The investigation of physical dan mechanical properties of Nipah-based particle board

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Abstract: The excessive use of wood as a raw material in furniture industries has raised environmental concerns that have attracted the attention of many individuals. Consequently, various innovations have been explored in developing alternative materials for the furniture industry. One promising resource that has the potential to be developed as a raw material for furniture applications is Nipah palm husk. Nipah palm husk is classified as an agricultural waste that is barely used within society and industries. Hence, in this study, Nipah palm husk will be utilized as the primary material to fabricate particle board by involving tapioca as an adhesive. This research aimed to investigate the effect of tapioca concentrations on water absorption, modulus elasticity, modulus of rupture, and screw-holding strength of the produced Nipah palm husk particleboard. The results of this study showed that the particle board produced with a 40% tapioca adhesive concentration exhibited the most favorable physical and mechanical properties with a water absorption rate of 25%, an elastic modulus of 21188.93 kg/cm^2, a modulus of rupture of 55.53 kg/cm^2, and a screw holding power of 7.53 kg. The findings indicated that Nipah-based particle board has the potential to be developed as an alternative for the furniture industry.

Keywords: Biodegradable material; renewable material; physical properties; elasticity rupture; absorption; screw holding power.

1. Introduction

Particleboard, a manufactured wood product used in furniture-making, is created by bonding wood particles or other lignocellulose-rich materials with adhesives and subsequently treated by pressing them [1], [2]. These wood particles or powders possess chemical components that is identical to wood, such as lignin, cellulose, silica, and ash content [3], [4]. Among the lignocellulose-rich plants, Nipah palm husk has the potential to be used as a substitute material for particleboard production. Nipah palm, scientifically known as the *Nipah fruicans Wurmb*, normally thrives in coastal mangrove forests. Currently, the local community has limited use of the plant leaves for roofing and food wrapping, the sticks for firewood, and the fruit for beverage production. The Nipah palm husk contains fibers that can be utilized as reinforcing materials for natural fiber-reinforced composites or particleboard manufacturing. The innovation of this breakthrough can enhance the economic value of the Nipah palm husk. Hence, Nipah palm husk was utilized in this study as the main material for particle board production by transforming agricultural waste into a high value-added product. However, the particleboard should meet the required criteria and properties for furniture applications, such as an adequate design, suitable manufacturing technique, especially of elements in direct contact [5]. Hence, further studies need to be done to achieve the desired characteristics.

In order to increase the value of this agricultural waste, the fibers of Nipah palm husk should be processed into engineered materials for particleboard production through technological processes. Therefore, it can elevate the economic value of the produced product from waste material [6]–[9]. Currently, the development of particleboard is still limited due to the problem of high water content in natural fibers, especially cellulose fibers [10]. Numerous research related to the utilization of plant waste in particleboard production has been extensively conducted which has resulted in excellent properties. For instance, research has been carried out regarding the use of tea leaf waste as an alternative material, either independently or in combination with other wood particles, for particleboard production [11], [12]. In addition, particleboard material based on Nipah palm husk leaves has also been conducted and showed good tensile properties. However, only a few studies which reported the most appropriate mixture formula of Nipah-based particleboard to maintain its flexural strength [13], [14].

Prior to the utilization of Nipah-based particleboard for furniture applications, an evaluation of the quality characteristics of the particleboard is required. The information on the characteristics of the produced particleboard will be used as a reference for the furniture industry in using particleboard made from Nipah Palm fiber. Previous research reported that Nipah-based particleboard was successfully made by using tapioca as an adhesive in a ratio of 60:40 [15]. It was found that particleboard made from Nipah Palm fiber with tapioca adhesive have a density of 1.15 g/cm³, a moisture content of 5.8%, and swelling in thickness after immersion in water of 4.43% [16]. However, further research regarding other properties of Nipah-based particleboards, like water absorption, elastic modulus, rupture strength, and screw-holding power needed to be investigated in order to meet the required standards.

2. Material dan methods

2.1 Fabrication of Nipah-based particle board

The fabrication process of Nipah-based particleboard is illustrated in Figure 1. Firstly, Nipah fruits were harvested from a local plantation, and the husk of the fruits was removed to acquire its fibers. Then, the fibers were dried and ground into powder form. The Nipah powder was mixed with tapioca as its adhesive. Afterward, the mixture of these two materials was molded and subjected to cold compression at a pressure of 100 kg/cm^2, and then followed by hot pressing at a temperature of 120°C and a pressure of 100 kg/cm^2 for one hour.

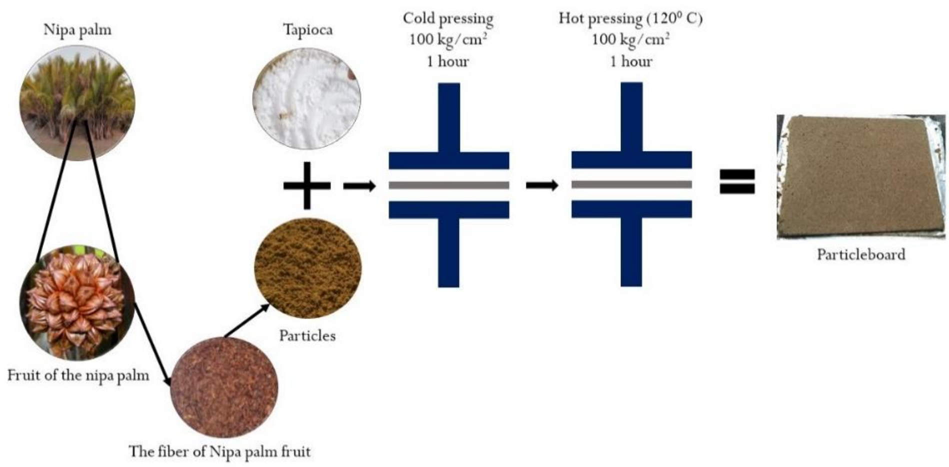

Figure 1: The fabrication of Nipah-based particle board

2.2 Water absorption test

A water absorption (Wa) test was conducted to investigate the ability of particle boards to absorb water during a 24-hour immersion. Test specimens were prepared with dimensions of 5 cm x 5 cm. The weight differences of the test specimen after immersion (b_2) and before immersion (b_1) were measured, and then the percentage of water absorption was calculated using Eq. (1).

$$\mathrm{Wa} = \frac{b_2 - b_1}{b_1} X\ 100\% \tag{1}$$

2.3 Tripoint bending test

The modulus of elasticity (MoE) and modulus of rupture (MoR) of Nipah-based particleboard were determined by the tripoint bending method, as can be seen in Fig. 3.

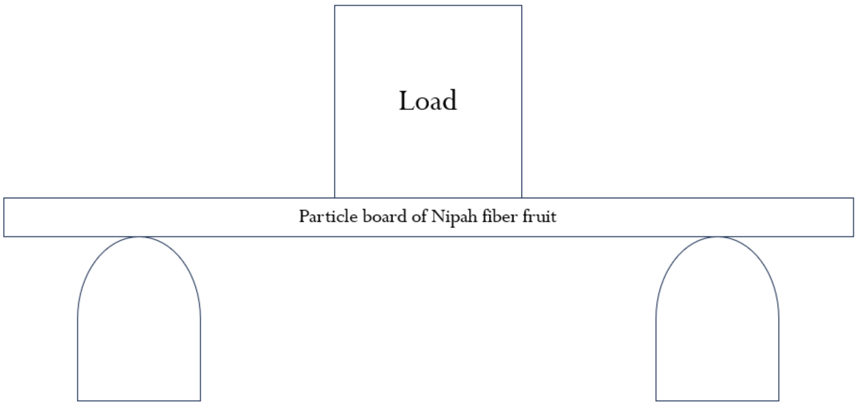

Figure 2: The scheme of tripoint bending test of Nipah-based particle board

The test samples of the Nipah-based particleboard were prepared in a size of 5 cm × 20 cm. The test was performed at various parameters, including the applied load (P), sample dimensions (length L, thickness h, and width b), and the deflection exhibited by the specimens (y). The modulus of elasticity and modulus of rupture were calculated using Equation (2) and Equation (3), respectively.

$$\mathrm{MoE} = \frac{P.L^3}{4.y.b.h^3} \tag{2}$$

$$\mathrm{MoR} = \frac{3.P.L}{2.b.h^2} \tag{3}$$

2.4 Screw-holding power

Test specimens were prepared in a length of 10 cm, width of 5 cm, and thickness of 12 mm. The measurement of screw holding strength involved the installation of a screw with a diameter of 2 mm and a length of 10 mm. Subsequently, the particleboard was subjected to a loading using the screw to determine its load-bearing capacity.

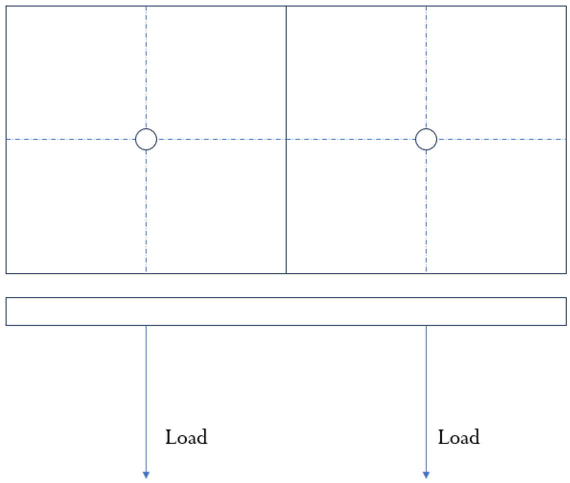

Figure 3: The scheme of screw holding power test of Nipah-based particleboard

3. Results and discussion

3.1 Water absorption Test

Water absorption is a crucial characteristic parameter of a particleboard, which indicates its ability to absorb water. The water absorption values of Nipah-based particleboard are depicted in Figure 4. The highest water absorption value was observed in the sample of 90%:10% fraction by around 150%, with lowest tapioca addition. Meanwhile, the lowest water absorption value was in the sample with a 60%:40% fraction by 25%, which was the sample with the highest tapioca content. However, the water absorption characteristic of the produced Nipah-based particleboard still needs to meet the required standard set by JIS A 5908.

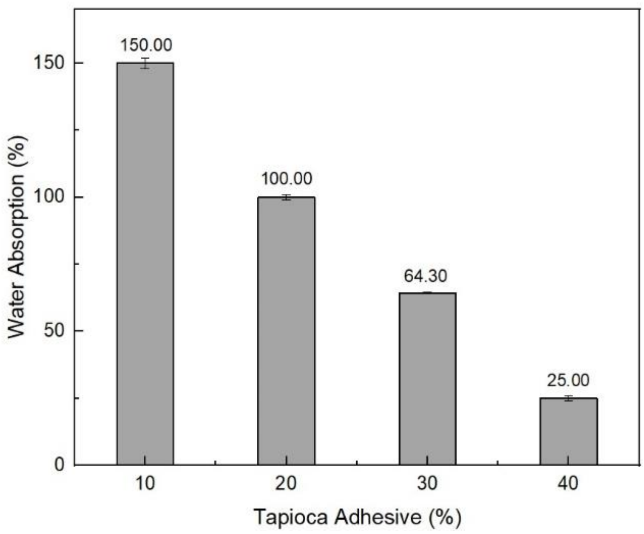

Figure 4: The water absorption percentage of Nipah-based particle board

The test results of Nipah-based particleboard with lower adhesive content have the tendency to absorb more water. This is possibly due to the increase of voids' size within the particleboard, leading to a reduction in the binding force between the particles. Furthermore, the sample with a high-water absorption percentage significantly affected the thickness of the particleboard. Therefore, this characteristic plays a crucial role in determining the compatibility of particleboard for various applications. Furthermore, particleboards with low water absorption can be employed for exterior furniture, while those with high water absorption are best suited for interior furniture.

3.2 Modulus of Elasticity

The Modulus of Elasticity (MoE) is a characteristic of a particleboard's ability to resist changes in shape due to applied loads and is directly related to its elasticity. A higher MoE value indicates more excellent elasticity. The MoE of the produced particleboards is presented in Figure 5. The test results showed that the average MoE of Nipah-based particleboards was in the range of 15,854.96 - 21,188.93 kg/cm². According to the JIS A 5908 standard, the minimum requirement of MoE for particleboard is 20,400 kg/cm².Hence, the result indicated that the particleboard with a variation of 60%:40% was found to fulfill the JIS A 5908 standard. In addition, with the increase of adhesive concentrations used, the MoE of the produced particleboards also increased. The particleboards with higher densities had the tendency to produce higher MoE values [17], [18]. Thus, it can be concluded that the Nipah-based particleboard with a variation of 60%:40% is suitable for interior furniture applications.

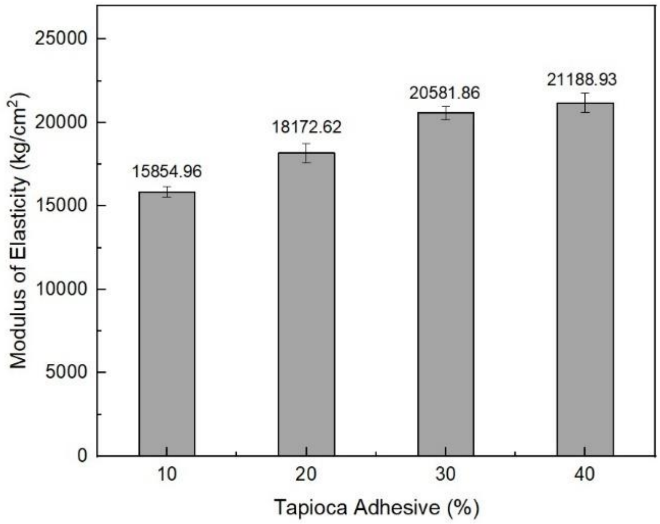

Figure 5: Modulus of Elasticity of Nipah-based particleboards at various tapioca concentrations

3.3 Modulus of Rupture

The modulus of rupture (MoR) is considered one of the essential properties of particleboard, which indicates the ability of the material to withstand a load until failure. This mechanical property significantly impacts the suitability of a particleboard for use within its application. According to the data obtained, the optimum modulus of rupture produced from Nipah-based particleboard was the sample with 40% tapioca concentration by around 55.53 kg/cm², as can be seen in Figure 6. However, the result indicated that the particleboard did not meet the required standard according to the JIS A 5908, which required a minimum modulus of rupture of 82 kg/cm². Furthermore, the result showed that the addition of tapioca adhesive influenced the strength of the Nipah-based particleboard. The higher the adhesive content, the higher the modulus of rupture obtained. In addition, the previous study also showed similar results to the present study [19], [20].

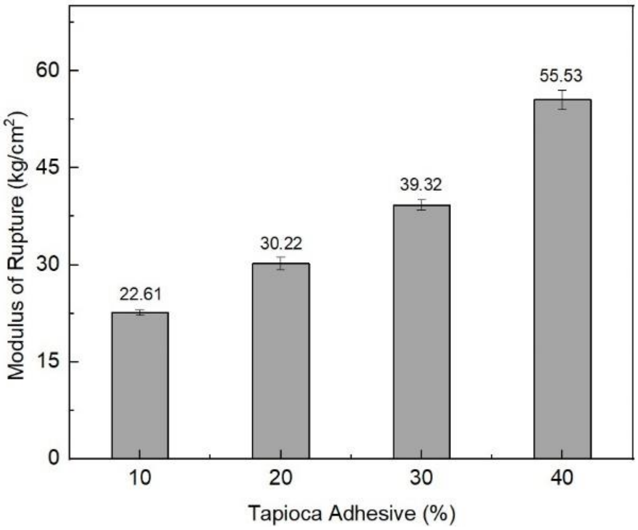

Figure 6: Modulus of Rupture of Nipah-based particleboards at various tapioca concentrations

3.4 Screw-holding power

The screw-holding strength values of Nipah-based particleboard are depicted in Figure 7. The highest screw holding strength was observed in Nipah-based particleboard with a variation of 60%:40% by around 7.53 kg, while the lowest screw-holding strength the one with a variation of 90%:10% with a modulus of rupture of 1.10 kg. However, according to the JIS A5908 standard, the minimum requirement for screw holding strength for particleboard is 30 kg. Thus, the results showed that the Nipah-based particleboard did not meet the required standard. In addition, Nipah-based particleboard with higher density exhibited a greater screw-holding strength which indicated that the screw-holding strength was significantly affected by the density of the particleboard. Moreover, the produced Nipah-based particleboards were assigned to the category of medium-density particleboard, which became a contributing factor to the ineligibility of the particleboard to meet the required standard.

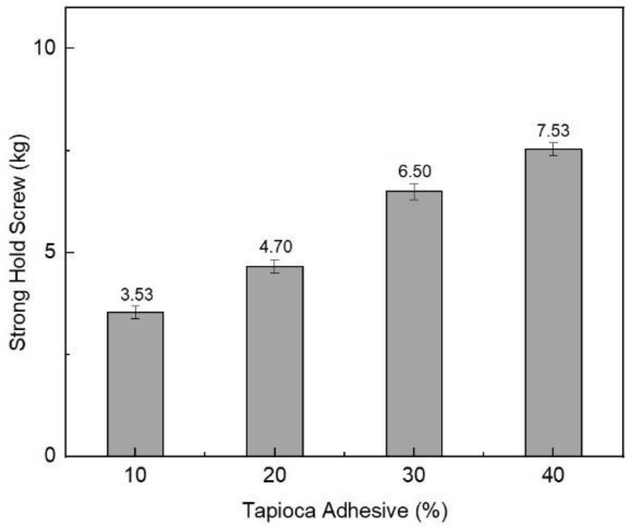

Figure 7: Screw-holding power of Nipah-based particleboards at various tapioca concentrations

The test result indicated that a higher adhesive content led to a lower minimum water absorption value in Nipah-based particleboard. In addition, the optimum modulus of elasticity obtained was 21,188.93 kg/cm^2 from the Nipah-based particleboard with a variation of 60:40, which was the addition of 40% tapioca adhesive. The strength of Nipah-based particleboard was influenced by the concentration and the type of adhesive used within the particleboard [15], [21]. Based on the results obtained, Nipah-based particleboard with a variation of 60:40 (40% tapioca concentration) can be used as a raw material for interior furniture, particularly for furniture that is not exposed to water or humid environments. Therefore, Nipah-based particleboard using tapioca adhesive has the potential to be used as a raw material for interior furniture production.

4. Conclusion

This research has successfully produced Nipah-based particleboard at various tapioca concentrations as its adhesive with specific characteristics. The particleboard with 40% tapioca adhesive exhibited the most optimum physical and mechanical properties with a water absorption of 25%, a modulus of elasticity of 21,188.93 kg/cm^2, a modulus of rupture of 55.53 kg/cm^2, and a screw holding strength of 7.53 kg. The results indicated that the water absorption and the modulus of elasticity met the required standards according to JIS A 5908. Meanwhile, the modulus of rupture and screw-holding strength of the produced Nipah-based particleboard did not meet the required standard. Hence, further studies are needed to be conducted to identify the most suitable adhesive type for Nipah-based particleboard. However, this research generally showed that Nipah-based particleboard with the use of tapioca adhesive has the potential for further development and improvement in furniture applications.

Author contribution

Hendri Nurdin: Writing - original draft, writing -review & editing. Waskito: Conceptualization, visualization and formal analysis. Anna Niska Fauza: Writing - review editing, conceptualization, formal analysis and investigation. Batu Mahadi Siregar: Investigation and resources. Bagdaulet Kenzhaliyevich Kenzhaliyev: Writing -review & editing and investigation.

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Competing interest

The authors declare that we have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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