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Mechanical Properties of Rice Husk Flour-Wood Particleboard by Urea-Formaldehyde Resin*1

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ABSTRACT

The objective of this research was to investigate the possibility of using rice husk flour as a partial substitute for the wood particles used as the raw material for manufacturing particleboards, by examining the physical and mechanical properties of the rice husk flour-wood particleboard as a function of the type of urea-formaldehyde resin used.

Commercial wood particles and two types of rice husk flours (A type (30 μm), B type (300 μm)) were used. E_1 and E_2 class urea-formaldehyde resin was used as the composite binder, combined with 10 wt.% NH_4Cl solution as a hardener. Rice husk flour-wood particleboards with dimensions of $27 \times 27 \times 0.7$ (cm) were manufactured at a specific gravity of 0.7 with rice husk flour contents of 0, 5, 10, and 15 (wt.%). We examined the physical properties (specific gravity and moisture content), mechanical properties (three point bending strength and internal bonding) of the composite.

In general, it can be concluded that composites made from rice husk flours are of somewhat poorer quality than those made from wood; however, blending in small amounts of rice husk flour (e.g., 5% to 10% by weight) may have no significant impact on quality.

Keywords: urea formaldehyde resin, rice husk flour, particleboard, mechanical property

1. INTRODUCTION

Since the mid-1960's the worldwide production and consumption of wood panel products has maintained a rapidly rising trend with different rates of increase in different regions. The panel industry relies mainly on the use of wood of different species as its raw material. Raw material costs represent a significant proportion of total panel manufacturing costs. Several lignocellulosics have been used to successfully produce particleboards, fiberboards and, to some extent, inorganic-bonded boards.

Agricultural lignocellulosic fibers, such as rice straw and wheat straw, can easily be crushed to form chips or particles, which are similar to wood particle or fiber, and may be used as substitutes for wood–based raw materials. In

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addition, such systems contribute to the recycling of agricultural wastes. In order to recycle natural resources to meet the demand created by the decrease in the available supplies of solid wood and wood-based materials, several researchers have succeeded in developing substitutes for wood particles, using lignocellulosic fibers (Ajiwe, 1998; Han et al., 1998; Lee & Kang, 1998).

Rice husk is an agricultural waste material produced as a by-products during the rice milling process in rice-producing countries, especially in the Asian, Pacific and United States regions. According to FAO (Food and Agriculture Organization) statistical data in 2000, the annual world rice production is approximately 600 million tons, of which 20% is wasted in the form of rice husks (The FAOSTA Database, 2000).

This rice husk is primarily used for producing bedding materials for domestic animals, but its industrial application is still quite limited. The remainder of the rice husk is now landfilled, but landfilling itself is becoming a serious social problem, because of the large areas required for landfill sites. A large quantity of husk, which is known to contain a fibrous material with a high silica content, is available as waste from rice-milling industries (Della et al., 2002). Therefore, there is a tremendous need to make useful and value-added products from rice husk (Teng & Wei, 1998).

Rice hull could be used either as a supplement, or as a direct substitute for wood in the manufacture of panel products, e.g. particleboard and rice hull insulation board (Lee, 1972 and 1998). Also, Lee and Han (2000) carried out research into the potential uses of rice hull and attempted to determine the optimum pretreatment conditions to use for the manufacture of rice hull board. Their conclusion was that the steam explosion method gave the best result.

The advantages of rice husk flour-wood particleboard are its built-in insulation properties and low cost. Few studies have been done on the manufacture of rice husk flour-wood particleboard using different sizes of rice husk flour.

The objective of this research was to characterize the mechanical properties of rice husk flour-wood particleboard. In this study, rice husk flour was used due to its wide availability among the different agricultural wastes, and the rice husk flour-wood particleboard was manufactured for the purpose of being used as indoor panels, using the commercial method employed in the wood-based panel industry. We examined the physical properties (specific gravity and moisture content), mechanical properties (three point bending strength and internal bonding) of the manufactured composite.

The objective of this research was to investigate the possibility of using rice husk flour as a partial substitute for the wood particles used as the raw material for manufacturing particleboards, by examining the physical and mechanical properties of the rice husk flour-wood particleboard as a function of the type of urea-formaldehyde resin used.

2. MATERIALS and METHODS

2.1. Materials

2.1.1. Urea Formaldehyde resin

Two kinds of UF resins, UF1 and UF2 were prepared. Their dry resin contents were 68.0 and 69.4%, respectively. According to the degree of formaldehyde emission, the UF resins were classified as belonging to either the E_1 class or the E_2 class. UF1 is an E_1 type resin and UF2 is an E_2 type resin.

Table 1. Chemical composition of rice husk flour and wood flour (unit: %)

Code	Moisture	Lignin	Cellulose	Fat	Ash
Rice husk flour particle size 30 μm	5.8	16.9	58.7	0.3	18.3
Rice husk flour Particle size 300 μm	6.0	21.0	60.0	0.2	12.8
Wood flour Particle size 163 μm	10.3	26.2	62.5	0.6	0.4

2.1.2. Rice husk flour

Two types of rice husk flour, were obtained from Saron Filler LTD in Ansung, Korea, and their particle sizes were as follows: A type (30 μm), and B type (300 μm). These were conditioned so as to have a moisture content of 5.8~6.0% and an ash content of 12.8~18.3% (Table 1).

2.1.3. Wood particle

The wood particles used for manufacturing the particleboard, were donated by the Donghwa Enterprise Co., Ltd. in South Korea, and the wood particles is used for face, which had a 10.3% of moisture content.

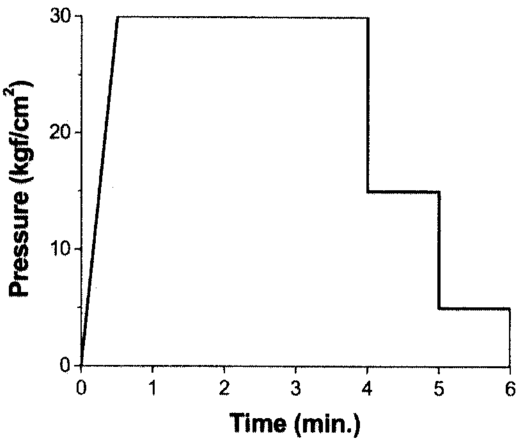

Fig. 1. Hot pressing schedule used for the manufacture of rice husk flour-wood particleboard.

2.2. Methods

2.2.1. Sample preparation

Commercial wood particles were used. Urea-formaldehyde resin was used as the composite binder, combined with 10 wt.% NH_4Cl solution which acted as a hardener.

Rice husk flour-wood particleboards with dimensions of 27×27×0.7 (cm) were manufactured at a specific gravity of 0.7 and with rice husk flour contents of 0, 5, 10, and 15(wt.%).

After mixing the rice husk flours and the wood particles, and placing the mixture into a rotary drum mixer, the mixture was slowly sprayed with 10 wt% (based on the weight of the oven dried raw material) urea-formaldehyde resin while rotating the mixer. The mixture of rice husk flour-wood particles and urea-formaldehyde resin was cold pressed using a pressure of about 5 kgf/cm^2 and left for 2 min before hot pressing.

The mixture was then hot pressed, to form the composite boards at a peak pressure of 25 kgf/cm^2 and a temperature of 140°C. The total pressing time was 6 min (0.5 min to reach full pressure ; pressure release in two steps of 1 min each). Fig. 1 shows the hot pressing schedule used for manufacturing the rice husk flour-wood particleboard. The board samples were preconditioned at 25°C and 65% RH for 3 weeks before testing.

2.2.2. Physical properties

Moisture content and specific gravity were examined using the ASTM D 1037-99 (American Society for Testing and Materials, 1999)

Table 2. Type of urea-formaldehyde resin

	Formaldehyde emission class	Non-volatile content (%)	Viscosity (mPas)
UF1	E_1	61.62	220±25
UF2	E_2	76.57	295±20

method. Specific gravity was controlled by quality control testing, with each value representing the average of five samples.

2.2.3. Mechanical properties

The three point bending strength (Modulus of rupture (MOR)) and internal bond (IB) were determined using a Universal Testing Machine (Zwick Co., NICEM at Seoul National University) using the ASTM D 1037-99 (American Society for Testing and Materials, 1999) method. Each value represents the average of five samples.

3. RESULTS and DISCUSSION

3.1. Physical properties

3.1.1. Specific gravity

The results regarding the actual densities of the rice husk flour-wood particleboard and control particleboard as a function of the formulation and target density are presented in Tables 3 and 4. Among the different particleboards manufactured using E_1 resin and E_2 resin and different rice husk flour sizes, there were no significant differences in the resulting specific gravity. The densities of the husk flour-wood particleboard and control particleboards ranged from 0.69 to 0.73.

3.1.2. Moisture content

The results concerning the moisture content of the rice husk flour-wood particleboard and control particleboard classified by formulation and target density, are presented in Tables 3 and 4. The analysis of the moisture content, as a function of the rice husk flour content and the urea formaldehyde resin type, did not reveal any clear tendency.

3.2. Mechanical properties

3.2.1. Bending modulus of rupture

Figs. 2 and 3 show the three point bending strengths (MOR) of the rice husk flour-wood particleboards. Fig. 2 shows the MOR values of

Table 3. Specific gravities and moisture contents of rice husk flour-wood particleboard for E_1 class U-F resin

Resin type	Rice husk flour content[a] (%)		Target density (g/cm³)	Board density[b] (g/cm³)	Moisture content (%)	Mat moisture content (%)
E1	Particle size A (30 μm)	0	0.7	0.71[c] (0.01)	5.20[d] (0.09)[e]	17.60
		5		0.73 (0.03)	5.65 (0.15)	17.83
		10		0.73 (0.02)	50.9 (0.17)	18.07
		15		0.72 (0.02)	5.55 (0.19)	18.30
	Particle size B (300 μm)	0		0.71 (0.01)	5.20 (0.09)	17.60
		5		0.70 (0.01)	5.10 (0.20)	17.75
		10		0.72 (0.03)	5.26 (0.15)	17.90
		15		0.71 (0.02)	5.00 (0.09)	18.05

[a] Based on oven-dry weight of wood particle and rice husk flour, [b] Based on oven-dry weight and oven-dry volume, [c, d] Each mean value from 5 replications, [e] Each standard deviation from 5 replications.

Table 4. Specific gravities and moisture contents of rice husk flour-wood particleboard for E_2 class U-F resin

Resin type	Rice husk flour content (%)		Target density (g/cm³)	Board density (g/cm³)	Moisture content (%)	Mat moisture content (%)
E1	Particle size A (30 μm)	0	0.7	0.69 (0.03)	5.88 (0.21)	14.74
		5		0.71 (0.04)	5.20 (0.18)	14.98
		10		0.70 (0.02)	5.71 (0.14)	15.21
		15		0.70 (0.03)	6.30 (0.15)	15.45
	Particle size B (300 μm)	0		0.69 (0.03)	5.88 (0.21)	14.74
		5		0.72 (0.05)	5.82 (0.14)	14.89
		10		0.73 (0.02)	6.05 (0.15)	15.04
		15		0.70 (0.04)	6.30 (0.19)	15.20

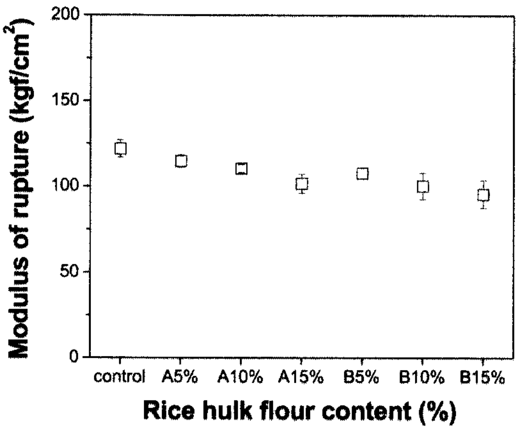

Fig. 2. Modulus of rupture of rice husk flour-wood particleboard for E_1 class UF resin.

the particleboard manufactured using the E_1 class type UF resin.

The MOR showed a decreasing tendency with increasing rice husk flour content for a given type of urea-formaldehyde resin. The MOR of the substituted wood-based composites, made with rice husk flour decreased with increasing substitute content. This result is in agreement with those of several previous studies (Ajiwe, 1998; Han et al., 1998; Lee & Kang, 1998; Viswanathan & Gothandapani, 1999). However, in the case of the particleboards made using rise husk flour with a particle size of 30 μm (type A), the amount of reduction in the MOR value was independent of the rice husk flour content.

In comparing the MOR values for rice husk flour particle sizes 30 μm (type A) and 300 μm (type B), the MOR of the particleboard made using type B decreased with increasing rice husk flour particle size. However, there was no difference in the MOR value for the particleboards prepared with type A and type B of rice husk flour size.

Also, the distribution of the 30 and 300 μm sized rice husk flour within the wood particles is excellent, which explains why the use of this type of rice husk flour has no effect on the bending strength.

Fig. 3 shows the MOR values of the particleboard made using the E_2 class type UF resin. In this case, the bending MOR also decreased slightly with increasing rice husk flour content.

In comparing the E_1 and E_2 resins, we found that the MOR of the control particleboard made using the E_2 resin was slightly higher than that made using the E_1 resin.

Generally, as the formaldehyde / urea ratio increases, the formaldehyde emission level increases and the mechanical properties also increase. The formation of methylol groups mostly depends on the formaldehyde / urea molar ratio, with higher molar ratios increasing the tendency to form highly methylolated species (Dunky 1998). The reversibility of the

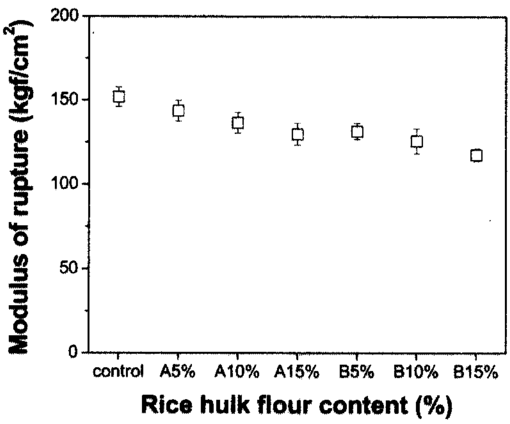

Fig. 3. Modulus of rupture of rice husk flour-wood particleboard for E_2 class UF resin.

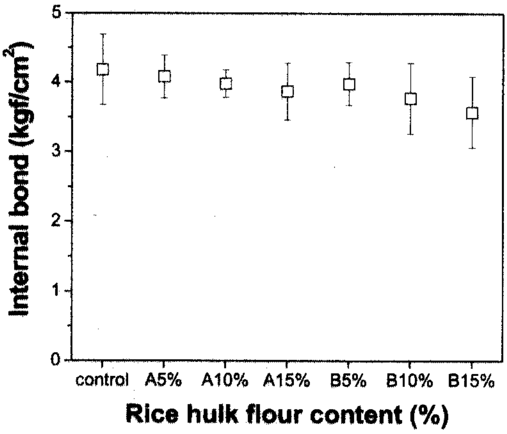

Fig. 4. Internal bond strength of rice husk flour-wood particleboard for E_1 class UF resin.

methylolation reaction is one of the most important features of UF resins, and is responsible for both the low resistance against hydrolysis caused by the attack of moisture or water and the subsequent formaldehyde emission.

Therefore, the MOR of the particleboard made using E_2 resin was higher than that of the particleboard made using E_1 resin. The bending MOR decreased in the particleboard prepared with E_1 and E_2 resin with increasing rise husk flour content . However, there was no difference in the MOR value for the particleboards prepared with 5 and 10 wt.% of rice husk flour.

Therefore, particleboard could be prepared by mixing rice husk flour up to 10 wt.% with no decrease in the composite strength. Since composite prepared with type A size rice husk flour and those prepared with type B size rice husk flour showed no difference in strength, we believe that particleboards could be prepared using rice husk flour without considering the particle size of the rice husk flour.

3.2.2. Internal bond

The internal bond of the rice husk flour-wood particleboard, classified by rice husk flour content, are presented in Figs. 4 and 5.

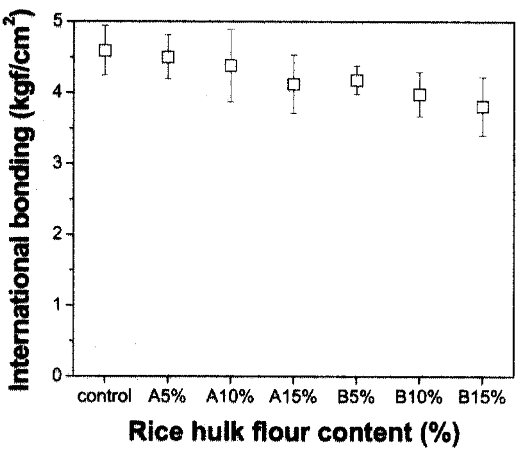

Fig. 5. Internal bond strength of rice husk flour-wood particleboard for E_2 class UF resin.

As can be seen in Figs. 4 and 5, the IB of the particleboards made using the 30 μm rice husk flour size was a little stronger by the rice husk flour content than those made using the 300 μm rice husk flour size.

The major constituents of rice husk are cellulose, lignin and ash, in proportions which depend on the variety, climate and geographic location of growth. The white ash obtained from the combustion of this raw material at moderate temperature contains 87～97% silica in an amorphous form and some amount of metallic impurities. The rice husk density increases with increasing silica content. In the untreated rice husk, the silica content is 25.81 wt%, and the silica content of the ash is 92.92 wt% (Della et al. 2002; Kim & Eom 2000; Talcin & Sevinc, 2000). These inorganic compounds have an effect on the properties of the particleboard.

But, 30～300 μm rice husk flour particle size have no effect on physical and mechanical properties.

Therefore, composites could be prepared by mixing rice husk flour up to 10 wt.% with no decrease in composite strength. Since composite boards prepared with rice husk flour into type A size and those prepared with type B size rice husk flour showed no difference in strength, we believe that particleboards could be prepared using rice husk flour without considering the content.

4. CONCLUSION

The composite with an S.G. of 0.7 had a slightly lower bending MOR than the wood particleboard (used as a control board) at a rice husk flour content of 15 wt.%, and showed no differences compared to the control board at rice husk flour levels of 5 and 10 wt%. Rice husk flour can be used to partially substitute for wood particles, as the raw material used for making particleboards, at levels of up to 15 wt.%, without reducing the bending strength.

The internal bond of the particleboard mixed with rice husk flours were similar to those of the control boards and thus, there is no need to screen rice husk flour for size in the wood-based panel industry, and this should represent a considerable cost saving.

In general, it can be concluded that composites made using rice husk flour are of somewhat poorer quality than those made from wood; however, blending in small amounts of rice husk flour (e.g., 5%, to 10% by weight) may have no significant impact on quality.

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REFERENCE

1. Ajiwe, V. I. E., C. A. Okeke, S. C. Ekwuozor, and I. C. Uba. 1998. A pilot plant for production of ceiling boards from rice husks. *Biores. Technol.*, 66: 41～43.
2. American Society for Testing and Materials. 1999. Annual Book of ASTM Standards, Philadelphia, PA.
3. Della, V. P., I. Kuhn and D. Hotza. 2002. Rice husk ash as an alternate source for active silica production. *Materials Letters.* 57(4): 818～821.
4. Dunky, M. 1998. Urea-formaldehyde (UF) adhesive resins for wood. *International Journal of Adhesion & Adhesives.* 18: 95～107.
5. Han, G., C. Zhang, D. Zhang, K. Umemura, and S. Kawai., 1998. Upgrading of urea formaldehyde-bonded reed and wheat straw particleboards using silane coupling agents. *J. Wood Sci.* 44: 282～286.
6. Kim, H. J. and Y. G. Eom, 2001. Thernogravimetric analysis of rice husk flour for a new material of lignocellulosic fiber-thermoplastic polymer composites. *Mokchae Konghak*, 29(3): 59～67.
7. Lee, Hwa-Hyoung, 1972. Study on manufacture of hard board from rice hull, Master Thesis of Seoul National University.
8. Lee, Hwa-Hyoung and Chun-won Kang. 1998. Development of rice hull insulation board using urea formaldehyde resin. *Mokchae Konghak.* 26(4): 50～55.

9. Lee, Hwa-Hyoung and Kie-Sun Han. 2000. Study on the optimum pre-treatment condition for manufacture of rice hull board. *Mokchae Konghak.* 28(3): 9~13.
10. Talcin N. and V. Sevinc. 2001. Studies on silica obtained from rice husk. *CERMICS INTERNATIONAL.* 27: 219~224.
11. Teng, H. and Y.-C. Wei. 1998. Thermogravimetric studies on the kinetics of rice hull pyrolysis and the influence of water treatment. *Ind. Eng. Chem. Res.* 37: 3806~3811.
12. The FAOSTA Database, 2001. Food and Agriculture Organization of the United Nations (FAO).
13. Viswanathan, R. and L. Gothandapani., 1999. Mechanical properties of coir pith particle board. *Biores. Technol.,* 67: 93~95.