EXPERIMENTAL STUDY OF THE EFFECT OF VARIATIONS OF TAPIOCA, PVAC AND CITRIC ACID ADHESIVES ON PHYSICAL CHANGES OF PARTICLEBOARD

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ABSTRACT
The production of wood processing produces a large amount of wood powder waste, which can be reused to make particleboards . The study aims to see how the variation in the type of adhesive affects the physical and mechanical characteristics of teak wood powder-based particleboards. The particle board made in this study has a composition consisting of 60% teak wood powder and 40% adhesive material. The adhesive used pure tapioca flour, a mix of tapioca flour and citric acid (20% each), and a mix of tapioca flour and PVAc (20% each). The boards were formed using a hot press at 160°C and 3 MPa pressure. After fabrication particleboards and making test samples with SNI standards, particleboards are tested to determine their physical properties through density and moisture content (MC) tests, as well as mechanical properties that include modulus of elasticity (MOE) and modulus of fracture (MOR). The results obtained by all samples successfully met the JIS A 5908-2003 standard in terms of density and moisture content. However, for the MOE and MOR parameters, the test scores are not in accordance with these standards. Of the three variations, it can be seen that the mixture of tapioca flour and citric acid

produces the highest density, while the mixture of tapioca flour and PVAc shows the best performance in the MOR aspect. Based on these findings, it can be concluded that although all three types of adhesives are physically adequate, their mechanical strength still needs to be improved through further development.

Keywords: *citric acid, density, tapioca flour, teak wood, MC, MOE, MOR, particleboard, PVAc*

INTRODUCTION

Products derived from wood processing such as partike board, polywood, ketas, pencil and tissue have a very large market in the market. Particleboard and polywood are widely used in various fields ranging from room interiors, furniture, and as part of building construction. Particleboard itself is a wood-processed product derived from wood powder mixed with an adhesive, be it artificial or natural adhesive. One of the advantages of particleboard is that it is lightweight, easy to manufacture, flat and smooth surface, and flexible in interior design. From the advantages of particle board, there is a lot of market demand. This large market demand makes particle board one of the objects that many experiments are conducted to find better and more economical wood particle adhesives to improve the quality of particle board and reduce production costs. Currently, there are many materials that can be used as adhesives, whether it is obtained by natural processes or through the process of chemical reactions. Among the many substances that can be used as adhesives, in this study several types of adhesives will be used, namely tapioca flour, PVAc and citric acid.

As one of the adhesives used in this study, tapioca flour has been widely known in the community to be used in making foods such as cakes, besides that tapioca flour has an economical price and is easy to get. Tapioca flour itself is the result of processing cassava that contains starch by grinding it until it becomes smooth. The starch content in tapioca flour is quite high where there is amylose of 17% and amylopectin of 83%. This factor makes tapioca flour a better adhesive than other types of flour. Therefore, tapioca flour can be one of the alternatives that can be chosen as a tapestry material in the manufacture of particleboards.

In addition to tapioca flour, there are materials that can be used as adhesives for particleboards , including citric acid. Citric acid is an organic compound, tricarboxylic hydroxy acid, with three functional carboxylics. This tripletic compound undergoes three constant dissociations that allow it to form three types of salts and exhibit buffering properties. It is this buffering property that is the basis for citric acid to be the material for adhesives in particleboard. Citric acid itself can be found in plants, animal cells and fruits. Citric acid in crystalline form is divided into two forms, namely monohydrate and anhydrouss. Citric acid monohydrate is a citric acid that is crystallized in a cold solution at a temperature below 36.6oC which will form a colorless transparent crystal. While anhydrous citric acid is citric acid that crystallizes from a hot solution above 36.6oC, forming a white crystalline powder.

Furthermore, the type of adhesive used in this study is polyvinyl acetate (PVAc). PVAc or known in the community as white glue is a type of thermoplastic polymer that has long been used as an adhesive material. In addition, PVAc is a polymer that has very high adhesion characteristics so it is often used as the main material for the production of glue, fabric, paper and wood. PVAc is obtained from the process of polymerization of vinyl-acetate monomers by mass polymerization, solution polymerization, or emulsion polymerization. The thermoplastic properties of PVAc allow PVAc to melt when heated and to harden when cooled makes it chemically unchangeable. Due to this property, PVAc as a highly considered choice is highly considered to be an adhesive material in the manufacture of particleboard.

A. ADHESIVE FORMULATION AND PANEL FABRICATION PROCESS

The materials used in this study include tapioca flour, citric acid monohydrate, polyvinyl acetate (PVAc), and teak wood biomass powder. Tapioca flour was used as one of the primary adhesives in the particleboard formulation. Citric acid monohydrate, a weak organic acid commonly used as a cross-linking agent, was utilized in crystalline form and is characterized by its high water content, typically ranging from 60% to 75%. PVAc, a synthetic polymer adhesive, was also incorporated as a binder due to its strong bonding properties and compatibility with lignocellulosic materials.

Teak wood biomass powder served as the primary raw material for the particleboard matrix. The powder was sieved using a mesh size 10 to ensure uniform particle size distribution prior to processing. Supporting equipment included a washbasin for the mixing of raw materials and adhesives, an analytical balance with 0.01 g precision for accurate weighing, and a wooden mold measuring 27 cm × 27 cm for shaping the particleboard during pressing.

A hydraulic press machine was used to pre-compact the mixture, followed by a hydraulic hot press machine for heat curing under controlled temperature and pressure conditions. Pressing was conducted at a temperature of 160°C and a pressure of 30 kg/cm^2 (approximately 3 MPa), in accordance with previous studies. After pressing, the particleboards were cut using a jigsaw into sizes suitable for testing: 10 cm × 10 cm for density and MC analysis, and 5 cm × 20 cm for mechanical testing, including MOE and MOR. Mechanical testing was performed using a Universal Testing Machine (UTM), while a wood moisture meter was employed to assess the moisture content of the prepared samples.

The experimental procedure began with the preparation and drying of teak wood biomass powder, followed by sieving to ensure consistency in particle size. Three different adhesive formulations were used in the manufacture of the particleboards: (1) 40% tapioca flour, (2) a mixture of 20% tapioca flour and 20% citric acid, and (3) a mixture of 20% tapioca flour and 20% PVAc. In all formulations, the total mass of the composite was maintained at 490 grams, consisting of 60% teak wood powder (294 grams) and 40% adhesive (196 grams).

The raw materials were thoroughly mixed to form a homogeneous dough, which was then placed into a wooden mold for pre-pressing using a hydraulic press. The precompacted mixture was subsequently hot-pressed at 160°C under 30 kg/cm^2 of pressure to form solid particleboards. After pressing, the boards were conditioned at ambient temperature for five days to stabilize their physical and mechanical properties.

Once conditioning was complete, the particleboards were cut into standard sizes for physical and mechanical testing in accordance with national standards. The tests conducted included density and moisture content (MC) analysis, as well as evaluations of mechanical performance through MOE and MOR measurements. The final step involved analyzing the results to assess the quality and structural integrity of the particleboards produced.

B. EVALUATION STANDARDS AND TESTING PROTOCOLS

Testing was conducted based on the Japanese Industrial Standard JIS A 5908:2003 for particleboard evaluation. According to Japanese Industrial Standard, acceptable ranges for particleboard properties include a density of 0.5–0.9 g/cm^3, moisture content between 5% and 13%, a minimum MOE of 20,000 kgf/cm^2, and MOR values ranging from 82 to 184 kgf/cm^2.

1. Density

The density of the particle board can be determined by adding the weight of the sample and then dividing it by the volume of the sample, which is 10 cm x 10 cm x 1 cm x 1 cm. Density is calculated using the Equation (1).

$$K = \frac{B}{V} \qquad (1)$$

Where

K = Density (g/cm^2)

B = Dry weight (g)

V = Dry volume (cm^2)

2. MC

In the MC test, particleboards use a measuring device called a wood moisture meter. The measurement procedure follows how to use a wood moisture meter, namely by inserting the sensor into the side of the particleboard sample made with a size following the SNI test standard of 10 cm x

10 cm x 1 cm.

3. **MOE**

To find the value of the modulus of elasticity, a sample measuring 2 cm x 10 cm x 1cm was used which will be tested on the universla testing machine. The MOE value can be obtained using the Equation (2).

$$MOE = \frac{\Delta pL^3}{4\,\Delta ybh^3} \quad (2)$$

Where

MOE = modulus of elasticity (kgf/cm^2)

P = load to proportional limit (kg)

L = length of the test sample span

Δy = change in deflection per change in load (cm)

b = test sample width (cm)

h = test sample thickness (cm)

4. **Modulus of Rupture (MOR)**

To obtain the value of the modulus of rigid, a sample with a size of 5 cm x 20 cm x 1 cm is required. Samples are tested using a universal testing machine. The MOR value can be searched using the Equation (3).

$$MOR = \frac{3pL}{2bh^3} \quad (3)$$

Where:

MOR = modulus of stiffness (kgf/cm^2)

p = maximum load weight (kg)

L = test sample span length (cm)

b = test sample width (cm)

h = test sample thickness (cm)

C. PHYSICAL PROPERTIES ANALYSIS OF PARTICLE BOARD

In the density test, data can be seen in Table 1, that were obtained quite varied with the smallest value being 0.51 g/cm^2 to 0.59 g/cm^2. The highest density value is owned by particle board with a mixture of tapioca flour and citric acid adhesive type while the lowest density value is owned by particle board with tapioca flour adhesive type. The results of the density test showed that all variables met the JIS A 5908-2003 standard which requires the density of a good particle board to be 0.5 – 0.9 g/cm^2.

Table 1. Particle board sample density test results

No	Types of Adhesives	Average density (g/cm^2)
1.	Tapioca Flour (40%)	0,51
2.	Tapioca Flour (20%) + Citric Acid (20%)	0,59
3.	Tapioca Flour (20%) + PVAc (20%)	0,52

The test results using the wood moisture meter showed in Table 2, MC value are 5% – 5.37%. The value with the highest moisture content can be found in the type of tapioca flour adhesive because tapioca flour needs water as an intermediate so that it can be used as a particle board adhesive. This water use is what causes the high moisture content in the particleboard. In other particle board variations the water function is replaced by citric acid and PVAc. According to the JIS A 5908-2003 standard for MC or the moisture content in the particle board is 5% to 13%. So the MC of the particle board that has been made has met the JIS standard.

Table 2. MC particle board sample test results

No	Types of Adhesives	Average MC (%)
1.	Tapioca Flour (40%)	5,37%
2.	Tapioca Flour (20%) + Citric Acid (20%)	5,25%
3.	Tapioca Flour (20%) + PVAc (20%)	5%

D. MECHANICAL PROPERTIES ANALYSIS OF PARTICLEBOARD

The value of MOE of the particle board tested using a universal testsing machine showed in a Table 3 with value of 2,818.8 kgf/cm^2 to 3,946.4 kgf/cm^2. Particleboard with tapioca flour adhesive mixture and PVAc has the smallest MOE value and particleboard with tapioca flour and citric acid mixture has the greatest value. The JIS A 5809-2003 standard says that the MOE of the particle board is above 20,000 kgf/cm^2, so it can be said that all the variations of particle board that have been made do not meet the MOE value requirements.

Table 3. Hasil uji MOE sampel papan partikel

No	Types of Adhesives	Average MOE (kgf/cm^2)
1.	Tapioca Flour (40%)	3.140
2.	Tapioca Flour (20%) + Citric Acid (20%)	3.946,4
3.	Tapioca Flour (20%) + PVAc (20%)	2.818,8

The results of the MORtest as can be seen in Table 4. The MOR value of the particle board obtained ranged from 37.23 kgf/cm^2 to 42.63 kgf/cm^2. Particle board with tapioca adhesive has the smallest MOR of the three particleboards made and particle board with tapioca flour and PVAc mixture adhesive has the largest MOR. The MOR value requirements according to the JIS A 5809-2003 standard for particleboards are valued at 82 kgf/cm^2 to 184 kgf/cm^2. So in this study, the MOR of the particle board made did not meet the JIS A5809-2003 standard.

Table 4. MOR test results particle board sample

No	Types of Adhesives	Average MOR (kgf/cm^2)
1.	Tapioca Flour (40%)	37,23
2.	Tapioca Flour (20%) + Citric Acid (20%)	40,38
3.	Tapioca Flour (20%) + PVAc (20%)	42,63

CONCLUSION

From the results of this study, it can be concluded that the physical properties of particle board with variations of tapioca flour, citric acid, and PVAC adhesives have a density of 0.51 g/cm^2, 0.59 g/cm^2 and 0.52 g/cm^2 with MC of 5.37%, 5.25%, and 5% respectively starting from tapioca flour adhesives, citric acid and tapioca, and PVAc and tapioca which all meet the requirements of the JIS A 5809-2003 standard. The physical resistance of this particle board includes MOE of 3,140 kgf/cm^2, 3,946.4 kgf/cm^2 and 2,818.8 kgf/cm^2 while for MOR 37.23 kgf/cm^2, 40.38 kgf/cm^2 and 42.63 kgf/cm^2. The physical resistance of the particles in this study did not meet the requirements of the JIS A 5809-2003 standard. From this study, it can be concluded that particleboards with variations of tapioca flour, citric acid, and PVAc adhesives can still be conducted further research to make MOE and MOR tests can meet the JIS 5809-2003 standard for particleboards.

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