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CHARACTERISTICS OF PARTICLE BOARD USING MAHOGANY TANNIN ADHESIVE WITH STARCH EXTENDER

Karakteristik Papan Partikel Menggunakan Perekat Tanin Mahoni Dengan Ekstender Pati

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ABSTRACT

The adhesive industry in Indonesia, which still relies on synthetic adhesives, requires other alternative materials such as tannin from mahogany bark (*Swietenia macrophylla* King) for sustainability. Still, the weakness of the adhesive power of mahogany tannin adhesives is overcome by adding starch as an extender, which effectively increases viscosity so that it is flexible in its use. This study aimed to determine the characteristics of particleboard bonded using mahogany tannin adhesive plus starch extender. The particles used came from mangium wood (*Acacia mangium*), which was then bonded using mahogany tannin adhesive (TRF) with the addition of 2 concentrations of starch extender, 10% and 20%. The size of the particleboard produced was 25 cm x 25 cm x 1 cm (each in the dimensions of length, width, and thickness). Physical and mechanical property testing was carried out based on SNI 03-2105-2006. The results showed that the higher the concentration of starch extender addition to the TRF adhesive, the higher the internal bond value, as well as the thickness expansion of the resulting particleboard.

Keywords: Particle Board; Mahogany Tannin Adhesive (*Swietenia macrophylla*), Starch Extender.

ABSTRAK

Industri perekat di Indonesia yang masih bergantung pada perekat sintetis memerlukan alternatif bahan lain yang lebih berkelanjutan, seperti tanin dari kulit kayu mahoni (*Swietenia macrophylla* King). Namun, kelemahan daya rekat dari perekat tanin mahoni dapat diatasi dengan penambahan pati sebagai ekstender, yang secara efektif meningkatkan viskositas sehingga lebih fleksibel dalam penggunaannya. Tujuan dari penelitian ini adalah untuk mendeterminasi karakteristik papan partikel yang direkat menggunakan perekat tanin mahoni ditambah ekstender pati. Partikel yang digunakan berasal dari kayu mangium (*Acacia mangium*), yang kemudian direkat menggunakan perekat tanin mahoni (TRF) dengan tambahan 2 konsentrasi ekstender pati, 10% dan 20%. Ukuran papan partikel yang dihasilkan adalah 25 cm x 25 cm x 1 cm (masing-masing pada dimensi Panjang, lebar, dan tebalnya). Pengujian sifat fisis dan mekanis dilakukan berdasarkan SNI 03-2105-2006. Hasil penelitian menunjukkan bahwa semakin tinggi konsentrasi penambahan ekstender pati pada perekat TRF meningkatkan nilai keteguhan rekat namun turut meningkatkan pengembangan tebal dari papan partikel yang dihasilkan.

Kata kunci: Papan Partikel; Perekat Tanin Mahoni (*Swietenia macrophylla*); Ekstender Pati.

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A. INTRODUCTION

The supply of timber in Indonesia is now shifting from natural forests to plantation forests, both industrial plantation forests and community plantation forests. As much as 96.04% of the wood supply comes from plantation forests from all forest areas in Indonesia (Ministry of Environment and Forestry 2023). Plantation forests are dominated by fast-growing wood species such as sengon (*Falcataria moluccana*), jabon (*Anthocephalus cadamba*), pine (*Pinus merkusii*), and mangium (*Acacia mangium*), which have a cutting rotation of around 5-10 years and a diameter of less than 30 cm and have a specific gravity of 0.4–0.7 (Hadi *et al.* 2020). Fast-growing wood species also have inferior quality compared to wood from natural forests. Timber from plantation forests has more juvenile parts, so it has a low density, which results in the wood having low MOE and MOR values (Hendrik *et al.* 2019). Therefore, one of the efforts to increase the utilization of this fast-growing wood is to use it as a raw material in the manufacture of composite products.

The use of natural adhesives as a substitute for synthetic adhesives in the manufacture of biocomposite products continues to concern world researchers (Lestari *et al.* 2025). Natural adhesives are renewable and abundantly available in nature, which are expected to help the biocomposite product manufacturing industry such as particle board in solving the problem of shortages and rising prices of adhesive raw materials as a result of the dwindling supply of petroleum which is the main raw material in the manufacture of synthetic adhesives (Widyorini and Nugraha 2015).

Research related to adhesives with renewable raw materials, such as tannin, has been widely conducted. In Indonesia, tannin extracts that have been utilized come from Intsia bijuga bark in wood flooring products (Santoso *et al.* 2014), Acacia mangium bark for cross-laminated timber products (Hendrik *et al.* 2019), and the latest research is using tannin extract from mahogany bark (*Swietenia mahagony*) in glued-laminated timber products, with results showing that the quality of mahogany tannin adhesive is the same as synthetic PRF adhesive (Lestari *et al.* 2018). This success is the basis for developing the use of mahogany tannin adhesive in other composite products, namely particle boards, which have different production techniques from glulam products. However, mahogany adhesive has a low viscosity of 130 Cps (Lestari *et al.* 2019), where the viscosity requirements for particle board adhesives according to SNI 06-4567-1998 range from 200-300 (Cps).

Increasing viscosity can be done by adding an extender to the adhesive (Yusmaniar *et al.* 2023). The extender commonly used is starch. Starch is a natural polymer that is widely used due to its easy availability and relatively low cost (Jiang *et al.* 2020). The purpose of this study was to identify the characteristics (physical and mechanical properties) of particleboard using mahogany tannin adhesive with the addition of starch extender.

B. METHODS

Research Tools and Materials

The tools used in this study include an oven, a desiccator, a pH-meter, a viscometer, electric scales, measuring cups, calipers, and a Universal Testing Machine. Meanwhile, the raw materials used in this study are acacia (*Acacia mangium*) wood, mahogany (*Swietenia macrophylla* King) tannin adhesive, and phenol formaldehyde adhesive.

Particle Board Manufacturing

The wood particles used are acacia wood particles (*Acacia mangium*) with a water content of around 10%. The particle board made is 25 cm x 25 cm x 1 cm in size with a target density of 0.7 g/cm^3 using mahogany tannin adhesive (TRF) with the addition of 10% (MA) and 20% (MB) starch extender and PF adhesive as a comparison (MP), each with 5 repetitions. Pressed using a hot pressing machine with a pressing time of 10 minutes, a pressing temperature of 110 ^{o}C, and a pressing pressure of 25 kg/cm^2. The board is conditioned by stacking using stickers and is placed indoors for 14 days.

Physical and Mechanical Properties Testing

Characterization of physical properties carried out on the particle board that has been produced includes moisture content and density tests. The characterization of mechanical properties includes internal bond tests, modulus of rupture (MOR), modulus of elasticity (MOE), and thickness swelling tests. All of these tests are based on SNI 03-2105-2006.

Data Analysis

This study used a completely randomized design (CRD) with adhesive treatment factors. If a significant difference exists, further testing is carried out using Duncan's multirange test.

C. RESULTS AND DISCUSSION

Physical Properties of Particleboard

1. Moisture Content

Moisture content is a physical property measured after going through a drying process in an oven. Water content describes the amount of water present in particleboard when in equilibrium with its surroundings (Dukarska *et al.* 2021). The test results that have been carried out show that the moisture content of particleboard ranges from 11.1% to 12.0% (shown in Figure 1). The moisture content value in each treatment as a whole has been in accordance with the criteria of SNI 03-2105-2006, which ranges from <14%. The moisture content of the raw materials influences the amount of moisture in particleboard. According to Sijabat *et al.* (2017), the moisture content of particleboard is influenced by the moisture content of the raw materials that form it; the higher the moisture content of the raw materials, the higher the moisture content of the particleboard produced. The moisture content of composite boards is highly dependent on the surrounding air conditions because composite raw materials contain hygroscopic lignocellulose. Besides, the analysis of variance results (Table 1) show no significant difference between the three types of adhesives on the moisture content of the particleboard produced.

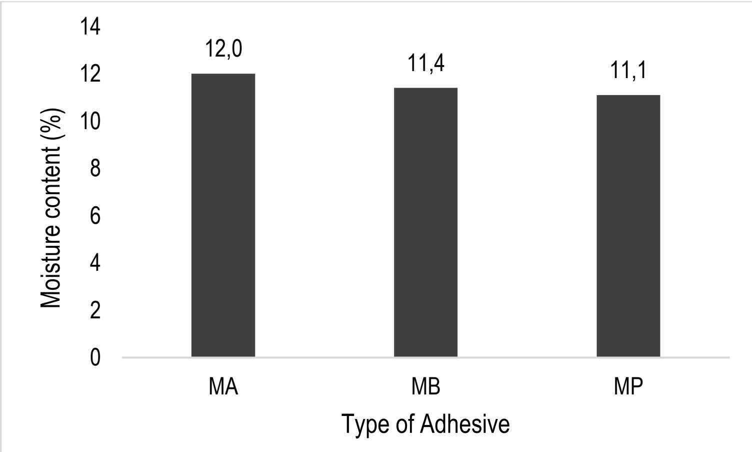

Figure 1. Particleboard moisture content test result

Table 1. ANOVA test results of the physical and mechanical properties of particle board

Test Parameters	Type of Adhesive
Density	NS
Moisture content	NS
MOR	*
MOE	*
Thickness Swelling	*

Note: *Significant difference (*p-value* ≤ 0.01); NS = Not significant difference

2. Density

Density is very important in determining the quality and physical properties of particleboard. The physical property of density is measured to understand how dense a material, in this case particleboard, is. In Figure 2 above, it can be seen that the density value of the particle board is in the range of 0.78 g/cm^3 to 0.80 g/cm^3. The density value of all particle boards produced fulfilled the standard of SNI 03-2105-2006, which is between 0.40 and 0.90 g/cm^3. The use of TRF adhesive with the addition of 20% starch developer has a high density value compared to other boards. According to Mirza *et al.* (2020), high and low density values are influenced by the raw materials and the pressure applied during the pressing process, so that this can cause varying density values.

However, based on the diversity analysis results (Table 1), there is no significant difference between particle boards using TRF adhesive with 10% starch developer, TRF with 20% starch developer, and PF adhesive. This phenomenon occurs because the density of the particle board is influenced by the density of the type of wood used. According to Auliarta *et al.* (2021), the density of acacia wood is in the range of 0.40-0.80 g/cm^3. This result indicates that the density value is not much different from the density of the particle board produced in this study. In addition, in the manufacture of particle boards, the proportion of wood particles and TRF adhesive used in each treatment is the same, so the weight of the particle board is almost the same.

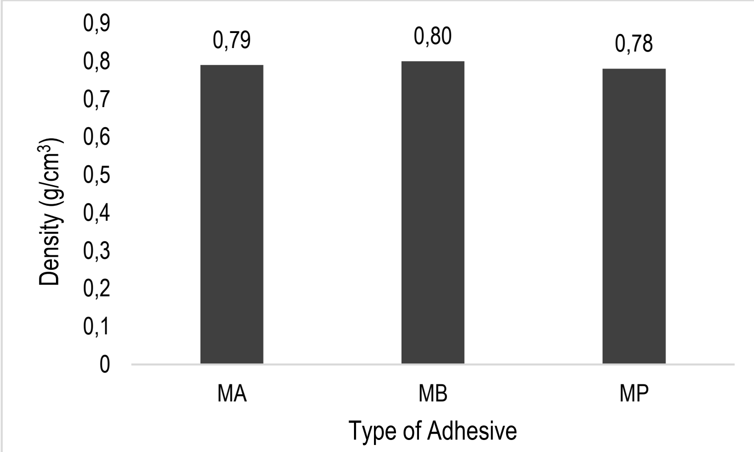

Figure 2. Particleboard density test result

3. Thickness Swelling

Thickness swelling of particleboard is one of the important physical properties used to evaluate the quality and performance of particleboard, especially under different environmental conditions. Thickness swelling measures the change in thickness of particleboard when exposed to moisture or water (Radam *et al.* 2018). The results of particle board testing (Figure 3) showed that after being soaked for 24 hours, the particle board experienced thickness expansion ranging from 18.69% to 47.62%. The manufacture of this particle board used type 24-10 with a thickness of ≤ 12.7 mm. Only the thickness expansion value of the particle board using PF adhesive met the criteria of SNI 03-2105-2006, with a thickness expansion below 25%. The highest percentage of thickness expansion was found in the particle board on TRF adhesive with an additional extender of 20%. The analysis of variance (Table 1) showed that there was a very significant difference between the three types of adhesives used. After further testing using Duncan's multirange test (Table 2), it was seen that the thickness expansion value of the particle board using PF adhesive had the lowest value compared to the other two types of adhesives. The results obtained indicate that the higher the percentage of starch extender addition, the higher the percentage of thickness expansion.

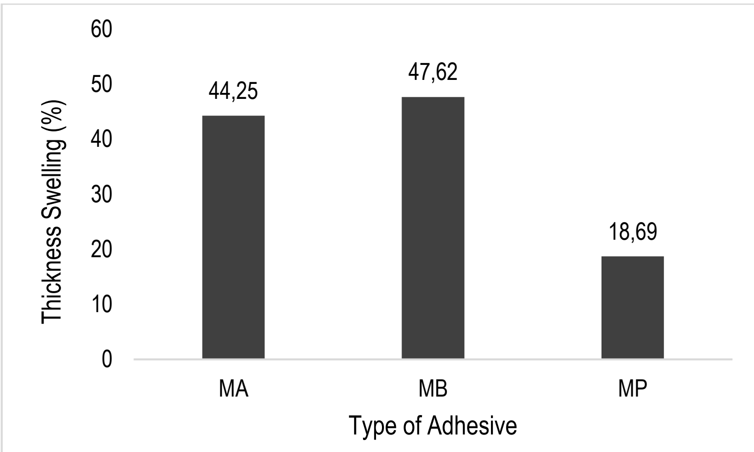

Figure 3. Particleboard thickness swelling test result

Mechanical Properties of Particleboard

1. Internal Bond

Internal Bond is the tensile strength perpendicular to the surface of the particleboard sheet. From the internal bond value, conclusions can be drawn about the bond strength between particles and the adhesive. So that the internal bond can also be used as a good indicator in determining the quality of the particleboard sheets produced (Reh *et al.* 2024). The internal bond values shown in Figure 4 range from 1.12 kg/cm^2 to 12.20 kg/cm^2. The smallest bond strength is produced on particleboard using TRF adhesive with an additional extender concentration of 10%. Based on SNI 03-2105-2006, the bond strength requirement for the ordinary particleboard category with type-8 has a minimum value of 1.5 kg/cm^2. Thus, the particleboard products produced using TRF adhesive with 20% starch extender and PF adhesive meet the standards.

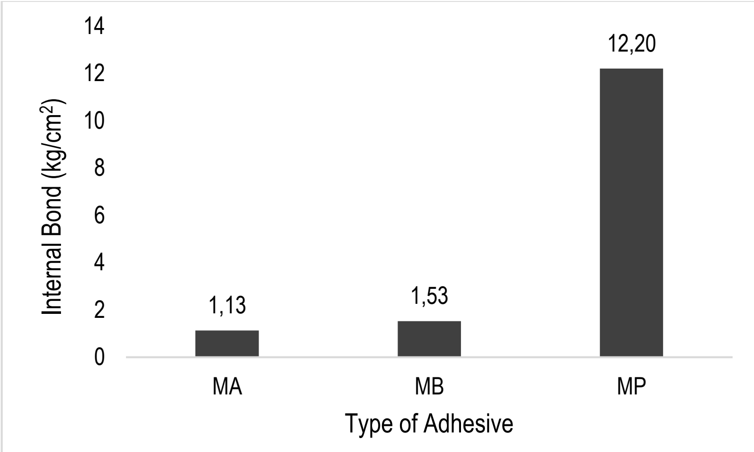

Figure 4. Particleboard internal bond test result

Table 2. Duncan's multirange test

Type of Adhesive	Thickness Swelling	Internal bond	MOR	MOE
TRF Starch 10% (MA)	44.25[b]	1.13[a]	54.8[a*]	7262.8[a]
TRF Starch 20% (MB)	47.62[b]	1.53[a]	65.0[a]	10727.6[b]
PF (MP)	18.69[a]	12.20[b]	135.4[b]	14648.2[c]

Note: *The same letters in the same column do not differ significantly

The results of the analysis of variance (Table 1) show that there are very significant differences between the three types of adhesives used. Furthermore, the results of further tests (Table 2) show that PF adhesive has a different bond strength value (with the highest value) compared to the other two types of adhesives. This phenomenon can be caused by mahogany tannin adhesive, after being given the addition of starch extender, which is still less suitable for medium to high-density wood. The results of Lestari *et al.* (2019) stated that TRF adhesive is more suitable for low-density wood than for high-density wood.

2. Modulus of Rupture (MOR)

Modulus of Rupture (MOR) is one of the important mechanical properties to evaluate the fracture strength of particleboard. MOR measures the maximum force that particleboard can withstand before breaking when subjected to a bending load (Desiasni *et al.* 2023). The test results in Figure 5 show that each particle board's fracture toughness (MOR) value is in the range of 55 to 132 kg/cm^2. The MOR value of particle board using PF adhesive meets the requirements of SNI 03-2105-2006, with a fracture toughness value of more than 82 kg/cm^2, in the category of type-8 ordinary particle board. The analysis of variance results (Table 1) show that the fracture toughness between the three types of particle board has a very significant difference, with the value of particle board using PF adhesive having the highest value (Table 2). Meanwhile, the results of further tests (Table 2) also show that the two TRF adhesives are not significantly different.

3. Modulus of Elasticity (MOE)

Modulus of Elasticity (MOE) is one of the mechanical properties used to evaluate the stiffness and elasticity of particleboard. MOE measures the ability of a material to undergo elastic deformation when subjected to a load, namely how far the material can bend before reaching its elastic limit (Li et al, 2024). Figure 6 is a diagram of the flexural strength (MOE) produced by particleboard. The range of MOE values for particleboard is 0.73 x 104 kg/cm^2 to 1.46 x 104 kg/cm^2. The flexural strength of TRF adhesive with a starch extender concentration of 20% is lower than that of particleboard from the other two types of adhesives. However, based on SNI 03-2105-2006 with the type of ordinary particleboard type-8, the overall MOE value does not fall within the criteria with a minimum value of 2.04 x 104 kg/cm². This indicates that the resulting particleboard cannot be used as a product for high loads. Nurhilal, (2017). The level of elasticity of particleboard with a mixture of bran gives varying elasticity results between each composition. The fine powder element will actually easily bind the adhesive, so that the finer powder elements can facilitate the bonding between particles of each powder. Meanwhile, the analysis of variance analysis results (Table 1) show that the MOE values of the three boards are significantly different. Furthermore, from the results of further tests (Table 2), it can be seen that each board has a different value.

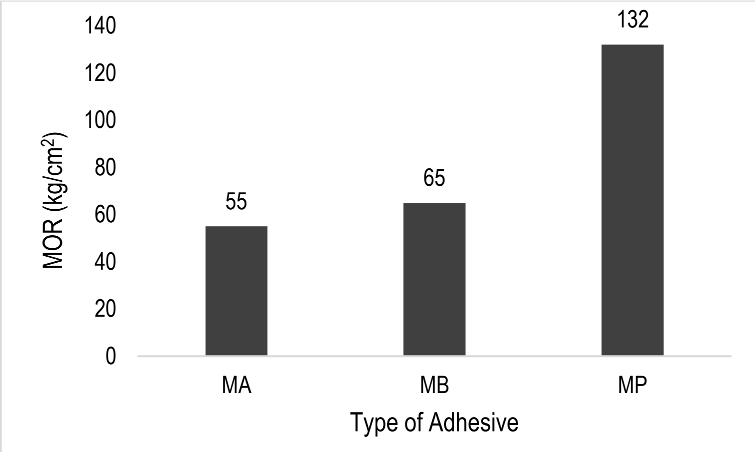

Figure 5. Particleboard Modulus of Rupture (MOR) test result

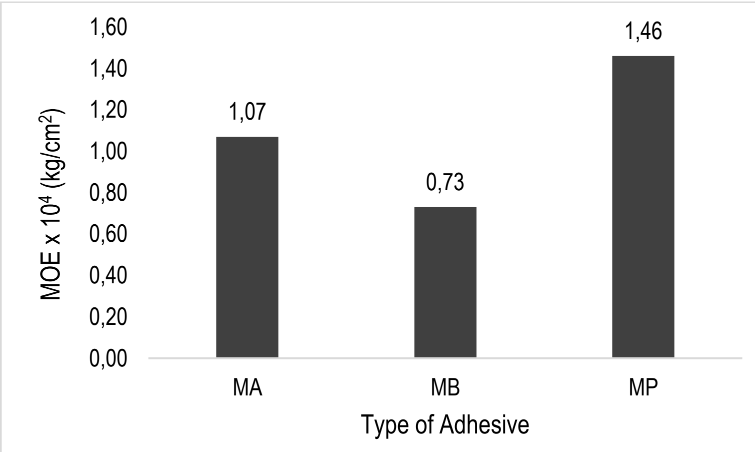

Figure 6. Particleboard Modulus of Elasticity (MOE) test result

D. CONCLUSION

The manufacture of particle board using the three types of adhesives meets the requirements of SNI 03-2105-2006 on physical properties in the form of water content and density. While in terms of thickness development, only particleboard with PF adhesive meets the standard. In the mechanical test results, TRF adhesive with an additional starch extender concentration of 20% meets the standard, as does particle board with PF adhesive, which meets the standard for testing adhesive strength and MOR. While in the MOE test, the three types of particleboard do not meet the standard. Thus, it can be concluded that the higher the concentration of starch extender addition to TRF adhesive, the greater the adhesive strength value but also the greater the thickness development of the resulting particle board.

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AUTHOR'S DECLARATION

- Conflicts of Interest: None.
- We here by confirm that all the Figures and Tables in the manuscript are ours. Furthermore, any Figures and images, that are not ours, have been included with the necessary permission for republication,which is attached to the manuscript.
- No animal studies are present in the manuscript.
- No human studies are present in the manuscript.
- No potentially identified images or data are present in the manuscript.

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