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Short Communication

Incorporation of hazelnut shell and husk in MDF production

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Abstract

Hazelnut shell and husk (*Coryllus arellana* L.) is an abundant agricultural residue in Turkey and investigating the possibilities of utilizing husk and shell in panel production might help to overcome the raw material shortage that the panel industry is facing. The aim of this work was to investigate the possibilities of utilizing hazelnut shell and husk in medium density fiberboard (MDF) production. To produce general purpose fiberboards, fiber–husk and fiber–shell mixtures at various percentages were examined in this study. The results indicated that panels could be produced utilizing hazelnut husk up to 20% addition without falling below the properties required in the standards. Shell addition was restricted up to 10%, because higher addition levels diminished the elastic modulus and internal bond strength below the acceptable level.

Keywords: Medium density fiberboard; Hazelnut shell; Hazelnut husk; Physical properties; Mechanical properties

1. Introduction

Wood based panels composed of wood or other lingocellulosic materials are produced by breaking wood down into small elements and then reconstituting it to form high value products using different binders under pressure and heat. The production of medium density fiberboard (MDF) has been constantly increasing due to its several advantages compared to solid wood and other composite materials. MDF has uniform fiber distribution in its structure that meets the various end-use requirements like high dimensional stability. Smooth and solid edges can easily be machined and finished for various purposes, especially in furniture production. Smooth and uniform surface also provides an excellent substrate for painting or applying decorative overlays.

MDF industry usually utilizes wood based raw materials in production. On the other hand, the use of renewable agricultural residues in production is preferred because of economical and environmental concerns. The use of agricultural residues as an industrial raw material has been practiced in panel industry for years. Today panels made of wheat and other crop residues are being commercially manufactured in a number of countries due to the high global consumption of wood, which is over 3.23 billion ton/year. If the consumption rate of wood fiber and the rate of population growth stay constant, demands for wood fibers will increase more resulting in deforestation, and supplying global needs for wood and fiber is becoming increasingly problematic in the future. If the world continues to rely only on the current natural forest and plantations, the annual growth of wood would soon be insufficient to support current per-capita consumption, which attests the importance of utilizing agricultural residues and annual plants in forest industry.

Several studies examined the viability of substituting wood based materials with crops residues from annual plants, such as cotton carpel (Alma et al., 2005), cotton stalks (Güler and Özen, 2004; Gençer et al., 2001), straw (Mantanis et al., 2000) and kiwi prunings (Nemli et al., 2003) to produce wood based panels.

Hazelnut shell and husk is an abundant agricultural material in Turkey. The shell and husk production is approximately 200,000 ton/year (Midilli et al., 2000).

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Hazelnut shell is utilized in the forest industry as shell powder in plywood production. Studies with various shell powder ratios indicated that 10–12% shell addition in the adhesive material had no negative effect on the mechanical properties of the plywood (Çolakoğlu and Örs, 1992). In our earlier paper, we (Copur et al., 2007) examined the suitability of hazelnut husk in particleboard production. Therefore, there are very limited studies about the possibilities to utilize hazelnut shells and husk in the forest industry, and presently hazelnut shells have mainly been utilized as fuel in Turkey. After kernel harvesting, husk stays in the field, burned or left for biodegradation for soil enrichment. Utilizing hazelnut husk and shell in MDF production is not studied yet. The aim of this study is to investigate the potential utility of hazelnut shells and husk; which are found in abundance in Turkey; in MDF production as supplement and to alleviate the shortage of raw material in forest industry.

2. Methods

The experimental procedures divided into two main categories based on the objectives and expected results. In all cases the main raw material was beech (*Fagus orientalis* L.) and pine (*Pinus nigra* V.) fiber mixtures (60% and 40%), 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. Hazelnut shells were obtained from Çalıkoğlu Fındık A.Ş. Turkey and husk was collected from the field right after hazelnut harvesting. The obtained materials were cleaned from dirt and dust. Both shells and husk were passed through a Willey mill to break them into smaller pieces and then the product was screened. Hazelnut shells passing through 40 meshes and husk passing through 50 meshes were used in the production. All material was dried at 100–110 °C until the material reached 3% moisture content.

The panels comprised of furnishes with varying degrees of hazelnut shells (panel B: 10, C: 20 and D: 30%) and husk (panel E: 10, F: 20 and G: 30%) along with fiber mixtures were produced and the resultant panels were compared with the control panel produced using 100% fiber (panel A). Urea formaldehyde (8% based on oven dry fiber) additive was used in production. As a hardener 1% of ammonium chloride (solid content 33%) solution based on oven dry fiber was added in all the board production. The materials were mixed for 3 min to accomplish a homogenized resin distribution. The fiberboards prepared were pressed at a max pressure of 2.6 N/mm^2 at 150 °C for 5 min. Two experimental fiberboards having dimension of $48 \times 48 \times 2$ cm were produced and then the produced fiberboards were conditioned at 20 ± 1 °C and 65 ± 5 relative humidity to the moisture content of about 12%. Panels were prepared at the thickness of 10 mm. Edges of the boards were trimmed to the final dimension of $46 \times 46 \times 2$ cm. The specific gravity of the produced fiberboards was 0.80 g/cm^3.

The produced fiberboards were subsequently evaluated for physical and mechanical properties. Test specimens were cut from the fiberboards according to TS-EN 326-1 (1999) and the samples were kept in the conditioning room. The water absorption and thickness swelling of the materials were determined according to TS-EN 317 (1999). The specimens were also tested for bending (TS-EN 310, 1999) and internal bond strengths (TS-EN 319, 1999). The obtained data were statistically analyzed by using the analysis of variance (ANOVA) and Duncan mean separation tests.

3. Results and discussion

The results of ANOVA and Duncan's mean separation tests for water absorption and thickness swelling of fiberboards made from mixtures of fiber–husk and mixtures of fiber–shell are shown in Tables 1 and 2, respectively. Under the same conditions, the mean thickness swelling ($p > 0.05$) and water absorption ($p > 0.001$) of the fiberboards made from the mixtures of fiber–husk significantly differ from the fiberboards made from the mixtures of fiber–shell.

It is obvious from the Table 1 that the mean thickness swelling percentage of all types of boards showed a sharp increase from 2 to 24 h soaking time and then the increase continued from 24 to 72 h but in lower magnitude. The Duncan mean separation tests resulted that the increase in the mean thickness swelling from 48 to 72 h is insignificant for fiber–shell mixtures. Increase in husk and shell percentage in the mixture gave panels having higher mean thickness swelling. The mean thickness swelling of panels increased considerably as husk and shell percentages in the mixture increased from panel A to B and then the slight increase continued through panel C–D. For all the soaking times the highest mean swelling percentage was observed for 30% husk-containing fiber–husk mixtures (panel D). The 15% thickness swelling for 24 h (14%) required in TS64-5 EN 622 (1999) standard was even surpassed by panels containing 100% wood fiber with a thickness swelling of 19.1%. This finding was explained by not using any water repellent chemicals in the panel production. Utilizing resin-type adhesive and waxes, changing the production parameters and modifying fiber (Grigoriou et al., 2001), would have improved the water repellency of the produced panels with husk and shells. Literature reports higher thickness swelling for boards produced by using flax and hemp fibers (Kozlowski and Piotrowski, 1987), cotton carpel (Alma et al., 2005), and sunflower based particleboards (Kalaycıoğlu, 1992).

The water absorption percentage was determined for soaking times of 2, 24, 48 and 72 h. For all the soaking times studied, all panels absorbed increasing amount of water from 2 to 72 h. An increase on the amount of husk and shell percentages in the total mixture made panels less water resistant and panel D and G gave the highest water absorption for fiber–husk and fiber–shell mixtures, respectively.

Table 1
The results of ANOVA and Duncan mean separation test for the water absorption (WA) and thickness swelling (TS) percent of the fiberboards made from fiber and husk mixtures

Board type	Soaking time	Mean (%)^{a}	SD	$X_{\min}^{b}$	$X_{\max}^{c}$	P^{d}
Water absorption						
A	2	35^{p}	8.75	21	56	*
B	2	49^{s}	10.9	30	71	*
C	2	64^{u}	12.9	45	91	*
D	2	73^{v}	14.1	57	111	*
A	24	63^{x}	9.53	45	85	*
B	24	69^{x}	8.76	58	89	*
C	24	77^{y}	12.4	63	104	*
D	24	86^{z}	12.9	73	121	*
A	48	68^{m}	8.41	53	86	*
B	48	72^{m}	7.16	61	88	*
C	48	84^{n}	14.2	69	106	*
D	48	98^{o}	16.5	78	127	*
A	72	76^{h}	9.86	61	95	*
B	72	74^{h}	7.61	63	89	*
C	72	87^{i}	14.2	72	108	*
D	72	100^{j}	15.9	81	127	*
Thickness swelling						
A	2	12^{p}	2.84	8	18	*
B	2	21^{s}	4.51	13	31	*
C	2	31^{u}	3.11	23	37	*
D	2	37^{v}	5.46	30	47	*
A	24	27^{x}	2.16	23	30	*
B	24	32^{y}	3.78	23	38	*
C	24	39^{z}	3.09	31	43	*
D	24	42^{t}	6.36	35	59	*
A	48	30^{m}	1.77	28	34	*
B	48	34^{n}	1.59	31	36	*
C	48	42^{o}	2.50	37	46	*
D	48	43^{o}	5.10	36	51	*
A	72	23^{h}	2.05	19	26	*
B	72	36^{i}	0.79	35	37	*
C	72	44^{j}	2.88	41	53	*
D	72	46^{k}	6.26	40	58	*

[a] Mean values are the average of 20 specimens.
[b] Maximum value.
[c] Minimum value.
[d] Significance level.
[*] Significant at 0.001 for ANOVA.
[p,s,u,v,x,y,z,t,m,n,o,h,i,j,k] Values having the same letter are not significantly different (Duncan test).

Table 2
The results of ANOVA and Duncan mean separation test for the water absorption (WA) and thickness swelling (TS) percent of the fiberboards made from fiber and hazelnut shell mixtures

Board type	Soaking time	Mean (%)^{a}	SD	$X_{\min}^{b}$	$X_{\max}^{c}$	P^{d}
Water absorption						
A	2	35^{p}	8.75	21	56	*
E	2	59^{s}	12.3	33	83	*
F	2	84^{u}	21.1	53	125	*
G	2	88^{u}	14.0	70	113	*
A	24	63^{x}	9.54	45	85	*
E	24	78^{y}	7.84	61	93	*
F	24	95^{z}	20.6	76	140	*
G	24	98^{z}	12.7	83	121	*
A	48	68^{m}	8.41	53	86	*
E	48	80^{n}	7.57	64	95	*
F	48	99^{o}	13.9	83	122	*
G	48	100^{o}	11.9	86	123	*
A	72	76^{h}	9.86	61	95	*
E	72	89^{i}	8.32	77	100	*
F	72	101^{j}	14.6	84	128	*
G	72	112^{k}	13.5	89	136	*
Thickness swelling						
A	2	12^{p}	2.84	8	18	*
E	2	19^{s}	2.84	14	25	*
F	2	32^{u}	4.80	25	43	*
G	2	33^{u}	3.36	27	42	*
A	24	27^{x}	2.16	23	30	**
E	24	28^{x}	1.95	24	31	**
F	24	34^{xy}	24.4	-67	54	**
G	24	38^{y}	3.19	34	45	**
A	48	30^{m}	1.77	28	34	*
E	48	30^{m}	2.08	27	35	*
F	48	41^{n}	3.85	35	49	*
G	48	41^{n}	3.38	36	48	*
A	72	23^{h}	2.05	19	26	*
E	72	33^{i}	3.00	29	38	*
F	72	45^{j}	5.62	36	57	*
G	72	44^{j}	4.78	37	54	*

[a] Mean values are the average of 20 specimens.
[b] Maximum value.
[c] Minimum value.
[d] Significance level.
[*] Significant at 0.001.
[**] Significant at 0.05 for ANOVA.
[p,s,u,x,y,z,m,n,o,h,i,j,k] Values having the same letter are not significantly different (Duncan test).

For all soaking times studied, panels produced using fiber–husk mixtures absorbed higher amount of water compared to the fiber–shell mixtures. Differences in water absorption may be attributable to the chemical composition (Urquhart and Williams, 1924; Ziegler, 1974; Sjostrom, 1993) and the specific surface area (Stone and Scallan, 1965). Higher lignin and hemicellulose content in husk and shell may be the reason for higher water holding ability. On the other hand, higher amount of crystalline cellulose in wood structure due to its intra- and intermolecular hydrogen bonds may restrain water acceptability (Sjostrom, 1993) in wood fibers.

The results of mean bending strength, internal bond strength and mean modulus of elasticity for fiberboards were shown in Table 3. The general finding is that the addition of husk and shell in panel production decreased the bending and internal bond strength and made panels less elastic compared to the panels produced utilizing 100% wood fiber. It can be seen from the Table 3 that the mean bending strength of the fiberboards varied from 34.9 to 13.9 N/mm^{2}, the mean modulus of elasticity varied from 3287 to 1481 N/mm^{2} and the mean internal bond strength varied from 0.59 to 0.22 N/mm^{2} for panel type A (100% wood fiber) and for panel type G (70/30% fiber–shell mixture), respectively. The decrease in strength properties and elasticity of the fiberboards showed inverse proportionality to the husk and shell percentages in the mixture.

The panels produced from mixture of fiber–husk and fiber–shell was significantly different on the basis of Duncan mean separation tests for all strength properties. Under the same production conditions, fiber–shell mixture

Table 3
Mechanical properties of produced fiberboards

Board types	Bending strength (BS) (N/mm^2)	Modulus of elasticity (MOE) (N/mm^2)	Internal bond strength (IB) (N/mm^2)
A	34.9 (0.11)[a]	3287 (230)	0.59 (0.09)
B	30.3 (3.36)	2852 (438)	0.44 (0.04)
C	24.2 (1.95)	2667 (209)	0.34 (0.07)
D	18.6 (3.12)	2320 (179)	0.29 (0.01)
E	27.8 (1.70)	2635 (282)	0.44 (0.06)
F	22.3 (2.93)	2346 (301)	0.28 (0.06)
G	13.9 (0.98)	1481 (116)	0.22 (0.04)

[a] Values in parenthesis are the standard deviations of the averages.

resulted in lower mean bending strength and lower mean modulus of elasticity compared to the fiber–husk mixtures. A sharp decrease was observed in the mean bending strength and the mean modulus of elasticity for panel types D and G, both including 30% husk and shell in the mixture. The mean internal bond strength of the panels produced using husk and shell showed almost similar strength values except panel type G. All strength characteristics, bending strength, elastic modulus and internal bond strength were significantly different according to the Duncan mean separation test for panels produced utilizing 100% wood fiber and fiber–shell mixtures at significance level of 0.001. Similar to shell mixture, the bending strength of the panels produced utilizing 100% wood fiber and fiber–husk mixtures was significantly different at significance level of 0.001. On the other hand, the mean elastic modulus of the panels produced using 20% and 30% and the mean internal bond strength of the panels produced using 10% and 20% and 20% and 30% fiber–husk mixtures were not statistically different. Higher husk percentages in the mixture did not alter the elastic modulus and internal bond strength of the panels produced.

The mean bending strength of all fiberboards met the minimum bending strength value (22.0 N/mm^2) required in TS64-5 EN 622 (1999) but exception observed with panel types of D and G. In addition, with the exception of panel type D, F and G, the mean modulus of elasticity of the panels met the minimum modulus of elasticity (2500 N/mm^2) required in TS64-5 EN 622 (1999) for medium density fiberboards. On the other hand, the minimum internal bond strength (0.50 N/mm^2) required in TS64-5 EN 622 (1999) for medium density fiberboards did not met with any of the panels that were produced while adding hazelnut husk or hazelnut shell in the mixture.

The strength properties of the MDF are mainly attributable to the physical and mechanical properties of individual wood fibers, fiber orientation and the manner in which these components were combined in the structure. The lower mechanical properties with shell and husk addition in MDF panels could be explained by the small size of husk and shell particles in the structure resulting in low fiber aspect ratios and ultimately leading to poor physical fiber-to-fiber contact. Groom et al. (1999) found similar results with mixtures comprising various fine contents: there was a negative correlation between the amount of fines in the mixture and the mechanical properties of panels produced. The higher strength properties with fiber–husk mixtures may be explained by the higher compactness of the husk compared to the fiber–shell mixtures.

4. Conclusions

The results of this study showed that it was possible to produce fiberboards utilizing hazelnut shell and husk at various percentages as a mixture with the wood fiber. Husk-mixed panels showed advantages in strength characteristics over shell mixed panels. Husk-mixed panels produced minimum strength values that met general purpose panel requirements regardless of the husk amount in the mixture up to 20%. On the other hand, shell addition in fiberboard production was restricted up to 10%, and higher addition levels resulted in panels having lower elastic modulus than the minimum requirement according to TS64-5 EN622 standards. Solely panel produced using 100% fibers met the minimum internal bond strength value required by TS64-5 EN622 standard. Addition of hazelnut husk and shell reduced significantly the internal bond strength of the panels. The increase in wood material consumption due to the increasing world population requires optimum utilization of the natural recourses. The feasibility of adding husk and shell to the wood fibers to produce fiberboards would reduce the dependence of Turkish panel industry on the raw material which is rather scarce.

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