Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 8 (12): 2333-2336, 2008
ISSN 1812-5654

Pepper Stalks (*Capsicum annuum*) as Raw Material for Particleboard Manufacturing

Ergun Guntekin, Birol Uner, H. Turgut Sahin and Beyhan Karakus
Department of Forest Products Engineering, Faculty of Forestry,
Suleyman Demirel University, 32260 Isparta, Turkey

Abstract: The aim of this study was to investigate possible feasibility of pepper stalks in the production of particleboard. Chemical composition and fiber properties of the pepper stalks were determined and three-layer experimental particleboards with density of 0.53, 0.63 and 0.73 g cm^{-3} were manufactured from pepper stalks using certain ratios of Urea Formaldehyde (UF) and Melamine Urea Formaldehyde (MUF) adhesives. Some physical and mechanical properties of the boards were tested. The experimental results have shown that production of general purpose and furniture grade particleboard used in dry conditions using pepper stalks is technically feasible. The results of the study demonstrated that pepper stalks can be an alternative raw material for particleboard industry.

Key words: Pepper stalks, fiber properties, chemical composition, particleboard manufacturing

INTRODUCTION

The wood composite industry is facing with serious shortage of forest resources and showing increased interest in production of ligno-cellulose based composites from other materials. The biggest alternative is agricultural residues. Agricultural waste materials and annual plants have become alternative raw materials for the production of particleboard or fiber composite materials. The most frequently referred alternative non-wood materials are flax, bagasse, hemp, reed and cereal straws such as rice and wheat straw (Younquist *et al*., 1994). Today, chemical pulp and panel products using wheat straw and other crop residues are being commercially manufactured in a number of countries including Turkey (Copur *et al*., 2007). There is still an outgoing research interest to find alternative sources of raw materials for composite manufacturing.

In recent studies; cotton stalks (Guler and Ozen, 2004), cotton carpel (Alma *et al*., 2005), hazelnut husk (Copur *et al*., 2007), vine prunings (Ntalos and Grigoriou, 2002), bamboo chips (Papadopoulos *et al*., 2004), kenaf core (Xu *et al*., 2004; Grigoriou *et al*., 2000a), kenaf core and bast fiber chips (Grigoriou *et al*., 2000b), date palm branches (Nemli *et al*., 2001), wheat straw (Zhang *et al*., 2003), peanut-shell flour (Batalla *et al*., 2005), sunflower stalks (Bektas *et al*., 2005) and eggplant stalks (Guntekin and Karakus, 2008) have been investigated and found technically suitable in particleboard manufacturing. The high cost of collecting, transporting and storing seem to the biggest obstacles for use of agricultural residues in forest products industry. Some of these problems could be overcome by building local, small scale mills close to the rural areas (Copur *et al*., 2007).

In the future, plant-based composites may replace polymer based composites and wood in terms of their attractive specific properties, lower cost, simple process technologies, eco-friendliness and ability to be recycled after use (Ndazi *et al*., 2006). Performance of plant-based composites can be improved by applying appropriate processing techniques.

Peppers (*Capsicum annuum*) are native to Central and South America. Portuguese traders introduced them to India, Indonesia and other parts of Asia around 450-500 years ago. Today, peppers are cultivated world-wide and their plants reach 0.5-1.5 m height. Approximately 1 million ha land is utilized for vegetable farming including eggplant, tomato, pepper, etc. in Turkey (Seniz, 2004). A small town in Antalya region produces more than 100,000 tons of dry vegetable waste every year (Gultekin, 2004). Today, vegetable stalks have been mostly burned or left in the disposal areas, but costs of disposal are rising and burning creates environmental pollution. Recent economic, technological and political changes are opening up new markets for agricultural wastes. These markets could provide the foundation for a re-industrialization of many rural economies.

The objectives of this study were to investigate fiber properties, chemical composition and suitability of pepper stalks for particleboard manufacture. Suitability of the stalks were measured in terms of some physical (thickness swelling (TS)) and mechanical properties (modulus of rupture (MOR), modulus of elasticity (MOE) and internal bond strength (IB)).

Corresponding Author: Ergun Guntekin, Department of Forest Products Engineering, Faculty of Forestry, Suleyman Demirel University, 32260 Isparta, Turkey

MATERIALS AND METHODS

The pepper stalks used in the study was gathered in green form in Antalya region of Turkey in the summer of 2006. The stalks were carried to Forest Products Engineering facilities in Isparta and left in the open environment for six months before utilizing in the production. They were cleaned from roots, then turned into particles through a hammer mill and screened.

Refined stalks were used in determination of fiber properties. Fiber length and thickness were measured using a light microscope.

In order to investigate chemical composition, specimens were prepared according to TAPPI T 257 om-85. Holocellulose and cellulose contents were quantified according to the chloride method and TAPPI T 203 om-71 method, respectively. Lignin content was assessed using TAPPI T 222 om-98. In order to determine extractive content TAPPI test method T-204 was applied (TAPPI, 1992).

For experimental particleboard production; particles remained on the 2-3 and 1-1.5 mm sieves were used in middle-layer and surface-layer on panel production, respectively. Then, the particles were dried at 105±5°C until at least 3% moisture content obtained. In the production of experimental panels; urea formaldehyde-UF and melamine urea formaldehyde-MUF resins were used as binder. Properties of the adhesives are given in Table 1. As a hardener, 35% of ammonium chloride solution was used for all of the UF resin panels. Table 2 presents experimental design set up for the study. After spraying the adhesive on the particles in a drum blender, particleboard mat was manually formed inside a 40×40 cm wooden box on a metal plate which was used in carrying the mat to the hot press. The shelling ratio, the ratio of the outer thickness to the total thickness of the boards, was 0.35 for all experimental boards. The target board thickness 16 mm was achieved in 5 min under 2.5-3 MPa pressure at 155±5°C. Two experimental boards were manufactured representing each treatment group. Experimental panels were trimmed to avoid edge effects on test parameters and kept in 20°C and 65% relative humidity for 48 h. Test samples were cut from the experimental panels to determine some physical and mechanical properties in accordance with TS EN 310 (TS, 1999), TS EN 317 (TS, 1999) and TS EN 319 (TS-EN 312-2, 1999) standards. Collected data were statistically analyzed using analysis of variance (ANOVA) and Duncan's mean separation tests.

Table 1: The properties of the adhesives used

Properties	UF	MUF
Solid (%)	65±1	55±1
Density (g cm^{-3})	1.27-1.29	1.125
pH (25°C)	7.5-8.5	8.5
Viscosity (cps, 25°C)	150-200	200
Gel time (sec 100°C)	25-30	50-60
Storage time (day)	60	60
Flowing time (sec 25°C)	20-30	20-40
Free formaldehyde (max.) (%)	0.19	0.16

Table 2: Experimental design used in the study

Board type	Density (g cm^{-3})	Adhesive type	Adhesive used (%) Middle	Adhesive used (%) Surface
A	0.53	UF	8	10
B	0.63	UF	8	10
C	0.73	UF	8	10
D	0.53	UF	10	12
E	0.63	UF	10	12
F	0.73	UF	10	12
G	0.53	MUF	8	10
H	0.63	MUF	8	10
I	0.73	MUF	8	10
J	0.63	MUF	10	12
K	0.73	MUF	10	12
L	0.78	MUF	10	12

RESULTS AND DISCUSSION

Pepper stalks had very low lignin content when compared to some other agricultural residues and wood. However, cellulose contents seem to be very high when compared to hardwoods and softwoods. Fiber properties of pepper stalks are similar to hardwoods (Table 3). Analysis of variance (ANOVA) procedure was utilized for data with SAS statistical analysis software to interpret effects of density and adhesive ratio on the properties of the panels manufactured. Duncan test was used to make comparison among board types for each property tested if the ANOVA found significant.

The MOR and MOE mean values presented in Table 4 and they were ranged from 6.10 N mm^{-2} (MPa) to 15.38 MPa and 1894 to 3881 MPa, respectively. The MOR and MOE of the experimental particleboards increased with an increase in panel density and adhesive ratio. This suggests that the board density and adhesive ratio had significant effect on the MOR and MOE. Therefore it may be possible to manufacture stronger and stiffer boards by increasing density and adhesive ratio of the panels.

Generally, experimental boards which contain MUF type adhesives achieved higher MOR, MOE values and lower TS values. While the highest average MOR and MOE values obtained from L-type boards, A-type boards yielded the lowest MOR and MOE values. Considering only MOE values; all of the board types complied with the minimum requirements for general grade and furniture grade particleboards. Test results indicated that F, I, K and L type boards met to the minimum requirements for general grade particleboards as indicated by TS EN-312-2

Table 3: Comparison of characteristic values of some agri-residues and wood

Source	Extractive content (%)	Lignin content (%)	Holocellulose content (%)	Cellulose content (%)	Fiber length (mm)	Fiber thickness (μm)
Pepper	5.92	4.89	95	60.51	0.4-0.6	25-35
Cotton carpel (Alma *et al*., 2005)	5.54	20.5	71	42.5	-	-
Cereal straw (Eroglu, 1988)	3-12	12-17	64-71	35-39	1.4	15
Hazelnut husk (Copur *et al*., 2007)	8.22	35.1	55	34.5	-	-
Softwood (Fengel and Wegener, 1984)	1-5	25-35	63-70	29-47	3-8	30-40
Hardwood (Fengel and Wegener, 1984)	2-8	30-35	70-78	38-50	0.8-2	15-25
Cotton (Tank, 1980)	0.4	0.9	97	95	18	20
Cotton Stalks (Gencer, 1998)	-	10.7	76.8	51.8	-	-
Flax (Tröger *et al*., 1998)	6-13	2.5	81	65	20-40	26
Jute (Sahin and Young, 2008)	3.70	21-26	18-21	58	1.1-2.5	20-26

Table 4: Some properties of the boards manufactured using pepper stalks

Board type	MOR (MPa)	MOE (MPa)	IB (MPa)	TS (%)
A	6.10F (1.60)	1894D (518)	0.35 (0.11)	76BC (18)
B	8.43DE (1.71)	2585BCD (588)	0.43 (0.22)	98A (19)
C	10.13CD (0.72)	2548BCD (510)	0.46 (0.07)	90AB (10)
D	7.98E (1.78)	2383CD (929)	0.45 (0.22)	68CD (15)
E	10.76BC (1.48)	2943BC (489)	0.67 (0.55)	82ABC (22)
F	12.32B (1.14)	2877BC (325)	0.83 (0.32)	63CDE (16)
G	7.16EF (1.03)	2203CD (268)	0.56 (0.16)	62CDE (7)
H	10.13CD (0.66)	2736BC (423)	0.59 (0.18)	63CDE (6)
I	12.07B (0.92)	2899BC (193)	0.49 (0.05)	72BC (4)
J	10.85BC (0.5)	2456BCD (687)	0.56 (0.21)	44E (8)
K	12.30B (0.92)	3221AB (197)	0.41 (0.02)	49DE (7)
L	15.38A (0.43)	3881A (94)	0.49 (0.01)	49DE (11)

Each value represents the mean of at least 6 replications. Values sharing the same capital letter(s) within a column are not statistically different at the 0.05 level of confidence. Values in parentheses are standard deviations

(1999). L-type boards also carry the minimum requirements for furniture grade particleboards used in dry conditions as indicated by TS EN 312-2 (1999).

The IB mean values ranged from 0.35 to 0.83 MPa. It is interesting to find out that there was no significant difference among IB of the experimental boards.

TS of the boards were affected by both the density and the adhesive ratio. The results indicated that particleboards produced using pepper stalks gave higher amount of TS values compared to the boards made from wood and other ligno-cellulosic materials. This could be explained by strong polar character of plant fibers which creates problems of incompatibility with adhesive matrices (Ndazi *et al*., 2006). Adding water repellent chemicals such as paraffin during board production may reduce the rate of thickness swelling and water absorption (Copur *et al*., 2007). Use of phenolic resins may also decrease the rate of thickness swelling.

Utilization of smaller particles in the surface layers may yield to panels that have better physical and mechanical properties. Furthermore, these stalks could also be mixed with wood chips to achieve better panel properties. The boards having lower mechanical properties may be used as an insulating material in buildings because such materials would not be used in load carrying conditions.

CONCLUSIONS

Pepper stalks have higher cellulose content than hardwoods and softwoods. The amount of extractive and lignin content is significantly lower than hardwoods and softwoods. Pepper stalks fiber properties are similar to hardwood fibers.

The results indicated that the manufacture of particleboards from pepper stalks using UF and MUF adhesives is technically viable. The MOR and MOE increased as the panel density and adhesive ratio increased; whereas IB was not statistically different among experimental boards. TS was affected by density and adhesive ratio, MUF adhesives yielded lower TS values in the experimental panels.

Use of renewable materials such as pepper stalks for manufacturing particleboards could contribute the solution of raw material shortage for the particleboard industry and some environmental problems due to the burning can be prevented. Furthermore, the pressure on other forest resources can be reduced and some job opportunities can be created.

REFERENCES

Alma, M.H., H. Kalaycıoglu, I. Bektas and A. Tutus, 2005. Properties of cotton carpel-based particleboards. Ind. Crops Prod., 22: 141-149.

Batalla, L., A.J. Nunez and N.E. Marcovich, 2005. Particleboards from peanut-shell flour. J. Applied Polymer Sci., 97: 916-923.

Bektas, I., C. Guler, H. Kalaycıoglu, F. Mengenoglu and M. Nacar, 2005. The manufacture of particleboards using sunflower stalks (*Helianthus annuus* I.) and poplar wood (*Populus alba* L.). J. Composite Mater., 39 (8): 467-473.

Copur, Y., C. Guler, M. Akgul and C. Tascioglu, 2007. Some chemical properties of hazelnut husk and its suitability for particleboard production. Build Environ., 42: 2568-2572.

Eroglu, H., 1988. Fiberboard Industry. Karadeniz Technical University Publication No. 304, Trabzon, Turkey.

Fengel, D. and G. Wegener, 1984. Wood Chemistry, Ultrastructure, Reactions Walter de Gruyter, Berlin.

Gencer, A., 1998. Research on medium density fiberboard manufacturing possibilities from cotton stalks (*Gossypium hirsitum* L.). Unpublished M.Sc. Thesis, ZKU Graduate School of Natural and Applied Sciences. Zonguldak, Turkey.

Grigoriou, A., C. Passialis and E. Voulgaridis, 2000a. Experimental particleboards from kenaf plantations grown in Greece. Holz Roh-Werkstoff, 58: 309-314.

Grigoriou, A., C. Passialis and E. Voulgaridis, 2000b. Kenaf kore and bast fiber chips as raw material in production of one-layer experimental particleboards. Holz Roh-Werkstoff, 58: 290-291.

Guler, C. and R. Ozen, 2004. Some properties of particleboards made from cotton stalks (*Gossypium hirsitum* L.). Holz Roh-Werkstoff, 62: 40-43.

Gultekin, H.A., 2004. Kumluca (Antalya) Chamber of Commerce unpublished report.

Guntekin, E. and B. Karakus, 2008. Feasibility of using eggplant stalks (*Solanum melongena*) in the production of experimental particleboard. Ind. Crops Prod., 27: 354-358.

Ndazi, B., J.V. Tesha and E.T.N. Nisanda, 2006. Some opportunities and challenges of producing bio-composites from non-wood residues. J. Mater. Sci., 41: 6984-6990.

Nemli, G., H. Kalaycıoglu and T. Alp, 2001. Suitability of date palm branches for particleboard production. Holz Roh-Werkstoff, 59: 411-412.

Ntalos, G.A. and A.H. Grigoriou, 2002. Characterization and utilisation of vine prunings as a wood substitute for particleboard production. Ind. Crops Prod., 16: 59-68.

Papadopoulos, A.N., C.A.S. Hill, A. Gkaraveli, G.A. Ntalos and S.P. Karastergiou, 2004. Bamboo chips (*Bambusa vulgaris*) as an alternative lignocellulosic raw material for particleboard manufacture. Holz Roh-Werkstoff, 62: 36-39.

Sahin, H.T. and R.A. Young, 2008. Auto-catalyzed acetic acid pulping of jute. Ind. Crops Prod. (In Press).

Seniz, V., 2004. Pepper Cultivation. Uludag University Press.

Tank, T., 1980. Fiber and Cellulose Technology. Istanbul University Publication No. 2362, Istanbul, Turkey.

TAPPI, 1992. Tappi Test Methods. Tappi Press, Atlanta, GA, USA.

Tröger, F., G. Wegener and C. Seman, 1998. Miscanthus and Flux as raw material for reinforced particleboards. Ind. Crops Prod., 8: 113-121.

TS-EN 310, 1999. Wood based panels-determination of modulus elasticity in bending and of bending strength.

TS-EN 317, 1999. Particleboards and fibreboards-determination of swelling in thickness after immersion in water.

TS-EN 319, 1999. Particleboards and fibreboards-determination of tensile strength perpendicular to the plane of the board.

TS-EN 312-2, 1999. Particleboards-specifications-part 2: Requirements for general-purpose boards for use in dry conditions.

Xu, J., R. Sugawara, R. Widyorini, G. Han and S. Kawai, 2004. Manufacture and properties of low-density binderless particleboard from kenaf core. J. Wood Sci., 50: 62-67.

Younquist, J.A., B.E. English, R.C. Scharmer, P. Chow and S.R. Shook, 1994. Literature review use on non-wood plant fiber for building materials, panels, General technology report FPL-GTR-80: USDA Forest Service, Forest Products Lab. Madison, Wisconsin.

Zhang, Y., X. Lu, A. Pizzi and L. Delmotte, 2003. Wheat straw particleboard bonding improvements by enzyme pretreatment. Holz Roh-Werkstoff, 61: 49-54.