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FOREWORD

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

The purpose of this congress was to provide an up-to-date discussion in the field of forest products in general. ORENKO 2018 was 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 2018 is a credit to a large group of people, and everyone should be proud of outcome. We would also like to take this opportunity to express our sincere gratitude and thanks to our congress sponsors once again. Without their supports, it would not have been possible for us to organize this congress successfully.

Finally, we would like to specially thank to Prof. Dr. Bülent VEREP, Editor in Chief of the journal and Co-Editors in Chiefs Prof. Dr. Fikri BALTA and Prof. Dr. Turan YÜKSEK for providing an opportunity to bring out this special issue which composed of some selected papers of the conference.

Assoc. Prof. Dr. Engin Derya GEZER, Section Editor of the JAES
Chair of the ORENKO 2018 Congress

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ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

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, concentration, fire-retardant, mechanical properties, plywood, retention level.

Yangın Geciktirici Kimyasallarla Emprenye Edilmiş Kontrplakların Retensiyon Miktarları ve Mekanik Dirençlerinin Yapay Sinir Ağları ile Tahmin Edilmesi

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Öz: Yangın geciktirici kimyasallar ile emprenye işlemi, ahşap ve ahşap esaslı ürünlerin yangından korunmasında çok etkili bir işlemdir. Bu yüzden, yangın geciktirici kimyasalların kullanımı tüm dünyada artmaktadır. Ancak, yangın geciktirici kimyasallar, uygulanmış oldukları malzemelerin fiziksel, mekanik ve diğer bazı teknolojik özellikleri üzerinde bir etkiye neden olmaktadır. Bu çalışmada ilk olarak, ağaç türlerinin ve konsantrasyon miktarlarının kaplamaların retensiyon miktarları üzerindeki etkilerini incelemek için yapay sinir ağı (YSA) ile retensiyon miktarı tahmin modeli geliştirilmiştir. Daha sonra YSA ile geliştirilen mekanik direnç tahmin modeli ile ağaç türleri, konsantrasyon miktarları ve retensiyon miktarlarının kontrplağın mekanik özelliklerine etkileri araştırılmıştır. En iyi performansa sahip tahmin modelleri, istatistiksel ve grafiksel karşılaştırmalarla belirlenmiştir. YSA modellerinin kabul edilebilir sapmalarla oldukça tatmin edici sonuçlar verdiği görülmüştür. Sonuç olarak, bu çalışmanın bulguları, deneysel araştırmalar için zaman, enerji ve maliyeti azaltmak için orman ürünleri endüstrisinde etkin bir şekilde kullanılabilecektir.

Anahtar kelimeler: Konsantrasyon, kontrplak, mekanik özellikler, retensiyon miktarı, yangın geciktirici, yapay sinir ağları.

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 (Yao et al., 2012; He et al., 2014).

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.

MATERIALS AND METHOD

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 in 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 (g)
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.

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 were 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.

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

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

(3)

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

In Equations 2, 3 and 4, *ti* is the actual output values, *tdi* 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.

Wood Species	Fire-Retardant Chemicals	Concentration Aqueous Solution (%)	Retention Level (kg/m^3) Actual	Predicted	Error (%)
Training Data					
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					
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**	

Figure 1 shows the ANN models containing one input layer, one or two hidden layers and one output layer. The selected ANN models represent 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.

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)		
				Actual	Predicted	Error (%)	Actual	Predicted	Error (%)	Actual	Predicted	Error (%)
Training Data												
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**	

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.

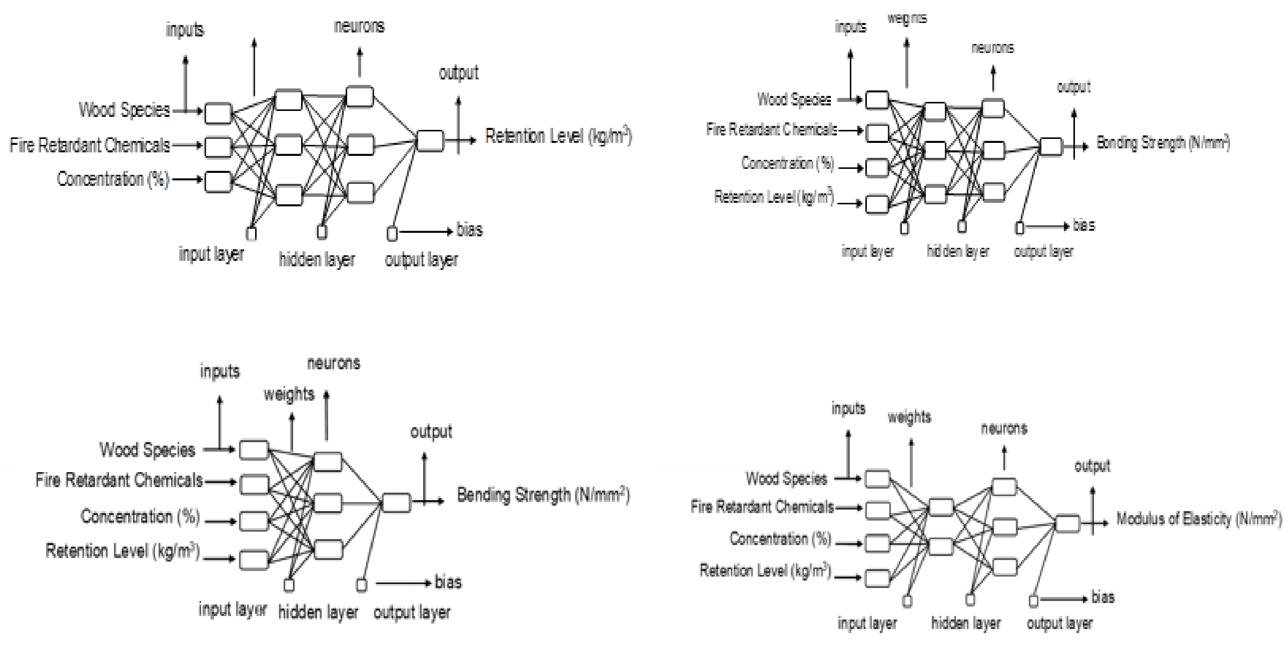

Figure 1. The ANN architecture selected as the prediction models.

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.

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

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.

$$\mathbf{X_{norm}} = \mathbf{2} \times \frac{\mathbf{X - X_{min}}}{\mathbf{X_{max} - X_{min}}} \mathbf{- 1} \qquad (6)$$

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.

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 3 and 4 show 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.

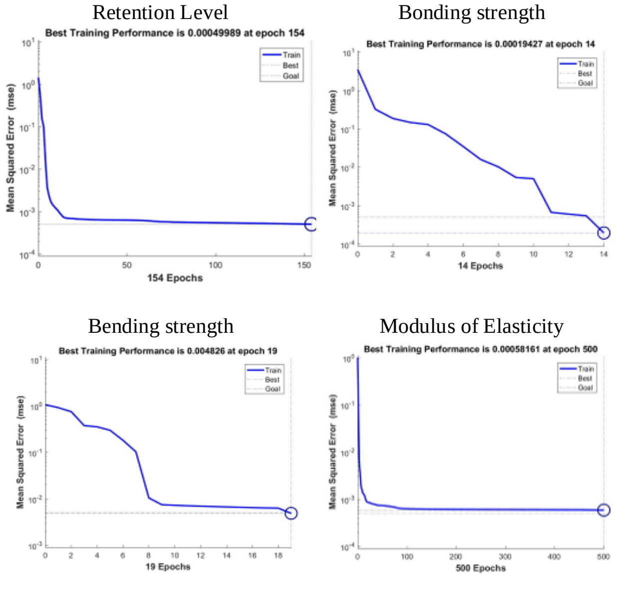

Figure 2. A plot of error variation depending on iteration of the ANNs.

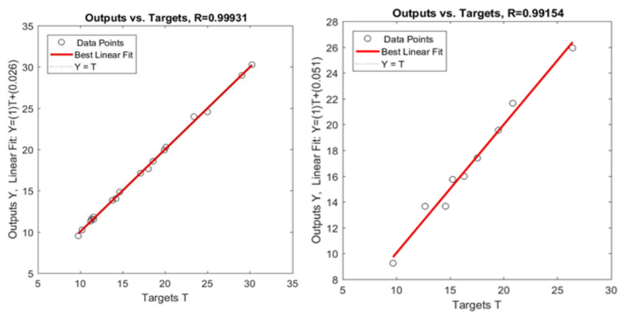

Figure 3. The relationship between experimental results of retention level and ANN predicted results.

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 prediction. 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.

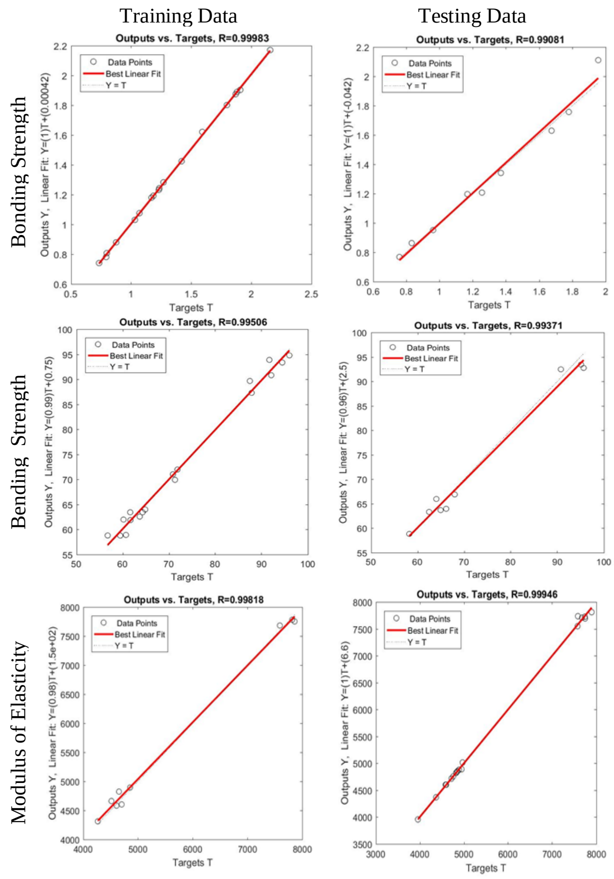

Figure 4. The relationship between experimental results of mechanical strength and ANN predicted results.

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

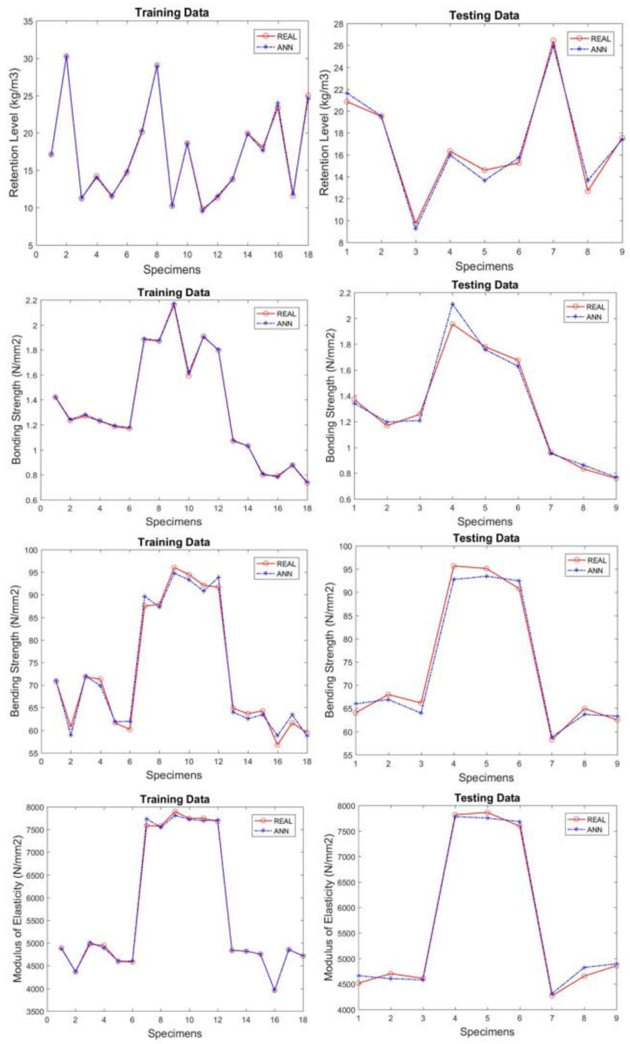

Figure 5. The comparison of the real and calculated values.

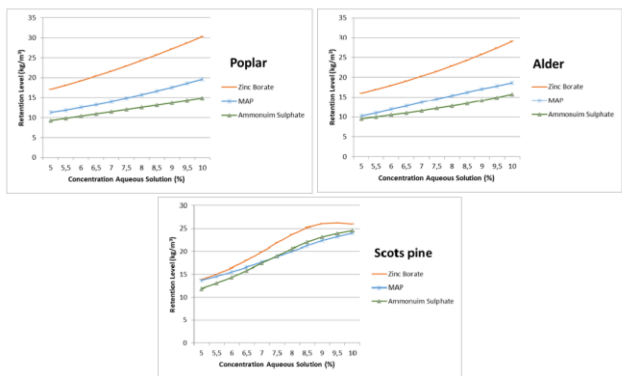

Figure 6. The change of retention level with increasing concentration of aqueous solution.

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 & 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)

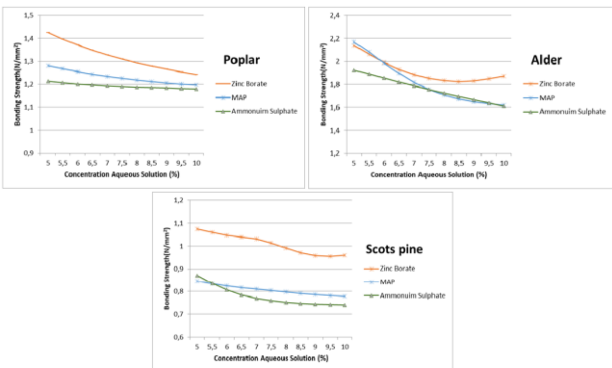

Figure 7. The change of bonding strength with increasing concentration of aqueous solution.

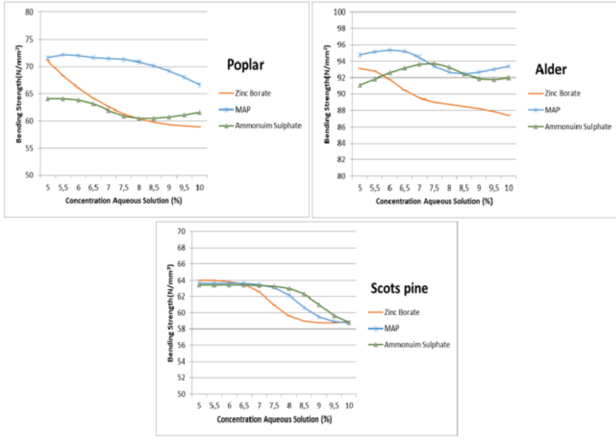

Figure 8. The change of bending strength with increasing concentration of aqueous solution.

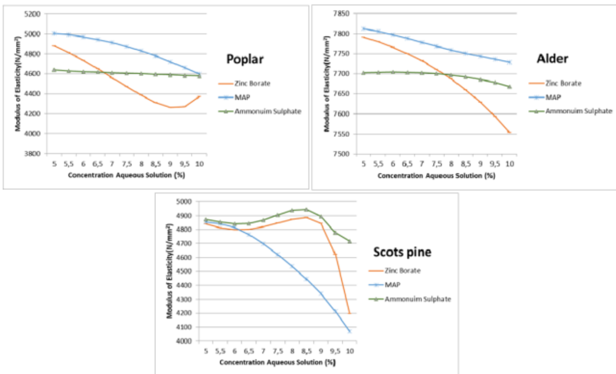

Figure 9. The change of modulus of elasticity with increasing concentration of aqueous solution.

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.

CONCLUSIONS

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 result 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.

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. This study was presented in ORENKO 2020 held by Karadeniz Technical University, Trabzon.

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ARAŞTIRMA MAKALESİ RESEARCH PAPER

Investigation of The Effect of Building Material Selection and Design Style on Kiln Thermal Properties in Solar Kilns

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Abstract: The negative effects of intensive energy consumption in timber drying on costs and environmental pollution have strengthened the tendency to utilize solar energy in recent years. Although drying of timber in flat collector solar furnaces 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 was evaluated in terms of thermal properties. Materials with different thermal capacities create different thermal properties in different designs. Therefore, it is possible to control the course of the temperature distribution in the solar timber drying oven throughout the day with the choice of different building materials and design forms.

Keywords: Building material, drying, solar kiln, thermal properties.

Güneş Fırınlarında Yapı Malzemesi Seçimi ve Tasarım Stilinin Fırın Isıl Özelliklerine Etkisinin İncelenmesi

***Sorumlu yazarın:**
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Öz: Kereste kurutmada yoğun enerji tüketiminin maliyetlere ve çevre kirliliğine olumsuz etkileri son yıllarda güneş enerjisinden yararlanma eğilimini güçlendirmiştir. Düz toplayıcılı güneş fırınlarında kerestenin kurutulması klasik kurutmaya oranla fazla zaman almasına rağmen enerji maliyetleri düşük ve olumsuz çevresel etkileri yoktur. Bu çalışmada güneş fırınlarının tasarımında kullanılacak yapı malzemelerinin ve tasarım şeklinin seçimi ısıl özellikler bakımından değerlendirilmiştir. Farklı ısıl kapasiteye sahip malzemeler farklı tasarım şeklinde farklı ısıl özellik oluşturmaktadır. Dolayısıyla, farklı yapı malzemesi ve tasarım şekli seçimi ile güneş enerjili kereste kurutma fırınında gün boyu sıcaklık dağılımının gidişinin kontrolü mümkün olabilmektedir.

Anahtar kelimeler: Güneş fırınları, kurutma, termal özellikler, yapı malzemesi.

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.,1974; 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.

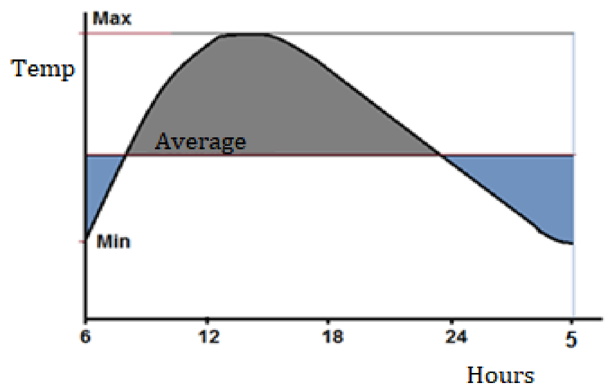

Figure 1. Hourly change graph of temperature in solar furnace.

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.

MATERIALS AND METHOD

Materials: 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 30º and 25.5 m^2 slope of 60º (Üçüncü,1995).

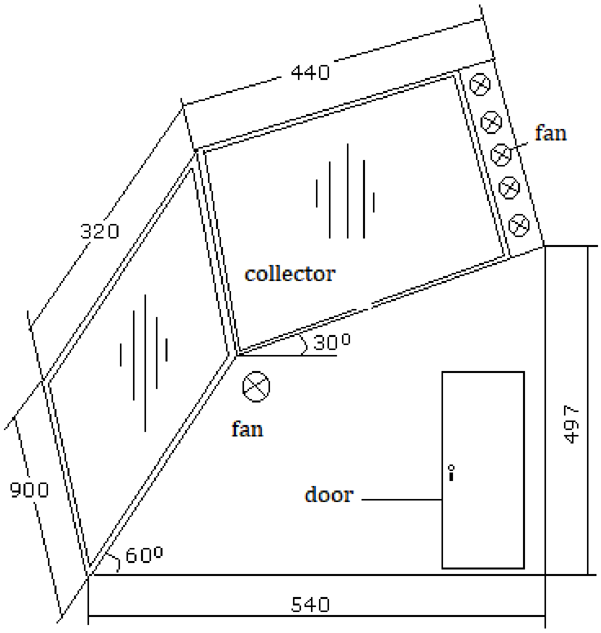

Figure 2. Solar furnace.

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

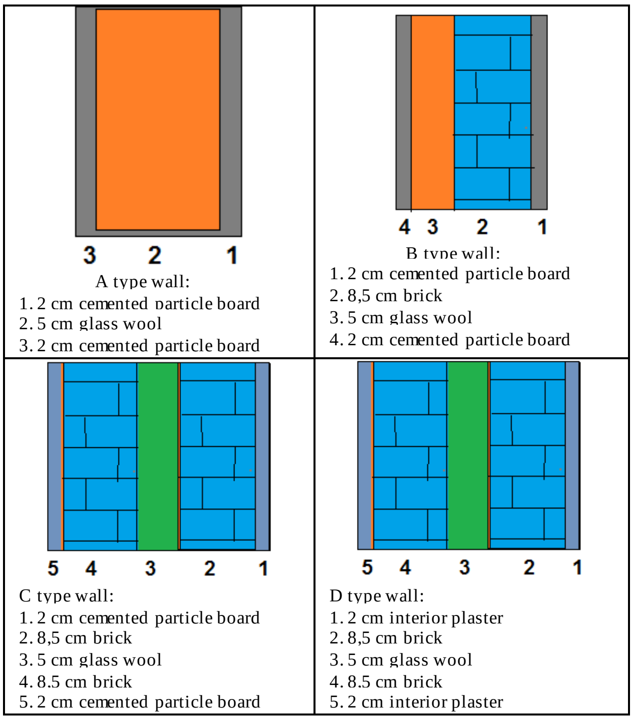

Figure 3. Wall design and building materials

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

$$Qg = \eta\ Ac\ Ie \quad (2)$$

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

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

Lost heat

$$Qk = K\ Ad\ (t_i - t_o) \quad (4)$$

Table 1. Hourly solar radiation coming to the collector surface in Trabzon and monthly average values of outdoor temperature, Ie (W/m^2).

Months	Hours																								Total	Tempreture (°C)
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5		
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), ∑mCp 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/m^2 °C), Ad is the furnace wall area (m^2). Based on the equations given, the following equation is obtained for the oven temperature.

$$t_i = \frac{\eta\ Ac\ Ie + \sum mCp\, t_{i-1} + KAd t_o}{\sum mCp + KAd} \quad (5)$$

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 m^3 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:

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

For wall type B:

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

For type C wall:

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

For wall type D:

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

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 6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5	t1	S1	MAX	MİN	CI
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.

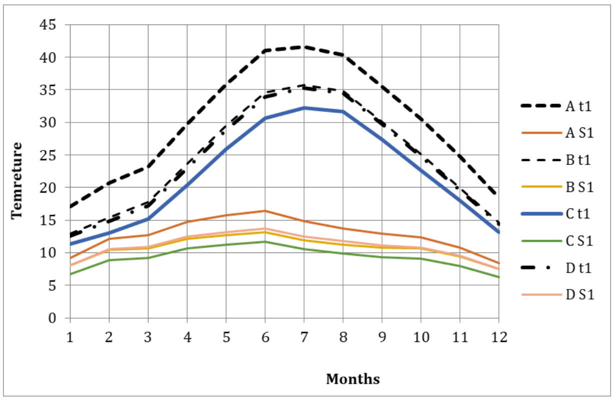

Figure 4. Monthly average temperatures.

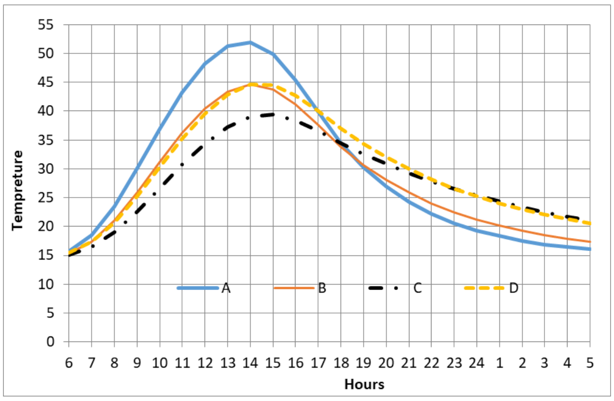

Figure 5. Hourly temperature distribution according to wall types.

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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ARAŞTIRMA MAKALESİ RESEARCH PAPER

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: Forest products industry, quality management system, scale development, total quality management.

Toplam Kalite Yönetimi Uygulamalarının İncelemesine Yönelik Bir Ölçek Geliştirme Çalışması

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Öz: Toplam kalite yönetimi yaklaşımı, insan faktörünün öne çıktığı, sürekli gelişim ve iyileştirmenin benimsendiği, işletmede grup çalışmasına önem verildiği ve kalite sorumluluğunun tüm çalışanlara yayıldığı bir yönetim tarzıdır. Toplam kalite yönetiminin amacı, iyi eğitimli ve motive olmuş çalışanlarla müşteriye sürekli ve mükemmel hizmet sunmaktır. Bu çalışma kapsamında orman ürünleri sektöründe uygulanan toplam kalite yönetimi faaliyetlerinin bazı özellikleri (müşteri odaklılık, yönetim liderliği, tam katılım, sistematik süreç analizi ve önce insan anlayışı) incelenmiştir. Bu amaçla ISO 9001 Kalite Yönetim Sistemi Belgesine sahip 14 büyük firmada görev yapan 377 mühendis ve ustabaşına anket yöntemi ile ulaşılmıştır. Kullanılan anket iki bölümden oluşmaktadır. İlk bölümde 13 soru ile çalışanların bazı demografik özellikleri değerlenmiş ikinci bölümünde işletmelerde uygulanan yönetim sistemi 50 soruyla araştırılmıştır. Anket verileri SPSS ve AMOS istatistik paket programlarında hazırlanan Yapısal Eşitlik Modeli (SEM) ile değerlendirilmiş ve sonuçlar ortaya çıkarılmıştır. Sonuç olarak, orman ürünleri sektöründe toplam kalite yönetimi çalışmalarını incelemek isteyen araştırmacılar için istatistiksel olarak kabul edilebilir bir ölçek ortaya koyulmuştur.

Anahtar kelimeler: Toplam kalite yönetimi, ölçek geliştirme, orman ürünleri endüstrisi, kalite yönetim sistemi.

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.

MATERIALS AND METHOD

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) package program, analyzes were performed and the results were presented.

RESULTS AND DISCUSSION

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	n	%	Position in business	n	%
20-24	19	5,0	Engineer	183	48,5
25-29	77	20,4	Foreman	152	40,3
30-34	85	22,5	Unanswered	42	11,1
35-39	50	13,3			
40-44	22	5,8	**Working time in the position (years)**	**n**	**%**
45-49	18	4,8			
>50	3	0,8	0-5	154	40,9
Unanswered	103	27,3	6-10	92	24,4
			11-20	61	16,2
			<21	13	3,4
Gender	**n.**	**%**	Unanswered	57	15,1
Male	301	79,8			
Female	42	11,1	**Total working time (years)**	**n**	**%**
Unanswered	34	9,0			
			0-5	173	45,9
			6-10	101	26,8
Marital status	**n.**	**%**	11-20	56	14,9
married	200	53,1	>21	15	4,0
Single	98	26,0	Unanswered	32	8,5
Other	4	1,1			
Unanswered	75	19,9			

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.

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.

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

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.

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

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.

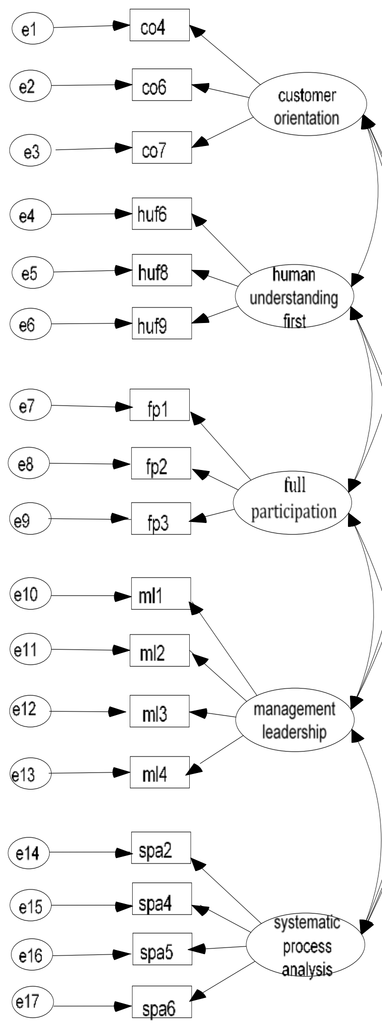

Figure 1. Measurement model.

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

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

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.

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.

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ARAŞTIRMA MAKALESİ RESEARCH PAPER

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: Civilization, human-nature interactions, wood, woodlover approach, woodloverness.

Doğayla Bağlantılı Medeniyete Giden Bir Yol Olarak Ahşapseverlik

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Öz: Ahşapseverlik; deneyimlere dayalı öğrenme uyarınca hem tutum ve davranışları bütünleştiren hem de duygu ve düşünceleri birleştiren davranış boyutu ile hayatın her evresinde yansımalarıyla ortaya çıkan uzun zamandır dünya çapında bilinen geniş bir konu olmasına rağmen, ahşap bilimi ve teknolojisi alanında neredeyse çok yakın zamanda isimlendirilip tanımlanmış bir terim olup coğrafyası birbirinden uzak insanları ahşapsever yaklaşım odağında doğanın uyumlu bir parçası olma açısından aynı amaç çerçevesinde bir arada tutarak tamamlayan doğası ile tüm insanlığı kucaklayan evrensel bir olgudur. Daha genel anlamda, Usta'nın deyimiyle (Usta, 2019), ahşapseverlik; medeniyetin gelişmesine katkı sağlayan ve insanlığın ilerlemesinde önemli rol oynayan tematik bir konudur ve insanı doğayla bütünleştirmeyi amaçlayan ahşapsever yaklaşım odağında ele alınmaktadır. Açıkçası, ahşapseverlik, derin ve kapsamlı varlığı ile bilim ve teknoloji eşliğinde, sanat ve edebiyatla birlikte doğa ile bütünleşerek medeniyetin gelişmesinde net bir şekilde öne çıkan disiplinlerarası bir kavramdır ve kültürel boyutu ile tüm insanlığın özünü oluşturan doğa ve çevre ile özdeşleşme çabasının öncelikli pekiştiricisidir. Bu çalışmada, ahşapseverlik, ahşapsever yaklaşım esas alınarak doğayla bütünleşmek suretiyle gerçekleşen uygarlaşma sürecinde, insanlara sonsuz fayda sağlayan derin ve kapsamlı bir olgu olarak sunulmuştur.

Anahtar kelimeler: Ahşap, ahşapsever yaklaşım, ahşapseverlik, insan-doğa etkileşimi, medeniyet.

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..

THE NOTION 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 and chemical composition, and 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 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.

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 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 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.

c. Wood, which is a common material that meets the needs and requirements of people with its versatility and functionality, is a marvelous material that stands out clearly in the relationship between technology and civilization with its superior material properties.

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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ARAŞTIRMA MAKALESİ
RESEARCH PAPER

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: EDAS, FAHP, multicriteria decision-making, structural composite lumber, TOPSIS.

Yapısal Kompozit Kereste Ürünlerinin Çok Kriterli Değerlendirilmesi

Öz: Bu çalışmada, tabakalanmış kaplama kereste, paralel şerit kereste ve tabakalanmış şerit kereste çok kriterli karar verme yöntemleri ile değerlendirilmiştir. Modelde dokuz değerlendirme kriteri belirlenmiştir: rutubet miktarı, yoğunluk, eğilme direnci, elastikiyet modülü, liflere paralel basınç direnci, dinamik eğilme direnci, yüzeye paralel yönde çekme direnci, yüzeye dik yönde çekme direnci ve vida tutma kabiliyeti. Kriterlerin ağırlıkları bulanık analitik hiyerarşi prosesi (BAHP) kullanılarak hesaplanmıştır. Alternatiflerin sıralamasını belirlemek için ortalama çözüm uzaklığına göre değerlendirme (EDAS) ve ideal çözüme benzerliğe göre tercih sıralama tekniği (TOPSİS) kullanılmıştır. Borda sayım yöntemi kullanıldıktan sonra birleşik bir sıralama elde edilmiştir. Sonuçlara göre, ilk üç önemli alt kriter yoğunluk, eğilme direnci ve elastikiyet modülüdür. Buna ilaveten, tabakalanmış kaplama kereste en iyi alternatif olarak belirlenmiştir. Sonuç olarak, bu çalışma ahşap malzemelerin değerlendirilmesi için bir yol haritası sunabilir.

Anahtar kelimeler: BAHP, çok kriterli karar verme, EDAS, TOPSİS, yapısal kompozit kereste.

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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 (Ahmad & Kamke, 2011; Arwade et al., 2010; Bal, 2016; Bayatkashkoli & Faegh, 2014; Çolak et al., 2007; Çolak et al., 2019; Moses et al., 2003; Yazdani et al., 2004). 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 & Singh, 2016; Ecer, 2018; Karakuş et al., 2017). 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. Lipušček 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.

MATERIALS AND METHODS

Sample Preparation: The experimental data used in this study were obtained from the literature (Özçifçi et al., 2010; Sizüçen, 2008). 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 ºC 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 ºC and a pressure of 30 kg/cm^2 (ASTM D 5456, 1996). After pressing, the samples were conditioned at a temperature of 20±2 ºC 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.

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 & 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 & 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):

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

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:

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

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

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

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 & Laosirihongthong, 2014):

Step 1: The value of fuzzy synthetic extent with respect to the *i*th 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 $S_i = (l_i, m_i, u_i) \geq S_j = (l_j, m_j, u_j)$ is calculated using the following equation:

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

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

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

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

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

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

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)

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.

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

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

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 *j*th 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.

$$AS_i = \frac{NSP_i + NSN_i}{2}, \quad 0 \le AS_i \le 1 \tag{17}$$

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 & Yoon, 1981):

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

Step 2: The normalized decision matrix is obtained.

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

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

$$V_{ij} = w_j r_{ij} \tag{19}$$

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

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

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

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

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

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

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

$$C_i = \frac{d_i^-}{d_i^+ + d_i^-} \tag{24}$$

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).

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.

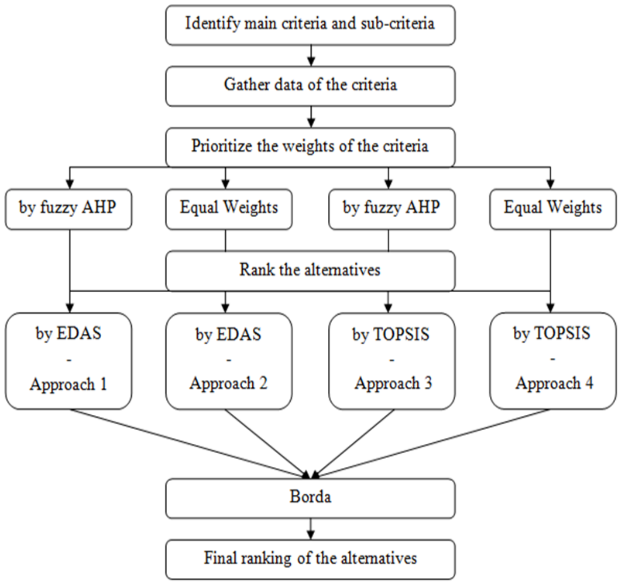

Figure 1. The evaluation model used in the study.

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.

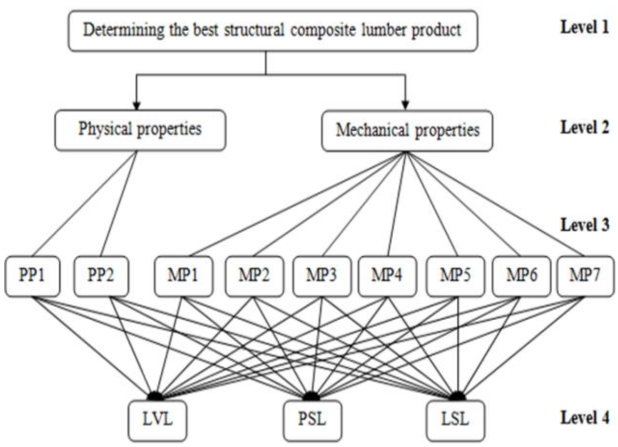

Figure 2. The decision hierarchy.

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.

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/cm³)	MP1 (N/mm²)	MP2 (N/mm²)	MP3 (N/mm²)	MP4 (kgm/cm²)	MP5 (N/mm²)	MP6 (N/mm²)	MP7 (N/mm²)
LVL	8.13	0.40	64.51	7907.2	49.87	0.46	25.97	805.01	6.10
PSL	8.00	0.44	60.23	7864.6	43.85	0.50	25.88	796.66	5.46
LSL	8.34	0.50	61.83	8022.5	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.

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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ARAŞTIRMA MAKALESİ RESEARCH PAPER

Paper and Paper Products and Wood and Wood Products Sectors Competition Analysis: BRICS Countries and Turkey

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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, Turkey, paper-paper products, wood-wood products, revealed comparative advantages.

Kağıt-Kağıt Ürünleri Sanayi ve Ahşap-Ahşap Ürünleri Sanayi Sektöründe Rekabet Analizi: BRICS Ülkeleri ve Türkiye

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Öz: Dünya ölçeğindeki finansal krizler, yeni ekonomik yapıların ve güçlerin ortaya çıkmasına neden olmuştur. Gelişmiş ülkelerin finansal verimliliği düşerken, gelişmekte olan ülkeler konumlarını yükseltmektedir. 2008 yılındaki finansal krizin ardından alternatif bir ekonomik güç olarak ortaya çıkan BRIC (Brezilya, Rusya, Hindistan ve Çin), 2011 yılında Güney Afrika'nın da eklenmesiyle BRICS ülkeleri olarak bilinmeye başladı ve önemli bir ekonomik yapı haline geldi. Ekonomik ve demografik gücüyle dünyada aktif pozisyonda yer almak isteyen Türkiye, BRICS'e katılmaya isteklidir. Türkiye'nin sektörel yapısının bu ülkelerle rekabet konumunun belirlenmesi son derece önemlidir. Bu çalışmada Türkiye Kağıt ve Kağıt Ürünleri ile Ağaç ve Ağaç Ürünleri Sektörünün BRICS ülkelerine karşı nasıl bir konumda olduğunun belirlenmesi amaçlanmıştır. 2010-2019 yıllarını kapsayan çalışmada Karşılaştırmalı Üstünlükler yaklaşımı kullanılmıştır. Çalışma sonucunda ülkeler yıl bazında karşılaştırılmış ve üstün sektörel yapılar tespit edilmiştir.

Anahtar kelimeler: BRICS, Türkiye, kağıt-kağıt ürünleri, ahşap-ahşap ürünleri, rekabet analizi.

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 and Kutlay, 2015), and they will be among the top 10 economies of the world in 2050 (Wilson and 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.

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. 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.

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

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

MATERIALS AND METHOD

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.

RESULTS AND DISCUSSION

BRICS countries and Turkey Paper & Paper Products Industry Sectors competitive analysis of the results in Table 7 are also seen. As a result of the analysis of the competitive power of countries, when the values in Table 7 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.

Table 7. BRICS countries and Turkey: Paper and Paper Products Industry

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**

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.

When Table 8, 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..

Table 8. BRICS countries and Turkey: Wood and Wood Products Industry.

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**

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.

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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ARAŞTIRMA MAKALESİ RESEARCH PAPER

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 (ANN), scots pine, spruce.

Türkiye'de Yetiştirilen Sarıçam ve Doğu Ladininden Üretilen Çapraz Lamine Ahşap (CLT) Yapısal Performans Analizi

Öz: Hafif, dayanıklı, depreme dayanıklı, sağlıklı, yalıtkan ve estetik olması gibi pek çok avantaja sahip olan ahşap yapılar, deprem bölgeleri başta olmak üzere her türlü mekan için uygundur. Çapraz lamine ahşap (CLT), sürdürülebilir olması, enerji verimliliği ve yapım hızı ile ilgili mükemmel özellikleri nedeniyle, diğer yapısal malzemelere giderek artan bir şekilde daha uygun bir alternatif haline geldi. Bu, yakın zamanda dünya çapında inşa edilen önemli sayıda CLT binasının ortaya çıkmasıyla sonuçlanmıştır. Yapılan bu çalışma Türkiye'de yetişen ağaç türlerinden üretilen CLT panellerin özelliklerinin belirlenmesi, yapısal davranışı ve depreme dayanıklılık performanslarının incelenmesi üzerinedir. CLT imalatında kullanılan 100 mm (genişlik) x 50 mm (kalınlık) x 2400 mm (uzunluk) ölçülerindeki keresteler, Doğu Ladini (*Picea orientalis L.*) ve Sarıçam (*Pinus slyvestris*) tomruklarından elde edilmiştir. Her bir grup için 2400 mm × 2400 mm × 150 mm boyutlarında iki adet üç tabakalı CLT paneli üretilmiştir. CLT panellerinin yoğunluğu EN 323'e göre, perde duvarların sismik dayanıklılık performansı ise ASTM E 72 standardına göre belirlenmiştir. Sarıçamdan üretilen CLT paneller, ladinden üretilen CLT panellere göre daha yüksek sismik performans sağlamıştır. CLT panellerinin yoğunluk değerleri arttıkça duvarların maksimum yük taşıma kapasitesi artmıştır.

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Anahtar kelimeler: CLT (Çapraz Lamine Ahşap), yapısal davranış performansı, yapay Sinir ağları, sarıçam, doğu ladin.

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.

MATERIALS AND METHOD

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 (Pinus slyvestris) 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.

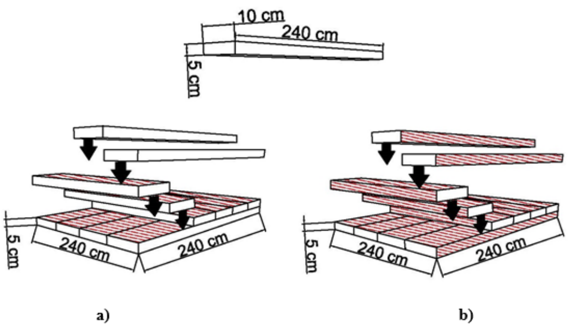

Figure 1. a) Non-edge gluing, b) Edge gluing (The shaded area shows the surfaces where gluing is applied).

Hydraulic cold press which can apply vertical clamping pressure and side clamping pressure as shown in Figure 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.

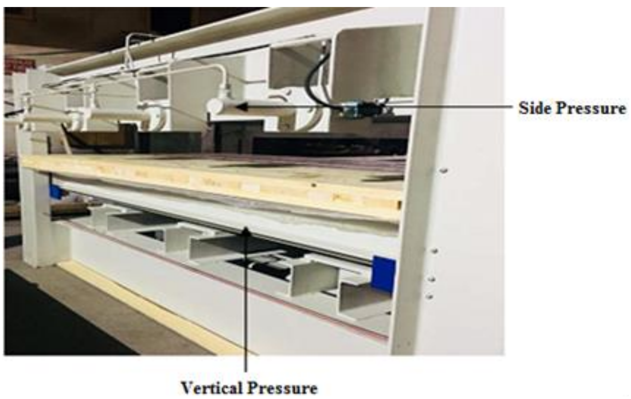

Figure 2. Hydraulic cold press.

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.

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 Figure 3a (Popovski and Karacabeyli, 2012). CLT wall during the testing is shown in Figure 3b. CLT shear walls in platform-type construction consist of two parts: connections and CLT panels (Figure 3b) (Shahnewaz et al., 2019).

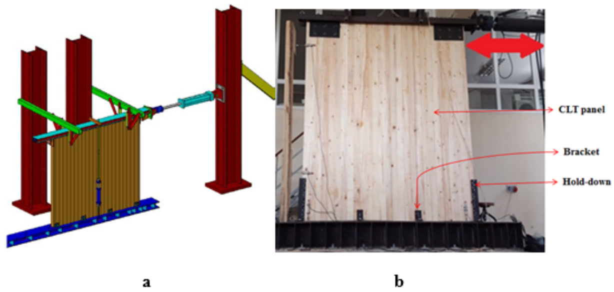

Figure 3. a) Sketch of the test setup used for CLT walls b) CLT wall during test.

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).

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	Scots pine		Spruce	
(gr/cm^3)	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

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.

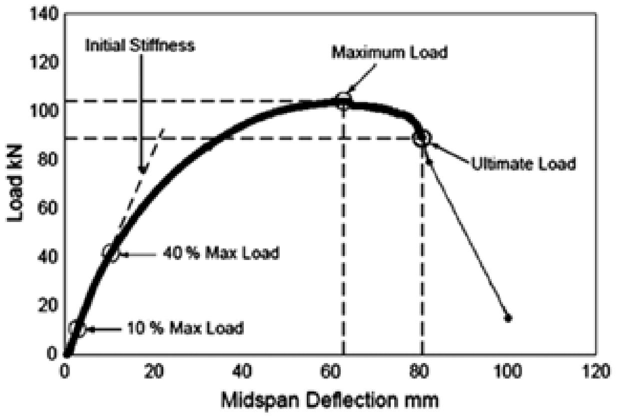

Figure 4. Analysis of a load-displacement curve (Pirvu 2008).

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.

Figure 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.

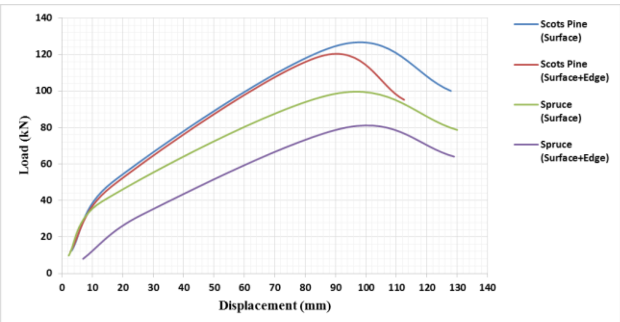

Figure 5. Load-displacement relationship for the test groups.

Table 2. Results of seismic resistant performance test.

Wood Species	Gluing Method	Max. Load (kN)	Max. 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 Figure 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 2). 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).

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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ARAŞTIRMA MAKALESİ RESEARCH PAPER

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-EPS and extruded polystyrene-XPS) 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 XPS as insulation material. The use of XPS as an insulation material in plywood has given lower thermal conductivity values than EPS.

Keywords: Thermal conductivity, Polystyrene, Fiber direction, Black pine, Spruce.

Polistiren Türü ve Lif Yönünün Kontrplakların Isıl İletkenliği Üzerine Etkisi

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Öz: Ahşap malzemenin ısı iletkenliği gözenekli yapısı nedeniyle diğer yapı malzemelerinden üstündür. Isı iletkenliği, malzemenin yalıtım kabiliyetini tahmin etmek için kullanılır. Ahşap malzemenin ısıl iletkenliği, ağaç türü, ağaç lifinin yönü, özgül ağırlığı, nem içeriği, reçine türü ve ahşap kompozit panellerin imalatında kullanılan katkı maddelerine göre değişmektedir. Bu çalışmanın amacı, polistiren türlerinin ve lif yönünün kontrplak panellerin ısıl iletkenliği üzerindeki etkisini belirlemektir. Çalışmada, iki farklı ağaç türü (karaçam ve ladin), iki farklı lif yönü (kontrplak lif yönüne paralel ve dik), iki farklı tipte yalıtkan (genleştirilmiş polistiren-EPS ve ekstrüde polistiren-XPS) ve tutkal türü olarak fenol formaldehit tutkalı kullanılmıştır. Panellerin ısıl iletkenliği ASTM C 518 ve ISO 8301'e göre belirlenmiştir. Çalışma sonucunda, en düşük ısıl iletkenlik değerleri liflere dik yöndeki ladin kontrplaklarda izolasyon malzemesi olarak XPS kullanılması durumunda elde edilmiştir. Kontrplaklarda izolasyon malzemesi olarak XPS kullanılması durumunda EPS ye göre daha düşük ısıl iletkenlik değerleri elde edilmiştir.

Anahtar kelimeler: Isıl iletkenlik, Polistiren, Lif yönü, Karaçam, Doğu Ladin.

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.

MATERIALS AND METHOD

Wood Material and Manufacturing of Plywood: Black pine (*Pinus nigra*) and spruce (*Picea orientalis L.*) were used in this study. 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).

Seven-ply plywood panels, 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 14 min. Two replicate plywood panels were manufactured from each group.

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 14 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.

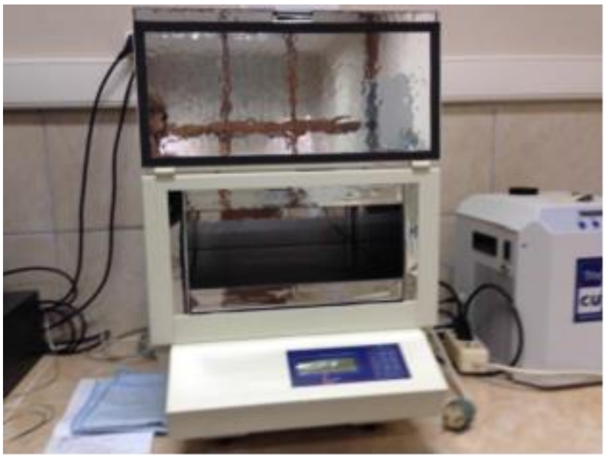

Figure 1. Lasercomp Fox-314 heat flow meter.

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.

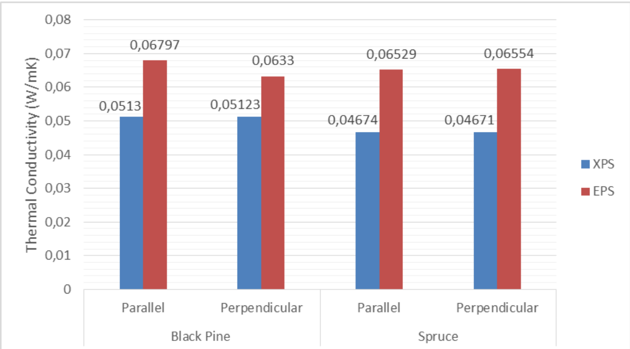

Figure 2. Thermal conductivity coefficients according to combination groups.

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 spruce plywood shows a better insulation feature than the 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). When the fiber directions were examined, it was determined that the measurement made in parallel with the fibers gave higher thermal conductivity coefficient values than the measurement made vertically. 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). 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).

When the effect of the type of insulation materials used in thermal conductivity measurements was examined, as can be seen from Figure 2, plywoods used with EPS gave the highest thermal conductivity values, while plywoods used with XPS gave the lowest values. It is known that the thermal conductivity coefficient of XPS plates used in the study is 0.033 W / mK, and that of EPS plates is 0.039 W / mK. As expected thermal conductivity values of the plywood samples decreased with the decreasing in thermal conductivity values of the insulation materials. 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 recommended to use materials with low thermal conductivity coefficient values in studies where it is desired to improve the thermal insulation of buildings.

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 plywood. 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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ARAŞTIRMA MAKALESİ
RESEARCH PAPER

Chemical Changes in Historical Wooden Structures in Rize-Fırtına 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.

Rize- Fırtına Vadisindeki Tarihi Ahşap Yapılardaki Kimyasal Değişimlerin Tespiti

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Öz: Ülkemizde tarihi ahşap binalardaki zarar yapan etmenlerin belirlenmesi amacıyla yapılan çalışmalar oldukça sınırlıdır. İklim indeksi 65'ten yüksek olan Rize-Fırtına Vadisi ülkemizde en fazla yağış alan bölgelerden biridir. İklim indeksi yüksek olan bu bölgede bulunan tarihi ahşap yapılardaki çürüme riski yüksektir. Bu durumun bir sonucu olarak ahşabın direnç özellikleri olumsuz etkilenmektedir. Bu bulgudan hareketle ülkemizin doğa ve kültür turizmi açısından popüler destinasyonlarından biri olan ve bu vadide bulunan Rize ili Çamlıhemşin ilçesinde farklı yükseltilerdeki çeşitli tarihi yapılar araştırmaya dahil edilmiştir. Araştırma kapsamında söz konusu bölgede bulunan en az 150 yıllık ahşap konaklardan örnekler alınmıştır. Örnekler üzerinde meydana gelen kimyasal değişimleri tespit etmek amacıyla selüloz, lignin ve hemiselüloz tayini yapılmıştır. Bu değişimlerin yapılardaki elemanların taşıyıcı özellikleri üzerindeki etkisine bakılmıştır. Bu sonuçlar ışığında tarihi yapılardaki ahşap malzemenin korunması ve sürdürülebilirliği noktasında müdahale yöntemleri önerilebilecektir.

Anahtar kelimeler: Fırtına Vadisi, Tarihi ahşap yapılar, Kimyasal analizler, Selüloz, Lignin.

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.

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.

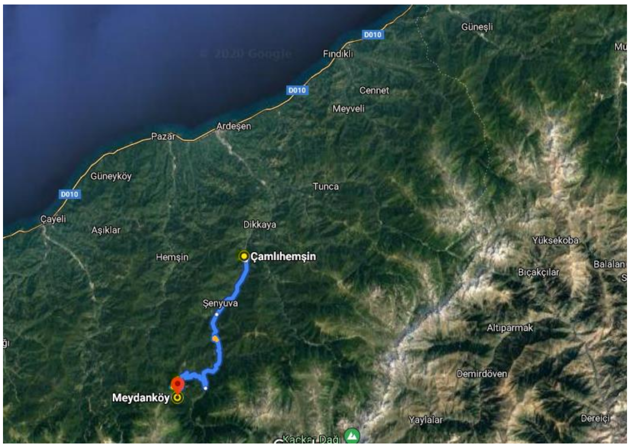

Figure 1. General view of research area (Meydanköy- area 1; Çamlıhemşin-area 2).

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 ± 20C. Following chemical analysis were conducted.

Figure 2. Historical some wooden buildings.

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 ± 20C 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:

$$r = \frac{Mr - Mo}{Mo} \times 100 \qquad (1)$$

r: Moisture of sample (%)
Mr: The weight of the sample in the damp state (g)
Mo: Weight of the sample in the dry state (g)

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).

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.

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.

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% $H2S0_4$ 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.

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 5th,10th, 15th and 25th 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.

RESULTS AND DISCUSSION

Chemical analyses of samples taken from historical wooden building at different elevations were conducted and the results are shown Figure 3. 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

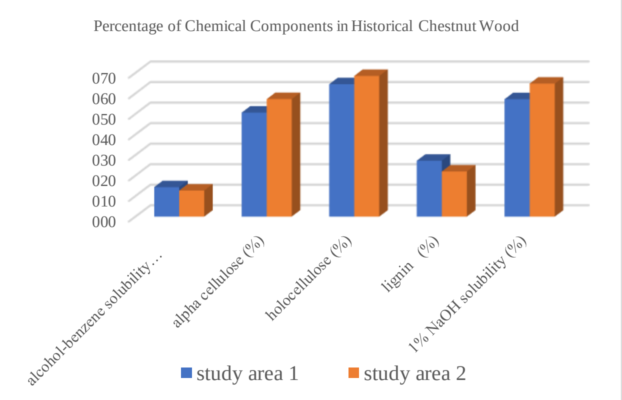

Figure 3. Percentage of Chemical Components in Chestnut Wood taken from Historical Wooden Structures.

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.

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.

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ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

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: Drying process, emission of wood based panels, volatile organic compounds (VOC), wood based panels.

Ahşap Esaslı Levha Sektöründe Kurutma Kaynaklı Emisyonlar

***Sorumlu yazarın:**
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Öz: Ahşap esaslı levhaların başta mobilya olmak üzere birçok kullanım alanında tercih edilmesinin sebebi istenilen özelliklerde üretilebilmesi ve ucuz olmasıdır. Ayrıca masif odunda görülen üç boyutta farklı çalışma, direnç değerlerinde farklılıklar, iç gerilmeler ve fiziksel değişimler gibi odun kusurlarına nispeten ahşap esaslı levhalarda karşılaşılmaz. Ahşap esaslı levhalardan kaynaklanan uçucu organik bileşik (VOC) emisyonları, levhaların hammaddelerinden ve tutkallama, depolama, presleme, kurutma gibi üretim aşamalarında oluşmaktadır. Odun hammaddesinden kaynaklanan VOC ların büyük kısmı kurutma işlemi sırasında oluşur. VOC lar azot oksitlerin ve güneş ışığının varlığında foto-oksidanların oluşumuna katkıda bulunur. Foto-oksidanlar solunum yollarında ve akciğerlerin hassas kısımlarında tahrişe neden oldukları için insanlar için zararlıdır. Ayrıca fotosentezi bozar, ormanlara ve ürünlere zarar verir. Bu çalışmanın amacı ahşap esaslı levhalarda kurutma işleminde oluşan emisyonları etkileyen faktörlerin ve emisyonu düşürmek için uygulanan işlemlerin değerlendirilmesidir.

Anahtar kelimeler: Ahşap esaslı paneller, ahşap esaslı panellerden kaynaklanan emisyonlar, kurutma işlemi, uçucu organik bileşikler.

INTRODUCTION

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; Böhm et al., 2012).

Asia-Pacific region accounted for 61 percent of global production in 2018 (248 million m³), followed by Europe (90 million m³, or 22 percent), Northern America (48 million m³, or 12 percent), Latin America and the Caribbean (19 million m³, or 4 percent) and Africa (3 million m³ 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. The fifth-largest consumer is Poland (overtaking Turkey and Japan in 2015), where consumption increased from 9 million m³ in 2014 to 12 million m³ 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.

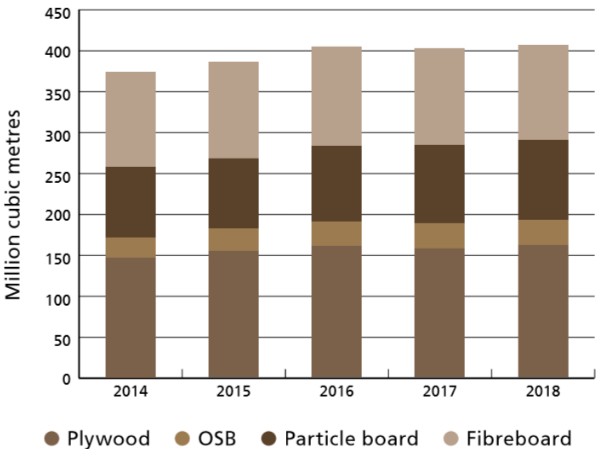

Figure 1. Wood based panel production in the World (FAO, 2018).

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

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 (Rowell, 2005). Free and bound water are shown in Figure 2.

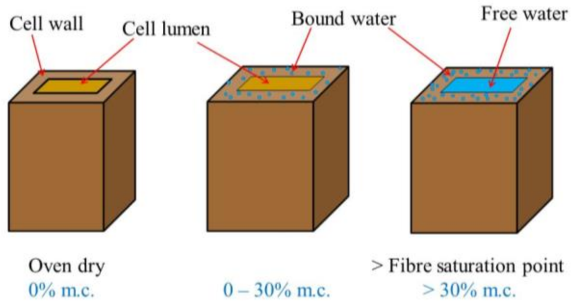

Figure 2. Water in wood (Web-1).

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).

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.

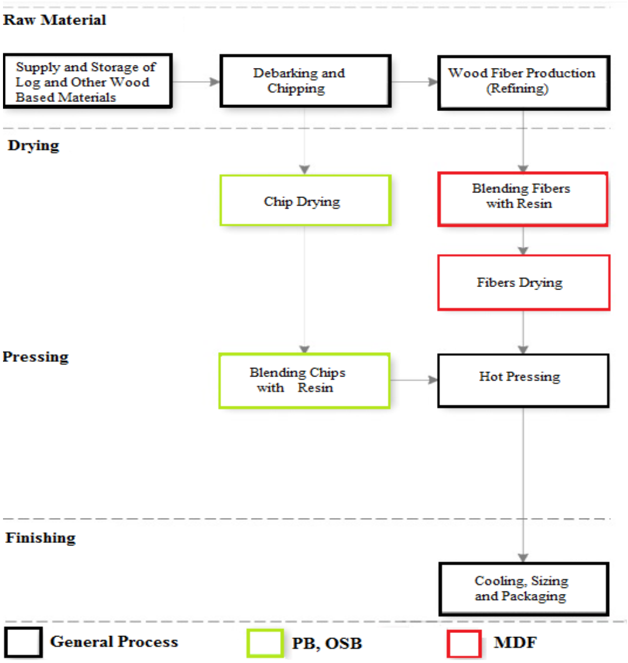

Figure 3. General process for PB, OSB and MDF.

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).

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).

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).

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).

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.

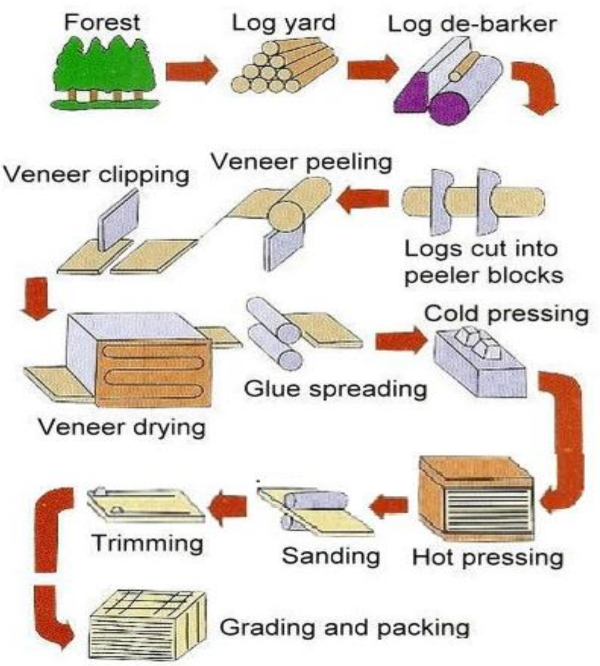

Figure 4. Plywood production (Bilgin, 2019).

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).

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 (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 (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 mg kg 1), fruits and vegetables (6.3–35 mg kg 1) wood (0.04 mg kg 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).

VOC from Wood: The cell wall of wood consists of carbohydrate (cellulose and hemicellulose), lignin and extractive substances. 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. 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.

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).

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. 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).

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).

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).

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 ºC 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..

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 ($\mu g/m^3$)	Formaldehyde ($\mu g/m^3$)	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).

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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ARAŞTIRMA MAKALESİ RESEARCH PAPER

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) 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 fiberboard (MDF) production with Pareto analysis method. MDF 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 fiberboard (MDF), Pareto analysis, scenarios.

MDF Üretimindeki Karbon Ayak İzinin Değerlendirilmesi: Türkiye'de Odun Bazlı Levha Üretimi Üzerine Bir Örnek Çalışma

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Öz: Günümüzde karbon ayak izi, mal ve hizmetlerin ekolojik olarak üretimiyle yakından ilgili bir konu haline gelmiştir. Son yıllarda tüm insanların faaliyetlerinde enerji kullanımı ve kullanımdan gelen sera gazı emisyonları küresel ısınma şeklinde dünya iklimini etkilemektedir. İnsan faaliyetleri sonucunda ortaya çıkan en baskın sera gazı karbondioksittir. Karbon ayak izi, belirli bir süre için birim ürün başına salınan CO_2 ve diğer sera gazlarıdır. Bu çalışmanın temel amacı, orta yoğunluklu lif levha (MDF) üretimi sırasında karbon ayak izi problemine katkı sağlayan en önemli kritik süreçlerin Pareto analiz yöntemi ile belirlenmesidir. MDF, ısı ve sıcaklık altında tipik olarak sentetik reçineler ve katkı maddeleri kombinasyonu ile selülozik lifler içerir. Bu amaçla, karbon ayak izini her bir süreç için incelemek üzere bir odun bazlı levha endüstrisi seçilir. Sonuç olarak bu çalışma, panel bazlı endüstrideki emisyon sorunlarını Pareto analizi yardımıyla görmeye ve geleceğe yönelik çevre odaklı bir üretim yapışmasına önemli katkı sağlamaktadır. Ayrıca seçilen tesiste toplam karbon ayak izini azaltmak için iki senaryo oluşturulmuştur. Dolayısıyla analiz sonuçları iki senaryo ile desteklenmektedir. Dahası bu çalışma, karbon ayak izinin odun panel bazlı endüstriyel sektördeki önemi hakkında genel bir bakış açısı ve algı sağlayacaktır.

Anahtar kelimeler: Karbon ayak izi, Orta yoğunluklu liflevha (MDF), Paretö analiz, senaryolar.

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 & 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

Moroşanu et al. (2001) 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 fort 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 analysis is applied for determine the footprint' problem.

MATERIALS AND METHODS

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 Figure 1. The MDF production follow the processes such as chipping, screening, evaporation, refiner, gluing, drying, laying, pressing, sizing, climatization, and sand- papering. 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.

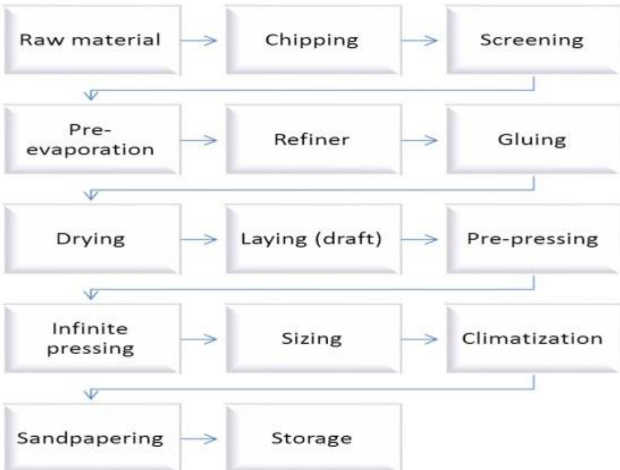

Figure 1. Flow chart for medium-density fiberboard panel production in XYZ plant (Erdil, 2018).

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 the 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 (460472653kWh) 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 the 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).

Energy balance: In this plant, natural gas, biomass 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.

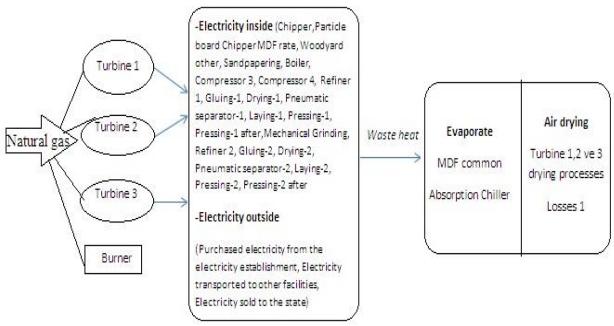

Figure 2. Energy balance flow chart 1 in medium density fiberboard (Erdil, 2018).

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.

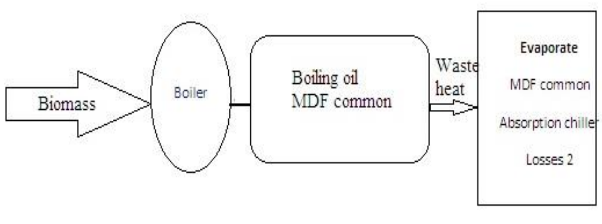

Figure 3. Energy balance flow chart 2 in medium density fiberboard (Erdil, 2018).

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).

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).

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 et al., 2017; Keskin et al., 2017; Erdil, 2018).

$$\text{Emission} = \text{Energy consumption} \times \text{Emission factor} \times \text{Oxidation factor} \quad (1)$$

(Oxidation factor is taken as 1)

$$CF = \text{Emissions (kg } CO_2e\text{)} / \text{Amounts of annual production } (m^3) \quad (2)$$

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 assist 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 et al., 2017; Erdil et al., 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.

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.

RESULTS AND DISCUSSION

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.

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_2 e/m^3MDF of all other processes as secondary sources in Figure 4-b.

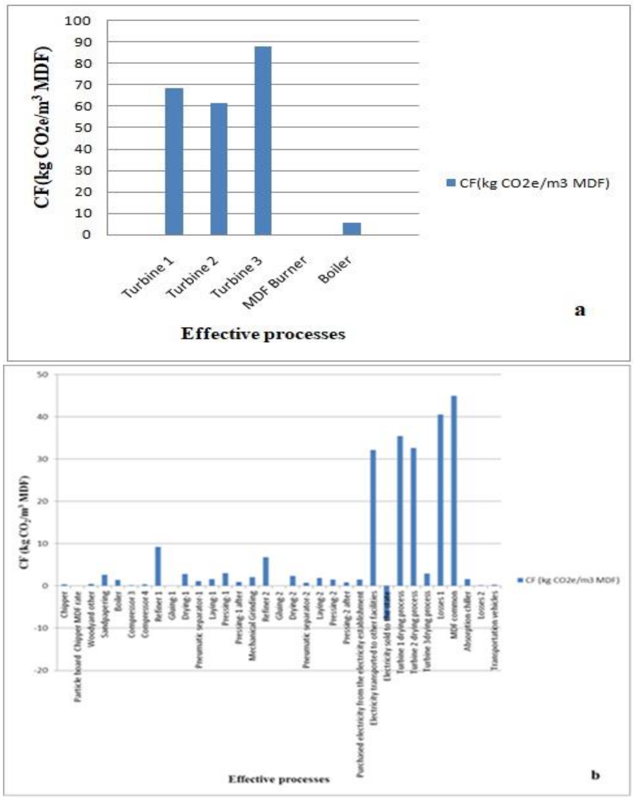

Figure 4. Carbon footprint (CF) for each effective process (a-Primary and their' CF b-Secondary and their' CF).

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_{2e}/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	Transportation vehicles	0.22

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.

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.

Table 2. CF data 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	Transportation 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		

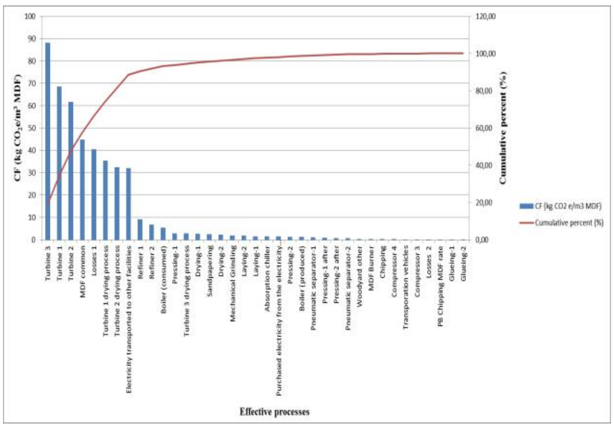

Figure 4. Application of Pareto analysis according to relationships between effective processes and carbon footprint values.

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-MDFtaking 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 CO_2e/m^3 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	-
Primary Total		**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**

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, here 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. These researches was based on occurring cause effect diagram and evaluate the Pareto diagram to see the reasons which cause the highest emission problem(s).

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 is 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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ARAŞTIRMA MAKALESİ RESEARCH PAPER

The Problems of Furniture Sector and Suggestions for Solutions (A Case Study of Van)

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Abstract: This study was carried out in order to determine the current situation and the problems faced by the enterprises operating in the Furniture and Carpenters Industrial Site in the city center of Van. For this purpose, 71 businesses were randomly selected from the businesses in Van furniture and carpenters industrial site. Businesses were visited and a questionnaire consisting of 12 questions was applied using face-to-face question-answer technique. With the questionnaire, data on the defining information of the enterprises such as the establishment date, number of employees and education status, production type, machines types, sales and order method, problems experienced and supports received were collected. As a result; the problems identified by the enterprises are respectively, the use of low technology machinery (93%), website not having (85.9%), insufficient vocational training (81.9%), capital insufficiency (69%), insufficient demand (49.3%), transportation (46.5%), workplace rent (45.1%), raw material (39.4%). In addition, it is determined that the average operating time of the enterprises is 26 years and the average working personnel is 3.1 people. Recommendations on consultancy services, cooperation with vocational training institutions and increasing the level of technology use were included for the furniture businesses within the scope of the research.

Keywords: Enterprises, Furniture, Production, Van, Woodwoorking.

Mobilya Sektörünün Sorunları ve Çözüm Önerileri (Van İli Örneği)

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Öz: Bu çalışma Van il merkezinde bulunan Mobilyacılar Sanayi Sitesi'nde faaliyet gösteren işletmelerin mevcut durumunu ve yaşadığı sorunları belirlemek amacıyla yapılmıştır. Bu amaçla Van mobilyacılar ve marangozlar sanayi sitesindeki işletmelerden rastgele 71 işletme seçilmiştir. İşletmeler ziyaret edilmiş ve yüz yüze soru-cevap tekniği kullanılarak 12 sorudan oluşan anket uygulanmıştır. Anket ile işletmelere ait kuruluş tarihi, çalışan sayısı ve eğitim durumu, üretim türü, mevcut makineler, satış yöntemi, yaşanan sorunlar ve alınan destekler gibi işletmeyi tanımlayıcı bilgilere ilişkin veriler toplanmıştır. Sonuç olarak; işletmelere ait tespit edilen problemler sırasıyla, düşük teknolojili makine kullanımı (% 93), web sitesine sahip olmamak (% 85,9), mesleki eğitimi yetersiz personel (% 81,9), sermaye yetersizliği (% 69), talep yetersizliği (% 49,3), ulaşım (% 46,5), işyeri kirası (% 45,1), hammadde (% 39,4) ile ilgili olduğu tespit edilmiştir. Ayrıca işletmelerin ortalama faaliyet süresi 26 yıl ve işletme başına düşen ortalama personel sayısı 3,1 kişi olduğu belirlenmiştir. Araştırma kapsamındaki mobilya işletmelerine yönelik olarak danışmanlık hizmeti, mesleki eğitim kurumları ve diğer ilgili kurumlar ile iş birliği ve teknoloji kullanım düzeyinin artırılması konusunda önerilere yer verilmiştir.

Anahtar kelimeler: Ağaç işleri, İşletme, Mobilya, Üretim, Van.

INTRODUCTION

Furniture, which has always been a valuable item for people in the historical process, can generally be defined as equipment that meets needs such as resting, storage, and sitting (Ulay, 2011). Furniture is used in different geographical cultures of the world for purposes such as sitting, storage and display. Today, due to the increasing demand for furniture products, the level of technology usage in production processes has increased. With the creation of technological production processes, the furniture industry has become one of the world's advanced industries. Turkey, as the location for the furniture production facilities in terms of access to the necessary supply of raw materials is more advantageous as compared to other countries (Yegin, 2020).

Turkey in the furniture industry; It is traditionally thought to operate in the national and even local market with low technology, insufficient capital, labor intensive and expensive inputs. In fact, Turkey recently the furniture industry is undergoing a rapid technological transformation (Agras and Korkmaz, 2020) and compared to the past is transformed into more knowledge and capital-intensive fashion industry (TOBB, 2017). The most important factor behind this transformation is the competitiveness of the furniture industry and the rapid globalization process (Gurpinar and Barca, 2007). Furniture product is a typical example of global products that naturally comply with the requirements of international trade with their features such as fulfilling their basic functions and high design input (Yeniceri, 2005). Turkey's economy, producing value-added products and a significant number of jobs created (Okan, 2013), but also in the foreign trade surplus furniture industry has a special position in the economy.

However, the furniture industry in Turkey; lack of design (Karagoz and Sevim Korkut, 2017; Gurpinar and Doven, 2007), funding shortage (Akyuz et al., 2020; Malkocoglu et al. 2015; Serin and Sahin; 2020), lack of qualified personnel (Ulay, 2011; Ulay 2015; Ulay 2020), raw material and branding (Demirci, 2005), low technology usage level (Gurpinar and Doven, 2007), management deficiencies (Gurpinar and Doven, 2007), inadequate promotion and marketing (Coskun, 2019; Ustuner, 2010). It has been shown in many researches and sector reports in the literature that it has very important problems.

In general, in particular the problems of Turkey's Van furniture industry and is thought to be similar advantages. The province of Van has borders with Agrı in the north, Bitlis and Siirt in the west, Iran in the east and Sırnak and Hakkari in the south. Neighboring provinces are behind Van province in terms of production and infrastructure and at the same time have a market position (Ulay, 2020a). Van province of Turkey, with a total of 1.136.757 people in 2019 in terms of population is the 19th most populous province among 81 provinces (TUIK, 2019). The fact that the city population is over 1 million shows the importance of the need and production amount related to furniture consumption. Sub-Industry Fields of Activity Operating in the TRB2 Region The localization values (LQ) of furniture manufacturing in the years 2009-2014 are 0.25 (Deliktas and Celik, 2019). Considering the potential and numbers of furniture manufacturers in Van, no scientific research was found, except for the report prepared by DAKA (2017) for the furniture manufacturing sector. Considering the furniture production potential in the TRB2 Region of Van province and the surrounding provinces, scientific research on the furniture sector is of great importance.

According to Arslan (2018), there is also a lack of awareness in the furniture sector regarding the necessity of production at the quality standards required to increase the sales amount and profit of the goods produced in TRB2 in domestic and foreign markets. In the few studies conducted on enterprises in the province of Van, it was emphasized that SMEs do not receive support from professional companies when making investment decisions and that businesses need to develop ways to benefit from external resources in order to become more efficient and healthy (Kilicli, 2016; Kilicli and Aygun, 2018).

The aim of this study is; to determine the current structure and problems of small-scale furniture enterprises (SMEs) operating in the province of Van through the sample. As a result, in particular in Van province and its surroundings, usually the small-scale furniture business in a very important furniture manufacturing industry for Turkey's manufacturing industry (SMEs) to contribute to the development and be a pioneer for a more comprehensive future studies.

Turkey Furniture Industry: Turkey's furniture industry, mainly small-scale, which lack employees and exports by traditional methods consist of business owners the flexibility capabilities (BAKKA, 2012; Demirci, 2005; IMG, 2020; Sogutlu and Eroglu, 2009; Malkocoglu et al., 2013; TOBB, 2017). Furniture exporting countries in the world ranking of 11th. and that Turkey continued to rise in 2017 for 2.360.407 million dollars, 2.686.740 million dollars in 2018, while in 2019 has made exports of 3.055.447 million dollars. With this figure, it has 1.6% of the world furniture export market (IMG, 2020). Turkey Furniture employment of the industry is the most intense first 10 cities, respectively, Istanbul, Bursa, Kayseri, Ankara, Izmir, Kocaeli, Antalya, Duzce, Sakarya and Mersin (Karagoz and Sevim Korkut, 2017).

When examined compulsorily insured employment figures registered a total of 14.314.313 million people are working in Turkey and their 154.829 people work in the field of manufacturing of furniture and constitute 1.08% of the total number of insured employees (SGK, 2019). The number of registered workplaces operating in the field of furniture manufacturing is 21.758. The total number of registered businesses producing wood, wood products and mushrooms is 10.161 and 60.456 insured people are employed in this sector (SGK, 2019).

When analyzed according to the number of employees of enterprises scale furniture manufacturing sector in Turkey, 86.6% of 1-9 people working, 81.1% of 1-6 people working, while 65.2% which runs between 1-3 people consists of businesses (SGK, 2019).

The furniture industry has some vulnerabilities to future uncertainties and to improve its position; It is stated that improvement should be made by focusing on concepts such as job satisfaction and productivity (Yapar, 2005) and strategic management (Yegin, 2020). Turkey's furniture industry; strategic management, quality control, export, research, design and university&industry cooperation (Ulay and Çakicier 2020) and the industrial estates of concepts such as discussion and adoption in business scale and is of great importance for the future of the industry.

Van Province Furniture Industry and Its Importance: Van province of Turkey's poorest provinces to TRB2 maintainde in the classification and socioeconomic development index (SEDI) ranks 75th in the ranking of 81 cities (SEDI, 2013). It is important to identify potential competitive sides and advantage by analyzing the existing sectors in the TRB2 region (Deliktas and Cekil, 2019).

According to the data of the Turkey Social Security Institution (SGK) in 2019, the total number of registered workplaces in the province of Van is 9440 and the total number of employees with compulsory SGK is 94.043 (SGK, 2019). It has been determined that there are 41 workplaces producing furniture with 31 activity codes and a total of 166 people work in these enterprises with insurance (SSI, 2019). A total of 117 people work in 36 workplaces registered in Wood, Wood Products and Mushroom Production with 16 activity codes, which is another business line where wood material is used as raw material (SGK, 2019).

According to DAKA (2017), it has been reported that there are 350 furniture manufacturers operating in Van registered to Van Chamber of Commerce and Industry and the current situation research of the sector covering 199 of these enterprises has been conducted. Similar to the general problem of the furniture industry in Turkey; in a different study in which all enterprises were included in the scope of the study, regardless of the scale, financial difficulties, lack of raw materials, insufficient demand, energy prices (Malkocoglu et al., 2015), unfair competition, raw materials, lack of capital, financing (Kilicli, 2016), technology used We are faced with low capacity utilization levels and a shortage of qualified personnel (Demirci, 2005; Ulay, 2011).

There is no scientific research other than the study prepared by DAKA (2017) for the Van furniture industry. The deficiency in this area should be filled with different studies. It has been reported that the furniture sector should be handled with a holistic perspective, taking into account the R&D and innovation capability, product quality, taxes and incentives, informality, demand and similar problems (DAKA, 2017).

MATERIALS AND METHODS

In the first phase of the research, the carpenter and furniture industry site in the center of Tusba district of Van province was visited and the current situation of the industrial site was observed physically. 71 businesses registered in Van Chamber of Tradesmen and Craftsmen and Chamber of Furniture and Carpenters, randomly selected among the enterprises operating in the industrial site were included in the study.

Research Approach: The business scale classification determined by TUIK and operating in the Carpenter and Furniture Manufacturers Industrial Site located in the city center of Van is based on the number of employed personnel in Table 1.

Table 1. Enterprise size according to the number of employees (Ustuner, 2010).

Number of employees	Business size
1- 9	Micro-scale business
10 - 49	Small-scale business
50 - 99	Medium-scale business
100 and above	Large-scale business

Method: The questionnaire consisting of 14 questions defining the basic information and current problems of the enterprises producing furniture, wooden doors and windows operating in the industrial site was applied using the face-to-face interview technique.

The questionnaires were applied to the responsible employee and / or business owner at the time of the visit. Considering that the research population is approximately N = 200 businesses, a sample group was formed in the study due to its size. It was calculated that n = 54 using the formula below. In the literature, 30 or more sampling diameters (n) are considered sufficient for the sampling section to be normal (web-1, 2020). For this reason, 71 enterprises were investigated by increasing the sample diameter above 54 as much as possible (n> 30). Thus, the results to be obtained were tried to be more inclusive and reliable (Sogutlu and Eroglu, 2008; Malkocoglu et al., 2013; 2015).

In the survey application, the sample size (n) was calculated from below equation (Cil, 2000; Malkocoglu et al., 2013).

$$n = \frac{Z^2 \times N \times P \times Q}{N \times D^2 + Z^2 \times P \times Q} \quad (1)$$

Z = Confidence Coefficient (1.96 was taken for 95% confidence), N = Large mass size, P = Probability of the property to be measured in the main mass (95%), Q = The probability of the feature to be measured is not found in the main mass (5%), Q = 1-P and D = indicate the accepted sampling error (10%) (Malkocoglu et al., 2013). Data entries of the survey results were analyzed using MS Excel program. Tables were created by calculating the frequency percentages (%) of the information provided by the enterprises to the surveys, and the data were discussed and evaluated.

RESULTS

Within the scope of this research, the answers given by the enterprises to the questionnaire consisting of 14 questions prepared by the researcher are evaluated and given in tables in this section.

The average number of personnel in the enterprises participating in the survey was determined as 3.1 people.

It was determined that the operating years (age of the enterprise) of 71 enterprises within the scope of the research are 26 years on average.

The data on the education status of the personnel working in the enterprise are given in Table 2.

Table 2. Education status of employees.

Graduation degree	F	%
University	16	7,2
Vocational High School	25	11,3
High School	55	24,9
Primary School	126	57,0

*F: Frequency

According to Table 2, 7.24% of the employed personnel are university graduates, 11.31% vocational high school graduates, 24.89% high school graduates and 57.01% primary education graduates. The product groups that businesses produce are given in Table 3.

Table 3. Production types of enterprises.

Product Types	F	%
Furniture	62	87,3
Woodworking	41	57,8
Decoration	49	69,0
Other	15	21,1

According to Table 3, 87.3% of the enterprises produce furniture manufacturing, 57.8% woodworking (doors and windows etc.), 69% decoration and 21.1% other types of products. It has emerged that some of the businesses have a flexible structure that they can do both furniture and joinery or decoration works together. The data of the machine types in the enterprise are given in Table 4.

Table 4. Machine types found in the enterprises.

Machine types	F	%	Machine types	F	%
CNC	5	7,0	Thickness	47	66,2
Edgebant	36	50,7	Band-saw	29	85,0
Circular-saw	61	85,9	Drilling	43	60,5
Plane	47	66,2	Milling	46	64,8
Other type	45	63,4			

According to Table 5, 90.1% of the enterprises ordered by phone, 12.7% from the internet, 5.6% from the showroom, 97.2% from acquaintances, 90.1% by coming to the workshop it was determined that he ordered.

In this research, it was determined that there are businesses that use more than one and different order taking methods. Data on the most common problems faced by businesses are given in Table 6.

Table 6. The most common problems in enterprises.

Problem type	F	%	Problem type	F	%
About personnel	26	36,6	Rent	32	45,1
Lack of demand	35	49,3	Transport	33	46,5
Raw material	28	39,4	Workshop area	27	38,0
Lack of capital	49	69,0	Other	18	25,4

According to the data in Table 6, business problems; 36.6% personnel, 49.3% lack of demand, 9.4% raw material, 69% lack of capital, 45.1% rent, 46.4% transportation, 38% one of them is due to workshop area and 25.3% from other reasons.

Among the other reasons reported as; insurance premiums, lack of qualified apprentices and journeymen, advertising, promotions, insufficient support and incentives. The data regarding the training requests for the employees of the enterprises are given in Table 7.

Table 7. The status of requesting free training for employees in the business.

Sucject training	F	%	Subject training	F	%
Furniture desing	35	49,3	Oparetor and maintenance	29	40,9
AutoCAD	31	43,7	Planning/organization	31	43,7
Computer	26	36,3	Work safety	39	54,9
CNC Machine	30	42,3			

Training subjects requested by enterprises according to Table 7; 49.3% furniture design, 43.7% use AutoCAD, 36.3% computer use, 42.3% use CNC, 40.9% operator and maintenance, 43.7% planning and organization and 54.9% work safety. The data on the ownership of a website by the enterprises are given in Table 8.

Table 8. The state of ownership of the website of enterprises.

Do you website of enterprises ?	F	%
Yes	10	14,1
No	61	85,9

According to Table 8, while 14.1% of the enterprises have a website, it has been determined that 85.9% of the enterprises do not have a website. The reasons why businesses do not have a website are given in Table 9.

Table 9. The reason for the lack of a web page belonging to businesses.

The reason for lack of web page	F	%
Economic reasons	28	39,4
Not needing	22	31,0
Lack of time	7	9,9
Not to find opportunities	12	16,9
Lack of information	9	12,7

According to Table 9, enterprises; It was determined that 39.4% due to economic reasons, 31% due to not needing, 9.9% to lack of time, 16.9% not to find opportunities and 12.7% due to lack of information. Cooperation status of enterprises with any educational institution is given in Table 10.

Table 10. The cooperation of enterprises with any educational.

Type of institution	F	%
Vocational High School	15	21,1
University	11	15,5
Public Education Center	2	2,8
Dont Cooperation	43	60,6

According to Table 10, enterprises; It was determined that 21.1% cooperate with vocational high schools, 15.5% with the university, 2.8% with the public education center, but 60.6% of the enterprises do not cooperate with any institution. The data on whether the business receives financial support from any institution or not is given in Table 11.

Table 11. Whether businesses receive support from any institution.

Support status	F	%
Yes	16	22,5
No	55	77,5

According to Table 11, enterprises; It was determined that 22.5% received KOSGEB project support and 77.5% did not receive support from any institution. Data pertaining to the need for social equipment required for enterprise employees are given in Table 12.

Table 12. The social facilities required by employees working in enterprises.

Types of social facilities	F	%
Banyo-WC	45	63,4
Restaurant	46	64,8
Cafe-tee home	53	74,6
Other	41	57,8

According to Table 12, employees; It was determined that 74.6% needed cafe-tea house, 64.8% restaurant, 63.3% bathroom and WC, 57.8% other social facilities in the industrial site. The demands of the working personnel from the relevant institution for the industrial site are given in Table 13.

Table 13. The demand of working personnel from the relevant institution.

Demand subject	F	%	Demand subject	F	%
Health center	21	29,6	About financial support	20	28,2
Moque	7	9,9	Demand and promotion	15	21,1
Park	6	8,5	Fire station	2	2,8
Transportaion	10	14,1	New workshop area	5	7,0

As the general demand of enterprises in Table 13; health center 29.6%, information on financial support 28.2%, demand and promotion 21.1%, transportation 14.1%, mosque 9.9%, park 8.5%, new workshop area 7%, fire-station 2.8%. The data regarding the need for showrooms where the enterprises will display their products are given in Table 14.

Table 14. The need for a showroom for businesses to display products.

Do you need showroom ?	F	%
Yes	40	56,3
No	19	26,8

According to Table 14, the enterprises; 56.3% stated that there is a need for a common showroom within the industrial site, 26.8% stated that there is no need for a showroom.

DISCUSSION and CONCLUSION

Within the scope of the research, it was determined that the activity year (age of the enterprise) of 71 furniture manufacturing enterprises in the city center of Van is 26 years on average. In the literature, according to Kilici and Aygun (2018), 37% of the 54 enterprises in the Van Organized Industrial Zone (OIZ) have an average of 16 years and above. According to DAKA (2017), 56.8% of the enterprises in the Van furniture industry have been operating for 10 years or more, and 28.1% have been operating for 6-10 years. It can be thought that enterprises can have their experience in the sector and the ability to survive against crises at different times. The relationship between the approaches of the enterprises that have adopted the traditional production and management style against innovations and change and their activity durations can be examined with different studies.

According to the education level of the working personnel; it was determined that they graduated from primary education (57%), high school (24.9%), vocational high school (11.3%) and university (7.2%). It is thought that the education level and type of training of the employees should be suitable for manufacturing in the technical field such as furniture and decoration (table 2).

However, it was determined that approximately 82% of the personnel did not receive vocational training. In the literature in Turkey furniture industry professional trained to be in need of qualified personnel (BAKKA, 2012; Coskun, 2019; DAKA, 2017; Demirci, 2005; Gorguc, 2008; Gurleyen et al., 2010; Malkocoglu et al., 2013; TOBB, 2017; Ulay, 2011; Ulay, 2020) and 68% of enterprises do not employ training staff (Gurleyen et al., 2010). The findings of the study are consistent with the literature. The vocational and technical training needs of the personnel can be met through in-service or vocational training institutions.

According to the findings, the majority of the enterprises produce furniture (87.3%), decoration (69%) and woodwork (57.8%) and other (21.1%) products (Table 3). It has been reported that the majority of the enterprises are manufacturing furniture and decoration, and more than half of them produce woodwork and related production.

It is understood that businesses keep their product range wide rather than specializing in certain areas. This situation is considered as an indicator of the flexibility characteristics of SMEs. Data consistent with the literature (DAKA, 2017; Malkocoglu et al., 2017).

The average number of employees for 71 workplaces in the Van furniture sector is 3.1 people. It is included in the micro enterprise definition made by TUIK. SGK (2019) argues that employ 1-3 people, 65.2% of the furniture business in Turkey, is made up of enterprises which employ staff while 86.6% between 1-9 people. It has been determined that Kilicli and Aygun (2018) constitute 9.3% (5) of the 54 enterprises in Van OIZ and the rate of those with less than 10 employees is 29.6% for all enterprises. According to DAKA (2017), 98.5% (196) of 199 furniture businesses in Van province are micro-scale and 1.5% are small-scale enterprises. The results of the study are compatible with the literature. On the other hand, it is thought that the high number of furniture enterprises in the province of Van, the low number of employees, working with low capacity and the increase in the number of enterprises due to unplanned expansion in the sector. Investment consultancy can be recommended to remedy the deficiency in this matter.

When the data on the machine capacity of the enterprises are examined; It has been determined that 93% of the enterprises, that is almost all of them, use conventional type machines. According to DAKA (2017) in the literature, it is reported that 90% of the enterprises use traditional machinery. It is thought that the technological machine usage levels of the enterprises are low and accordingly there is a deficiency in meeting their demands and customer satisfaction.

Businesses demand from customers; It was determined that 97.2% was done by acquaintances, 90.1% by coming to the workshop, 90.1% by phone, 12.7% by internet and 5.6% by showroom (Table 5). It is thought that traditional methods are widely used for businesses to gain new business and customers, which may cause a lack of demand and a decrease in sales. Similar problems have been reported in furniture businesses in different provinces in the literature. Coskun (2019) stated that foreign language web pages of businesses can increase their sales and export opportunities. Ustuner (2010) stated that the activities they did not allocate resources for promotion and marketing were insufficient.

Common problems in businesses; lack of capital, insufficient demand, lack of transportation, rent, raw materials, workshop area, and qualified personnel (Table 6). The results of the study were similar to the results of the study in the literature (Akyuz et al., 2020; DAKA; 2017; Malkocoglu et al., 2015; Ustuner, 2010; Serin and Sahin, 2020; Kilicli, 2016) for reasons such as lack of capital, shortage of raw materials and financing.

It is recommended to benefit from R&D and incentive supports, focusing on products with specific features (BAKKA, 2012) and producing innovative products.

According to Table 8, it was determined that 85.9% of the enterprises do not have a website where they can display their products. Businesses are considered to be insufficient in introducing their products and services to the market. According to DAKA (2017) in the literature, the promotional and marketing activities of most furniture companies in Van are carried out at a primitive level; According to Coskun (2019), it has been reported that businesses that do not have websites in a foreign language, not promoting their target markets negatively affect their export potential. According to BAKKA (2012), it has been reported that enterprises cannot carry out promotional and marketing activities and the content of those who have a web page is insufficient. There are studies stating that there is a lack of publicity and image in the furniture sector (BAKKA, 2012; Ustuner, 2010; TOBB, 2017). For this reason, it is thought that small and medium-sized enterprises should improve themselves in advertising and promotion, allocate a budget for these issues, and receive professional support for promotion and digital marketing activities.

According to Table 9, 39.4% of the enterprises are due to economic reasons, 31% due to not needing, 9.9% due to lack of time, 16.9% not to find opportunities and 12.7% due to lack of information. It has been determined that they do not have a website. It has been reported in the literature that advertising and marketing activities are not carried out because the lack of qualified personnel to prepare web pages of furniture businesses and their costs are avoided (BAKKA, 2012; Coskun, 2019; Ustuner, 2010). While the lack of a web page where businesses can display their products causes a lack of promotion, this may result in a lack of demand.

According to Table 10, 21.1% of the enterprises cooperate with a vocational high school, 15.5% with a university and 2.8% with a state education center. According to DAKA (2017), organizations that produce information with clustering, non-governmental organizations, suppliers and educational institutions have stated that they should be in interaction. According to TOBB (2017), the subject of qualified labor as school, employee, boss/employer should be considered together and sustainable solutions should be produced. Aksin et al. (2020) emphasizes the cooperation between universities and enterprises with high infrastructure and technology in order to adapt to the developments in our rapidly developing age. It has been reported that some enterprises have protocols for the admission of intern students to vocational high schools. According to Ulay (2020), it has been reported that as an academician observation, furniture and decoration students who graduated from vocational school are unwilling to work in this sector. It has been observed that many businesses do not cooperate with any educational institution. Turkey businesses operating in the furniture industry and one of the biggest shortcomings of professional training institutions of the co-culture is unsettled. This situation is thought to be one of the most important factors in development.

According to Table 11, it was determined that 22.5% of the enterprises received support from KOSGEB, while 77.5% did not receive support from any institution. Results of studies in the literature; In the study conducted by DAKA (2017) for Van furniture businesses, approximately 29% of 199 businesses benefited from KOSGEP and DAKA supports; According to Kilicli and Aygun (2018), it is compatible with the information that SMEs in Van OIZ benefit the most from KOSGEB and Halk Bank as credit source after commercial banks. However, despite these results, it was evaluated that many enterprises had capital shortages and did not receive any support and could not meet the necessary conditions for the support provided (Ulayi 2020a). Reducing bureaucratic difficulties and sustainability should be taken into consideration in the conditions sought in enterprises that will receive support. In support applications, free consultancy services can be created for enterprises within the scope of university-industry cooperation (Ulay and Cakicier, 2020).

According to Table 12, it has been determined that 74.6% of them need social facilities such as cafe-tee house, 64.7% restaurants, 63.3% bathrooms and wc. Söğütlü and Eroglu (2008) found that employees in furniture businesses do not have sufficient knowledge about the use of physical equipment and infrastructure. It is also found in the literature that meeting the physical needs of the employees will provide employee motivation and job satisfaction and affect productivity (Yapar, 2005). Ensuring employee satisfaction is considered necessary and beneficial for businesses and the social environment.

In Table 13, as the general demand of the enterprises; health center, qualified personnel, lack of demand, advertisement and promotion, transportation facilities, mosque, park, fire station. It is thought that deficiencies in demand issues may negatively affect employee motivation and job satisfaction levels. According to Yapar (2005) in the literature, he reported that employee motivation has an effect on work efficiency.

According to Table 14, the enterprises 56.3% of them stated that a common showroom is needed in the industrial site, 26.8% stated that there is no need. It is understood from these results that businesses lack awareness about sales and marketing. Electronic Commerce (E-Commerce) in the literature can be used in the furniture industry as in almost every field (Kurt, 2019). Businesses with low demand and difficulties in advertising (Ustuner, 2010) should be aware of up-to-date solution opportunities such as showrooms, e-showrooms and e-fairs, online catalogs, furniture stores, and recognize effective methods of delivering their products to customers. Cluster models such as industrial sites are thought to have shortcomings in sales and marketing by store when it comes to reaching customers. Convenience in product sales and an increase in demands can be achieved when businesses come together and create a common showroom or electronic commerce platform / page.

As a result, this research on the Van furniture industry is very important for the development of the furniture industry in terms of increasing community employment and welfare in the province and region. Conducting research that reveals the results of the cooperation between qualified personnel and institutions for the furniture sector and sharing the results with the sector will raise awareness and encourage the parties. Knowing the strengths and weaknesses of the Van furniture industry, the number of businesses that will create innovation should be increased. New research can be conducted on strategically important issues such as technology usage levels to improve institutionalization and branding skills.

SUGGESTIONS

- Training in the field of furniture manufacturing should be given to those who have not received vocational training (81.9%) in cooperation with vocational training institutions.

- The use of machinery with CNC technology (7%), which is inadequate, is increased and the level of technology usage in production is improved.
- Businesses that do not have a website (85.9%), insufficient demand (49.3%) and lack of promotion / advertising (21.1%) should update their ordering patterns and provide accessibility with the website.
- The most demanded training subjects are work safety (54.9%), furniture design (49.3%), Autocad and planning (43.7%), CNC machine use (42.5%), the institutions that provide relevant vocational training and training within the scope of the project.
- The website that cannot be made due to economic difficulties, raw material supply, rent, etc. For situations, initiatives can be taken to get support from KOSGEB, DAKA etc. institutions that provide financial support and loans.
- Another reason for insufficient demand may be insufficient quality level and customer satisfaction in products and services, so the quality level should be increased.
- Employees' physical and social needs such as tea houses and restaurants (74.6%), bathroom-wc (63.4%), healthcare station (29.6%) should be met and employee satisfaction should be measured regularly.
- Enterprises that do not receive any support from any institution (77.5%) should improve their ability to benefit from grant support. KOSGEB, DAKA, Van TSO etc. It is recommended to carry out studies in institutions to gain grant and fundraising skills to micro-enterprises.

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ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

Effect of Pre-Treatments on Wear Index of Varnished Wood Plastic Composites (WPC) With Pigmented

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Abstract: The utilization and usage areas of the wood plastic composites (WPC) have increased over the years. In addition, the importance of wood plastic composites produced by adding pigments has increased in terms of usage area. To be able to increase the coating ability of plastics, different pre-treatment had been used and some improvements were achieved. It is the purpose of this study to determine the wear index in abrasion of the WPC with pigmented using various coating and pre-treatments. For this purpose, it was used 2 different coating types (acrylic and cellulosic based) and 4 different pretreatments (sanding, acid treatment, UV, microwave). WPC with pigmented were manufactured and samples after various pretreatment and coating were prepared. The adhesion strength values were determined after coating. The results showed that pre-treatments used in this project affected the wear index. Acrylic based coating gave the best results of wear index in abrasion.

Keywords: Acrylic varnish, Coating properties, Wear index, Wood plastic composites.

Pigmentli Vernikli Ahşap Plastik Kompozitlerin (WPC) Aşınma İndeksi Üzerine Ön İşlemlerin Etkisi

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Öz: Ahşap plastik kompozitlerin (WPC) kullanım ve kullanım alanları yıllar içinde artmıştır. Ayrıca pigment ilavesiyle üretilen ahşap plastik kompozitlerin kullanım alanı açısından önemi artmıştır. Plastiklerin kaplama kabiliyetini artırabilmek için farklı ön işlemler kullanılmış ve bazı iyileştirmeler yapılmıştır. Bu çalışmanın amacı, çeşitli kaplama ve ön işlemler kullanılarak WPC'nin pigmentli aşınmasındaki aşınma indeksini belirlemektir. Bu amaçla 2 farklı kaplama tipi (akrilik ve selülozik esaslı) ve 4 farklı ön işlem (kumlama, asit muamelesi, UV, mikrodalga) kullanılmıştır. Pigmentli WPC üretildi ve çeşitli ön işlem ve kaplamalardan sonra numuneler hazırlandı. Kaplama sonrası yapışma mukavemeti değerleri belirlenmiştir. Sonuçlar, bu çalışmada kullanılan ön işlemlerin aşınma endeksini etkilediğini gösterdi. Akrilik esaslı kaplama, aşındırmada en iyi aşınma indeksi sonuçlarını vermiştir.

Anahtar kelimeler: Aşınma indeksi, Ahşap plastik kompozitler, Akrilik vernik, Kaplama özellikleri.

INTRODUCTION

Plastics are widely used in all areas of our lives. In the last century, the developments in polymer chemistry have made polymers used in our daily life and almost every part of the industry, depending on the reasons such as the lifestyle consumption habits of the developing and changing society. When the plastics are thrown away, they remain in nature for a long time without rotting, rusting, dissolving and biodegradable. Some plastics can remain in nature for 700 years. It causes contamination of water and soil. It harms the creatures in the waters and even causes their deaths. Plastics are materials that are solid at normal temperature and can be shaped or molded by different methods using pressure and temperature. Polymerization is the bonding of similar molecules that make up the polymer chain.

The production and use of wood plastic composites (WPC) continue to increase. One of the important problems encountered with the use of WPC is the color changes seen on the surfaces of the materials. Color-changed thermoplastic parts must be replaced, or their surfaces painted. However, it is extremely difficult to paint thermoplastics, especially polyethylene (PE) and polypropylene (PP) surfaces, which are called polyolefin, due to their low surface energies. Within the scope of this study, the dyeability of the surfaces of WPC materials, whose usage is increasing, was investigated (Novak and Florian, 2001).

UV lamps between 250-400nm are commonly used to change and improve the surface properties of polymer surfaces (Ryntz, 1998). Generally, UV treatment is applied in the presence of oxygen and ozone in the environment and in the presence or absence of another photo initiator. After the energy carrier (photon) activates the chemical species, it replaces the hydrogen atom in the polymer chain, resulting in free radicals. Chemical species follow two pathways of crosslinking and fragmentation (Ryntz, 1994). Benzophenone (BP) is most commonly used as photo initiator. This is due to the fact that BP absorbs UV light at wavelengths at 340-360nm and excitation / activation occurs rapidly with removal of hydrogen from the polymer in singlet and triplet state to form free radicals (Ranby et al., 1999). Free radicals react with applied chemicals (paint, varnish, etc.) and provide a better adhesion. Studies on the determination of surface characteristics of wood plastic composites are quite limited. Clemons et al. (1999) described the outer-middle layer morphology that occurs in injection-pressed and extruded wood polymer composites. It has been found that in composites produced by injection, the direction of the fibers in the middle layer is perpendicular and in the outer layers the fibers are oriented parallel to the flow direction (Clemons et al., 1999).

In addition, they found that the fiber volume ratio in the middle layer was higher than in the outer layer (Yang and Ranby, 1997). Processing parameters also affect the outer-middle layer morphology. Low temperature slow processing speed causes thick outer layer formation, high temperature high processing speed causes thin outer layer formation (Fu et al., 1999).

Similarly, the extrusion process leads to differences in outer-middle layer morphology and dehumidification properties. The surface of the wood plastic composite produced by extrusion shows that it has higher density and more fiber connections than the middle layer (Barbosa and Kenny, 2000). In addition, planed wood composites contain much more wood than wood plastic composites produced either by extrusion or injection. Therefore, in general, it appears that the nature of wood plastic composites depends on processing conditions, sampling depth, and sample preparation method.

For this purpose, it was aimed to determine the adhesion strength values of wood plastic composites after pre-treatment.

MATERIALS AND METHODS

In this study; High density polyethylene (YYPE_ S 0464, PETKİM) found in the laboratories of Kahramanmaraş Sütçü İmam University, Faculty of Forestry, Forest Industry Engineering Department was used as polymeric material. As lignocellulosic filler, band saw wastes were obtained from sawmills processing red pine timber in Kahramanmaraş industry.

Waste of band saw was collected from sawmills processing red pine timber in the Kahramanmaraş industry. These provided red pine wastes were first grinded with the help of the grinding machine shown in Figure 14 (a), then they were sized with the help of a shaker sieve and passed through a 40 mesh (0.400 mm) sieve and remained on a 60 mesh (0.250 mm) sieve. Lignocellulosic filler, red pine wood floors were prepared by drying at 103 ± 2 0C for 24 hours before production.

The quantities of materials to be used in thermoplastic composite production are given in Table 1.

Table 1. Trial design for the production of thermoplastic composites.

Sample Code	Polymer Amount (%)	Lignocellulosic Filler Amount (%)	MAPE (%)	Zinc Sterate (%)	Waks (%)	Iron Oxide (%)
TE	44	50	2	2	2	2

Production of HDPE Based Composites: The production of HDPE-based composites was carried out according to the scheme given in Figure 1.

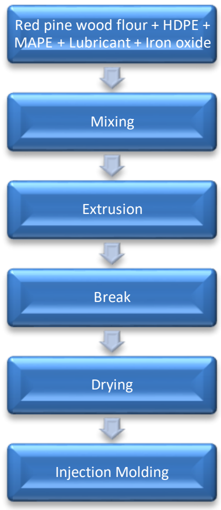

Figure 1. Composite manufacturing workflow.

Pre-Processing Samples: Before painting processes, some pre-treatments were carried out on WPC plates to determine their effects on their painting performance. These pretreatments are mechanical etching, chemical etching (diluted acid treatment), ultraviolet (UV) light and microwave applications.

Mechanical abrasing: Sanding process was carried out as mechanical abrasion. Examples; They were subjected to two different sanding processes with 60 and 80 numbered sandpaper. These samples are coded Z60 (sanded with 60 nl sandpaper) and Z80 (sanded with no 80 sandpaper).

Chemical etching: Two different concentrations of peracetic acid, 5% and 10%, were applied as chemical etching. These samples were coded as PA5 (samples treated with 5% concentration of peracetic acid) and PA10 (10% concentration treated samples).

Ultraviolet (UV) Light: Composite samples were applied in two different UV applications as 10 and 20 minutes.

Microwave: Microwave application was applied at two different times of 15 and 30 seconds. Microwave application was carried out in the microwave oven purchased under the project.

Painting of Pre-Treated and Unapplied WPC Sheet Samples: In order to determine the painting performance of WPC boards, painting processes were carried out using different paints on pre-treated and unprocessed surfaces. For this purpose, 4 different paint applications which are mostly used in the literature and industrially were selected. These paints are polyurethane (two-component), acrylic (two-component), synthetic (one-component) and water-based (one-component) paints, and their application is based on the manufacturer's mixture recommendations.

Paint applications were carried out according to the spraying method, using a normal pressure bottom-tank varnish gun with a spray tip opening of 1.8 mm, two layers of filling and single layer topcoat application with 125-150 gr paint per m2. After the paint application, all samples were kept in the air conditioning room after they were completely dried.

Wear Index Test: In order to determine the weight loss in abrasion, 5 samples of 100x100x7 mm of each varnish were used and made in accordance with ASTM D 4060-10 principles. According to this; the wear index (1), weight loss (2) and the amount of wear in each cycle (3) were determined on the samples. For this purpose, the weights of the samples before and after wear resistance were determined at a sensitivity of ±0.01 g.

The wear index I is calculated with the help of the following equation:

$$I=\frac{(A-B)1000}{C} \quad (1)$$

Here:

A = Weight of sample before abrasion test, g,
B = Weight, g, of the sample after the wear test
C = Number of revolutions recorded in wear.

Coding Samples: The samples obtained were coded as follows.

TED-Z60 60 no. Sanded
TED-Z80 80 no. Sanded
TED-UV10 UV-treated for 10 minutes
TED-UV20 UV-treated for 20 minutes
TED-MD15 15 seconds microwaved
TED-MD30 15 seconds microwaved
TED-PA5 5% peracetic acid applied
TED-PA10 5% peracetic acid applied

FINDINGS

Wear Index: Average abrasion resistance results are given in Table 2 below according to varnish types.

Table 2. Abrasion results

TED	Water based	Acrylic
Control	0,6000	0,4333
MD15	0,7667	0,5667
MD30	0,9000	0,3667
UV10	0,8333	0,5000
UV20	0,5333	0,5000
PA5	0,7000	0,4667
PA10	0,6333	0,5333
Z60	0,5333	0,4667
Z80	0,7333	0,6667

Statistical Evaluation Results for Abrasion Resistance: Variance analysis was performed for the results obtained in the wear index values and the results of the variance analysis are given in Table 3.

Table 3. Variance analysis results for wear index

		Sum of squares	df	Mean Square	F	Level of importance
Water-Based Ted	Between Groups	0,399	8	0,050	12,227	0,000
	Within Groups	0,073	18	0,004		
	Total	0,472	26			
Acrylic Ted	Between Groups	0,173	8	0,022	10,324	0,000
	Within Groups	0,038	18	0,002		
	Total	0,211	26			

The Duncan test was performed for the homogeneity tests of the groups whose effects were investigated according to the varnish types according to the Duncan test results and the results are given below.

Duncan Test For Water-Based Varnish: Pigmented (TED) Duncan test results for abrasion resistance for synthetic varnish are given below.

Table 4. Abrasion index Duncan test results for pigmented (TED) samples for water based varnish.

GROUPS	N	1	2	3	4	5	6
UV 20	3	,5333					
Z60	3	,5333					
Kontrol	3	,6000	,6000				
PA5	3	,6333	,6333	,6333			
PA5	3		,7000	,7000	,7000		
Z80	3			,7333	,7333	,7333	
MD15	3				,7667	,7667	
UV 10	3					,8333	,8333
MD30	3						,9000
Level of importance		,094	,085	,085	,241	,085	,217

According to the Duncan test results obtained, it was determined that the wear index value was collected in 6 different groups, the highest index value was in the samples with 30 seconds of microwave application and the lowest index value was in the 20 minutes of UV application. Statistically, it was determined that 15 seconds and 30 seconds of microwave application decreased the abrasion index value of all preliminary trials except the 80 numbered sandpaper.

Duncan Test For Water-Based Varnish: Pigmented (TED) Duncan test results for abrasion resistance for synthetic varnish are given below.

Table 5. Abrasion index Duncan test results on pigmented (TED) samples for acrylic varnish.

GROUPS	N	1	2	3	4	5
MD30	3	,3667				
Kontrol	3	,4333	,4333			
PA5	3		,4667	,4667		
Z60	3		,4667	,4667		
UV 10	3		,5000	,5000	,5000	
UV 20	3		,5000	,5000	,5000	
PA5	3			,5333	,5333	
MD15	3				,5667	
Z80	3					,6667
Level of importance		,092	,125	,125	,118	1,000

According to the results of Duncan test obtained, it was determined that the abrasion index value was collected in 5 different groups, the highest index value was in the samples with 80 sanding and the lowest index value was in the samples with 30 seconds of microwave application. Statistically, it was determined that 10 and 20 minutes of UV, 15 seconds of microwave, 80 number of sandpaper and 10% acid application increased the wear index value.

CONCLUSION

Wear index values of samples are given in Figure 2.

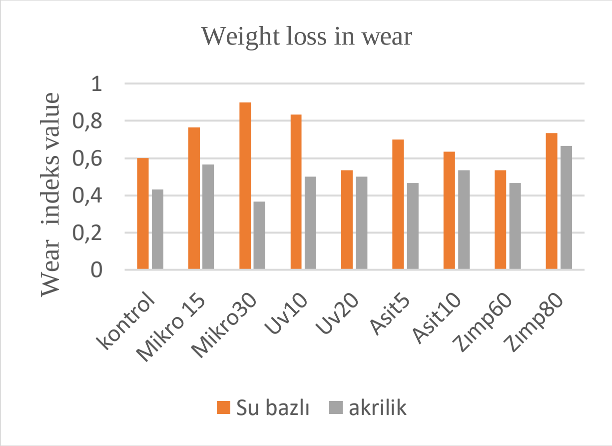

Figure 2. Abrasion index values

When the pigmented (TED) groups were examined, some pre-treatments increased the index value while others decreased it. When examined according to varnish types, the abrasion index value of acrylic varnish was low, while the highest was obtained in water-based varnish. It can be said that water-based varnishes wear easily.

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ARAŞTIRMA MAKALESİ RESEARCH PAPER

Mechanical Properties of Wood Members in Santa Maria Church

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Abstract: Wood is one of the oldest building materials used on earth. Wood as a building material; it has been evaluated in different ways according to the socio-economic, cultural and natural resource structures of the countries. In addition, wood is a building material used in the construction of places of worship such as mosques and churches according to the belief structures of the societies. Our country, which has a deep-rooted culture and history, is also rich with its places of worship, houses, architecture and use of houses. It is possible to come across some of these building examples in the black sea region. One of them is the Santa Maria church, which was built between 1869-1874 in the Merkez Kemerkaya district in Trabzon, and is a religious center where foreigners who visit the city still worship. The aim of this study is to evaluate the performance of the wooden materials of the church of Santa Maria by testing them non-destructive test methods. In this way, it was aimed to determine the current bearing properties without damaging the structural materials in a wooden structure built in our country and surviving for many years. For this purpose, the damage, defects and resistance properties of the building's bearing elements were tried to be determined with non-destructive test devices. The results obtained were compared with the values specified in the EN 338 standard. It was determined that most of the wooden elements in the structure still maintained their load-bearing properties and provide the minimum mechanical resistance properties specified in the standards.

Keywords: Non-destructive tests, historical wooden structures, santa maria church, deterioration and decay.

Santa Maria Kilisesindeki Ahşap Taşıyıcıların Mekanik Özellikleri

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Öz: Ahşap, yeryüzünde kullanılan en eski yapı malzemelerinden biridir. Yapı malzemesi olarak ahşap; Ülkelerin sosyo-ekonomik, kültürel ve doğal kaynak yapılarına göre farklı şekillerde değerlendirilmiştir. Ayrıca ahşap, cemaatlerin inanç yapılarına göre cami ve kilise gibi ibadethanelerin yapımında kullanılan bir yapı malzemesidir. Köklü bir kültüre ve tarihe sahip olan ülkemiz ibadethaneleri, evleri, mimarisi ve ev kullanımıyla da zengindir. Bu yapı örneklerinden bazılarına Karadeniz Bölgesinde rastlamak mümkündür. Bunlardan biri, Trabzon'un Merkez Kemerkaya Mahallesi'nde 1869-1874 yılları arasında inşa edilen ve şehri ziyaret eden yabancıların hala ibadet ettikleri bir dini merkez olan Santa Maria Kilisesidir. Bu çalışmanın amacı, Santa Maria Kilisesi'nin ahşap malzemelerinin performansını, hasarsız test yöntemleriyle test ederek değerlendirmektir. Bu sayede ülkemizde yapılan ve uzun yıllar ayakta kalan ahşap bir yapıda yapı malzemelerine zarar vermeden mevcut taşıyıcı özelliklerin belirlenmesi hedeflenmektedir. Bu amaçla binanın taşıyıcı elemanlarının hasar, kusur ve dayanım özellikleri hasarsız test cihazları ile belirlenmeye çalışılmıştır. Elde edilen sonuçlar EN 338 standardında belirtilen değerlerle karşılaştırılmıştır. Söz konusu yapıdaki ahşap elemanların birçoğunun halen taşıyıcı özelliklerini koruduğu tespit edilmiştir.

Anahtar kelimeler: Tahribatsız testler, tarihi ahşap yapılar, santa maria kilisesi, tahribat ve çürüklük.

INTRODUCTION

Wood is one of the oldest building materials used on earth. Wood as a building material; It has been evaluated in different ways according to the socio-economic, cultural and natural resource structures of the countries. In addition, wood is a building material used in the construction of places of worship such as mosques and churches according to the belief structures of the societies. Our country, which has a deep-rooted culture and history, is also rich with its places of worship, houses, architecture and use of houses. It is possible to come across some of these building examples in the Black Sea Region. One of them is the Santa Maria Church, which was built between 1869-1874 in the Merkez Kemerkaya District in Trabzon, and is a religious center where foreigners who visit the city still worship.

The aim of this study was to determine the defects and damages in Santa Maria Church 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.

MATERIALS AND METHODS

In this study, Santa Maria Church (Figure 1) which is about 150 years old was studied. The damage and defects in the Santa Maria Church were determined by non-destructive test devices including Resistograph and FAKOPP Screw withdrawal resistance meter. In addition, screw holding, shear and elasticity modulus of the wooden beams in the structure were determined.

Figure 1. Santa Maria Church.

Resistograph: The IML-RESI F-300 instrument is used to determine the internal decay and defects in wooden structures, poles and beams. Possible defects are usually foundin the interior of the wooden structures and can't be observed 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).

Screw withdrawal resistance meter: The beams in Santa Maria Church were tested using screw withdrawal resistance meter (Figure 2). 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).

Figure 2. The beams in Santa Maria Church were tested using screw withdrawal resistance meter.

RESULTS AND DISCUSSION

Resistograph: The wooden beams in 15 rooms of the Santa Maria Church were evaluated by Resistograph in order to determine the internal defects and deteriorations (Figure 3). Some of the Resistograph outputs obtained are given in Figure 4. As shown in the outputs, the higher peaks show the solid zone whereas the lower peaks indicate the decay, cracks, splits or deteriorated zones. The explanation of the Resistograph outputs was given on the outputs for each beam tested.

The results showed that beams in (Figure 4a) had partial 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 (Figure 4b), intensive internal cracks with rot insect damage were detected in the inner parts of the beam. The obtained results from Resistograph testing verified the visual inspection observation. 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.

Screw withdrawal resistance results: The wooden beams in 15 rooms of the Santa Maria Church were evaluated by Screw withdrawal resistance meter in order to determine screw withdrawal resistance, modulus of rupture (MOR) and shear resistance. Screw withdrawal resistance, MOR and shear resistance of the beams are given in Table 1.

Figure 3. Evaluation of the beams by Resistograph.

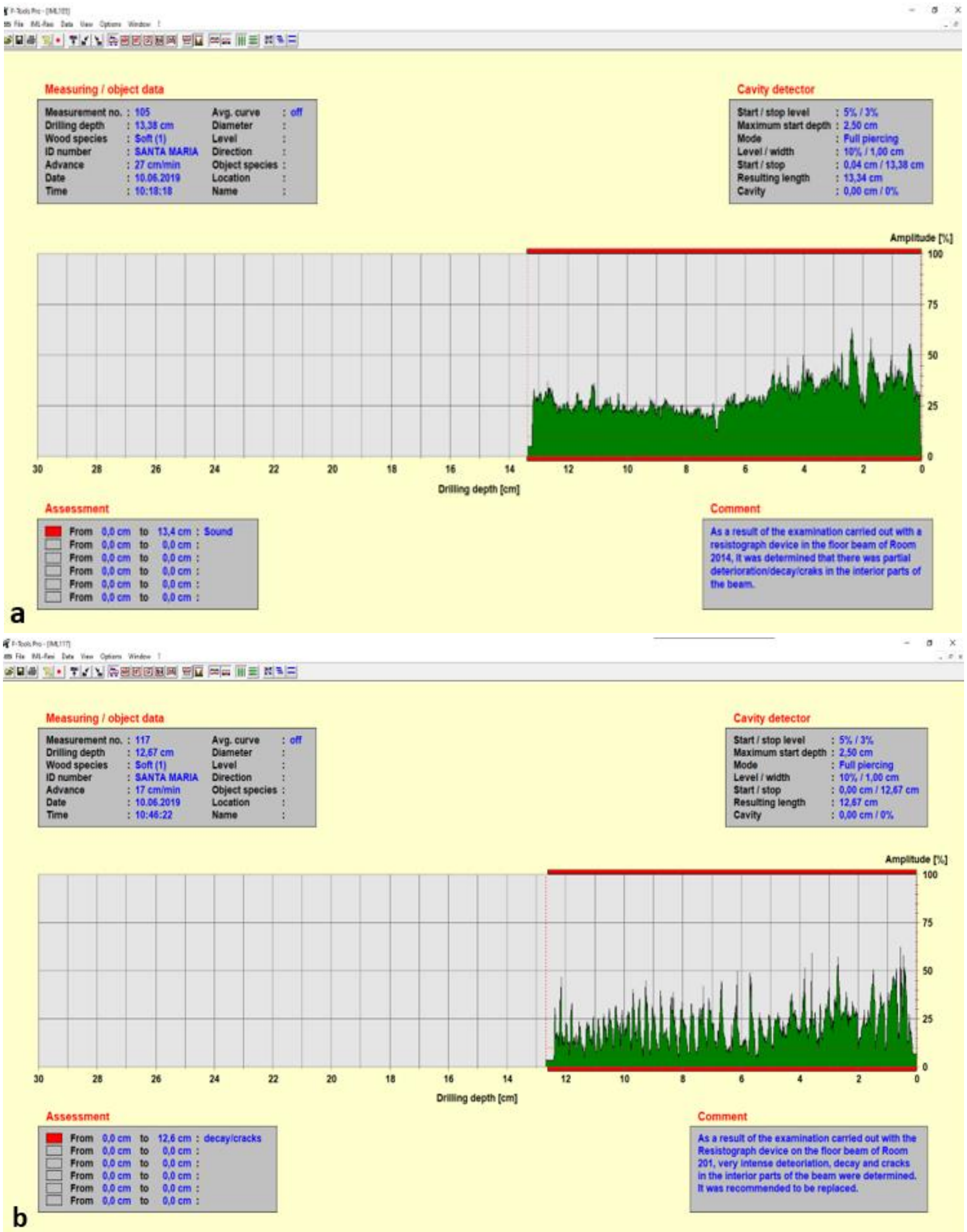

Figure 4. Some Resistograph output of the beam.

Screw withdrawal resistance values of the beams in the wooden structures examined in this study were ranged from 1.18 to 2.18 kN. According to the results, it was found that the beams in the room 103 and 113 had the highest shear resistance, MOR and screw withdrawal resistance. The lowest results were obtained from the beams in rooms located in the second floor of the church where the water pipeline was broken and beams got soaked with water.

Table 1. Screw withdrawal resistance meter results.

Room no	Screw withd. res. kN	MOR MPa	Shear resistance MPa
102	1,84	61	622
102	1,80	60	613
103	2,08	70	676
103	1,62	54	574
104	1,94	65	644
105	1,98	66	653
105	1,37	45	516
105	1,46	48	536
106	1,25	41	490
106	1,43	48	531
111	1,67	56	584
111	1,73	58	597
111	1,90	63	635
112	1,64	54	576
112	2,07	69	673
112	2,06	69	670
113	2,18	73	698
113	1,74	58	601
201	2,01	67	661
201	1,85	62	624
202	1,65	55	580
203	1,23	41	485
203	1,39	46	521
204	1,29	43	498
204	1,68	56	587
204	1,55	52	558
205	1,38	46	519
205	1,61	54	571
210	1,18	39	475
210	1,74	58	600
213	1,57	52	561
214	1,51	50	549

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.

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 is 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 device.

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 in rooms 106, 203 and 204 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. Decay and insect damage were detected on some of the wooden elements in the attic.

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ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

A Study on The Biomass Energy Potential of Turkey: Example of Wood Pellets

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Abstract: 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.

Türkiye'nin Biyokütle Enerji Potansiyeli Üzerine Bir Araştırma: Odun Peleti Örneği

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Öz: Odun Peleti, üretim teknolojisi kolaylığı, çevre dostu olması ve benzeri özellikleri ile tüm yenilenebilir enerji kaynakları içinde öne çıkmaktadır. Odun artıklarının kurutulup, öğütülerek talaş haline getirildikten sonra yüksek basınçla sıkıştırılmasından elde edilen 6-10 mm çapındaki yakıt topakları olan odun peletin ekonomik açıdan günümüzde fosil yakıtlar ile karşılaştırılabilir konuma gelmiştir. Dünya genelinde odun peleti ticareti, bir önceki yıla kıyasla 2018'de % 21'den fazla artış göstermiş olup 22.3 milyon tonluk ticaret hacmine ulaşmıştır. Dünya'da 2012 yılından itibaren en büyük pelet ihracatçısı ülkeler sırasıyla ABD, Kanada, Vietnam, Letonya ve Rusya'dır. Bu ülkeler 2018 yılında dünya ihracat hacminin yaklaşık% 69'unu oluşturmuşlardır. Beş ülke haricinde Çin'de alternatif enerji kaynakları ve özellikle odun peletinin üretimi, teknolojisi, kullanımı ve özellikleri üzerine çalışmalarını devam ettirmektedirler. Türkiye'de ise odun peletinin üretimi ve ekonomisi üzerine çalışmalar bulunmaktadır. Ancak bu çalışmalar gerek üretim gerekse ekonomik açıdan güncellenmesi gerekmektedir. Çalışmada, Türkiye'nin sahip olduğu potansiyel güncel veriler ile analiz edilerek bu potansiyelin kullanımına yönelik öneriler geliştirilmiştir.

Anahtar kelimeler: Ormancılık, ekonomi, biyo-yakıt, enerji talebi.

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 & 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.

MATERIALS AND METHOD

Data Collection: 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.

Methods: Literature review method was used in the study. 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.

RESULTS AND DISCUSSION

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.

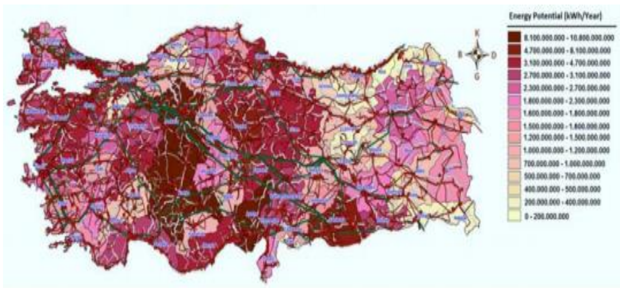

Figure 1. Turkey’s total biomass potential (MEF, 2009).

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 & 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).

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 T urkey. 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 m^3 with an annual growth of about 45.9 million m^3 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.

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) stated that approximately 4 million m^3 of forest residues could be obtained from 10 million m^3 of industrial wood production. According to General Directorate of Forestry (GDF) estimated that 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.

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 increased. 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) stated that this value as $586 million. This difference is due to the change in the amount of wood used in production and the dollar rate. Besides, Bayramoğlu and Toksoy (2015) stated that wood pellet is more economical than other energy sources.

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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ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

Situation of Forest Carbon Projects in Carbon Markets

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Abstract: 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.

Karbon Piyasalarında Ormancılık Karbon Projelerinin Durumu

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Öz: Atmosferdeki artan sera gazı emisyonlarını stabilize etmek için Birleşmiş Milletler İklim Değişikliği Çerçeve Sözleşmesi, Kyoto Protokolü ve Paris Anlaşmaları çerçevesinde küresel işbirliği çalışmaları yürütülmektedir. İklim Değişikliğiyle mücadele kilit rol oynayan ormanlar iklim değişikliği müzakerelerinde görüşülen en önemli konular arasında yer almaktadır. İklim değişikliğinde ormancılık sektörünün iki önemli ayağı bulunmaktadır. Bunlardan biri azaltım diğeri ise uyumdur. Azaltım kapsamında müzakerelerde görüşülen ormancılıkla ilgili hususlar Arazi kullanımı arazi kullanım değişikliği ve ormancılık (LULUCF) ve REDD konularıdır. Uyum ise; iklim değişikliğinin etkilerine yanıt olarak ekolojik, sosyal ve ekonomik sistemlerdeki düzenlemeleri ifade etmektedir ve iklim değişikliği nedeniyle ortaya çıkabilecek risklerin yönetimini kapsamaktadır. Ormancılıkta uyum iklim değişikliği odaklı sürdürülebilir orman yönetimi anlamına gelmektedir. Azaltımla ilgili mekanizma karbon piyasalarıdır. Karbon piyasalarında ormancılık projelerinin oranı ise düşüktür. Türkiye gönüllü karbon piyasalarında işlem görmekte olup zorunlu karbon piyasalarına göre oldukça düşük gelir elde etmektedir. Bununla birlikte işlem gören karbon kredileri yenilenebilir enerji sektöründen sağlanmaktadır. Bu krediler içinde ormancılık faaliyetleri bulunmamaktadır. Bununla birlikte Türkiye, müzakereler haricinde de kurumsal ve teknik alt yapısında değişiklikler yapmak zorundadır.

Anahtar kelimeler: İklim değişimi, Kyoto protokolü, karbon kredisi, ormancılık.

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.

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.

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.

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".

MATERIALS AND METHOD

Data Collection: 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.

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.

RESULTS AND DISCUSSION

Forest Carbon Sequestration Potential of Turkeyy: 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.

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.

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).

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.

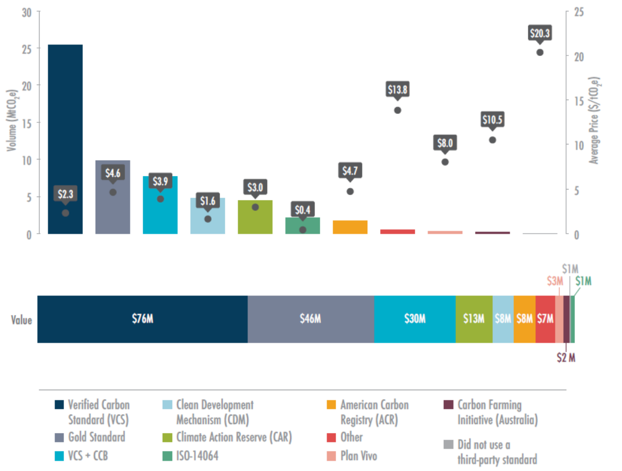

Figure 1. Transaction volume and values of forestry-based emission reductions in voluntary and compulsory markets (Hamrick and Gallant, 2017).

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.

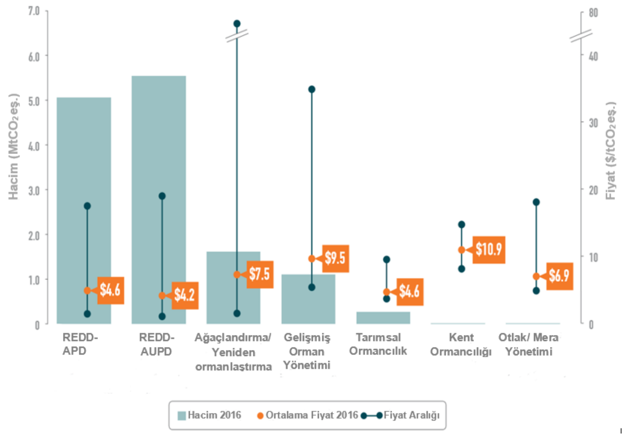

Figure 2. Distribution of forestry carbon projects by project type.

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.

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.

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).

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.

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ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

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.

Yaşlandırılmış Kayın Odununun Mantar Çürüklük Dayanımı

Öz: Ahşap dış mekan uygulamalarında foto-degradasyona karşı hassas bir malzeme olup, yüzeyinde mikro veya makro çatlaklar ile renk değişiklikleri gibi deformasyonlar meydana gelmektedir. Özellikle çatlaklar, ahşap malzemeyi biyotik saldırılara karşı daha savunmasız hale getirmektedir. Bu çalışmada, doğal ve hızlandırılmış yaşlandırma testi uygulanmış kayın örneklerinin esmer (*Coniophora puteana*) ve beyaz çürüklük (*Coriolus versicolor*) mantar saldırılarına karşı dayanımı araştırılmıştır. Bu amaçla, 393 gün boyunca doğal dış ortam testi (NW) ve 1512 saat süreyle hızlandırılmış yaşlandırma testine (AW) maruz kalan kayın örnekleri, 2 ve 4 hafta boyunca malt ekstrakt agar ortamında çürüklük testine tabi tutulmuştur. 2 hafta boyunca *C. versicolor* mantarının saldırısına bırakılan örneklerin ağırlık kaybı kontroller için %24,30, AW örnekleri için %13,29 ve NW örnekleri için %24,38 olarak bulunmuştur. *C. puteana*'ya maruz bırakılan kontrol, AW örnekleri ve NW örnekleri için ise ağırlık kaybı sırasıyla %21,15, %21,49 ve %30,61 olarak bulunmuştur. 4 hafta boyunca *C. versicolor*'a maruz bırakılan örneklerin ağırlık kaybı kontroller için %61,82, AW örnekleri için %30,72 ve NW örnekleri için %37,62 olarak bulunmuştur. *C. puteana*'ya 4 hafta boyunca maruz bırakılan örneklerin ağırlık kaybı kontroller, AW örnekleri ve NW örnekleri için sırasıyla %21,43, %28,44 ve %37,67 olarak bulunmuştur. Doğal dış ortam testi, her iki mantar türü için hızlandırılmış yaşlandırma testinden daha fazla ağırlık kaybına neden olmuştur.

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Anahtar kelimeler: Beyaz çürüklük, esmer çürüklük, doğal dış ortam testi, hızlandırılmış yaşlandırma testi, kayın.

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 depolymerization 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 (Brischke and Meyer-Veltrup, 2015; Metsa-Kortelainen and Viitanen, 2017; Tomak et al., 2018).

In outdoors, wood undergoes biological decay by white, brown and soft rot fungi. Basidiomycetes are responsible for the most of wood decay in constructions (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 fungi caused greater change in weight-loss in naturally aged samples than white-rot fungi did (Chow and Bajwa, 1998). Reinprecht and Grznárik (2015) reported that the artificial ageing decreased 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 (controls).

MATERIALS AND METHODS

Materials: Beech samples were obtained from Sulekler Forest Industry, Bursa, Turkey. The samples were produced industrially. 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).

Method

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.

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 principles of ASTM G7 (2013) and EN 927-3 (2003) standards.

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 (1)

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.

RESULTS AND DISCUSSION

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.

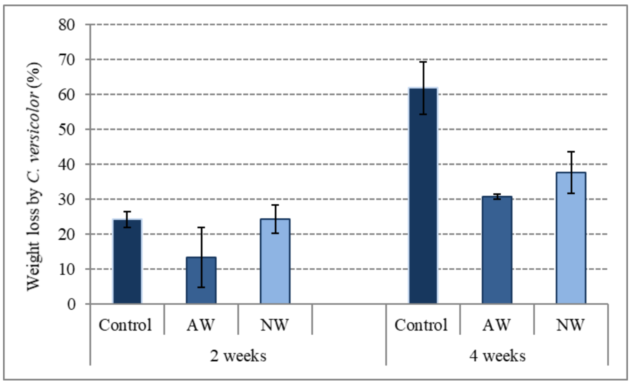

Figure 1. Weight loss of samples caused by *C. versicolor* attack.

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 (especially lignin) 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 (Figure 1). Panek et al. (2014) stated that artificial weathered beech samples exhibited less weight loss than the untreated control samples.

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 samples for both decay fungi. Cracks and voids in the natural weathered samples could cause an entrance for fungi mycelium, and cause an increase in the moisture uptake during the decay test, and therefore may create more suitable conditions for fungal growth. Furthermore, different degradation rates of wood components between the weathering methods could also have an important role on the weight losses by fungi attacks.

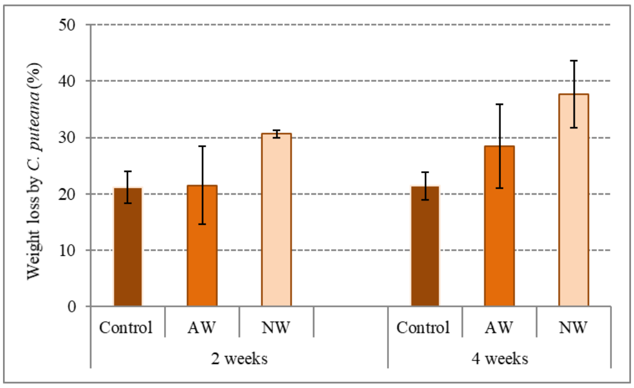

Figure 2. Weight loss of samples caused by *C. puteana* attack.

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. Brown rotter's primarily attack the cell-wall carbohydrates, leaving a modified lignin at the end of the decay process. Simultaneous white-rotter's attack all cell-wall constituents (Zabel and Morell, 1992). Weathering also causes a decrease in lignin component. In fact, weathering is a surface phenomenon. But in this study the thickness of the samples is quite small, and therefore the degradation could be deeper inside the sample. 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 *C. versicolor* growth than weathered samples. In the decay process of *C. puteana*, wood carbohydrates were degraded, and lignin was previously degraded in weathered samples. However, only carbohydrate degradations occurred during *C. puteana* attack in controls. This could cause a less weight loss in controls than weathered samples after *C. puteana* attack.

CONCLUSION

This study aimed to investigate the decay resistance of natural and accelerated weathered beech samples against *C. puteana* and *C. versicolor* attacks. The results showed that fungi species and weathering methods affected the decay resistance of samples. Natural weathering samples degraded more than artificial weathering samples after both decay fungi exposure. Different degradation rates of wood components between the weathering methods probably played an important role on the weight losses by fungi attacks. Control samples showed higher weight loss than weathered samples after *C. versicolor* exposure, however, they had lower weight loss than weathered samples after *C. puteana* exposure probably related with the decay mechanism of white and brown rot fungi. 4 weeks of exposure to *C. versicolor* caused more weight loss than *C. puteana* for all samples since white rots in hardwoods are generally more severe. More studies are needed for better understanding in decay mechanism of weathered wood.

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