The Characteristics of Particle Board from Empty Fruit Palm Oil (elaeis guineensis jacq) using an Adhesive of Liquid Guava Rod Bark

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Abstract. Empty Palm bunches is the raw materials in the making of particle board with the adhesive of Liquid Guava Rod Bark, The Hot Pressing process at 16 Mpa and temperature 150oC. The particle board was created with a size of 20 x 15 x 2 cm with a target density of 0.7 g/cm3. This research aims to know the characteristics of particle board using adhesive liquida guava rod bark on the empty Palm bunches and performed tests to find out the quality of particle board with reference to standard JIS A 5908-2003. The result showed an adhesive has a real effect on fiber moisture content particle board and influential real pressure against temperature MOR (Modulus of Rupture). From the testing that was performed the particle board have 0.837 gr/cm3 density, moisture content, and strong 8.67% hold screws 18.25 kg at the rate of 20% of the adhesive that has been standard JIS A 5908-2003 while the absorption of water, development of thick, elastic modulus, modulus of a broken and sticky firmness has not met internal standards.

Keyword : Empty Fruit Palm Oil, Particle Board, Liquid Adhesive Guava Rod Bark

1. Introduction
Generally, particle board has a flat shape with a relative size of long, wide, and thin, thus known as a panel. Particle board is a panel product produced by solidification of wood particles or small pieces of wood using a binder. Panel board prepared from lignocellulose material in small pieces which are bind together using a synthetic binder or another binder which fulfill the requirement for temperature and pressure on pressing equipment. In 2011, total empty palm bunches in South Sumatera was 2.11 million Tonnes, which is abundant and unutilized optimally. These empty palm bunches is preferred to be regarded as by product instead of a waste. Solid waste from palm plantation includes empty palm bunches (23%), boiler ash (0.5%), fiber (13.5% from TBS), and shell (5.5%). Generally, this solid waste does not require complicated handling. The chemical composition of palm bunch, on the other hand, consists of ash (6.04%), cellulose (35.81%), lignin (15.70%) and hemicellulose (27.01%) [1].

Particle board prepared from empty palm bunches is more suitable for furniture application instead of construction material because only 5-7% preservative agent (from particle board weight) was added. Particle board prepared from empty palm bunches has been investigated intensively by Sofyana [2] by a certain ratio of base material and adhesive which successfully produced particle board as SNI standard requirement.

Guava rod bark is one of the natural resources which has potential to be beneficial material, because guava leaves, rod bark, and fruit contains high tannins. Chemical structure of tannin is shown
in figure 1. In this research, tannins were used as an adhesive. Guava rod bark contains more tannins than guava leaves. The guava rod bark contains 12-30% tannins while guava leaves contain 11-17%. Thus, guava rod bark was used in this research to prepare the particle board.

![Figure 1. Chemical structure of tannin.](image1)

Scientifically, tannin was defined as polyphenol compound with high molecular weight and contain a hydroxyl group and another group (such as carboxyl), thus create a complex with protein and other macromolecules in a certain condition.

![Figure 2. Molecular structure of hydrolysable tannin.](image2)

Tannin was classified into 2 polymer groups:

- **Hydrolysable tannin**
  
  *Hydrolysable tannin* is a derivative of gallic acid which is easier to be hydrolised in acid condition. The structure of hydrolysable tannin is shown in Fig. 2.

- **Condensed tannin**
  
  *Condensed tannin* is a polyflavonoid polymer. Tannin is water, glycerol, alcohol, and hydroalcohol soluble compound, however, it is nonsoluble in petroleum, benzene. It can be decomposed at 210°C, the flash point at 210°C, and burnt at 526°C. Extractive components based on 95% alcohol and hot water extractions of rod bark was higher 15-26% from initial rod bark weight compared to wood, 2-9%.

2. Experimental procedure

2.1. Materials

Empty palm bunches was crushed into very small pieces like powder form and washed to remove the filth. The dried powder was then boiled at 100°C for 30 min and dried again until the maximum moisture content of 10%.

2.2. Equipments

Mixing Tank, mat forming equipment, oven, Hot Press Machine
2.3. Methods

2.3.1. Manufacture of liquid adhesive
The manufacture of liquid adhesive from guava rod bark is in following procedure adapted from Tito (2015): powdered guava rod bark was boiled in hot water with a ratio of 1:5 for 3 hours, 80-90°C, then dried in an oven until the moisture content of ±5%. A hundred gram of the dried powder was mixed with H₂SO₄ 98% and stirred thoroughly for 30 min. The mixture was incubated for 24 h, and then phenol was added to the mixture with a ratio of 1:5 to the weight of powdered guava rod bark. The mixture was stirred until homogeneity and was cooled. NaOH 50% was added until pH reached 11, and formaldehyde 10% was also mixed with a molar ratio of phenol to formalin 1:1.5. The mixture was then filtered and boiled in hot water bath at 80oC, 2 h with constant stirring.

2.3.2. Blending
Powdered guava rod bark was mixed with the liquid adhesive with the percentage of 30% from the material weight. The mixing of powder and the liquid adhesive was conducted by spraying until the mixture was homogeneous.

2.3.3. Mat forming
The mixture of powder and the liquid adhesive was put into the mold. Mat forming was conducted using mat forming equipment with the size of 25 cm x 15 cm x 1.5 cm and aluminium foil layer, so the particle board produced was in uniform size.

2.3.4. Hot pressing
Hot pressing was conducted using hot press machine with a temperature of 150°C and pressure of 16 Mpa for 30 min.

2.3.5. Conditioning
The fresh particle board was previously conditioned before being stacked together. The stacking of particle board in hot condition would avoid cooling process and brought negative effect such as color degradation, a detachment of surface layer and strength degradation. Conditioning process was also aimed to stabilize the moisture content

3. Results and discussion
The manufacture of particle board was conducted using hot press method. This method was extensively used by researchers, however, under different treatment. Particle board was produced in 20 x 15 x 2 cm size. On the hot press method, stable pressure of 16 Mpa, the temperature of 150°C, and treatment time of 30 min was applied.

3.1. Particle board testing
Physical and mechanical test of particle board consists of density, moisture content, water absorption, development of thick, MOE, MOR, IB and hold screw strength as refers to Japanese Industrial Standard JIS A 5908-2003 and SNI 03-2105-1996.
Table 3. The Standard of Mechanic Testing of Particle board.

| No. | The Characteristic of Physichs dan Mechanics | SNI 03-2105-1996 | JIS A 5908-2003 |
|-----|-----------------------------------------------|-----------------|-----------------|
| 1   | Density (gr/cm³)                              | 0,5-0,9         | 0,4-0,9         |
| 2   | Water Content (%)                             | <14             | 5-13            |
| 3   | Water Absorption (%)                          | -               | -               |
| 4   | Tickness Swelling (%)                         | Max 12          | Max 12          |
| 5   | MOR (kg/cm³)                                 | Min 80          | Min 80          |
| 6   | MOE (kg/cm³)                                 | Min 15000       | Min 20000       |
| 7   | Internal Bond (kg/cm³)                        | Min 1,5         | Min 1,5         |
| 8   | Holding Power (kg/cm³)                        | Min 30          | Min 30          |

Resources: Standard National Indonesia and Japanese Industry Standard

3.2. Density test
Density is the ratio between wood weight and volume. The result shows that the density value of empty palm bunches shows the highest value for the boiling process with the addition of 30% adhesive (0,85 g/cm³). This value has fulfilled the requirement from JIS A 5908 (2003) for medium density particle board.

Figure 3. Graph of density and liquid adhesive ratio.

The effect of the adhesive ratio in particle board was hypothesized to modify the density of the particle board. The moisture content of the particle board showed the ratio of the amount of water and dry weight. The result shows moisture content of 9.03% for particle board with 30% liquid adhesive ratio using the boiling process. The non boiling process, on the other hand, resulted in particle board with 7.66% moisture content. This moisture content had met the requirement of JIS A 5908 which is 5-13%. Generally, the moisture content of the particle board is lower than the moisture content of its materials.

As shown from the graph of moisture content and adhesive ratio, the non-boiling process resulted in lower moisture content. It might be due to high oil and wax content of the material which avoids the absorption of water from the environment. Particle board produced with the boiling process, on the other hand, resulted in high moisture content on the average. It is assumed that ununiformed adhesive distribution to the empty palm bunches powders at the mat forming process.

3.3. Water absorption
Water absorption was defined as the amount of water absorbed by product after 24 h immersion and was calculated as a percentage of initial weight. Based on JIS A 5908-2003, water absorption was not the essential requirement for physical characteristic, but it might affect the quality of particle board.
produced. The lower the water absorption would produce a higher quality of the product. In addition, water absorption has a linear relationship with the development of thickness.

![Graph of water absorption and liquid adhesive ratio.](image)

**Figure 4.** Graph of water absorption and liquid adhesive ratio.

Measurement of water absorption showed in figure 4 that highest water absorption (123%) was exhibited by particle board produced with the boiling process with 15% liquid adhesive. However, the lowest water absorption (110%) was shown by particle board prepared with 20% adhesive. The non boiling process resulted in the highest water absorption of 166% and lowest of 77% for 20% adhesive. On the average, water absorption was 117,61%.

Generally, higher temperature and a longer period of hot press process would result in lower water absorption [3]. However, it was not proven in this research. Water absorption result from particle board was improved as more adhesive was added. High water absorption value was affected by different particle used. There are some factors affecting water absorption of particle board, which is the natural characteristic of the board itself. Hygroscopic characteristic of fiber in the particle board caused the high water absorption value. This water absorption test was also conducted to gain the information on Development of thickness is particle board thickness improvement after 24 h immersion compared to initial thickness. The result shows that particle board prepared with 10% adhesive and through the boiling process would improve the thickness for 83.87% and 15% adhesive would improve the thickness for 44.67%. The non boiling process, on the other hand, resulted in 93.10% development of thickness for 10% adhesive. This value, however, does not meet the standard by JIS A 5908-2003 which require 12% development of thickness. From the graph, it is known that the addition of adhesive would improve the development of thickness. The ununiformed mixing of adhesive and fiber caused fragile fiber bond when water was mixed. In addition, the higher temperature and longer period of hot press process will cause lower development of thickness [4].

The particle board resistance to water this would be beneficial for its exterior or interior application. Based on the result, this particle board is preferred to be as interior application.

### 3.4. Development of thickness

However, the result shows that the development thickness was increased. An extractive compound in particle board will affect the quality of particle board itself. The empty palm bunches has high extractive compounds (14.9%). This high development of thickness revealed that the application of this particle board is not suitable for exterior application because of the low dimension standard of the product in a short period.
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### 3.5. Modulus of elasticity (MOE)

Modulus of elasticity defined as the ability of a material to hold elasticity without permanent deformation. The higher the MOE, the material will be stiffer and stronger to hold external weight. From the analysis, highest MOE was exhibited by particle board prepared with 20% adhesive and through boiling process 524.15 kg/cm$^2$ and the lowest MOE for particle board with 25% adhesive 182.79 kg/cm$^2$. For non boiling process, the highest MOE was achieved by particle board with 10% adhesive addition 298.18 kg/cm$^2$ and the lowest value was achieved by particle board with 15 and 20% adhesive, which was 69.81 kg/cm$^2$. MoE achieved in this study has not yet met the requirement by JIS A 5908 2003 20.000 kg/cm$^2$.

The addition of an adhesive to the material was found to mostly affect the MOE value. The higher amount of adhesive would lower the MOE value. Based on the average of boiling and non boiling process, the addition of 10% adhesive has the highest MoE value. This was in line that the optimum adhesive phenol formaldehyde was 5-7% from dry weight. The decrease in MOE value might also be caused by the ununiformity of the mixture.
3.6. Modulus of rupture (MOR)

Modulus of rupture on particle board shows the maximum loadable to be held by particle board per unit area until the particle become rupture. The result shows that highest MOR 10.13 kg/cm² were achieved by particle board with 10% adhesive addition, while the lowest value 4.84 kg/cm² by 25% adhesive addition for boiling process.

For now boiling process, the result shows that highest MOR 5.59 kg/cm² were achieved by particle board with 10% adhesive addition, while the lowest value 2.94 kg/cm² by 15% adhesive addition. Unfortunately, this value has not met the standard by JIS A 5908-2003 value 82 kg/cm². The relationship between MOR and boiling and not boiling process is shown on the following graph.

![Graph of the modulus of rupture and adhesive ratio.](image)

It can be stated that non boiling process achieved lower value than the boiling process. There are several factors affecting lower MOE result, such as ununiform particle size which would affect the particle distribution on the mat forming process. Furthermore, the bound between powder guava rod bark would be weak, thus decrease the MOR. The presence of an extractive compound in palm was also assumed to be one of the factors.

The addition of resin would produce stiffer and more stable board particle (Danarto, 2015). However, a recent study did not show the same conclusion since the addition of adhesive would cause the decrease in MOR value. Another factor revealed was the un-uniform distribution of adhesive on mat forming.

3.7. Internal bond

Internal bond defined as the adhesive power per unit area. Internal bond is the durability of particle board to rupture. The result shows the highest IB for boiling process was achieved by particle board with 10% and 20% adhesive addition 0.11 kg/cm² and the lowest value by 25% adhesive addition, that is 0.05 kg/cm².

For non boiling process, the highest IB was achieved by particle board with 10% adhesive 0.68 kg/cm² and the lowest IB 0.06 kg/cm² for 20% adhesive. Meanwhile, particle board with 15, 20, and 30% adhesive addition could not be analyzed because of the deformation of the fiber layer. The average value of the internal bond was 0.2282 kg/cm². This result has not fulfilled the requirement from JIS A 5908 (2003) for an internal bond of particle board 1.5 kg/cm². The result shows that the addition of adhesive to empty palm bunches fiber increased the IB of particle board.
Figure 8. Graph of internal bonding and adhesive ratio.

That lower might be caused by the high moisture content of empty palm bunches, thus in the hot press process, thermal distribution is insufficient to bake the adhesive agent in which the surface layer would receive more heat than the inside layer causing lower IB.

3.8. Screw holding power
Screw holding power defined as maximum force exposed to particle board per certain unit area until the screw was detached. The result shows that screw holding power for 30% adhesive addition was 15.75 kg which fulfilled the standard of JIS A 5908 [5,6].

Figure 9. Graph of screw is holding power and adhesive ratio.

The graph in figure 9 shows the relationship between the addition of adhesive and screw holding the power of particle board.

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5. Conclusions

- Particle board contains 15.7% lignin. The addition of 30% adhesive resulted density of 0.458 gr/cm³, moisture content 7.86%, water absorption 77.5%, development of thickness 79.69%, MOE 69.68 kg/cm², MOR 3.29 kg/cm², IB 0.0635 kg/cm², and hold screw strength 24.80 kg
- Based on the result, density, moisture content and hold screw strength has fulfilled the requirement of JIS A 5908-2003.

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