Journal of Sylva Indonesiana (JSI) Vol. 06*, No.* 02, 2023 *| 195 – 206*

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JSI Journal of Sylva Indonesiana

Enhancement Quality of Particleboard from Oil Palm Trunk and Mahogany Sawdust with Layering of Talang Bamboo (*Schizostachyum brachycladumc*)

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Abstract. Oil Palm Trunk (OPT) is a natural fiber used as an alternative material in wood-derived products such as particleboard. The OPT has low characteristics when using complete trunk, it is expected that its application would be a solution to reduce this plantation waste. In this investigation, the raw material of OPT particles was mixed with Mahogany, and Talang bamboo lamina to improve the physical and mechanical properties of the particleboard. This study aims to evaluate the addition of particleboard with various layerings of Talang Bamboo. The particleboard has three layers, with Talang bamboo (bamboo outer and inner part) on the face and back layers. There are six types of particleboard made: control, bamboo inner layering, bamboo outer layering, two bamboo inner layerings, two bamboo outer layerings, and a mixture of inner and outer bamboo layerings. The physical and mechanical properties of particleboard were testing according to JIS A 5908-2003 standard. The results of the physical properties showed that the density was 0.56-0.70 g/cm^3, moisture content was 3.03-4.22%, water absorption was 52.01-87.15%, and thickness swelling was 11.62-24.68%. The mechanical properties showed MOE values was 9975.76-84246.63 kg/cm^2, MOR was 81.64-670.77 kg/cm^2, and IB was 0.91-3.38 kg/cm^2. The physical and mechanical properties of particleboard met the JIS A 5908-2003 standard. According to this investigation's findings, Layering with the outer part of the Talang bamboo on the face and back of the particleboard is the best.

Keywords: Bamboo, Layering, Mahogany Sawdust, Oil Palm Trunk, Particleboard

Received 22 December 2022 | Revised 25 July 2023 | Accepted 30 July 2023

1 Introduction

Oil palm is cultivated in the plantation business and has become one of the country's largest foreign exchange providers. The expansion of oil palm plantations in Indonesia proves this. In

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Published by Talenta Publisher, ISSN: 2622-5093 e-ISSN: 2622-5158 DOI : 10.32734/jsi.v6i02.10643
Journal Homepage: http://jsi.usu.ac.id

2022, Indonesia reported an area of 14.9 million ha of oil palm plantations [1]. Considering the total area of this oil palm plantation, it is reasonable that it will produce a huge amount of waste during the land rejuvenation process. According to Bakar [2], one rejuvenating oil palm land cycle will generate 220 m^3 of palm oil waste per hectare. As a result, it is important to make an effort to reduce the amount of palm oil trunk waste.

Oil palm trunks (OPT) have a spherical structure [3]. However, the direct application remains limited due to the high water content (100%-500%), low density [4], and mechanical qualities that are relatively poor [5]. Thus, one potential application for OPT waste is to develop it into new products such as particleboard [6,7]. The previous study successfully utilized OPT on particleboard manufactured [8-10]. According to Jumhuri *et al*. [7], particleboard manufactured from OPT using UF adhesives has poor mechanical qualities with low dimensional stability. Therefore, an effort is required to improve the particleboard's properties.

One method is to mix particleboard raw components. Using more than one suitable material in manufacturing particleboard can improve its qualities. Tawasli *et al.* [11] reported that combining sawdust with coconut coir can improve particleboard's physical and mechanical properties. In addition, Mirindi *et al*. [12] found that combining adhesive in the form of acacia gum with raw material macadamia nut shells at a 50:50 ratio produced the best results on several particleboard parameters such as water absorption, density, thickness swelling, and bending test. Another method successfully improves the quality of particleboard is layering. Layering will improve some physical and mechanical properties. Chin [13] reported the surface layer and OPT as the core layer of particleboard, successfully improving mechanical qualities and dimensional stability. In addition, Umam *et al*. [14] and Hartono *et al.* [15] reported that adding layerings to particleboard can improve certain qualities.

Manufacturing particleboard from OPT as raw material is expected to solve the increasing palm oil waste. In this study, the raw material for OPT was mixed with mahogany sawdust, which is expected to improve some properties of OPT. The bamboo layerings from Talang bamboo were also added. Hartono et al. [15] reported that layering bamboo can enhance the mechanical and physical characteristics of particleboard. This research investigates the physical and mechanical qualities of several bamboo layerings on particleboard made from a mixture of OPT and mahogany sawdust as raw materials.

2 Material and Method

2.1 Material

The oil palm tree that is no longer productive is felled and cut into multiple samples with a chainsaw. All part of the oil in the palm trunk is cut to 50 cm x 20 cm x 5 cm before shaving into particles with a shaver machine. The particles are then dried to 5% moisture content. The prepared mahogany wood is also shaved into 4-20 mesh particles. Talang bamboo lamina with dimensions 25 cm x 3 cm x 2 mm was utilized as a layering.The inner part bamboo with a density of 0.52-0.58 g/cm^3 and the outer part with a density of 0.72-0.90 g/cm^3 are used. The adhesive used is urea-formaldehyde (UF), with an adhesive content of 12%.

2.2 Particleboard components preparation

The size of particleboards was 25 cm x 25 cm x 1 cm and a target density of 0.7 g/cm^3. The raw materials OPT and mahogany on particleboard are prepared in a 50:50 ratio with the variations of a layering bamboo lamina. Table 1 shows the raw material requirements for particleboard manufacturing. Mixing material with adhesive is conducted in a blender with a spray gun. The prepared bamboo lamina is sprayed with 12% adhesive for each board using a spray gun. The bamboo lamina is then arranged with the size and layering of the board sheets that will be made by combining OPT and mahogany particles.

Table 1. Material requirements for particleboard manufacturing

Bamboo Lamina Variation	The thickness of Bamboo Lamina (mm)	OPT Particle (g)	Mahogany Sawdust (g)	Urea Formaldehyde (g)
Control	-	214.85	214.85	122.09
Face	2	193.35	193.35	109.88
Face and back	2	171.90	171.90	97.67

2.3 Particleboard manufacturing

There are six types of particleboard: control, bamboo inner layering, bamboo outer layering, two bamboo inner layerings, two bamboo outer layerings, and a mixture of inner and outer bamboo layerings. Figure 1 illustrates the particleboard's layering variations.

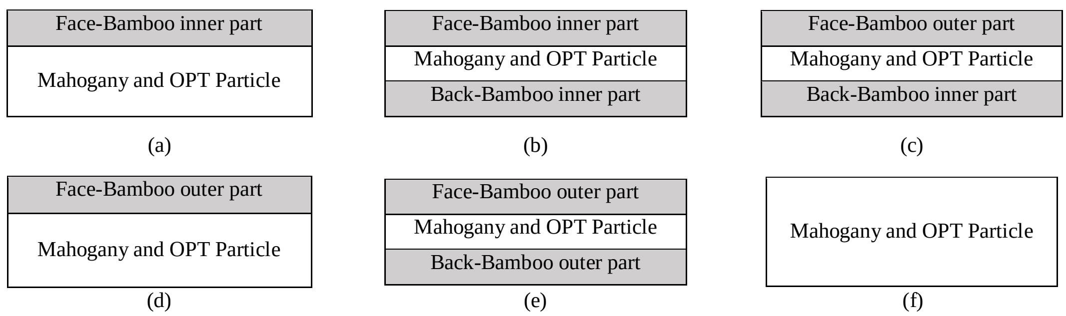

Figure 1. Layering variations of the particleboard in this study

The finished boards are 25 cm x 25 cm x 1 cm and have a target density of 0.7 g/cm^3. The formation was hot pressed at 170 °C with a pressure of 30 kg/cm^2 for 10 minutes or until the target thickness was 1 cm. Conditioning was then performed for 14 days at room temperature to uniform the moisture content. The particleboard was conditioned for 14 days. The physical and mechanical properties were tested based on JIS A 5908-2003 standard.

2.4 Testing for physical and mechanical properties

The physical properties of particleboard were density (D), moisture content (MC), water absorption (WA), and thickness swelling (TS). The mechanical properties of particleboard were modulus of rupture (MOR), modulus of elasticity (MOE), and internal bond (IB). Density testing is done by measuring the mass and volume in air-dry conditions. The moisture content of the particleboard is calculated using the initial weight (IW) and oven dry weight (ODW). ODW was obtained after ovening the test sample for 24 hours at 103±2 °C. Water absorption was calculated based on the weight before (W1) and after immersion in water for 24 hours (W2). Thickness swelling was determined using the thickness before (T1) and after a 24-hour immersion in water (T2).

The Universal Testing Machine (UTM, Tensilon) was used to determine the modulus of rupture (MOR) and modulus of elasticity (MOE) tests. Internal bond strength (IB) testing was performed with samples bonded to two iron blocks using epoxy adhesive and left to dry for 24 hours. Using UTM, the two iron blocks are pulled perpendicular to the surface of the test sample to the maximum load. The following is the formula used in the testing of particleboard:

$$P \text{ (g/cm}^3\text{)} = \frac{m}{v} \quad (1)$$

$$\text{MC (\%)} = \frac{IW - ODW}{ODW} \times 100 \quad (2)$$

$$\text{WA (\%)} = \frac{W_2 - W_1}{W_2} \times 100 \quad (3)$$

$$\text{TS(\%)} = \frac{T_2 - T_1}{T_2} \times 100 \quad (4)$$

$$\text{MOE (MPa)} = \frac{\Delta PL^3}{4\Delta Ybt^3} \quad (5)$$

$$\text{MOR (MPa)} = \frac{3PL}{2bt^2} \quad (6)$$

$$\text{IB (MPa)} = \frac{P}{bl} \quad (7)$$

Where in formulas (5), (6), and (7), P is the maximum load (N), L is the load range (15 times the sample thickness) (mm), b is the sample width (mm), t is the sample thickness (mm), Y is the deflection (mm), and l is the sample length.

2.5 Data Analysis

Non-factorial Completely Randomized Design (CRD) analysis was used in this study. Each level was repeated four times with a total of 24 trials. Suppose the variation layering bamboo lamina significantly affects the particleboard's physical and mechanical properties. In that case, the Duncan test (Duncan Multi Range Test) is performed with a 95% confidence level. The treatment was a variation layering of the bamboo lamina on particleboard with the following

Levels: (a) without layering (control), (b) face layering with the bamboo outer part, (c) face layering with the bamboo inner part, (d) face and back layering with the bamboo outer part, (e) face and back layering with the bamboo inner part, and (f) face layering with the bamboo outer part and back layering with the bamboo inner part.

3 Result and Discussion

3.1 Physical properties of particleboard

The density and moisture content of the particleboard are shown in Figure 2. The average density value of particleboard made from OPT waste with mahogany and Talang bamboo lamina layering variations ranged from 0.56-0.70 g/cm^3. Particleboard with layering (face and back) using Talang bamboo outer lamina had the greatest density (0.70 g/cm^3). Meanwhile, particleboard without layering Talang bamboo lamina had the lowest particleboard density of 0.56 g/cm^3. The analysis of variance (ANOVA) shows that the variation layering significantly affects particleboard density (Table 2). In this investigation, the density increased with the addition of bamboo layerings. Hartono *et al.* [15] reported that layerings with Betung bamboo on particleboard affect the particleboard's characteristics. This phenomenon is due to bamboo being denser than wood and other materials [16].

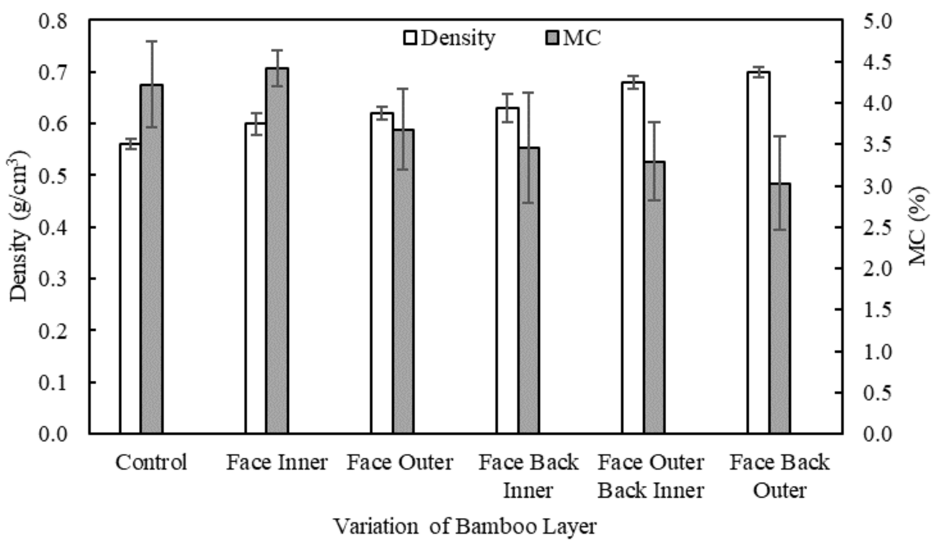

Figure 2. Density and MC of OPT and mahogany sawdust particleboard

The density of particleboard is affected by the density of the raw material used in its manufacturing. The final density value of the produced particleboard is proportional to the density of the raw material used. In this study, the particleboard density was 0.56 g/cm^3. The results of this study are lower when compared to Cosereanu *et al.* [17] research on particleboard with a variety of raw materials with a mixture of straw and sawdust with a value of 0.6-0.8 g/cm^3 and Lestari and Mora [18] research on particle board with a variation of a mixture of the banana trunk and palm shells with a value of 0.9-1.2 g/cm^3. Based on the JIS A 5908-2003 standard, the particleboard met the standards.

Table 2. ANOVA of particleboard physical properties

Parameter	ANOVA
Density	0.000**
MC	0.036*
WA	0.000**
TS	0.000**

***highly significant, *significant*

Furthermore, Figure 2 shows that the MC value of particleboard made from OPT waste and mahogany wood with a Talang bamboo lamina layering variation ranges from 3.03% to 4.22%. The control had the highest MC of particleboard, with a moisture content value of 4.22%. In contrast, layering variations with the face and back of the outer lamina of Talang bamboo had the lowest moisture content, with a moisture content value of 3.03%. Hartono et al. [15] reported that layering bamboo can reduce the moisture content of particleboard. The value of MC satisfies JIS A 5908-2003, which requires a maximum particleboard moisture content value of 14%. The ANOVA showed that the layering variation factor significantly affects the moisture content of the particleboard (Table 2). The utilization of the outer part of the bamboo resulted in a lower moisture content value than the others in this investigation (Table 3). This is due to the bamboo outer part anatomical structure, which has more vascular bundles that are less able to bind water [16, 19]. This study's moisture content was also lower than Hartono *et al.* [15] on particleboard with elephant dung and a variety of bamboo-type layerings, with a value of 7.88-10.35%.

Table 3. Duncan test (DMRT) of particleboard physical properties

Variation	Density	MC (%)	WA (%)	TS (%)
Control	0.56^{a}	4.22^{bc}	87.15^{e}	24.68^{d}
Face Inner	0.60^{b}	4.42^{c}	72.13^{d}	18.42^{c}
Face Outer	0.62^{b}	3.68^{bc}	65.08^{cd}	16.55^{bc}
Face Back Inner	0.63^{b}	3.46^{bc}	60.60^{bc}	13.32^{ab}
Face Outer Back Inner	0.68^{c}	3.29^{ab}	53.04^{ab}	11.88^{a}
Face Back Outer	0.70^{c}	3.03^{a}	52.01^{a}	11.62^{a}

The same letters in a column are not significantly different (p.0.05)

Figure 3 shows the results of the water absorption (WA) and thickness swelling (TS) tests. The water absorption values of particleboard made from OPT and mahogany waste with different Talang bamboo lamina layerings ranged from 52.01% to 87.15%. The ANOVA demonstrate that the layering variations of the Talang bamboo lamina have a highly significant effect on the particleboard's water absorption (Table 2). According to the study's findings, the more Talang bamboo layerings are used on the face and back of the particleboard, the lower the resulting water absorption capacity. Hartono et al. [15] reported bamboo had a T/R ratio of 0.56 and 0.97 from air-dry to oven-dry conditions. T/R ratios of bamboo that are close to or equal to 1 have consistent dimensions. Therefore, the utilization of Talang bamboo outer lamina as a layering also impacts particleboard water absorption.

The results of this study are lower when compared to particleboard made from macadamia nut shells by Mirindi et al. [12] (9.42-38.76%). In addition, the value was lower than particleboard made from coconut coir and sawdust by Tawasli *et al.* [11] (49.01%). This study confirms the findings of Hartono *et al.* [15], who discovered that bamboo layerings to elephant dung particleboards improved dimensional stability. According to Mirindi *et al.* [12], adding adhesive to particleboard can minimize water absorption value. According to Karlinasari *et al.* [20], the size of the particles utilized can affect the water absorption value. In this study, particleboard layered with bamboo outer part showed the lowest water absorption. It was because the bamboo outer part absorbed less water.

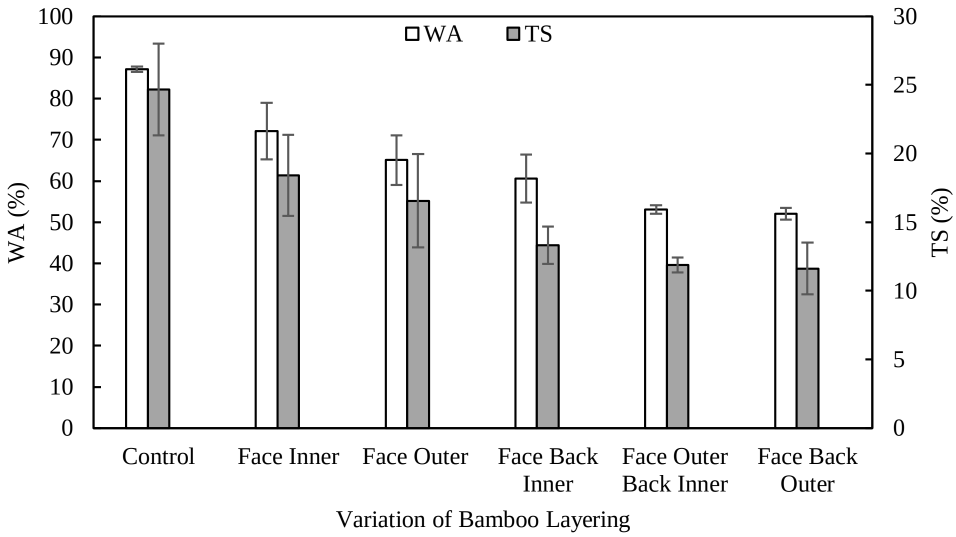

Figure 3. WA and TS of OPT and mahogany sawdust particleboard

The particleboard's thickness swelling (TS) (Figure 3) was measured simultaneously with the water absorption due to the identical test sample. The lowest thickness swelling discovered in this investigation is the layering treatment of Talang bamboo lamina on the face and back of the particleboard utilizing the outer Talang bamboo lamina at 11.62%. The control had the maximum thickness swelling, with a value of 24.68%. It is made possible by the treatment's lack of an exterior layering layer on the surface of the particleboard, which causes the swelling of wood particles owing to water infiltration into the wood. The ANOVA revealed that the layering variations significantly affected particleboard thickness swelling (Table 2).

In this study, the thickness swelling value of the particleboard was 24.68%. Compared to research by Yano *et al.* [21] on particleboard with a mix of bagasse and sawdust, the findings of this study were lower, with a value of 25.64%. However, compared to the results of Akinyemi *et al.* [22] on particleboard with corn stumps and sawdust as raw materials with a value of 8-12%, the findings of this study are greater. A previous study by Hartono *et al.* [15] showed that variations in the addition of Talang bamboo layerings to particleboard had a good effect, which is in line with this study (10.87–30.00%). Nevertheless, the results of this study show better dimensional stability when compared to those studies.

3.2 Mechanical properties of particleboard

Figure 4 shows the modulus of elasticity (MOE) and modulus of rupture (MOR) testing results on particleboard with various bamboo layering. The average MOE value of particleboard made from OPT and mahogany waste with layering Talang bamboo lamina ranged from 9.976 to 84.247 kg/cm^2. The MOE of the particleboards met to JIS A 5908-2003 standard. The MOE value is 20.400 kg/cm^2. The particleboard with the face and back layering with Talang bamboo outer part had the greatest MOE value of 84.247 kg/cm^2. The control had the lowest MOE value of 9.976 kg/cm^2. The particleboard with the face and back layering with Talang bamboo outer part had a significantly higher MOE than the control (approximately 8 times). According to the findings of this study, the control particleboard has a MOE value of 9.976 kg/cm^2. This study's results are lower compared to research by Garcia *et al.* [23] on particleboard with Canaria palm leaf-spine (17.295.71 kg/cm^2). In addition, the MOE value was lower than research by Zakaria *et al.* [24] on particleboard with a mixture of raw materials of palm oil trunk and tapioca starch with a value of 17.202.40 kg/cm^2. In this work, adding bamboo layerings can significantly raise the MOE of particleboard. Since the MOE of Talang bamboo is relatively high [25]-[26], hence increases the value of the particleboard's mechanical qualities in general.

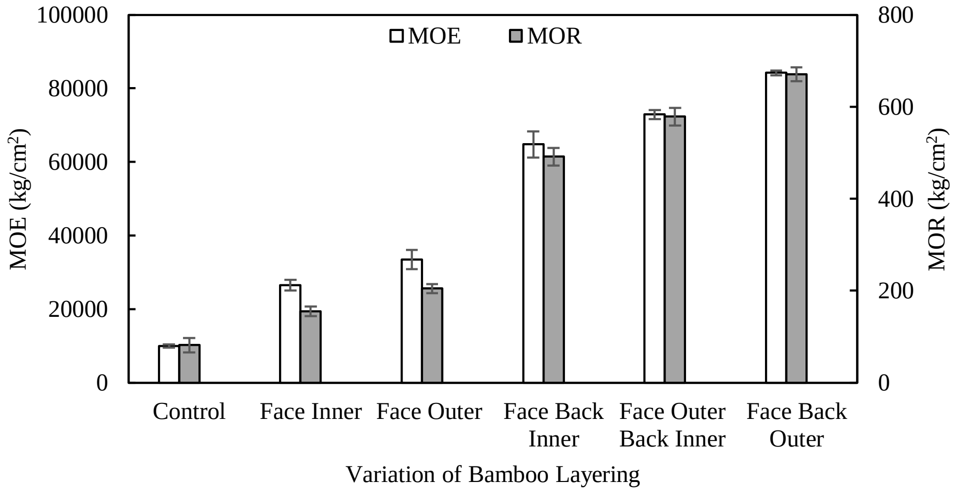

Figure 4. MOE and MOR of OPT and mahogany sawdust particleboard

Table 4. ANOVA of particleboard mechanical properties

Parameter	ANOVA
MOE	0.000**
MOR	0.000**
IB	0.036*

***highly significant, *significant*

Table 5. Duncan test (DMRT) of particleboard mechanical propeties

Variation	MOE	MOR	IB
Control	9975.76[a]	81.64[a]	0.91[a]
Face Inner	26480.74[b]	155.62[b]	2.59[bc]
Face Outer	33531.70[c]	204.61[c]	2.38[bc]
Face Back Inner	64799.89[d]	491.43[d]	3.38[c]
Face Outer Back Inner	72900.41[e]	578.70[e]	2.58[bc]
Face Back Outer	84246.63[f]	670.77[f]	1.92[ab]

The same letters in a column are not significantly different (p.0.05)

The MOR values of OPT and mahogany waste particleboard with Layering Talang bamboo lamina ranged from 81.64 to 670.77 kg/cm^2 (Figure 4). The control produced the lowest particleboard MOR value, with 81.64 kg/cm^2 of MOR value. In contrast, the face and back layering with Talang bamboo outer lamina produced the greatest particleboard MOR value (670.77 kg/cm^2). The particleboard with the face and back layering with Talang bamboo outer part had a significantly higher MOR than the control (approximately 8 times). According to the findings of this investigation, the MOR of bamboo meets the JIS A 5908-2003 standard ($\geq$ 82 kg/cm^2). The ANOVA showed that the variation layering significantly affected the particleboard's MOR value (Table 4).

In this investigation, the MOR value of the control particleboard was 81.64 kg/cm^2. The results of this study are smaller than the previous study. Baskaran *et al.* [27] reported particleboard with a raw oil palm chip material having a MOR value of 129.92 kg/cm^2. In addition, Sulaiman *et al.* [28] said particleboard with rubberwood raw materials and adhesives extracted from oil palm trunks has a MOR of 131.23 kg/cm^2. The MOR value of particleboard is influenced by the pressing pressure and the amount of adhesive applied [29]. Since Talang bamboo has fairly good mechanical strength, layerings significantly affected the increase in MOR in this investigation. It is consistent with a previous Hartono et al. [15] study. Layering bamboo found a significant increase in the mechanical properties of elephant dung particleboards.

As shown in Figure 5, the average IB value of particleboard made from OPT and mahogany waste with a variety of Talang bamboo lamina layerings ranged from 0.91-3.38 kg/cm^2. The lowest IB of particleboard was obtained from the control particleboard (0.91 kg/cm^2). The highest IB value was obtained from particleboard with face and back layering with the inner part of Talang bamboo lamina (3.38 kg/cm^2). According to the findings of this investigation, only the IB value of the particleboard control did not meet the JIS A 5908-2003 standard. In addition to these treatments, the entire particleboard produced fulfilled the standard of $\geq$ 1.5 kg/cm^2.

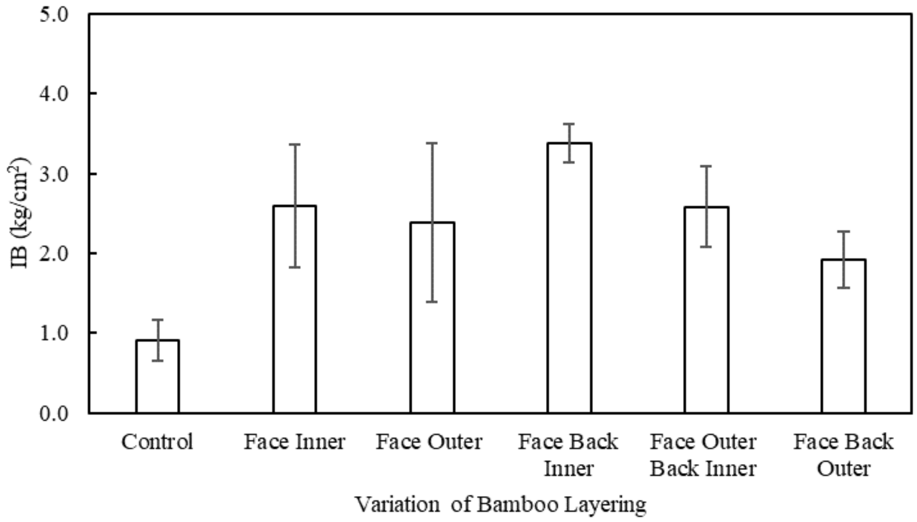

Figure 5. IB of OPT and mahogany sawdust particleboard

The ANOVA revealed that the layering variation had a very significant effect on the IB value. The density of the raw material used significantly impacts the IB value of particleboard. According to Hua *et al*. [8], particleboard with a core of palm oil trunk has a lower IB value than particleboard with a core of rubberwood. Layerings can also have an impact on the IB of the resulting particleboard. Hartono *et al.* [15] discovered that adding bamboo layerings to particleboard might improve IB.

4 Conclusion

Layering Talang bamboo lamina to OPT and mahogany waste particleboards significantly improves physical and mechanical qualities. According to testing its physical and mechanical properties, the outer part of Talang bamboo layerings on the face and back of particleboard provide the best results compared to other layering varieties.

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