Characteristics of Binderless Particleboard Made of Three Species of Sulawesi Bamboos

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Abstract

Binderless particleboards (BP) were produced from three different species of Sulawesi bamboos. Parring bamboo (*Gigantochloa ater*) was extracted from Tanralili Maros while betung bamboo (*Dendrocalamus asper*) and tallang bamboo (*Schizostacyum barcahycladum*) were extracted from Batu Papan Makale Tana Toraja. The bark and nodes were removed, followed by cutting into chips; air drying, and finally converting into fine particles. The particles were oxidized using hydrogen peroxide 15% based on oven dry particle weight and 7.5% ferrous sulfat based on hydrogen peroxide weight. Hot pressing was applied for 12 min at 180ºC. Seven types of bamboo BP were produced based on the raw materials, i.e. the bamboo species namely; parring bamboo, betung bamboo, tallang bamboo, parring-betung bamboo with ratio 1 : 1, parring-tallang bamboo with ratio 1 : 1, betung-tallang bamboo with ratio 1 : 1, and parring-betung-tallang bamboo with ratio 1 : 1 : 1. The results indicated that the characteristics of betung bamboo BP were better than the two other bamboos. The physical and mechanical properties however have not fulfilled JIS A 5908 2003 yet. Differences in BP characteristics were caused by the chemical contents of bamboo, especially lignin that is different from species to species.

Keywords: bamboo, binderless particleboard, hydrogen peroxide, oxidation.

Introduction

Particleboard manufacturing technology involves the use of adhesive bonding agent, wood or other lignocellulosic material particles. Research development on particle board is still more focused on conventional particleboard using adhesive. In fact, the majority (96.6%) of the industries use the adhesive containing formaldehyde compounds which are potentially detrimental to health (Li 2002). Adhesive raw materials are still dominated by petroleum derived compounds which are non-renewable.

This study was an alternative approach in the manufacture of particleboard without adhesives. Theoretically, the lignin in lignocellulosic materials can be activated to trigger the formation of self bonding (Yelle *et al.* 2004). Widsten *et al.* (2003) has successfully developed a method of oxidation in the manufacture of fiberboard of wood spruce (*Picea abies*) and beech (*Fagus sylvatica*), species that grow in sub-tropical regions. The success of this method in particle board has not been proven yet, and it is advisable to add technical lignin in the manufacturing process. Contrary to Widsten *et al.* (2003) statement, a research in 2010 has successfully proved that oxidation method can be applied to produce binderless particleboard made of andong bamboo (*Gigantochloa pseudoarundinaceae*) (Suhasman *et al.* 2010). However, the characteristics of the product were not equal to the conventional particleboard. The internal bond and bending strength of the board were still lower. This is apparently related closely to various factors such as the chemical components of bamboo, particle size, and other factors. This hypothesis indicates that there are opportunities to develop the technology of binderless particleboard made from bamboo if the key factors can be determined and supported with good characteristics.

Bamboo has the capability to be one of the alternative sources of particleboard raw materials. It is available abundantly, easy to cultivate, and a fast growing species (Muin *et al*. 2006). This study aims to develop a new technology to utilize bamboo as an alternative source of particleboard raw material. It focused on examining three different bamboo species available in South Sulawesi as the most suitable particleboard raw materials.

Materials and Methods

Ater or parring bamboo (*Gigantochloa ater*), betung bamboo (*Dendrocalamus asper*), and tallang bamboo (*Schizostacyum barcahycladum*) were among the bamboo species that are cultivated widely in South Sulawesi (Muin *et al*. (2006). These species were used in this research and were extracted from 2 different sites: Tanralili, Maros District (Parring bamboo) and Batu Papan Makale, Tana Toraja District (tallang and betung bamboos).

Chemical Component

Sample was prepared according to TAPPI T 257 0m-85 "Sampling and Preparing Wood for Analysis", while moisture content was determined according to TAPPI T 264 om-88. Extractive soluble contents in hot water, NaOH 1%, and ethanol benzene were analyzed according to TAPPI T 207 0m-93, TAPPI T 212 om-93, and TAPPI T 264 om-88 respectively. Analysis of cellulose, hemicelluloses and lignin contents were conducted according to TAPPI 17 m-55, TAPPI 223 cm-84 and TAPPI T 203 os-74 respectively.

Binderless Particleboard Characteristics

Binderless particleboard was produced from air-dried particles of three different species of bamboos. Three species of bamboos were felled, cut into 1 m length, and then taken to the laboratory. The bark and nodes of bamboo strips were removed and then made into chips using a machete. Bamboo chips were air dried and later converted into particles with size of 10 mesh sieve using wood mill refiner.

Particle boards for each species of bamboo were made by oxidizing the particles. Before oxidizing, bamboo particles were weighted to produce particleboard with a density target of 0.75 g/cm^3 with dimension of 30 x 30 x 0.7 cm. Bamboo particles were then oxidized with hydrogen peroxide 15% based on dry particle weight and 7.5% of ferrous sulfat based on weight of hydrogen peroxide (Suhasman *et al*. 2010). Conditioning was allowed for 15-30 minutes before forming into a mat. The sheets were then hot pressed for 12 minutes at a temperature of 180°C with a pressure of 25 kgf/cm^2. The produced boards were conditioned for 2 weeks at room temperature before cutting into sample with size according to Japanese Industrial Standard (JIS) A 5908 2003.

Seven types of binderless particleboards were produced in this study, i.e. boards from parring bamboo, tallang bamboo, betung bamboo, boards made of parring bamboo mixed with tallang bamboo with ratio 1: 1, boards made of parring bamboo mixed with betung bamboo with ratio 1: 1, boards made of tallang bamboo mixed with betung bamboo with ratio 1 : 1, and boards made of parring bamboo mixed with tallang bamboo and betung bamboo with ratio 1 : 1 : 1.

Results and Discussion

Chemical Components of Bamboo

The chemical components of bamboo are presented in Table 1. The data show that tallang bamboo has the highest solubility both in polar or non-polar solvents. This indicates that the tallang bamboo has the highest extractive content compared to the other two species. The solubility in hot water indicates that the bamboo has high extractive substances, achieving 15.5% for tallang bamboo and 12.25% for parring bamboo. The high solubility in water may be due to the presence of starch as part of the extractive substances.

In terms of cellulose content, again, tallang bamboo has the highest and betung bamboo has the lowest. There is no significant difference of cellulose content among these three species.

Lignin plays an important role in producing particleboard without adhesive. Theoretically, the formation of free radicals in methoxy groups or hydroxyl groups when oxidized (Widsten *et al*. 2003), will produce bond formation among the particles during the hot pressed process. Based on the hypothesis, betung bamboo was expected to have high bond strength because it has the highest lignin content compared to the other two bamboos.

Binderless Particleboard Characteristics

Water absorption and thickness swelling data are presented in Figure 1 and 2. Water absorption and thickness swelling of binderless particleboard made from parring bamboo generated the highest value, while those of betung and tallang bamboo were relatively similar. This indicates that parring bamboo naturally has a higher hygroscopicity than the other species. Parring bamboo tends to absorb water which implies a change of dimension. Therefore, this type of bamboo is not promising to be a prospective raw material when compared to the two other species. Betung bamboo indicates having a low water absorption as in both test: 2 hours and 24 hours, the water absorption remains stable (Figure 1).

Figure 2 shows that the particleboard containing parring bamboo have a high thickness swelling, although its value is still lower than the particle board that uses only parring bamboo species. However, when compared to the particle board without parring bamboo, its value remains higher. Decreasing of water absorption and thickness swelling value on the boards using mixed particle indicates that to produce particle board with high dimensional stability, the use of parring bamboo as raw materials still possible, but needs to be mixed with other types of bamboo.

Table 1. Chemical Components of Bamboo.

Chemical Component	Parring bamboo	Tallang bamboo	Betung bamboo
Hot water extractive soluble content (%)	12.25	15.50	9.00
NaOH extractive soluble content (%)	24.00	26.00	21.25
Ethanol-benzene extractive soluble content (%)	4.93	6.15	2.78
Cellulose (%)	46.74	46.94	46.02
Hemicellulose (%)	22.05	20.50	16.32
Lignin (%)	29.20	27.88	30.61

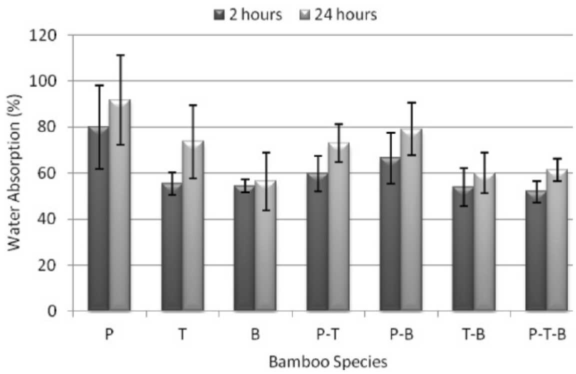

Figure 1. Water absorption (%) (P = Parring, T = Tallang, B = Betung)

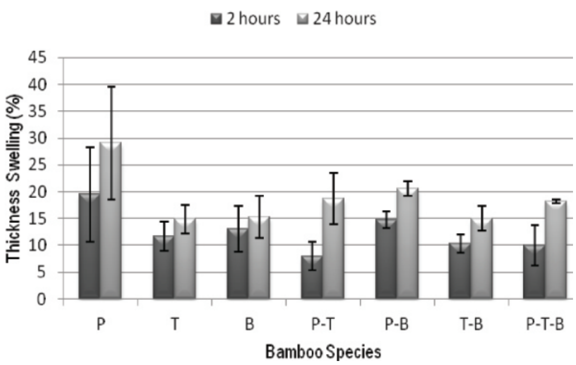

Figure 2. Thickness swelling (%).

Particleboards made of tallang and betung bamboos had the similar thickness swelling. The thickness swelling of these two species increased less than 5% after 24 h immersion, compared to almost 10% increasing of the thickness swelling of parring bamboo on the same test (see Figure 2). It means that the moisture fiber saturation point of parring bamboo is higher than the other two species. Tallang and betung bamboos reached slower saturation point.

Although variations in thickness swelling between these selected species does exist, the value of thickness swelling of all types the particleboard still not fulfill the JIS A 5908 2003 standards: a maximum of 12% of thickness swelling. This means further research is needed in order to meet the commercial product standard.

Figure 3 presents the values of modulus of rupture (MOR). Unfortunately, none of the results have met the JIS A 5908 2003 requirement: 80 kgf /cm^2. The best MOR was the board made of betung bamboo, and the lowest MOR was the board made of tallang bamboo. Particleboard that used mixed of species showed that the combination of betung bamboo as raw material with other species provides a better and high MOR compared without this species.

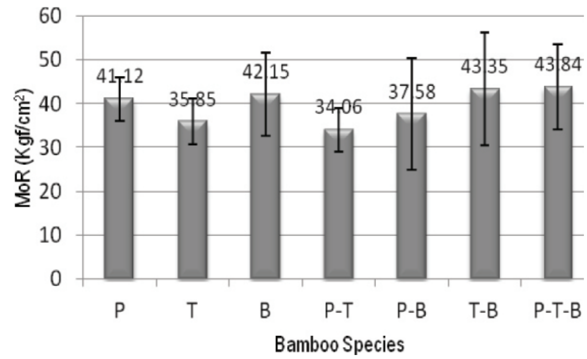

Figure 3. Modulus of rupture (kgf/cm^2).

Low MOR indicates that the ability to support heavy load is relatively low. Particleboard with low MOR is brittle. It is caused by oxidized materials that are capable of activating the chemical components of bamboo, and damaging the chemical components of bamboo, thus reducing its strength.

Figure 4 shows the values of modulus of elasticity (MOE). Similar to MOR, MOE is also relatively low. The particleboards have not met the JIS A 5908 2003. MOE of the particleboard made of parring bamboo has the lowest MOE, and tallang bamboo has the highest. In all particleboards using mixed species, all boards contains tallang bamboo tend to have a high MOE.

Surprisingly, tallang bamboo has the lowest MOR and the highest MOE. Generally, the value of MOR is in line with MOE. The stronger the board, the rigid it is. This research showed that the strongest board made of betung bamboo apparently was not the most rigid board. As the process of producing binderless particleboard involves chemical modification, especially on lignin, this was made it possible. Lignin has a significant effect on the rigidity of materials.

Figure 5 presents the relationship between internal bond and bamboo species. The results show that the particleboards have met the JIS A 5908 2003 (above 1.5 kgf/cm^2). This means the bonds between the particles have been formed even though dimensional stability, modulus of rupture, and modulus of elasticity have not met the standard.

The high internal bond strength is an indicator that oxidation treatment succeed in activating chemical components and able to form a high internal bond between the particles without the use of adhesive. Therefore, further research will be focused more on improving the strength and stiffness and dimensional stability board through modifications in processing technology and oxidation treatment.

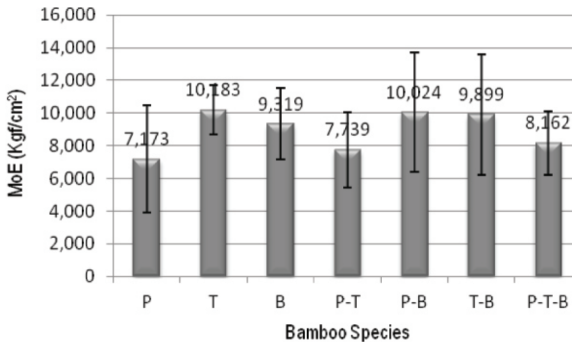

Figure 4. Modulus of elasticity (kgf/cm2).

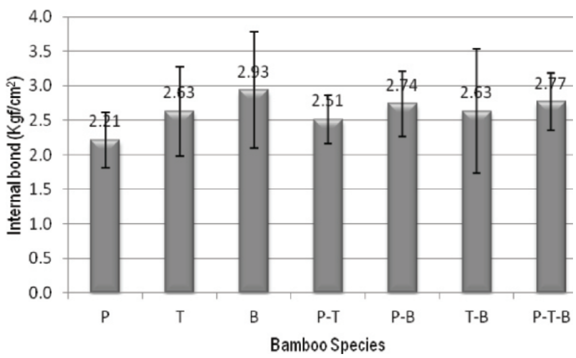

Figure 5. Internal bond (kgf/cm2).

In relation to choose the best species as an alternative source of raw material, betung bamboo shows a promising option. It has the highest bonding strength and the highest lignin content. The use of 15% hydrogen peroxide and 7.5% ferrous sulfate oxidant can activate the chemical components of betung bamboo to the fullest. The activation levels of the chemical components of bamboo are highly affected by the microstructure of the chemical components. However, high lignin content is not the only determinant of bamboo reactivity. The structure of lignin may also have an effect on the process such as the ratio of siringyl and guaiacyl.

Conclusions

This study indicated that the application of oxidation method using hydrogen peroxide and ferrous sulfate as a catalyst have been successful to produce binderless particleboard using bamboos as raw materials. Betung bamboo has the highest lignin content compared to the other two species. Therefore it is the best option to use as a raw material in producing particleboard without adhesive, as lignin plays a pivotal role in the manufacturing process. In fact, binderless particleboard made of betung bamboo has the best characteristics compared to binderless particleboard made of parring or tallang bamboos.

Acknowledgments

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References

Japanese Standards Association (JSA). 2003. Particleboards. Japanese Industrial Standard (JIS) A 5908-1994. Japanese Standards Association. Japan.

Li, K. 2002. Use of Marine Ahesive Protein as a Model to Develop Formaldehyde-Free Wood Adhesives, in Proceeding the 6th Pacific Rim Bio-Based Composites Symposium, Oregon-USA. Oregon State University.

Muin, M; Suhasman; N.P. Oka; B. Putranto; Baharuddin; S. Millang. 2006. *Pengembangan Potensi dan Pemanfaatan Bambu sebagai Bahan Baku Konstruksi dan Industri di Sulawesi Selatan*. Badan Penelitian dan Pengembangan Daerah. Makassar.

Suhasman; M.Y. Massijaya; Y.S. Hadi; A. Santoso. 2010. Optimization of Oxidator Level to Produce Binderless Bamboo Particleboard. Working Paper No. 26 December 2010. Center for Environmental Research IPB. ISSN 2085-3599.

TAPPI. 1996. TAPPI Test Methods. TAPPI Press. Atlanta.

Widsten, P; P. Qvintus-Leino; S. Tuominen; J. E. Laine. 2003. Manufacture of Fiberboard from Wood Fibers Activated with Fenton's Reagent (H_2O_2/$FeSO_4$). Germany. Holzforschung, 57: 447-452.

Yelle, D; B. Goodlell; D.J. Gardner; A. Amirbahman; P. Winistofer; S. Shaler. 2004. Bonding of Wood Fiber Composites Using a Synthetic Chelator-Lignin Activation System. Forest Product Journal. 54 (4): 73-78.

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