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MANUFACTURE OF MEDIUM DENSITY FIBERBOARD (MDF) PANELS FROM AGRIBASED LIGNOCELLULOSIC BIOMASS

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ABSTRACTS

Lignocellulosics fibers and commercially-manufactured-chip (*Pinus sylvestris* L., *Fagus orientalis* and *Quercus robur* L.) with 11% moisture conten twere used for the experiment. The mixingratios of lignocellulosics fibers was 20% which is from okra and tobaccos talks, hazelnut and walnuts hell, and pinecone for each mixture in preformed panel and commercially-manufactured-chip was 100 % for the control sample. A commercial ureaformaldehyde (UF) adhesive was used as a binder. The physical and mechanical properties such as density, thickness swelling (TS), bending strength (BS), modulus elasticity (MOE), internalbond (IB), screw holding ability (SHA) perpendicular to the plane of panel, Janka hardness perpendicular to the plane of panel properties of MDF were measured.The results indicated that all the panels met the general purpose-use requirements of TS-EN. Thus, our results suggest that biomass from different sources can be an alternative raw material for MDF manufacturing process.

KEYWORDS: Lignocellulosic biomass, MDF, physical and mechanical properties.

INTRODUCTION

The demand in forest products industry is increasing with population and new product development. As a result, there is a significant pressure on standing forest resources. In addition to that, collecting industrial wood from the natural forests continues to decline due to the depletion of the resources and the withdrawal of forest areas from industrial production for recreational utilization. Therefore, the shortage of raw material is causing to search for alternative resources in forest products industry.

The agricultural residues have been used in forest industry for a long time because of renewable and fast growing materials. These materials considered to be waste and it contains the leaves and stalks of plants left over after harvesting. Today, chemical pulp and panel products using wheat straw and other crop residues are being commercially manufactured in a number of countries including Turkey.The total available cellulosic agricultural biomass is found to be about 122 million tonnes per year in EU(Searle and Malins 2013). The annual amount of agricultural residues produced in Turkey is almost 56 million m^3 and the bulk of these agricultural residues are available for industrial usage (Akgül et al.2005). There are also many studies that have examined the feasibility of substituting wood-based materials with renewable biomass (Barbu et.al. 2013, Ye et al. 2007), including peanut hull (Guler et al. 2007), agro-based fiber (Lee et al. 2006) hazelnut husk (Copur et al. 2007), cotton carpel (Alma et al. 2005), cotton stalks (Guler and Ozen 2004), kenaf core and bast fiber (Grigoriou et al. 2000), sunflower stalks (Bektas et al. 2005), rhododendron biomass (Akgül and Çamlıbel, 2008), wood residues of mixed Species (Chow and Zhao 1992), non-wood plant fibers (Youngquist et al. 1994) reed and wheat straw (Han et al. 1998) kiwi prunings (Nemli et al. 2003), peanut husk (Akgül, Tozluoğlu, 2008), Hazelnut Shell and Husk (Copur et al. 2008) Canola straw (Yousefi 2009), bagasse (Ashori et al. 2009), wheat straw (Halvarsson et al. 2010), corn (Akgül et al. 2010) and corn cotton stalks (Kargarfard and Latibari 2011),rice straw (El-Kassas and Mourad 2013) banana plant stem and midrib (Rashid et al. 2014), palm pruning (Hosseinkhani et al. 2015), reed stem (Kord et al. 2015) and rape straw (Dziurka et al. 2015) to produce composite panels. Traditionally, farmers harvest grain and burn or other wise dispose the residues (stalks, husk, etc.), but the heigh tened interest in industrial utilization of agricultural wastes can mean for farmers second income from grain plantings.

Burning agricultural residues als ocauses environmental problems such as air pollution, soi lerosion, and a decrease in soil biologica lactivity. Therefore, utilizing agricultural residues not only prevents air pollution due to residual burn which adversely affects air quality and human and environmental health, but also economically profitable for farmers. In addition to that, if there is little or no wood resources available or any restrictions are in place to limit the use of wood then alternate sources of lignocellulosics materials are needed for those countries whose natural fiber industry is in place and continues to produce.

To overcome the shortage of the raw material, this study aimed to examine the feasibility of using some of oak wood parts that are especially not suitable for other forest industries to produce medium density fiberboard. In some cases some of these waste materials are being used for cost compared to other resources (Rowell and Norimoto 1988). In some cases, specific fiber properties are important then it becomes important to characterize and utilize in the production.

MATERIALS AND METHOD

Lignocellulosic materials were harvested from the western Black SeaRegion (Düzce country) of Turkey and commercially-manufactured-chips (*Pinus nigra* V., *Fagus orientalis* L. and *Ouercus robur* L.) were used.

The plantmaterials (okra andtobaccostalks, hazelnut and walnut shell, and pinecone) were cleaned from dirt and dust. Biomass was passed through a Wiley mill to break them into smaller pieces and then screened. The screened biomass pass through 40 meshes were used in the production. The commercially-manufactured-chips were pine (*Pinus nigra* V.), beech (*Fagus orientalis* L.) and oak (*Ouercus robur* L.) fiber mixtures (30, 35 and 35%), obtained from Divapan A.Ş. Turkey where fibers were generated with a pressurized disc refiner at feed pressure of 10 and 40 psi and were air dried and bagged for panel manufacturing. All materials were dried at 100-110°C until the material reached 3 % moisture content. Panels were manufactured at a target density of 0.70 g·cm^{-3} with 11 % panel resin content using urea formaldehyde based on the oven dry (o.d.) weight of the materials and the panels were prepared at the thickness of 18 mm. The panels comprised of furnishes at varying degrees (20 %) of biomass (okra and tobacco stalks, hazelnut and walnuts hell, and pinecone) and pine, beech and oak fiber mixtures (Tab. 1).

Tab. 1: Board content.

Board typea	Raw material	
	Biomass fiber (%)	Beech, oak and pine[b] (%)
R	-	100
O	20	80
T	20	80
H	20	80
W	20	80
P	20	80

[a]The density of the boards made from okra (O) and tobacco (T) stalks, hazelnut (H) and walnut (W) shell, and pine (P) cone, and wood (R) (pine, beech and oak) fibers was 0.70 g·cm^{-3},

[b] Pine (*Pinus nigra* V.), beech (*Fagus orientalis* L.) and oak(*Ouercus robur* L.) mixture at 30 %, 35 % and 35 % ratio.

The properties of the urea-formaldehyde resin used in this study were given in Tab. 2. As a hardener 1 % of ammonium chloride (solid content 33 %) solution was added in all the board production.All panels were consolidated using steam heated press in the laboratory of Duzce University. Panels were pressed to 25 kg·cm^{-2} at 150°C for 6 min. Test panels having dimensions of 50 x 50 x 1.8 cm was conditioned at 20±2°C, and 65±5 % of relative moisture content to reach the moisture content of 12 %. Finally, the edges of the boards were trimmed to the final dimension of 48 x 48 x 1.8 cm. Fiberboard production parameters were summarized in Tab. 3.

Tab. 2: The properties of urea-formaldehyde (UF) adhesive.

Properties	UF
Solid (%)	55±1
Density (g·cm^{-3})	1.20
pH	8.5
Viscosity (cps)	160
Ratio of water tolerance	10/27
Reactivity	35
Free formaldehyde (%)	0.15
33 % NH4Cl content (max, %)	1
Gel point (100°C, sec.)	25-30
Storage time (25°C, max day)	90
Flowing point (25°C, sec.)	20-40

Tab. 3: Production parameters of fiberboards.

Parameter	Value
Press temperature. (ºC)	150
Pressing time (min)	6
Press pressure (N·mm^{-2})	2.4-2.6
Thickness (mm)	18
Dimensions (mm)	480×480
Specific gravity (g·cm^{-3})	0.75
Number of board for each type	2

Mechanical and physical properties were tested according to TS-EN 326-1 (1999) and thedensity of panels were tested according to TS-EN-323 (1999). The water absorption and thickness swelling of the specimens were measured according to TS-EN 317 (1999). The specimens were also tested for bending strengths (TS-EN 310, 1999), internal bond strengths (TS-EN 319, 1999) and screw holding ability perpendicular to the plane of panel (ASTM D 1037-78). A universal tester (Imal Mobiltemp shc22, model ib400) was used to assess mechanical properties; values represent the mean of 10 specimens.

The TS-EN 326-1 (1999) standard was used to obtain panel samples. Following TS EN 325 (1999) standards, sample thickness and length were measured using a digital micromete and compass having 0.01 mm gradients. The obtained data were statistically analyzed by using the analysis of variance (ANOVA) and Duncan mean seperation tests.

RESULTS AND DISCUSSION

The results of ANOVA and Duncan's mean separation tests for thickness swelling and water absorption of fiberboards made from mixtures of fiber-biomass are shown in Tab. 4.

Tab. 4: The results of ANOVA and Duncan mean separation test for density, the thickness swelling (TS) and water absorption (WA) percent of the fiberboards madef rom fiber and biomass mixtures.

Board type	Physical properties		
	Density ($g \cdot cm^{-3}$)	TS* (%) 24 h	WA** (%) 24 h
R	0.707^{ab} (69.14)	25.76^{bc} (4.05)	98.26^{ab} (22.436)
O	0.717^{ab} (37.99)	28.79^{c} (1.94)	103.98^{ab} (16.70)
T	0.663^{b} (32.86)	19.85^{a} (3.36)	116.46^{b} (27.44)
H	0.692^{ab} (30.56)	18.68^{a} (1.78)	95.90^{ab} (21.36)
W	0.723^{a} (65.04)	23.90^{b} (3.33)	89.70^{a} (15.30)
P	0.681^{ab} (79.96)	26.86^{c} (4.95)	98.64^{ab} (21.37)

* Thickness swelling ** Water absorption

The mean thickness swelling and water absorption properties of the board made from wood fiber was 25.76 % and 98.26 % respectively. The mean water absorption percent of fiberboards produced using okra and tobacco husk significantly differed ($p<0.001$). However, thickness swelling percent of okra was the highest and tobacco is the lowest. This could be due to chemical content and interaction of the materials. Tobacco stalks contains nicotine and other extractive materials to bind and crosslinked with the adhesives. Nitrogen containing material may show hydrophilic properties however, swelling maybe prevented with crosslinking. Okra stalks contains high cellulose (65-70 %), hemicellulose (10-15 %) and paranchyme cells (5 %) that can absorb water and increase swelling ability (Kumar et.al. 2013). In contrast, lignin is hydrophobic materials which is high in tobacco (Shakhes et.al. 2011). Density of the board made with tobacco stalks was also low. Low density may imply more spaces in the materials and more water absorption. However, it may not be swelling as much as the others due to more space in. Tobacco comformability may be higher than the rest of the other materials (Shakhes et.al. 2011).

In general, softwood produces longer fiber than hardwood and agricultural residues. The bending strength of the fiberboards affected by several factors such as fiber diameters, lumen thicknes sand fiber length (Tab. 5). In addition to that, it is affected by processing conditions. Fiber length of the wood is considered to be higher in control samples therefore it has the highes tbending strength. Pinecone has the fibrillated structure. As a result of that, it shows the bette rbending strength than the rest of the agricultura lresidue samples. Walnut and hazelnut husk shows brittle structure. Therefore, their bending strength are less than other materials. Modulus of elasticity (MOE) not only is related to density but also is related to fiber properties. Longer fiber has higher MOE value than shorter fiber. Internal bond strenght also changes with density but it is also affected by the fiber properties. Fibrillated and conformable structure could have better binding properties. Wood, pinecone and okra shows better properties. Other materials has the smaller fiber and particles to effect binding properties. Okra fiber is considered to be in paper production and its fiber length is higher than hardwood species 2.4 mm (Kumar et al. 2013, Shakhes et al. 2011) .

Tab. 5: The mechanical properties of fiberboards made from biomass mixtures and the test results of ANOVA and Ducan'smean separation tests.

Board Type	BS ($N \cdot mm^{-2}$)	MOE ($N \cdot mm^{-2}$)	IB ($N \cdot mm^{-2}$)	SHA (Kp)
R	21.97^{a} (2-95)	4247.64^{d} (6.207.7)	0.49^{d} (0.03)	113.9^{c} (4.90)
O	17.96^{c} (3.01)	3454.97^{bc} (6.712.1)	0.26^{bc} (0.04)	66.3^{b} (3.00)
T	14.98^{b} (3-09)	2928.92^{ab} (8.44.44)	0.19^{a} (0.03)	36.5^{a} (1.52)
H	$13\text{-}61^{b}$ (1.67)	2640.40^{a} (3.39.98)	0.23^{ab} (0.05)	67.9^{b} (2.36)
W	15.42^{b} (2.29)	2948.37^{ab} (4.38.31)	0.20^{a} (0.04)	131.7^{c} (3. 04)
P	18.36^{c} (2.57)	3554.46^{c} (6.55.28)	0.30^{c} (0.10)	54.0^{ab} (1.72)

Values in parantheses are standard deviation. Homogenou sgroups: letters in each column indicate groups that are statistically differen taccording to Duncan's multiple range test at $P < 0.05$, comparisons were between each contro land its test. (BS: Bending strength, IB: Internal Bond, SHA: Screw Holding ability)

Surface hardness is the measure of abrasion and scratching when in use. During heat treatment, strength is developed, at the same time, fiber deterioration takes place. Addition of different fiber into the mixture changes the interfacial phenomena among the fibers and reduces surface hardness significantly except for walnut mixtures. Walnut shell is already hard materials. When it is on the surface of MDF it improves the SHA (screw holding ability) and it is better than wood fiber. This could be used to improve surface properties of the panelboards to use in different applications.

CONCLUSIONS

The results of this study indicated that it is possible to use different lignocellulosic materials in the production of MDF. However, internal bond strength needs to beim proved to meet standards. These findings showed that lignocellulosic materials from different sources (Walnutshell, pine cone, okra stalks, tobacco stalks, hazelnut shell) can be used to produce fiberboard sand they met the minimum requirements for bending strength, MOE, thickness swelling an dsurface hardness.

Longer fiber has better bending strength than shorter fiber. Longer fiber has also better refined and fibrillated to have bonding strength. Refining improves the surface area increases fiber-to-fiber interaction and the bonding strength. It also makes longer fiber more conformable to each other and increases elasticity. Low fiber aspect ratio decreases the strength properties. However, hard shell improves the surface properties.

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