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EFFECT OF TREE SPECIES ON SOME MECHANICAL PROPERTIES OF MDF[1) 2)]

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Abstract

In this study, effect of tree species on mechanical properties of Medium Density Fiberboards (MDF) manufactured from furnishes of oak *(Quercus robur)*, beech *(Fagus orientalis)*, pine *(Pinus nigra)*, and a mixture of these species (a mixture of 40 percent oak, 40 percent beech, and 20 percent pine furnish) was investigated. Tests were made on specimens conditioned at 20±2°C and 65±5 percent relative humidity. Analysis of variance and multiple-range test (Duncan) were carried out to evaluate test results at a 95 percent confidence level. According to the results of this research, except for Janka hardness, the other mechanical properties of the panels made from pine furnish were better than those of panels made from oak, beech, and a mixture of these species furnish.

1. INTRODUCTION

MDF (Medium Density Fiberboard) is a dry formed panel product manufactured from lignocellulosic fibers combined with a synthetic resin or other suitable binder (WINISTORFER / YOUNG 1996). Although MDF is a relatively new product in Turkey, its production has been increasing in recent years. Today, there are six MDF plants in the country with a total capacity of 720.000 m^3/year (YAMAN 2002). Most of the MDF panels are used as a substrate for thin

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overlays such as melamine-impregnated papers in the furniture industry. In addition, various types of finishes are directly applied to the sanded panel surface to be as furniture panels.

MDF has been one of the most rapidly growing composite panel products to enter the world market in recent years. The combination of increasing population and decreasing prime timber supply suggests a continuing shift to use composite panels, among which MDF offers many advantages.

The surface of MDF is flat, smooth, uniform, dense, free of knots, and grain patterns, all of which make finishing operations easier and consistent, especially, for demanding uses such as direct printing and thin laminates. The homogenous edge of MDF allows intricate and precise machining and finishing techniques for superior products, such as streo cabinets and relieved door fronts, and mouldings. Trim waste is significantly reduced when using MDF compared to other substrates. MDF's stability contributing to better holding tolerances in cut parts. Its strength allows the parts' size or thickness to be reduced in some instances. MDF is an excellent substitute for solid wood in many interior applications except when the higher stiffness of solid wood is required.

MDF is made in much the same manner as particleboard with a few important diffirences. Prior to refining, the wood furnish is "cooked" in a moderate pressure steam vessel (digester). During this step, the wood changes both chemically and physically, becoming less susceptible to the influences of moisture and less brittle as the lignin softens. During the refining step, the wood is "rubbed" apart into fiber bundles instead of being mechanically "broken" apart in particle preparation. Since fibers are all basically the same size, they need no screening, but can have the resin binder added directly after refining and/or drying. The most common binder for MDF is urea-formaldehyde. Other types of resin can be used to provide special properties such as moisture and fire resistance. The wood-fiber resin combination is then formed into a homogeneous mat of random fiber orientation and hot pressed, completing the rough manufacture. Further mill processing steps include sanding, sawing, and quality inspection prior to shipment. Many MDF mills also provide cut-to-size or other value-added services for their customers (ANONYMOUS 1998).

The differences in properties of boards produced was much less than the differences in properties of raw material woods.This effect may be partially attributed to the fact the fiber wall density of all woods is about the same differences in wood properties are caused mainly by size of the fibers and the distribution and size of void spaces in wood represented by vessels, resin canals etc. Since the void spaces in wood represented by vessels, thin wall fibers etc are mainly or partially lost during the fiberization operation, this tends to reduce differences between whole wood fibers produced from different wood species (JENKS 1979).

Surface absorption, surface roughness, and formaldehyde emission of commercially manufactured MDF from furnishes of oak, beech, pine, and a mixture of these species were investigated at a study made by AKBULUT, HIZIROGLU and AYRILMIŞ in 2000. Surface absorption and formaldehyde emission values of the specimens are given in Table 1.

Table 1 displays the results of panel surface absorption of panel manufactured from different species. Samples made from 100 percent oak furnish were the most absorbent, with an average value of 179.07 mm; the panels made from mixed furnish had an average value of 281.83 mm, which was the least absorbent among the four types of specimens.

Surface roughness values (average roughness, mean peak-to-valley height, maximum peak-to-valley) of the specimens are given in Table 2.

Table 1: Surface Absorption and Formaldehyde Emission Values Of The Specimens
Tablo 1: Numunelerin Yüzey Emiciliği ve Formaldehit Emisyon Değerleri

Furnish Type Elyaf Tipi	Surface Absorption (mm) Yüzey Absorpsiyonu		Formaldehyde Emission (mg/100g) Formaldehit Emisyonu	
	Average Ortalama (mm)	Standard Deviation Standart Sapma (mm)	Average Ortalama (mg/100g)	Standard Deviation Standart Sapma (mg/100g)
100 % Oak % 100 Meşe	179.07	22.47	40.64	1.12
100 % Beech % 100 Kayın	197.38	32.56	42.90	0.80
100 % Pine % 100 Çam	235.11	18.70	42.18	0.92
Mixed Species (40 % Beech + % 40 Oak + 20 Pine) (% 40 Kayın + % 40 Meşe + % 20 Çam)	281.83	24.08	39.75	1.20

Table 2: Surface Roughness Values (Average Roughness, Mean Peak-to-valley Height Maximum Peak-to-valley) Of The Specimens
Tablo 2: Örneklerin Yüzey Pürüzlülük Değerleri (Ortalama Pürüzlülük, On Nokta Yüksekliği, Maksimum Pürüzlülük)

Furnish Type Elyaf Tipi	Average Roughness Ortalama Pürüzlülük (R_a)		Mean peak-to-valley height On Nokta Yüksekliği (R_Z)		Maximum peak-to-valley height Maksimum Pürüzlülük (R_{max})	
	Average Ortalama (μm)	Standart deviation Standart sapma (μm)	Average Ortalama (μm)	Standart deviation Standart Sapma (μm)	Average Ortalama (μm)	Standart deviation Standart Sapma (μm)
100 % Oak	4.1	0.63	31.1	4.1	38.3	5.9
100 % Beech	3.6	0.56	29.1	3.9	36.6	5.8
100 % Pine	3.8	0.65	28.4	5.1	35.7	7.1
Mixed species	3.2	0.55	25.7	3.9	32.7	6.3

Panels made from oak furnish had the roughest surface, as seen Table 2. Average values of 4.1 μm, 31.1 μm, and 38.3 μm were found for Ra, Rz, Rmax respectively Table 2.

In an another study made in North China; Medium density fiberboard panels (MDF) made from steam-pressure-refined wood residues (a mixture of 70 % hardwoods and 30 % softwood species) and bonded with 8 percent phenol-formaldehyde (PF) resin met most of the specifications required for service class hardboard and achieved equal to or better strength properties than commercial plywood. The MDF wood residues of mixed hardwood from birch *(Betula)*, ash *(Fraxinus)*, lime *(Tilia)*, douglas fir *(Pseudotsuga)*, spruce *(Picea)*, and larch *(Larix)* furnishes on condition that as 70 % hardwood, and 30 % softwood furnishes with 8. It was determined that panels manufactured from this furnishes had strong technological properties as well as plywood (CHOW / ZHAO 1992).

Wood species has long been recognized as a major variable in the manufacture of MDF. If a single species is used, the production process can be adjusted to have maximum uniformity in panel properties. However, a mixture of species is an important factor influencing both physical and mechanical properties of the final product. In general, low quality oak, beech, and pine are used as raw materials, either as a single species or as a mixture for MDF manufacture in Turkey (AKBULUT/HIZIROĞLU/AYRILMIŞ 2000).

HIZIROGLU and KAMDEM (1995) investigated physical and mechanical properties of hardboard made chemi-thermo-mechanical pulp fibers from black locust *(Robinia pseudoacacia)* furnish. It was determined black locust fibers can be used as furnish for wet process manufacture of hardboard with acceptable mechanical properties. In light of the acceptable properties found in this study of labarotory-made hardboards, black locust can be considered as a viable fiber source for hardboard manufacture.

Objective of the Study

No study has been done concerning the effect of tree species on mechanical properties of MDF in our country under laboratory conditions so far. Good quality MDF could be manufactured if such studies were done.

2. MATERIALS AND METHODS

Stem and branch woods were used in producing experimental panels which were taken from Trakya (*Quercus robur* L.), Yalova (*Fagus orientalis* Lipsky), Geyve-Adapazarı (*Pinus nigra pallasiana*). They were 8-15 cm in diameter and average 1 m in lenght.

Medium Density Fiberboard panels (3660 by 2230 by 18 mm) were manufactured at Kastamonu Integrated Wood Company located in Gebze, Turkey. Panels made from oak, beech, pine, and a mixture of these species were used in the experiments. A total of 12 panels, 3 for each type of furnish, were tested. The chips having an average size of 20 by 25 by 5 mm were produced from roundwood. Raw material was converted into fiber furnish in an Asplund defibrator using a steam pressure of 7.5 bar at a temperature of 178°C for 5 minutes. The following were added to the fiber furnish: 1 percent wax, 0.8 percent NH_4CL as hardener, and 11 percent urea-formaldehyde resin. Mats with an average moisture content of 10.5 percent were pressed at temperature of 206°C for 4 minutes at a pressure of 3.5-4 N/mm^2. The panels were sanded with a sequence of 150, 180, and 200 grit size following the cooling process. Density profiles of MDF made from oak and mixed species are given in Figure 1.

Preliminary experiments were first made on 20 samples in order to determine minimum sample numbers for each test. Thus, it was calculated minimum sample numbers varying from 10 to 25, according to test type. Fifty samples from each panel type were used to determine tension strength perpendicular to the plane of panel, tension strength parallel to the plane of panel, screw holding ability perpendicular to the plane of panel, screw holding ability perpendicular to the plane of panel, and janka hardness perpendicular to the plane of panel. Thirty samples from each panel type were used to determine bending strength and modulus of elasticity.

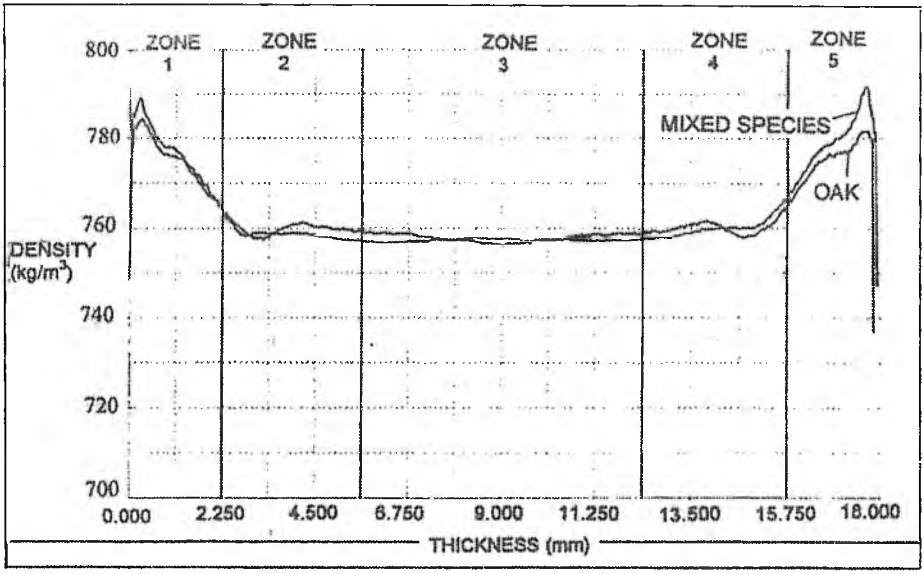

Figure 1: Density profiles of MDF made from oak and a mixture of these species.
Şekil 1: Meşe ve ağaç türlerinin karışımından üretilen MDF'lerin yoğunluk profilleri.

Specimens taken from experimental panels were carried out based on European Norm 326-1, 1999 (TS EN 326-1). Each panel was divided into panel piece of bigger than 800 mm by 1600 mm. After that, test samples were cut from this piece of panel according to the above standard.

Dimension of the specimens, number of the samples and standard numbers of the experimental specimens used in the test are as follows;

Tests	Dimension of Specimen	Number of Sample	Standard Number
Bending strength	50 x 410	30	TS EN 310 (1999)
Modulus of elasticity	50 x 410	30	TS EN 310 (1999)
Tension strength perpendicular to the plane of panel	50 x 50	50	TS EN 319 (1999)
Tension strength parallel to the plane of panel	51 x 254	50	ASTM D 1037-78 (1994)
Screw holding ability perpendicular to the plane of panel	76 x 152	50	ASTM D 1037-78 (1994)
Janka hardness perpendicular to the plane of panel	75 x 150	50	ASTM D 1037-78 (1994)

Tests were made on specimens conditioned at 20 ± 2 °C and 65 ± 5 percent relative humidity. Analysis of variance and multiple-range test (Duncan) were carried out to evaluate test results.

Measuring and weighing of test specimens were done according to TS EN 325 (1999). For this purpose, thickness of specimens were measured with a digital micrometer (sensitive to 0.001 mm) and lenghts were measured with a digital compas (sensitive to 0.01 mm).

3. RESULTS

3.1 Bending Strength

Number of sample, arithmetical mean, maximum value, minimum value, standard deviation, variance, and coefficient of variation in connection with panels made from beech, oak, pine, and a mixture of these species are given in Table 3.

Table 3: The Values Of Bending Strength
Tablo 3: Eğilme direnci değerleri

Statistical parameters İstatistik parametreler	**Beech**	**Oak**	**Pine**	**Mixed species (%40 B+%40 O+%20 P)**
Number of sample Örnek sayısı	30	30	30	30
Arithmetical mean (N/mm^2) Aritmetik ortalama	34.05	27.04	40.12	30.80
Maximum value (N/mm^2) Maksimum değer	39.09	31.08	44.30	33.91
Minimum value (N/mm^2) Minimum değer	29.45	24.34	36.28	27.57
Standard deviation (N/mm^2) Standart sapma	27.217	15.492	24.666	18.741
Variance-Varyans	740.779	240.021	608.416	351.242
Coefficient of variation (%) Varyasyon katsayısı	7.993	5.730	6.147	6.084

Variance analysis indicated that panel types showed a difference at the confidence level of 95 % and then Duncan test were applied to the data in order to reveal the differences in the panel group or groups (Table 4).

Table 4: Results Of Duncan Test
Tablo 4: Duncan testi sonuçları

Duncan Test	X_2	X_3	X_4
X_1 (R_p)	60.737 (11.26)	93.178 (11.86)	130.872 (12.26)
X_2 (R_p)	–	32.441 (11.26)	70.135 (11.86)
X_3 (R_p)	–	–	37.694 (11.26)

X_1: Pine X_3: Mixed species
X_2: Beech X_4: Oak

As shown in Table 4, a significant difference (at a 95 percent confidence level) was found between the panel types manufactured from beech, pine, oak, and mixed species based on the arithmetical mean values and the R_p values in bending strength.

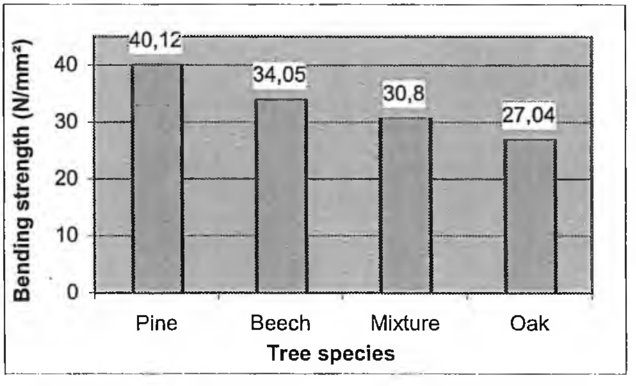

Figure 2: The arithmetical mean values of bending strength.
Şekil 2: Eğilme direnci aritmetik ortalama değerleri.

3.2 Modulus of Elasticity

Number of sample, arithmetical mean, maximum value, minimum value, standard deviation, variance, and coefficient of variation in connection with panels made from beech, oak, pine, and a mixture of these species are given in Table 5.

Table 5: The Values Of Modulus Of Elasticity
Tablo 5: Eğilmede Elastikiyet Modülü Değerleri

Statistical parameters İstatistik parametreler	**Beech**	**Oak**	**Pine**	**Mixed species** **(%40 B+%40 O+%20 P)**
Number of sample Örnek sayısı	30	30	30	30
Arithmetical mean (N/mm^2) Aritmetik ortalama	3139.32	2857.87	3494.33	2951.69
Maximum value (N/mm^2) Maksimum değer	3481.39	3185.36	3721.09	3133.20
Minimum value (N/mm^2) Minumum değer	2770.8	2624.64	3206.72	2649.29
Standard deviation (N/mm^2) Standart sapma	2007.289	1445.946	1418.359	1285.619
Variance-Varyans	4029211.41	2090761.60	2011744.90	1652817.44
Coefficient of variation (%) Varyasyon Katsayısı	6.394	5.059	4.059	4.355

Variance analysis indicated that panel types showed a difference at the confidence level of 95 % and then Duncan test were applied to the data in order to reveal the differences in the panel group or groups (Table 6).

Table 6: Results Of Duncan Test
Tablo 6: Duncan testi sonuçları

Duncan Test	X_2	X_3	X_4
X_1 (R_p)	3550.121 (799.58)	5426.417 (842.41)	5426.417 (870.97)
X_2 (R_p)	–	1876.296 (799.58)	2814.493 (842.41)
X_3 (R_p)	–	–	938.197 (799.58)

X_1: Pine X_3: Mixed species
X_2: Beech X_4: Oak

As shown in Table 6, a significant difference (at a 95 percent confidence level) was found between the panel types manufactured from beech, pine, oak, and mixed species based on the arithmetical mean values and the R_p values in modulus of elasticity.

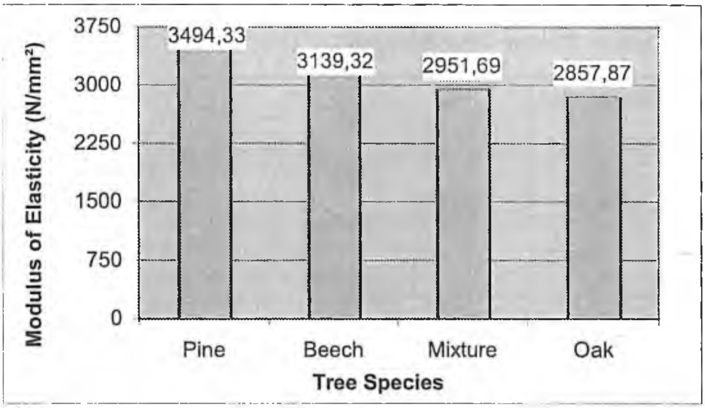

Figure 3: The arithmetical mean values of modulus of elasticity.
Şekil 3: Eğilmede elastikiyet modülü aritmetik ortalama değerleri.

3.3 Tension Strength Perpendicular To The Plane Of Panel

Number of sample, arithmetical mean, maximum value, minimum value, standard deviation, variance, and coefficient of variation in connection with panels made from beech, oak, pine and, a mixture of these species are given in Table 7.

Table 7: The Values Of Tension Strength Perpendicular To The Plane Of Panel
Tablo 7: Levha Yüzeyine Dik Yönde Çekme Direnci Değerleri.

Statistical parameters İstatistik parametreler	**Beech**	**Oak**	**Pine**	**Mixed species (%40 B+%40 O+%20 P)**
Number of sample Örnek sayısı	50	50	50	50
Arithmetical mean (N/mm²) Aritmetik ortalama	0.83	0.78	0.95	0.80
Maximum value (N/mm²) Maksimum değer	9.98	1.03	1.25	0.99
Minimum value (N/mm²) Minimum değer	0.67	0.52	0.71	0.63
Standard deviation (N/mm²) Standart sapma	0.733	1.041	1.395	0.963
Variance-Varyans	0.538	1.083	1.948	0.928
Coefficient of variation (%) Varyasyon katsayısı	8.789	13.290	14.747	12.034

Variance analysis indicated that panel types showed a difference at the confidence level of 95 % and then Duncan test were applied to the data in order to reveal the differences in the panel group or groups (Table 8).

Table 8: Results Of Duncan Test
Tablo 8: Duncan Testi Sonuçları

Duncan Test	X_2	X_3	X_4
X_1 (R_p)	1.118 (0.41)	1.457 (0.44)	1.630 (0.46)
X_2 (R_p)	–	0.339 (0.41)	0.512 (0.44)
X_3 (R_p)	–	–	0.172 (0.41)

X_1: Pine X_3: Mixed species
X_2: Beech X_4: Oak

As shown in Table 8, in a given panel type except for oak/mixed species and beech/ mixed species, a significant difference (at a 95 percent confidence level) was found between the other panel types based on the arithmetical mean values and the Rp values in tension strength perpendicular to the plane of panel.

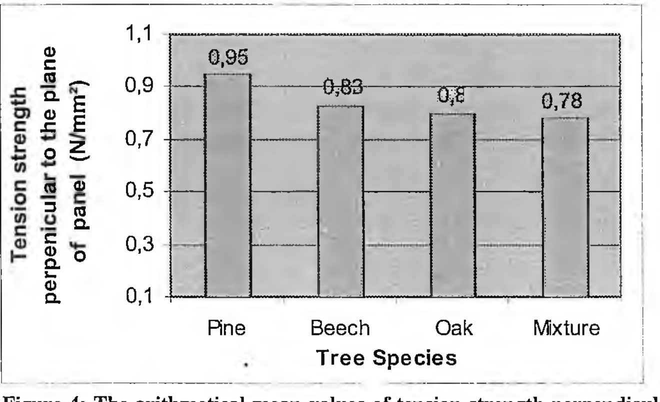

Figure 4: The arithmetical mean values of tension strength perpendicular to the plane of panel.
Şekil 4: Levha yüzeyine dik yönde çekme direnci aritmetik ortalama değerleri.

3.4 Tension Strength Parallel To The Plane Of Panel

Number of sample, arithmetical mean, maximum value, minimum value, standard deviation, variance, and coefficient of variation in connection with panels made from beech, oak, pine, and a mixture of these species are given in Table 9.

Table 9: The Values Of Tension Strength Parallel To The Plane Of Panel
Tablo 9: Levha Yüzeyine Paralel Yönde Çekme Direnci Değerleri

Statistical parameters İstatistik parametreler	**Beech**	**Oak**	**Pine**	**Mixed species (%40 B+%40 O+%20 P)**
Number of sample Örnek sayısı	50	50	50	50
Arithmetical mean (N/mm²) Aritmetik ortalama	16.56	13.41	18.79	13.43
Maximum value (N/mm²) Maksimum değer	18.68	15.11	21.00	15.36
Minimum value (N/mm²) Minumum değer	14.40	11.37	16.01	11.75
Standard deviation (N/mm²) Standart sapma	8.6652	8.7202	12.2790	9.1190
Variance-Varyans	75.086	76.043	150.775	83.156
Coefficient of variation (%) Varyasyon katsayısı	5.231	6.502	6.533	6.788

Variance analysis indicated that panel types showed a difference at the confidence level of 95 % and then Duncan test were applied to the data in order to reveal the differences in the panel group or groups (Table 10).

Table 10: Results Of Duncan Test
Tablo 10: Duncan Testi Sonuçları

Duncan Test	X_2	X_3	X_4
X_1 (R_p)	22.283 (3.88)	53.594 (4.09)	53.817 (4.23)
X_2 (R_p)	–	31.311 (3.88)	31.534 (4.09)
X_3 (R_p)	–	–	0.223 (3.88)

X_1: Pine X_3: Mixed species
X_2: Beech X_4: Oak

As shown in Table 10, in a given panel type except for oak/mixed species, a significant difference (at a 95 percent confidence level) was found between the other panel types based on the arithmetical mean values and the Rp values in tension strength parallel to the plane of panel.

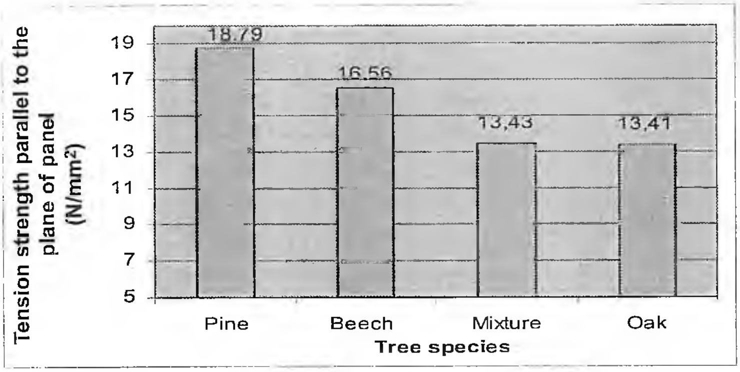

Figure 5: The arithmetical mean values of tension strength parallel to the plane of panel.
Şekil 5: Levha yüzeyine paralel yönde çekme direnci aritmetik ortalama değerleri.

3.5 Screw Holding Ability Perpendicular To The Plane Of Panel

Number of sample, arithmetical mean, maximum value, minimum value, standard deviation, variance, and coefficient of variation in connection with panels made from beech, oak, pine, and a mixture of these species are given in Table 11.

Table 11: The Values Of Screw Holding Ability Perpendicular To The Plane Of Panel
Tablo 11: Levha Yüzeyine Dik Yönde Vida Tutma Gücü Değerleri

Statistical parameters İstatistik parametreler	**Beech**	**Oak**	**Pine**	**Mixed species (%40 B+%40 O+%20 P)**
Number of sample Örnek sayısı	50	50	50	50
Arithmetical mean (N) Aritmetik ortalama	1023.46	927.10	1090.64	962.38
Maximum value (N) Maksimum değer	1172	1052	1194	1167
Minimum value (N) Minimum değer	855	779	954	794
Standard deviation (N) Standart sapma	7.519	6.3852	5.7115	7.6113
Variance-Varyans	56.542	40.771	32.621	57.933
Coefficient of variation (%) Varyasyon katsayısı	7.347	6.887	5.236	7.908

Variance analysis indicated that panel types showed a difference at the confidence level of 95 % and then Duncan test were applied to the data in order to reveal the differences in the panel group or groups (Table 12).

Table 12: Results Of Duncan Test
Tablo 12: Duncan Testi Sonuçları

Duncan Test	X_2	X_3	X_4
X_1 (R_p)	6.718 (2.71)	12.826 (2.85)	16.354 (2.95)
X_2 (R_p)	–	6.108 (2.71)	9.636 (2.85)
X_3 (R_p)	–	–	3.527 (2.71)

X_1: Pine X_3: Mixed species
X_2: Beech X_4: Oak

As shown in Table 12, a significant difference (at a 95 percent confidence level) was found between the panel types manufactured from beech, pine, oak, and mixed species based on the arithmetical mean values and the Rp values in screw holding ability perpendicular to the plane of panel.

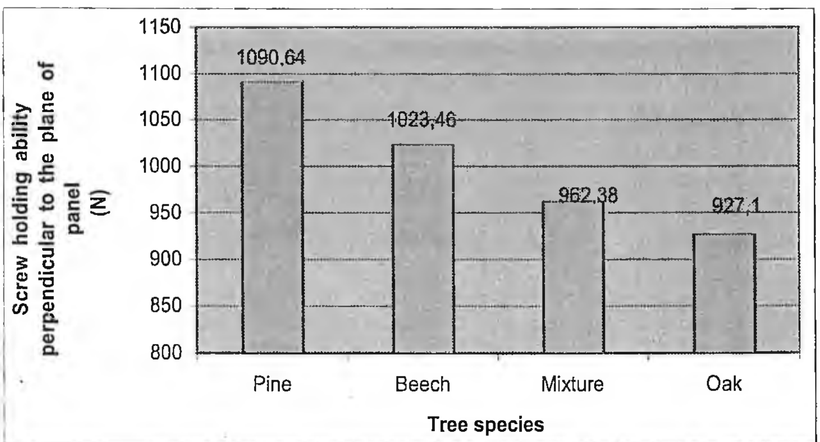

Figure 6: The arithmetical mean values of screw holding ability perpendicular to the plane of panel.
Şekil 6: Levha yüzeyine dik yönde vida tutma gücü aritmetik ortalama değerleri.

3.6 Janka Hardness Perpendicular To The Plane Of Panel

Number of sample, arithmetical mean, maximum value, minimum value, standard deviation, variance, and coefficient of variation in connection with panels made from beech, oak, and a mixture of these species are given in Table 13.

Table 13: The Values Of Janka Hardness Perpendicular To The Plane Of Panel
Tablo 13: Levha Yüzeyine Dik Yönde Janka Sertlik Değerleri

Statistical parameters İstatistik parametreler	**Beech**	**Oak**	**Pine**	**Mixed species (%40 B+%40 O+%20 P)**
Number of sample Örnek sayısı	50	50	50	50
Arithmetical mean (N/mm^2) Aritmetik ortalama	56.58	55.51	52.10	53.51
Maximum value (N/mm^2) Maksimum değer	59.12	58.28	53.88	55.08
Minimum value (N/mm^2) Minimum değer	54.33	52.25	50.01	51.53
Standard deviation (N/mm^2) Standart sapma	12.1136	13.0626	10.2098	8.8765
Variance-Varyans	146.741	170.631	140.240	78.793
Coefficient of variation (%) Varyasyon katsayısı	2.141	2.353	1.959	1.658

Variance analysis indicated that panel types showed a difference at the confidence level of 95 % and then Duncan test were applied to the data in order to reveal the differences in the panel group or groups (Table 14).

Table 14: Results Of Duncan Test
Tablo 14: Duncan Testi Sonuçları

Duncan Test	X_2	X_3	X_4
X_1 (R_p)	10.7 (4.42)	30.62 (4.66)	44.72 (4.82)
X_2 (R_p)	–	19.92 (4.42)	34.02 (4.66)
X_3 (R_p)	–	–	14.09 (4.42)

X_1: Beech X_3: Mixed species
X_2: Oak X_4: Pine

As shown in Table 14, a significant difference (at a 95 percent confidence level) was found between the panel types manufactured from beech, pine, oak, and mixed species based on the arithmetical mean values and the Rp values in janka hardness.

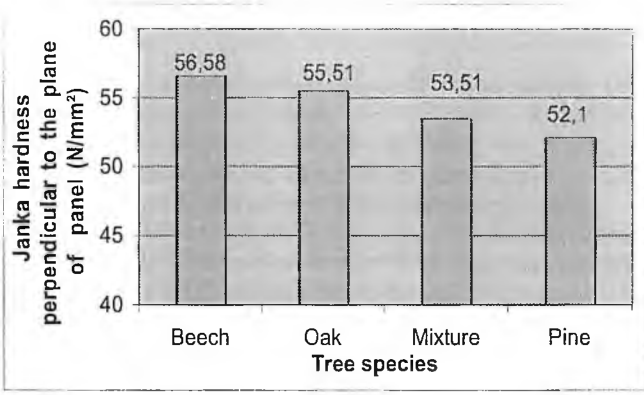

Figure 7: The values of janka hardness perpendicular to the plane of panel.
Şekil 7: Levha yüzeyine dik yönde janka sertlik değerleri.

4. DISCUSSION AND CONCLUSIONS

According to the results of this research, except for Janka hardness, the other mechanical properties of the panels made from pine furnish were better than those of panels made from oak, beech, and mixed species furnish.

The results (arithmetical means) are as follows:

Tests		Panel Type			
		Pine	Beech	Oak	Mixed
Species					
Bending strength	N/mm^2	40.12	34.04	27.03	30.80
Modulus of elasticity	N/mm^2	3494.33	3139.32	2857.87	295169
Tension strength perpendicular to the plane of panel	N/mm^2	0.95	0.83	0.78	0.80
Tension strength parallel to the plane of panel	N/mm^2	18.79	16.56	13.41	13.43
Screw holding ability perpendicular to the plane of panel	N	1090.60	1023.50	927.10	962.40
Janka hardness perpendicular to the plane of panel	N/mm^2	52.10	56.57	55.50	53.51

Values of bending strength, modulus of elasticity, and tension strength perpendicular to the plane of panel (internal bond) of all panels types were more than minimum standard values of TS EN 64-1, 1999 (20 N/mm^2 for bending strength, 2200 N/mm^2 for modulus of elasticity, and 0.55 N/mm^2 for internal bond).

In a given panel type except oak and mixed species, a significant difference (at a 95 percent confidence level) was found in tension strength parallel to the plane of panel. At the same time, in a given panel type except for oak/mixed species and beech/mixed species, a significant difference (at a 95 percent confidence level) was found in tension strength perpendicular to the plane of panel.

Fiber tensile strength would appear to have considerable importance in developing strength in MDF. In figure 8, where LS = the lenght of overlap between two fibers, which may be considered to be proportional to the relative bonding area in a panel mat. As L_S is shortened, that is, the quality of the bond is reduced, the failure due to applied tensile forces will occur in the bond rather in the fiber, regardless of the fiber strength (SUCHLAND / WOODSON 1991). Because panels manufactured from pine wood have the longest fibers in the panel groups used in the experiment panels, the lenght of overlap between two pine fibers would be more than those of the other species. Thus, especially, tension strength parallel to the plane of panel and bending strength of MDF manufactured from pine furnishes (40.89 N/mm^2) would be higher than MDF manufactured from oak (27.55 N/mm^2) and beech furnishes (34.70 N/mm^2). Furthermore, when searched bending strength values of the solid woods used in the experimental were parallel as bending strength of MDF panels (bending strength for pine wood: 109.6 N/mm^2, beech wood: 112.3 N/mm^2 and oak wood: 88 N/mm^2 (GÖKER 1977; MALKOÇOĞLU 1994; BOZKURT / ERDİN 1998).

Fiber lenght has a strong influence on the physical and mechanical properties of MDF as well, as compression ratio. This is explained by the larger number of bonding areas in the panel, which may allow tensile stresses in the fiber to reach the breaking strength (SUCHLAND / WOODSON 1991). Since pine wood has longer fibers than oak and beech, it would have a larger number of bonding area and a longer lenght of overlap between two pine fibers (L_S, figure 8) than other species. Thus, bonding between pine fibers would be stronger and this may result in a higher physical and mechanical properties than other panel types. As oak fibers is the shortest in the experimental species, bonding strength between oak fibers would be weaker than other species, as seen in figure 8.

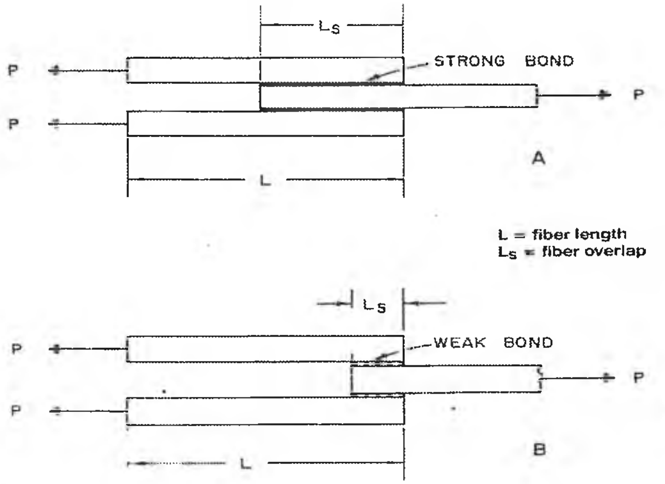

Figure 8: Fiberbonds under tensile stress (schematic). A - Conditions favoring fiber failure (maximum strength). B-Conditions favoring bond failure (low strength) (SUCHLAND/WOODSON 1991).

Şekil 8: Çekme gerilimi altında lif bağları (Şematik) A- Maksimum direnç B- Düşük direnç.

Pine woods have finer fibers than oak and beech wood fibers. This finer fibers provide a hardboard appearance to MDF, is reported to provide slightly better machinability and higher internal board values.

Compression ratio has a strong effect on the physical and mechanical properties of MDF. Compression ratio is described as ratio of panel density to wood specific gravity. High specific gravity wood will generally result in higher bulk density of the fiber furnish and the mat and, at a given panel density, in a lower compression ratio. High compression ratios obtained with low wood specific gravity promote more intimate contact between fibers, as seen in figure 9 (SUCHLAND/WOODSON 1991).

Compression ratio of panels made from pine furnish is the hightest in the experimental panels, as seen above. Because the mat prepared from pine furnish is lighter and softer than those of beech, and oak furnishes, it can be pressed easily in a hot press. As known, fiber cells of hardwood such as beech, oak, and chesnut having thicker walls and narrower lumen than those of softwoods such as pine, spruce, and fir. A high compression ratio to softwood fibers can be applied. Through high compression ratio, there would be better bonding between pine fibers in the mat during hot pressing. Consequently, physical and mechanical properties of panels made from pine furnish were better than those of panels made from oak, beech, and mixed species furnish.

Compression ratios for each panel type used in the experimental as follows;

		Pine	Beech	Oak
Wood specific gravity	g/cm³	0.52	0.64	0.65
Panel specific gravity	g/cm³	0.763	0.758	0.763
Compression ratio		**1.467**	**1.184**	**1.173**

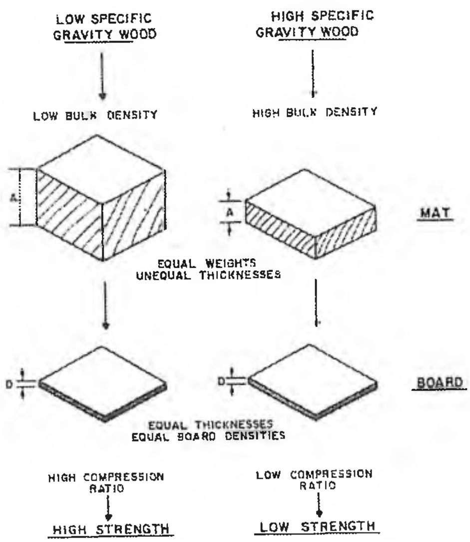

Figure 9: Manufacture of fiberboards of equal thickness and equal panel density from low-and high-specific-gravity wood (SUCHLAND/WOODSON 1991).

Şekil 9: Düşük ve yüksek yoğunluktaki odunlardan eşit levha kalınlığında ve yoğunluğunda liflevha üretimi.

At the same time, pH value of wood affects the curing rate of synthetic resins before hot press, which could result in curing of a resin before hot pressing known as precure in the mat. If pH value of wood is low (between 3-4), it could initiate the curing of synthetic resins in the bunker. Thus, precure could take place in the oak mat before coming to hot press. These panels manufactured in this manner have low physical and mechanical properties. NH_3 must be added into the mat, or a suitable resin mixture should be used to prevent precure before hot pressing. Moreover, extractives, extraneous matters, growth location, annual ring width, sapwood/heartwood proportions, latewood/earlywood proportions, etc. affect the mechanical properties of MDF. Tree species having high extractive ratios such as, tanen, and coloring components are not prefered in the MDF manufacturing.

MDF'NİN BAZI MEKANİK ÖZELLİKLERİ ÜZERİNE AĞAÇ TÜRÜNÜN ETKİSİ

Ar. Gör. Nadir AYRILMIŞ

Özet

Bu çalışmada, MDF'nin bazı mekanik özellikleri üzerine ağaç türünün etkisini incelemek amacıyla saplı meşe (*Quercus robur* L.), doğu kayını (*Fagus orientalis* Lipsky), karaçam (*Pinus nigra* var. *pallasiana*) ve bunların karışımlarından (%40 saplı meşe+ %40 doğu kayını+ %20 karaçam) üretilen levhaların mekanik özellikleri tespit edilmiştir. Deneyler 20±2°C sıcaklık ve 65±5 bağıl nemde kondisyonlanmış örnekler üzerinde yapılmıştır. Deneyler sonucunda elde edilen sonuçları istatistiksel olarak değerlendirmek amacıyla %95 güven düzeyinde Basit Varyans Analizi ve Duncan testleri yapılmıştır. Çalışma sonucunda, karaçam liflerinden yapılan MDF'lerin janka sertlik değerleri hariç, diğer bütün mekanik özelliklerinin saplı meşe, doğu kayını ve bu üç türün karışımlarından yapılan levhalardan daha üstün olduğu tespit edilmiştir.

1. GİRİŞ

MDF orta sertlikte bir liflevha olup, termomekanik olarak odun veya diğer lignoselülozik hammaddelerden elde edilen liflerin belirli bir rutubet derecesine kadar kurutulduktan sonra yaklaşık %9-11 oranında termosetting (sıcakta katılaşan) karakterli bir tutkal ile karıştırılarak sıcaklık ve basınç altında preslenmesiyle oluşan homojen yapıda levhadır. MDF'nin kalınlığı 1.80-60 mm, yoğunluğu ise genelde 0.55-0.80 g/cm³ arasında değişmekte olup, çoğunlukla 0.70-0.80 g/cm³ arasındadır (AKBULUT 1999).

Odun kökenli levha ürünleri arasında MDF üretimi, endüstriyel bakımdan Dünya'da 1965 yılında başlamış olmasına rağmen hızlı bir gelişme kaydetmiştir. MDF'nin kontrplak ve yongalevhadan daha düşük kaliteli odunlardan üretilebilmesi fiziksel ve mekanik özelliklerinin masif ağaç malzemeye yakın olması pek çok kullanım yerinde masif ağaç malzemeye alternatif olarak kullanılmasına imkan sağlamaktadır.

MDF'nin ana hammaddesini odun veya diğer ligno-selülozik maddeler ile tutkal oluşturmakta olup, bunun yaklaşık % 80-90'unu odun veya diğer ligno-selülozik maddelerdir. Dolayısıyla levha üretiminde kullanılan odunun türü levhanın teknolojik özelliklerini son derece etkilemektedir.

Ülkemizde henüz laboratuar şartlarında yerli ağaç türlerimizin MDF'nin teknolojik özellikleri üzerine etkisi incelenmemiş olduğundan bu konuda yerli bir literatür bulunmamaktadır. Bu araştırmanın amacı; MDF üretiminde en fazla kullanılan ağaç türlerinin MDF'nin mekanik özellikleri üzerine etkisini inceleyerek levhanın teknolojik özelliklerinin en yüksek olmasını sağlayan ağaç türlerini ve karışım oranlarını tespit etmektir. Bu çalışma ile odun kökenli levha ürünleri arasında mobilya endüstrisi başta olmak üzere bir çok kullanım alanında en fazla tercih edilen MDF'nin mekanik özelliklerini yüksek olmasını sağlayan ağaç türlerinin tespit edilerek orman ürünleri sektörüne önemli bir katkı sağlanması hedeflenmiştir.

2. MATERYAL VE METOT

Denemelere tabi tutulan MDF'ler (3660 x 2230 x 18 mm) Kastamonu Entegre Ağaç Sanayi MDF fabrikasında üretilmiştir. Levhalar saplı meşe, doğu kayını, karaçam ve bunların karışımlarından üretilmiştir. Gövde ve dal odunları 20 x 25 x 5 mm boyutlarında yongalanarak Asplund defibratöründe 7.5 bar ve 178°C'de 3-5 dakika doygun buhar altında liflendirilmiştir. Tam kuru lif ağırlığına oranla %1 parafin, %0.8 NH_4CL ve %11 üre-formaldehit liflere ilave edilmiştir. Ortalama %10.5 rutubetteki levha taslağı sıcak preste 206°C'de ve 3.5-4 N/mm^2 basınç altında 4 dakika preslenmiştir. Levhaların her iki yüzeyi klimatize işlemini takiben zımpara makinesiyle sırasıyla 150, 180 ve 200 kumlu zımpara bantları ile zımparalanmıştır.

Numuneler üzerinde yapılan deneylerin adları, kullanılan numunelerin boyutları ve sayısı ile uygulanan standart numaraları aşağıda verilmiştir.

Deneyler	Numune Boyutları (mm)	Örnek Sayısı (Adet)	Standart No
Eğilme direnci	50 x 410	30	TS EN 310 (1999)
Eğilmede elastikiyet modülü	50 x 410	30	TS EN 310 (1999)
Levha yüzeyine dik yönde çekme direnci	50 x 50	50	TS EN 319 (1999)
Levha yüzeyine paralel yönde çekme direnci	51 x 254	50	ASTM D-1037-78 (1994)
Levha yüzeyine dik yönde vida tutma gücü	76 x 152	50	ASTM D-1037 -78 (1994)
Levha yüzeyine dik yönde janka sertlik değeri	75 x 150	50	ASTM D-1037-78 (1994)

Deneyler 20±2°C ve 65±5 bağıl nemde kondisyonlanmış numuneler üzerinde yapılmıştır. Deneyler sonucunda elde edilen sonuçları istatistiksel anlamda değerlendirme amacıyla Basit Varyans Analizi ve Duncan testi yapılmıştır.

3. BULGULAR

Her bir levha grubuna ait deney sonuçlarının aritmetik ortalamaları aşağıda toplu halde verilmiştir.

Deneyler		Levha Tipi			
		Çam	Kayın	Meşe	Karışım
Eğilme direnci	N/mm²	40.12	34.04	27.03	30.80
Eğilmede elastikiyet modülü	N/mm²	3494.33	3139.32	2857.87	2951.69
Levha yüzeyine dik yönde çekme direnci	N/mm²	0.95	0.83	0.78	0.80
Levha yüzeyine paralel yönde Çekme direnci	N/mm²	18.79	16.56	13.41	13.43
Levha yüzeyine dik yönde Vida tutma gücü	N	1090.60	1023.50	927.10	962.40
Levha yüzeyine dik yönde janka sertlik değeri	N/mm²	52.10	56.57	55.50	53.51

4. TARTIŞMA VE SONUÇ

Çalışma sonucunda, diğer üretim değişkenleri sabit kaldığında, karaçam liflerinden yapılan MDF'lerin janka sertlik değerleri hariç, diğer bütün fiziksel ve mekanik özellikleri saplı meşe, doğu kayını ve bu üç türün karışımlarından yapılan levhalardan daha üstün olduğu tespit edilmiştir. Deneme levhalarında yapılan mekanik deneylerin aritmetik ortalamaları ilgili standartların ön gördüğü değerlerden daha yüksek çıkmıştır.

Eğilme direnci, eğilmede elastikiyet modülü, levha yüzeyine dik yönde vida tutma gücü, levha yüzeyine dik ve paralel yönde çekme direnci ve levha yüzeyine dik yönde janka sertlik değeri deneylerinde yapılan varyans analizi sonucunda levha grupları arasında %95 güven düzeyinde anlamlı bir farklılık olduğu tespit edilmiştir. Farklılık gösteren grup veya grupları ortaya çıkarmak amacıyla Duncan testi yapılmış ve aritmetik ortalama değerleri ile Rp değerleri karşılaştırıldığında levha yüzeyine dik yönde çekme direnci deneyi için kayın/ağaç türlerinin karışımı ile meşe/ağaç türlerinin karışımından yapılan levhalar arasında anlamlı bir farklılık olmadığı bulunmuştur. Levha yüzeyine paralel yönde çekme direnci için ise meşe/ağaç türlerinin karışımından yapılan levhalar arasında da anlamlı bir farklılık bulunmamıştır. Diğer deneyler için yapılan Duncan testi sonuçlarında levha gruplarının birbirlerinden farklılık gösterdiği tespit edilmiştir.

Çam odunu liflerinden yapılan deneme levhalarının kayın meşe ve bu üç türün karışımlarından üretilen levhalardan daha üstün özelliklere sahip olmasını sağlayan en önemli etkenlerin başında liflerinin daha uzun olması ve sıcak preste taslağın sıkıştırılma oranının (Levha yoğunluğunun kullanılan ağaç türü yoğunluğuna oranı) daha yüksek olması gelmektedir. Lif uzunluğu arttıkça levha içerisindeki liflerin birbirleri üzerine binme uzunluğu artacağından iki lif arasındaki yapışma hattı uzunluğu da fazla olacak ve uygulanan çekme kuvvetlerine karşı bu lif bağının direnci yüksek olacaktır. Buna karşın iki lif arasındaki binme uzunluğu kısalırsa bağ kalitesi azalacağından uygulanan çekme kuvvetleri sonucu meydana gelen kopma lif tek başına ne kadar dirençli olursa yapışma hattından olacaktır (SUCHLAND/WOODSON 1991). Ayrıca odunun pH değeri, ekstraktif madde oranı, diri odun/öz odun oranı, yıllık halka genişliği, yaz odunu katılım oranı gibi faktörler MDF'nin teknolojik özellikleri üzerinde etkiye sahiptir.

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