Some of the Properties of Binderless Particleboard Manufactured from Bamboo

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Abstract

Bambo particles as a waste byproduct from bamboo processing industry are suggested to be a promising material for binderless particleboard. The quality of binderless particleboard is affected by several factors, such as pretreatment, pressing method, pressing condition, moisture content, and particle size. This study was focused on the effect of particle size and moisture content on the physical and mechanical properties of binderless particleboard from Petung bamboo (*Dendrocalamus asper* Backer) and conducted using the completely randomized design with two factors. Bamboo particles in three types of particle size, i.e. coarse (10~20 mesh), medium (20~60 mesh), and fine (passed 60 mesh), were used as materials for binderless board. Each particle size was then prepared for two moisture content conditions: air dry and 20±2%. Binderless boards were prepared by hot pressing at temperature of 200°C for 15 min, and the properties of the binderless boards were then evaluated according to the Japanese Industrial Standard for particleboard, JIS A 5908. The results showed that the binderless boards made from 20±2% moisture content particles showed better mechanical and dimensional properties than those made from air-dried particles. The binderless particleboard made from medium size and the moisture content of 20±2% recorded a modulus of rupture of 94 kg/cm², water absorption of 29%, thickness swelling of 5%, internal bond strength of 2.7 kg/cm², and modulus of elasticity of 19.490 kg/cm².

Keywords: Binderless particleboard, moisture content, particle size, Petung bamboo.

Introduction

Bamboo belongs to Graminales Gramineae, and is a perennial plant with woody culms. According to Lee *et al*. (1994) bamboo mature in about 3~5 years, which means its growth is more rapid than any other plant on the planet. One of them is *Dendrocalamus asper* that is commonly recognized as Petung bamboo, which usually is used for structural products. Local names for this species are pring betung, tiing betung, au petung, bulo patung, bamboo batung, buluh petong, buluh swanggi, pering petung, betung, and bulo lotung (Widjaja *et al.* 2004). It grows well in Asia, such as Indonesia, Malaysia, China, and Thailand. The specific gravity of Petung bamboo varies from about 0.5 to 0.79 (Mohmod and Liese 1995).

Bamboo is a fast growing species and a high yield renewable resource. Because of their high productivity, the development of effective utilization of plants materials attracts more and more attention. Production of board using bamboo particle as a waste byproduct from bamboo processing industry, is one of the value-added products supporting the zero-emission concept. In Petung bamboo, cellulose and hemicellulose are present in the form of holocellulose which amounts to more than 50% of the total chemical constituents (Dransfield and Widjaja 1995). This research will use bamboo particles as raw materials for manufacturing binderless boards. Activated chemical components during treatment or pressing are an effective process to build self-bonding in producing binderless board. It was found that partial degradation of the three major chemical components of the kenaf core by the steam-injection pressing increased the bonding performance and dimensional stability of the binderless boards (Widyorini *et al.* 2005a). The presence of cinnamyl units in non-woody plants seemed also to be cleaved due to the degradation of hemicelluloses and lignin during steam or heat treatments, where the effect of hot pressing system was lower than steam-injection pressing on the chemical composition (Widyorini *et al.* 2005b; Widyorini *et al.* 2005c).

The quality of binderless particleboard is affected by several factors, such as chemical composition of raw materials, pretreatment, pressing method, pressing condition, moisture content, and particle size. Large surface area of raw materials enhanced the self-bonding strength of binderless board. Increasing chip mixing ration in kenaf core binderless board reduce the internal bond strength value, which indicated contribution of powders to the improvement of bonding strength (Okuda and Sato 2004). Velasquez *et al.* (2002) also found that the binderless fiberboards obtained with the ground pulp were of better quality that those obtained with the non-ground pulp.

In resin-bonded boards, low moisture content particle or fiber is recommended to avoid the delamination occurred. However, considering that no resin is used in binderless board manufacturing, high moisture content is supposed to be required to promote the hydrogen bonding and lignin bonding among particles or fibers. Xu *et al*. (2006) showed that the binderless fiberboards made from 30% moisture content kenaf core fibers showed better mechanical and dimensional properties than those from air-dried fibers. In this study, binderless boards were manufactured from Petung bamboo particles using hot pressing system. Three kinds of particle sizes were used in this experiment. Effects of particle size and moisture content on the board properties were then evaluated and discussed.

Materials and Methods

Petung bamboo particles were used as the raw material. The particles were first air-dried to a moisture content of around 10%. This study was conducted using completely randomized design with two factors; particle size and moisture content. Three classifications of particle size were used are coarse (10~20 mesh), medium (20~60 mesh), and fine particles (passed 60 mesh), as shown in Figure 1. The particle used in this research is in two conditions; air-dried particles and 20±2% moisture content. The particle moisture content of 20±2% was obtained by spraying water onto the air-dried particles for each particle size.

Figure 1. Bamboo particles as raw materials in this research.

The dimensions of the binderless boards were 25 x 25 x 7 cm. The target board density was set at 0.9 g/cm^3. Three kinds of particles sizes and two kinds of particle moisture content (air-dried and 20±2%) were used for board fabrication. The particles were then hand-formed into a mat by using forming box, followed by hot pressing into particleboard. The boards were pressed at a temperature of 200°C for 15 min. Three boards were manufactured in each condition. Prior to the evaluation of the mechanical and physical properties, the boards were conditioned at ambient conditions for about 10 days. The properties of the binderless particleboards (thickness swelling, water absorption, moisture content of rupture, modulus of elasticity, and internal bond strength) were then evaluated basically according to the Japanese Industrial Standard for Particleboards (JIS A 5908 2003).

Result and Discussion

Particles and Its Binderless boards

The moisture content of air-dried particle reached 9.9~10.8%. The particles moisture content of 20±2% was obtained by spraying water onto air-dried particles. After the particles were sprayed, 2 g particles were taken for checking the moisture content, and the other particles were directly hand-formed into a mat. The values of particle mat moisture content reached around 22.6~23.3%. It showed that the method was relatively good and could be used in this study. The moisture content of all binderless boards was ranged from 5.5~6.0% for all condition process.

All of binderless boards in this study could be manufactured without any delamination, with the board densities were relatively high (0.75~0.85 g/cm^3). In the preliminary study, binderless boards made from 26~31% particle moisture content were delaminated. Some part of the boards was exploded and the color became dark. Xu *et al*. (2006) found the same trend, where the binderless fiberboards made from 30% fiber moisture content with relatively high board density (0.7 g/cm^3) were delaminated. It might due to the steam pressure inside the board was very high, because of high compaction ratio in high density and high moisture content in the mat. When the steam pressure inside the board is higher than the internal bond strength of the board, the delamination will be occurred.

Dimensional Stability

The thickness swelling value of binderless boards was shown in Figure 2 and the average of water absorption was shown in Table 1. Figure 2 shows that all of the thickness swelling of bamboo binderless particleboards in this study was below than 12%, meeting the requirements of JIS A 5908 for particleboard. This study showed relatively good result, considering that all of binderless boards were made by hot pressing system. It might be due to the high temperature (200°C) was applied in this experiment, as mentioned by Okuda and Sato (2004).

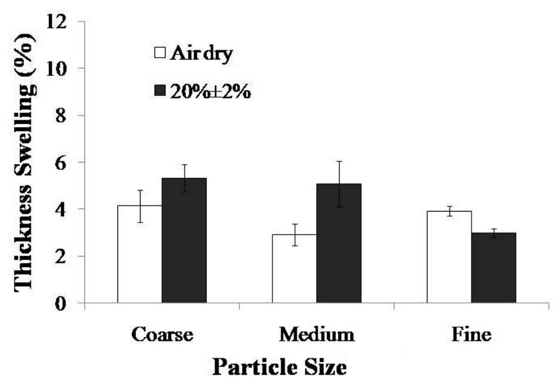

Figure 2. Effects of particle size and particle moisture content on thickness swelling of bamboo binderless particleboards. *Vertical lines* through the bars represent the standard deviation from the mean.

The interaction between two factors (particle size and particle moisture content) significantly affected on the thickness swelling, while the effect of each factor was not significant. For coarse and medium particle, the dimensional stability of the binderless boards made from air-dried particles was higher than those of 20±2% moisture content particles. The result of kenaf core (Xu *et al.* 2006) showed that fiberboard made from 30% MC fibers showed lower thickness swelling values than those of air-dried fibers. The moisture content of a mat entering the hot press is supposed to be a great importance in pressing composition board. Because no binder was added during board manufacturing, relatively high mat moisture content is required to promote the formation of hydrogen bonding and lignin bonding among the fibers (Xu *et al.* 2006). Sekino *et al.* (1999) indicated that the reduction in hygroscopicity, which is due to the changes in hemicelluloses during steam pretreatment, is one factor for improving the dimensional stability.

Table 1 shows the water absorption of binderless boards ranged from 26% to 35%. Interaction between particle size and particle moisture content factors gave a significant effect on water absorption, but the same effect was not found for each factor. Binderless particleboard made from fine particles in air-dried condition showed the higher water absorption (35%) compared to coarse particles (26%) in the same condition. Otherwise, binderless particleboards made from fine particles in 20±2% moisture content condition gave lower water absorption compared to coarse particles in the same condition. Nevertheless, the water absorption of binderless boards in this study was relatively low compared to kenaf core binderless particleboard (55%) in the same pressing temperature (200°C) (Okuda and Sato 2004).

Table 1. Water absorption of bamboo binderless particleboards.

Particle moisture content	Water absorption (%)			Average (%)
	Coarse	Medium	Fine	
Air-dried	26	29	35	30
20 ± 2 %	31	29	28	29
Average (%)	29	29	31	

Bending Strength

The effects of particle size and mat moisture content on the modulus of rupture (MOR) and modulus of elasticity (MOE) of bamboo binderless boards are shown in Figure 3 and Figure 4, respectively. The average MOR values of bamboo binderless particleboards made from 20±2% moisture content of medium and fine particles in this study was exceed the minimum requirements (82 $kg/cm^{2)}$ for grade 8 type particleboard by JIS A 5908, while the average MOE values of the binderless boards almost reached the minimum requirements.

The result showed that moisture content of particles affected significantly on MOR of the binderless boards. The MOR value of binderless board made from fine air-dried particles was 65 kg/cm^2, whereas it was increased to 95 kg/cm^2 when using 20±2% moisture content particles. The same trend was also found by Xu *et al.* (2006) that fiberboard made from 30% moisture content fibers showed higher MOR and MOE values than those of air-dried fibers. High moisture content aids in plasticizing the fibers, enables faster heat transfer to the mat core, decreases the melting point of lignin, and therefore creates better contacts among fibers (Xu *et al.* 2006).

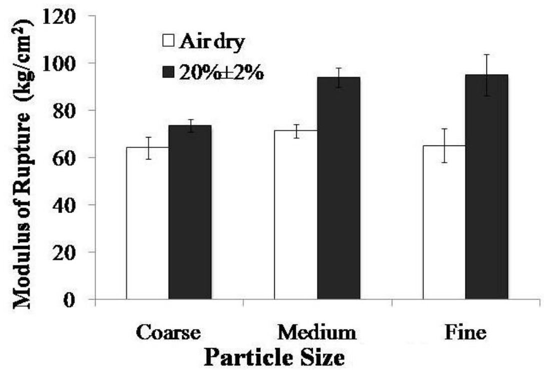

Figure 3. Effects of particle size and particle moisture content on modulus of rupture of bamboo binderless particleboards. *Vertical lines* through the bars represent the standard deviation from the mean.

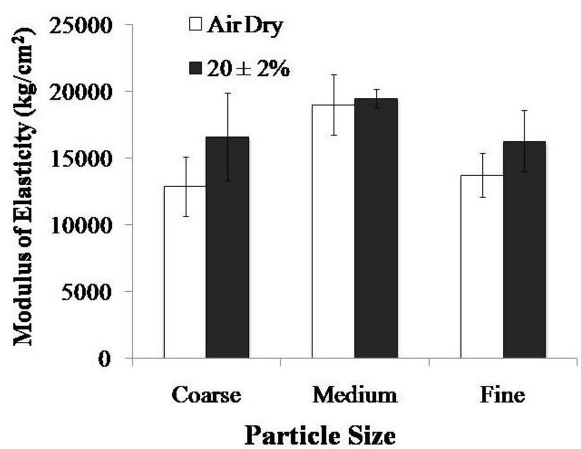

Figure 4. Effects of particle size and particle moisture content on modulus of elasticity of bamboo binderless particleboards. *Vertical lines* through the bars represent the standard deviation from the mean.

The effect of particles size was not significant on MOR in this study. It might due to the differences of particle size was not so high. In other study, Okuda and Sato (2004) used two kinds of kenaf core particles; i.e. coarsely ground particles (3.3 mm grain size) and finely ground particles (53 μm). They found that MOR value of kenaf core binderless board decreased with increasing chip content. This study showed that there was no significant effect on MOE due to the particles size and mat moisture content factors. However, slightly increasing of modulus of elasticity could be found with decreasing particle size. Velasquez *et al.* (2002) pointed out that the grinding process did not significantly affect the MOR and MOE of *Miscanthus Sinensis* binderless board.

Internal Bond Strength

Figure 5 shows the effect of particle size and particle moisture content on internal bond strength of bamboo binderless particleboards. Almost half of the boards have internal bond strength that exceed the minimum requirements for grade 8 type JIS A 5908 particleboards, i.e. 1.5 kg/cm^2. The highest internal bond strength was 2.7 kg/cm^2, while the lowest one was 1.2 kg/cm^2. This result was still lower compared than the internal bond strength of kenaf core binderless boards (Okuda and Sato 2004), while it was higher than that of bagasse pith and bagasse rind binderless board (Widyorini *et al.* 2005c). Considering that no binder is used in the board manufacturing, in general, the large surface area of finely ground raw materials enhances the self-bonding strength (Okuda and Sato 2004). The binderless boards made from coarse particles in this study have lower internal bond strength compared than that made from other particle sizes.

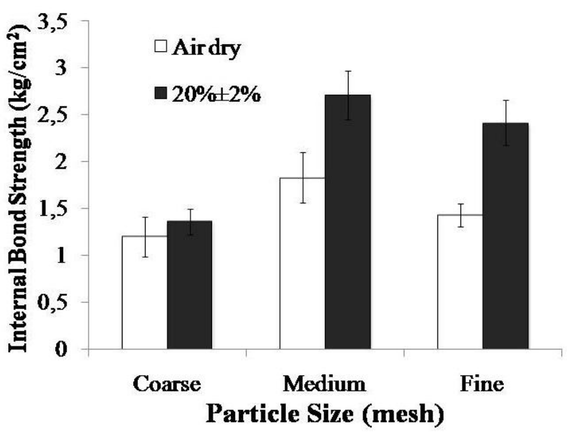

Figure 5. Effects of particle size and particle moisture content on internal bond strength of bamboo binderless particleboards. *Vertical lines* through the bars represent the standard deviation from the mean.

Effect of moisture content could be significantly shown on internal bond strength of bamboo binderless board. Relatively high moisture content is required to promote the hydrogen bonding and lignin bonding among particles, considering that no resin was added during board manufacturing. The average internal bond strength of binderless board made from air-dried particles was 1.5 kg/cm^2, while it was 2.2 kg/cm^2 for binderless board made from 20±2% moisture content particles. The same result was also reported by Xu *et al*. (2006), which the internal bond strength of binderless fiberboard made from 30% moisture content fiber was higher than that of binderless board made from air-dried fibers. However, in the preliminary experiment, the board was found to be delaminated when using the high particles moisture content to make high-density board. It was due to the high mat moisture content with high compaction ratio will produce very high steam pressure inside in the board. Therefore, the mat moisture content is one of the important points in binderless boards manufacturing, especially for high-density board.

Conclusions

Bamboo binderless particleboard could be manufactured by using the hot pressing system without any delamination. Interaction between two factors (particle size and moisture content) affected significantly on thickness swelling and water absorption of the binderless board. Effect of particle size was significant on internal bond strength of binderless boards, while effect of moisture content was significant on internal bond strength and MOR of binderless board. The binderless particleboards made from 20±2% mat moisture content showed better mechanical and dimensional properties than those made from air-dried particles. The binderless particleboard made from medium particle size (20~60 mesh) and the moisture content of 20±2% recorded a modulus of rupture of 94 kg/cm², water absorption of 29%, thickness swelling of 5%, internal bond strength of 2.7 kg/cm², and modulus of elasticity of 19.490 kg/cm², that can meet the requirement of JIS A 5908.

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