The properties of particleboards made from non-wood lignocellulose materials bonded with melamine formaldehyde resin

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\textbf{Abstract.} The use of non-wood lignocellulosic materials is currently limited as organic fertilizer, fuel, and animal feed. These materials have the opportunity to be used in the manufacture of particleboard. This study aimed to analyze the properties of the panel made of non-wood lignocellulosic material bonded using melamine-formaldehyde adhesive. Non-wood lignocellulosic materials used in this study include bagasse, corn cobs, durian skin, coconut fiber, and rice husks. The material was converted into 20 mesh size particles. The level of melamine-formaldehyde adhesive used was 10%. Hot pressing was done for 10 min at 140°C using 30 kg/cm\textsuperscript{2} pressure. The board is made of 25 x 25 cm\textsuperscript{2} with a target density and thickness of 0.80 g/cm\textsuperscript{3} and 1 cm, respectively. The findings revealed that bagasse board has superior physical and mechanical properties to other lignocellulosic materials. This board has the highest internal bond and the lowest thickness swelling value. Most of the test parameters in this study did not meet the JIS A 5908-2003 because the density target was not achieved.

\textbf{1. Introduction}

The need for wood for building construction or furniture continues to increase along with the increase in population. Meanwhile, the availability of timber continues to decline in line with the increasing rate of forest degradation. This condition is one of the problems for the timber industry, so that many industries cannot survive. Particleboard technology is expected to be able to overcome these problems.
This is because particleboard can utilize all materials containing lignocellulose, including wood and non-wood.

Several studies have previously been conducted on the use of non-wood materials as raw materials in particleboard manufacture, including particleboard made from corn stalks, bamboo belangke, fibers, and bagasse using UF adhesives and isocyanates [1-7]. Furthermore, particleboard made from sorghum stems has been studied by [8-12].

The lignocellulosic content of several non-wood materials can be used as raw material in the manufacture of particleboard. Bagasse contains cellulose and lignin, respectively 45% and 18% [13]. Corn cobs contain cellulose and lignin of 26.81% and 15.52% [14]. Durian skin with cellulose and lignin content of 50-60% and 5% [15]. Coconut coir with cellulose and lignin content of 21.07% and 29.23% [16]. And rice husks with cellulose and lignin content of 34.34% and 21.40% [17]. So far, lignocellulosic materials are used as organic fertilizer, fuel, animal feed, or just thrown away so that it becomes waste and has not been used optimally. One way to utilize non-wood lignocellulosic material is to use it as a raw material in particleboard manufacture. It can be an alternative to the use of wood substitute raw materials that are decreasing in availability.

The manufacture of particleboard cannot be separated from the use of adhesives. One type of thermosetting adhesive that can be used in the manufacture of particleboard is melamine-formaldehyde. The advantages of melamine-formaldehyde resin have good water and weather resistance [18]. In addition, it is resistant to attack by microorganisms, resistant to water and weather. In addition to its advantages, this adhesive also has several disadvantages; namely, the storage time is not durable, and the price is relatively high [19].

2. Materials and Methods

2.1. Materials
Bagasse, corn cobs, durian skin, coconut fiber, and rice husks as raw materials in this study. The adhesive used was Melamine Formaldehyde (MF), with a solid content of about 53%.

2.2. Methods

2.2.1. Particle Preparation. Non-wood lignocellulosic materials were cleaned and air-dried. Furthermore, the material was converted into particles measuring 20 mesh. The particles were then oven-dried until they reached 5% moisture content at 103°C.

2.2.2. Panel Manufacturing. The particles were mixed with MF adhesive with 10% adhesive content. Mixing the particle and resin was done using a spray gun to help distribute the adhesive throughout the raw materials evenly. After that the particles were put into a mold measuring 25 x 25 cm². Furthermore, hot pressing was carried out at 140°C for 10 min using a pressure of 30 kg/cm². According to [19] that melamine-formaldehyde can be hot-pressed at a temperature of 120-140 °C without hardeners in a relatively short time. The last stage is the board conditioning process for seven days. This process was carried out at conditions of temperature and humidity according to room conditions.

2.2.3. Particleboard Testing. Before the testing process is carried out, the board is first to cut into several test samples according to the parameters to be tested. The board testing includes the physical (density, moisture content, water absorption, and thickness swelling) and mechanical properties (modulus of elasticity, modulus of rupture, and internal bond). Cutting and testing of boards refer to the JIS A5908 (2003) standard.
2.3. Data Analysis
This study used a non-factorial, Completely Randomized Design with three replications. Analysis of variance with a 95 percent confidence level was used to determine the effect of treatment on the parameters of particleboard's physical and mechanical properties.

3. Results and Discussion

3.1. Physical Properties

| No | Properties          | Bagasse | Corncob | Durian skin | Coconut fiber | Rice husk |
|----|---------------------|---------|---------|-------------|---------------|-----------|
| 1  | Density (g/cm$^3$)  | 0.64 b  | 0.60 a  | 0.66 c      | 0.63 b        | 0.59 a    |
| 2  | MC (%)              | 7.97    | 7.70    | 7.92        | 8.21          | 7.69      |
| 3  | WA 2 H (%)          | 52.77 a | 60.13 a | 70.25 a     | 90.79 b       | 90.24 b   |
| 4  | WA 24 H (%)         | 77.26 a | 81.10 ab| 89.82 bc    | 99.16 c       | 97.44 d   |
| 5  | TS 2 H (%)          | 6.81 a  | 8.51 b  | 8.80 b      | 13.51 c       | 12.9 d    |
| 6  | TS 24 H (%)         | 12.56 a | 17.2 b  | 24.24 b     | 34.9 e        | 30.69 d   |

3.1.1. Density. The highest density value was present by boards made of durian skin, while the lowest values were found on boards made of rice husks. The resulting particleboard density value does not meet the target density to be achieved of 0.80 g/cm$^3$. This is probably due to spring back. Non-wood particleboard has a low density so that it is volumetric; as a result, after the compression process, the board will swell in thickness after conditioning. The next possibility is due to the wasted particles during the board manufacturing. During the compression process, the particles come out of the iron frame so that the resulting particleboard has a larger area and a lower density. According to [20], the low value of particleboard density is due to several wasted particles during the board manufacturing process. The final density of particleboard is influenced by the conditions of the production process, especially the compression process, drying of raw materials, adhesive content, and other additives [21].

Statistical analysis shows that the type of non-wood material has a significantly different effect on the density of the resulting board. Overall, the panel density value has met the JIS A 5908 (2003), requiring a particleboard density value of 0.40-0.90 g/cm$^3$[22].

3.1.2. Moisture Content (MC). The highest MC value is found on boards made of coconut fiber, while the lowest water content values are found on boards made of rice husks. The value of the moisture content of particleboard adjusts to environmental conditions [23]. Particleboard raw material has hygroscopic properties so that it can absorb and release water.

Statistical analysis shows that the type of non-wood material has not significantly different on the MC of board. Overall the value of the moisture content of the resulting particleboard has met the standard. JIS A 5908-2003 requires the value of the moisture content of the particleboard to be in the range of 5%-13% [22].

3.1.3. Water Absorption (WA). The highest WA value for 2 and 24 h immersion was found on boards made of coconut fiber, while the lowest was found on boards made of bagasse. The value of water absorption is directly proportional to the duration of immersion. The longer the board is soaked, the more water will enter the board. According to [24], the amount of water that enters the board is based on the board's condition, the type of water, the method of water entry, and the duration of water entry. Statistical analysis shows that the type of non-wood material had a significant effect on the WA of board for 2 and 24 h.

3.1.4. Thickness Swelling (TS). The highest TS values for 2 and 24 h immersion were found on boards made of coconut fiber, while the lowest values were found on boards made of bagasse. The high swelling value of the resulting particleboard thickness is thought to be due to the raw material's high level of WA.
The TS value is related to the WA by the particleboard. As stated by [25], the more water that is absorbed and enters the structure of the particleboard, it will weaken the bonds between the particles and make the panel expand.

The higher the water absorption capacity, the higher the thickness swelling and vice versa [24]. The board produced in this study has a high thickness swelling so that it cannot be used for exterior purposes. High thickness swelling could not be used for exterior purposes because it has low product dimensional stability and inferior mechanical properties [26].

Statistical analysis shows that the type of non-wood material had a significant effect on the thickness of the board for 2 and 24 h. The value of the thickness of the resulting particleboard exceeds the standard. JIS A 5908 (2003) requires a TS value of a maximum of 12% [22].

3.2. Mechanical Properties

| No | Test Parameter | Bagasse | Corncob | Durian skin | Coconut fiber | Rice husk |
|----|----------------|---------|---------|-------------|---------------|-----------|
| 1  | MOE (x10³ kg/cm²) | 3.94    | 2.79    | 2.87        | 2.92          | 3.29      |
| 2  | MOR (kg/cm²)      | 56.35   | 40.24   | 43.82       | 44.09         | 43.94     |
| 3  | IB (kg/cm²)       | 3.55    | 1.83    | 2.03        | 1.91          | 1.63      |

3.2.1. Modulus of Elasticity (MOE). The highest MOE value was found on the board from bagasse, while the lowest value was found on the panel from corn cobs. The MOE value of the board is still very low. This possibility is related to the low slenderness ratio (SR) of the particles because the particles used are in powder form with a size of 20-mesh. The ideal value of SR for particles is 150 in the form of flakes [21]. Particles with a high SR value will be more easily oriented, resulting in an increase in the board's strength and require less adhesive in each contact surface area to bind the particles. The MOE value was influenced by the content and type of adhesive used, board density, adhesive bonding power, and particle geometry [23].

Statistical analysis shows that the type of non-wood material had no significant effect on the MOE value. The average value of the Modulus of Elasticity does not meet the JIS A 5908 (2003) standard, which requires a minimum MOE value of 20,400 kg/cm² [22].

3.2.2. Modulus of Rupture (MOR). The highest MOR value is found on the board from bagasse, while the lowest value is on the board from corn cobs. Similar to MOE, the MOR value of the board as a result of this study is also very low. This is presumably because the density of particleboard produced is still low and has not yet reached the target to be achieved. The strength of the particleboard will be linearly positively correlated with the density of the board [23]. Statistical analysis shows that the type of non-wood material had no significant effect on the MOR value. The average value of MOR does not meet the JIS A 5908 (2003) standard, which requires a minimum value of particleboard fracture strength of 82 kg/cm² [22].

3.2.3. Internal Bond (IB). The highest value of IB is found on the bagasse board, while the lowest value is on the rice husk board. The value of IB indicates the internal bonding strength of the particles, where this value will determine the value of the thickness expansion of the board. The IB value is also affected by board density. The higher value of panel density causes the bonds between the particles to be more compact so that the internal adhesive strength is higher. Statistical analysis shows that the type of non-wood material had a significant effect on the IB value. The value of internal bonding strength has met the JIS A 5908 (2003) standard, which requires a particleboard IB value of at least 1.5 kg/cm² [22].

4. Conclusion

Among several physical properties tested, the density and moisture content met the JIS A 5980 (2003) standard, while the TS did not meet the standard. The mechanical properties of particleboard for
parameters MOE and MOR have not met the standard of JIS A 5980 (2003), while for the value of IB, particleboard has met the standard of JIS A 5980 (2003). The type of raw material significantly affected the density, \( WA \), \( TS \), and \( IB \) of particleboard.

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