Variation Of Bamboo And Adhesive Types On Physical And Mechanical Properties Of Particle Board

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Abstract.

Bamboo can be used as a material in the manufacture of particleboard. The purpose of this study was to examine the effect of various types of bamboo and their adhesion on the physical and mechanical properties of particleboard. The study used a factorial completely randomized design with three repetitions. Particleboard made using cold pressing made of bamboo betung (Dendrocalamus asper Schult.), bamboo apus (Gigantochloa apus Kurz), bamboo ori (Bambusa arundinacea Retz), and Urea Formaldehyde and Polyvinyl Acetate adhesives. The particle size used was through eight meshes with an adhesive concentration of 20% and a target board density of 1 gram/cm³. Board testing using SNI 03-2105-2006, correlation analysis, and regression to see the relationship between variables. The resulting particleboard has a density between 0.5 – 0.69 gram/cm³, air content between 12.7% - 15.2%, thickness expansion between 2.2% - 17.55%, MOE 1.963 - 4.898 kg/ cm², MOR 4.89 – 9.36 kg/cm². The type of bamboo has no significant effect on density, moisture content, MOE, and MOR of particleboard. The type of adhesive has a significant effect on the density, MOE, and MOR of the particleboard. The interaction between the type of bamboo and the type of adhesive has a significant effect on the thickness development of the particleboard.

***Keywords**: Adhesive; Bamboo; Biomaterial;and Particleboard.*

I. INTRODUCTION

Bamboo is a type of grass that grows very quickly and has a high strength-to-weight ratio, which makes it an attractive alternative to traditional wood-based materials for use in composite materials like particleboard. Bamboo can be processed into strands or fibers, which can then be bonded together using an adhesive to form particleboard. Many materials are typically known as "wood-based composites" and can be made using various manufacturing techniques. Many particles have been made from raw wood or leftover wood [1]. Besides wood, other materials such as bamboo can be used as particleboard because it contains lignocellulose[2]. Bamboo is a material of "Mother Nature's Magic" because it is very abundant, strong, and able to grow in various conditions[3]. Bamboo grows widely in various regions in Indonesia, reaching 157 species, with variations of species dominated by Bambusa, Gigantochloa, and Dendrocalamus[4]. Particleboard made of bamboo has the same strength as particleboard made of wood[5]. Many types of research on bamboo particleboard have been carried out, but various types of bamboo are still infrequent. The density of the particleboard produced is influenced by the density of the raw materials used; The higher the density of particleboard from a particular raw material, the higher the firmness of the resulting board [6]. Bamboo has a density ranging from 0.48 – 0.66 gram/cm³[7], [8].

Another factor that affects particleboard is the adhesive.The types of adhesives commonly used in the manufacture of particleboard are phenol-formaldehyde (PF) and urea-formaldehyde (UF). This type of adhesive is an adhesive that is included in thermosetting, while other types of thermoplastic adhesives can also be used in the manufacture of particle boards such as polyvinyl acetate (PVAc) but are still rarely used [9]. However, both thermosetting and thermoplastic adhesives have their respective advantages and disadvantages.Previous research on galar laminated boards with various adhesive variations showed that the variation of adhesive materials and galar composition significantly affected the MOE, MOR, and shear strength values of the adhesive[10]. The purpose of this study was to determine whether the density of bamboo raw materials and different types of adhesives affected the resulting particleboard. In addition, it also aims to determine the interrelated variables of the physical and mechanical properties of particleboard.

II. METHODS

The study used a 3x2 factorial completely randomized design (CRD) repeated three times, three types of bamboo (A) consisting of betung bamboo (D. asper), bamboo (G. apus) and ori bamboo (B. bamboos) and two types of adhesive (B).) consists of UF and PVAc. The bamboo particles were dried to a moisture content of 20% and sieved through an eight-mesh sieve. Particles were weighed with a target particleboard density of 1 gram/cm³, with an adhesive concentration of 20%[11]. The mixed particles were compressed using a cold press until the thickness of the board reached 1 cm, then clamped for 24 hours. The particleboard conditioning was carried out for seven days; then, the particle board was tested using SNI (Indonesian National Standard) 03-2105-2006[12]. Observations on physical properties variables included density, moisture content and thickness expansion, and mechanical properties, including flexural elasticity modulus (MOE) and flexural toughness (MOR). Analysis of variance (ANOVA) and Tukey's Honestly Significant Difference Test (Tukey's HSD test) was used to determine the effect and differences between treatments, while correlation and regression analysis were used to determine the relationship and form of relationship between variables[5]. All of these analyzes use the Minitab 18 application.

III. RESULTS AND DISCUSSION

1. Particleboard Density

Table 1 shows that the types of bamboo betung, bamboo apus, and bamboo ori were not significantly different in density, respectively 0.6267 gram/cm³, 0.5950 gram/cm, 0.5900 gram/cm. The treatment of the UF adhesive type resulted in higher density and was significantly different from the PVAc adhesive type, respectively 0.6922 gram/cm³, and 0.5156 gram/cm³.

Table 1. Average Density, Moisture Content, MoE and MoR Value of Particle Board

Treatment	Density (gram/cm³)		Moisture Content (%)		MoE (kg/cm²)		MoR (kg/cm²)	
Types of Bamboo								
Betung	0,6267	a	15,0567	a	1.980,16	a	9,3617	a
Apus	0,5950	a	12,7267	a	4.370,87	a	5,8317	a
Ori	0,5900	a	15,2100	a	3.942,87	a	5,4717	a
Types of Adhesives								
UF	0,6922	a	13,9678	a	4.898,68	a	8,8867	a
PVac	0,5156	b	14,6944	a	1.963,92	b	4,8900	b

Information:
Numbers accompanied by the same letter are not significantly different at the level of 0.05%

The particleboard density has not met the target density of 1.0 gram/cm³ because of the spring back in the compression process. Spring back can be reduced by adding wax to make particleboard[13], [14]. Differences in bamboo species have no significant effect on the properties of particleboard[15]. Data shows that other factors affect the density of particleboard. Several factors that affect the value of board density include the type of wood, compression pressure, the number of particles, and additives added[16].A urea-formaldehyde adhesive has a viscosity of 60 – 150 cPs, while a PVAc adhesive has a viscosity of 32000 – 38000 cPs. The low viscosity makes it easier for the adhesive to penetrate the micropores of the wood (cellulose)[17]. In addition, UF adhesive is the optimum adhesive to work in acidic conditions according to the acidic pH of bamboo ranging from 5.72 to 6.61[18], [19].

2. Particle Board Moisture Content

Table 1 shows that the types of bamboo betung, bamboo apus, and bamboo ori were not significantly different in water content, respectively 15.0567%, 12.7267%, 15.2100%. The type of UF adhesive treatment was not significantly different from that of the PVAc adhesive to the moisture content, respectively

13.9678% and 14.6944%.The moisture content shows that not all of the particleboard produced complies with SNI 03-2105-2006 because making particleboard is done manually using a cold-press, while temperature has a role in the moisture content of the particleboard[20]. Particleboard is composed of particles that still have hygroscopic properties due to the holocellulose content in bamboo[21], [22]. The different types of bamboo and the adhesive each have no significant effect on the moisture content of the particleboard produced because the material does not affect the moisture content of the resulting board[23]. The moisture content of particleboard is influenced by environmental conditions (temperature and humidity) where the particleboard is placed, the characteristics of the chemical content (cellulose, lignin, and extractive substances), physical properties (form of raw materials, specific gravity, density, hardness) of raw materials and hygroscopic properties. (absorption and evaporation of water vapor) the resulting particleboard[24].

3. Particleboard Thickness Development

Table 2. shows that the combination treatment of bamboo betung with PVAc adhesive resulted in the highest thickness development of particleboard, namely 17.5467% and significantly different from the combination treatment of bamboo betung and UF adhesive, apus bamboo and UF adhesive, ori bamboo, and UF adhesive, bamboo apus, and PVAc adhesive and bamboo ori and PVAc adhesive, respectively 5.1867%, 2.6267%, 2.1967%, 7.8600%, and 7.2467%, respectively.

Tabel 2. Average Particle Board Thickness Development After Soaking in Water

Treatment	Thick Development (%)	
Combinations		
Betung UF	5,1867	b
Apus UF	2,6267	b
Ori UF	2,1967	b
Betung PVac	17,5467	a
Apus PVac	7,8600	b
Ori PVac	7,2467	b

Information:
Numbers accompanied by the same letter are not significantly different at the level of 0.05%

Particleboards that do not meet SNI 03-2105-2006 are particleboards made of betung bamboo and PVAc adhesive. The nature of the PVAc adhesive has an active atomic group so that it can bind other materials utilizing hydrogen bonding or chemical absorption so that if the particleboard with PVAc adhesive is immersed, the PVAc will be hydrolyzed by water so that the bonds between particles are weaker than UF Adhesive. and the dimensions of the board are more easily degraded. UF adhesives have good adhesive strength, fast compression, and are relatively resistant to water[25]. UF adhesive can produce good mechanical properties, water resistance, and thickness development[26]. In addition, the manufacture of particleboard without a hot press also affects the thickness of the particleboard. Heat treatment can increase the dimensional stability of the board by reducing the thickness of the particleboard[27]. The dimensional stability of the particleboard is seen with a decrease in the value of the resulting thickness expansion[28]. The dimensional stability of the particleboard will increase significantly as the density of the particleboard increases [28], [29].

4. Modulus of Elasticity (MOE)

Table 1 shows that the types of bamboo betung, bamboo apus, and bamboo ori produce the Modulus of Elasticity (MOE) value not significantly different, respectively 1,980.16 kg/cm², 4,370.87 kg/cm², 3,942.87 kg/cm². The treatment of the UF adhesive type resulted in a higher MOE and was significantly different from the PVAc adhesive type, respectively 4.898.68 kg/cm² and 1.963.92 kg/cm², respectively.

The manufacture of particleboard without hot pressing causes a weak MOE of the resulting particleboard, while the temperature can increase the adhesive bond for better mechanical strength result[30]. Differences in bamboo species showed no significant effect on MOE[15]. This shows that other factors affect the MOE of particleboard. Several factors that affect MOE are the type of adhesive, adhesive content, adhesive bond, and particle size(Ustaömer et al., 2019). Using UF adhesive with a dry mass of 65% resulted in particleboard with better strength than PVAc adhesive with a dry mass of 31% [32], [33].

5. Modulus of Rupture (MOR)

Table 1 shows that the types of bamboo betung, bamboo apus, and bamboo ori produce no significantly different Modulus of Rupture (MOR) values, 9.3517 kg/cm², 5.8317 kg/cm², and 5.4717 kg/cm². The treatment of the UF adhesive type resulted in a MOR of 8.8867 kg/cm² and was significantly different from the PVAc adhesive type, which was 4.8900 kg/cm².In the manufacture of particleboard, the temperature and duration of the compression process have an essential role that can affect the strength of the particleboard[20], [34]. Differences in bamboo species showed no significant effect on MOR[35]. This shows that other factors influence the MOR. Factors that affect MOR are the content and type of adhesive used, adhesive bonding power, and particle size[31]. Using UF adhesive with a dry mass of 65% resulted in particleboard with better strength than PVAc adhesive with a dry mass of 31%[32], [33].

6. Relationship Between Variables

The correlation analysis in Table 3. shows that the variables that have a significantly positive relationship consist of density with water content, density with MOR, each having a correlation value of 0.516 and 0.855. Variables with a significantly negative relationship are water content and thickness expansion with a correlation value of -0.694.

Table 3. Correlation Matrix of Particleboard Physical and Mechanical Properties

		Density	MC	TD	MOE	MOR
Density	Pearson Correlation	1				
	Sig.					
MC	Pearson Correlation	.516*	1			
	Sig.	.034				
TD	Pearson Correlation	-.420	-.694**	1		
	Sig.	.083	.002			
MOE	Pearson Correlation	.361	.431	-.487	1	
	Sig.	.169	.109	.056		
MOR	Pearson Correlation	.855**	.325	-.097	.317	1
	Sig.	.000	.204	.702	.231	

Information
MC: Moisture Content
TD: Thick Development
MoE: Modulus of Elasticity
MoR: Modulus of Rupture
*: Significant correlation at the level of 0.05
**: Significant correlation at the level of 0.01

Figure 1. shows a model of the relationship between particleboard density and water content following the equation y = 3.39 + 0.66x with a value of $R^2 = 0.266$. The density of particleboard increases with increasing water content because the use of a cold press causes the moisture content of the particleboard not to evaporate so that it remains stored and fills the cavity of the resulting particleboard [36].

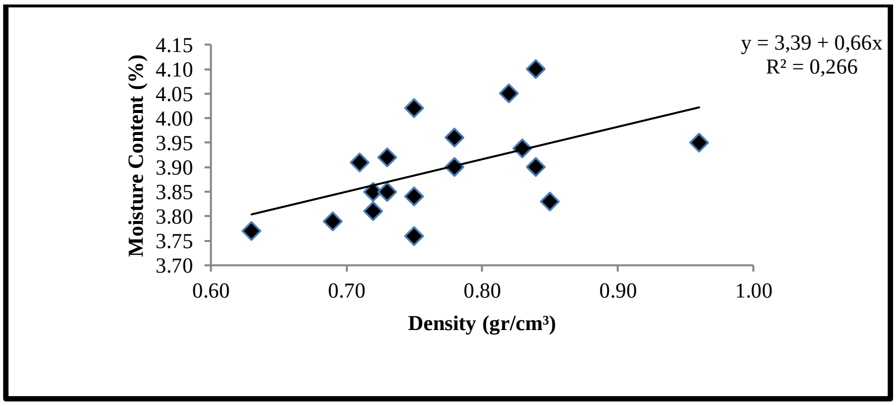

Fig 1. Graph of Relationship Pattern between Particle Board Density and Moisture Content

Figure 2. shows a model of the relationship between particleboard density and MOR following the equation $y = -1.1 + 4.286x - 1.063x^2$ with a value of $R^2 = 0.733$. This shows that high density results in high MOR, but the MOR decreases after reaching the peak point even though the density increases. The MOR of particleboard has a linear relationship with increasing board density[37]–[39].

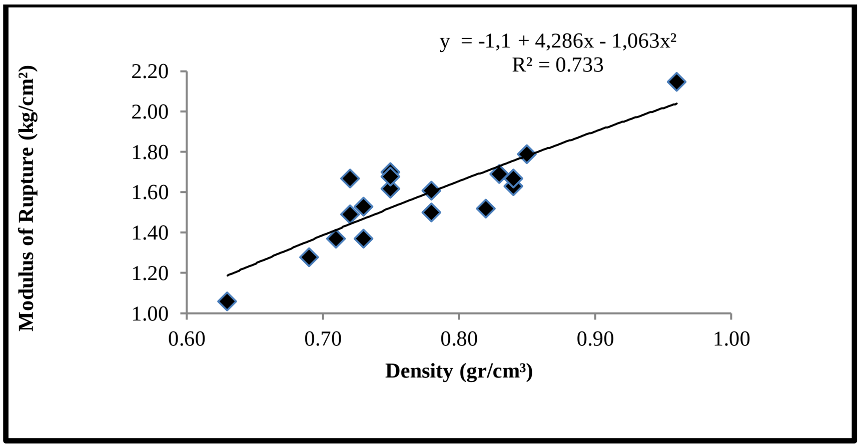

Fig 2. Graph of Relationship Pattern between Particle Board Density and MOR

Figure 3. shows a model of the relationship between particleboard moisture content and thickness expansion following the equation $y = 110.08 – 47.84x + 5.19x^2$ with $R^2 = 0.485$. The water absorption capacity of the particleboard decreases with the increase in the water content of the material[35].

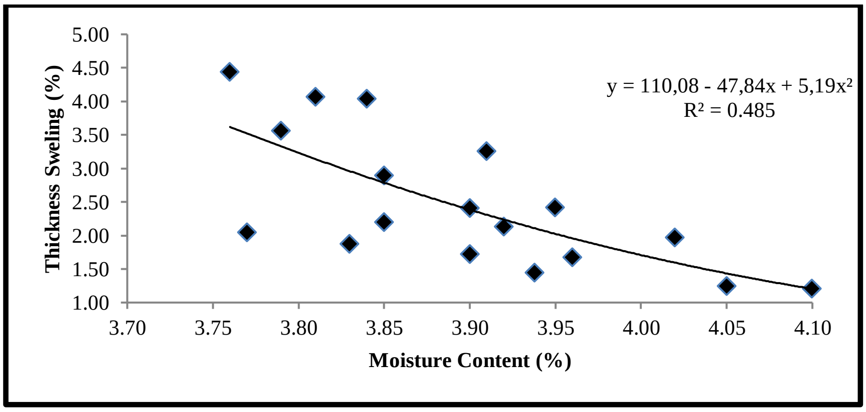

Fig 3. Graph of Relationship Pattern between Particleboard Moisture Content and Thickness Development

The water absorption of particleboard is strongly influenced by the volume factor of the space that can accommodate water between the particles, the presence of capillary channels connecting the space, and the surface area of the particles that can be covered by the adhesive and the depth of penetration of the adhesive into the particles[5].

7. Impact Of Variation of Bamboo And Adhesive Types For Particleboard Industry

Bamboo is a popular raw material to produce particleboard due to its high strength-to-weight ratio and availability. However, the type of bamboo used can impact the properties of the final product. Similarly, the type of adhesive used can also significantly affect the performance and cost of the particleboard.By varying the bamboo and adhesive types, particleboard manufacturers can tailor the properties of the particleboard to meet specific requirements for different applications, such as furniture, cabinetry, and building construction[40]. This can also have implications for cost, as some types of bamboo and adhesives may be more expensive than others.Furthermore, using sustainable and eco-friendly materials can enhance the environmental credentials of the particleboard industry, which can be an important consideration for consumers and stakeholders concerned about the impact of industrial production on the environment[41].

IV. CONCLUSIONS

The resulting particleboard has a density between 0.5 – 0.69 gram/cm³, water content between 12.7% - 15.2%, thickness expansion between 2.2% - 17.55%, MOE 1,963 – 4,898 kg/ cm², MOR 4.89 – 9.36 kg/cm². The model of the relationship between particleboard density and water content follows the equation $y = 3.39 + 0.66x$ with a value of $R^2 = 0.266$, the model for the relationship between particleboard density and MOR follows the equation $y = -1.1 + 4.286x - 1.063x^2$ with a value of $R^2 = 0.733$, the relationship model of particleboard moisture content with thickness expansion follows the equation $y = 110.08 – 47.84x + 5.19x^2$

with $R^2 = 0.485$. The type of bamboo has no significant effect on density, moisture content, MOE, and MOR of particleboard. The type of adhesive has a significant effect on the density, MOE, and MOR of the particleboard. The interaction between the type of bamboo and the type of adhesive has a significant effect on the thickness development of the particleboard.

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