Synthesis and Characterizations of Kubukatebu Particle Board from Cacao Peels and Bagasse

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Abstract. This research concerns on the manufacture of KUBUKATEBU particle board from a mixture of cacao peels and bagasse, with variations in the length of the bagasse fibers and the particle size of cacao peels in terms of their physical and thermal properties. The measured parameters were water content, density, water absorption, and thermal conductivity. This particle board was made with 5 variations of cacao peels powder, the ones that could get through the sifter namely 20, 40, 60, 80, and 100 mesh (149, 177, 250, 400, and 841 µm), and 5 variations of bagasse fiber length, namely: 1, 2, 3, 4, and 5 cm. The composition of cacao peels and bagasse fibers were 50:50 and 16% isocyanate adhesive content. The obtained physical properties of particle board variations in particle size of cacao peels were water content values 9.27-13.05%, densities 0.89-1.23 g/cm³, water absorption 11.11-52.28%, and thermal conductivity properties 7.26×10⁻³-9.0×10⁻³ W/m°C. As for the particle board variation of bagasse fiber length variation, the obtained values were 0.100-0.135% for water content, 0.9-1.30 g/cm³ for density, 0.2-0.6% for water absorption, and 6.5x10⁻³-8.5×10⁻³ W/m°C for thermal conductivity properties. Hence, the produced physical properties of KUBUKATEBU particle board had achieved the standards set by SNI 03-2105-2006, and JIS A 5908 (2003), on the contrary to the thermal conductivity properties.

1. Introduction
The high demand of wood for buildings, furniture, and others has resulted a significant reduction in forest area. One of the efforts to overcome this problem is the manufacture of particleboard by utilizing plant wastes as raw material [1-2]. According to the Indonesian National Standard on particle board (SNI.03-2105-2006), particle board is a wood product that is produced from hot pressing between a mixture of wood particles or lignocellulose with organic adhesives and other complementary materials made from two plates flat pressing, flat. Particle board has several advantages compared to the original wood, including defect-free (eye wood, broken, and cracked), and the size and density of the board can be adjusted to the needs [1-2].

Many agricultural wastes containing lignocellulose have not been used maximally such as sugarcane bagasse and cacao peels. So far, the use of sugar cane is still limited to the sugar industry by only making use of its water. Sugarcane bagasse which reaches 35% -40% of the sugar cane weight is only used as industrial fuel in a small portion, the rest is disposed as waste [2]. On the other hand, cacao peels take the largest volume of chocolate fruit waste. The production of one ton of dried cocoa
beans produces about 10 tons of fresh cacao peels [3]. Previous studies have utilized cacao peels as corrosion inhibitors [3-6], particle boards [7], adsorbsents [8-9], briquettes [10-12], additive [13], activated carbon [14], recovery the mechanical properties [15] to overcome cocoa skin waste and sugarcane bagasse. However, up to date the utilization has not been maximized, thus it is necessary to do further research in order to produce a useful product, one of which is to manufacture particleboard to resolve the scarcity of wood.

Previous research has carried out the manufacture of particle board with raw materials of bagasse fiber and cacao peels [7]. In this study, physical and mechanical properties of particle board testing are carried out with variations in the composition of the ingredients and adhesives, with the size of the cacao peels powder passing 60 mesh (250 µm). The results obtained are that almost all particle board testing meet the standard of SNI 03-2105-2006, JIS A 5908 (2003) and FAO (1996). To see the potential of particle board of cacao peels and bagasse, further research on the effect of particle size in cacao peels and of length in bagasse fiber onto their physical properties and thermal conductivity is carried out. The particle board produced from a mixture of bagasse and cacao peels is named KUBUKATEBU particle board.

2. Research Methods

The ingredients used were cacao peels, bagasse, isocyanate adhesives, and water. The equipments used were digital balance, Universal Testing Machine (UTM), sieve (size 149, 177, 250, 400, and 841 µm), hot press, ball milling, mold size 12 cm × 8 cm × 1 cm, oven, calipers, thermometers, and thermal test equipment.

The sample manufacturing stages began with cutting and thinly slicing the skin of the cacao peels, and then sun-drying. When it was dried, then mashed up to get the required powder size. While sugarcane bagasse was soaked for 2 hours to remove the remaining sugar, then dried in the sun for 2 days. Dried sugarcane bagasse was cleaned to bring its fiber out.

The prepared basic ingredients were weighed according to what is needed, with a ratio of 50:50 (bagasse fiber and cacao peels powder) with the addition of 16% isocyanate adhesive from the overall mass of the sample. Particle board variation of bagasse fiber length with size 1, 2, 3, 4, and 5 cm for the size of 60 mesh cacao peels. Particle board for variations in cacao peels powder were in the measurement of 20, 40, 60, 80, and 100 mesh or 149, 177, 250, 400, and 841 µm sieve escapes with 3 cm long bagasse fiber, as seen in the composition of the mixture in Table 1 and 2.

Each variation of the material was mixed with isocyanate adhesives and stirred until homogeneous, then put into the mold until evenly distributed. The next stage was the sample was hot-pressed for 6 minutes at a temperature of 150 °C, and 2.083 N/m² pressure. Then the sample was conditioned for 7 days at room temperature, and finally the physical properties and thermal conductivity were tested. The physical properties of particle board (water content, density and water absorption) were tested based on SNI 03-2105-2006 standard. Whilst the thermal conductivity properties testing was done by the dual plate method. The result of physical and thermal conductivity was analysed by Design Experiment Software.

| Sample code | Particle size (Mesh) | Bagasse fiber (%) | Cacao peels powder (%) | Adhesive (%) |
|-------------|---------------------|-------------------|------------------------|-------------|
| A1          | 20                  |                   |                        |             |
| A2          | 40                  |                   |                        |             |
| A3          | 60                  | 42                | 42                     | 16          |
| A4          | 80                  |                   |                        |             |
| A5          | 100                 |                   |                        |             |
Table 2. Particle board composition for variations in fiber length

| Sample code | Fiber length (Cm) | Bagasse fiber (%) | Cacao peels powder (%) | Adhesive (%) |
|-------------|-------------------|-------------------|-----------------------|--------------|
| A1          | 1                 |                   |                       |              |
| A2          | 2                 |                   |                       |              |
| A3          | 3                 | 42                | 42                    | 16           |
| A4          | 4                 |                   |                       |              |
| A5          | 5                 |                   |                       |              |

3. Results and Discussion

3.1 Analysis of Physical Properties

3.1.1 Water Content. The particle board water content is influenced by the water content of raw materials [1], [16]. The higher the water content of raw materials, the higher the water content of the particle board produced, because during the compression process not all moisture can be removed from the board [17]. The result obtained show that the smaller the particle size of cacao peels, the lower the water content, as shown in Figure 1.

In terms of the length of the fiber, the value of water content decreases with the length of the bagasse fiber used (Figure 2). The water content of a particle board depends on the condition of the surrounding air, because the particle board consists of material containing lignocellulose that is able to absorb water, therefore the particle board becomes hygroscopic and moist [2], [16]. Nemli G et al., 2007 states that the water content of a particle board is influenced by its density value. High density boards have very strong molecular bonds, consequently water molecules find difficulty filling cavities in particle boards, so their levels are low. Conversely, boards with low density have low molecular bonds, so they have many cavities that are easily filled by water molecules. The resulting water content of particle board meets SNI 03-2105-2006 standard which requires a maximum water content value of 14%.

![Figure 1](image)

Figure 1. Effect of particle size of cacao peels on particle board water content
3.1.2 Density. Density values are obtained from measurements of particle boards’s mass and volume. M Rollin et al, (2009) points out that important factors affecting the density of particle board are density, raw material used, and sheet density. Figure 3 shows the smaller the particle size of cacao peels, the greater the density of the particle board produced. This is due to the specific gravity of cacao peels raw material (1.0204 g/cm^3) which is higher than the density of bagasse (0.12 g/cm^3), resulting in an increase in particle board density as the size of the cacao peels powder decreases.

The smaller the particle size, the higher the density obtained [2] [17]. Seen from Figure 3, the particle size of 841 µm cacao peels is in the SNI 03-2105-2006 interval. The results of density measurements based on variations in the size of cacao peels that meet SNI 03-2105-2006 are 841 µm and others larger than 0.9 g/cm^3. These results indicate that the particle board is categorized as high density because the density value of the particle board obtained is more than 0.8 g/cm^3 [1], [17].
Figure 4. Effect of bagasse fiber length on particle board density

Figure 4 shows the density value of the particle board variation in the length of bagasse fiber. The highest density value is obtained at a fiber length of 5 cm that is equal to 1.3 g / cm³, and the lowest density value at the length variation of 1 cm bagasse fiber that is equal to 1.11 g / cm³. Whereas SNI standard 03-2105-2006 requires that the particle board density is 0.5 g / cm³ - 0.9 g / cm³. The particle board density values obtained for all variations of the length of the cane fiber used are higher than the established quality standards.

3.1.3 Water Absorption. Maloney [1993] and Nemli G et al, 2007 highlights that wood density is closely related to the estimated number of air cavities or cell cavities. The larger the particle size, the more air cavities, and the easier the cavity filled by water. Thus, the water absorption becomes higher. This is caused by large particles having many cavities, which will absorb water easily. SNI 03-2105-2006 standard does not require water absorption value, nevertheless this test is still carried out as a consideration to determine the use of this particle board, whether it is adequate to be used on the exterior or interior.
The effect of particle size on water absorption in Figure 5 shows that the particle board water absorption value ranges from 11.13% to 52.26%. The smaller the particle size of cacao peel powder, the smaller the water absorption value. [18]. It is because small particles have a higher density than large particles [1]. Whereas in the variation of bagasse fiber length, the highest absorption value of particle board water is obtained at 1 cm cane fiber length which is 0.6%, and the lowest value at 5 cm cane fiber length is equal to 0.2%.

3.2 Analysis of Thermal Conductivity
Thermal conductivity testing is conducted to find a type of sample with good insulating properties. The thermal conductivity testing of the particle board is carried out by the double-plate method using
an isolated chamber. Afterward, continued to administer room temperature into the chamber by utilizing a 75 watt incandescent light bulb.

Figure 7. Effect of particle size of cacao peels on the thermal conductivity of the particle board

Figure 7 shows that the thermal conductivity values range from $7.26 \times 10^{-3}$ to $9.0 \times 10^{-3}$ W/m$^\circ$ C. It turns out that the smaller the particle size, the smaller the thermal conductivity value of the particle board. This is because smaller particles are arranged more closely, and minimize the formation of cavities in the board [1]. Cavities formed on the board will reduce the heat insulation properties of the board, thus causing the convection process inside the board [12]. According to M. Assael et al, (2008) a good material for heat insulation has a thermal conductivity value of around 0.1 W/m$^\circ$C.

Whilst the particle board with a fiber length of 5 cm has a high density value compared to the particle board with a fiber length of 1 cm. The longer the fiber, the more cavities are formed, and make the thermal conductivity becomes greater, as shown in Figure 8. Another factor that can affect the thermal conductivity of the particle board is density or porosity. If the resulting particle board has many pores, the thermal conductivity of the board will be smaller [18-19].
4. Conclusion
The resulting of KUBUKATEBU particle board has met SNI 03-2105-2006 standard based on physical properties test, in contrast to the thermal properties test. The particle size of cacao peels and the length of bagasse fiber used affect the physical properties and the thermal conductivity of the resulting particle board. The smaller the size of the cacao peels powder, the higher the thermal conductivity value. The longer the cane fiber used, the higher the density. In regard to the density value of the resulting particle board, it can be said that the particle board is included into the type of high density particle board where it can be used for the manufacture of dividing walls, doors and others.

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