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MEDIUM DENSITY FIBERBOARD (MDF) MANUFACTURING FROM WHEAT STRAW (*Triticum aestivum* L.) AND STRAW WOOD MIXTURE

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ABSTRACT

In this study wheat straw was taken from Ankara province. In order to produce dry process MDF, urea formaldehyde resin was used at the ratio of 8 %, 10 % and 12 %, 1 % ammonium chloride was used as hardening agent on the basis of dry fiber weight. On the other hand, 5, 6 and 7 min. pressing times were applied. Alcohol benzene, cold water, hot water and 1 % NaOH solubility of wheat straw were 5.15 %, 7.31 %, 9.84 % and 40.79 % respectively. In addition, holocellulose, cellulose, lignin and ash contents were found as 74.79 %, 52.67 %, 20.17% and 4.21 % respectively. Optimum fiber morphology values were as follow; fiber length 1.2-1.5 mm, fiber width 12-16 μm, lumen diameter 4-6 μm and double wall thickness 7.5 -11.5 μm Optimum fiber production conditions for MDF manufacturing were as follows; Vapor pressure : 10.5 atm, steaming time : 4 minutes, defibration time : 2 minutes. 0.700 g/cm^3, 0.800 g/cm^3 density straw MDF boards and 0.800 g/cm^3 density wood fiber MDF boards were manufactured. On the other hand, 0.800 g/cm^3 straw-wood fiber mixture MDF boards were produced at the rates of 70% -30%, 50%-50% and 30%-70%. Modulus of rupture (MOR), modulus of elasticity (MOE), internal bonding (IB), thickness swelling and water absorption of the boards were measured. After the evaluations of the results obtained, optimum straw MDF boards manufacturing conditions were as follows; Adhesive ratio : 12 %, pressing time : 6 minutes, press temperature : 150 °C, pressure : 200-220 kp/cm^2, hardening agent : 1 % and straw - wood ratio 50 %-50 %.

Key Words : Wheat straw (*Triticum aestivum* L.), Medium density fiberboard (MDF), Fiber, Fiberboard

BUĞDAY SAPLARINDAN (*Triticum aestivum* L.) VE SAMAN-ODUN KARIŞIMI LİFLERDEN ORTA YOĞUNLUKTA LİF LEVHA (MDF) ÜRETİMİ

ÖZET

Bu çalışmada, hammadde olarak Ankara ilinden temin edilen buğday (*Triticum aestivum* L.) sapları kullanılmıştır. Kuru yöntemle MDF üretiminde % 8, 10 ve 12 oranında üre formaldehit tutkalı yapıştırıcı, sulu amonyum klorürün % 30'luk çözeltisinden % 1 oranında sertleştirici olarak kullanılmıştır. Ayrıca, 5, 6 ve 7 dk'lık presleme süreleri denenmiştir. Buğday saplarının alkol-benzen, soğuk su, sıcak su ve % 1'lik NaOH çözünürlüğü sırasıyla; % 5.15, % 7.31, % 9.84 ve % 40.79 olarak bulunmuştur. Ayrıca, holoselüloz, selüloz, lignin ve kül miktarları sırasıyla; % 74.79, % 52.67, % 20.17 ve % 4.21 olarak belirlenmiştir. Yapılan lif morfolojisiyle ilgili çalışmalarda kullanılan buğday saplarının lif uzunluğu 1.2-1.5 mm, lif genişliği 12-16 μm, lümen çapı 4-6 μm ve çift çeper kalınlığı 7.5-11.5 μm bulunmuştur. Buğday saplarından MDF eldesi için en uygun lif üretim şartları; buhar basıncı 10.5 atm, buharlama süresi 4 dk ve liflendirme süresi 2 dk olarak belirlenmiş ve uygulanmıştır. Saman liflerinden 0.700 g/cm^3 ve 0.800 g/cm^3, odun ve saman-odun karışımı (% 30 saman + % 70 odun, % 50 saman + % 50 odun, % 70 saman + % 30 odun) liflerden ise 0.800 g/cm^3 özgül kütleli MDF levhaları üretilmiştir. Tüm levhaların elastikiyet modülü, eğilme direnci, yüzeye dik çekme direnci ile 24 saatteki su alma ve kalınlığına şişme değerleri belirlenmiştir. Laboratuar koşullarında elde edilen MDF levhaların fiziksel ve mekanik özellikleri üzerinde yapılan değerlendirmeler sonucunda buğday saplarından en uygun MDF üretim koşulları; tutkal miktarı % 12, pres süresi 6 dakika, pres sıcaklığı 150 °C, pres basıncı 200-220 kp/cm^2, sertleştirici miktarı % 1 ve saman/odun oranı % 50 -% 50 şeklinde belirlenmiştir.

Anahtar Kelimeler : Buğday sapı (*Triticum aestivum* L.), Orta yoğunlukta liflevha (MDF), Lif, Liflevha

1. INTRODUCTION

Fiberboard is an industrial product manufactured by drying and pressing of wet board obtained from vegetative fibers and fiber bundles having natural bonding and felting properties or by means of additional adhesives. In other words, it is a board obtained by the rearrangement of lignocellulosic fibers and fiber bundles. Medium Density Fiberboard is obtained from thermo-mechanically produced fibers after 9-11 % adhesive addition, drying and hot pressing (Eroğlu, 1988).

Fiberboard industry was developed in conjunction with the paper industry. Paper manufacturing from wood pulp is about 150 years old. Manufacture of first isolation board realized during World War I. Whereas, the first hardboard plant was built in 1926. Later, Medium Density Fiberboard (MDF-dry) developed in the United States in 1965 (Suchsland and Woodson, 1986).

In the production of MDF, raw material used are lower value roundwood, forest thinning material, sawdust, stained wood by micro organisms, plywood industry residues and fuel wood. As fiberboard contains 80 % of vegetative fibers, its technological properties can be adjusted at will. Physical and mechanical properties of fiberboard depends on specific gravity and fiber properties such as fiber length, fiber width, lumen diameter and the amount of additive used. As well as, fiberboard manufacturing method, preparation of wet web, pressing time, pressure, temperature and finishing treatments profoundly affect its physical and mechanical properties (Eroğlu, 1988).

Fiberboards have some advantages over massive wood such as their homogenous structure in every directions and do not contain defects such as knots, fiber distortion and decay encountered in massive wood. It is possible to manufacture larger dimension boards. Nailing, screwing are easily made. Painting, covering, machining, varnishing and carving are also easily applied. In addition, resistance against fungi, insects and fire can be obtained by using certain chemical substances. Whereas, massive wood is an anisotropic material. It contains heartwood, sapwood, springwood, summerwood, youngwood, knots, fissures and other pathological defects. Therefore, it expands differently in the radial, tangential and longitudinal directions. As a result, it may be bended, distorted and ondulated. In addition, fiberboards have more uniform structure than other wood based panels such as waferboard, strandboard, flakeboard and particleboard. Besides, a wide range of lower value raw material can be used in the manufacture of MDF (Eroğlu, 1988; Rowell, 1992).

It has been reported by Wieche that a MDF mill using sugar cane bagasse was installed in South Korea with a capacity of 70 tons/day, specific gravity being 0.700 g/cm^3 and thickness varying between 6 and 30 mm. These MDF boards have been utilized in the construction of furniture, cabin and wardrobe etc. As the harvest of bagasse is seasonal, there is a problem of storage. However, bagasse fibers have the advantages of easy web formation and give long bulky fibers (Wiecke, 1988).

On the other hand, in a study realized by Gençer on cotton stalks it is concluded that cotton stalk fibers give lower physical properties MDF boards than wood, but mechanical properties were similar to those of wood fibers (Gençer, 1998).

Deppe and Knoll manufactured MDF having the properties of 19 mm thickness and 720-730 g/cm^3 specific gravity from the mixture of waste papers and wood fibers by using 9-14 % melamine isocyanate and urea-formaldehyde. They concluded that waste papers and mechanical pulp paper wastes have been practically suitable for MDF production (Deppe and Knoll, 1984).

In a study made at Bartın Forestry Faculty gypsum fiber boards were made by using different chemical pulps such as bleached and unbleached sulfate, Kraft and straw pulps and different waste papers. It has been found that fiber length is an important factor for mechanical properties and water absorption values were higher than those indicated in the standards (Akşen, 1998).

Rowell and his coworkers, manufactured fiberboard from acetyleted fibers, specific gravity varied between 0,2-0,5 kg/cm^3. They have concluded that acetylation provide higher dimensional stability (Rowell et all., 1995).

Zhang and his colleagues produced composite boards with the mixtures of wood and bamboo fibers at the ratios of 1/0, 3/1, 1/1, 1/3 and 0/1, by using 10 % isocyanate resin and specific gravities were between 0.6-0.8 g/cm^3. They have concluded that mechanical properties increase by the increase of bamboo fibers ratio (Zhang et all., 1995).

2. MATERIAL AND METHOD

2. 1. Material

It has been reported that cereal growing area in the world is about 800 million hectares and annual production is around 2.9 billion tons (Kün, 1988).

Turkey is one of the important cereal producing countries in the world and classified as 7th within wheat producing countries with 20 million tons of production. Normally, grain/straw yield ratio is 1/2. However, at most 70% of wheat straw can be collected above the soil surface. Also there are certain losses during collection, carrying and storing, as a result, only 49% of straw can be available as fodder or industrial raw material (Uslu, 1995; İstek, 1999).

According to the statistics, annually 20-26 million tons of wheat straw produced in Turkey. On the other hand, 20 % of this amount is produced in Konya and Ankara provinces, other high production areas are Thrace, Adana province and South East Anatolian project region. Potentially MDF plants using cereal straw may be installed in these areas in the near future. So that, peasants growing cereals would have additional income from straw selling.

In this study wheat (*Triticum aestivum* L.) straw was used as raw material for the production of MDF. Wheat straw used in the study was procured from Şereflikoçhisar within the border of Ankara province. Ankara region was chosen because of its high amount of wheat producing capacity.

In order to prevent the negative effects of sample variations raw material must have homogenous structure. For this reason, care had been taken in material collection in a manner that climate, inclination, land position etc. represent optimum conditions of the region. Samples were collected and stored in bags of 100 kg in August 1996.

2. 2. Method

2. 2. 1. Chemical Analyses

It is important to know chemical properties and fiber dimensions of raw material for estimating MDF properties and fiber yield. For example higher or lower cellulose ratios affects fiber yield, on the other hand, higher or lower lignin content determines easy or difficult defibration (Eroğlu, 1980).

For chemical analyses wheat straw was ground in a laboratory type Willey Mill according to TAPPI T11 m-45 standard method. Analyses were made on wood meal remained on 60 mesh screen. Alcohol-benzene, cold water, hot water, 1% NaOH solubility were made according to standard methods TS 4568, TS 4567, TS 4567, TAPPI T11 m-54 respectively. Hollocellulose, cellulose, lignin and ash content were measured according to standard methods of Wise's chlorite method, Kurschner-Holfner TS 4467 and TS 4432 respectively. Different morphological parts of wheat straw disintegrated to fibers by maceration method (chlorite). Long standing preparate was obtained by means of glycerin -gelatin solution from macerated fibers.

2. 2. 2. Fiber Production and Adhesive Addition

Fiber production was made at Artvin ORÜS Fiberboard Manufacturing Plant Laboratories. For preliminary trials, fibers were obtained thermo-mechanically by Krakow (103-22489 type Defibrator unit with a capacity of 300-500 g under 12 atmosphere vapor pressure. Under 12 different experimental conditions, vapor pressure and vaporization time were varied at different levels. Whereas, defibration time was kept constant at 2 minutes. For every experiment, 5 cooking were made and optimum values calculated. In order to determine optimum fiber manufacturing conditions for MDF production, firstly some hardboard experiments were made. Defibration conditions and some physical and mechanical properties of the hardboards are given in Table 1.

Table 1. Defibration Conditions and Some Physical and Mechanical Properties of Hardboard

No	Straw humidity (%)	Pressure (atm.)	Steaming time (sec.)	Defibration time (sec.)	Freeness (defibrator sec.)	Fiber yield (%)	Board thickness (mm)	Specific gravity (g/cm^3)	Moisture content (%)	Bending strength before conditioning (N/mm^2)	Bending strength after conditioning (N/mm^2)	Water absorption in 24 h (%)
1	7.99	9.0	5	2	32.61	77.69	2.53	1.036	5.05	40.037	41.306	189
2	7.29	9.0	4	2	26.66	79.64	2.62	0.994	4.76	39.421	44.364	187
3	7.64	9.0	3	2	24.61	80.77	2.63	0.987	4.68	43.732	47.392	180
4	9.17	9.5	5	2	27.18	76.36	2.58	0.989	4.96	38.224	39.721	184
5	10.86	9.5	4	2	31.25	74.19	2.55	1.027	4.59	37.591	41.210	170
6	8.83	9.5	3	2	25.34	77.92	2.60	0.995	4.68	34.762	39.028	179
7	8.69	10.0	5	2	26.23	74.08	2.61	1.080	4.55	34.399	35.237	159
8	10.37	10.0	4	2	22.23	76.66	2.61	1.074	4.85	27.241	28.661	169
9	9.64	10.0	3	2	21.96	76.14	2.38	1.055	4.68	33.405	41.935	158
10	8.56	10.5	5	2	32.61	73.57	2.52	1.008	4.57	40.033	41.291	112
11	7.75	10.5	4	2	27.61	75.11	2.58	0.985	4.63	43.732	47.287	130
12	9.03	10.5	3	2	26.66	78.20	2.80	0.986	4.43	38.969	44.365	128

After the evaluation of these values, optimum fiber production conditions for MDF manufacture were determined as follows: Vapor pressure 10.5 atmosphere, steaming time 4 minutes, defibration time 2 minutes, freeness 27.61 defibrator second, straw moisture 7.75 % and fiber yield 75.11 %.

Under the conditions mentioned above fibers were produced in the defibrator unit of Artvin Hardboard Mill. If the fibers are left in wet conditions some felting would occur, then they were dried in a laboratory type oven. After taking from the oven cooled fibers, they were preserved in polyethylene bags.

Before the MDF production 8 %, 10 %, 12 % urea-formaldehyde resin were added on oven dry fiber weight basis. Formaldehyde addition was made by means of adhesive addition laboratory machine having single injection, 6 kg/cm2 maximum pressure with five mixing handles. On the other hand, 1 % NH_4Cl was used as hardening agent on the basis of dry fiber weight.

2. 2. 3. Dry Mat Forming and Pressing Conditions

For dry mat formation 56.5 X 56.5 X 0.7 cm dimensions form was used. Fibers taken from adhesive addition machine were spread over the form by hand. Straw and Straw-wood mixture MDF board production conditions are given in Table 2. 18 (3 x 3 x 2) kinds of MDF boards were manufactured under different conditions.

Table 2. MDF production Conditions of Straw and Straw-Wood Fiber Mixtures

Properties	Straw		Straw-Wood Mixture
Specific gravity (g / cm^3)	0.700	0.800	0.800
Adhesive ratio (%)	8, 10, 12	8, 10, 12	8, 10, 12
Hardening agent (%)	1 (as 30 % solution)	1 (as 30 % solution)	1 (as 30 % solution)
Pressing time (min)	5, 6, 7	5, 6, 7	5, 6, 7
Pressing pressure (kp/cm^2)	200-220	200-220	200-220
Pressing temperature (°C)	150	150	150

In addition, MDF boards of straw fiber and wood fiber mixtures were made at the straw-wood fiber ratios of 0/100 %, 30/70 %, 50/50 %, 70/30 % and 100/0%. Wood raw material consisted of hardwood species of rhododendron, poplar and beech.

Pressing was made on a laboratory single layer hot press. Press plate dimensions were 70 X 89 cm. Dimensions of MDF boards produced were 56.5 X 56.5 cm and press temperature was 150 °C. Because of existing press having maximum 150 °C temperature capacity, pressing amount over this temperature could not be realized. Pressing time were 5, 6, 7 minutes and pressures were 200-220 kp/cm^2 for all boards manufactured. After pressing, board climatization was realized in a room of 20 °C and 65 % relative humidity according to TS 642 standard method.

2. 2. 4. Measurement of Physical and Mechanical Properties

Samples were prepared according to TS 64. Specific gravity, moisture content, water absorption in 24 hours and thickness swelling of MDF boards were measured according to TS 3634, TS 1811, TS 3639 and TS 3639 respectively. Values obtained were compared with those MDF boards of related standards.

Modulus of rupture (bending strength) (MOR), modulus of elasticity (MOE) and internal bond strength (tensile strength perpendicular to surface) of MDF boards were measured according to TS 3636, TS 3636 and DIN 52365 respectively. Values obtained were compared with those MDF boards of related standards. MOR and MOE were tested in TSE Wood Working Laboratory with the PC software apparatus of Zwich Z1001. Whereas IB was measured in KTÜ. Forestry Faculty Physical and Mechanical Wood Technology Laboratory with Zwich Universal test apparatus.

3. RESULTS

3. 1. Chemical Analyses

Alcohol-benzene, cold water, hot water, 1 % NaOH solubilities, hollocellulose, cellulose, lignin and ash contents obtained are given in Table 3. These results were compared with those of Eroğlu, Rowell and Uslu. It can be seen from Table 3 that the results were similar to those of Eroğlu, Uslu and Rowell except that Rowell obtained lower cellulose values than other researchers. Chemical composition and especially ash content of wheat straw vary with soil conditions and other growing conditions (Eroğlu, 1980; Rowell, 1992; Uslu, 1995).

Table 3. Different Solubility and Chemical Properties of Wheat Straw

Properties	Values	Eroğlu (1980)	Rowell (1992)	Uslu (1995)
Alcohol-benzene (%)	5.15	5.33	--	5.27
Cold water (%)	7.31	7.63	--	7.54
Hot water (%)	8.84	10.48	--	10.55
1% NaOH (%)	40.79	40.08	--	41.96
Hollocellulose (%)	74.79	76.25	70-75	70.40
Cellulose (%)	53.67	51.20	29-35	53.24
Lignin (%)	20.17	18.03	16-21	22.61
Ash (%)	4.21	4.44	4.5-9	4.17

3. 2. Fiber Morphology

The results of fiber dimension measurements made on macerated straw and thermo-mechanical straw fibers are given in Table 4. The results obtained were found similar to those obtained by Eroğlu. It has been found that wheat straw fiber length was between 1.2-1.5 mm. This can be considered as short fiber. Short fibers give smooth surface, consequently they are more suitable for MDF production then sortwood fibers. On the other hand, wheat straw fibers have narrow lumen and larger wall thickness (Eroğlu, 1980).

Table 4. Fiber Properties of Wheat Straw

Properties	Macerated	Thermo-Mechanical	Eroğlu (1980)
Fiber length (mm)	1.2-1.5	1.0-2.5	1.2
Fiber width (μm)	12-16	10-20	15.5
Lumen diameter (μm)	4-6	3-7	5.8
Double wall thickness (μm)	7.5-11.5	6-13	9.7

3. 4. Physical and Mechanical Properties of Wheat Straw and Wood Based MDF Boards

Average specific gravity, moisture content, board thickness, water absorption, swelling in thickness, bending strength, modulus of elasticity and tensile strength values of 0.700 g/cm^3 wheat straw MDF boards are given in Table 5.

Table 5. Some Physical and Mechanical Properties of Wheat Straw MDF Boards of 0.700 g/cm^3 Specific Gravity

Adhesive (%)	8			10			12		
Pressing time (min.)	5	6	7	5	6	7	5	6	7
Board thickness (mm)	6.58	6.75	6.67	6.59	6.53	6.60	6.67	6.66	6.64
Specific gravity (g/cm^3)	0.729	0.698	0.707	0.678	0.681	0.675	0.719	0.707	0.706
Moisture content (%)	10.53	8.60	8.66	7.70	7.76	8.17	13.79	12.91	13.12
Water absorption (%)	103	101	100	93	88	90	83	78	78
Swelling in thickness (%)	41.10	35.02	34.29	28.00	26.95	27.63	26.02	24.13	24.37
Bending strength (N/mm^2)	19.35	26.12	26.00	25.19	32.65	31.98	30.09	33.57	29.35
Modulus of elasticity (N/mm^2)	15356	18326	18421	21045	25765	24781	22596	29351	29120
Internal bonding strength (N/mm^2)	0.635	0.655	0.660	0.720	0.735	0.735	0.750	0.805	0.795

Wheat straw, wheat straw-wood fiber mixtures and wood fiber MDF boards were produced under 36 different conditions, of which 18 of them were made of wheat straw fiber, and 9 of them wood fiber and 9 of them made from wheat straw-wood fiber mixture. On the other hand, in Table 6, Table 7 and Table 8 some physical and mechanical properties of wheat straw, wood fibers and wheat straw-wood fiber mixture MDF boards of 0.800 g/cm^3 are given respectively.

Overall physical and mechanical properties of wheat straw, wood fibers and straw-wood fiber mixture MDF boards made under the conditions of 150 °C, 6 minutes pressing time and 200-220 kp/cm^2 pressure are given in Table 9.

Table 6. Physical and Mechanical Properties of 0.800 g/cm^3 Wheat Straw MDF Boards

Adhesive (%)	8			10			12		
Pressing time (min..)	5	6	7	5	6	7	5	6	7
Board thickness (mm)	6.77	6.86	6.90	6.58	6.60	6.73	6.64	6.65	6.60
Specific gravity (g/cm^3)	0.825	0.810	0.811	0.832	0.825	0.823	0.835	0.829	0.833
Moisture content (%)	7.28	7.29	6.67	14.89	14.39	13.58	8.96	12.59	12.41
Water absorption (%)	79	77	76	60	58	59	58	55	53
Swelling in thickness (%)	32.61	31.93	29.82	28.16	25.98	26.42	21.85	21.49	20.74
Bending strength (N/mm^2)	23.30	25.37	24.57	28.31	34.02	31.73	33.72	36.75	34.98
Modulus of elasticity (N/mm^2)	18955	20324	21632	28411	25739	30561	29971	31891	31621
Internal bonding strength (N/mm^2)	0.673	0.685	0.680	0.740	0.750	0.743	0.763	0.820	0.790

Table 7. Physical and Mechanical Properties of 0.800 g/cm^3 Wood Fiber MDF Boards

Adhesive (%)	8			10			12		
Pressing time (min.)	5	6	7	5	6	7	5	6	7
Board thickness (mm)	6.67	6.70	6.81	6.41	6.71	6.57	6.53	6.59	6.64
Specific gravity (g/cm^3)	0.844	0.849	0.841	0.842	0.834	0.830	0.843	0.826	0.840
Moisture content (%)	13.77	11.18	9.76	11.80	11.80	9.21	12.46	12.09	12.71
Water absorption (%)	24	23	24	23	22	22	22	19	16
Swelling in thickness (%)	13.15	12.47	12.79	12.87	11.17	10.11	9.52	7.82	7.60
Bending strength (N/mm^2)	28.15	30.87	28.06	30.93	34.72	35.60	37.46	40.47	40.68
Modulus of elasticity (N/mm^2)	21303	23107	23054	21370	26248	25117	28194	32368	32596
Internal bonding strength (N/mm^2)	0.725	0.780	0.763	0.815	0.840	0.828	0.865	0.903	0.890

Table 8. Physical and Mechanical Properties of Wheat Straw-Wood Fiber Mixture of 0.800 g/cm^3 MDF Boards

Percentages of Wheat straw-wood fibers mixture (%)	30 + 70			50 + 50			70 + 30		
Adhesive (%)	6			6			6		
Pressing time (min.)	8	10	12	8	10	12	8	10	12
Board thickness (mm)	6.67	6.64	6.53	6.72	6.69	6.51	6.69	6.71	6.54
Specific gravity (g/cm^3)	0.836	0.832	0.831	0.811	0.830	0.825	0.820	0.828	0.834
Moisture content (%)	9.88	13.63	13.81	7.40	13.33	10.23	9.36	11.25	11.44
Water absorption (%)	31	28	24	64	34	30	76	60	32
Swelling in thickness (%)	13.36	12.57	9.61	20.58	17.92	16.79	31.77	21.09	17.02
Bending strength (N/mm^2)	30.35	36.14	39.61	28.22	38.90	42.22	26.99	32.17	38.68
Modulus of elasticity (N/mm^2)	23519	25566	32634	23606	28709	31706	22602	23968	30551
Internal bonding strength (N/mm^2)	0.805	0.850	0.888	0.790	0.838	0.858	0.748	0.775	0.825

Table 9. Some Physical and Mechanical Properties Wheat Straw, Wood Fibers and Straw-Wood Fiber Mixture MDF Boards of 0.800 g/cm^3 Specific Gravity

Physical and mechanical Properties	Adhesive Ratio (%)	Wheat Straw	Wood Fibers	Straw-wood fibers mixture (%) 30+70	50+50	70+30
Water absorption (%)	8	77	23	31	64	76
	10	58	22	28	34	60
	12	55	19	24	30	32
Swelling in thickness(%)	8	31.93	12.47	13.36	20.58	31.77
	10	25.98	11.17	12.57	17.92	21.09
	12	21.49	7.82	9.61	16.79	17.02
Bending strength (N/mm^2)	8	25.37	30.87	30.35	28.22	26.99
	10	34.02	34.72	36.14	38.90	32.17
	12	36.75	40.47	39.61	42.22	38.68
Modulus of elasticity(N/mm^2)	8	20324	23107	23519	23606	22602
	10	25739	26248	25566	28709	23968
	12	31831	32368	32634	31706	30551
Internal bonding strength (N/mm^2)	8	0.685	0.780	0.805	0.790	0.748
	10	0.750	0.840	0.850	0.838	0.777
	12	0.820	0.903	0.888	0.858	0.825

It can be seen from Table 9 that water absorption and thickness swelling values of straw MDF boards are higher than wood fiber and straw-wood fiber mixture boards. On the other hand, mechanical properties of wood fiber and straw-wood fiber mixture boards are generally slightly higher than those of straw boards.

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4. DISCUSSION

Wheat straw MDF boards have generally higher water absorption and thickness swelling values. This is attributed to the higher hemicellulose content of wheat straw which is more hygroscopic than cellulose. This can be easily prevented by using 1 or 2 % paraffin during manufacture. Whereas, straw-wood fiber mixture MDF boards have slightly higher water absorption and thickness swelling values than wood fiber boards. but the difference increases with the increase of straw fiber ratio. At the 30/70 straw-wood ratio these values are nearly similar to wood fiber boards and the values are conform to the values cited in the standards. On the other hand, these values decreases more than 100 % with the increase of adhesive ratio.

Finally, there were no important differences of mechanical properties of all kinds of MDF boards. Mechanical properties of wood fiber MDF boards were slightly higher than those of straw and straw-wood fiber mixture MDF boards.

It has been concluded that 50/50 straw wood fibers mixture is economically and technically more suitable. After the evaluation of the results, optimum MDF production conditions were found as follows:Adhesive ratio 12 %; Pressing time 6 minutes; Press temperature 150 °C; Pressure 200-220 kp/cm^2 ; Hardening agent 1 % and Straw / Wood ratio 50/50 (%).

It is concluded that straw fibers can be easily used in MDF production solely or mixture and higher water absorption value may be prevented by using 1% or 2 % paraffin. Mechanical properties of straw boards were found highly convenient for practical purposes. It is recommended that straw MDF boards mills should be installed in wheat production areas such as Central Anatolia, Cilicia and Thrace.

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