The Properties of Sandwich Particleboard (SPB) Made From Bamboo Belangke and Corn Stalk Bagasse Bonded With Isocyanat in Various Levels

A H Iswanto\textsuperscript{1*}, H D Anjarani\textsuperscript{1}

Department of Forest Product, Faculty of Forestry, Universitas Sumatera Utara, Padang Bulan, Medan 20155, Indonesia

\textsuperscript{*}) Email: apriheri@yahoo.com

Abstract. Generally, the problem of wood industry in Indonesia is about wood supply for its raw material. Utilization of non-wood materials is alternative solution. Bamboo and corn stalk for example of non-wood lignocellulosic materials had a good potention to develop as biocomposite materials especially for particleboard. The objective of this research was to evaluate of physical, mechanical and durability properties of sandwich particleboard (SPB) made from bamboo Belangke and corn stalk bagasse bonded with isocyanat resin in various level. Board was produced in size of 25 by 25 cm\textsuperscript{2} with density and thickness target of 0.70 g/cm\textsuperscript{3} and 1 cm respectively. Bamboo was place for surface layer and corn stalk bagasse as core layer with composition ratio of 1:2:1. Various level of Isocyanat resin consited of 4, 6, 8, and 10% used as binder in SPB manufacturing. Hot pressing temperature and time were set on 160\textdegree C and 5 minutes with pressure of 30 kg/cm\textsuperscript{2}. Durability testing of SPB with graved yard test method and sample weight loss was calculated to determine of durability class. The results showed that the physical and mechanical properties generally had fulfilled the JIS A5908-2003 except of internal bond parameter. According to economical reason, board bonded with 4% Isocyanat was recommended as a better product. The durability test showed that weight lost value of board ranged of 8.48 to 10.33 \%. Sandwich particleboard was produce in this research classified into durability class moderate to not durable.

Keywords: Sandwich particleboard, bamboo, corn stalk, adhesive levels.

1. Introduction
Particleboard is a composite product made of wood or other lignocellulosic materials, bonded with thermosetting or thermoplastic adhesives, and then continued by hot pressing process [1]. In general, particleboard had a low in terms of stabilization dimension and strength. This research was focused on increasing strength of particleboard using non-wood raw material through sandwich particleboard was bonded by isocyanate adhesive at various level.

Corn stalk selected because it contains holoselulosa, cellulose, hemicellulose, and lignin klason each at 82.1, 39.0, 42.0, and 7.3\% [2]. Furthermore bamboo was selected as a coating material because it had advantages in terms of strength. As stated by [3], that bending strength of bamboo is 2600 to 8000 N/mm\textsuperscript{2}. Furthermore, particleboard made from bamboo bonded UF adhesive produce MOE value of 2000 N/mm\textsuperscript{2} [4,5]. The purpose of this research was to analyze the effect of isocyanate
adhesive level on physical, mechanical, and durability of sandwich particleboard made from bamboo belangke and corn stalk bagasse (*Gigantochloa pruriens* W).

2. Materials and methods

2.1. Materials
The materials used in this study were corn stalks (*Zea mays*), bamboo belangke (*Gigantochloa pruriens* W) and 4, 6, 8, and 10% isocyanate adhesives (98% solid content).

2.2. Methods

2.2.1. Particle preparation
Corn stalks particles and bamboo belangke strand as presented in Table 1, dried to achieve moisture content of 8.02% for corn stalk and 7.24% for bamboo strand.

| Particle type | Size (cm) | Material type       |
|---------------|-----------|---------------------|
| Particle      | 5 x 2 x 2 | Corn stalk bagasse  |
| Strand        | 25 x 2.5 x 0.1 | Bamboo Belangke |

2.2.2. Board manufacturing
The first, bamboo and corn stalk mixed with adhesive. After that, it was inserted into a 25 cm by 25 cm mold. After mat forming, hot pressing was then carried out at a temperature of 160°C for 5 minutes, and pressure of 30 kg/cm². The last step is conditioning of board for 14 days at room temperature, it aims to get the uniformity of moisture content and eliminates the residual stress that occurred during hot pressing process.

2.2.3. Model of sandwich particleboard
The sandwich particleboard made in this study had a 3-layer composition consisting of a face, core, and back layer with a composition ratio of 1: 2: 1 (face:core:back).
3. Results and discussions

3.1. Density
The board density values ranged from 0.55 to 0.61 g/cm³ (Fig. 2). The highest density values resulted on boards with 4% and 8% adhesives content, furthermore the lowest density values are on boards with 10%.

![Figure 2. Density and moisture content of sandwich particleboard](image)

Sandwich particleboard density value has not reached the density target of 0.70 g/cm³. This is due to two things, first is waste particles during board manufacturing [6]. Furthermore, the second caused was springback of board after conditioning process. The average value of springback was 26%. Springback in this study due to utilize of non-wood materials especially of corn stalk bagasse which have bulky nature. Several factors that influence value of board density include wood species, pressure of pressing, amount of particle, adhesive and additives level [7]. Some research had been done by [8,9] showed that the utilized of non-wood materials causing density values did not reach of target. All the board density value in this research had met standard JIS A 5908 (2003) which requires the density values ranged from 0.40 to 0.90 g/cm³ [10].

3.2. Water Absorption (WA) and Thickness Swelling (TS)
Water absorption values of boards range from 65.41 to 69.63% (Fig. 3). The highest of WA value was generated board with 4% adhesive content and lowest on board with 6%.

![Figure 3. Water absorption and thickness swelling of sandwich particleboard](image)
Trends data indicates a higher level of adhesive causing decreased WA board. It was due to the more levels of adhesive was used it will be more even spread of adhesive. The water absorption values of boards are still higher compared with [11]'s study using sorghum stalk and isocyanate resin as raw material in the manufacture of particleboard. The hygroscopicity properties of material also had important role in determining of water absorption value [8].

The thickness swelling value of boards ranged from 3.89 to 9.04% (Fig. 3). The highest value is on board with 4% adhesive level and lowest on board with 10% level. Data trends indicated that an increased in adhesive level caused a decrease in TS value. As stated by [12], that large amounts of adhesives will increase the bonding between particles to result of particleboard is more stable and resistant to the water. Thickness swelling of board is influenced by several factors such as insufficient amount of adhesive and distribution, moisture content furnish inadequacy, lack of compatibility furnish with adhesive, the chemical composition of furnish, etc [13]. According to [14] that the correlation between TS and internal bond (IB) is negative where the lower IB will cause higher TS value. Overall, TS value of sandwich particleboard had met JIS A 5908 (2003) that requires a maximum value of 12% [10].

3.3. Modulus of Elasticity (MoE) and Modulus of rupture (MoR)
MoE and MoR values of boards ranged between 24,073.23 to 33,761.03 kg/cm² and 175.38 to 300.02 kg/cm² respectively (Fig. 4). The highest MoE value is on board with 4% adhesive level, meanwhile for the highest MoR value on board with 10% adhesive level. The lowest MoE and MoR values were on board with 8% adhesive level.

![Figure 4. Modulus of elasticity and modulus of rupture of sandwich particleboard](image)

In this research, there was no linearity pattern of relationship between increasing adhesive level with MoE and MoR value. Board surface using a bamboo strand becomes one of contributing factors. According to the basic principle of mechanical properties that bending strength resulted by surface section, because this section is directly related to the load. One disadvantage of particleboard is a low strength. The use of higher strength coatings has a significant impact on MoE and MoR values. As reported by [15], coating of particleboard using veneer and thin plywood can improve the strength of particleboard made from empty fruit bunches of palm oil. Furthermore [16] reported that the use of woven bamboo and thin plywood able to increase the strength of particleboard made from sorghum bagasse. Modification of particleboard by using bamboo as surface coating can improve of MoE and MoR value so that it meets JIS A 5908 (2003) standard. The standard requires a minimum MoE value of 20,000 kg/cm² and a minimum MoR value of 80 kg/cm² [10].

3.4. Internal Bond (IB)
Internal bond values ranged between 0.48 to 0.67 kg/cm² (Fig. 5). The highest IB value was on board with 10% adhesive level and the lowest was on 8% level.

![Figure 5. Internal bond of sandwich particleboard](image)

In this research, IB value was determined by corn stalk particle as core layer in particleboard. Corn stalk particles used in this study still contain bark. The bark had a more slippery character and was hydrophobic so that would be a barrier in gluing process. Similar conditions were also shown by [16] who reported that low of IB value the sorghum bagasse particleboard was due to the presence of bark from sorghum bagasse. The IB value of sandwich particleboard did not met JIS A 5908 (2003) standard that requires a minimum IB value of 1.5 kg/cm² [10].

3.5. Weight loss

Weight loss is parameter to determine of durability of board. In this study, weight loss value of boards ranged from 8.48 to 10.33% (Fig. 6). The highest weight loss value is on board with 6% adhesive level and the lowest value is on 8% level.

![Figure 6. Weight loss of sandwich particleboard](image)

Highest value of weight loss resulted by board with adhesive levels of 6%. This is presumably because the effect of isocyanate levels on board. Isocyanates are toxic to termites. Based on Indonesian National Standard (SNI) 01-7207-2006, sandwich particleboard in this study was classified into medium class [17].
Forms damage test samples found were in form of holes on surface and core of board. Cornstalk more eaten by termites, it due to corn was soft, easily bitten and easily destroyed. Termites tend to attack on the side, because this section had a termite accessibility gap. Termites will tend to choose foods that contain a lot of cellulose, easily bitten, and destroyed, termites eat only on the side [18].

All species of termites are able to eat wood or materials containing cellulose, as evidenced by the presence of various flagella protozoa in the intestine behind the termites [18]. Based on the observations, the species of termites that attack of sandwich particleboard was Coptotermes curvignathus. Furthermore, Coptotermes curvignathus Holmgren termites have special features, namely yellow head, antennae, lambrum, and pale yellow pronotum. Round head shape slightly larger in length than width, have a wide fontanelle [18]. The antenna consists of 15 segments, second and fourth segments of the same length. Termite worker caste has a pale white body and able to create channels that are covered by the soil and attached to the wall or wood. The soil as a protection from predators, sunlight, and retain moisture temperatures.

4. Conclusion
The 10% adhesive level produced the best physical and mechanical properties, which was indicated by the lowest of thickness swelling parameters and the highest MoE, MoR and IB values. Based on the results of durability tests, sandwich particleboard in this study was categorized into moderate resistance to not durable.

Reference
[1] Maloney TM 1993 Modern Pariticleboard and Dry-Process Fiberboard Manufacturing (USA: Miller Freeman Inc. San fransisco)
Acknowledgement
We would like to express my sincere thanks to University of Sumatera Utara for supporting research fund through to “Talenta Research Grant” No: 5388/UN5.1.R/PPM/2017 Date of May 22, 2017.