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PRODUCING PARTICLEBOARDS FROM HAZELNUT (*CORYLUS AVELLANA* L.) HUSK AND EUROPEAN BLACK PINE (*PINUS NIGRA* ARNOLD)

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ABSTRACT

This research was conducted to investigate the suitability of utilizing hazelnut (*Corylus avellana* L.) husk along with European Black Pine (*Pinus nigra* Arnold) chips to produce general purpose particleboards. Panels with a target density of 0.70 g/cm^3 were manufactured using 0, 10, 20, 30, 40, 50 and 100 % husk in the mixture. Urea-formaldehyde (UF) was the adhesive utilized in the production. Produced panels were tested for certain mechanical and physical properties. Experimental results indicated that increase in husk percentage in the mixture generally diminished the mechanical and physical properties; however, the test results showed that husks could be utilized up to 30% in the mixture to produce particleboards while maintaining the minimum values required in the Standard (TS-EN 312).

KEY WORDS: particleboard, hazelnut husk, *Corylus avellana,* European black pine (*Pinus nigra*), physical properties, mechanical properties

INTRODUCTION

It is a general trend that forest industries` demand for raw material increases. On the other hand, the decline of wood production from the natural forests forces the forest industry to alternative raw materials. To overcome the shortage of raw material, alternative bio-based materials, higher recycling rate, more efficient raw material conversions and new products expected to play a key role in the future (Kalaycioglu et al. 2005, Bektas et al. 2005). Based on that approach, some nations have changed their agricultural policies and encouraged their farmers to devote their land to non-food crops. Therefore, alternative biomasses have started to receive a considerable attention in the last 10-15 years (Wang and Sun 2002). Recycling of agro-fiber wastes in production is also encouraged due to the environmental and socio-economic reasons (Rowell 2002). As a result, in many different regions of the world, a wide variety of agricultural residues, such as wheat straws (Mosesson, 1980, Han et al. 1988), bamboo (Rowell and Norimoto 1988), waste of tea leaves (Yalinkilic et al. 1998), bagasse (Turreda 1983), date palm leaves (Nemli et al. 2001), cotton stalk (Guler et al. 2001, Alma et al. 2005), sunflower stalks (Khristova et al. 1998, Guler et al. 2006) have been investigated for their utility for forest industry.

The cultivated hazelnut (*Corylus avellana* L.) is native to the Black Sea coast of Turkey and almost 70% of the world's hazelnut is produced in Turkey (Mennan et al. 2006). Therefore, hazelnut husk is an abundant agricultural waste (approximately 500.000 t/years) and it has no economic value yet. After hazelnut harvest it is either burned or left in the field. Recently, the chemical properties of hazelnut husk and its suitability for particleboard (Copur et al. 2007) production has been investigated. Earlier we (Copur et al. 2007) studied the effect of various additives, such as urea formaldehyde (UF), phenol formaldehyde (PF) and melamine-urea formaldehyde (MUF), in three layer particleboard production using hazelnut husk.

In the current study, we investigated the potential utilization of hazelnut husk in three-layer particleboard production as a mixture with pine chips. The outcome is expected to reduce the wood demand in forest industry.

MATERIAL AND METHODS

The raw materials for this study consisted of hazelnut (*Corylus avellana* L.) husk and Europan Black Pine (*Pinus nigra* Arnold) wood chips. Hazelnut husks were collected from the field right after hazelnut harvest, and the wood chips were obtained from Düzsan Particleboard Company, Düzce in Turkey. Hazelnut husks were coarsely chipped and then the husk and wood chips were classified using a horizontal screen shaker. The particles that remained between 3-1.5mm sieve and between 1.5-0.8 mm sieves were used in the core and middle sections, respectively. Husk and wood chips were dried in an oven at 100-110 °C to reach the target moisture content (3 %, oven dry). The urea formaldehyde (UF) resin at 8% and 10% (o.d. chips) adhesive levels were used for the core and outer layers based on oven dry weight, respectively. The properties of the UF resin are given in Tab. 1. 1% (o.d. chips) ammonium chloride (NH_4Cl) was added to the resin as hardener. The chips were placed in a drum blender and sprayed with urea formaldehyde and ammonium chloride for 5 minutes to obtain a homogenized mixture. Panels were designed to consist of 35% chips at the face layer and 65% at the core layer. The experimental design is detailed in Tab. 2. The target density of the panels was 0.70 g/cm^3 and two panels were produced for each group. The dimensions of particleboards were 48x48x2cm in pressing, and after edge trimming the particleboards` final dimensions were 45x45x2cm. The panel production parameters were given in Tab. 3.

Tab. 1: Properties of the UF adhesive

Properties	UF[a]
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% NH_4Cl content (max. %)	1
Gel point (100°C. sec.)	25-30
Storage time (25°C. max day)	90
Flowing point (25°C. sec.)	20-40

[a] Urea formaldehyde

Tab. 2: Experimental design

Board type	Raw material ratio (%)
	Hazelnut Husk/European black pine
A	0/100
B	100/0
C	10/90
D	20/80
E	30/70
F	40/60
G	50/50

Tab. 3: Production parameters of particleboards

Parameter	Value
Press temperature (^{0}C)	150
Pressing time (min)	7
Peak pressure (N/mm^{-2})	2.4-2.6
Thickness (mm)	20
Dimensions (mm)	480x480
Outer layer (Whole of board %)	35
Middle layer (Whole of board %)	65
Number of board for each type	2

Water absorption (WA) and thickness swelling properties of the produced particleboards were tested according to EN 317 (1996). The mechanical properties, static bending MOR, MOE (EN 310, 1996), IB (EN 319, 1996), screw-holding (perpendicular to the surface and lateral) strengths (EN 320, 1996) were determined. An average of 10 measurements was reported for each test, and the collected data were statistically analyzed by using the analysis of variance (ANOVA) and Duncan's mean separation tests.

RESULTS AND DISCUSSION

The results of ANOVA and Duncan's mean separation tests for water absorption and thickness swelling of particleboards produced using mixtures of hazelnut husk and European Black Pine wood chips for 2 and 24h water immersion times are shown in Tab. 4. Results showed that the highest thickness swelling (2-hr 19.9% and 24-hr 24.5%) and water absorption (2-hr 64.0 and 24-hr 80.2) was observed for board type F consisting of 40% husk in the mixture. The observed thickness swelling value for all the particleboards produced from mixtures with varying amounts of husk were found to be higher than 14%, which is the minimum required value for the 24h water immersion in Standard (TS-EN 312, 2005). Higher hemicellulose content (Copur et al. 2007) in hazelnut husk may be the reason for higher water holding ability of particleboard produced from the mixture consisting of husk. The values obtained with hazelnut husk were found to be comparable with other agricultural residues investigated earlier in the literature: thickness swelling and water absorption values of 17% and 60% for tobacco (Kalaycioglu 1992), 29% and 70% for tea leaves (Kalaycioglu 1992), and 30% and 72% for cotton stalks (Guler et al. 2001) were reported for 24h water immersion time, respectively. Utilizing water repellent chemicals, such as paraffin in the production may improve these properties.

Tab. 4: Thickness swelling (TS) test results of ANOVA and Duncan's mean separation tests of particleboards produced from Hazelnut husks and European black pine

Physical Properties	Board Type	Soaking time (min)	Mean (%)[a]	Std. Deviation	Std. Error	X_{Min}[b]	X_{Max}[c]	p[d]
Thickness Swelling (TS)	A	2	10.2[p]	0.68	0.15	9.24	11.5	*
	B	2	14.1[s]	4.76	1.06	6.17	22.3	*
	C	2	17.5[u]	1.79	0.40	12.6	20.8	*
	D	2	17.2[u]	1.99	0.45	13.7	19.9	*
	E	2	15.6[s]	1.45	0.32	12.2	17.6	*
	F	2	19.9[t]	2.79	0.62	14.7	25.5	*
	G	2	18.3[u]	1.81	0.40	15.6	21.5	*
	A	24	12.7[w]	0.69	0.15	11.5	14.3	*
	B	24	19.6[x]	2.16	0.48	16.4	24.6	*
	C	24	21.9[yz]	2.13	0.48	16.8	24.9	*
	D	24	22.5[z]	2.82	0.63	19.0	28.2	*
	E	24	20.6[xy]	2.48	0.55	14.1	23.9	*
	F	24	24.5[v]	2.72	0.61	18.5	28.9	*
	G	24	24.0[v]	2.40	0.54	18.7	27.8	*
Water Absorption (WA)	A	2	53.6[s]	2.70	0.60	45.9	58.3	*
	B	2	17.8[p]	4.09	0.91	12.9	28.5	*
	C	2	55.1[s]	6.12	1.37	44.9	68.1	*
	D	2	56.1[s]	8.25	1.84	44.8	79.5	*
	E	2	53.4[s]	7.31	1.63	42.4	71.2	*
	F	2	64.0[u]	12.5	2.80	37.6	91.2	*
	G	2	53.6[s]	8.98	2.01	36.4	67.9	*
	A	24	61.8[t]	2.81	0.63	53.2	65.9	*
	B	24	37.0[v]	3.37	0.75	30.1	43.2	*
	C	24	70.1[x]	6.75	1.51	58.2	84.2	*
	D	24	70.8[x]	7.47	1.67	61.1	92.0	*
	E	24	69.7[x]	7.57	1.69	59.2	90.9	*
	F	24	80.2[y]	13.0	2.91	54.9	110	*
	G	24	71.7[x]	7.37	1.65	60.3	85.4	*

[a]Mean values are the average of 20 specimens. [b]Maximum value; [c]Minimum value; [d]Significance level of 0.001 (for ANOVA); [p.s.u.t.v.w.x.y.z]Values having the same letter are not significantly different (Duncan test).

Tab. 5 shows the mechanical properties of the produced panels. The results indicated that increase in husk percentage in the mixture generally diminished the mechanical properties of the particleboards. It can be seen from Tab. 5 that the mean modulus of rupture of the particleboards varied from 15.6 (panel type A) to 11.9 N/mm^{-2} (panel type B). The decrease in modulus of rupture showed an inverse proportionality to the husk in the mixture. The Standard (TS-EN 312, 2005) recommends a minimum of 11.5 N/mm^{-2} modulus of rupture (MOR) for the particleboards manufactured for general propose-use and all panel types produced in this study met this requirement. For indoor use (including furniture), TS-EN 312 requires 13.5 N/mm^{-2} MOR and panels produced using up to 30 % husk in the mixture met the required standard value. The lowest MOE was observed when panels were produced from 100% husk. Adding 10% husk to the mixture resulted in the best MOE but increasing the husk in the mixture generally lowered the MOE. Particleboards produced in this study met the required MOE value (1600N/mm[-2]) for general purpose end-use (TS-EN 312, 2005) except for the panel type B consisting of 100% husk. The lowest MOR (11.9 N/mm[-2]) and MOE (1547.8 N/mm[2]) values obtained with panels including 100% husk is explained by the small size of husk particles in the structure and lower density (Copur et al. 2007) of the husk material.

Tab. 5: The mechanical properties of particleboards made from Hazelnut husks and European black pine and the test results of ANOVA and Duncan's mean separation tests

Mechanical properites	Board type	Mean	Std. Deviation	Std. error	X_{Min} [b]	X_{Max} [c]	p[d]
MOR (N/mm^{-2})	A	15.6 [u]	2.52	0.9	11.0	19.1	***
	B	11.9 [p]	0.85	0.3	10.4	13.0	***
	C	14.7 [su]	2.64	0.9	9.2	16.4	***
	D	14.0 [psu]	1.81	0.6	11.4	15.7	***
	E	13.5[psu]	1.91	0.7	11.6	17.0	***
	F	12.7 [ps]	2.95	1.0	8.2	16.8	***
	G	12.8[ps]	2.06	0.7	10.8	15.8	***
MOE (N/mm^{-2})	A	2312[xy]	374.1	132.3	1677	2637	*
	B	1547[v]	108.9	38.5	1381	1750	*
	C	2601[y]	237.4	84.0	2267	2918	*
	D	2437 [xy]	279.9	99.0	1813	2648	*
	E	2451[xy]	254.0	89.8	2175	2775	*
	F	2341[xy]	422.2	149.3	1516	2850	*
	G	2224[x]	421.7	149.1	1434	2694	*
IB (N/mm^{-2})	A	0.382[ps]	0.08	0.03	0.237	0.539	***
	B	0.505[s]	0.08	0.04	0.405	0.600	***
	C	0.420[ps]	0.10	0.03	0.252	0.571	***
	D	0.359[p]	0.12	0.04	0.086	0.482	***
	E	0.381[ps]	0.20	0.07	0.071	0.618	***
	F	0.303[p]	0.13	0.04	0.084	0.464	***
	G	0.319[ps]	0.10	0.03	0.279	0.566	***
PSHS (N)	A	819.2[ps]	92.6	41.4	686.0	931.0	NS
	B	713.4[p]	113.3	50.7	578.2	862.4	NS
	C	925.1[s]	156.3	69.9	666.4	1087	NS
	D	862.4[ps]	119.0	53.2	764.4	1038	NS
	E	807.5[ps]	114.6	51.3	637.0	931.0	NS
	F	803.6[ps]	176.4	78.9	597.8	1029	NS
	G	811.4[ps]	55.6	24.9	735.0	872.2	NS
LSHS (N)	A	562.5[p]	122.9	55.0	421.4	705.6	NS
	B	491.9[p]	115.0	51.4	362.6	666.4	NS
	C	599.7[p]	121.1	54.2	450.8	735.0	NS
	D	539.0[p]	112.4	50.3	343.0	617.4	NS
	E	531.2[p]	43.5	19.5	480.2	578.2	NS
	F	570.4[p]	118.3	52.9	441.0	735.0	NS
	G	574.3[p]	67.4	30.1	480.3	637.0	NS

[a]Mean values are the average of 10 specimens, [b]Maximum value; [c]Minimum value; [d]Significance level ; *significant at 0.001, ** significant at 0.01, *** significant at 0.05, NS not significant (for ANOVA); [p.s.u.v] Values having the same letter are not significantly different (Duncan test). LSHS = Lateral screw-holding strength. PSHS = Perpendicular screw-holding strength

In the case of IB, the measured values ranged from 0.303 to 0.505 N/mm^{-2}. The highest IB value was observed with the particleboard produced using 100% husk. The reason for this finding could the flatter and thinner structure of the husk material compared to the wood chips. On the other hand, the lower density of husk (0.23 g/cm^{-3} (±0.21) (Copur et al. 2007) compared to the wood chips resulted in better bonding. All produced particleboards met the IB requirement of 0.24 N/mm^{-2} for general purpose end-use. This finding is compatible with previous results reported in literature (Kozlowski et al. 1987, Goker et al. 1993, Akbulut 1995, Bektas et al. 2002). Lateral and perpendicular screw-holding strengths were found to be 492 N and 713 N respectively for 100% husk panels. Screw-holding strength diminished when husk was added into the mixture. However, all panels met the requirements of British Standard (BS 2604, 1970).

CONCLUSIONS

This study investigated the possibility of using hazelnut husk and European Black Pine wood mixture to manufacture three-layer particleboards. The results indicated that it is possible to produce particleboards from hazelnut husk alone and from the mixture of hazelnut husk and wood chips. All the produced panels tested for mechanical properties complied with the minimum requirements in the standards for the general grade particleboards. However, thickness swelling and water absorption properties of the panels produced from any mixture with husk were found to be inferior and could be improved by the use of hydrophobic materials in production. The boards produced entirely form husk resulted in lower property values except for the IB strength. The boards manufactured from the mixture of husk (up to 30%) and wood chips could be utilized for situations where higher mechanical properties were required. Overall, this study showed that hazelnut husk could be utilized as a raw material in particleboard production by itself or in combination with European Black Pine wood mixture.

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