PROPERTIES OF PARTICLEBOARD MADE FROM CHILI PEPPER STALKS

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OH YS & YOO JY. 2011. Properties of particleboard made from chili pepper stalks. Chili pepper stalks were used as raw material for particleboard. Urea–formaldehyde (UF) resin was synthesised in the laboratory with resin solids at 50% content as a particleboard binder. The laboratory particleboards were made using chili pepper stalks and tropical hardwoods based on 0, 23, 48, 73 and 100% oven-dry weight of chili pepper stalks with UF resin. The physical properties of the particleboards were tested according to the ASTM procedure, D 1037-99. Internal bond and bending strength (modulus of elasticity and modulus of rupture) of the particleboards decreased gradually with increasing chili pepper stalk content. However, all board types made in this study showed good physical and mechanical properties. Overall, chili pepper stalk can be used as a raw material for particleboard manufacture.

Keywords: *Capsicum annuum*, agricultural residues, physical and mechanical properties

OH YS & YOO JY. 2011. Ciri-ciri papan serpai yang diperbuat daripada tangkai lada. Tangkai lada *Capsicum annuum* diguna sebagai bahan mentah untuk menghasilkan papan serpai. Urea–formaldehid (UF) disintesis di makmal menggunakan pepejal resin sebanyak 50% sebagai pengikat. Papan serpai tersebut dibuat daripada tangkai lada dan kayu keras tropika dalam campuran 0%, 23%, 48%, 73% dan 100% tangkai lada dan resin UF. Ciri fizikal papan serpai diuji berdasarkan prosedur ASTM (D 1037-99). Ikatan dalaman serta kekuatan lentur (modulus kekenyalan serta modulus kepecahan) papan serpai beransur-ansur berkurangan apabila kandungan tangkai lada berkurangan. Bagaimanapun, semua papan serpai dalam kajian ini menunjukkan ciri-ciri fizikal dan mekanikal yang baik. Secara keseluruhan, tangkai lada dapat digunakan sebagai bahan mentah untuk menghasilkan papan serpai.

INTRODUCTION

The global consumption of particleboard was 93.9 mil m^3 in 2009 (FAO 2010). The demand for particleboard has increased greatly with the growth of the world economy and trade especially in housing construction and furniture manufacturing. The low cost of raw materials such as wood particles and urea–formaldehyde (UF) resins makes it relatively cheap to produce wood products from particleboard.

Worldwide, sustainable agricultural residues are potential sources of raw materials for the manufacture of bio-based panel products. In wood-deficient countries, the use of agro-based fibres as alternative renewable sources for panel products has increased, and this trend is expected to continue through the 21st century (Bowyer & Stockmann 2001). The abundance of agricultural residues has stimulated new interests in using agricultural fibres for global panel industries because of their environmental and profitable advantages (Rowell et al. 1997).

Panels made from cereal straw such as wheat, barley and oat fibres are manufactured commercially in a number of countries, including the United State (Bowyer & Stockmann 2001). Many studies have examined a wide range of renewable agricultural residues for agro-based fibres such as sugar cane bagasse, banana stem, kiwi branch, coffee husk, cotton, kenaf, sunflower stalks and rice husk (Rowell et al. 1997, Guler et al. 2006). Chili pepper is native to South America, including the Yucatan Peninsula in Mexico. Chili pepper is an annual plant in temperate regions, easy to harvest and a commercial crop. Chili pepper planted in the field grows to approximately 60–90 cm height. In 2008, the world production of chili pepper was 28 mil tonnes with 38 500 tonnes being produced in Korea (FAO 2010). After harvesting chili pepper, the stalk is of no economic value. However, instead of just being a huge waste, the stalk can be utilised as an alternative fibre source

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for commercial production of engineered value-added panel products.

This study examined properties of particleboard made from a mixture of tropical hardwoods and chili pepper stalks. UF resin was formulated for bonding the particleboard. Properties of the particleboard were compared with those of panels made from different proportions of chili pepper stalks.

MATERIALS AND METHODS

UF resin synthesis

Urea–formaldehyde resin was formulated in the laboratory with a target level of resin solids at 50% and a formaldehyde:urea mole ratio of 1.15. The general procedure was similar to that outlined by Oh and Lee (2004). Table 1 lists the UF resin formulation procedure synthesised in this study. A formaldehyde solution (37%) was charged into a stirred reactor, heated to 50 °C and the pH was adjusted to 7.8. Urea was then added over a period of 10 min while the reaction temperature was held at 70–80 °C. The reaction temperature was increased gradually to 90 °C and pH of the reaction mixtures was decreased to 5.1. This reaction temperature was maintained until the resin achieved polymerisation in approximately 30 min, i.e. when the desired viscosity was reached. The pH was then increased to 7.4 and the same quantity of urea was added again. Resin synthesis was completed by cooling to room temperature.

To calculate the targeted levels of resin solids, the charged urea solid value was recorded and the formaldehyde-derived solids were taken as the methylene group (CH_2) values, which were obtained by multiplying the charge weights with a factor of 14/30.

Properties of UF resin

The viscosity of the UF resin was measured using Brookfield RVF viscometer, spindle number 1 at 20 rpm. Free formaldehyde content was measured using the hydroxylamine hydrochloride method (Walker 1964). Gel time was measured at 100 °C while pH and specific gravity were at 25 °C. The level of resin solid was determined by heating 1 g of resin on an aluminum pan at 125 °C for two hours and the following formula was used:

$$\text{Resin solid level (\%)} = \frac{\text{Sample weight after 2 hours}}{\text{Initial sample weight}} \times 100$$

Manufacture of particleboard

Chili pepper (*Capsicum annuum*) stalks were collected from Gyeongsan, South Korea. Particles (12–3.5 mesh) of the stalks were dried to 4–5% moisture content prior to use. A mixture of tropical hardwood particles comprising 55% *Calophyllum inophyllum* and 45% *Terminalia brassii* from Papua New Guinea was obtained from a commercial particleboard plant in Korea. The hardwood particles which were between 1000 and 6000 µm were used for the core layer. Their moisture content was also 4–5%. Five different ratios of chili pepper stalk to tropical hardwood were tested in this experiment (Table 2). To obtain a better mixture of both woods and chili

Table 1 Formulation of synthesised urea–formaldehyde resin

Step	Material	Wet weight (g)	Time (min)	Temperature (°C)	Procedure and observation
A	HCHO (37%)	726.5	1	25	Charge and heat
			-	50	pH = 7.8, agitate
B	Urea	268.4	10	70–80	Charge, heat with agitation Complete urea addition
C			-	90	pH = 5.1, maintain agitation
D			30	-	At 90 °C hold for polymerisation
			-	-	Hold 10 min
E	Urea	198.8	2	80	pH = 7.4, charge and mix well, cool to room temperature
F			-	-	Storage
Total		1193.7			

pepper stalks, the two types of particles were blended with the laboratory-synthesised UF resin in a rotary drum blender. The liquid UF resin was applied using an air spray system at 172 kPa. Single-layer homogeneous particleboards were manufactured using the processing parameters shown in Table 3.

Particleboard performance test

Test specimens were cut from the manufactured boards. The internal bond (IB), modulus of elasticity (MOE) and modulus of rupture (MOR) were determined according to procedure D 1037-99 (ASTM 2002). Water absorption and thickness swelling properties of the panels were investigated at 20 °C after the 2- and 24-hour soaking tests.

Statistical analysis

Results were analysed using the Statistical Analysis System (SAS) 1998 program package. Analysis of variance (ANOVA) was used to determine the differences within each panel type. Significant differences ($p < 0.05$) were further compared using *t*-test for the least significant differences.

RESULTS AND DISCUSSION

UF resin properties

The synthesised UF resin viscosity was 126 mPa s, which was suitable for resin spray application with a compressed air sprayer. The resin produced in this study had very low free formaldehyde content (0.4%), as expected. The resin had a pH of 7.4, solid content of 50.6% and specific gravity of 1.19. Gel time of the UF resin was 31.4 min, considerably long due to no catalyst addition in the resin.

Characteristics of chili pepper stalk

The cold water extractive, ethanol–benzene extractive and lignin contents of chili pepper stalk were 5.5, 2.6 and 25.4% respectively. The ash content and pH of chili pepper were 2.6% and 6.1 respectively. The chili pepper stalk has short fibre length of 0.47 mm (Anonymous 1994). It has been proven that fibre length affects the physical and mechanical properties of panel products; the shorter the fibre the weaker the boards (Oh 2010).

Table 2 Experimental design of the particleboards in this study

Board type	Chili pepper stalk (%)	Tropical hardwoods (%)
1	0	100
2	23	77
3	48	52
4	73	27
5	100	0

Table 3 Particleboard manufacturing parameters

Panel dimensions	250 × 250 × 6.3 mm
Mat moisture content	8–9%
Wax and resin solids loading	1 and 8% respectively, based on oven-dry wood weight
Target board density	700 kg m^{-3}
Catalyst	None
Resin flow rate	130 ml min^{-1}
Hot press temperature	160 °C
Hot press time	5 min
Hot press pressure	3.45 MPa
Replication	Five boards per condition (total 25 boards)

Particleboard performance test

Particleboard densities ranged from 685 (board type 4) to 710 kg m^{-3} (board type 2, $p < 0.05$, Table 4). However, board types 1, 2, 3 and 5 had similar densities, showing that panel density was relatively constant regardless of the content of chili pepper stalks.

Internal bond ranged from 0.61 to 0.88 N mm^{-2} (Table 4). In general, the IB value decreased with increasing amount of chili pepper particles. The ANOVA showed that IB was significantly ($p < 0.01$) affected by board type while the LSD test showed that IB was significantly affected by chili pepper particle contents. This decreasing trend of IB with increasing chili pepper particle contents suggested that chili pepper particles required a larger resin loading to obtain the same IB as wood particles (0.88 N mm^{-2}). However, the panels exceeded the minimum strength requirements for IB according to the Korean Standard KS F 3104 for particleboard type 8.0 (KSA 2002).

The MOE in this study ranged from 1856 to 2532 N mm^{-2} (Table 4). However, board types 2, 3 and 4 showed no significant variations. Also there were no differences among board types produced from chili pepper stalks. The MOR range for panels produced in this study was between and 12.2 and 16.3 N mm^{-2} (Table 4). Panels made using chili pepper stalks had the highest MOR values in board types 2 and 3. The relatively large amount of the short fibre length and reduced fibre interface contact areas among the particles of chili pepper stalks had an adverse effect on the flexural strength properties such as MOE and MOR. However, the panels exceeded the minimum strength requirements for MOR according to the Korean Standard KS F 3104 for particle type 8.0 (KSA 2002).

The thickness swell for all panels ranged from 10.0 to 13.4% for the 2-hour test and 31.8 to 43.9% for the 24-hour test (Table 4). The ANOVA showed that thickness swell after 24-hour water soak test was significantly ($p < 0.01$) affected by board type. The LSD test for thickness swell after the 24-hour water soak test showed that board type 1 had significantly lower thickness swell values compared with the rest of the boards. There were no differences between boards 4 and 5 and between 3 and 4 after 2 and 24 hours of soaking respectively. However, from the results obtained we concluded that board type 3 showed the best performance.

The water absorption values for panels ranged from 10.5 to 14.7% for the 2-hour test and 64.1 to 82.0% for the 24-hour test (Table 4). Board type 5 using all chili pepper stalks absorbed the highest amounts of water after 2- and 24-hour soaking compared with the rest of the boards while board type 1 absorbed the least. Board types 3 and 4 had similar water absorption. Results showed that thickness swell and water absorption of the panels decreased with increasing fibre length or decreasing total fibre surface area.

CONCLUSIONS

Chili pepper stalks were used as raw material for the manufacture of particleboard. Results of this study showed that mechanical properties of particleboards produced gradually decreased with increasing chili pepper stalk content. The board type 2 (23:77 mixture of chili pepper stalk and tropical wood particles) had the highest IB, MOE and MOR properties. Although the

Table 4 Performance test results of the particleboards made from chili pepper stalks

Board type	Panel density (kg m^{-3})	IB	MOE	MOR	Thickness swell (%)		Water absorption (%)	
		(N mm^{-2})			2 hours	24 hours	2 hours	24 hours
1	705 (0.8) ab	0.88 (3.2) a	2532 (10.9) a	16.3 (9.3) a	10.0 (2.3) d	31.8 (3.9) d	10.5 (6.3) d	64.1 (3.1) d
2	710 (1.1) a	0.73 (6.8) b	2279 (8.4) b	14.5 (11.2) b	10.9 (10.6) c	34.9 (9.7) c	12.6 (4.9) c	69.8 (5.4) c
3	693 (0.9) ab	0.71 (7.3) b	2152 (10.8) bc	14.2 (11.7) b	12.9 (5.6) b	41.6 (8.2) b	13.6 (7.9) b	75.4 (4.8) b
4	685 (0.7) b	0.66 (10.6) c	2025 (14.2) c	13.0 (8.7) c	13.2 (10.4) a	42.2 (10.8) b	13.9 (7.4) b	76.9 (7.1) b
5	701 (0.6) ab	0.61 (13.4) d	1856 (6.5) d	12.2 (7.2) d	13.4 (4.9) a	43.9 (3.5) a	14.7 (5.7) a	82.0 (4.5) a

Values in parentheses are coefficients of variations; means with the same letter in the same column are not significantly different ($p > 0.05$).

physical and mechanical properties differed significantly according to the board types, all boards showed good physical and mechanical properties. Generally, chili pepper stalks were suitable as raw material for the manufacture of particleboard.

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REFERENCES

Anonymous. 1994. *Agricultural Resources, Wood Properties and Uses of the Major Tree Species Grown in Korea.* Korea Forestry Research Institute, Seoul.

ASTM. 2002. *Standard Test Methods for Evaluating Properties of Wood-Based Fibre and Particle Panel Materials.* ASTM D 1037-99. ASTM International, West Conshohocken.

Bowyer JL & Stockmann VE. 2001. Agricultural residues an exciting bio-based raw material for the global panels industry. *Forest Products Journal* 51: 10–21.

FAO (Food and Agricultural Organization of the United Nations). 2010. *Statistics of Agriculture and Forest Products.* FAO, Viale delle Terme di Caracalla.

Guler C, Bektas I & Kalaycioglu H. 2006. Properties of particleboard from sunflower stalks (*Helianthus annuus* L.) and Calabrian pine (*Pinus brutia* Ten.) *Forest Products Journal* 56: 56–60.

KSA (Korean Standards Association). 2002. *Korean Standard: KS F 3104 Particleboards.* KSA, Seoul.

Oh YS & Lee JK. 2004. Evaluation of Korean softwood plywood bonded with urea–formaldehyde resin adhesive. *Forest Products Journal* 54: 77–80.

Oh YS. 2010. Effects of recycled fibre additions on high-density fibreboard for laminated flooring bonded with phenol-formaldehyde resin adhesive. *Journal of Applied Polymer Science* 115: 641–645.

Rowell RM, Young RA & Rowell JK. 1997. *Paper and Composites from Agro-Based Resources.* CRC Press Inc, Boca Raton.

Walker JF. 1964. *Formaldehyde.* Reinhold, New York.