmental, has an impact on all areas of humanity's life. Global problems such as poverty, economic and sustainable development, population growth and the management of natural resources are affected. Therefore , it is a desired and expected situation that solutions for climate change come from research and development fields and all disciplines (Öztekin, 2019).

Climate change; In addition to natural climate change observed in comparable time periods, it is defined as a change in climate resulting from human activities that directly or indirectly disrupt the composition of the global atmosphere (UNFCCC, 1992). Global warming means that the global temperature has increased by 0.5 C^0 compared to a century ago and can be explained largely by the greenhouse effect. The greenhouse effect theory sees the increasing concentration of certain gases (carbon dioxide, chlorofluorocarbons, methane and nitrogen oxides) in the atmosphere as the cause of the problem. The most effective greenhouse gases are damp and carbon dioxide. 95% of the total greenhouse effect consists of these gases (Serengil, 1995).

The economic growth and population growth experienced with the industrial revolution caused the accumulation level of carbon dioxide and other greenhouse gases in the atmosphere to rise rapidly. Globally, economic growth and population growth continue to be the most important drivers of increases in carbon dioxide (CO_2) emissions from fossil fuel use (IPCC, 2014). According to the 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), the concentration of carbon dioxide, methane and nitrogen oxide in the atmosphere has increased unprecedentedly over the past 800,000 years. Emissions from fossil fuel use were shown as the primary cause of this increase, and net emissions from land use change were shown as the secondary cause (IPCC, 2013a).

Between 1750 and 2011, about half of the total human-induced CO_2 emissions occurred in the last 40 years, and 2040 ± 310 $GtCO_2$ total human-made CO_2 emissions were added to the atmosphere. Since 1970, cumulative CO_2 emissions from burning fossil fuels, cement production and ignition have tripled, and cumulative CO_2 emissions from forestry and other land use have also increased by about 40%. Annual CO_2 emissions arising from fossil fuel combustion, cement production and exacerbation in 2011 were 34.8 ± 2.9 $GtCO_2$, while the average annual emissions from forestry and other land use between 2002 and 2011 were 3.3 ± 2.9 $GtCO_2$ (IPCC, 2014).

In Turkey forests are considered to be an important mechanism in the combat against climate change mitigation. However, there are no forestry carbon projects that can be subject to carbon markets until today. The reasons for this situation are high costs of credits obtained from forestry projects, methodology and calculation difficulties, lack of a measurable, reportable and verifiable system, etc. are the reasons.

In this study, the reasons for the low rate of forestry projects in carbon markets were investigated and the possibilities of increasing the share of forestry were examined. Turkey's determination of its own as well as the carbon potential, these legal and institutional arrangements for examining solutions to do to fulfill the potential use and obligations in international processes have been developed.

1.1. The Global Carbon Cycle and Forests

Carbon is one of the most important elements in the world in terms of life. Life influences the regulation of carbon content in the atmosphere dominated by geological forces throughout geological time periods. Earth's heat and carbon content in the atmosphere are linked to geological time scales. Carbon cycle processes take place between hours and millions of years. The global carbon cycle refers to the biochemical cycle of carbon stored in different places on our planet between the pedosphere, hydrosphere, atmosphere, biosphere and geosphere (Lorenz and Lal, 2010). As carbon moves between these reservoirs, the length of stay in each also varies significantly (Mackey et al., 2008).

One of the carbon stocks, the atmosphere contains 839 gigatons of carbon (Gt C) predominantly in the form of carbon dioxide. The world's largest carbon stock; It is located in the continental crust and upper mantle of the earth (122.576.000 Gt C), most of which are formed by sedimentary rocks formed over millions of years. The next largest stock is ocean carbon (37,100 Gt C). More than 95% of the carbon found in the ocean is mainly in the form of inorganic dissolved carbon. Only 900 Gt C is available for exchange on the ocean surface. The oceans release 78.4 Gt C a year and hold 80 Gt C. Terrestrial systems, on the other hand, emit 119 Gt C per year and keep it at 123 Gt C. Generally, both oceans and terrestrial systems store more carbon than they emit in a year, with 2.3 Gt C (ocean) per year and 2.6 Gt C (land) per year net intake. Greenhouse gas emissions caused by human activities resulting from fossil fuel consumption and land use change are 9 GtC per year (Janowiak et al., 2017).

In the terrestrial biosphere, carbon is stored in living biomass (450 - 650 PgC) and in dead organic matter (1500 - 2400 PgC) in debris and soils. Wetland soils (300 - 700 PgC) and frozen soils (1700 PgC) also contain carbon. Carbon dioxide in the atmosphere is transported from the atmosphere through plant photosynthesis and stored within the plant (Gross Primary Production (GPP), 123 ± 8 PgC yr^{-1}). The deposited carbon is used to make plant tissues. Leaves and branches shed by the plant decompose in the soil and stored in the soil as carbon. Plant tissues, debris and carbon in the soil are released back to the atmosphere by plant respiration (autotrophic respiration), microbial soil respiration and animal respiration (heterotrophic respiration) and natural disasters (fire, insect, etc.) A large amount of terrestrial carbon is transported from soils to river streams (1.7 PgC yr^{-1}). Some of this carbon is released into the atmosphere as CO_2 by rivers and lakes. Some of it is stored in freshwater organic sediments, and the remaining amount (0.9 PgC yr^{-1}) is delivered to the coastal ocean as dissolved inorganic carbon, dissolved organic carbon and particulate organic carbon by rivers. Atmospheric CO_2 is transported by diffusion between the ocean surface and the atmosphere. In the ocean, carbon is mostly found in the form of Dissolved Inorganic Carbon (DIC, ~ 38,000 PgC), which is carbonic acid (CO_2 dissolved in water), bicarbonate and carbon ions, but also as dissolved organic carbon (DOC, 700 PgC). Marine biota, composed predominantly of phytoplankton and other microorganisms, represents a small pool of organic carbon (3 PgC). Only a small fraction (~ 0.2 PgC yr^{-1}) of carbon reaches the ocean floor and is stored in sediments (IPCC, 2013b).

According to global calculations made in the last decade between 2007 and 2016, the difference between human-induced emissions released into the atmosphere by sources and removed by sinks was determined as 0.6 GtC / yr^{-1}. This difference in the global carbon cycle is called stock imbalance. The emissions released into the atmosphere are caused by fossil fuel consumption of 9.4 ± 0.5 GtC / yr^{-1} and industrial facilities. Emissions emitted by land use change were determined as 1.3 ± 0.7GtC / yr^{-1}. When we look at the emissions removed by sinks, it is calculated that 4.7 ± 0.5 GtC / yr^{-1} is stored by the atmosphere, 3.0 ± 0.8 GtC / yr^{-1} by terrestrial ecosystems, and 2.4 ± 0.5 GtC / yr^{-1} by the oceans (Le Quere et al., 2018).

In this period, 88% of the emissions were caused by fossil fuel consumption and industrial facilities, and 12% from land use change. While 44% of the total emissions were shared between the atmosphere, 28% between the terrestrial ecosystem and 22% between the ocean, the remaining 5% was the stock imbalance (Le Quere et al., 2018). The reasons for this stock imbalance are; re-growth of forests can be explained as various processes in plant growth, including carbon dioxide fertilization, nitrogen storage and their interactions (Schimel, 2006).

The world's forest area is approximately 4 billion hectares, and this amount corresponds to 31% of the total terrestrial area (FRA, 2010). Forests, which contain three quarters of the terrestrial biological diversity, constitute about half of the terrestrial carbon pools. Therefore, forests come to the fore in regulating the world climate (FAO, 2008).

According to the Forest Resources Assessment Report (FRA) (2010), forests at a global scale store 289 Gt of carbon only in their biomass. Globally, forests store 650 billion tons of carbon, 44% of which is biomass, 11% of dead wood and debris, and 45% in soil. Sustainable management, planting and rehabilitation of forests increase forest carbon stocks, while deforestation, forest degradation and poor management of forests reduce this stock. Globally, carbon stocks in forest biomass have been estimated to decline by 0.5 Gt annually over the period 2005-2010. The main reason for this is the decrease in the global forest area. While 16 million hectares of forest area was destroyed annually in the 1990s, approximately 13 million hectares of forest area have been destroyed due to changes in land use and natural reasons since the 2000s.

1.2. Emissions Trading

An Annex-I Party that has a commitment to quantify emission limitation and reduction within the scope of the Emission Trade, which is included in Article 17 of the Kyoto Protocol and is a market-based mechanism, may procure or transfer Kyoto units from another Annex-I Party. It can use these acquired units to meet some of their commitments in Article 3 of the Protocol.

In other words, countries emitting less than the committed emission amount can sell the excess emission units they obtain to the Parties that emit more than the committed emission amount (Dagoumas et al., 2006).

With the emission trade, the parties also include the removal units (RMU) obtained from land use land use change and forestry activities, certified emission reduction units (CERs) obtained from project activities carried out within the scope of the Clean development mechanism and emission reduction units (ERUs) obtained from Joint Execution projects. they can transfer within the scope of the system (Hepburn, 2007).

The amount of units transferred by the Party to other countries is limited to the commitment period reserve of the Party. Each Party is obliged to preserve the minimum level of units' reserve in its national register in order to prevent Parties from being unable to meet their emission targets by transferring excess units. Known as the "commitment period reserve", this reserve must equal 90% of the Party's allocated unit of quantity or 100% of the Annex-A emissions from the most recently reviewed inventory. This reserve, known as the commitment period reserve, cannot be less than 90% of the allocated amount of the Party or less than 5 times the Annex-A emissions (8 for KP2) of the last revised inventory. Whichever is the lowest is considered (UNFCCC, 2005).

The transfer and purchase of these units are tracked and recorded through the Kyoto Protocol registration system. The international transaction record (ITL) ensures that emission reduction units are securely transferred between countries. Thus, a new commodity subject to trade in the form of emission reduction or removal was created. Since carbon dioxide is the main greenhouse gas, the term carbon trade is used. Carbon is now traced and traded like any other commodity. This is known as the "carbon market".

2. Materials and Methods

2.1. Materials

In the study, many studies in the literature on climate change, carbon economy and emission trade and international conventions, protocols, meeting and conference final declarations related to the emergence and functioning of carbon markets were also used as material. Especially in Turkey, carbon markets, legal and institutional report prepared by the relevant ministries for the section dealing with regulations, national action plans and strategy documents were also used.

2.2. Methods

Literature review method was used in the study. First of all, detailed information on the subject was obtained and analyzed. The deductive method was used to form the conceptual framework of the study. First of all, the concepts of global warming, carbon cycle, and climate change were introduced and carbon markets formed as a result of international processes were explained. In addition, general information was given on forests and the place of the forestry sector in the carbon cycle. Again, subjects such as forestry projects, certification processes and pricing within the scope of carbon markets have been examined in detail depending on the literature. Also next to the position of Turkey in the carbon market, the situation in the international process, scientific and technical infrastructure and legal and institutional arrangements were discussed.

3. Results

3.1. Forest Carbon Sequestration Potential of Turkey

LULUCF party Annex I countries are obliged to submit their greenhouse gas inventory reports and common reporting format (CRF) tables to the LULUCF Secretariat on April 15, at the latest every year. In this context, NIR (2019), our last national inventory report submitted to the secretariat; The total amount of the attitude of Turkey in the LULUCF sector is calculated as 99.907 kt CO_2 eq^{-1}. The areas subject to calculation within the scope of the inventory are: forest land, agricultural land, meadow and pasture areas, wetlands, residential areas, harvested forest products, other lands and others.

Table 1. The total emissions and removals in the LULUCF sector in Turkey

	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**
Total (kt CO_2 eq.)	-55.765	-57.400	-61.556	-74.693	-73.492	-97.206	-95.930	-99.907
4.A Forest Area	-52.830	-54.963	-57.890	-69.356	-67.614	-87.669	-85.233	-90.195
4.B Farming Area	0.69	153	38	207	453	457	344	368
4.C Pasture Area	0.03	262	81	211	551	929	592	640
4.D Wetland	12	169	188	40	426	93	344	328
4.E Work Area	NO,IE	132	145	273	426	419	406	413
4.F Other Area	NO	181	187	310	601	764	617	653
4.G Harvested Wood Product	-2.948	-3.333	-4.305	-6.379	-8.334	-12.200	-13.000	-12.115

Turkey's LULUCF sector, providing a net removal. Forests have a large share in the removal of this sector. Within the LULUCF sector, the emission attitude amount of forest areas has been determined as 90.195 kt CO_2 eq^{-1}. The attitude amount provided by the harvested wood products (HWP) sector is 12.115 kt CO_2 eq^{-1}. Other land uses generated net emissions. LULUCF sector has increased by 79.2% compared to 1990. In 2017, total CO_2 emissions and removals in the LULUCF sector increased by 4.1% compared to 2016.

Significant improvements have been made in the LULUCF reporting system. With the new system, transparency increased, integrity, accuracy and consistency were improved. Land use definitions have been updated with the new land monitoring system. The forest definition used in NIR 2018 is a national legal definition with a threshold value of 3 hectares, while in the new definition, the forest area is divided into 2 sub-categories as fertile forest and other forest area. The fertile forest has been defined as the trees and shrubs larger than 1 hectare, which grow naturally and with human influence, with more than 10% coverage. The other forest area is defined as trees and shrubs larger than 1 hectare, which grow naturally and with human impact, with less than 10% coverage. Inconsistency between forestry and other land use activity data has been corrected. Providing area, increment and other data on forests, ENVANIS was based on the national legal definition as a forest area. This definition did not allow the creation of land use matrices consistent with CORINE used as a land cover map. The new Satellite-based land cover monitoring system provided the opportunity to monitor every 1 hectare of land unit. In this way, since 1990, matrixes regarding land transformations and land uses have been developed and no duplicate calculations or skips have been made. Ecological zones have been associated with established climate types.

3.2. Turkey's Position in the International Process

Turkey, the United Nations Climate Change in the Framework Convention adopted in 1992, the Economic Cooperation and Development Organization's Convention on account of being a member of both Annex I and Annex II list, has been involved with the developed countries. Turkey since 1992, supporting the purpose and the general principles of contract together not a party to the contract due to the unfair position in the contract and gave a long struggle to change that position. Made on the Moroccan city of Marrakech in 2001 7th Conference of Parties (COP.7), "Turkey's name to be deleted from Annex II and the special circumstances recognized and other Annex I will include in Annex I in a different location in the country Became a party to the contract on 24 May 2004 following the decision.

The Draft Law on the appropriate location of our participation in Kyoto Protocol "05 February 2009, the Grand National Assembly of Turkey was adopted by the General Assembly and as of 26 August 2009 Turkey was formally ratified the Kyoto Protocol. Turkey's first Kyoto Protocol (2008-2012) and Second (2013-2020) Liability Period There is no greenhouse gas emission reduction commitments. It became a party to the Paris Agreement on 22 April 2016 and submitted the National Contribution Declaration on 30/09/2015.

3.3. Situation in Turkey's Emissions Trading System

The World Bank has implemented a technical assistance program called the "Partnership for Carbon Market Readiness (PMR)" to provide developing countries and emerging economies with the development of the necessary capacity to actively benefit from market mechanisms.

Multi Donor Fund for the Grant Agreement Carbon Market Readiness Partnership (PMR) Partnership support program was implemented by the World Bank and the Undersecretariat of Treasury, numbered TF010793, made by the World Bank and the Undersecretariat of Treasury. Fund Grant numbered TF015591 for the Partnership for Preparation for the Carbon Market was published in the Official Gazette numbered 28910 on 11 February 2014. With contracts, 3,350,000 dollars were allocated to the Ministry of Environment and Urbanization. The Ministry of Environment and Urbanization has been designated as the Implementing Agency for the above mentioned Grant Agreement.

A pilot study in coordination with all relevant stakeholders for the implementation of the Regulation on Monitoring of Greenhouse Gases (MRV) in voluntary sectors, analytical studies, capacity building, awareness raising and training studies to support decision-making processes for the use of carbon market mechanisms will be carried out within the scope of the project.

In April 2012, Turkey has adopted a new regulatory framework for a comprehensive and compulsory MRV system. Monitoring and reporting in 2015 (2015 emissions) started in 2016.

Turkey, since 2013, energy, cement and refinery sectors through pilot studies in order to improve the regulation MRV is working with PMR. A series of workshops and analytical studies have been conducted to explore the options for using emission trading and other market-based tools in MRV sectors.

A synthesis report in November 2018 Climate Change and Air Management stating that carbon markets of policy options were presented to the Coordination Committee for Turkey.

Turkey is a candidate at the same time EU membership and thus aims to fulfill its environmental obligations of EU membership (including the EU ETS Directive) MRV Turkey MRV legislation has established a system at the installation level for CO_2 emissions for about 900 businesses. The scope of the sector includes the energy sector (combustion fuels > 20 MW) and industrial sectors (coke production, metals, cement, glass, ceramic products, insulation materials, paper and pulp, chemicals according to specified threshold sizes / production levels) (ICAP, 2019).

3.4. Status of Forest Carbon Credits in Voluntary and Mandatory Markets

Compared to the mandatory markets, the forestry sector took a higher place in voluntary markets as a transaction volume. While the value of voluntary forest carbon offset transactions in 2016 was 74.2 million dollars, it was 551.4 million dollars when 41.9 million dollars excluding the Australian ERF in mandatory markets were included. 2/3 of the voluntary markets in total transaction value were obtained from forestry carbon offsets. The transaction volume decreased by 21% in 2016 compared to 2015.

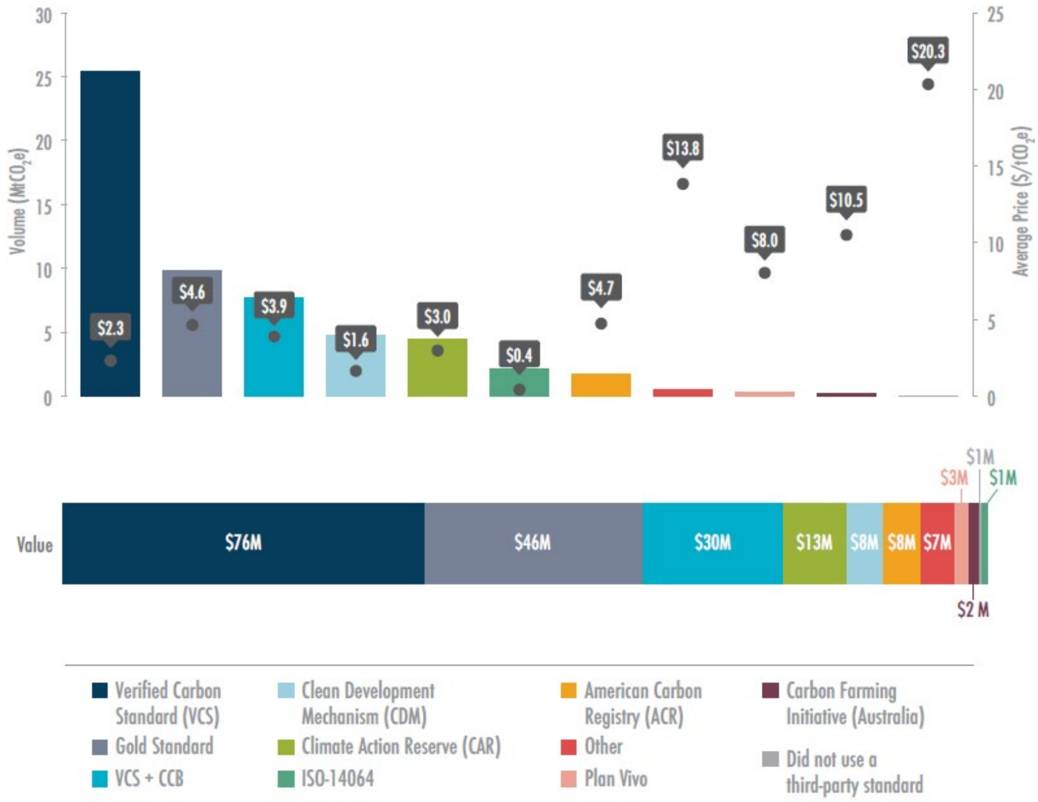

Figure 1. Transaction volume and values of forestry-based emission reductions in voluntary and compulsory markets (Hamrick and Gallant, 2017).

The activities used to create forest carbon credits under CDM in mandatory markets are afforestation and reforestation. According to the latest data, only 66 of 7804 registered CDM projects are forestry projects and the share of A / R loans in CDM loans is only 0.8%. The important reason for this is the difficulties it faces in terms of proving the additional contribution and effectiveness. Within the scope of the Paris Agreement, negotiations on CDM are continuing.

Forestry and land use projects in the voluntary carbon market are certificated and traded within the framework of certain standards. These standards; Verified Carbon Standard (VCS), American Carbon Registration Standards (ACR), Plan Vivo Standard, Gold Standard, Climate Action Reserve (Reserve) CAR and Climate, Community and Biodiversity Standards (CCB Standards).

82% of forestry and land use projects in the voluntary market have the Verified Carbon Standard. Different project types such as tree-planting, agroforestry and advanced forest management are certified within the scope of VCS. But the most common is REDD +. 73% of VCS certified offsets also carry Climate Community and Biodiversity (CCB) Standards. The CCB standard is a non-carbon common benefit standard and is added to VCS forest carbon projects. Historically, VCS and CCB certified offsets have been sold at higher prices than those approved by VCS alone, but this did not apply in 2016. VCS certified offsets average $ 4.6 / tCO_2 equivalent, VCS + CCB offsets 4.1 / tCO_2 equivalent sold. This is probably due to the locations of these projects; VCS + CCB Offset prices tend to be produced in low-income countries, with offset prices generally lower. ACR certified offsets made up the second largest share of the market in terms of value and volume in 2016. Most of the offsets published by the processed ACR came from either improved forest management or tree planting. ACR offsets are 8.9 $ / tCO_2 equivalent above average prices. This is partly because ACR certified projects are mostly found in the United States. The Gold Standard and Plan Vivo both place great emphasis on shared benefits and although they have no geographic constraints, both standards approve forestry and land use projects in small, rural communities in low- or middle-income countries. Gold Standard accounts for about 4% of the market volume, with these offsets traded at an average price of $ 5.7 / tCO_2 equivalent. Tree planting constituted the main project type. Plan Vivo accounted for 2% of the market volume and these offsets were traded at an average price of $ 8 / tCO_2. Plan Vivo is forest project types-tree planting, agro-forestry, mangrove restoration, REDD + and advanced land and forest management. In 2016, project transactions that did not use a third-party verification standard accounted for only 0.3% of the market volume and were sold at the highest price (20.1 $ / tCO_2 equivalent). Offsets in the 'other' category also accounted for the second highest price (11.5 $ / tCO_2 equivalent), but they accounted for less than 1% of total forest and land use offsets, all of which are in North America, where prices are higher. are available. Similarly, the Australian Carbon Agriculture Initiative offsets have high prices (average 8.9 $ / tCO_2 equivalent), making up a very small portion of the market (2%) and were used only in Australia. 99% of all forest carbon projects include at least one co-benefit type (Hamrick and Gallant, 2017).

Voluntary carbon markets In 2016, more than US $ 66 million forest carbon offset projects were processed. These offset projects have 99% VCS standards.

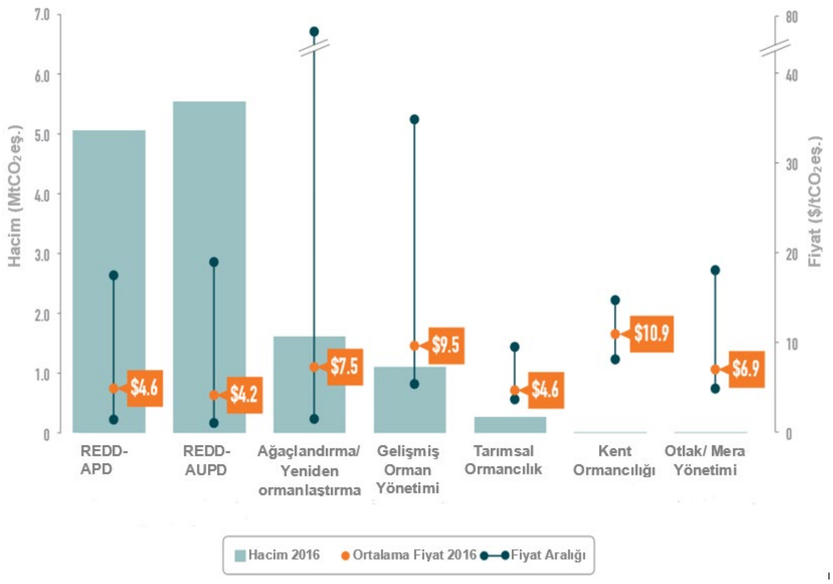

Figure 2. Distribution of forestry carbon projects by project type

When Figure 2 is examined, 26.8% of the traded volume constitutes the forestry and land use category. 46.5% of the total value of voluntary carbon markets comes from forestry and land use offsets. Renewable offsets sold at an average of $ 1.4, while forestry and land use offsets were sold at $ 5.1 (Hamrick and Gallant, 2017).

In 2016, the most traded project categories in the voluntary carbon markets were renewable energy resources with a transaction volume of 18.3 $MtCO_2$ equivalent, and forestry and land use with a transaction volume of 13.1 $MtCO_2$.

According to the project types the transaction volume of the forestry and land use category in the voluntary carbon markets in 2016 was 13.1 $MtCO_2$ equivalent. The volume of forestry project types in this category was 12.1 $MtCO_2$ equivalent. REDD + project type 9.7 $MtCO_2$ equivalent, Afforestation and Reforestation (A / R) 1.3 $MtCO_2$ equivalent and Advanced Forest Management (IFM) with 1.1 $MtCO_2$ equivalent volume have taken place in this market. In 2016, the most purchased and sold project type in terms of volume was 9.7 $MtCO_2$ equivalent and wind energy followed REDD + with 8.2 $MtCO_2$ equivalent. The average price of offsets from the REDD + project type was $ 4.2, Afforestation and Reforestation (A / R) offsets averaged $ 8.1, Advanced Forest Management (IFM) offsets were traded at $ 9.5 (Hamrick and Gallant, 2017).

Approximately one-third of carbon credits in voluntary markets are from forest carbon credits. The majority of forest carbon credits are generated in developing countries. Recently, the supply in the market is high and the price of loans remains low. In forest carbon projects, the CO_2 price per tonne varies between 3 and 10 US dollars.

3.5. Carbon Market in Turkey

Turkey, although the Kyoto Protocol does not benefit from the flexibility mechanisms which are subject to emissions trading in functioning independently of these mechanisms, established within the framework of environmental and social responsibility principles Volunteer projects for the Carbon Market has long been developed and implemented (NC, 2016). Voluntary Carbon Market, if we represent a very small percentage in the World Carbon Market, effective way to benefit from this market in Turkey offers an important opportunity for future participation in the carbon market. Currently, there are 348 projects that improve the carbon presence in the Voluntary Carbon Market. These projects are expected to achieve 26 million CO_2 equivalent greenhouse gas emissions annually (NC, 2017). 72% of voluntary carbon projects project is located in the top five countries hosting: India (442), China (426), United States (351), Turkey (124) and Brazil (97) (Hamrick and Gallant, 2017).

Table 2. Industry distribution of the carbon project in Turkey (NC, 2017)

Project Type	**Number of Project**	**Annual Potential of GHG Emission Reduction (tCO_2-eq)**
Hydroelectric	146	8.543.540
Wind Power	145	11.223.783
Biogas/ Waste Energy System	34	4.104.066
Geothermal	11	1.868.256
Energy Efficiency	12	268.557
TOTAL	348	26.008.202

Turkey plays a significant role in the global voluntary carbon market and is the largest seller of voluntary carbon credits in Europe. 2007-2015 period, Turkey has made 35 million tonnes of CO_2 equivalent transactions with a value of over $200 million. This transaction volume represents around 70 percent of the total market volume in Europe so far. Turkey in 2015, 3.1 million tons, which is about half of all primary operations in Europe are responsible for the CO_2 equivalent. This is Turkey equally with other major players, including the United States and Kenya after Brazil, India and Indonesia has the world's fourth largest provider of voluntary carbon exchange. However, despite the high transaction volume, the total value of these transactions fell from USD 18.6 million in 2013 to USD 4.3 million in 2015. Most of Turkey's voluntary carbon transactions, wind, were obtained from the sale of VERs generated by hydro and landfill methane projects.

Turkey average price of \$ 1.1 with traded volume of 1.9 $MtCO_2$ equivalent in 2016 from is stated that the total value of \$ 2M.

Carbon projects in Turkey is primarily developed in one of the two standards. These; It is Gold Standard and Verified Carbon Standard. As of April 2016 Turkey, has completed 235 projects registered with the Gold Standard which 125 of them, 110 of them are Verified Carbon Standard. Both standards stand out as an internationally respected framework for the development and implementation of emission reduction projects and are traded worldwide.

4. Discussion

The basis of the United Nations Framework Convention on Combating Climate Change and its accompanying Kyoto Protocol is based on the "polluter pays" philosophy. Parties have made emission reduction commitments in line with this philosophy. However, for both economic and political reasons, developed countries with historical responsibility have taken less emission reduction commitments than they could. While Kyoto Protocol's first term emission reduction target was 5%, this target was realized as 22.6% at the end of the period. This situation reveals that especially developed countries make less effort in combating climate change than they can.

Since the developed countries that are party to the contracts have completed their industrialization, current emission trends are lower than those in developing countries that cannot complete their industrialization. However, developed countries, which have been in a polluting position in the historical process, do not make enough effort and continue to contribute to their economies by transferring technology to developing countries through mechanisms. For example, while the Green Climate Fund, whose establishment purpose is to provide funds to developing countries from developed countries in adaptation to climate change, 100 billion dollars should be transferred until 2020, it was announced at the Lima Conference that the amount provided for this fund was only 10 billion dollars.

Although the issue of climate change is an environmental reality today, the economic and political attitudes of the party countries have a negative effect on the solution of this problem. Some of the developed countries (Japan, Australia, Canada, Russia) that have emission reduction and limitation targets in the first period of the Kyoto Protocol are not included in the second period of the Kyoto Protocol with the Doha Regulation. One of the main factors for countries to make this decision is the avoidance of emission reduction commitments by major economies such as the USA, India and China. Again, since the second period emission reduction target of the Kyoto Protocol is 18%, these countries did not take part in the second period of the Kyoto Protocol in order to avoid the negative effects to be experienced on their industries and thus on their economies.

A study examining the share of sectors in KP1 emission reductions revealed that the energy sector contributed to the highest greenhouse gas emission reductions, with most countries achieving a limited amount of greenhouse gas reductions from their chosen LULUCF activities. It has been determined that LULUCF's contribution to greenhouse gas emission reduction has a significant but small share. This suggests that unless there are significant changes in accounting rules, future emission reductions will mainly result from actions to reduce fossil fuel consumption, and the agriculture and LULUCF sectors will continue to play a supporting role (Liua et al., 2016).

According to 2016 data, the total volume of the global carbon market is 6.03 $GtCO_2$ and its monetary value is 30.2 billion dollars. Almost all (99%) of the trading volume of the carbon market consists of mandatory markets. Mandatory markets have a trading volume of 5.96 $GtCO_2$ and a monetary value of approximately \$ 30 billion. When the carbon credits obtained from forestry projects traded in compulsory and voluntary markets are analyzed;

While the total amount of forest loans traded in the mandatory market is 41.9 million dollars, this value is 74.2 million dollars in voluntary markets. While carbon credits obtained from forestry projects constitute 37.1% of the total value of voluntary markets, these credits constitute 0.14% of the compulsory market. Forests are of great importance in efforts to combat global climate change. For this reason, this situation has been emphasized and continues to be done in all international processes, especially the Kyoto Protocol. However, forestry carbon credits cannot be traded in most of the existing mandatory markets (limited trade in New Zealand and Canada), especially in the European Union Emission Trading System. The reason for this situation; countries evaluate their forestry projects within the scope of risky investment.

Parties taken so far regarding Turkey Conference decisions 26 / CP.7, 1 / CP.16, 2 / CP.17 1 / CP.18 and 21 / CP.20 'dir. There has been no change in the state of Turkey. Turkey, in a different location from the UNFCCC's other Annex I Parties, the particular circumstances of the well-known, not included in the agreement's Annex II list, as defined in KP's Annex-B binding greenhouse gas does not have any commitment to reduce emissions. Turkey constitute the basic principles of historical responsibility for the contract, the principle of common but differentiated responsibilities, equity and revise again the differences in the classification of countries is important Annex.

Turkey has not yet ratified despite the signing of the Paris Agreement. Turkey, the necessary arrangements in the energy sector in reducing the use of fossil fuels 2 C temperature increase within the confines of this agreement is one of the declared objectives would do. However, CAT (2019), of which Turkey is a country located in (the US, Russia, like Saudi Arabia) at the National Contribution Statement was found critically inadequate. Turkey's growing energy demand planning to meet the new coal power plants sourced from literally create a contrast with the National Contribution Agreement under the Paris Declaration. Turkey, 88'n% of its energy needs, according to data of 2017, or 33% of the fossil fuel and electricity supply (16% increase compared to 2016) have met from the coal. In this case, the CAT (2019) to verify the report with the revision of policy towards Turkey, especially renewable energy sources reveals the necessity. Also, in case the point of meeting the targets set by Treaty of Paris that Turkey is not sufficient in forestry legislation and in particular to continue to be considered as developed countries needed extensive editing is in Turkey's forestry legislation (Gencay et al., 2019).

Bouyer and Serengil (2017) in Turkey between the years 2013- 2020 forest carbon credits that can be obtained from 179.1 $MtCO_2$ (nearly 22.4 $MtCO_2$) found equivalent. In this study, the cost per ton was found as 66.7 dollars for forest management and 86.4 dollars for afforestation. These values indicate that only very costly for the operation of Turkey's forests and carbon sequestration is quite high in terms of producing only carbon projects in terms of retention, although low compared to other sectors.

Kuş et al. (2017) entitled, obtain carbon credits from afforestation and reforestation projects in the voluntary carbon market in Turkey The legal and technical conditions have been examined. Working with Turkey hectare basis with a small amount to be obtained A/R carbon credits were increased disproportionately the certification costs and a 30-year A/R project of the cycle carbon certification cost was estimated that approximately $ 110,000. Project design development, registration, approval and verification processes are included in this cost calculation and excluding afforestation cost and net present value. In order to earn income from carbon credit sales, it was estimated that an area of 187 hectares should be subject to afforestation. providing reforestation carbon certification in the private sector in the implementation of the socio-economic responsibility program in Turkey has observed that the economically and technically.

Turkey, the world takes its place among the few countries that increase the presence of the forest. In combating climate change, the forestry sector is important in terms of mitigation and adaptation policies. One of the ecosystem services provided by forests is that it acts as a sink in terms of greenhouse gas emissions. Therefore, the effect of correct and sustainable management of forests on carbon stocks is indisputable. Turkey, however, inadequate to the legal framework on this issue (Coskun and Gencay, 2011), the institutional embodiment there are shortcomings. Yet rural development with forestry activities in Turkey in the fight against climate change and the use of tools such as agroforestry is important (Toksoy and Bayramoglu, 2017). Positive effects can be made on issues such as reduction of greenhouse gas emissions and biodiversity as well as increasing the welfare levels of regional development and rural societies through both rural development and agricultural forestry studies (Toksoy and Bayramoğlu, 2020).

5. Conclusion

The following recommendations are developed alongside of climate change more effectively use the carbon markets and forestry projects located in the struggle with Turkey's on what to do about it.

• For the continuity of the mechanisms established by the Kyoto Protocol, first of all, developing countries should fulfill their economic obligations.

• Countries with similar economic indicators should be re-evaluated and the classification should be revised in order to correct the problems in the country classification made as a result of international processes.

• In order to make carbon markets more effective and efficient, besides taking into account the special circumstances of the countries in the creation of new market rules, practices that encourage the market should be encouraged.

• As a carbon pricing mechanism in the fight against climate change, regulations are made to encourage Carbon Markets private sector solutions. Particularly with regard to the issue of forestry forest ownership in Turkey does not permit the private sector to take part in this market. Must make the necessary arrangements in this regard the relevant public institutions and organizations in Turkey.

•Turkey's strong international position with the change, measurable - verifiable - reportable (MRV) are required to establish the system. For this, institutional capacity should be developed first.

• In Turkey, the only competent authority responsible for the management of the forests within the General Directorate of Forestry will conduct studies on the fight against climate change at a level sufficient (nowadays are active in the working group level) does not have a unit. The General Directorate of Forestry should establish a unit at the level of departments on climate change in its current structure, and give importance to developing its institutional capacity and training expert teams.

6. Acknowledgments

The authors declare that there are no conflicts of interest. This study is derived from the master thesis "Stiuation of Forest Carbon Projects In Carbon Markets" conducted in the Karadeniz Technical University, Institute of Science, Forest Engineering Department.

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A STUDY ON THE BIOMASS ENERGY POTENTIAL OF TURKEY: EXAMPLE OF WOOD PELLETS

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Abstract

Today, with the increasing population, the pressure on natural resources varies in terms of quality and quantity in parallel with the developments in the living standards of people. In addition to being the natural resource that experiences this pressure most severely, forests play an important role in the production of sustainable and clean energy, especially within the scope of combating global climate change, together with the technological developments. In addition to energy forestry, the use of trunk parts and bark, roots, branches and leaves that remain idle in forests as a result of production activities has gained importance today. "Wood Pellet", one of the biomass fuels in renewable energy sources, stands out among all renewable energy sources with it's ease of production technology, environmental friendliness and similar features. Wood pellets, which are fuel pellets of 6-10 mm diameter, which are obtained from the drying of wood waste, milling it into sawdust and then compressing it with high pressure, have become economically comparable with fossil fuels today. Wood pellet trade worldwide increased by more than 21% in 2018 compared to the previous year, reaching a trade volume of 22.3 million tons. The biggest pellet exporter countries in the world since 2012 are USA, Canada, Vietnam, Latvia and Russia respectively. These countries accounted for approximately 69% of the world export volume in 2018. Except for five countries, they continue to work on alternative energy sources and especially the production, technology, use and properties of wood pellets in China. In Turkey, there are studies on the production of wood pellets and the economy. However, these studies need to be updated both in terms of production and economics. In the study, analyzed the current data with the potential that Turkey has developed proposals for the use of this potential.

Keywords: Forestry, Economy, Biofuel, Energy demand

1. Introduction

Renewable sources particularly biomass account for an increasing proportion of energy generation. Efforts to limit the use of fossil fuels and the development of alternative energy resources are also effective in this increase (Kaygusuz et al., 2017). Wood pellets are the most popular and traded among biomass fuels (Jagers et al., 2020). Wood pellets from biomass fuels have emerged as a substitute for coal, natural gas and fuel oil both in industry and residential heating (Junginger et al. 2019). Wood pellet is obtained by smashing and compressing the wood residuals such as wood chips and tree bark. Sawdust or wood chips that are compressed under high temperature and pressure bind together, due to their lignin content, to form wood pellet. Wood pellet, which is a subsidiary product obtained from sawdust as a result of wood processing, can now also be obtained from round chocks and battens. Wood pellet is highly preferable to other solid biomass fuels due to its low humidity (less than 10%) and high energy density (Junginger et al., 2011; Stewart, 2006).

Compared to wood pellets to produce 1 MWh of energy; natural gas 3, fuel oil 5 and electric heating release 10 times as much CO_2 into the atmosphere (Saraçoğlu, 2010). For this reason, the production and use of wood pellets is increasing, especially in developed countries Many countries have made legal regulations on the use and trade of wood pellets in response to this interest (Bayramoğlu and Toksoy, 2015).

The use of renewable energy sources in Turkey has not yet reached the desired level. The use of fossil fuels in industry and residences is quite high. The share of the overall power generation of renewable energy sources, despite a great potential to renewable energy sources is low in terms of Turkey. There has been an increase in energy production from renewable energy sources with the legal regulations (subsidy etc.). Turkey's energy potential of biomass is also high. However, the use and trade of this potential is almost nonexistent. The reason for this situation; Inadequate studies on biomass fuels (especially wood pellets), lack of a market for biofuels produced from wood raw materials, lack of legislation, and not encouraging private sector investments.

Turkey's biomass potential has been demonstrated with this study with updated data. Compared with other energy sources of wood pellets. The amount of wood pellets that can be produced and its economic value have been calculated.

2. Materials and Methods

2.1. Materials

In the study, many studies in the literature on climate change, biomass energy and wood pellet and international conventions, protocols, meeting and conference final declarations related to the emergence and functioning of wood pellet were also used as material. Especially in Turkey, biomass potential and wood pellet, use, trade, legal and institutional report prepared by the relevant ministries for the section dealing with regulations, national action plans and strategy documents were also used.

2.2. Methods

Literature review method was used in the study. First of all, detailed information on the subject was obtained and analyzed. The deductive method was used to form the conceptual framework of the study. First of all, the concepts of renewable energy, biomass energy and wood pellet were introduced and wood pellet formed as a result of international processes were explained. Also next to the position of Turkey in the wood pellet market, the situation in the international process, scientific and technical infrastructure and legal and institutional arrangements were discussed.

3. Results

3.1. Biomass Energy Potential of Turkey

Turkey has a significant amount of biomass and bioenergy potential. However, there are different studies regarding the total bioenergy potential. Turkey's total bioenergy potential was estimated Taşdemiroğlu (1986) 17 Mtoe (million tonnes of oilequivalent), WECTNC (1996)

16.92 Mtoe, Ediger and Kentel (1999) 17.2 Mtoe, Kaygusuz (2002) 16.9 Mtoe, Demierbaş et al. (2006) 65 Mtoe, Toklu (2017) 17 Mtoe and Öztürk et al. (2017) 16.92 Mtoe.

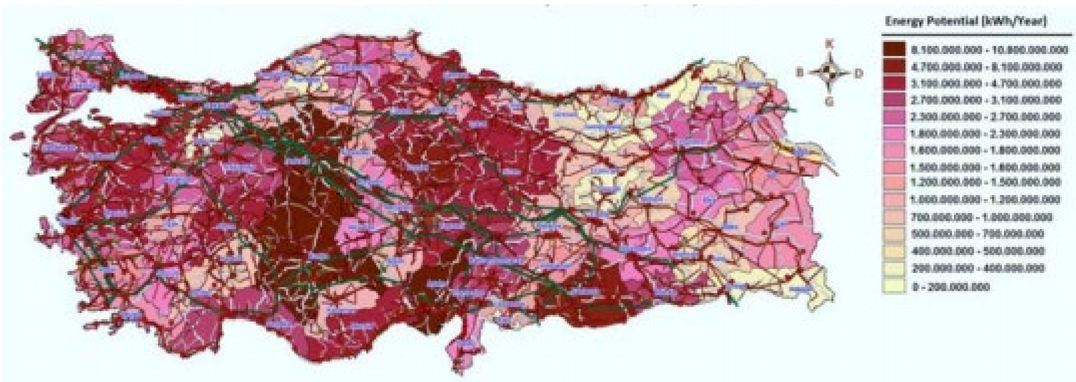

Figure 1. Turkey's total biomass potential (MEF, 2009)

Turkey's main biomass production is given in Table 1. Turkey's main biomass production is based on wheat straw, wood and woody materials, cocoon shell, hazelnut shell, grain dust, crop residues and fruit tree residues (Melikoğlu, 2013). Various agricultural residues such as grain dust, wheat straw and hazelnut shell are available in Turkey as the sources of biomass energy. Approximately 2.6 x 10^7 tonnes of wheat straw was produced annually in Turkey. The straw is disposed of in the fields either by burning or sometimes by ploughing it back into the soil. Because the higher heating value of straw is about ½ that of high-grade coal (its higher heating value is about 28 MJ/kg), the surplus straw is equivalent to about 1.3 x 10^7 tonnes. The hazelnut shell is a potentially important energy source and the amount produced annually in Turkey is estimated to be about 3.5 x 10^5 tonnes. The higher heating value of the hazelnut shell is 19.2 MJ/kg and its calorific value is equivalent to about 1.9x10^6kWh (Demirbaş and Şahin, 1998; Sürmen, 2002).

Table 1. Turkey's annual biomass potential (İlleez, 2020)

	Amount (tone/year)	**Energy Potential (TEP/year)**	**Economical Energy Potential (TEP/year)**
Animal wastes	193.878.079	4.385.371	1.084.506
Agricultural residues	62.206.754	6.009.049	1.462.159
City residues	32.170.975	3.373.011	485.858
Forest residues	2.739.865	859.899	-
TOTAL	**290.995.673**	**14.627.330**	**3.032.523**

Turkey's electricity generation in the year 2018 303.625 GWh (26 million toe) 68% of this production is from fossil sources, 32% is produced from renewable energy sources. However, the share of biomass in renewable energy remained at a very low level with a share of 2.75% and 0.88% in total electricity generation (İlleez, 2020). In 1990, the heat produced from biomass sources worldwide was realized as 6.2 million TEP and met only 1.6% of the total heat production. In 2018, heat production from biomass reached 7.5% with 26 million TEP. Europe is the world leader with 87% share of heat generated globally due to its widespread and effective use of all biomass resources, including municipal waste, solid biofuels and industrial waste (WEO, 2019). Turkey at the end of 2018 the production of heat energy biomass has had a 10.2% share by approximately 133.000 TEP (IEA, 2020; ETKB, 2020; IRENA, 2019).

Table 2. Present and planned biomass energy production in Turkey (SSI, 1996).

Years	Modern Biomass (ktoe)	Classic biomass (ktoe)	Total (ktoe)
1999	5	7012	7017
2000	17	6965	6982
2005	766	6494	7260
2010	1660	5754	7414
2015	2530	4790	7320
2020	3520	4000	7520
2025	4465	3345	7810
2030	4895	3310	8205

Since the early 2000s, it has prepared the biomass energy production program in Turkey. Present and planned biomass energy production in Turkey is given in Table 2. According to a study by Demirbaş (2006), Turkey's biomass production was 7 million tonnes in 1999, and is predicted to increase to 8.2 million tonnes in 2030. According to the index published by Ernst & Young (2012), Turkey is ranked 30th of 40 countries (index value 39.8) for renewable energy and 28th for biomass (index value 35).

3.2. Wood and Woody Biomass Potential of Turkey

Interest in forests is increasing, especially due to its role in carbon sequestration in mitigation global climate change. In order to reduce the greenhouse gas accumulation of forests; It is necessary to protect forests, planting new forest areas, reducing harvest density, increasing forest growth and carbon storage in harvested wood products (Bilgen, 2014).

Woody biomass (especially fuelwood), as in the world, it is important for rural areas in Turkey because fuelwood is very important source of energy and the major source of energy in rural Turkey. About half of the world's population rely on woody biomass or other biomass for cooking and other domestic use.. About half of the total demand for fuelwood is met through informal cutting of State forests and other woody biomass resources in agricultural areas (Bilgen et al., 2008). Among the biomass energy sources, woody biomass is the most interesting. Because it is high in Turkey's total energy production and conversion techniques are useful to it is not necessarily complicated. Forest biomass consumption compared to total energy has decreased from 22% to 14% (Kaygusuz, 2010).

The latest data of the forest assets in Turkey published in 2015. Turkey's forest area of 22,342,935 hectares have been based on these data in 2015. Turkey forest area constitutes 29% of the 78 million hectares of the country up to the surface. According to 2015 data, 57% (12,704,148 ha) of forest areas are forest areas with more than 10% canopy cover, which is qualified as productive forest in terms of wood raw material production. The remaining 43% of the forest areas (9,638,787 ha) consists of hollow closed forest areas with a closure less than 10% and called degraded or inefficient forest areas. The total forest potential of Turkey is around 1.6 billion m3 with an annual growth of about 45.9 million m3 in 2015 (TOD, 2019).

Table 3. Turkey's 2015-2019 industrial and firewood production.

Years	Industrial Wood (m^3)	Firewood (Stere)
2015	16.637.598	5.022.986
2016	17.009.998	4.877.067
2017	15.521.622	4.359.646
2018	19.080.137	4.890.455
2019	22.113.248	5.589.798

Turkey has produced 22.3 million m^3 industrial wood and 5.58 million stere firewood in 2019. Turkey's 2015-2019 industrial and firewood production are given in Table 3. In the last 5 years, it has produced an average of 18.072.520,6 m^3 industrial wood and 4.947.990,4 stere firewood.

3.3. Wood Pellet Potential of Turkey

The forestry sector is a rising trend in Turkey. In order to meet the demand of the sector, industrial wood production has been increased by approximately 33% in the last 5 years. Approximately 25% of a tree is left in the forest as production residue at the end of the production activity (Karayılmazlar et al., 2011). In Turkey, annually about 5 million m^3 wood residues is left in the forest. These residues are left to rot as they do not set off the transportation costs. There are different studies on the amount of production residues. Bayramoğlu and Toksoy (2015) state approximately 4 million m^3 of forest residues can be obtained from 10 million m^3 of industrial wood production. According to General Directorate of Forestry (GDF) estimates, there was a total of 3.528.320 stere of production residues in 27 Regional Forest Directorates (RFD) between 2007 and 2009.

Assuming that 1 m^3 is equal 0.600 tone, 5 million m^3 wood is equal to 3 million tone. Approximately 600 kg wood pellet is produced from 1 tone wood. In this context 1.8 million tone wood pellet can be produced from 3 million tone wood which market value nearly 274 million dollar. The energy value that can be obtained from 1.8 million tonnes of wood pellets is approximately 0.72 Mtep which represents 0.57% of total primary energy consumption in 2015, and 0.75% of the imported amount of energy (95.1 mtep); 0.54% of total primary energy consumption in 2016 and 0.74 % of imported energy (97.3 mtep); 0.49% of total primary energy consumption in 2017 and 0.65% of imported energy (110.1 mtep) of TurkeyFrom 2015 to 2017, Turkey paid 37.8, 27.1 and 37.2 billion dollars, respectively for imported energy. According to these calculations, if Turkey utilized wood pellet potential, this would result in saved of 28.3 billion dollars in 2015, 20 billion dollars in 2016 and 24.1 billion dollars in 2017.

Economic comparison of the Turkish context indicates that wood pellet is more advantageous than other energy sources. One house in Turkey requires approximately 50.2 GJ heating energy, which would require 2 tonnes of coal, 1142 kg oil fuel, 1454 m^3 natural gas or 2.66 tonnes wood pellets.

Table 4. Compare of Energy Sources

Energy Sources	Energy (kcal)	Amount (kg)	Unit Price ($)**	Total ($)
Coal	6000	2000	0.28	560
Fuel Oil	10500	1142	0.47	541
Natural Gas	8250	1454*	0.31	450
Wood Pellet	4500	2660	0.14	371

*Amount of Consumption calculated m3 for natural gas

** 19.09.2020 date 1 $ = 7.90 TL exchange rate

Wood pellet has lower energy value than other energy sources because it has lower energy density (18 MJ/kg) . However, this low energy value and high rate of usage means that wood pellet is cheaper than other energy sources.

4. Discussion

In 2017, approximately 23.8 million tone of wood pellets were traded in the world. In 2023, this trading volume is expected to be 29 million tone. The use of wood pellets in developed countries has increase. In 2018, Japan imported over 1 million tone, South Korea 3.4 million, Netherlands 2.5 million and United Kingdom 1.5 million tone of wood pellets. Unfortunately, there is not data on the wood pellet trade in Turkey. If Turkey uses the potential of wood pellet, it is inevitable that it will get a share of the international market.

In this study, Turkey's wood pellet potential was calculated at 1.8 million tone, while Bayramoğlu and Toksoy (2015) calculated approximately 400,000 tone. Although the value of wood pellet is calculated as $274 million, Bayramoğlu and Toksoy (2015) have stated this value as $586 million. This difference is due to the change in the amount of wood used in production and the dollar rate. Similar to Bayramoğlu and Toksoy (2015), wood pellet is more economical than other energy sources.

5. Conclusion

As a result of the increase in energy prices in the world, events in energy supply security, the development of alternative energy sources and the legal regulations and policies to reduce the use of fossil fuels in the combat against climate change, the share of renewable energy sources, especially biomass fuels, in energy production is increasing. Wood pellet is a prominent product in biomass fuels due to its ease of production and high raw material potential. Although legal regulations on renewable energy have been made in Turkey, the wood pellet has been in lower demand than expected, especially due to high costs.

Turkey should try to raise more awareness about its bioenergy potential. Legal arrangements must be made to create a market for wood pellets. Private sector investments should be encouraged and national production standards should be created.

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PAPER AND PAPER PRODUCTS AND WOOD AND WOOD PRODUCTS SECTORS COMPETITION ANALYSİS: BRICS COUNTRIES AND TÜRKİYE

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Abstract

Financial crises on a world scale cause the emergence of new economic structures and powers. While the financial efficiency of developed countries decreases, developing countries are increasing their positions. BRIC (Brazil, Russia, India and China), which emerged as an alternative economic power after the financial crisis in 2008, started to be known as BRICS countries with the addition of South Africa in 2011 and became an important economic structure. Its economic and demographic strength of thanks and wishing to take part in the active position in the world Turkey is willing to take part in the BRICS. Determination of Turkey's infrastructure sector as competitive with these countries is extremely important.

In this study of the important sectoral groups of Turkey Paper and Paper Products and Wood and Wood Products Sector is intended to determine whether a location opposite of how the BRICS countries. Revealed Comparative Advantages approach was used in the study covering the years between 2010-2019. As a result of the study, countries were compared at year level and superior sectoral structures were determined.

Keywords: BRICS, TÜRKİYE, Paper and Paper Products, Wood and Wood Products, Revealed Comparative Advantages

1. Introduction

With the end of the cold war, countries in different parts of the world began to become visible with the economic power they caught, and they argued that an order in which many powers would be effective, not just one power, was adopted in the world economy. (Chen, 2003; Poyraz, 2019) The conflicts, especially due to lack of resources, forced the formation of different economic unions and created alternative economic power centers to the USA and liberal economic thought. China, Russia, Brazil, India and Turkey adopted to create alternative to the IMF and World Bank. (Ateş, 2012; Çelik, 2017)

Established in 2006 under the name of BRIC countries (Brazil, Russia, India, China) and later named BRICS with the addition of South Africa in 2011, the formation created an alternative center of attraction and new cooperation opportunities for developing countries (Önder, 2019). In 2001, according to the report published by Jim o Neill, the chairman of the board of directors of Goldman Sachs, an international investment bank, it took its place in the economic structure (O'Neill, 2001; Sezer, 2018). In a report prepared in 2003, in less than 40 years, BRIC countries; It has been hypothesized that France, Germany, Italy, Japan, the UK and the USA will catch up with the G6 countries and then these countries will become the main engine of new demand growth and spending power that will balance the slowing growth and population in developed economies (Atabay Baytar, 2012). According to the economic predictions made for the near future, it is stated that the BRICS countries will surpass the G7 countries in 2035 (Öniş & Kutlay, 2015), and they will be among the top 10 economies of the world in 2050 (Wilson & Purushothaman, 2003). The last 20 years have shown that Turkey's economic success is also considered one of the leading countries in 2050 is stated to be Turkey. Therefore it emphasized the necessity of Turkey's inclusion in this association and Turkey has expressed he wanted to be a member of this mechanism in 2018.

Turkey's membership of BRICS searching for new markets, and technological partnerships will help support their desire to become a global actor. Therefore, Turkey should revise the existing economic structure. When examining the literature of Turkey and the BRICS member countries seem to be limited studies comparing economic performance. In this study, it is aimed to determine the competitive position of Paper and Paper Products Industry and Wood and Wood products industry groups, which are sub-industrial groups of the Forest Products Industry Sector, against BRICS countries. It is important for the future of the country to support industrial groups that have a high competitive position against BRICS countries and to plan their resource use in this direction.

1.1. Paper and Paper Products Industry and Wood and Wood Products Industry in Foreign Trade

The foreign trade figures of the countries within the scope of the study in the field of paper and paper products and wood and wood products are given in the tables below. Table 1 show that Brazil has a significant foreign trade surplus at both sectoral levels. When the situation is evaluated in terms of the years analyzed, it is seen that the foreign trade surplus in the field of paper and paper products increased by 143%. The increase in the foreign trade surplus in the wood and wood products industry is around 55%. Paper and paper products industry realized approximately 0.8% of Brazil's average exports between 2010 and 2019, while this rate is 1% for the wood and wood products industry. A portion of 1.1% of the average paper exports made throughout the world within the specified years was realized by Brazil. In the field of wood and wood products industry, approximately 2.2% of the average export realized between 2010 and 2019 was made by Brazil.

Table 1. Brazil's export-import level by years (1,000 dollars)

Paper and Paper Products				Wood and Wood Products			
Years	Export	Imports	Current Account Balance	Years	Export	Imports	Current Account Balance
2010	2.008.555	1.540.653	467.902	2010	1.917.872	133.087	1.784.785
2011	2.187.577	1.754.203	433.374	2011	1.900.096	176.455	1.723.641
2012	1.951.228	1.606.042	345.186	2012	1.887.658	167.639	1.720.019
2013	1.970.194	1.505.819	464.375	2013	2.003.924	144.449	1.859.475
2014	1.922.181	1.441.538	480.643	2014	2.243.112	150.617	2.092.495
2015	2.020.964	957.817	1.063.147	2015	2.271.395	116.236	2.155.159
2016	1.871.020	738.456	1.132.564	2016	2.361.479	98.880	2.262.599
2017	1.013.080	838.173	1.074.907	2017	2.779.920	96.932	2.682.988
2018	2.072.495	883.457	1.189.038	2018	3.182.252	100.556	3.081.696
2019	1.986.916	846.891	1.140.025	2019	2.886.205	108.418	2.777.787

Foreign trade data of Russia can be seen in Table 2. As a result of the evaluation made, it is seen that the foreign trade deficit in the field of paper and paper products between 2010 and 2017 turned into a foreign trade surplus in 2018 and 2019. This change shows that Russia is turning into a production center in the paper and paper products sector. When the level of exports in the field of paper and paper products is analyzed, it corresponds to approximately 0.4% of Russia's overall export level in terms of the average of all years. Russia realizes 1.2% of the paper exports made worldwide. When the data of the wood and wood products sector are examined, an increasing foreign trade surplus of Russia in all years draws attention. The foreign trade surplus, which increased approximately by 53% between 2010 and 2019, shows Russia's effectiveness in this area. The wood and wood products industry sector, which has a share of 1.7% in Russia's total foreign trade average, constitutes 5.6% of the world's wood and wood products exports.

Table 2. Russia's export-import level by years (1,000 dollars)

Paper and Paper Products				Wood and Wood Products			
Years	Export	Imports	Current Account Balance	Years	Export	Imports	Current Account Balance
2010	1.457.976	3.844.758	-2.386.782	2010	6.093.699	860.844	5.232.855
2011	1.732.652	4.309.085	-2.576.433	2011	6.973.754	1.087.167	5.886.587
2012	1.924.464	3.748.744	-1.824.280	2012	6.734.568	1.450.095	5.284.473
2013	2.055.067	3.814.418	-1.759.351	2013	7.330.193	1.653.171	5.677.022
2014	2.260.193	3.542.705	-1.282.512	2014	7.763.748	1.323.914	6.439.834
2015	1.790.874	2.250.991	-460.117	2015	6.151.899	691.874	5.460.025
2016	1.899.540	2.255.626	-356.086	2016	6.523.925	601.922	5.922.003
2017	2.197.132	2.404.796	-207.664	2017	7.901.564	657.998	7.243.566
2018	2.737.863	2.653.242	84.621	2018	9.009.168	707.265	8.301.903
2019	2.491.263	2.454.115	37.148	2019	8.619.543	616.044	8.003.499

The data of India in the field of paper and paper products industry and wood and wood products industry are shown in Table 3.

Table 3. India's export-import level by years (1,000 dollars)

Paper and Paper Products				Wood and Wood Products			
Years	Export	Imports	Current Account Balance	Years	Export	Imports	Current Account Balance
2010	784.177	1.887.451	-1.103.274	2010	163.784	1.697.604	-1.533.820
2011	906.988	2.454.710	-1.547.722	2011	220.651	2.410.817	-2.190.166
2012	930.360	2.266.894	-1.336.534	2012	258.874	2.606.741	-2.347.867
2013	1.139.895	2.364.880	-1.224.985	2013	351.496	2.680.339	-2.328.843
2014	1.115.993	2.610.041	-1.494.048	2014	353.812	2.703.642	-2.349.830
2015	1.127.113	2.425.519	-1.298.406	2015	427.377	2.435.878	-2.008.501
2016	1.183.920	2.662.456	-1.478.536	2016	400.748	2.145.530	-1.744.782
2017	1.284.054	3.069.063	-1.785.009	2017	415.073	2.186.864	-1.771.791
2018	1.827.352	2.994.535	-1.167.183	2018	435.525	2.227.212	-1.791.687
2019	2.061.320	2.886.570	-825.250	2019	477.641	2.178.456	-1.700.805

India has a significant foreign trade deficit in both product groups (Table 3). Although the foreign trade deficit in the field of paper and paper products has decreased over the years, the deficit in wood and wood products has gradually increased. In India's average export, the paper and paper products sector is 0.4%, and the wood and wood products sector is 0.1%. In the evaluation made by taking into account the world export figures, it is seen that India has a share of 0.7% in the paper and paper products sector and 0.2% in the wood and wood products sector.

The foreign trade figures of China at both sector levels are shown in Table 4.

Table 4. China's export-import level by years (1,000 dollars)

Paper and Paper Products				Wood and Wood Products			
Years	Export	Imports	Current Account Balance	Years	Export	Imports	Current Account Balance
2010	9.561.194	4.611.778	4.949.416	2010	9.651.544	11.234.863	-1.583.319
2011	12.905.511	5.054.829	7.850.682	2011	11.354.387	15.857.712	-4.503.325
2012	13.721.805	4.596.226	9.125.579	2012	12.315.248	14.937.027	-2.621.779
2013	15.987.710	4.372.835	11.614.875	2013	12.748.095	18.768.839	-6.020.744
2014	17.818.529	4.308.838	13.509.691	2014	14.469.960	22.797.545	-8.327.585
2015	18.849.401	4.046.927	14.802.474	2015	14.211.187	18.627.016	-4.415.829
2016	18.172.109	3.944.806	14.227.303	2016	13.613.182	19.596.941	-5.983.759
2017	18.417.669	4.985.630	13.432.039	2017	13.693.413	23.411.325	-9.717.912
2018	19.460.630	6.201.170	13.259.460	2018	14.888.332	24.914.414	-10.026.082
2019	22.008.827	5.265.825	16.743.002	2019	13.410.436	21.976.449	-8.566.013

When the data in Table 4 are examined, it is noteworthy that the foreign trade figures are high. Especially in recent years, China, which has become the production center of the world, has created trade activity at the level of sectors. The foreign trade volume of paper and paper products in 2010 reached 27 billion dollars in 2019 from approximately 14 billion dollars. Within the same period, the foreign trade surplus increased approximately 4 times. On average, 0.7% of all exports made by China in the years 2010-2019 were realized by the paper and paper products industry sector. Considering the average of world paper exports for the years 2010-2019, it is seen that 10% of it was made by China. Having a foreign trade deficit in the field of wood and wood products, China realized an average of 10.1% of world exports. The share of wood and wood products in China's own exports is 6% in terms of the 2010-2019 average.

South Africa's foreign trade data are shown in Table 5. Having a negative foreign trade balance in the paper and paper products industry for all years, South Africa is in a position to have a foreign trade surplus in the field of wood and wood products. The paper and paper products industry sector has a 0.8% share in the country's foreign trade, while the share of wood and wood products in foreign trade is 0.5%. In the world trade, South Africa has a share of 0.4% in paper and paper products and 0.3% in wood and wood products.

Table 5. South Africa's export-import level by years (1,000 dollars)

Paper and Paper Products				Wood and Wood Products			
Years	Export	Imports	Current Account Balance	Years	Export	Imports	Current Account Balance
2010	910.164	992.383	-82.219	2010	513.759	334.443	179.316
2011	916.871	1.080.319	-163.448	2011	538.660	400.081	138.579
2012	809.829	1.048.274	-238.445	2012	471.249	400.126	71.123
2013	733.495	1.057.978	-324.483	2013	451.334	393.037	58.297
2014	727.116	1.043.424	-316.308	2014	510.265	396.521	113.744
2015	665.762	973.476	-307.714	2015	500.958	375.820	125.138
2016	635.106	896.427	-261.321	2016	475.342	346.874	128.468
2017	625.648	909.485	-283.837	2017	535.495	360.382	175.113
2018	706.252	1.076.186	-369.934	2018	588.922	382.758	206.164
2019	595.931	1.035.157	-439.226	2019	516.639	362.633	154.006

Turkey's foreign trade figures in Table 6 are also shown. When the figures in Table 6 are examined, it is seen that both sectors have a positive foreign trade trend. The increase in exports in the paper and paper products industry over the years has an important effect on reducing the foreign trade deficit. Paper and paper products forming part about 1% of Turkey's trade with Turkey has the capacity to add to the positive change that has industrial economy. Paper and paper products in world trade, which owns a 0.8% share at the level of Turkey holds the power industry, this rate may increase rapidly. When the foreign trade figures of wood and wood products are examined, it is seen that the balance, which was negative over the years, has moved to positive with the increase in exports. sector, which has a weight of 0.4% in Turkey's foreign trade is a 0.5% share of world trade in general.

Table 6. Turkey's export-import level by years (1,000 dollars)

Paper and Paper Products				Wood and Wood Products			
Years	Export	Imports	Current Account Balance	Years	Export	Imports	Current Account Balance
2010	1.216.835	2.819.743	-1.602.908	2010	573.203	1.098.395	-525.195
2011	1.427.255	3.109.936	-1.682.681	2011	652.927	1.427.786	-774.860
2012	1.033.096	2.882.665	-1.849.569	2012	657.954	1.619.738	-961.783
2013	1.140.574	3.091.816	-1.951.242	2013	724.631	1.563.578	-838.948
2014	1.203.724	3.170.718	-1.966.994	2014	853.305	1.487.632	-634.328
2015	1.185.524	2.683.944	-1.498.429	2015	692.752	1.505.159	-812.407
2016	1.353.499	2.684.714	-1.330.141	2016	675.873	1.265.054	-589.131
2017	1.520.374	2.811.916	-1.291.542	2017	763.956	1.132.785	-369.895
2018	1.715.787	2.749.839	-1.034.052	2018	826.635	827.893	-1.258
2019	1.796.339	2.513.824	-717.485	2019	885.456	405.913	479.543

2. Materials and Methods

BRICS countries and Turkey's Paper and Paper Products Industry and Wood & Wood Products 2010-2019 year study of competition in the industry sector analysis of foreign trade data are used. The data used for analysis was obtained from the TradeMap (2020) website.

In order to measure the competitiveness of the firm, industry and countries, it primarily uses foreign trade data. In our study; The Revealed Comparative Advantage (RCA) method, which was created by Liesner (1958) to measure competitiveness and later developed by Balassa (1965) and has been widely used until today, was used. The Balassa index was formulated as follows:

$$RCAij= (xij / Xj)/ (xiw / Xw) \quad (1)$$

where;

RCAij; revealed comparative advantage index for the ith goods of the jth country.

xij : jth country's ith exported goods

Xj : jth country's total exports

xiw : ith goods of the global exports

XW : total global exports

A value less than 1 to be obtained as a result of the analysis made indicates that the country does not have competitive power in terms of comparative advantages explained at the relevant goods level, that is, it has a disadvantage, and a value greater than 1 indicates that it is specialized in that product group, that is, it has announced mutual advantage.

3. Results and Discussion

BRICS countries and Turkey Paper & Paper Products Industry Sectors competitive analysis of the results in Table 7 are also seen.

Table 7. BRICS countries and Turkey (Paper and Paper Products Industry) RCA Results

Years	Brazil	Russia	Indian	China	South Africa	Turkey
2010	0,896	0,330	0,320	0,545	0,992	0,962
2011	0,829	0,325	0,292	0,660	0,824	1,027
2012	0,903	0,412	0,361	0,752	0,920	0,761
2013	0,904	0,533	0,376	0,804	0,857	0,834
2014	0,938	0,428	0,386	0,835	0,862	0,839
2015	1,124	0,571	0,545	0,878	0,865	0,876
2016	1,063	0,700	0,477	0,902	0,872	0,999
2017	0,512	0,678	0,478	0,893	0,770	1,067
2018	0,954	0,673	0,623	0,862	0,819	1,129
2019	0,996	0,662	0,716	0,989	0,740	1,179
Average	**0,9119**	**0,5312**	**0,4574**	**0,812**	**0,8521**	**0,9673**

As a result of the analysis of the competitive power of countries, when the values in Table 1 are examined, it is seen that all countries have averages less than 1, which is the accepted competitive power value indicator in terms of years average.

In comparison with the countries in its internal years Turkey has the highest value in terms of average. It is seen that it has a competitive advantage in the field of Paper and Paper Products industry against BRICS countries. Turkey is followed by Brazil and South Africa. Changes occurring in the country in the years when it is observed that increased 22.5% between the years 2010-2019 at the level of Turkey's competitiveness. Especially in recent years, it can be clearly seen that it has exceeded the accepted value of 1 in 2017, 2018 and 2019 and is in an increasing trend in this direction. With the BRICS countries in terms of foreign trade data owned by Turkey Paper and Paper Products are in position to compete in the industrial area has a structure.

Brazil, which ranks second in terms of average values, has achieved an 11% increase in competitive power over the years. It could not maintain the competitive advantage it had achieved in 2015 and 2016.

South Africa reduced its competitiveness value in 2010 in 2019 and showed a decline of -25% in annual average. In general, South Africa, which does not have a competitive value of 1 or more, shows a negative situation in the field of Paper and Paper Products Industry.

China, which has been effective in the world economy in recent years, has a competitive position far from expected in the field of Paper and Paper Products Industry. The competitive advantage it has in many different areas is not seen in this product group. Considering the change over the years, it can be seen that China, which has increased by 81%, will have a say in this field in the near future.

Russia and India share the last places in the ranking of competitive advantage in this product group. When it is considered that both countries showed annual growth (in Russia 100% India 124%) between Paper and Paper Products Industry in the BRICS countries and Turkey is seen that there will be serious competition to the war.

Analysis results of Wood and Wood Products Industry sectors are shown in Table 8.

Table 8. BRICS countries and Turkey: Wood and Wood Products Industry (RCA Results)

Years	Brazil	Russia	Indian	China	South Africa	Turkey
2010	1,351	2,183	0,105	0,870	0,884	0,715
2011	1,124	2,043	0,110	0,906	0,756	0,733
2012	1,215	2,005	0,139	0,939	0,745	0,674
2013	1,199	2,014	0,151	0,836	0,688	0,691
2014	1,365	2,136	0,152	0,846	0,754	0,741
2015	1,584	2,459	0,215	0,830	0,816	0,642
2016	1,593	2,856	0,191	0,803	0,775	0,592
2017	1,649	2,858	0,189	0,778	0,772	0,628
2018	1,745	2,638	0,176	0,785	0,814	0,640
2019	1,794	2,839	0,205	0,747	0,795	0,720
Average	**1,4619**	**2,4031**	**0,1633**	**0,834**	**0,7799**	**0,6776**

When Table 2, which includes the competitiveness of countries in the field of Wood and Wood products industry, is examined, it is clearly seen that Russia has a significant competitive advantage in this field in terms of both annual average value and values in all years. Brazil and China follow Russia.

Russia increased its competitiveness value in 2010 (2,183> 1) by 30% in 2019 (2,839> 1). During this period, Brazil showed an increase of 33% and showed that it was a significant power in competition.

China and South Africa, which can provide an alternative to these two countries, showed a decrease of approximately 14% and 10% within this period and showed that they were losing power in competition. India's increase in this area remained far from a competitive position.

Turkey has managed to maintain its competitiveness although that experience increases and decreases in the studied years. Turkey in this area who wants to take part in the BRICS countries are quite difficult to compete with Russia and Brazil.

4. Conclusion

Technological infrastructure and power that Turkey has experienced production Paper and Paper Products are qualities that can have a significant competitive advantage the BRICS countries across the industry. The analysis, which has adopted a position on the standard values in some years it was increasing its strength over the years indicate that Turkey's power in the market may be effective in this area. Paper and paper products with the support of Turkey will be held in the investment industry and will have an important place in the economic growth of the sector and will consist seems to be able to access the production center of Turkey in the world order. Turkey, paper and paper products are in a strong position in the industrial area opposite the BRICS countries. Turkey is in the paper and paper products industry can compete with Brazil and South Africa.

In the field of wood and wood products, the undisputed superiority of Russia and Brazil is seen in the analysis results due to the raw material availability they have among the BRICS countries. There is no country that can rival these two countries within the scope of the years examined. Turkey should act in this area and knowing the position which should encourage rational investment resources.

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WOODLOVERNESS AS A PATHWAY TO CIVILIZATION CONNECTED WITH NATURE

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Abstract

Woodloverness, although is a vast subject that has been well known throughout the world for a long time in terms of learning based on experiences that emerge with its reflections in every phase of life with its behavioural dimension that integrates attitudes and behaviours and combines feelings and thoughts, is a term that has been named and defined almost very recently in the field of wood science and technology with the focus of woodlover approach with its inherentness that complements people whose geography is far from each other by keeping them together around the same purpose in terms of being a harmonious part of nature, and is a universal phenomenon that embraces all humanity. In a more general sense, woodloverness, in Usta's words (Usta, 2019), is a thematic issue that contributes to the development of civilization and plays an important role in the progress of humanity, and is considered in the focus of the woodlover approach that aims to integrate human with nature. Obviously, with its deep and comprehensive presence, woodloverness is an interdisciplinary phenomenon that stands out clearly in the development of civilization by integrating with nature in the company of science and technology, together with art and literature, and it is a preliminary reinforcer of the effort to identify with nature and the environment, which constitute the essence of all humanity with its cultural dimension. In this study, woodloverness is presented as a deep and comprehensive phenomenon that provides endless benefits to humans through the integration of nature on the way to civilization, focusing on the woodlover approach.

Keywords: Wood, Woodlover Approach, Woodloverness, Human-Nature Interactions, Civilization

1. Introduction

Wood, which is a natural and organic material obtained from trees with its fibrous and porous structure, is the oldest and widely used material in the history of humanity with a very wide area of use in reference to its easy processing and has played a major role in the development of civilization and the progress of humanity. It is clear that the use of wood alone or indirectly with other materials in order to meet the needs and fulfill the requirements as a sustainable natural material is closely related to its unique material properties in terms of its anatomical structure, chemical composition, physical properties and mechanical properties. At this point, despite the fact that the breadth and depth of the presence of wood in almost every area of life have been revealed through the ongoing researches since a relatively long time, and significant contributions have been made to the enrichment of the knowledge about wood, these studies are not sufficient in number and scope in terms of fully recognizing wood and have not yet been completed. And here, while the material properties of wood, as well as its existential dimension affecting all of life, are being studied comprehensively with an inexhaustible effort, like an inquisitive and resourceful traveler sailing to the wind in unstable weather conditions on the shore of a vast ocean, it has been attempted to show how important wood is to the communities all across the world from the past to the present as a material and an entity, in the light of some special facts or theories, due to its unlimited availability. In this context, woodloverness, as a privileged theory reinforced with the principle of causality on the basis of woodlover approach, emerges as an important phenomenon that clearly expresses that wood is a valuable object embracing the whole universe and all humanity. However, although woodloverness is a phenomenon known to all societies since the beginning of human history, it is still a privileged subject waiting to be defined in detail and in depth. Therefore, in this particular study, which is provided basically by benefiting from the articles of Usta (2019) titled "A fact of woodloverness on the basis of woodlover approach" and "Woodloverness", the theory of woodloverness is presented with annotations and conceptual characterizations centered on the woodlover approach to allow for understanding in a holistic and in-depth manner. From this point of view, this study is very highly important with its content, because the case of "woodloverness", which is the main reinforcement of the subject of "woodlover approach", will be explained in greater detail here as a holistic and complementary new theory by associating causality with many issues in terms of its content that directs life and its effect that unites people. In this regard, presenting woodloverness, which focuses on universality with its deep and comprehensive content, as a multi-faceted theory, will open a new horizon in the field of wood science and technology. It is also envisaged that the explanations made here will shed light on all humanity as an indicator of the universality of wood. And hence, the scope of this study is twofold: firstly to prepare good explanations with the intention of drawing attention to the phenomenon of woodloverness on the basis of woodlover approach, and to create awareness about this special issue in the worldwide public opinion with the field of wood science and technology, and secondly to explain and promote in a way that will benefit everyone, which is a global situation that makes globalization continuous. Therefore, this study has a special content that will allow the woodlover approach to come to the fore with a conscious awareness with a new perspective.

2. Theoretical Explanations of Woodloverness

It is obvious that wood, which is a fascinating component of life and an indispensable part of life with its unlimited variety of products that integrate with daily life practices, is the only material standing by people in the ordinary course of life and is a valuable entity that embraces the whole society. In this respect, it is certain that the endless efforts that put wood into life with a wide variety of product types are realized with the concept of woodloverness that focuses on the woodlover approach. Truly, considering the fact that wood is a common value of humanity as a means of intercultural interaction that connects the past to the present and the future with the numerous benefits that has provided to humanity as a material throughout history, it is clearly seen that all the activities carried out with the concept of woodloverness on the basis of woodlover approach are in harmony with the essence of creativity and the mental process of innovation and in close relationship with each other within an integrated fiction.

Based on innovation and creativity throughout history, the latent aspect of woodloverness, which has always emphasized the entrepreneurial attitude and behaviour accompanied by wood, has brought it to a very special position that is easily perceived and immediately noticed in the design of the unlimited variety of products or applications that are persistently put forward with a woodlover approach. Ultimately, woodloverness, which is a common theory accompanied by a woodlover approach, is a pure reality that allows the civilization process, which facilitates life by integrating with nature, and enables people to live comfortably, by consciously using wood, which is a typical reflection of nature, with creative and innovative solutions. From this perspective, woodloverness is not only a certain term that has a relatively long validity in the field of wood science and technology, but also is a very special assumption that has guided evaluation for underlying either prospective or retrospective studies of welfare and quality of life in social and technical literatures in order to provide scientific evidences that can be properly acquired by experimental and observational investigations. In this context, a fact of woodloverness that is evaluated within the framework of woodlover approach, which is a universal phenomenon focused on the theme of giving importance to nature and people by taking care of both nature and people, by using wood supplied from trees as a sustainable and renewable natural material correctly and effectively, includes a progressive and enlightenment perspective that prioritizes optimism and positive thinking in the focus of the science and technology of wood, which has made great contributions to the development of humanity and the progress of civilization, because the phenomenon of woodloverness has a detailed content that embraces all humanity without any distinction, representing the individual and social reality with its internality prioritizing the individual and society, and contributing to the development of civilization by nature and human adaptation.

In the light of these explanations, it is an indisputable reality that woodloverness, which focuses on the woodlover approach, is a fundamental phenomenon that coexists with humans, and it is undoubtedly certain that woodloverness has a thematic content that can be comprehensively explained by comparable definitions in terms of its effect on the ordinary course of life by making causality associations with all theories and practices that are intertwined with life in one way or another. In essence, "woodloverness" is endless efforts based on making meaning of life and beautifying it with unlimited freedom by overcoming difficulties by designing wood from a very wide angle and using it in the best possible way in terms of many different applications and various types of products in order to improve daily life. If a broader definition is made, "woodloverness", which is a common attitude of those who realize the beauty and importance of living with an indispensable passion for wood, a natural and organic material obtained from trees, by valuing nature as an indicator of human dignity, is a multidimensional phenomenon that adds value to human life and makes life meaningful, due to the many successful and effective solutions of wood that make daily life easier and more enjoyable. At this point, considering the possible marginalization of wood in the understanding and interpretation of current discussions and suggestions for the evaluation of wood as an important material and a valuable entity on the basis the woodlover approach, the phenomenon of woodloverness can be spoken as a subjective concept that can be evaluated in detail by directly or indirectly associating with theories or concepts from almost all disciplines.

In fact, it is clear that woodloverness, which is an indicator of the woodlover approach that integrates wood, which is always in harmony with humans, as a constructive or supportive material into life, is a significant phenomenon that can be conceptualized with its unique position in the development of civilization and the progress of humanity, and is influenced by the descriptions revealed by the knowledge about wood as a material and as an entity due to a vast array of opportunities for sustainable solutions what it provides for people around the world since ancient times. Therefore, the fact that wood is a versatile and functional material and also a valuable entity for people from similar or different cultures throughout history has a great effect on the comprehensive presentation of the subject of woodloverness, which is an important and multidimensional phenomenon that is intertwined with the concepts of authenticity and cultural existentialism and expressionism on the basis of woodlover approach that focuses on universality, as a theory that has a unique internal consistency and adequate explanatory power. Of course, in the company of this reality, it is obvious that activities or researches aiming to reveal wood as a material and an entity with a woodlover approach will allow the efforts to reconcile woodloverness with almost all existing areas with a wider perspective.

Since it is absolute that a life without wood can never exist, the realization of woodlover efforts with an unprecedented enthusiasm and deep commitment that envisage the continuous inclusion of wood into life in terms of an unlimited variety of products and applications will make a great contribution to the consolidation of the notion of woodloverness. This is because woodlover efforts are at the heart of woodloverness, which is a dominant phenomenon in both the development and spread of civilization in the company of nature and the progress of humanity, and such that these indescribable efforts, which make wood stand out with its content that directs life, both create the common perception of all people in the focus of a life integrated with wood and support the adoption and internalization of woodloverness as a global phenomenon. All these woodlover endeavors in the context of woodloverness involve various types of causal propositions realized with the woodlover approach that places wood at the center of universal thought, and contain a number of unique considerations to clarify the existence of wood as a material and as an entity. Ultimately, as we all get to know and learn about wood, it will become easier and more common to associate almost any theme or subject or concept directly or indirectly with the phenomenon of woodloverness.

If we make an inference according to the above explanations, it is obvious that the woodlover approach, which forms an inseparable integrity with environmental awareness, includes innovative and creative actions to increase the quality of life, and hence it is essential to constantly examine the whole existence of wood from a multi-dimensional perspective in order to consolidate woodloverness as a general acceptance. A lot of things can be said about this issue, but what we particularly draw attention to here is the necessity to unearth the content of wood that provides countless benefits to all humanity by examining the properties of wood as an important material and as a valuable entity. Frankly, based on a woodlover approach with a holistic perspective that focuses on sustainability, wood, which is defined as a versatile and functional material in terms of its anatomical structure, chemical composition, physical properties and mechanical properties, is considered to be a universal entity that affects people's feelings, thoughts, attitudes and behaviours as a distinguished intercultural interaction tool. Therefore, the introductory and informative activities foreseen on wood, a natural and organic material used alone or in combination with other materials to meet the various needs and different requirements that arise in the ordinary course of daily life, are about wood that has existed since the beginning of human history, contains an undeniable reality that it will be very useful in terms of creating an individual and social consciousness and awareness and gaining strong insight. From this viewpoint, because consciousness of woodloverness would not shaped without awareness of the technical, social and cultural aspects of wood that have been brought to light with extensive experience and scientific research methods, it is inevitable to examine the whole possible existence of wood as an extraordinary material and a considerable entity in depth and comprehensively with the woodlover approach.

Since knowledge is built with science, it is essential to demonstrate scientifically all the peculiar properties of wood that have been noticed by experience from past to present in order to be associated with almost all matters related to life and to be established causality link with all possible disciplines in terms of evaluating and interpreting the phenomenon of woodloverness with a broad knowledge. For this, when an assessment of the basic assumptions about wood is made, it is obvious that the following truths known to everyone in a definite reality are prioritized as a final determination: 1) wood, which is a natural and organic material obtained from trees, is healthy with its fibrous and porous structure and is a versatile and functional material that is used in different ways for different purposes in daily life with its easy processability, 2) wood, which is a renewable natural resource since it is obtained from trees as a reflection of nature with sustainable forestry activities, offers almost endless options thanks to its anatomical structure, chemical composition, physical properties and mechanical properties, 3) the science and technology of wood has made wood a considerable material used directly or indirectly in meeting the needs and requirements that arise in the normal course of daily life, 4) wood is not only a material, but also a valuable entity that influences people's attitudes and behaviours, feelings and thoughts, and their outlook on life, and is also an important object that contributes to people's communication with each other and is of course a unique tool in intercultural interaction, 5) wood, which is a good and useful material that has always stood by people since the beginning of history with its naturalness, aesthetic appeal, characteristic feature that is convenient to provide unlimited solutions, and functionality, becomes strong and durable, even almost indestructible when prepared in accordance with the foreseen usage conditions, 6) wood, a natural and organic material that can be used almost everywhere with its superior material properties, is an outstanding material that has played a major role in the development and spread of civilization, and therefore the contribution of wood to the progress of humanity to the present day is an indisputable extent, 7) wood, which is a unique material and a perfect entity in accordance with its versatility and functionality, is intertwined with almost all thoughts based on living as an integral part with nature in unity and harmony, and is integrated with almost all approaches to make sense of life accompanied by the principles that guide life, 8) wood is an incredible material that can be used alone or in combination with other materials in almost all arrangements and adaptations that make life easier, and it is a transcendent entity that makes people behave in the same or similar way in a positive thought.

To summarize, all of the above explanations clearly show how important the efforts made with the woodlover approach are in evaluating woodloverness as a pathway to civilization connected with nature, and firmly emphasize that we should realize how much wood is actually present in our lives as a material and an entity. As a result, the effects of wood on our lives contain an undeniable reality, and woodloverness, which focuses on wood, which is a widely used material with activities carried out with a woodlover approach, is an important phenomenon with its multi-dimensional interiority.

3. Conclusion

It is clear that woodloverness is a deep and comprehensive phenomenon that guides life with an unlimited number of products and applications that are constantly realized with the woodlover approach that focuses on wood and can be associated with almost all disciplines. In this regard, since wood is a universal material that provides numerous benefits to people directly or indirectly, either alone or in combination with other materials, in meeting the needs and requirements that arise in the ordinary course of daily life, and since it is an international entity that embraces everyone by contributing to the living in the same or similar attitudes, behaviours, emotions and thoughts with a positive thinking, it is normal and inevitable that the phenomenon of woodloverness, which focuses on wood as a material and as an entity, with its continuous and discrete quantities and features that can be transformed into benefits, is defined in both concrete and abstract contexts and evaluated in universal dimensions with its unique content, referring to the woodlover approach. In this framework, defining woodloverness as a multi-dimensional phenomenon with a woodlover approach is only possible by placing wood in the center as a thematic element in terms of individual and social awareness with its unique subjectivity.

In accordance with these explanations, it is the basic starting point to make a common determination and inference about wood as a material and an entity in order to make a reconciliation between the phenomenon of woodloverness and other possible phenomena with cause-effect relation, and it is necessary to make this beginning very accurately in order to successfully realize the theoretical explanation towards woodloverness. Accordingly, in the context of determining the phenomenon of woodloverness in general terms, the known determinations about wood in accordance with the woodlover approach can be emphasized as follows: a) wood is a universal material that provides numerous benefits to all people directly or indirectly, either alone or in combination with other materials, in meeting the needs and requirements that arise in the ordinary course of daily life, b) wood is an inexhaustible renewable natural material derived from trees grown with sustainable forestry activities as a unique reflection of nature with extraordinary and immense beauty, b) wood is a marvelous material that stands out clearly in the relationship between technology and civilization with its superior material properties, c) wood is a common material that meets the needs and requirements of people with its versatility and functionality, d) wood is an outstanding material that has a great share in the development and spread of civilization and the progress of humanity by reinforcing intercultural interaction, e) considering globalization and cultural sharing and empathy, wood, which is an important intercultural interaction tool, is a valuable entity that affects people's feelings, thoughts, attitudes and behaviours, referring to its natural and organic structure with its fibrous and porous structure, f) wood, as a material and an entity, is fully or partially integrated with almost all phenomena that shape life and make sense of life with its versatile and functional aspects, g) wood has a comprehensive identity, whose properties have been continuously researched throughout history and recognized by experience from past to present, such that the knowledge of wood, which is a natural and organic material that contains sustainability in its nature, is constantly renewed by extensive experience and vast research, h) wood is an excellent material that incorporates creativity and innovative thinking and highlights an entrepreneurial perspective, and is the most influential entity in the entire universe that stimulates emotions.

Consequently, in order to define woodloverness as a unique phenomenon in the focus of wood as an extraordinary material and a wonderful entity, it is possible to make comprehensive evaluations by looking at a broader perspective with a woodlover approach. Lastly, it is obvious that woodloverness is a deep-rooted phenomenon with its holistic identity that continues its existence from past to future with its life-guiding effect and its presence that sheds light for all humanity.

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CHEMICAL CHANGES IN HISTORICAL WOODEN STRUCTURES IN RİZE-FIRTINA VALLEY

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Abstract

Studies conducted to determine the factors that cause damage in historical wooden buildings in our country are quite limited. Rize-Fırtına Valley, with a climate index higher than 65, is one of the regions with the highest rainfall in our country. The risk of decay in historical wooden buildings in this region due to the high climate index is quite high. As a result of this situation, the resistance properties of wood are negatively affected. Within the scope of the research, samples were taken from wooden mansions which are at least 150 years old in the region. Cellulose, lignin, and hemicellulose contents were determined in order to detect chemical changes occurring in the chemical structures of the wood samples. Thanks to the obtained results from this study, intervention/restoration methods may be suggested for the protection and sustainability of wooden materials in historical buildings.

Keywords: Fırtına Valley, Historical wooden structures, Chemical analysis, Cellulose, Lignin

1. Introduction

For centuries, wood has been used for the construction of numerous items that are now part of the cultural heritage due to their unique properties (strength, elasticity, thermal and sound insulation, color, odor, durability, etc.). Accordingly, wood is one of the oldest traditional construction materials used for religious and civil architecture in the Black Sea Region of Turkey.

As with all wood for all time, deterioration depends on a number of chemical and biological factors. Losses in mechanical strength due to deterioration raise concerns about shortening the life of wood. The degradation of wood can be accelerated as a result of its chemical or biological degradation, and this can be induced or accelerated by the outdoor effect [Almkvist and Persson,2008 ; Sandström et al., 2005]. It is extremely difficult to generalize the effect of degradation on the material properties of wood and this is largely dependent on the wood. The type, age, environmental factors, rot mechanisms and other parameters active in the wood material, as well as the degree of exposure to oxygen, or its contact with the soil affect the life of the place of use [Highley, 1995; Thaler and Humar, 2013; Björdal, 2000].

Studies conducted to determine the factors that cause damage in historical wooden buildings in Turkey are quite limited. Chemical and physical change in weathering. How fast it will be does not only depend on the durability against rot and wood pests. It is an indication of how effective the weather conditions on the wood material is. It is the fiber loss caused by the deformation and the slow wearing of the damaged surface.

The factors of the special location of Rize-Fırtına Valley (climate, landscape and elevation) will have an effect on the physical, mechanical and biological properties of historical wooden structures. Climate indices was developed by the American Weather Forecasting Office to determine the decay risk for wood materials based on the climatic conditions of the environment as follows.

It was reported that the risk and risk of decay is relatively low in regions with a climate index of 35 or less, moderate in regions between 35 and 65, and the risk of decay of wood material in regions with a climate index of more than 65. The risk of decay in historical wooden buildings in this region due to the high climate index is quite high. Rize-Fırtına Valley, with a climate index higher than 65, is one of the regions with the highest rainfall with a 95-climate index in Turkey (Gezer, 2003). In the scope of this paper, two historical wooden mansions located in rural areas of Çamlıhemşin district were studied in detail.

As high climate index results in high risks of decay in historical wooden structures, various historical buildings at different heights in Çamlıhemşin district of Rize province, which is one of the popular destinations in Turkey in terms of nature and cultural tourism and located in this valley are included in this study.

It is important to investigate the chemistry and structure of the material in order to detect structural changes and deterioration in historical wooden structures and to contribute to the protection and sustainability of wood. For this reason, in this paper, it was aimed to investigate the chemical changes in samples taken from historical wooden structures located at different elevations in the Rize-Fırtına Valley.

2.. Materials and Methods

Two different areas were selected in Çamlıhemşin Rize for this study. Within the scope of the research, samples were taken from wooden mansions which are at least 150 years old in the region and are at different elevations above sea level. Wood samples were taken from the south facing exteriors of historical wooden buildings and subjected to some chemical analysis. Those wooden houses studied in this project were constructed from chestnut (*Castanea sativa* Mill.). Chestnut is easily obtained from the close environment. In addition, natural durability of chestnut is very high. Therefore, it is the most preferred material in building such mansions.

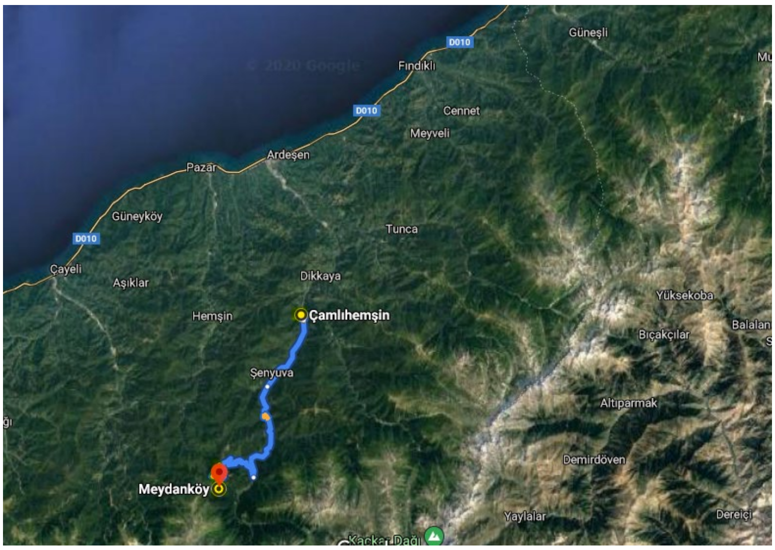

Figure 1. General view of research area (Meydanköy- area 1; Çamlıhemşin-area 2)

Wood samples used in chemical analysis were mechanically chipped and ground in a laboratory type Willey mill. These samples were sieved according to the grain size that remained in the 60-mesh sieve in accordance with standard analysis methods. Since the samples were taken from different elevations above sea level, they were then placed in sealed nylon bags and stored separately. Samples taken from each house were subjected to chemical analysis in triplicate. The moisture content of the test samples was determined by drying in a n oven at 103 ± 2^{0}C. Following chemical analysis were conducted

Figure 2. Historical some wooden buildings

2.1. Determination of Moisture

Moisture determinations of the wood samples used in the study were made before starting the chemical analysis. Moisture determinations were made according to TS 2471. Accordingly, 2g of sample was weighed on a precision scale and the first weight was determined and the sample placed in the oven at 103 ± 2^{0}C was dried until it reached full dry weight. The samples taken out of the oven were cooled in a desiccator and their exact dry weights (Mo) were determined by weighing on a precision scale.

The% moisture content of the samples was calculated using the following equation:

$$r = \frac{Mr - Mo}{Mo} \text{ x } 100$$

r: Moisture of sample (%)
Mr: The weight of the sample in the damp state (g) (g)
Mo: Weight of the sample in the dry state (g) (1)

2.2. Solubility in Alcohol-benzene

Solubility processes in alcohol benzene were carried out to determine the proportions of substances such as oil, wax, resin and possibly ether-insoluble wood gum in the wood. Chemical analysis was carried out in triplicate by taking 10 grams from each sample group. For this, wood samples in 300 ml alcohol-benzene mixture were extracted for four hours in Soxhlet extraction device and the ratios of soluble substances were determined. Transactions were carried out according to the method in the TAPPI T 204 Om-88 standard (1988).

2.3. Determination of Holocellulose content

Holocellulose; it is the carbohydrate complex that remains after the lignin substance of the wood is separated. In the study, the most widely used and most reliable Chlorite Method was applied to determine the amount of holocellulose, which contains all of the carbohydrates in the wood. Three repetitive holocellulose determinations were made by taking 5 g from sample groups exposed to alcohol-benzene solubility. Chemical analysis was made according to Wise's chlorite method. As a result of the analysis, the samples were dried at 103 ± 2 ° C and weighed. This weight was found to be holocellulose % in proportion to its original dry weight.

2.4. Determination of Alpha-Cellulose content

Approximately 2g was taken from wood dust previously extracted from alcohol benzene and used as a test sample. Alpha-cellulose determination was made according to the TAPPI T 203 OS-71 standard. Alpha cellulose ratio was determined using 17.5% NaOH on holocellulose samples. As a result, the amount of alpha cellulose was calculated as% compared to full dry wood. The crucible and the residue in it were weighed after drying at 103 ± 2 ° C, cooling in a desiccator, and the ratio of alpha cellulose in percent (%) to the complete dry sample weight was determined.

2.5. Determination of Lignin content

When wood is treated with strong acids, carbohydrates are hydrolyzed and residual lignin is obtained. Since chestnut contains a high percentage of tannins. samples were treated with alcohol to remove tannins. Then cellulose was removed using with 72% H_2S0_4 and lignin was obtained as the final product.

For the determination of lignin, some extractives remaining undissolved in the samples must be removed together with lignin first. For this, standard alcohol extraction was applied to the samples. For the determination of lignin, 1 g of air-dried samples, which were extracted from alcohol before, will be transferred to a beaker and 15 ml of 72% H_2SO_4 are poured on it and kept at 12-15 ° C for 2 hours. At the end of this period, the mixture in the beaker was transferred to a 1-liter flask and the amount of liquid in the flask was 560 ml so that the acid concentration was 3%. The residue was filtered through the crucible and washed with hot distilled water. The residue obtained was dried in an oven at 103 ± 2 ° C and calculated in proportion to the initially used sample weight. TAPPI T211 om-02 standard method (2002) was used to determine the amount of lignin.

2.6. Solubility in 1% NaOH

The experiment carried out in accordance with the TAPPI T212 om-02 standard (2002), 2 g of air-dry sample with a sensitivity of 0.0001 g was placed in a 200 ml Erlenmeyer, then 100 ml of 1% NaOH solution was added with a pipette. The mouth of the Erlenmeyer was closed with a small flask, placed in a water bath at 100 ° C and kept in the water bath for one hour. It was mixed four times at the 5^{th},10^{th}, 15^{th} and 25^{th} minutes. At the end of this period, the residue in the flask was filtered by vacuum on a tared crucible and then washed with 10% acetic acid and hot water, the crucible and its contents were dried at 103 ± 2 ° C and cooled in a desiccator and weighed.

3. Results and Discussion

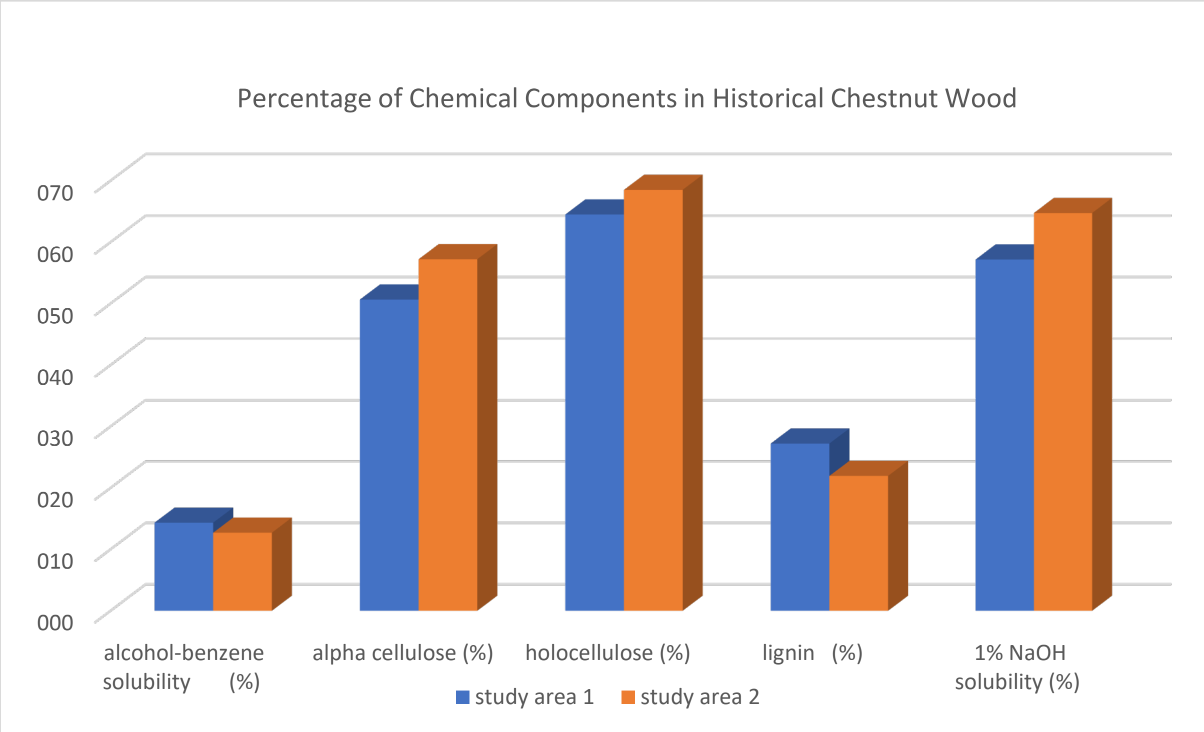

Figure 3. Percentage of Chemical Components in Chestnut Wood taken from Historical Wooden Structures

Chemical analyses of samples taken from historical wooden building at different elevations were conducted and the results are shown Figure 1. Similar results were obtained from the percentage of alcohol-benzene solubility in the samples. While the highest percentage of alpha-cellulose was found in the sample taken from the first region; the lowest percentage was found in the sample from the second region. Holocellulose percentage was higher in the sample taken from the second region, when compared to the sample taken from the first region. With regard to 1% NaOH solubility of the samples, it was higher in the second region.

Table 1. Percentage of Chemical Components in Historical and original Chestnut Wood

Experiments	Study Area 1		Study Area 2		Chestnut wood
	x	Std	x	Std	
Alcohol-benzene	14,34	0,11	12,71	0,03	19,84
Alpha cellulose	50,66	1,10	57,22	4,02	53,35
Holocellulose	64,50	0,67	68,51	0,70	68,00
Lignin	27,22	0,87	21,95	0,81	25,23
1% NaOH solubility	57,18	0,76	64,74	0,84	32,90

It was reported that percentage of holocellulose, cellulose, lignin, alcohol-benzene solubility and 1% NaOH solubility of newly cut chestnut wood were 68%, 53.35%, 25.23%, 19.84% and 32.90%, respectively (Akgün, 2005).

The results showed that rather than main wood components, alcohol benzene solubility and 1% NaOH solubility dramatically changed in wood samples taken from historical buildings regardless of their locations. The reason for lower alcohol-benzene solubility was that extractives might have washed out from wood due to the rain and other climatic conditions. The reason for higher 1%NaOH solubility in wood samples taken from historical buildings could be because of weathering, UV degradation and insect infestation.

4. Conclusions

(1) The results of study area-1 showed that percentage of cellulose, holocellulose, lignin, alcohol-benzene solubility and 1% NaOH solubility of chestnut wood were 50,66%, 64,50%, 27,22%, 14,34% and 57,18%, respectively.

(2) The study area-2 results revealed that 57.22%, 68.51%, 21.95%, 19.84% and 32.90%, respectively, were the percentage of cellulose, holocellulose, lignin, alcohol-benzene solubility and 1% NaOH solubility of newly cut chestnut wood.

(3) The results showed that rather than main wood components, alcohol benzene solubility and 1% NaOH solubility dramatically changed in wood samples taken from historical buildings regardless of their locations. The reason for lower alcohol-benzene solubility was that extractives might have washed out from wood due to the rain and other climatic conditions. The reason for higher 1%NaOH solubility in wood samples taken from historical buildings could be because of weathering, UV degradation and insect infestation.

5. Acknowledgments

This work has been funded by the Scientific Research Project Coordination Office of Karadeniz Technical University (Project No: FBA-2019-8102).

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DETERMINATION OF DAMAGE AND DEFECTS IN HISTORICAL WOODEN STRUCTURES USING NONDESTRUCTIVE TEST DEVICES

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Abstract

The rich accumulation of historical and cultural mosaic of Anatolian geography can be found in Rize. The examples of civil architecture in the region have survived to the present day, largely without deteriorating their original qualities. The preservation of the historical urban texture in the region where the historical wooden structures that defy the centuries are intense are of great importance in terms of transferring to future generations and maintaining the cultural memory. There are not many studies in the forest industry engineering literature to determine the damage and defects in historical wooden structures and to protect the original texture of these defects. Within the scope of the study, a research was conducted in Cinan mansion, a 200-year-old wooden mansion in Rize Pazar district. In this study, the damage and defects in the historical wooden structure were determined by non-destructive test methods. In addition, screw holding, shear and elasticity modulus of the wooden carrier beams in the structure were determined. With this study, it is aimed to determine the defects and damages in historical wooden structures and to develop appropriate protection techniques that can contribute to the solution of the problems encountered. In addition, it is aimed to be able to intervene without damaging the texture of the wooden structure and to ensure the sustainable use of historical wooden structures for many years.

Keywords: Historical wooden structures, Non-destructive Tests, Deterioration and decay

1. Introduction

The rich accumulation of historical and cultural mosaic of Anatolian geography can be found in Rize. The examples of civil architecture in the region have survived to the present day, largely without deteriorating their original qualities. The preservation of the historical urban texture in the region where the historical wooden structures that defy the centuries are intense are of great importance in terms of transferring to future generations and maintaining the cultural memory. There are not many studies in the forest industry engineering literature to determine the damage and defects in historical wooden structures and to protect the original texture of these defects.

Today, restoration works of wooden structures are generally perceived to be carried out under the monopoly of architects or civil engineers. It is obvious that the knowledge of forestry industrial engineering having technical knowledge about wood material is not benefited and, it is identified with architects and is addressed only from an architectural perspective. Despite all technological developments, wood has continued its existence in many different areas, especially in the fields of architecture and design, and forest industry.

Wooden material has been preferred in all periods because of its advantages (Sayar et al, 2009). However, wood material is very weak when it cannot be protected against negative external factors. Sustainable use of wood materials is also of great importance in terms of its role in carbon storage and the carbon cycle (Erdin, 2003; Lippke et al, 2010). Wooden structures also play an active role in reducing global warming, as they continue to store carbon as long as they live.

In expanding the service life of wooden materials in historical structures it is essential to assess drilling resistance, screw holding, shear and elasticity modulus of the wooden carrier beams in the structure. Historical wooden materials must be preserved in order to maintain their original structural purpose as much as possible, and to protect our values and ensure that this heritage can survive for generations. This is partly caused by the concept of globalization, which is under the control of strong economies and aims at the unification of all life expressions at a single level that lead to the disappearance of cultural heritage over time. In order to restore and keep the historical and wooden structures alive without damaging their original texture, the damaged or defective areas of the wooden material should be removed with appropriate intervention methods. Therefore, an accurate condition assessment is needed to evaluate the serviceability of the materials. One of the most convenient way of determining the mechanical properties, deterioration and decay is non-destructive methods.

On the other hand, there are several non-destructive methods that can be used in the assessment and determination of the quality and properties of wooden structures (Niemz, 2009):

- Mechanical (drilling resistance, hardness, intrusion behaviour);
- Electrical (correlation between electrical resistance and moisture, correlation between electrical resistance and fungal decay);
- Acoustic (sound velocity, sound reflection, sound attenuation);
- Thermal (heat radiation);
- Electromagnetic waves (visible light, ir/nir radiation, x-ray, neutron radiation, synchrotron radiation).

In the light of the information given above, the aim of this study is to determine the defects and damages in historical wooden structures in Rize Region through non-destructive methods such as drilling resistance, screw holding, shear and elasticity modulus and to develop appropriate protection techniques that can contribute to the solution of the problems encountered.

2. Materials and Methods

In this study, a mansion situated in Rize Pazar district called Cinan mansion (Figure 1), which is about 200 years old and made from chestnut wood, was studied. Wooden materials were taken from different exterior sides of the mansion.

The damage and defects in the historical wooden structure were determined by non-destructive test devices including Resistograph, FAKOPP Screw withdrawal resistance meter and FAKOPP Microsecond Timer. In addition, screw holding, shear and elasticity modulus of the wooden beams in the structure were determined.

Figure 1. Cinan Mansion, Pazar-Rize

2.1. Resistograph

The IML-RESI F-300 instrument is used to inspect structures such as poles and beams. Often, possible defects are located in the interior of the wooden structures and can't be identified from the outside. The IML-RESI System is based on a drilling resistance measuring method. The variation in resistance results in increases and decreases in the amount of torque applied to the drill shaft. A drilling needle with a diameter of 1.5 mm to 3.0 mm penetrates into the wooden structure with a regular advance speed, and the drilling resistance is measured. The data is recorded on a wax paper strip at a scale of 1:1 and also transferred to computer for further evaluation. The wood is only insignificantly injured, and the drilling hole closes itself due to a special drilling angle that was customized for the drill bit. (Gezer et al., 2015)

2.2. Screw withdrawal resistance meter

Screw withdrawal force is an indicator of the wood material strength, density and shear modulus. Fakopp Enterprise developed a portable screw withdrawal force meter. The applied screw diameter is 4mm, the length of the thread is 18 mm. The screw withdrawal force is a local parameter but selecting a representative location on a beam it is a useful information in wooden structure evaluation. (Fakopp Enterprise, 2010).

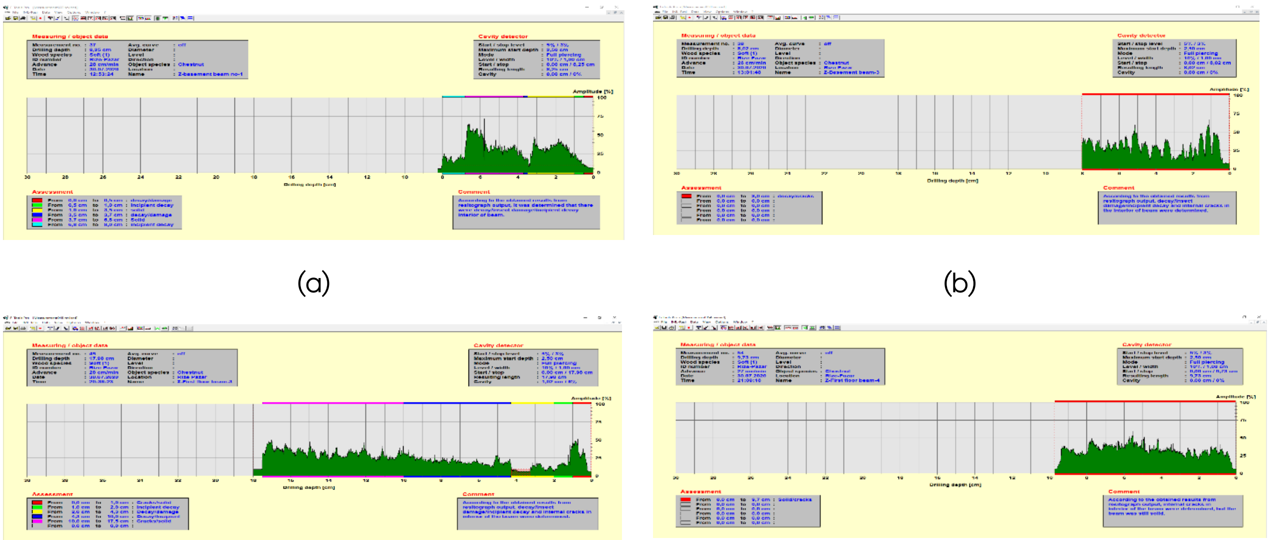
2.3. Microsecond Timer

Microsecond Timer equipment developed by FAKOPP designed for evaluation of living trees. The equipment is able to detect holes, decay, cracks in trees by non-destructive technique. FAKOPP measures the transit time of stress wave between two transducers. Another important application of the equipment is the determination of residual strength of old timbers and log evaluation. (Fakopp Enterprise, n.d.).

3. Results and Discussion

3.1. Resistograph

The wooden beams in basement and north, south, east facing exterior of the Cinan Mansion were evaluated by Resistograph in order to determine the internal defects and deteriorations. Some of the Resistograph outputs obtained are given in Figure 2. As shown in the outputs, the higher peaks represent the solid zone whereas the lower peaks represent the decay, cracks, splits or deteriorated zones.



(a) (b)

(c) (d)

Figure 2. Some Resistograph output of the beam

The results indicate that beams in (a) and (c) had damage, rot, cracks/voids in the interior. Rot/insect damage and the onset of rot were detected in the inner parts of the beam examined. As shown in the shaded area in (b), internal cracks with rot insect damage were detected in the inner parts of the beam. (d) output internal cracks in interior of the beam were determined but the beam was still solid.

3.2. Screw withdrawal resistance results:

Six measurements were made on the basement floor, seven on the north and south sides, and one on the west side of the historical wooden building. Screw withdrawal values and shear resistance of the wood material were showed in Table 1.

Table 1. Screw withdrawal resistance meter results

Basement	Screw witdrawal (kN)	Shear resistance(MPa)
1B	0,94	420,11
2B	**1,84**	**622,16**
3B	1,64	576,91
4B	1,73	598,42
5B	**1,89**	**633,36**
6A	1,00	433,10
Entrance floor (North)		
1	1,40	523,15
2	1,27	493,58
3	1,49	543,76
4	1,47	539,73
5	1,49	542,86
6	1,20	479,25
7	1,21	481,49
South		
8	1,05	444,75
9	0,95	422,35
10	0,96	425,04
11	0,98	429,52
12	1,04	442,06
13	0,60	344,40
14	0,92	416,08
East		
15	1,07	450,13

Screw withdrawal resistance values of the beams in the wooden structures examined during the study were determined between 0.60 and 1.89 kN. Measurement results were assessed according to EN 338 standard (2003). According to the results, second and fifth beam have shown the highest shear resistance and same beams also have the highest screw withdrawal resistance. The lowest results were obtained from the beam in the Southern side.

3.3. Fakopp Microsecond timer results:

The sample graph for determining the time correction coefficient of a measurement made on the wooden beams determined in the study area is given in Figure 6. The speed of sound in wood material is regulated according to the correction coefficient.

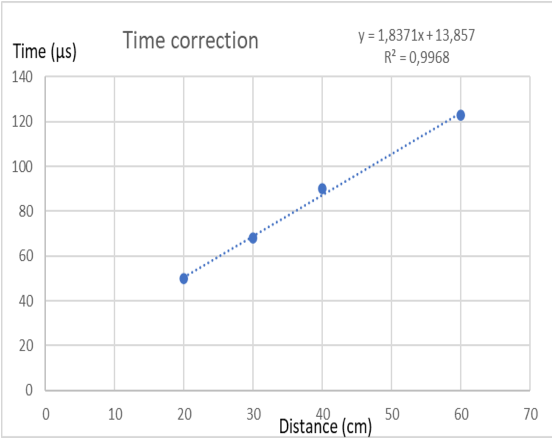


Figure 6. Microsecond Timer (V = distance / (transit time - correction))

Six measurements were made on the basement floor, seven on the north and south sides, and one on the west side of the historical wooden building for Fakopp Micro Second Timer results. As seen in Table 2, while the speed of sound is higher in the solid parts, the speed of the sound decreases in the rotten and destructive parts.

Table 2. Microsecond Timer results

Basement	Velocity [m/s]	Entrance floor North	Velocity [m/s]
1B	**45,09**	**1**	**44,42**
2B	**39,71**	**2**	**44,09**
3B	**41,07**	**3**	**44,42**
4B	**44,75**	**4**	**44,09**
5B	**39,20**	**5**	**44,42**
6A	**46,48**	**6**	**44,09**
		7	**45,77**
South	**Velocity [m/s]**	**East**	**Velocity [m/s]**
8	**41,94**	**15**	**41,94**
9	**43,77**		
10	**44,75**		
11	**44,42**		
12	**29,18**		
13	**65,88**		
14	**50,81**		

Generally, the highest velocity was detected in the northern side; the lowest velocity was measured in the basement and the southern side. In general, the mechanical strength properties of the beams tested fall into classes D35 and D70 in accordance with the EN 338 standard and may still be used.

As a result of the investigations carried out with the Resistograph device, it was determined that some of the beams had partial damage, while some of them had severe damage/cracks/decay However, some of the beams recommended to be changed as a result of the findings obtained from both visual inspections and examinations made with non-destructive test devices. The screw withdrawal resistance, bending and shear strengths of the beams were calculated thanks to the data obtained with the non-destructive test device and it was determined that the strength properties of the beams had the lowest resistance properties in this structure in the resistance classes specified in the EN 338 standard. Although these beams still had enough strength properties, it might be recommended to replace them considering the fatigue resistance due to the service life.

4. Conclusion

1-As a result of the investigations carried out with the Resistograph device, it was determined that some of the beams had partial damage, while some of them had severe damage/cracks/decay.

2-Generally, the mechanical strength properties of the beams examined fell into D35 and D70 classes according to EN 338 standard and it may be still possible to use them. However, some of the beams recommended to be changed as a result of the findings obtained from both visual inspections and examinations made with nondestructive test devices.

3-The screw withdrawal resistance, bending and shear strengths of the beams were calculated thanks to the data obtained with the nondestructive test device and it was determined that the strength properties of the beams had the lowest resistance properties in this structure in the resistance classes specified in the EN 338 standard. Although these beams still had enough strength properties, it might be recommended to replace them considering the fatigue resistance due to the service life.

5. Acknowledgments

This work has been funded by the Scientific Research Project Coordination Office of Karadeniz Technical University (Project No: FBA-2019-8102).

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EMISSIONS FROM DRYING IN THE WOOD-BASED BOARD INDUSTRY

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Abstract

The reason why wood-based boards are preferred in many areas of use, especially in furniture, is that they can be produced in desired properties and are cheap. In addition, wood defects such as different work in three dimensions, differences in resistance values, internal stresses and physical changes seen in solid wood are not encountered in wood-based boards. Volatile organic compound (VOC) emissions from wood-based panels occur from the raw materials of the boards and during production stages such as gluing, storage, pressing and drying. Most of the VOCs from wood raw materials are formed during the drying process. VOCs contribute to the formation of nitrogen oxides and photo-oxidants in the presence of sunlight. Photo-oxidants are harmful to humans as they irritate the respiratory and sensitive parts of the lungs. It also disrupts photosynthesis and damages forests and crops. The aim of this study is to evaluate the factors affecting the emissions that occur during the drying process in wood-based boards and the processes applied to reduce the emission.

Keywords: VOC, Drying process, Emission of wood based panels, wood based panels

1. Wood-Based Panel Industry

Due to the rapid population growth, urbanization, economic, social and cultural developments in the world, the decrease in the availability of wood raw materials and the increase in the demand for wooden products caused the importance of wood-based panels products to increase. Wood-based panels such as plywood, medium density fiberboard (MDF), particleboard and oriented particleboard are among the most widely used materials all over the world. These materials are widely used in the construction, decoration and furnishing of homes, offices, schools as well as other non-industrial workplaces (Bilgin, 2019; Aydın et al.2010; Böhm et al., 2012).

Asia-Pacific region accounted for 61 percent of global production in 2018 (248 million m^3), followed by Europe (90 million m^3, or 22 percent), Northern America (48 million m^3, or 12 percent), Latin America and the Caribbean (19 million m^3, or 4 percent) and Africa (3 million m^3 or 1 percent). The four top consumers (China, Germany, Russia, USA) of wood-based panels are the same as the four largest producers, suggesting that the products are mostly consumed domestically. The trends in consumption are similar to those in production (Figure 9a). The fifth-largest consumer is Poland (overtaking Turkey and Japan in 2015), where consumption increased from 9 million m^3 in 2014 to 12 million m^3 in 2018 (FAO, 2018).

Wood-based panel production amounts in the world between 2014-2018 are given in Figure 1.

Turkey's fiberboard industry is the highest production level in 2017. it is followed by particleboard, plywood and OSB. Wood-based panels production amounts in Turkey between the years 2010-2017 is given in Table 1..

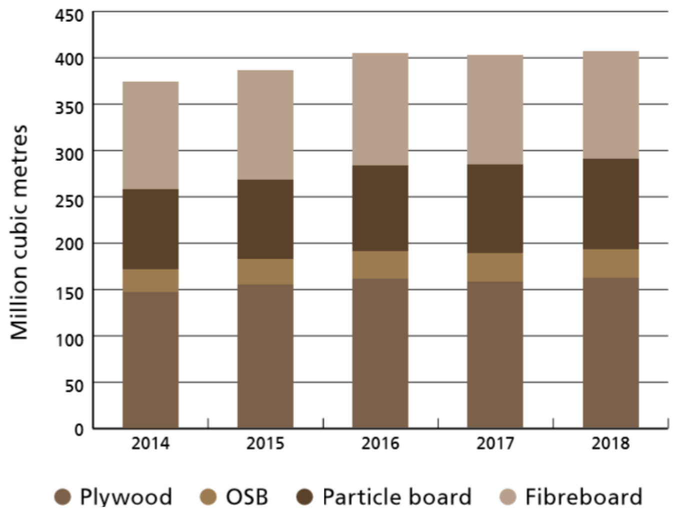

Figure 1. Wood based panel production in the World (FAO, 2018)

Table 1. Turkey forest product production (100 m^3) (Oğuz et al., 2019)

Product/Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Veneers	88	85	84	85	87	270	74
Plywood	115	116	116	150	116	120	105
Particle Board	3.580	3.875	4.225	4.425	4.361	4.202	4.286
OSB	40	75	75	75	75	80	75
MDF/HDF	3.570	3.900	4.285	4.885	4.777	5.069	4.747
Other Fiber Boards	15	15	15	15	15	15	59

2. Wood - Water Relationship

Wood is a porous material that contains air and water and wood cells. Wood loses or gains moisture depending on the environmental conditions to which it is exposed. Consequently, the weight of a piece of wood is not constant. This relationship is called moisture content and is expressed as the weight of water in the cell walls and lumen as a percentage of the weight of the oven dry (dry weight in the oven) (Walker, 2006; Rowell, 2005).

The cell wall consists of cellulosic polymers, non-cellulosic carbohydrates (hemicellulose etc.) and a lignin matrix that reinforces them. If water is adsorbed to cellulose and hemicellulose in the cell wall, it is bound water. The water in the lumen of the cells is free water. Free water is only found when all areas in the cell wall are filled with water; this point is called the fiber saturation point (FSP). All water added to wood after FSP is reached is called free water. The physical and mechanical properties of the wood material are mostly related to the fiber saturation point. For example, as the moisture rises below the fiber saturation point, the strength from mechanical properties decreases (Bozkurt and Erdin, 1997; Ramazan kantay; Rowell, 2005). Free and bound water are shown in figure 2.

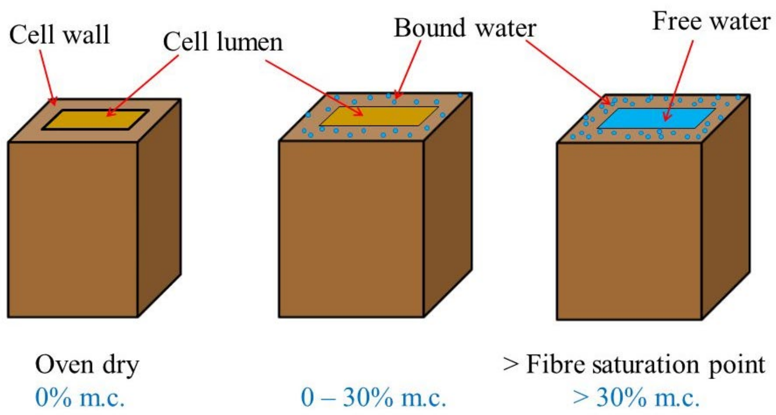

Figure 2. Water in wood (Web-1)

When drying from the green condition to the FSP (approximately 25–30% moisture content), only free water is lost and therefore the cell wall volume does not change. However, when the wood is dried further, the water bound from the cell walls is removed and the volume of the wood begins to change (Rowell, 2005). One of the main problems encountered is that wood shrinks as it loses moisture and swells again as it regains moisture (Walker, 2006). In addition, the structure and arrangement of cellulose in the cell wall, the parallel or vertical extension of the cells to the tree axis and their symmetrical placement within the tree trunk give the wood an anisotropic structure. Since wood material is anisotropic, it shows shrinkage and swelling at different rates in three main directions (longitudinal, tangent, radial) (Nurgün and Ergin, 1997).

3. Wood-Based Panels

The main products produced in the wood based panel production sector are plywood(PW), particleboard (PB), medium density fibreboard (MDF) and oriented particleboard (OSB). Although some structural features such as usage areas and strength values of particleboard, MDF and OSB products differ from each other, they are generally produced in a continuous process that includes the following basic process steps (Figure 3) (Web-2). Plywood production process is different from the others.

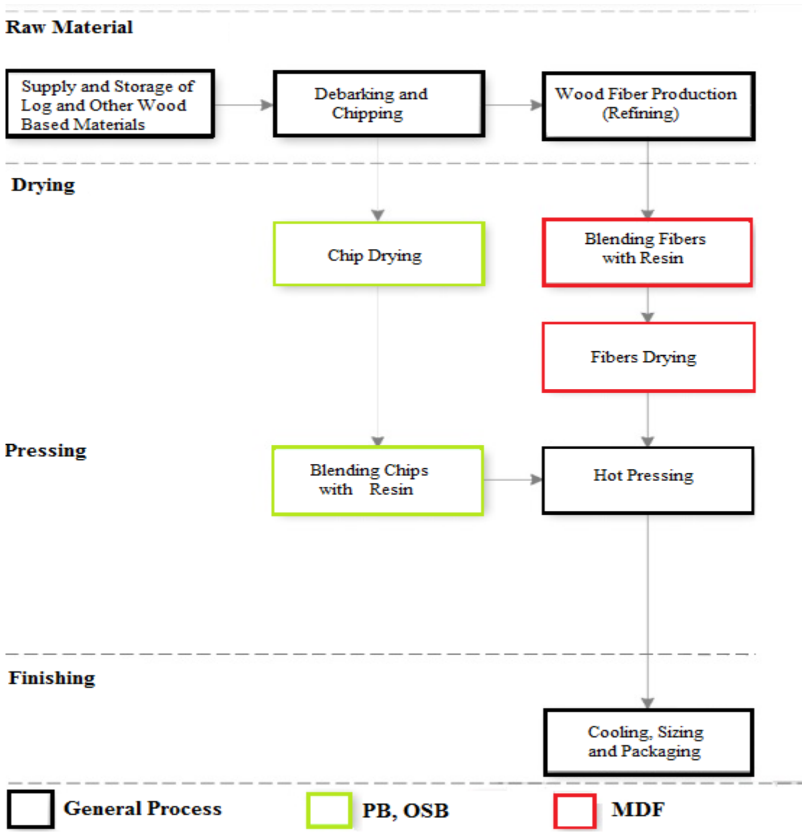

Figure 3. General process for PB, OSB and MDF

The drying process is very important from the wood panel production stages. Because drying is the process of removing the water (moisture) in the wood that is generally not suitable for the usage areas. The degree of dryness required in wood depending on where it will be used is very important (Altınok et al., 2009).

3.1. Drying in Particleboard Production

First trials on particleboard production, It was held in Europe and North America before World War II. The first particleboard factory was established in Bremen, Germany in 1941 during World War II and started commercial particleboard production. Technological and scientific studies on particleboard production have intensified after the years of World War II and the raw material shortage encountered by Germany was tried to be overcome in this way (Zengin, 2009).

Particleboard according to EN 309 standard; These are panels obtained by hot pressing of particle obtained from wood pieces (wood pieces, particle, sawdust, etc.) and / or lignocellulosic materials (from lignified plants such as flax, hemp yarn, dehydrated sugar cane pulp, etc.) (Özen and Kalaycıoğlu, 2008).

The process of drying the particle affects the curing time of the glue, the panel being loose or bursting. Therefore, the particles should be dried to a moisture content of 1% - 4% in accordance with the humidity of the panel exit from the press (Şahin, 2018).

3.2. Drying in Fiberboard Production

Although the first appearance of the fiberboard industry can go back to the early 1900s, large-scale commercial production only emerged between the second world wars and in the United States. The first fiberboard production factory was established in Great Britain in 1898, followed by factories established in New Jersey (United States of America) in 1908 and in Canada in 1909. The first equipped fiberboard factory was established in Mississippi in 1926 (Zengin, 2009).

Fiberboard; It is a product obtained by drying or pressing the panel draft created by using the natural adhesion and felting properties of vegetable fibers and fiber bundles or by using additional adhesive material. Briefly; It is a type of panel obtained by reshaping the fiber and fiber bundles formed by fibrillation of lignocellulosic materials (Eroğlu and Usta, 2000).

Before the drying process, the fibers are brought to a consistency that can be pumped with pumps with the addition of water and resin and directed to the dryer. The moisture of the fibers entering the dryer is around 50%, and this moisture should decrease to a value between 6-12%. If sufficient drying is not provided, steam exits from the panel by explosion (Eroğlu and Usta, 2000). If the fibers are dried for more than 7 seconds, there is a risk of fire (Önem, 2018).

3.3. Drying in OSB production

Particle board making from oriented particles is based on the work of Armin Elmendorf in the USA and Wilhelm Klauditz in Germany in the late 1940s and early 1950s. Generally, two OSB standards are used. OSB3 of these is produced for use in exterior and moisture resistant places. OSB2, on the other hand, is produced for use in interior and places requiring less moisture resistance (Çakmak, 2018).

OSB; It is a panel-shaped material produced by pressing the draft under temperature and pressure obtained by mixing specially prepared particles with a suitable glue and directing them in the desired direction during laying (Akbulut et al., 2002).

The moisture content of the particles to be used for OSB production should be around 2 - 5% after drying. The particle moisture content affects the panel resistance properties, panel pressing factor, glue consumption amount and the physical properties of the panel (Doğan, 2015).

3.4. Drying In Plywood Production

Veneer and plywood date back to the times of the pharaohs. It is stated that the first wood veneer panel was produced in Egypt 3000 years ago. Plywood obtained from veneers was used in king and prince furniture and coffins. The first machine that will constitute the basis of today's rotary-cut veneer machines in Europe was built in 1818 (Çolakoğlu, 2004).

Plywood according to EN 313-2; It is defined as a wood-based panel consisting of layers that are glued on each other with the fiber direction generally perpendicular. Layers defined as veneer are thin boards at most 7 mm thick obtained by peeling, cutting or sawn from wood (Çolakoğlu, 2004). Plywood production is shown in Figure 4.

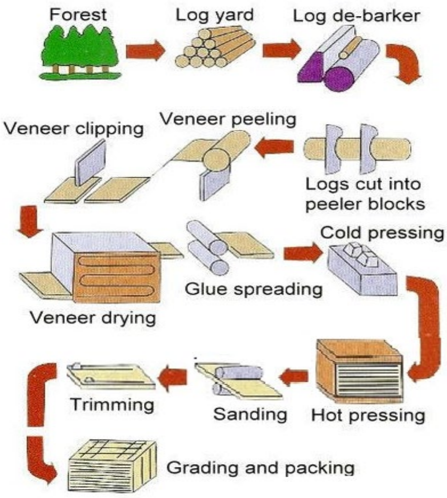

Figure 4. Plywood production (Bilgin, 2019).

Veneer drying is an important step in the manufacture of wood-based panel products such as plywood and laminated veneer lumber (LVL). If the wet veneers from the peeling and cutting machines are not dried immediately, undesirable color changes may occur due to the effect of fungi and chemical reactions (Çolakoğlu, 2004). The purpose of veneer drying is to reduce the moisture content to a suitable range for bonding plywood and other veneer-produced materials. The veneers are dried to an average moisture content of 3% in the manufacturing process because the moisture content of all veneers must be below 7% before bonding. High drying temperatures in the veneer production process are effective on both physical and mechanical properties of plywood (Aydin and Çolakoğlu, 2005).

4. Volatile Organic Compounds (VOC)

In the recent past, both wood and wood products, especially wood-based panels, have become environmental problems. Volatile organic compounds (VOCs) released from wood-based panels are harmful to humans when they cause irritation to the respiratory tract and parts of the lungs (Granström, 2005). In addition, wood and wood-based panels are one of the 10 most concentrated VOCs in office buildings, and these products cause poor air quality in buildings (Roffale, 2006; Yu et al., 2010).

VOCs can be classified into several types based on their chemical structure (alkanes, aromatic hydrocarbons, aldehydes, etc.), physical properties (boiling point, vapor pressure), or potential health effects (irritant, carcinogenic or neurotoxic), (Da Silva, 2017). The World Health Organization (WHO) defines a VOC as any compound with a boiling point between 50-100 ° C and 240-260 ° C and having a saturated vapor pressure of more than 100 kPa at 25 °C (WHO, 2010). VOCs can be found in vapor, liquid or solid form at room temperature (Burn et al., 1993). The World Health Organization has classified organic pollutants according to their boiling points into three types and summarized in Table 2.

Table 2. Classification of VOC (Da Silva, 2017)

Type	Boiling point (°C)
Very Volatile Organic Compound	< 0 to 50 - 100
Volatile Organic Compound	50 – 100 to 240 – 260
Semi – Volatile Organic Compound	240 – 260 to 380 - 400

Oxidation of VOCs generally results in formaldehyde formation (WHO, 2010). Ozone can easily oxidize naturally occurring terpenes in the air, leading to the formation of simple aldehydes such as formaldehyde (Roffael, 2006; Stefanowski, 2018). Some reports have mentioned that formaldehyde emission arises from wood during hot pressing of wood-based panels, but it is considered to have an insignificant contribution to the formaldehyde emission level (Böhm et al. 2012). In addition, Çolakoğlu et al. (2002) investigated the effect of waiting times of veneers before drying on formaldehyde emission. Immediately after the production, it has performed the drying process by waiting 1 week, 2 weeks and 1 month. No significant difference was found between formaldehyde emissions.

There are numerous sources of both VOCs and formaldehyde. Volatile organic compounds (VOCs) are found in all natural and synthetic materials, from gasoline to flowers, water to wine. The uses of these versatile compounds are numerous (Burn et al., 1993). Natural materials also emit different amounts of formaldehyde; It is known to produce meat (2-20 mgkg 1), fruits and vegetables (6.3-35 mgkg 1) wood (0.04 mgkg 1) and even volcanoes (WHO, 2010). It is also a product of human metabolism and can be detected in human breath at levels ranging from 1.2 to 72 ppb (Stefanowski, 2018).

4.1. VOC from Wood

The cell wall of wood consists of carbohydrate (cellulose and hemicellulose), lignin and extractive substances (Manninen et al., 2002). A significant portion of wood extractives are volatile organic compounds (VOCs) consisting of terpenes, terpenoids, flavonoids, alcohols, aldehydes and ketones. It also contains small to large alkenes and fatty acids (Adamová et al., 2020).

Wood VOC emissions can be divided into primary and secondary VOC emissions. Primary VOCs are free, unbound volatile compounds, such as terpenes, initially found in high concentrations in wood due to their biological functions in trees. On the other hand, secondary VOCs, including hexanal, pentanal, and acetic acid, are composed of chemically or physically bonded compounds released by chemical (egoxidation, hydrolysis) or physical (eg mechanical corrosion) degradation of wood or wood extractives (Pohleven et al. , 2019). Table 3 indicates the most abundant VOCs emitted from different trees.

Table 3. A group of the most abundant VOCs emitted from different tree species, containing VOC concentrations emitted from sapwood / heartwood on day 31 (Adamová et al., 2020)

Extractive/Group of VOCs	**VOC**
Terpenes	α-pinene, β-pinene, Camphene, Δ3-carene, Limonene
Aldehydes	Benzaldehyde, Decanal, Furfural, Hexanal, Nonanal, Octanal, Pentanal, Formaldehyde
Acids	Acetic acid

VOC emissions can be significantly affected by the raw materials and production techniques of the panels (He et al., 2012). VOC emission may occur as a result of oxidation, thermolysis or evaporation in plate production stages such as storage, drying and pressing (Çolak, 2002). Almost all of the VOCs generated during the drying process are caused by the wood itself. Most of the VOCs formed during the pressing process are caused by the glue.

4.1.1. Drying Process

VOC emission in the drying of the panels is caused by factors such as wood species, drying type, dryer, temperature and time (Velic et al., 2019; Çolak, 2002).

4.1.2. Wood species

VOC emissions from hardwoods are significantly lower than softwoods because they do not contain and emit volatile terpenes. Hardwood VOCs are mainly degradation products resulting from the thermal breakdown of wood tissue, including lignin, cellulose, hemicellulose and extractives (Banerjee et al., 1995). Mono-, di-, and sesquiterpenes are the predominant VOCs for softwoods; In hardwoods, triterpenes and sterols are dominant (Adamová et al., 2020).

The main emission in softwoods comes from terpenes. These terpenes are constantly spread from wood and during the processing of wood (Çolak, 2002; Pohleven et al., 2019). The most important ones among these are natural compounds such as a-pinene, b-pinene, camphene, limonene, b-mirocene, a-terpinol and the compounds formed as a result of the reaction of monoterpenes such as phenicylalcohol, borneol, campphone, verbenone with water or oxygen (Çolak, 2002). Softwood releases large amounts of VOCs, most of which are terpenes. However, the same VOCs originating from hardwood can be released from the softwood as the wood texture can undergo thermal degradation during drying of the softwood (Otwell et al., 2000).

In general, hardwoods contain higher non-volatile terpenes, except for some tropical species, including monoterpenes and sesquiterpenes (Fengel and Wegener, 1989). In addition to acetic acid, hardwoods emit a wide variety of carbonyl compounds (aldehydes, carboxylic acids and ketones) and alcohols, especially aldehyde hexanal and pentanal. Acetic acid emission, hardwoods have more acetic acid emission than softwoods, as hardwood hemicelluloses contain higher amounts of acetyl groups. Hexanal is the dominant emission (Pohleven et al., 2019).

4.1.3. Drying type

Drying under natural conditions or artificially changes the profile of VOCs emitted from wood. Because as the temperature of wood rises and dries, VOC emission occurs in different ways (evaporation, steam distillation and thermal decomposition) (Wilson and Sakimoto, 2007). For example, acetic acid is formed during the drying of wood by hydrolysis of the acetyl groups of hemicelluloses, and furfural is formed from wood xylose in a strong temperature-dependent reaction (Adamová et al., 2020).

4.1.4. Dryer

Dryers are normally heated directly with natural gas, but some dryers use sanding dust in a later process step. When wood dries in dryers at high temperatures, air emissions of particles and volatile organic compounds (VOCs) are released. The VOC emission during the drying process is also caused by the direct burning of sanding dust and wood (Wilson, 2010). The drying exhaust gas may contain substances formed by thermal decomposition of one or more components of wood (cellulose, ligrins, resins, and the like), various aldehydes and acids such as formaldehyde, acetaldehyde, acetic acid and acids. Some of these substances have a relatively low boiling point and are also volatile in steam (Schmidt, 1993).

4.1.5. Temperature and time

Sun et al. (2020) investigated the effect of time on the TVOC and VOC emissions of particleboards during the production stages. The longer the exposure time of the particleboards under all production conditions (density, thickness, resin content), the TVOC emission decreased. The higher density, thickness, and resin content of the particleboards resulted in higher TVOC emission concentration at each measurement time and showed a negative correlation on the TVOC emission level. Increased esters, aldehydes and ketones are most susceptible to change in production conditions. However, terpenes exhibited a positive increase in density and thickness, but a negative effect by increasing the resin content. This result showed that the terpene compounds in TVOC mostly originated from wood particles.

He et al. (2012) stated that the emission of formaldehyde has been decreased consecutively due to heat treatment in the drying and hot pressing phase. He also stated that urea formaldehyde glue contains the lowest VOC unlike formaldehyde. He stated that wood particles have the highest VOC content. He reported that VOC and formaldehyde release during the drying and hot pressing stages showed a similar trend.

The release of volatile organic compounds (VOCs) during convective drying of particles at high temperature has been experimentally and theoretically investigated. The drying medium was determined as superheated steam with a pressure of two bars. Two different temperature levels of the drying environment, 160 and 180 ° C, and two different materials, yellow pine and spruce, were used. It is noted that the major released components consist of various types of monoterpenes, with a-pinene predominant in each of the two materials. The amount released has shown that it depends on the drying temperature and the time of the drying process (Johansson and Rasmuson, 1998).

Ishikawa et al. (2009) dried 3 different veneer types at 140-180 °C and observed that VOC and aldehyde emissions increased with increasing temperature as a result of HPLC, GS / MS analysis. He also stated that longer drying time was realized for the species with high moisture content and this increased the emissions.

Murata et al. (2013) aimed to reduce the formaldehyde emission released from plywood without using any chemicals. After the veneers with a humidity of 6% are dried up to 130 ° C, 3-layer plywood is produced by heat treatment. Drying temperatures are determined as 130-150-170-190 ° C. It has been shown that heating the veneer layers in the temperature range of 150 to 170 ° C effectively reduces the formaldehyde emission of the plywood without reducing the mechanical properties of the pavement. When the coating layers were heated in the temperature range of 150 ° C to 170 ° C, the amount of hydrated water (monomolecular layer) was slightly reduced and the amount of dissolved water (polymolecular layer) remained unchanged. It is assumed that the formaldehyde emission of plywood is related to the state of the adsorption zone of the wood.

4.2. Health and Environmental Effect of VOC

In certain conditions, inhabitants of poorly ventilated buildings are more prone to suffer from "sick building syndrome" (SBS), which is a phenomen on characterized by various symptoms such as headache; eye, nose, or throat irritations; drycough; allergy reactions; dry and itching skin; non specific hypersensitivity; insomnia; dizziness and nausea or difficulty in concentrating; andtiredness. The intense odors may have a negative psychological influence as well (Adamová et al., 2020). In addition, when VOCs such as monoterpene emit together with NO2 and SO2, they contribute to acid accumulation and soil acidification (Granström, 2005)

Different TVOC definitions used by different countries make interlaboratory comparisons difficult. As shown in Table 4, there are a number of limits given by different regulations and specifications.

Table 4. Limit values after 28 days emissions testing in a ventilated test chamber required by various regulations across Europe and proposed by the WHO (Da Silva, 2017)

Organisation/Institute		**TVOC (μg/m³)**	**Formaldehyde (μg/m³)**	**Product/Standard**
WHO		-	100	-
Belgian regulation		100 or 1*	100	Construction products CEN/TS 16516
AgBB/DIBt (Germany)		1000 or 1*	100	Constructions products CEN/TS16516 and ISO 16000
EMICODE (Germany)	EC1^{PLUS}	≤ 60 or 1*	50[a]	Flooring products CEN/TS 16516
	EC1	100 or 1*	50[a]	
	EC2	300 or 1*	50[a]	
France regulation	Class A^{+}	1000	10	Construction products ISO 16000
	Class A	1500	60	
	Class B	2000	120	
	Class C	> 2000	>120	
Indoor air comfort-Eurofins	Standard	1000 or 1*	60	-
	Gold	750 or1*	10	

* For each individual carcinogenic compound.
[a] Emissions after 3 days stored in a ventilated environmental chamber.

The Construction Product Regulation (EU 2011/305) since 1st July 2013 defines the essential requirements for construction materials. This Regulation replaces the directive 89/106/EEC. Among the seven requirements number three, already present in the old directive, is dedicated to: hygiene, health and environment. Then the regulation prescribes that any construction work shall not be harmful to the health of occupants, meaning that no dangerous particles or gases shall be emitted in the air. The purpose of this regulation is to harmonize the technical and healthy description of products including also indoor emissions thus facilitating their marketing in the EU area. The goal is that the CE label applied on building materials and products will contain performance classes that cover all national regulations in Europe. Then each EU member state can specify which performance classes a product shall fulfil for being accepted on that national market. For indoor emissions and other types of releases, CEN has established a technical committee (TC 351) to undertake the work of developing the harmonised standards. A specific working group (WG 2) is dealing with indoor air. At the moment, WG2 has produced a test method (CEN/TS 16516) for indoor emissions based on the ISO 16000 series of standards concerning determination of emissions of VOCs from building products (Bulian ve Fragasa, 2016).

Considering instrumental methods used to determine the VOCs, gas chromatography–mass spectrometry (GC-MS) is commonly used to separate and identify the volatiles. For formaldehyde determination, liquid or gas chromatography is used, often after derivatization (Adamová et al., 2020).

5. Conclusion

Wood-based panels (plywood, fiberboard, particle board and OSB) widely used in the world were produced 400 million m^3 in 2018. These panels are widely used in the construction, decoration and flooring of homes, offices, schools as well as other non-industrial workplaces. During the production of all the panels, there is a drying process in which water is removed from the wood. VOCs formed during the drying process cause low air quality and therefore various disturbances. This review will make it easier to understand the factors affecting VOCs from wood during drying.

Different methods are used to prevent VOC emission from wood-based panels, which causes additional costs. More studies should be done on the temperature and time affecting the VOC in the drying process and a mathematical model should be created.

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MECHANICAL PROPERTIES OF MYCELIUM BASED MDF

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Abstract

Mycelium composites have been popular recently worldwide in terms of research interest and commercialization. Mycelium composites are biodegradable, produced renewable materials, environmentally friendly and show low density, good insulation properties, both related to acoustic and thermal aspects. However, mechanical properties of mycelium composites are obviously lower than alternative materials such as expanded polystyrene. In this study, hardwood and softwood fibers were inoculated with a white rot fungus and incubated in a climate chamber at 25 °C and 65% relative humidity for 15 and 30 days. Mycelium based medium density fiberboards were produced either without using any adhesive or with using 6% urea formaldehyde adhesive. The MOE, MOR, IB, thickness swelling and water absorption percentage of the mycelium based MDF were determined. The results showed that the MOE, MOR and IB values of the mycelium based MDF were low and did not meet the minimum required strength values given in the standards. However, these boards may still be used as insulation materials. Your abstract should give readers a brief summary of your article. It should concisely describe the contents of your article, and include key terms (especially in the first two sentences, to increase search engine discoverability). It should be informative, accessible and not only indicate the general aims and scope of the article, but also state the methodology used, main results obtained and conclusions drawn.

Keywords: Mycelium composites, MDF, White-rot fungi, Mechanical properties, Physical properties.

1. Introduction

Mycelium composites have been popular recently worldwide in terms of research interest and commercialization. Mycelium composites are biodegradable, produced renewable materials, environmentally friendly and show low density, good insulation properties, both related to acoustic and thermal aspects. However, mechanical properties of mycelium composites are obviously lower than alternative materials such as expanded polystyrene. Mycelium is the vegetative part of a fungus or fungus-like bacterial colony, consisting of a mass of branching, thread-like hyphae. Mycelium binds organic matter through a network of hyphal microfilaments in a natural biological process able to be exploited to produce both low-value materials, such as packaging, and higher-value composite materials from problematic agricultural and industrial waste materials with little or no commercial value (Jones et al. 2020). Mycelium composite materials such as foams, packaging materials, accessory materials, insulation boards etc., have been developed and some of them are available in the market in recent years. For example, Dell uses mycelium foams for packaging of business servers and IKEA has also expressed interest in adopting mycelium-based packaging (Jones et al. 2020). However, there are not many studies about mycelium based medium density fiberboards (MDF) in the literature. In addition, as is known, urea formaldehyde adhesive is commonly used in MDF production. It is also known that the formaldehyde emission from MDF containing formaldehyde above the standard amounts has a negative impact on the environment and human health. Formaldehyde emission causes severe allergic reactions in the skin, eye and respiratory system, weakens the immune system, and causes cancer like health problems depending on the concentration in the environment, exposure time and shape (İstek et al. 2020). Therefore, so many scientists are still trying to find a way to decrease/lower or eliminate the formaldehyde emissions from MDF. In order to solve this formaldehyde emission problem from MDF, mycelium based MDF production might be a very good option.

The objectives of this study were to produce mycelium based MDF either without using any adhesive or with using only 6% phenol formaldehyde adhesive and to determine some mechanical and physical properties of the mycelium based MDF.

2. Materials and Methods

Mixture of hardwood and softwood fibers (50/50%) was obtained from Kastamonu Integrated Wood Industry Company. Commercial urea-formaldehyde (UF) resin was provided by Camsan Wood Industries and Trade. Fibers were then moisturized around 70% and pH was adjusted to around 7 before the sterilization.

White-rot fungus culture was obtained from USDA Forest Products Laboratory, Wisconsin, USA. Fibers contained around 70% moisture content were put in polyethylene bags and sterilized at 121°C for 30 mins. The bags were then placed and cooled off in the laminar flow inoculation cabinet. A white-rot fungus mycelium was inoculated and then the bags were then incubated in a climate cabinet at 25 °C and 70% relative humidity for 15 and 30 days. One group of the incubated fibers was subjected to MDF production without using any resin while other group of the incubated fibers was dried to 2% initial moisture content before resin blending. The calculated quantities of the components were mixed. A UF resin (6 % solid resin based on wood oven-dry weight and 2% catalyst was applied based on wood oven-dry weight) were applied directly to the wood fibers using an air-pressure spray nozzle. The blended fibers were formed on steel caul-plates into one-layer mats of 40 mm x 40 mm (Figure 1). The mats were manually pre-pressed. These mats were pressed at a temperature of 180 °C for 7 min in a computer-controlled press (Figure 2) and conditioned in a climate room until they reached equilibrium moisture content. After climatizing of MDF panels, the specimens were cut from these panels to determine some physical and mechanical properties.

Figure 1. Preparation of mycelium based MDF

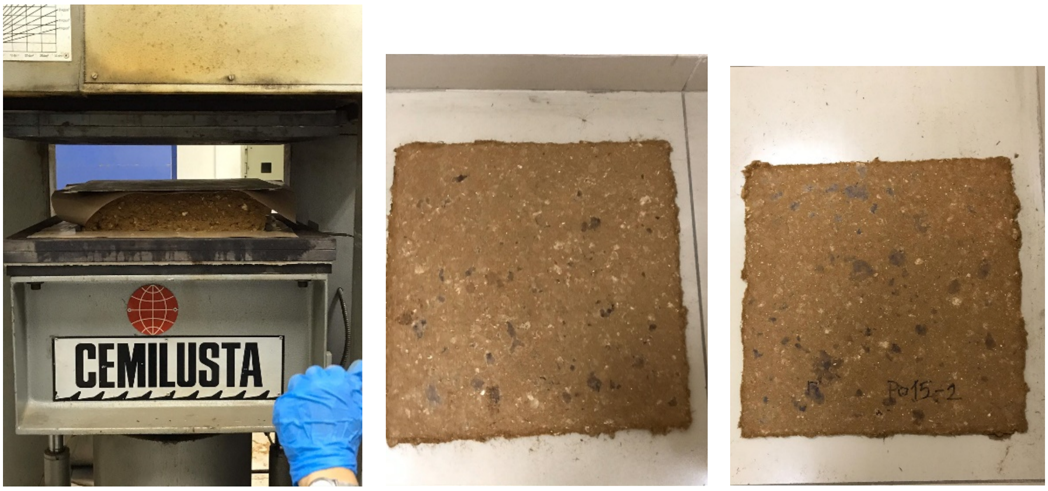

Figure 2. Production of mycelium based MDF

Some physical and mechanical properties of mycelium based MDF panels were determined according to EN 310 (1993), EN 317 (1993), EN 319 (1993) and EN 319 (1993) standards (Figure 3).

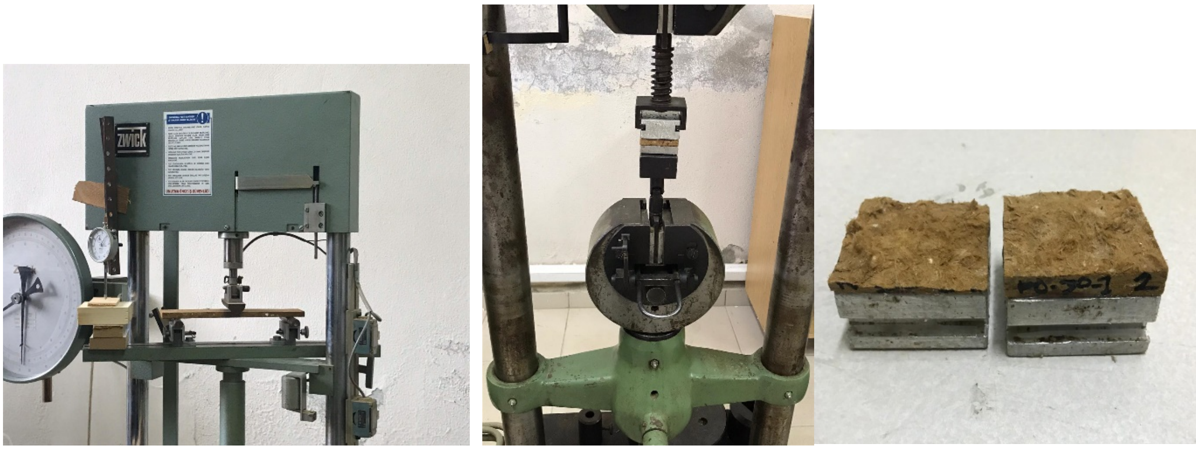

Figure 3. Mechanical tests of mycelium based MDF

3. Results and Discussions

The results section should detail the main findings and outcomes of your study. You should use tables only to improve conciseness or where the information cannot be given satisfactorily in other ways such as histograms or graphs. Tables and figures should be numbered serially and referred to in the text by number.

3.1. Physical Properties

The average values of physical properties results (water absorption (WA) and thickness swelling (TS) for 24 h) of MDF panels are represented in Table 1. Furthermore, the density values of mycelium based MDF panels ranged from 630 to 680 kg/m^3.

Table 1 Water absorption of mycelium based MDF

Incubation Period	UF content %	**WA %**	**TS %**
15 days	6	112.56 (13.61)	45.72 (4.55)
30 days	6	110.39 (5.78)	39.09 (3.47)

The results showed that incubation duration did not affect the water absorption percentage; however, thickness swelling decreased with increase in the incubation duration. The reason for this could be explained that the intensity and density of the mycelium/hyphea increases with the incubation duration. Therefore, mycelium binds more organic matter through a network of hyphal microfilaments which make difficult water molecules to bind organic material, in this case fiber. Haneef et al. (2017) reported that a low water uptake in mycelial mats is because of the hydrophobic nature of some fungal proteins and glycol-proteins, such as hydrophobins. Sun et al. (2019) developed and investigated novel hybrid panel composites based on wood, fungal mycelium, and cellulose nanofibrils. They found that the water absorption and thickness swelling of the mycelium-based composites they produced were around 120% and 70%, respectively.

3.2. Mechanical Properties

The average values for the modulus of rupture (MOR), modulus of elasticity (MOE) and internal bond strength (IB) of MDF panels are represented in Tables 2 and 3, respectively.

Table 2 MOE and MOR values of mycelium based MDF

Incubation Period	UF content %	**MOR** N/mm²	MO**E** N/mm²
15 days	0	3.84 (1.02)	408.73 (125.69)
15 days	6	3.33 (1.04)	514.15 (125.28)
30 days	6	7.15 (1.25)	848.92 (105.20)

The results showed that the highest MOR and MOE values were found for the mycelium based MDF produced from 30 days incubated fibers with 6% UF adhesive. The MOR value for the mycelium based MDF produced from 15 days incubated fiber with 6% UF was even lower than that of produced without adhesive. However, the MOE value for the mycelium based MDF produced from 15 days incubated fiber with 6% UF was lower. All the mycelium MDF investigated in this study did not meet required minimum strength values specified in the standard. Other researchers (Haneef et al. 2017; Sun et al. 2019) also reported that mycelium composite material's strength values were lower than the composites produced from virgin fiber/chips/particles mixed with higher amount of adhesive. The reason for the lower strength values for he mycelium based MDF was that there was not sufficient adhesion among the fibers with mycelium network.

Table 3 IB values of mycelium based MDF

Incubation Period	UF content %	IB N/mm²
15 days	0	0.05 (0.01)
15 days	6	0.02 (0.01)
30 days	6	0.11 (0.03)

Table 3 shows that similar findings were found for internal bonding of the mycelium based MDF investigated in this study. The reason for the weak internal bonding strength clearly revealed that there was not sufficient adhesion among the fibers with mycelium network.

4. Conclusion

The results showed that the MOE, MOR and IB values of the mycelium based MDF were low and did not meet the minimum required strength values given in the standards. However, these boards may still be used as insulation materials.

5. Acknowledgments

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ECONOMIC ANALYSIS OF TOY INDUSTRY TODAY AND THE IMPORTANCE WOODEN TOY IN TURKEY AND ITS COMMERCIAL VOLUME

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Abstract

With the influence of organic life and ecological approach, which is becoming widespread in the world, the use of wood materials is increasing in toy production. This situation was noticed in the transition from the plastic toy, which contains the social changes and the negative health elements, to the wooden toy with healthy materials. In addition, wooden toys are preferred due to their sustainable properties. In this study, the studies on the development, definition, importance of the toy industry, the market data it created in years 2014-2018, its economic analysis, raw material properties and the application of these principles in the subgroup wooden toy were conducted.

As of 2018, 46.27 billion dollars of exports and 124.9 billion dollars of imports actualized worldwide. In Turkey, in general of the toy industry in 2018 despite the production of $ 97.6 million with down 34%, level of 262.9 million dollars imports, 32.8 million dollars exports with decline of 21% was realized. In the Wooden Toy sector, in the period of 2014, production was realized with a value of 3.1% in our country with a value of 23.7 million, imported toys from domestic market consumption received 77% in value, and domestic produced toys accounted for 23%. The EU countries are seen to be the most important foreign market for Turkey and they are targeted as market. On the other hand, for Turkey that appears to be a lower share of the world market in terms of production and trade of wooden toys, the situation of this sector that is open to investment and development creates the reasons of the research. With the data obtained as a result of the economic analysis and literature research, forecasts have been developed in order to raise the awareness of wooden toys in our country, to develop market conditions and to increase their qualifications.

This study, which is carried out by emphasizing the meaning, quantity and value of the wooden toy industry and also by determining its share in the toy industry, but also by associating it with the intra-sector market share, is capable of meeting the deficiency in the field.

Keywords: Toy, Wooden Toy, Healthy Toys, Economic Analysis

1. Introduction

Today, it is very important to increase awareness by ensuring functionality and continuity in wooden toy production and to contribute to the sector in the long term by improving design and innovation capability. In addition to this, with the importance of toys for child development and education, the use of healthy materials is extremely important. Therefore, healthy wooden toys should be preferred instead of toys being plastic etc. which may have the risk of having carcinogenic active substances in raw materials and dyestuffs.

Information from the earliest dates shows that the history of toys is as old as human history (Jackson, 2001). It is known that the first toys belong to Egyptians and there is a rich variety of toys (Yalçınkaya, 2004). After Anatolia which has a rich toy culture, was conquered by the Turks in the 10th century, the toy tradition has survived to the present day through cultural transfer (Akbulut, 2009). It can be said that toy making first appeared in Eyüp in the 17th century as an organized industry in Anatolia (Onur, 2005). Toy production based on wood has undoubtedly been the source of the toy industry (Demircan, 2005).

The re-rise of sustainability practices in wooden toys has been realized with the introduction of environmentalist approaches (Aydın, 2012). Therefore, they are preferred by processing its nature-friendly features, which are connected to its environmentalist structure, as they provide a safe and healthy game life (Tunç & Adıgüzel, 2020). Developing alternative strategies based on environmental and social principles with a multidisciplinary approach will be able to make wooden toys more effective in terms of sustainability.

In addition, social and economic conditions are also related to materials and production processes that are reflected through toys (Onur, 1991). Wood is generally an easy-to-use natural raw material. Various types have been used in the toy industry for many years because of its natural aesthetic structure, elasticity module and comfortable touch feeling (Friso et al., 2015). In addition, behaviors such as new consumption patterns, reuse and recycling in the sustainable design phase of wooden toys should be applied in life (Manzini and Vezzoli, 2002).

Different materials have been used in toy production since the earliest times and today plastic has taken its place as the most used material (Ak, 2006). However, the most striking factor about plastic toys was the detection of excess lead ratios in the paint on the outer surface of the toy (Bapuji & Beamish, 2007). For this reason, the suitable material to be selected for the toy must first of all be appropriate to the quality and quantity of the model it is used, to identify the material, to be used with other materials and to know its physical and chemical properties and its properties (Elibol et al., 2006).

The amount of harmful substances such as lead and cadmium in the structure of plastic etc. toys should be limited and determined according to standards (Aslan, 1997). Water-based paints used in coloring on exterior surfaces are more permanent and do not have flammable properties (Sönmez, 2000). At this point, more water-based paints should be preferred for coloring wooden toys (Elibol et al., 2006). In addition, it is stated that wooden toys can be colored with natural root dye and buckthorn, which are harmless with appropriate painting techniques, and also some colored tree species can be used (Koyuncu, 2017).

The sense of touch is important in discovering and learning and in this context, wood is superior to plastic due to the chemical coldness of plastic. At the same time, wood is accepted as a warm material as the manual connection of the wooden toy changes over time (Barthes, 1998). In recent years, due to the efforts of people to create healthy living conditions, a negative approach is seen in the market for plastic toys that damage the nature and adversely affect the environment with their reactions. As a result of these developments, the reflection on the wooden toy industry has been positive, depending on the philosophy of healthy life in the society and it has come to the fore as it is preferred in the market.

It was pointed out that the toys in the past supported the development of children more and that the materials used in this were especially natural (Metin et al., 2017). Wood, which is a natural material, is an organic-based material with fibrous and porous texture and an easily processable material with aesthetic structure due to its organic structure (Usta, 2016). Hardwoods are the best choice in the production of toys rated as educational, especially due to their high density, better wear resistance and good handling (Ebner & Petutschnigg, 2007; Wood Handbook, 2010). In addition, wooden toys survive through mass production techniques, reinterpretation of foreign forms, various ornaments and adapt to changing market conditions (Akbulut 2009).

A good toy is a solid, durable, useful, easy-to-care toy that does not come off quickly, does not have sharp, sharp corners and can be cleaned easily (Çamur et al., 2008). It is also important that the toy is qualified, not multiplicity. Toys to be given to children should be preferred starting from the simple level to the difficult (Arıkan and Karaca, 2004). Another important issue in toy selection is the safety issue of the toy (Özmert 2006).

In accordance with the Toy Safety Regulation, sector companies have very serious responsibilities. The Ministry of Commerce made a new regulation and determined the usage limits of some chemicals used in toys and children's equipment. In our country, amendments regarding chemical restrictions will come into effect after a year, with the regulation of the Ministry of Commerce and the industry manufacturers will comply with the usage values until December 2020.

According to the findings of the competitiveness research of the Turkish toy industry conducted on the basis of market data fort he period 2007-2018, the competitive power of the Turkish toy industry is low today (Tunç & Adıgüzel, 2020). Low toy consumption compared to developed countries shows that the potential demand for toys in Turkey is too much. When Turkey's toys import and export prices are examined, it appears that the price of import is lower than the price of export and while Turkey imports expensive toys while exports value-added exports. Turkey has 0.04% share of total World imports of toys in 2108. Turkey has 0.01% share of the World total toy exports in 2018 (Pageva, 2019).

The world market in the toy sector consists of brand owner companies, national branded companies, that include contract firms, distributors and toy sales points at which production is carried out. Toy stores and supermarkets are important points for sales in meeting the toy with the consumer. However, today, toys are meeting with consumers via informatics from the Internet (Pagev, 2019).

2. Materials and Methods

Using the content analysis study, Toy World and Turkey Sector, Turkey Wooden Toys and Toy Industry production volumes, export and import volumes were examined collecting both valid data and field qualitative data. The obtained data are classified and summarized within the framework of a specific problem or purpose, and primarily the collected data are conceptualized. It was ensured that the theme explaining the data was determined by making a logical arrangement according to these concepts. The necessary comparisons and proportions are given. The reason for the world in general and Turkey's toys and wooden toys worth taking the examination, the results making comparisons is to identify both perspectives.

3. Results

In order for companies operating in the toy industry to reach new markets and customers, it will be of great benefit to develop appropriate plans and strategies together with the conditions in the market in order to make realistic economic analyzes.

3.1. Status and Trade of Toy Market in the World

In order for companies operating in the toy industry to reach new markets and customers, it will be of great benefit to develop appropriate plans and strategies together with the conditions in the market in order to make realistic economic analyzes. Examining at the World Toy Trade, the world toy trade volume, which was 56 billion 775 million dollars in 2007, reached 96 billion 484 million dollars in 2018 and increased by approximately 70% (Trademap, 2019).

The import and export figures expressing the world market distribution and size for the period of 2014-2018 are shown in Table 1. When Table 1 is analyzed by years, it is seen that the total exports and imports of the world increased continuously during the period.

Table 1. Worldwide toy import and export values (Trademap 2019).

Years	2014	2015	2016	2017	2018	Variation%)
Import	45.23	45.23	46.68	49.12	50.21	11.01
Export	34.5	34.91	37.74	43.92	46.27	34.11

Total exports, which were 34.5 billion dollars worldwide in 2014, increased by 34.11% in 2018 and reached 46.27 billion dollars. In addition, total imports, which were 45.23 billion dollars worldwide in 2014, rose to 50.21 billion dollars in 2018 with an increase of 11.01%. The toy industry is seen as a growing market in the world.

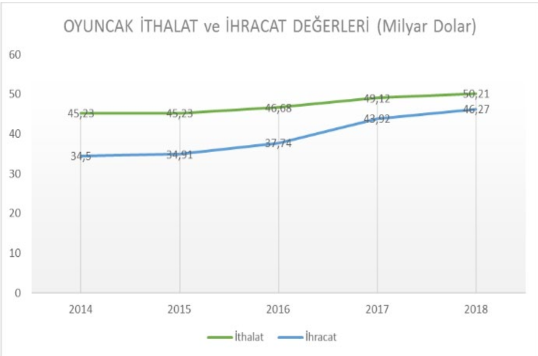

Figure 1. The status of the world toy market over the years

As seen in Figure 1, an increase rate of 11.01% in imports and 34.11% in exports is observed between 2014-2018. Considering the last 5 years, it is seen that especially in 2017, toy imports increased by 5% and exports by 14% compared to the previous year. However, compared to previous periods, 2018 shows a more steady increase and the rate is 2% in imports and 5% in exports.

The import and export figures of the 5 countries that make excessive import and export around the world in the period of 2014-2018 are included in Table 2. Considering the world in general, Europe, which has high import and export rates according to the volume ratios they create in the toy market, is the leading country, followed by the Far East countries. The USA follows these countries with the volume they create.

Table 2. Import and Export Countries for the World Toy Industry (Pagev 2019, Trademap 2019)

IMPORTER COUNTRIES			EXPORTER COUNTRIES		
Country	Value(billion$)	Share(%)	Country	Value(billion$)	Share(%)
The USA	34.4	27.6	CHINA	56.7	47.3
GERMANY	8.9	7.1	HONGKONG	7.2	6.0
JAPAN	6.4	5.1	The USA	6.8	5.7
ENGLAND	6.4	5.1	GERMANY	6.0	5.0
FRANCE	5.4	4.3	Czech Republic	3.6	3.0
Total of other countries	124.9	100	Total of other countries	119.9	100

Total toy import in the world was realized as 124.9 billion dollars in 2018 and 49.2% of the total imports were made by 5 countries USA, Germany, Japan, England and France. In the first place of the importer countries, the USA has a 30% share in the world total imports with its import of 14.75 billion dollars in 2018. Exports were realized as 119.9 billion dollars in 2018, 61% of total imports were made by 5 countries. China realized this export with a figure of 56.7 billion dollars and a high rate of 47.3%. China is also followed by the Far East country, Hong Kong.

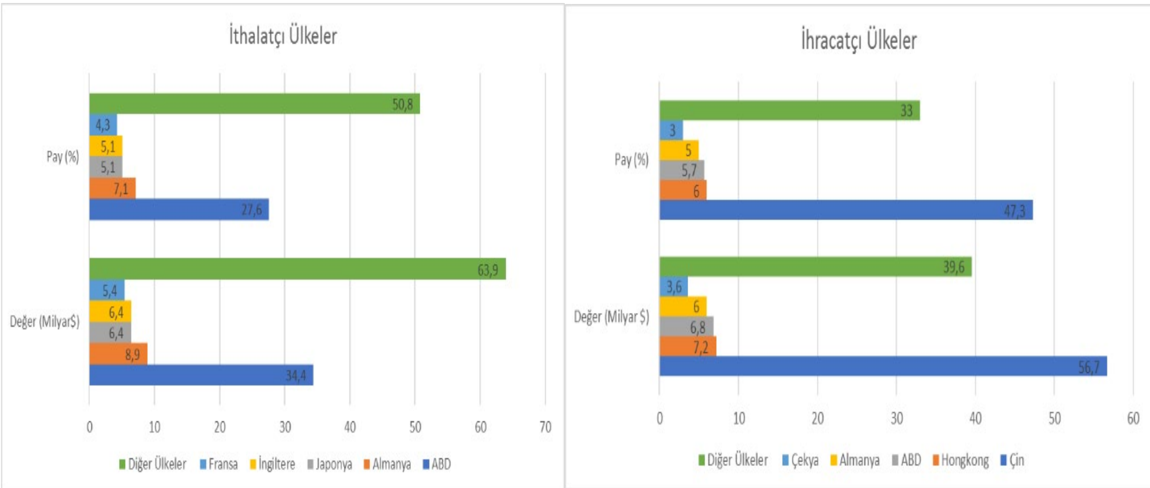

Figure 2: The toy market of the countries in the world market

As seen in Figure 2, the USA and Germany are the highest importers in terms of import and export value in the toy industry in the world, and they are in the 2nd and 3rd place after China, which has the highest export rate in the toy sector in terms of export value. On the other hand, other countries except Japan are in the European continent in the top 5 of the importing countries.

The data show us that Europe is the continent with the highest import rate and is the biggest potential buyer for our country's producers. Due to the position of Turkey, especially as logistics and quality processes are expected to receive a significant share of this market.

It is seen that the highest exporting countries in the world are China and Hong Kong in the Far East, these countries have reached these numbers with low raw material and labor costs, but they maintain their position despite their disadvantage in terms of logistics and quality.

3.2. Toy Industry Foreign Trade of Turkey

The most export from 10 countries during the period 2014-2018 exports by Turkey are set out in Table 5. Turkey's toy industry, taking into account countries with export and import data based on years 2014 and 2018 were examined.

Table 5. Turkey's toy exports by countries as of (Tredemap 2019; Bronze and Adıgüzel 2019)

	Export Cost (Thousand Dollar)									
Country	England	Iraq	Greece	Cyprus	Serbia	Iran	Italy	RF	Arabia	Germany	Total
2014	1419	2781	1.966	-	1324	523	1446	1735	848	788	41838
2018	2221	1935	1.871	1849	1559	1439	1412	1350	1322	1219	32829
Fark(%)	56	-31	-4.9	185	18	175	-2	-22	55	55	-21

As seen in Table 5; The export figure, which was 41.8 million dollars in 2014, was 32.8 million dollars in 2018, and a decrease of 21% is observed in exports. Considering the countries, there was no export for Cyprus in 2014, but it reached 1849 million in 2018 with an increase of 185%. When we look at the data of the UK in 2014 and 2018, it is observed that it is at the highest rate with an increase rate of 56%. Arabia and Germany follow England with an increase rate of 55%. As seen in the table,

European countries rank first in exports, followed by Middle Eastern countries. While making evaluations, it is observed that there is a fluctuating course in exports, as well as European countries lead the way.

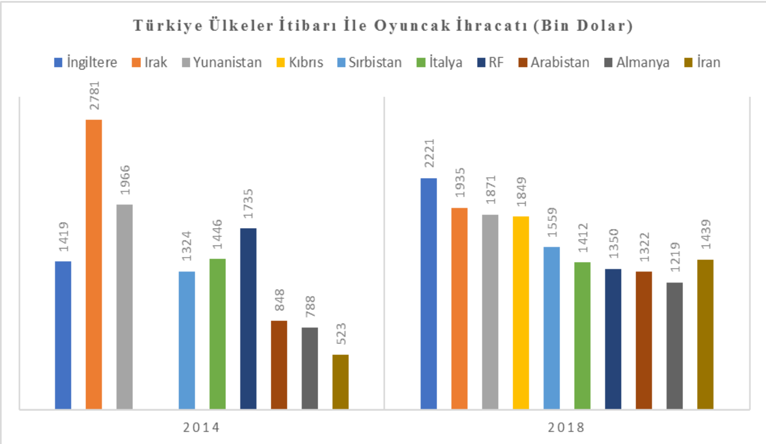

Figure 5. Toy export value of the country's reputation with Turkey

As stated in Figure 5; Turkey's toy industry exports 2014-2018 reputation is to be seen whether any country featured, $ 2.2 million with England in 2018 in total exports is the highest value of the first countries respectively Iraq, Greece, followed by Cyprus and Serbia.

Most of the imports carried out by 10 countries during the period 2014-2018 import figures as the value of Turkey are set out in Table 6. Turkey's toy industry for 2014 and 2018 based on the exchange rates are expressed examining their import rates.

Table 6. As of toy imports with countries Turkey (Trademap 2019; Bronze and Adıgüzel 2019)

	Import Cost (Thousand Dollar)									
Country	China	Indonesia	Vietnam	Czechia	Italy	Denmark	Hungary	Malesia	Tailand	Germany	Total
2014	351072	3264	2572	1045	4288	2854	288	2897	1390	2376	400600
2018	230690	6573	4337	4150	2742	2289	1686	1610	1385	886	262085
Fark(%)	-34	100	68	297	-36	-19	485	-44	-0,03	-62	-34

As seen in Table 6; Turkey's total imports during the period 2014-2018 has fluctuated. The toy import, which was 400.6 million dollars in 2014, was realized as 226.2 million dollars in 2018, and there is a decline in imports with a significant decrease of 34%. Turkey's total imports, China stands out as the most active countries. As of 2018, 230.69 million dollars of imports have been made from China. Another point that stands out in the table is that among the top 10 countries with the highest number of imports, apart from China, there are 4 Southeast Asian countries, namely Indonesia, Vietnam, Malaysia and Thailand.

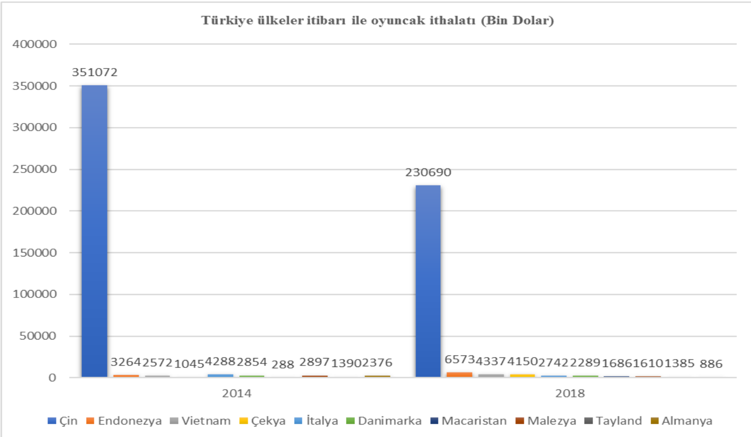

Figure 6. Turkey's toy import values with other countries

As indicated in Figure 6; In 2018, there was a 34% decrease in imports from China, but an increase in Indonesia and Vietnam, other Far Eastern countries. In addition, there was an increase of 297% in the Czech Republic and 485% in Hungary. it is seen that Turkey imports mainly in the Far East. A decrease is observed in the amount of imports from European countries, Italy, Denmark and Germany. The increase in imports from Far Eastern countries, which are said to be low in terms of quality and price, and the decrease in imports from European countries indicate that the move is price-oriented.

In 2018 due to shortage of negative economic indicators and problems related to rate, the toy market in Turkey has experienced some decline in both quantity and value. After the recession period it experienced, it had a tendency to grow again in 2019, and it is expected to slow down due to the world pandemic process and Kovid-19 disease experienced at the beginning of 2020.

The market grew by an average of 6 percent per year between 2013 and 2019. In 2018, toy production amounted to 19 thousand tons in quantity and 98 million dollars in value. 2019 was the year to make up for the losses in the sector. Production in the first half of the year was 11.7 thousand tons and 58.2 million dollars.

4. Discussion

4.1. Economic Situation of Toy Industry in Turkey

Turkey’s inability to achieve throughout the toy industry production in specialized areas, away from scattered production structure clustered without predominantly carries out its activities as a sector based on imports in the domestic market because of technological infrastructure and branding are not at the desired level.Despite the high import rate in recent years in Turkey, the expected value of the find began development trend in the toy industry for the last 5 years, the value and quantity of the production, import, export and domestic market sales data with foreign trade deficit and market share are shown in the statistics in Table 7 .

Table 7. Turkey Total Toy Production, Market and Supply-Demand Balance (Pagev 2019, Tüik 2019)

Years	2014		2015		2016		2017		2018	
	Quantity (Ton)	Million ($)	Quantity (Ton)	Million ($)	Quantity (Ton)	Million ($)	Quantity (Ton)	Million ($)	Quantity (Ton)	Million ($)
Production	20.9	158	18	126.1	19.4	135.3	19.7	145	18.9	97.6
Export	7,3	41,8	6.3	31.9	6.8	33.2	6.9	34.9	6.6	32.8
İmport	28.3	400.6	26.9	350.1	32.7	422.7	28.6	392.1	28.1	262.9
Foreign Trade Deficit	-21	-358.8	-20.6	-318.2	25.9	389.5	-21.7	-357.2	-21.5	-230.1
Domestic Consumption	41.9	516.8	38.6	444.3	45.3	524.8	41.4	502.2	40.4	327.7
İmport/Domestic Cons. (%)	67.5	77.5	69.6	78.7	72.1	80.5	69	78	69.5	80
Domestic market share(%)	32.5	22.5	30.4	21.3	27.9	19.5	31	22	30.5	20

Turkey's toy production as shown in table 7; While the amount was 20.9 tons in terms of amount and 158 million dollars on value basis in 2014, the amount decreased to 18.9 tons in 2018 and decreased to 97.6 million dollars. We can associate this decline with the economic crisis in 2018, which caused contraction in all sectors in the world. However, a total of 400.6 million dollars in 2014. Turkey imports the toy industry, exporting 41.8 million dollars and 516.8 million dollars in the domestic market consumption is realized, the industry has 358.8 million dollars in the foreign trade deficit. In 2018, 262.9 million dollars of imports, 32.8 million dollars of exports and 327.7 million dollars of domestic market consumption were realized, and the sector showed a foreign trade deficit of 230.1 million dollars and decreased in value.

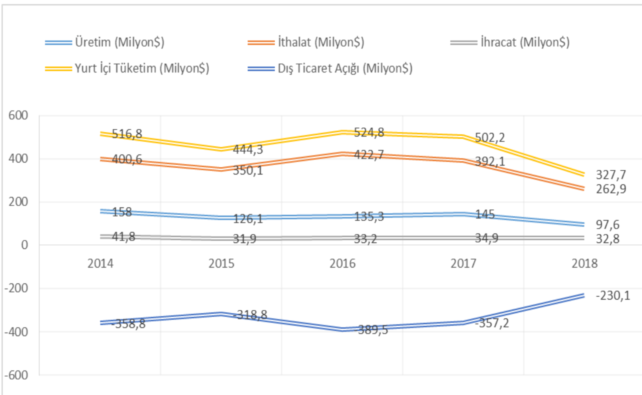

Figure 3: Turkey Total Toy Production, Market and Supply-Demand Balance (US $ Million)

As seen in Figure 3, despite the production of 158 million dollars in the toy industry in 2014, 401 million dollars of imports were realized. Domestic sales volume was 517 million dollars, while exports of 42 million dollars were made and production gained a share of 26% in the domestic market. In 2018, production declined to 98 million dollars and imports to 263 million dollars.

While the domestic sales volume decreased to 328 million dollars, the export amount was realized as 33 million dollars. Turkey's toy industry is a sector based mainly on imports. It is observed that it is in a process that increases its export-oriented activities with its infrastructure in international markets

4.2. Economic Analysis of Turkey's Wooden Toy Industry

The characteristics, preference reasons and technological processability of each of the raw materials from which the toy is made are very important for the sector. Accordingly, the manufacturer companies active in the world toy industry are named and classified according to the type of raw material they use in production. We can list these as plastic, fabric, plush, metal and wooden toys. Each of the toys separated according to the type of raw material used in production also has a commercial market.

The number of toy manufacturers operating in Turkey is seen as an industrial as 19 pieces. Among these companies, it manufactures wooden toys in the branded factory, which is established only in Düzce, for the market in industrial scale, as well as with the contract working principle in medium and large size workshops. In addition, it is observed that wooden toy manufacturers do not focus on certain regions throughout the country.

The total production of plastic toys in the toy industry in Turkey, imports and domestic consumption market, about 70% of the total toy production and imports, while exports accounted for approximately 90% (Pageva 2019). Among the total toy industry, wooden toys come with the highest rate after plastic toys. Wooden toy production, import and domestic market consumption constitute approximately 25% of the total amount of toys, and approximately 8% of the total amount of exports. These ratios were determined based on field and literature studies for toys other than plastic toys.

To be rich in tree species can be used as raw materials in manufacturing wooden toys in the wood sector in Turkey and grew up with wide infrastructure and manpower capabilities began to find the expected value. For these reasons, the statistics of production, import, export and domestic market sales as well as foreign trade deficit and market shares in the last 5 years in terms of quantity and value of the toy industry, which is in the development trend, are shown in Table 8.

Table 8. Turkey Wooden Toy Production, Market and Supply-Demand Balance

Years	2014		2015		2016		2017		2018		2014-2018 (%)	
	Quantity (Ton)	Million ($)	Quantity (Ton)	Million ($)	Quantity (Ton)	Million ($)	Quantity (Ton)	Million ($)	Quantity (Ton)	Million ($)	Quantity (Ton)	Million ($)
Production	5.22	39.5	4.5	31,52	4.85	33.82	4.92	36.25	4.72	24.4	-9.5	-38.2
Export	0.58	3,34	0.50	2.55	0.54	2.65	0.55	2.79	0.52	2.62	-10.3	-21.5
İmport	7.07	100.15	6.72	87.52	8.17	105.67	7.15	98.02	7.02	65.72	-0.01	-34.3
Foreign Trade Deficit	-6.49	-96.81	-6.22	- 84.97	-7.63	103.02	-6.60	- 95.23	-.6.50	-63.10	-0.01	-34.8
Domestic Consumption	10.47	129.20	9.65	111.07	11.32	131.2	10.35	125.55	10.10	81.92	-3.5	-36.5
İmport/Dom. Cons(%)	67.5	77.5	69.6	78.7	72.1	80.5	69.0	78.0	70.0	80.0	3.7	3.2
Domestic Market Share(%)	32.5	22.5	30.4	21.3	27.9	19.5	31.0	22.0	30.0	20.0	-7.6	-11

As seen in Table 48 imported toys have a share of 77.5% and locally produced toys have a share of 22.5% in the domestic market consumption in the wooden toy industry, which produced 5.22 tons and 39.5 million in 2014 in our country. In 2018, a decline was observed in the wooden toy industry in our country with a value of 4.72 tons and 24.4 million. Imported toys have a share of 80% and locally produced toys have a share of 20% in value from the domestic market consumption

It is observed that the production value of wooden toys has decreased over the years, albeit a little, and the import amount has increased. Between the years of 2014-2018, there was a decrease of 9.5% in terms of quantity, 38.2% in value, 10.3% in quantity, 21.5 in value in exports, and 0.01% in quantity and 34.3% in value in imports. However, there is an increase in domestic market consumption with a value of 3.2%.

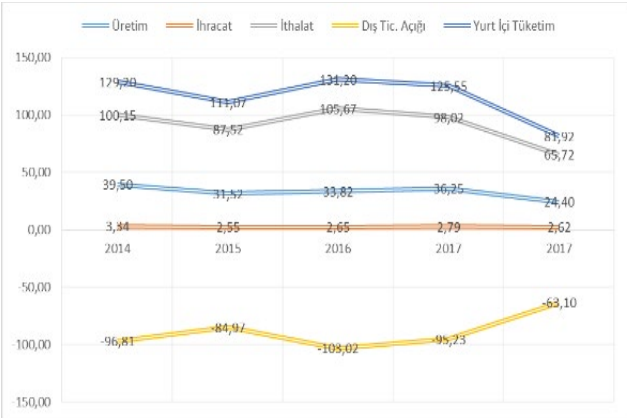

Figure 4. Turkey Wooden Toy Production, Market and Supply-Demand Balance ($ Million)

In Figure 4 as seen in manufacturing wooden toys Turkey, as the value of exports and imports, fluctuations in 2014-2017 but is noticeably seen a case in 2018 shows a decline. At the same time, it is seen that the foreign trade deficit grew at a noticeable level in 2018. In the year 2014-2018 in the amount of exports as compared to production in Turkey have made aint seen an increase.

5. Conclusion

The worldwide toy industry market grows with the development of changing preferences and technologies. It is observed that the toy companies in our country are in the development phase, their competitive power is generally low and they cannot get the desired market share in the world market. Negative consumer movements have occurred in Far Eastern toys due to negative thoughts on safety and health and changing market conditions. Turkey toy industry market is in development that will transform favor with advantages such as sources of raw materials, healthy products, skilled labor and logistics conditions of negative consumer requests that occur in the toy industry market

For the toy industry in the world, while exports were 34.5 billion dollars and imports were 45.23 billion dollars in 2014, exports reached 46.27 billion dollars and imports reached 50.21 billion dollars as of 2018, increasing in both markets. In the toy industry in 2014, Turkey's total imports of 400.6 million dollars, 41.8 million dollars of exports was realized, while in 2018 imports of 262.9 million dollars, it is observed decline in export market with 32.8 million dollars.

The sector in Turkey in 2014 158 million dollars in production, 358.8 million dollars in the foreign trade deficit and 516.8 million dollars the domestic market consumption took place, while in 2018, 97.6 million dollars of production, 230.1 million dollars in the foreign trade deficit and 327.7 million dollars, is the domestic market consumption have occurred, the sector has decreased in value.

In the developing Turkish Wooden Toy sector, 30.5 million dollars of production, 96.81 million dollars of foreign trade deficit and 129.20 million dollars of domestic market consumption were realized in 2014; internal market consumption has decreased in an equivalent sense to the toy industry. There is a contraction of 38.2% in production, 36% in domestic consumption, and the decrease in the purchasing power of individuals in 2018 has been seen as a reason.

The most important problem of the toy industry is that it has a large foreign trade deficit. When the data are examined, the toy industry; In 2018, there was a deficit of 21.5 tons and 230.1 million dollars. A deficit of 6.50 tons and 63.10 million dollars was provided in wooden toys. The reason for the significant foreign trade deficit in the market as the Turkish toy industry is expressed as the lower unit export price compared to the unit import price.

In our study, it has been determined that Turkish toy companies increase their market share not only in the domestic market, but also in European countries, which they consider very important for development and constantly increase their quality. When we look at the data of 2014 and 2018, it is observed that the toy export to England is at the highest rate with an increase rate of 56%. Britain is followed by Germany with a 55% increase rate and Serbia, Greece and Italy at lower rates.

It is seen that Turkey imports mainly in the Far East. A decrease is observed in the amount of imports from European countries, Italy, Denmark and Germany. Looking at 2018 data, China meets 88% of total imports with a value of 230.6 million dollars. When the results are evaluated, it is seen that uncontrolled imports from Far Eastern countries with high capacity and price advantages prevent the development of the domestic toy industry, cause many domestic brands to disappear, loss of employment and increase in the current account deficit.

Although the amount of wooden toys imported between 2014 and 2018 is close to each other, a decrease in the value corresponding to the amount is observed, especially in 2018. One of the factors that may cause this decline is the economic shrinkage process experienced in the world in 2018, and also the low quality that causes the imported toy products to be the same in quantity but low in price.

Along with the recently developed ecological life philosophy in the world toy industry, an important market is the toy market made of natural and healthy products. The most important and preferred one is toys made of wood, and these products have an increasing market share due to environmental and health concerns. The domestic wooden toy industry will not only provide employment and added value to our economy, but also contribute to our culture by gaining traditional production capability.

Low logistics cost should be used as an important advantage in the wooden toy industry, especially due to its proximity to the Middle East and EU markets. The market share will be increased by ensuring rapid adaptation to new models with toys for cultural and religious common values with the Middle East and the Turkic World.

With the fact that the conscious consumer will continue to increase, the number of consumers who demand transparency and expect loyalty to ethical values from the brands they buy their products are increasing day by day. For this reason, it should be ensured that the consumers who turn to wooden toys make the right decisions and have information about the product life cycle with the eco label placed on the product.

As a result, in achieving a healthy and secure quality of life for our children, investing in the production of wooden toys and development in Turkey it has emerged as a clear sector.

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POSTER PRESENTATIONS

LAND USE EVOLUTION OF MARITIME PINE IN THE CONTEXT OF LIFE CYCLE ASSESSMENT: A PORTUGUESE CASE STUDY

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Abstract

In a climate change scenario, the forestry sector faces important challenges globally and particularly in Continental Portugal, resulting in increased incidence of fires and the action of pathogens, which puts the sustainability of forest resources at risk.

Between 2005 and 2015 the forest area occupied by the maritime pine trees in Continental Portugal decreased by about 84700 hectares which is equivalent to -10.6% and the existing volume decreased by about 15 million cubic meters which corresponds to –18.4%.

Due to economic, social and environmental importance of Portuguese maritime pine forest, the objective of this work was to study the evolution of its land use environmental impact between 2005 and 2015.

The SimaPro software was used and the ILCD 2011 Midpoint+ method was chosen to assess the "land use" environmental impact.

Results show that land use impact category increases 9.6% during the studied period as a consequence of the variation in land occupation and forest production. The main contribution for results is forest land transformation into forest road (54%) followed by the forest occupation (40%). Forest road occupation represents only 6% and transformation from forest is a process with a slightly beneficial contribution (-0.3%) to the global result.

Keywords: Forest, Land use, Life cycle assessment, Maritime pine

1. Introduction

Currently, the forestry sector faces important challenges worldwide and particularly in Portugal, namely regarding the risks of sustainability of forest resources in the climate change scenario, with consequent increase in the incidence of fires and the action of pathogens.

The forestry sector has a high economic, social and environmental value in Portugal. In economic terms, in 2015, its Gross Value Added (GVA) represented more than 10 billion Euros, corresponding to 13% of industrial GVA and 3% of national Gross Domestic Product (GDP) (ICNF 2020 a). Forest products exports have been among the country's main exports, accounting in the current millennium for an average of 9% of the total exports, while the sector is only responsible for 4% of the imports (ICNF, 2019). In social terms, the forestry sector is responsible for creating about 94.3 thousand jobs (ICNF 2020 a) and in environmental terms, it contributes significantly to mitigating the effects of global warming by capturing a total of 333.92×10^6 ton CO_{2e} (data of 2015) (ICNF, 2020 b).

According to data from the last two National Forest Inventories, IFN5 and IFN6, (ICNF, 2020 b) in 2015, the Portuguese maritime pine forest (Pinus pinaster Ait.) occupied 713.3 thousands hectares (Kha), having been the forest ecosystems that one that presented the largest reduction (- 84700 ha) since 2005 and the volume of growing wood (i.e. from live trees) was 66.5 million cubic meters (Mm^3) which means a decrease of about 15 Mm^3 compared to 2005. This decrease in land use area and growing wood volume was mainly due to fires and pests, the most important being the nematode (*bursaphelenchus xylophilus*). During this period of time 228284 forest fires were recorded, which were responsible for a forest burnt area more than 492 thousands hectares (Pordata 2020).

Life cycle assessment (LCA) is a technique that addresses the environmental aspects and potential environmental impacts (e.g. land use) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal (i.e. cradle-to-grave) (ISO, 2006 a). LCA have been applied to evaluates the environmental impacts associated with the production of maritime pine wood in Portugal (Dias and Arroja 2012; Ferreira et al. 2020; González-García et al. 2014), but no one of them assessed the land use impact category.

The impact category 'land use' describes in LCA methodology the environmental impacts of land occupation and transformation for human purposes. Extensive research has been done on the impact category *land use* to enable the quantification of impacts of land occupation and land transformation on biodiversity, biotic production and soil quality (European Commission, Joint Research Centre, Institute for Environment and Sustainability 2011; Faragò et al 2019). In the International Reference Life Cycle Data System (ILCD) Handbook (European Commission, Joint Research Centre, Institute for Environment and Sustainability 2011) three midpoint models (ReCiPe, Milà i Canals and Baitz) and five endpoint methods (EPS2000, Eco-Indicator 99, ReCiPe, LIME and Swiss Ecoscarcity) were evaluated. At the endpoint level, no one is recommended by ILCD being the ReCiPe method suggested as an interim solution. At the midpoint level the method by Milà i Canals is considered the most appropriate among the existing approaches for Life Cycle Impact Assessment in the European context (European Commission, Joint Research Centre, Institute for Environment and Sustainability 2011). This method has a focus on soil quality, and its indicator describes the changes in soil organic matter (SOM) associated with land interventions (Milà ì Canals et al. 2007).

The goal of this study is to apply the life cycle assessment to evaluate the evolution on land use impact category of Portuguese maritime pine as a consequence of fires and pests between 2005 and 2015. The results of this study can be important to support future decision-making regarding the best management options for Portuguese forest planning.

2. Materials and Methods

The study was performed with the methodology recommended in the ISO 14040 (ISO 2006a) and ISO14044 (ISO 2006b) standards for Life Cycle Assessment.

2.1. Functional unit, System boundary and Inventory analysis

The functional unit (FU) in this study is given as 1 m^3 of maritime pine, standing in forest and the function of the system being studied is to produce maritime pine trees for different uses.

Figure 1 represents the system boundary for the product system being studied. The process included in the boundary is related with regeneration of maritime pine trees in the forest. The output is maritime pine standing in forest and the inputs are those related with the occupation and transformation of land.

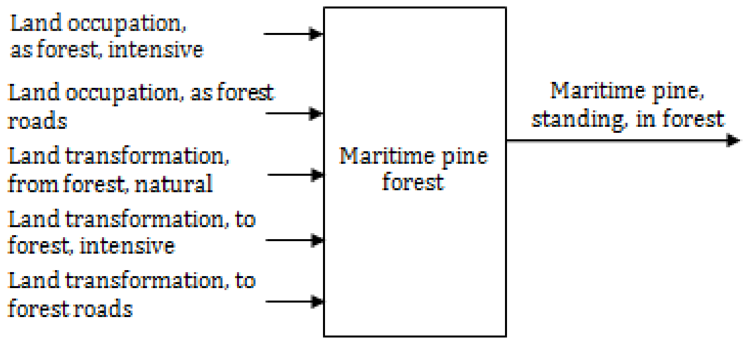

Figure 1 System boundary

The life cycle inventory data on maritime pine from plantations/managed natural forests in Portugal was based on the National Forest Inventory (IFN) (ICNF 2020 b) and others sources as illustrated in Table 1. The National Forest Inventory (IFN) is a process of statistical and cartographic nature, which allows assessing the temporal evolution of the state and the use of forest resources in Portugal. IFN5 and IFN6 report forest data for 2005 and 2015, respectively.

The life cycle inventory analysis has been performed with the help of SimaPro 9.1 software (PRé Consultant 2020).

Table 1 Datasets for land use/occupation and production of maritime pine (adapted from Werner et al 2007)

Nr.	Portuguese maritime pine	Mean value		Units	Source
		2005	**2015**		
1	Land occupation (IFN6) ($x10^3$)	798.0	713.3	ha	ICNF 2020 b
2	Volume (growing) (IFN5, IFN6) ($x10^6$)	81.558	66.52	m^3	ICNF 2020 b
3	Rotation length (time from birth/plantation to final tree harvest)	35		Years (yr)	AIFF 2013
4	Forest road length	71.3		m/ha	Faias et al. 2007
5	Forest road width	3.50		m	IC-EQUAL 2007
6	Forest road area	0.024955		m^2/m^2	Calculated [1]
7	Yield (including forest roads)	0.01022	0.00933	m^3/m^2	Calculated [2]
8	Yield (excluding forest roads)	0,01048	0.00957	m^3/m^2	Calculated [3]
9	Land use, forest	95.41	104.55	m^2/m^3	Calculated [4]
10	Land use, forest roads = Land transformation, forest road	2.442	2.676	m^2/m^3	Calculated [5]
11	Land occupation, forest	3339	3659	$m^2.yr/m^3$	Calculated [6]
12	Land transformation, forest	97.852	107.226	m^2/m^3	Calculated [7]
13	Land occupation, forest roads	85.46	93.65	$m^2.yr/m^3$	Calculated [8]

[1] Forest road area = (Forest road length x Forest road width)/10000
[2] Yield (including forest roads) = volume (growing) / Land occupation / 10000
[3] Yield (excluding forest roads) = Yield (including forest roads) / (1 - Forest road area)
[4] Land use, forest = Yield (excluding forest roads)$^{-1}$
[5] Land use, forest roads = Forest road area / Yield (including forest roads)
[6] Land occupation, forest = Land use, forest x Rotation length
[7] Land transformation, forest = Land use, forest + Land use, forest roads
[8] Land occupation, forest roads = Land use, forest roads x Rotation length

As we can see in Table1, land and production of Portuguese maritime pine decreased by 10.1% and 18.4%, respectively, between 2005 and 2015. The average standing volume of maritime pine per hectare is very low (102.2 $m^3.ha^{-1}$ in 2005 and 93.26 $m^3.ha^{-1}$ in 2015) with a still decreasing tendency.

Forests and forest roads are multifunction, like carbon sequestration, water storage, soil erosion prevention, landscape structuring, a place for recreation, etc., but in this study as in Werner et al (2007) the total forest area is allocated to the maritime pine.

With the help of SimaPro software, the data from Table 1 were used to build the inventory table. The results are illustrated in Table 2.

Table 2 Inventory table per functional unit (1 m^3 of maritime pine, standing, in forest)

Activity/Substance	Compartment	Subcompartment	Unit	Maritime pine, standing, in forest-(2005)	Maritime pine, standing, in forest-(2015)
Occupation, forest, intensive	Raw	land	m2a	3339.2	3659.3
Occupation, traffic area, rail/road embankment	Raw	land	m2a	85.46	93.65
Transformation, from forest, natural	Raw	land	m2	97.852	107.226
Transformation, to forest, intensive	Raw	land	m2	95.41	104.55
Transformation, to traffic area, rail/road embankment	Raw	land	m2	2.442	2.676

2.2. Life cycle impact assessment (LCIA)

Life cycle impact assessment (LCIA) translates the results of the inventory table into a limited number of environmental impact scores where one of them is land use. This is done by means of so-called characterization factors (CF) that indicate the environmental impact per unit of stressor (e.g. per m^3 of resource used).

LCIA was made with the help of SimaPro 9.1 software (PRé Consultant 2020) and the method chosen on the impact category *land use* was ILCD 2011 Midpoint+ V1.11 (PRé Consultant 2019) that uses the model by Milà i Canals et al. (2007) considered the most appropriate among the existing approaches by the European Commission-Joint Research Centre - Institute for Environment and Sustainability (2011) for Life Cycle Impact Assessment in the European context This method has a focus on soil quality, and its indicator describes the changes in soil organic matter (SOM) associated with land interventions. Indicator results are thus expressed as kilogram-C, reflecting changes in soil organic carbon (European Commission-Joint Research Centre - Institute for Environment and Sustainability 2012).

3. Results and Discussion

Land use impact assessment results (characterization) per functional unit (1 m3 of maritime pine, standing, in forest) for the years 2005 and 2015 using ILCD 2011 Midpoint+ V1.11 method is presented in Tab. 3. The comparative land use by substance is illustrated in Fig. 2.

Table 3 Land use impact (characterization) per functional unit using ILCD 2011 Midpoint+ method

Activity /Substance	Compartment	Sub-compartment	Unit	Maritime pine (2005)	Maritime pine (2015)
Occupation, forest, intensive	Raw	Land	kg C deficit	6678	7319
Occupation, traffic area, rail/road embankment	Raw	Land	kg C deficit	1026	1124
Transformation, from forest, natural	Raw	Land	kg C deficit	-1957	-2145
Transformation, to forest, intensive	Raw	Land	kg C deficit	1908	2091
Transformation, to traffic area, rail/road embankment	Raw	Land	kg C deficit	9157	10034
Total			kg C deficit	16812	18423

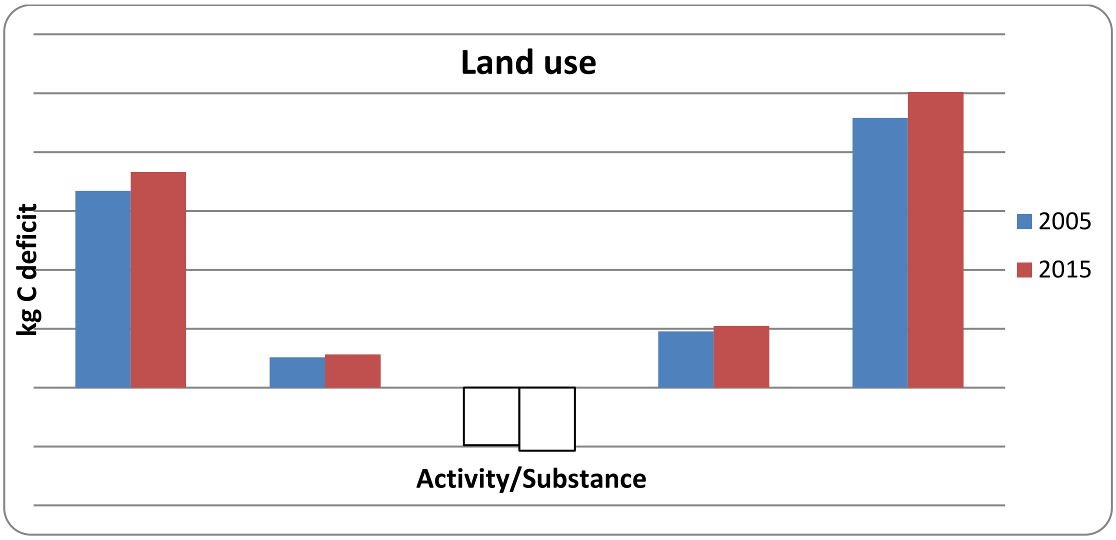

Figure 2 Comparative land use (by substance) of functional unit in 2005 and 2015 using ILCD 2011 Midpoint+ method. Acronyms: OFI (Occupation, forest, intensive); OTA (Occupation, traffic area, rail/road embankment); TFFN (Transformation, from forest, natural); TTFI (Transformation, to forest, intensive); TTTA (Transformation, to traffic area, rail/road embankment)

The results shown in Table 3 and illustrated in Fig. 2 refer to the impacts from activities on forest to produce 1 m^3 of maritime pine (FU) considering a rotation time of 35 years. The activities considered were: land (forest and forest road) occupation, land transformation from forest natural, and land transformation to forest intensive and to forest road.

Carbon deficit attributed to FU in 2005 was 16812 kg C deficit and 18423 kg C deficit in 2015. It means that the deficit in carbon increased of approximately 9.6% in this period of time. The impact category results are mainly due to transformation forest land into forest roads (transformation, to traffic area, rail/road embankment (TTTA)) representing 54 % of the total value followed by the occupation, forest, intensive (OFI) that represents approximately

40% and occupation of forest road (occupation, traffic area, rail/road embankment (OTA)) that accounts for 6%. The net value of land transformation, from forest natural into forest intensive and forest road is approximately -49 kg C deficit and -54 kg C deficit for 2005 and 2015, respectively that corresponds to the credit of land transformation from forest natural which is transformed into road. The carbon deficit attributed to land transformation, to forest, intensive (1908 kg C deficit in 2005 and 2091 kg C deficit in 2015) is equal to the credit attributed to the same quantity of land transformation, from forest, natural (--908 kg C deficit in 2005 and -2091 kg C deficit in 2015) so the sum of this two activities have a null effect on the global result.

Like in the Sandin et al. (2013) study, land use impacts from land transformation are much higher than impacts from land occupation.

4. Conclusion

This work proposed to study the evolution of land use impact category of Portuguese maritime pine forest between 2005 and 2015 using the ILCD 2011 Midpoint+ V1.11 method and the SimaPro software.

Results show that for the functional unit (FU, 1 m^3 of maritime pine, standing in forest) the deficit in carbon increased approximately 9.6% in this period of time. It was 16812 kg C deficit in 2005 and 18423 kg C deficit in 2015. Transformation forest land into forest roads (transformation, to traffic area, rail/road embankment) was the activity/substance that most contributed to the results, representing 54 % of the total value.

These results were expectable because during this period of time the maritime pine forest area presented a reduction of 84700 hectares and the volume of growing wood decreased of about 15 millions cubic meters. Fires and pests (mainly the nematode) played an important role in the results. During this period of time an average of 20753 forest fires per year were recorded, which were responsible for an average burnt area of more than 44.7 thousand hectares per year.

5. Acknowledgments

This work is financed by national funds through FCT - Fundação para a Ciência e Tecnologia, I.P., under the project UIDB/00681/2020. Furthermore we would like to thank the Instituto Politécnico de Viseu and CERNAS for their support.

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PSEUDOTSUGA BARK SUBERIN LIQUEFACTION IN POLYALCOHOLS

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Abstract

Douglas-fir (*Pseudotsuga menziesii*) outer bark is called a suberin-rich bark due to a significant amount of cork tissue. Although this cork tissue cannot be used for cork stoppers of other structural cork products since it is mixed with phloem, there is also the possibility of using this material by chemical conversion and use it as a source of chemicals. One of the most used chemical processes in the last years to liquefy lignocellulosic materials has been the liquefaction at moderate temperatures using a mixture of polyalcohols catalysed by acid or basic catalysts.

This work studies the possibility of using polyalcohol liquefaction to liquefy Douglas-fir bark and mainly its suberin fraction by alkaline catalysis. Liquefaction of bark was done in a reactor using glycerol/PEG (50/50) mixture catalysed by 0.9 g potassium hydroxide (KOH) at 180°C during 2 h. The reactor charge was 10 g of dried sample, bark/solvent ratio was 1/10. Suberin was extracted from a bark sample by use of methanolysis.

Results showed great differences in FTIR spectra between the initial material with and without suberin. The main differences were found to be the nearly disappearance of the peaks at 2919 cm-1, 2854 cm-1 and 1749 cm-1 (non-conjugated aliphatic esters) for the material without suberin. However, there was also a decrease in the peak at 1600 cm-1 (conjugates) and 1515 cm-1 (lignin) and at 1450 cm-1 and 1223 cm-1. In the solid residue after liquefaction we could observe a similar decrease in the suberin peaks, indicating that most of the suberin was liquefied.

Keywords: Bark, FTIR, Liquefaction, Pseudotsuga, Suberin.

1. Introduction

The outer bark of several woods has a significant amount of cork tissue like for example *Quercus cerris* (L. P. Cruz-Lopes et al., 2016) or *Betula pendula* barks (L. Cruz-Lopes et al., 2019). One of the major compounds of this cork tissue is suberin. Douglas-fir (*Pseudotsuga menziesii*) is one of such barks and might be an important source of chemicals once liquefied. As mentioned before by Graça and Pereira the suberin content of Douglas-fir bark is around 53%(Graça and Pereira, 1999) which is even higher than *Quercus suber* cork (Pereira, 1988). There have been numerous studies on the liquefaction of cork in the last years (Evtiouguina et al., 2002; Yona et al., 2014). Since *Quercus suber* cork has a high value, it is mostly used as a material to produce cork stoppers, flooring, cladding or other products with the solid bark. Only some dust resulting from the industrial process is available for liquefaction and production of chemicals. These cork-rich barks, although not suitable for cork industry, may be a good alternative to the production of chemical from suberin.

Attempts where made before to liquefy Pseudotsuga bark optimizing the process but no prove could be obtained about the extent of the suberin content of Douglas-fir bark liquefaction (Esteves et al., 2018). These authors stated that Pseudotsuga bark could be liquefied and that the higher the amount of KOH the higher the liquefaction yield with a maximum at around 6%. Also, the liquefaction yield increased both with the temperature and time of the liquefaction reaction, until a maximum was reached, decreasing afterwards. The present work focuses on confirming, by FTIR analysis, if liquefaction of suberin from Douglas-fir bark was achieved .

2. Materials and Methods

2.1. Materials

The bark of *Pseudotsuga menziesii* Mirb. Franco used in this work was collected from a 100-year-old tree, grown in Serra da Estrela, central region of Portugal. The barks were stored indoor in semidarkness and with good ventilation and dried at room temperature. Dried samples were milled in a Retsch mill SKI and sieved into three fractions: > 40 Mesh (0.425 mm), 40-60 Mesh and < 60 Mesh (0.250 mm). The 40-60 Mesh was used for the tests.

2.2. Methods

Before liquefaction, the samples were dried at 102 ± 2°C. Liquefaction was held on a double shirt reactor (Parr cylinder 600 ml LKT PED, Parr Instrument Company, IL, USA, heated with oil) using a mixture (glycerol/PEG = 1/1) and with 0.9 g KOH (Merck, Darmstadt, Germany) as additive. The reactor charge was 10 g of dried sample, bark/solvent ratio was 1/10. Liquefaction of bark was done at 180ºC during 2 h. The liquefied mixture was then dissolved in ca. 100 ml MeOH (Valente e Ribeiro, Belas, Portugal) and filtered over paper filter in a Buckner funnel and the liquefied material (Figure 1) was evaporated at reduced pressure in a rotary evaporator to remove water and MeOH. The residue was washed with water to remove excess glycerol and PEG and weighed to determine liquefaction percentage. Suberin was extracted from a bark sample by use of methanolysis and the remaining material was liquefied as stated before for normal Pseudotsuga bark.

Figure 4: Liquefied Pseudotsuga bark

Ftir ATR spectra of normal bark, desuberized bark, liquefied bark and solid residue were taken in a PerkinElmer UATR Two, FT-IR Spectrometer, Beaconsfield, UK. A resolution of 4.0 cm-1 was applied with seventy-two scans recorded in the range 4000–400 cm-1. The liquid was placed directly over the crystal covering completely the surface and the spectrum was taken, while for the solid samples after putting the powder over the crystal it was pressed before taking the spectrum

3. Results and Discussion

Figures 2 shows the FTIR spectra of initial Pseudotsuga bark before and after removing the suberin content and the solid residue obtained after liquefaction of normal bark with polyalcohols. Observing both spectra it is clear that the spectrum of initial Pseudotsuga after removing suberin is much similar to the spectra of the solid residue than the spectrum of original Pseudotsuga bark.

Results showed great differences in FTIR spectra between the initial material with and without suberin. The main differences were found to be the nearly disappearance of the peaks at 2919 cm-1, 2854 cm-1 and 1749 cm-1 (non-conjugated aliphatic esters) for the material without suberin. However, there was also a decrease in the peak at 1600 cm-1 (conjugates) and 1515 cm-1 (lignin) and at 1450 cm-1 and 1223 cm-1. In the solid residue after liquefaction we could observe a similar decrease in the suberin peaks. This similitude between initial Pseudotsuga after removing suberin and solid residue spectra indicate that most of the suberin was liquefied once the traditional suberin peaks are inexistent or significantly decreased.

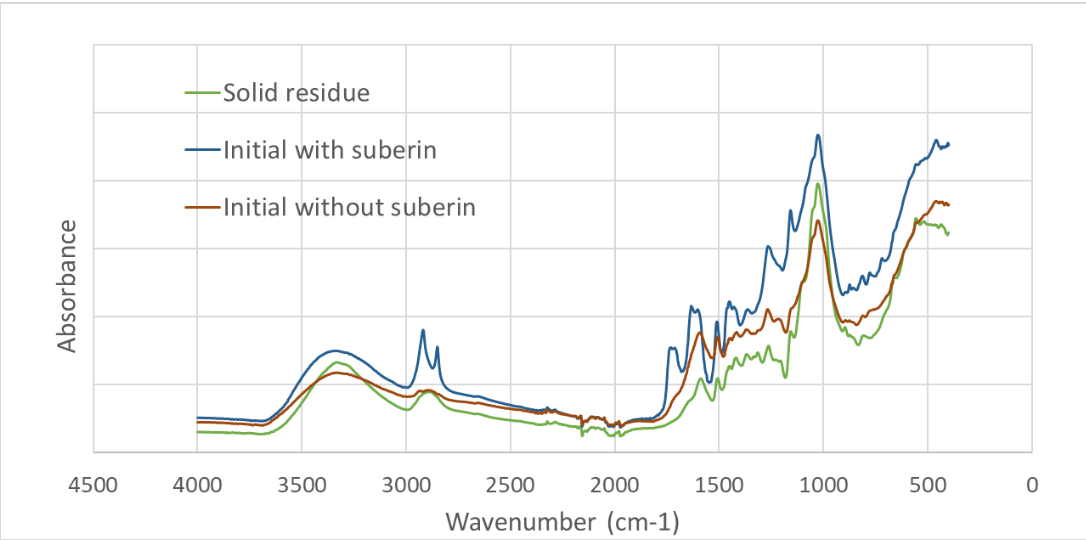

Figure 2: FTIR spectra of initial Pseudotsuga bark (with and without suberin) and solid residue after liquefaction

Figure 3 shows a comparison between liquefied Pseudotsuga bark and the solid residue. There are significant differences observed between both spectra. For instance, has expected the OH peak around 330 cm-1 is much higher in liquefied material due to the inclusion of the polyols used in the liquefaction process.

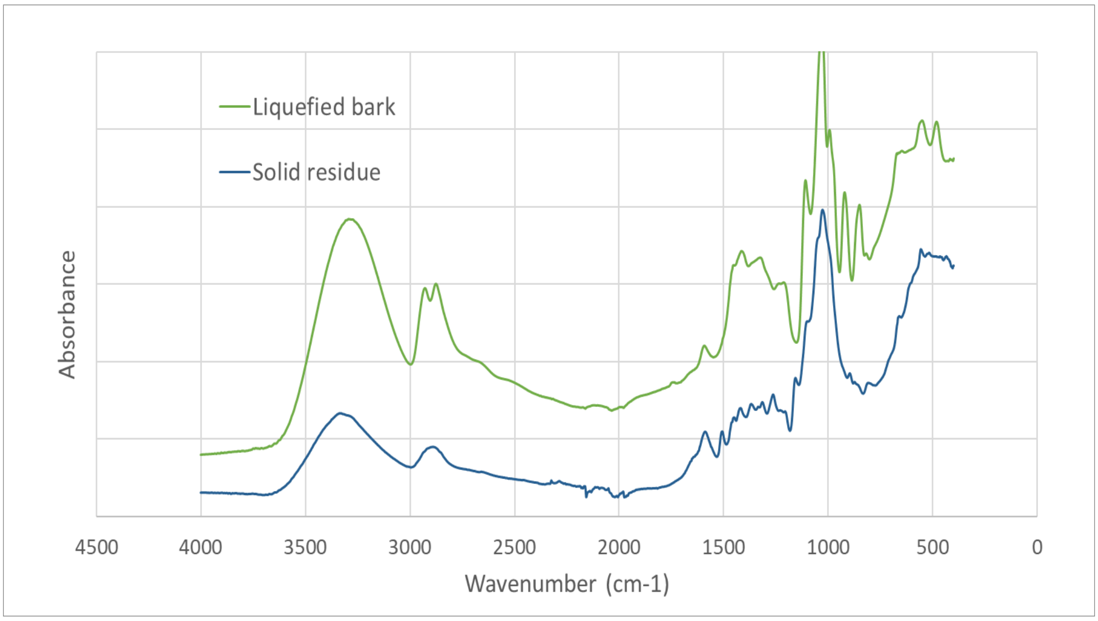

Figure 3: Comparison between liquefied Pseudotsuga bark and solid residue

4. Conclusion

Results have shown that suberin was successfully liquefied, proving that it is possible to liquefy cork-rich barks by polyols such as Douglas-fir (*Pseudotsuga menziesii*) outer bark, opening good opportunities to use this liquefied material to produce high valuable compounds.

5. Acknowledgments

This work is financed by national funds through FCT - Fundação para a Ciência e Tecnologia, I.P., under the project UIDB/00681/2020. Furthermore we would like to thank the Instituto Politécnico de Viseu and CERNAS for their support.

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LAND USE EVOLUTION OF EUCALYPTUS GLOBULUS IN THE CONTEXT OF LIFE CYCLE ASSESSMENT: A PORTUGUESE CASE STUDY

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Abstract

The eucalyptus globulus forest in Continental Portugal has shown a systematic increase over the last 50 years. In 20015 it was the species with the highest forest land occupation (845,000 hectares) representing 26.2% of the total Portuguese forest area. Although between 2005 and 2015 the occupation of the soil by eucalyptus globulus had grown about 7.5%, the existing volume increased slightly 0.2%. The wildfires had a strong impact on this with a total burnt area of 1.1 million hectares during this period.

Due to its economic value (national leader in exports of high added value) and social (contributes to the generation of thousands of jobs) this study aims to assess the evolution of the environmental impact of eucalyptus globulus in terms of land use between 2005 and 2015.

Life cycle inventory and life cycle impact assessment were done with the help of SimaPro software. The ILCD 2011 Midpoint+ method was chosen to assess the "land use" environmental impact.

Results show that land use impact category of functional unit (1 m3 of eucalyptus globulus trees, standing in forest) increased about 7.3% between 2005 and 2015. Transformation to forest road (from forest) is the process that most contributes for this impact category with approximately 78%. Forest occupation is the second most important process representing about 19.5% of the total impact category and forest road occupation represents only 3%. Transformation from forest is a process with a slightly beneficial contribution (-0.4%) to the total impact category.

Keywords: Forest, Land use, Life cycle assessment, Eucalyptus globulus

1. Introduction

Eucalyptus forest has existed in Portugal and Europe since the second mid-19th century and has shown a systematic increase in Continental Portugal over the last 50 years (CELPA 2016; ICNF 2020 a). According to National Forest Inventory (ICNF 2020 b) in 20015 eucalyptus globulus was the specie with the highest forest land occupation (845,000 hectares) representing 26.2% of the total Portuguese forest area. Although between 2005 and 2015 the occupation of the soil by eucalyptus globulus had grown about 7.5%, the existing volume increased slightly 0.2% mainly due wildfires. During this period of time an average of more than 44.7 thousand hectares (Kha) per year were burnt as a consequence of an average of 20753 forest fires per year (Pordata 2020). Furthermore the severity of wildfires in Portugal in 2017 with a total burnt area of more 539 Kha, equivalent to 500 Kha in forest space, comprising 329 Kha in forest stands and 170 Kha in scrublands (ICNF 2019), certainly caused an important degradation on the existing volume of eucalyptus. Forest fires like land conversion, tillage, overgrazing and soil erosion are anthropogenic causes of soil organic matter (SOM) loss (Brandão and Milà i Canals 2013).

Eucalyptus forest are multifunction systems that provide forest products (eg wood), non-forestry (eg essential oils) and environmental (eg carbon sequestration). Portuguese eucalyptus globulus is a leader in exports of goods with high national added value, contributes to the generation of thousands of jobs and creates value for forest owners and for the economic agents involved (CELPA 2016).

To assess the environmental impacts associated with the production of eucalyptus wood in Portugal the life cycle assessment (LCA) (ISO, 2006 a,b) have been applied (Dias & Arroja 2012; Dias et al. 2007; Lopes et al. 2003; Vieira et al. 2010), but no one of these studies assessed the land use impact category. Vieira et al (2010) only account for the direct land use (hectares) to produce 1 ton of paper from eucalyptus wood.

According achievements of Working Group 2 "Land Use" of COST Action E9 "Life Cycle Assessment of Forestry and Forest Products" (Doka et al 2002) far more than for other products, the assessment of impacts caused by land use is essential for the full assessment of forest products. Two different kinds of land use impact were identified: land use change (also called land use transformation); and land occupation. Land use change (transformation) is a man-made change of the land use from one type to another (e.g. from natural forest to intensive forest) and land occupation is continuous use of some area for a certain period of time for specified land use type (Doka et al 2002; Perminova et al 2016).

Extensive research has been done on the impact category *land use* to enable the quantification of impacts of land occupation and land transformation on biodiversity, biotic production and soil quality (European Commission, Joint Research Centre, Institute for Environment and Sustainability 2011; Faragò et al 2019; Perminova et al 2016).

In the International Reference Life Cycle Data System (ILCD) Handbook (European Commission, Joint Research Centre, Institute for Environment and Sustainability 2011) three midpoint models (ReCiPe, Milà i Canals and Baitz) and five endpoint methods (EPS2000, Eco-Indicator 99, ReCiPe, LIME and Swiss Ecoscarcity) were evaluated. At the endpoint level, no one is recommended by ILCD being the ReCiPe method suggested as an interim solution. At the midpoint level the method by Milà i Canals is considered the most appropriate among the existing approaches for Life Cycle Impact Assessment in the European context. This method has a focus on soil quality, and its indicator describes the changes in soil organic matter (SOM) associated with land interventions (Milà ì Canals et al. 2007).

keeping in mind the relevance economic, social and environmental of eucalyptus globulus, the aim of this study is to assess the evolution on land use impact category of Portuguese eucalyptus between 2005 and 2015. The results of this study can be important to support future decision-making regarding the best management options for Portuguese forest planning.

2. Materials and Methods

The methodology adopted in the study is the Life Cycle Assessment method recommended in the ISO 14040/44 (ISO 2006a; ISO 2006b) standards.

2.1. Functional unit, System boundary and Inventory analysis

The functional unit (FU) is given as 1 m^3 of eucalyptus globulus, standing in forest and the function of the system being studied is to produce eucalyptus trees for different uses.

The system boundary for the product system being studied is represented in Figure 1. The activities/substances included in the boundary are related with regeneration of eucalyptus trees in the forest. The output is eucalyptus trees standing in forest and the inputs are those related with the occupation and transformation of land.

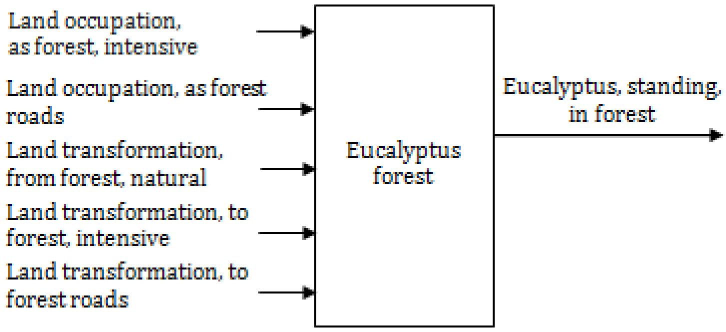

Figure 1 System boundary

The life cycle inventory data on eucalyptus trees from forests planted in Continental Portugal was based on the National Forest Inventory (IFN) (ICNF 2020 b) and others sources as illustrated in Table 1. The National Forest Inventory (IFN) is a process of statistical and cartographic nature, which allows assessing the temporal evolution of the state and the use of forest resources in Portugal. IFN5 and IFN6 report forest data for 2005 and 2015, respectively.

The life cycle inventory analysis has been performed with the help of SimaPro 9.1 software (PRé Consultant 2020).

Table 1 Datasets for land use/occupation and production of eucalyptus globulus in Continental Portugal (adapted from Werner et al 2007)

Nr.	Eucalyptus globulus	Mean value		Units	Source
		2005	2015		
1	Land occupation (IFN6) ($x10^3$)	785.9	845	ha	ICNF 2020 b
2	Volume (growing) ($x10^6$)	43.221	43.310	m^3	ICNF 2020 b
3	Rotation length (time from birth/plantation to final tree harvest)	12		Years (yr)	Almeida 2008
4	Forest road length	71.3		m/ha	Faias et al. 2007
5	Forest road width	3.50		m	IC-EQUAL 2007
6	Forest road area	0.024955		m^2/m^2	Calculated 1)
7	Yield (including forest roads)	0.0055	0.005125	m^3/m^2	Calculated 2)
8	Yield (excluding forest roads)	0,005641	0.005256	m^3/m^2	Calculated 3)
9	Land use, forest	177.281	190.253	m^2/m^3	Calculated 4)
10	Land use, forest roads = Land transformation, forest road	4.537	4.869	m^2/m^3	Calculated 5)
11	Land occupation, forest	2127	2283	$m^2.yr/m^3$	Calculated 6)
12	Land transformation, forest	181.818	195.122	m^2/m^3	Calculated 7)
13	Land occupation, forest roads	54.447	58.431	$m^2.yr/m^3$	Calculated 8)

1) Forest road area = (Forest road length x Forest road width)/10000
2) Yield (including forest roads) = volume (growing) / Land occupation / 10000
3) Yield (excluding forest roads) = Yield (including forest roads) / (1 - Forest road area)
4) Land use, forest = Yield (excluding forest roads)$^{-1}$
5) Land use, forest roads = Forest road area / Yield (including forest roads)
6) Land occupation, forest = Land use, forest x Rotation length
7) Land transformation, forest = Land use, forest + Land use, forest roads
8) Land occupation, forest roads = Land use, forest roads x Rotation length

Although land occupation of eucalyptus increased 7.5% the production increased slightly 0.2%, between 2005 and 2015 as we can see in Table1. The yield (average standing volume of eucalyptus per hectare) is very low (55 $m^3.ha^{-1}$ in 2005 and 51.25 $m^3.ha^{-1}$ in 2015) with a still decreasing tendency.

In this study as in Werner et al (2007) the total forest area is allocated to the eucalyptus even though forests and forest roads are multifunction, like carbon sequestration etc.

With the help of SimaPro software, the data from Table 1 were used to build the inventory table. The results are illustrated in Table 2.

Table 2 Inventory table per functional unit (1 m^3 of eucalyptus, standing, in forest)

Substance	Compartment	Sub-compartment	Unit	Eucalyptus, standing, in forest (2005)	Eucalyptus, standing, in forest (2015)
Occupation, forest, intensive	Raw	land	m2a	2127	2283
Occupation, traffic area, rail/road embankment	Raw	land	m2a	54.447	58.431
Transformation, from forest, natural [1)]	Raw	land	m2	181.818	195.122
Transformation, to forest, intensive	Raw	land	m2	177.281	190.253
Transformation, to traffic area, rail/road embankment	Raw	land	m2	4.537	4.869

[1)] Transformation, from forest, natural = Transformation, to forest, intensive + Transformation, to traffic area, rail/road embankment.

2.2. Life cycle impact assessment (LCIA)

Life cycle impact assessment (LCIA) translates the results of the inventory table into a limited number of environmental impact scores where one of them is land use. This is done by means of so-called characterization factors (CF) that indicate the environmental impact per unit of stressor (e.g. per m^3 of resource used).

LCIA was made with the help of SimaPro 9.1 software (PRé Consultant 2020) and the method chosen on the impact category *land use* was ILCD 2011 Midpoint+ V1.11 (PRé Consultant 2019) that uses the model by Milà i Canals et al. (2007) considered the most appropriate among the existing approaches by the European Commission-Joint Research Centre - Institute for Environment and Sustainability (2011) for Life Cycle Impact Assessment in the European context This method has a focus on soil quality, and its indicator describes the changes in soil organic matter (SOM) associated with land interventions. Indicator results are thus expressed as kilogram-C, reflecting changes in soil organic carbon (European Commission-Joint Research Centre - Institute for Environment and Sustainability 2012)

3. Results and Discussion

Land use impact assessment results (characterization) per functional unit (1 m3 of eucalyptus, standing, in forest) for the years 2005 and 2015 using ILCD 2011 Midpoint+ V1.11 method is presented in Tab. 3. The comparative land use by substance is illustrated in Fig. 2.

Table 3 Land use impact (characterization) per functional unit using ILCD 2011 Midpoint+ method

Activity /Substance	**Compartment**	**Sub-compartment**	**Unit**	**Eucalyptus (2005)**	**Eucalyptus (2015)**
Occupation, forest, intensive	Raw	Land	kg C deficit	4255	4566
Occupation, traffic area, rail/road embankment	Raw	Land	kg C deficit	653	701
Transformation, from forest, natural	Raw	Land	kg C deficit	-3636	-3902
Transformation, to forest, intensive	Raw	Land	kg C deficit	3545	3805
Transformation, to traffic area, rail/road embankment	Raw	Land	kg C deficit	17015	18260
Total			kg C deficit	21832	23430

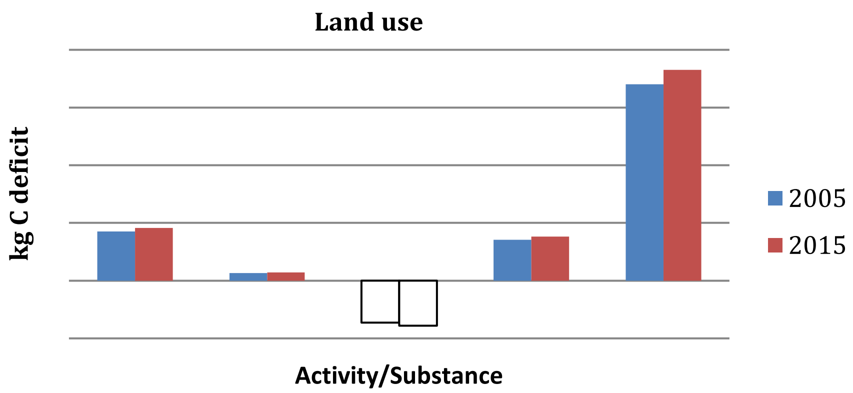

Fig. 2 Comparative land use (by substance) of functional unit in 2005 and 2015 using ILCD 2011 Midpoint+ method. Acronyms: OFI (Occupation, forest, intensive); OTA (Occupation, traffic area, rail/road embankment); TFFN (Transformation, from forest, natural); TTFI (Transformation, to forest, intensive); TTTA (Transformation, to traffic area, rail/road embankment)

The results shown in Table 3 and illustrated in Fig. 2 refer to the impacts from activities on forest to produce 1 m^3 of eucalyptus globulus (FU) considering a rotation time of 12 years. The activities considered were: land (forest and forest road) occupation, land transformation from forest natural, and land transformation to forest intensive and to forest road. Carbon deficit attributed to FU in 2005 was 21832 kg C deficit and 23430 kg C deficit in 2015. It means that the deficit in carbon increased of approximately 7.3% in this period of time. The impact category results are mainly due to transformation forest land into forest roads (transformation, to traffic area, rail/road embankment (TTTA)) representing 78 % of the total value followed by the occupation, forest, intensive (OFI) that represents approximately 19.5% and occupation of forest road (occupation, traffic area, rail/road embankment (OTA)) that accounts for 3%. The net value of land transformation, from forest natural into forest intensive and forest road is approximately -91 kg C deficit and -97kg C deficit for 2005 and 2015, respectively that corresponds to the credit of land transformation from forest natural which is transformed into road. The carbon deficit attributed to land transformation, to forest, intensive (3545 kg C deficit in 2005 and 3805 kg C deficit in 2015) is equal to the credit attributed to the same quantity of land transformation, from forest, natural (-3145 kg C deficit in 2005 and

-3765 kg C deficit in 2015) so the sum of this two activities have a null effect on the global result.

4. Conclusion

This work proposed to study the evolution of land use impact category of Portuguese eucalyptus forest between 2005 and 2015 using the ILCD 2011 Midpoint+ V1.11 method and the SimaPro software.

Results show that for the functional unit (FU, 1 m^3 of eucalyptus globulus, standing in forest) the deficit in carbon increased of approximately 7.3% in this period of time. It was 21832 kg C deficit in 2005 and 23430 kg C deficit in 2015. Transformation forest land into forest roads (transformation, to traffic area, rail/road embankment) was the activity/substance that most contributed to the results, representing approximately 78 % of the total value. Like in the Sandin et al. (2013) study, land use impacts from land transformation are much higher than impacts from land occupation.

These results were expectable because during this period of time the eucalyptus forest area increased by 7.5% and the production (volume growing) increased slightly 0.2% which represents a reduction of 6.8% in the yield (including forest roads). Forest fires (an average of 20753 per year) that burnt an average of more than 44.7 thousand hectares per year between 2005 and 2015 were probably the main responsible for the reduction in the eucalyptus yield.

5. Acknowledgments

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BIOCELLULOSIC MATERIAL IN PEELS OF IPOMOEA AND MONALISA POTATO

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Abstract

Sweet potato (Ipomoea potato), island potato, jatica or jetica is a plant of the family of convolvulaceae, of the order of Solanales (the same of potato, tomato, peppers, etc.) originating in the Andes and spread throughout the tropics and subtropics of the world. It has a good percentage of nutrients, is rich in vitamins A, C, E, B6, B12 and D and minerals such as calcium, iron, magnesium and potassium. The common potato (Monalisa potato) was used as a comparison enabling a better knowledge about the different benefits of each one. The main types of common potato are: monalisa, asterix, yacon, baraka, bintje, àgata, markies, cupid, caesar and mondial and sweet potato: purple, white sweet potato. The potato has a low amount of fat and contains B and vitamin C vitamins, phosphorus (in good quantity), iron, potassium, calcium and is an important source of starch.

This work aims to characterize the chemical composition of the peel from Ipomoea potato and Monalisa potato in order to understand the possible benefits of the peel from these products,

Regarding the chemical composition, ash content, extractives (in dichloromethane, ethanol and in methanol- water), proteins, cellulose, tannins, lignin and hemicelluloses were determined in triplicate using the 40-60 mesh fraction following Tappi T 264 om-97.

The studies carried out for the chemical composition of the common potato peel allowed us to conclude that the peel consists mainly of proteins (31.62%), tannins (21.45%) and extractable in methanol: water (17.39%), also presenting hemicelluloses (13.38%), ash (5.77%), lignin (5.91%) and cellulose (2.42%). Relative to the sweet potatoes peel allowed to conclude that the bark consists mainly of tannins (30.33%), proteins (19.45%) and extractable in methanol: water (16.26%), also presenting cellulose (9.85%), ash (7.27%), lignin (6.90%) hemicelluloses (6.06%).

Keywords: *Ipomoea potato peel, Monalisa potato peel*, chemical composition, biocellulosic material.

1. Introduction

In recent years, scientists have tried to find a solution to value waste by turning it into value-added products. Lignocellulosic residues have been used by several authors in recent years (Cruz-Lopes et al. 2016b, a, 2017) for this purpose. In this work, the authors used a new residue in an attempt to find a solution that would reduce potato peel waste (PPW).

Common potato (Monalisa potato) has low amounts of fat and contain b-complex vitamins and vitamin C, phosphorus (in good quantity), iron, potassium, calcium and are an important source of starch (Barker e Bárbara, 2020). Common potato peel waste (CPPW) consists essentially of 1% to 2% fiber and simple sugars, such as glucose, fructose and sucrose, ranging from 0.1% to 0.7% (Embrapa, 2015). Sweet potato (Ipomoea potato) is a root that has high nutritional content, high concentration of carbohydrates, minerals, sugars and vitamins A, C and those of b complex, varying its composition with cultivation, climatic conditions, harvest time, conditions and storage duration. When harvested it presents about 30% of dry matter containing on average 85% carbohydrates, whose main component is starch. During storage, part of the starch converts into soluble sugars, reaching 13.4% to 29.2% of starch and 4.8% to 7.8% of total sugars, 2.0 to 2.9% of protein, 0.6 to 1.7% of ash, 1.3 to 3.8% of crude fiber and 0.3 to 0.8% of fat (Glória 2009). During storage, part of the starch converts into soluble sugars, reaching 13.4% to 29.2% of starch and 4.8% to 7.8% of total sugars, 2.0 to 2.9% of protein, 0.6 to 1.7% of ash, 1.3 to 3.8% of crude fiber and 0.3 to 0.8% of fat (Glória, 2009).

According to the Food and Agriculture Organization of the United Nations (FAO), more than 368 million tons of potatoes were produced in 2018 worldwide, representing 47 million tons in America (about 12.66%) and 105 million ton in Europe (about 28.57%), and this amount continued to increase annually (Food and Agriculture Organisation 2020). Taking into account that waste from the potato industry accounts for approximately 27% of the weight produced. PPW can be used as a natural source of antioxidants that could otherwise create problems related to disposal, leading to environmental pollution; possible solutions to reduce its environmental impact have been studied (Schieber et al, 2001; Guechi and Hamdaoui 2016). The decomposition of potato peel is very fast and is generally used to feed the animals (Maske and Satyanarayan 2012). This residue has a wide range of biological properties, such as antioxidant, antibacterial, apoptotic, chemopreventive and anti-inflammatory properties (Wu 2016). The main components of PPW are generally water, starch, cellulose, hemicellulose, fermentable sugars, lignin, proteins, polyphenols and alkaloides (Liang and McDonald 2014; Liang et al 2014; Chintagunta et al. 2016; Guechi and Hamdaoui 2016). This is increasingly studied due to its rich nutrients and the presence of polysaccharides. Polysaccharides extracted from potato peel are considered to have an important potential value in the food or pharmaceutical field. The peel carries nutrients such as iron, calcium, potassium, magnesium, vitamin B6 and vitamin C in large quantities. For example, 100 grams of potato peel contains seven times more calcium and 17 times more iron than the same amount of the potato itself. The sweet potato peel waste (SPPW) is filled with a significant amount of beta carotene, which converts to vitamin A during digestion (de Francisco et al. 2019). Despite the difference between potato and sweet potatoes, both are rich in carbohydrates, antioxidants and fiber (Liang and McDonand 2014; Salawu et al. 2015).

2. Materials and Methods

2.1. Materials

The samples used were common potato (Monalisa potato) and Sweet potato (Ipomoea potato) supplied by companies in the Tondela region, Figure 1.A and B, respectively.

(A) (B)

Figure 1 CPPW (Monalisa potato) (A); SPPW (Ipomoea potato) (B).

The samples were milled in a Retsch SMI mill and sieved in a Retsch AS200 for 20 minutes at a speed of 50 rpm. Four fractions > 40 mesh (> 0.420 mm), 40-60 mesh (0.420 - 0.250 mm), 60 – 80 mesh (0.250 - 0.177 mm) and < 80 mesh (< 0.177 mm) were obtained and dried at 105°C for at least 24 hours afterwards.

2.2. Methods

The methods used to determine the chemical composition of sweet and common potato peels were repeated at least three times for each essay.

The determination of moisture content consisted of the determination of the mass loss of 1 g (±0.0001 g) of a sample of 40 mesh fraction , which was placed in an oven at 105 ± 3 °C around 3 h. The determination of the ashes consists of incinerating in a muffle at 525°C for 3 hours. A 10 g fraction sample of 40 mesh was used. In this study the determination of the extractable content was made using a Soxhlet apparatus, 10 g of sample was used and extracted sequentially with solvents of increasing polarity: dichloromethane (6 h), ethanol (16 h) and water (16 h). The protein content was determined by 5 g (± 0.0001 g), of a 40-mesh fraction sample, free of extractables, with a solution of 1% pepsin, in 0.1 M of HCl. The resulting solution was left in the bath for 16 h, at 37°C, with constant agitation. Then the solution was filtered with hot water until neutralization and the resulting residue was dried at 60°C, until constant weight. The determination of the tannin content is performed by the treatment of 4 g (± 0.0001 g), of a fraction sample of 40 mesh, free of extractables and proteins with 200 mL of NaOH solution, at 0.3 % (m/v). The resulting mixture was kept in reflux under a nitrogen atmosphere for 1h. The extracted material is filtered and washed with hot water until neutralization and dried at 60°C, until constant weight. In the lignin content, 0.7 g (± 0.0001 g), free from extractables, proteins and tannins, is used, and then the Klason method, described in the Standard TAPPI T222 om-88, which quantifies lignin as a solid residue was used. This method consists of the direct determination of lignin, based on its isolation, by hydrolysis in sulfuric acid (72%). According to specialized literature, there are other acids that can be used for hydrolysis, but have as a consequence the alteration of the structure of lignin (Sjöström, Eero, 1992, pp. 71-89).

To determine the cellulose content, approximately 1g (± 0.0001g) of sample (fraction of 40 mesh) free of extractables, which was first treated with a mixture of nitric acid and ethanol (1:4, v/v) is used. Then, the sample was refluxed in 50 mL of nitric acid and ethanol solution for 3 hours. Every hour, the supernatant was removed by decanting and 50 mL more of nitric acid and ethanol solution (1:4, v/v) was added. The insoluble residue obtained at the end of 3 hours is filtered in a G2 glass crucible and washed with hot water until neutralization. The hemicelluloses content was determined by difference.

3. Results and Discussion

In order to verify the constitution of the existing components in the common potato and sweet potato, a complete chemical characterization of these two peels was made. The results obtained are shown in Figure 1.

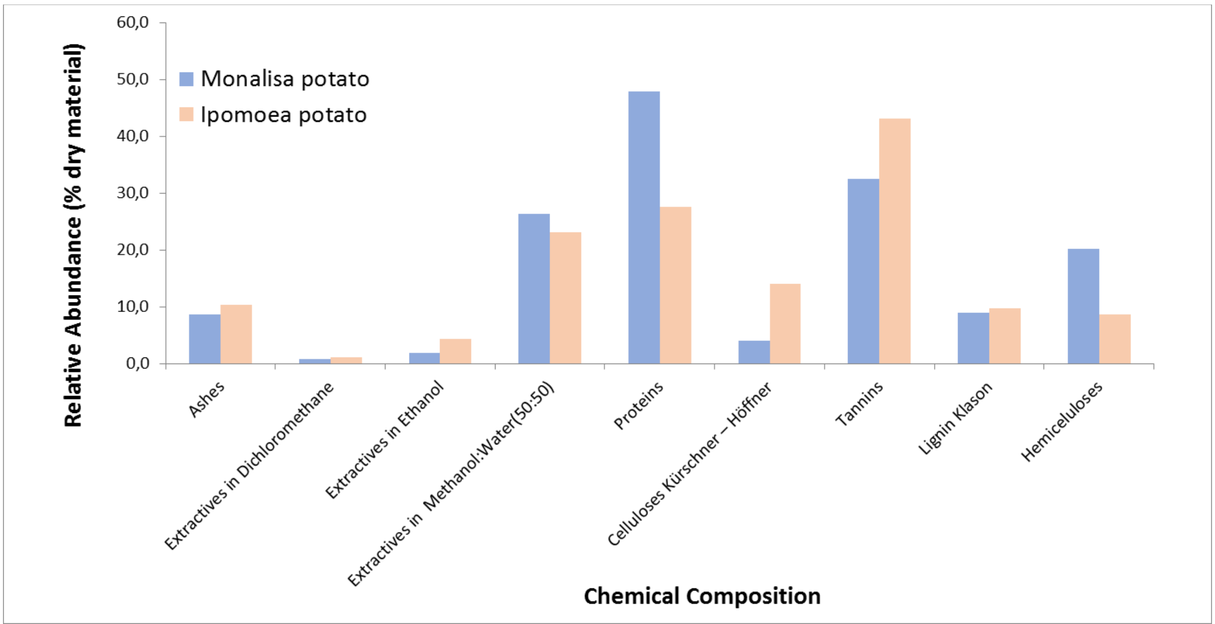

Figure 1: Chemical composition of CPPW and SPPW (% dry matter).

The analysis in Figure 1 shows that the CPPW consists primarily of proteins (about 32%), tannins (about 22%) and extractives in methanol: water (about 17%) while SPPW consists primarily of tannins (about 30%), proteins (about 20%) and extractives in methanol: water (about 16%). The lack of data in the bibliography in relation to the analyses performed did not allow comparing the values obtained. The high percentage presented of this residue in tannins offers good perspectives for its possible application as antidotes in heavy metal and alkaloid poisoning; external astringents: healing, hemostatic, protective and re-epithelializing and internal route: antidiarrheics; antiseptics; antioxidants; (due to their complexing effect, they decrease the absorption capacity of iron).

4. Conclusion

The realization of these studies, aimed to take advantage and value the CPPW and SPPW Resultsshow that this raw material has components that allow to increase its degree of use as raw material. The studies for the chemical composition of the CPPW allowed us to conclude that the peel consists mostly of proteins (31.62%), tannins (21.45%) and extractable in methanol: water (17.39%), also presenting hemicelluloses (13.38%), ash (5.77%), lignin (5.91%) and cellulose (2.42%). The studies for the chemical composition of the SPPW allowed us to conclude that the peel consists mostly of tannins (30.33%), proteins (19.45%) and extractable in methanol: water (16.26%), also presenting cellulose (9.85%), ash (7.27%), lignin (6.90%) hemicelluloses (6.06%).

5. Acknowledgments

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