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Physical and Mechanical Characteristics of Natural Adhesives in the Preparation of Composite Boards from Coconut Fiber as an Effort to Address Environmental Issues

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ABSTRACT

This research aimed to develop coconut fiber boards using a mixture of cassava starch adhesive with a focus on examining the physical characteristics (density, moisture content, and thickness development) and mechanical properties (modulus of elasticity and modulus of rupture) of the composite boards made from coconut fiber using cassava starch adhesive with the addition of 25% citric acid. Additionally, the research evaluated the physical and mechanical characteristics of the fiberboards, following the guidelines of SNI 01-4449-2006 using an experimental method. The results showed that the fiberboards produced from coconut fiber and modified cassava starch adhesive (25% citric acid) exhibited specific physical characteristics. The density, moisture content, and thickness development ranged from 0.46 to 0.57 g/cm³, 13.18% to 14.39%, and 8.39% to 10.60% after two hours of soaking as well as 19.05% to 32.06% after 24 hours. Furthermore, the mechanical properties of the boards indicated a modulus of elasticity (MOE) and a modulus of rupture (MOR) ranging from 19247.33 to 42740.38 kg/cm² and 116.36 to 178.07 kg/cm², respectively. These findings are expected to provide valuable information for further research to obtain environmentally friendly adhesive materials.

1. INTRODUCTION

The growing scarcity of wood, caused by its frequent use in construction and furniture industries and the slow regeneration rate of trees, has led to an increasing demand for alternatives. According to data from the Ministry of Environment and Forestry, the use of roundwood in Indonesia had increased by 28.3% over the past 5 years, from 46.12 to 59.27 million m^3 in 2016 and 2020, respectively (KLHK, 2020). The rising demand has made it difficult to find wood, increasing prices. Consequently, many people are seeking alternative solutions to fulfil their wood needs.

Fiberboards have gained widespread popularity as a substitute in the construction and furniture industries due to the growing scarcity of wood. Kollmann & Cote (1968) stated that composite boards are suitable for applications requiring larger dimensions, such as walls, floors, house platforms, cabinets, and furniture. With its abundant biological resources, Indonesia holds significant potential for using materials derived from natural fibers, small-diameter wood, agricultural waste, and other cellulosic sources. Among these alternative materials, coconut fiber is a highly promising option. It is extensively developed as a raw fiberboard material, representing the largest portion of the coconut fruit (approximately 35% of its weight). Data obtained from the Central Statistics Agency showed that coconut production in North Sulawesi amounted to 264,850.69 tons in 2020, and it could be assumed to yield approximately 92,697.74 tons of fiber (BPS, 2020). Therefore, coconut fiber is a highly favorable material used in meeting the demand for wood substitutes.

The production of composite boards from coconut fiber involves the use of both synthetic and natural adhesives (Xu *et al*. 2016). Synthetic adhesives, including urea, phenol, and melamine formaldehyde, are commonly used due to their excellent bonding strength. These adhesives emit formaldehyde, which could be harmful to human health. Additionally, synthetic adhesives are not environmentally friendly, which raises concerns and leads to the development of natural types.

One of the extensively developed natural adhesives is starch, which is usually extracted. It has gained recognition as a widely used adhesive, with cassava starch a notable example. Cassava starch is commonly employed as an adhesive for various purposes, including paper, textiles, and so on (Bemiller & Whistler, 2009). The use of cassava starch can serve as a bio-composite adhesive for products like briquettes, bio-pellets, and composite boards (Fitra *et al*., 2019; Xu *et al*., 2016). However, to meet the desired standards for composite boards, it was recommended to modify the starch molecules. Owodunni *et al*. (2020) stated that incorporating 25% citric acid as a modification agent could enhance the mechanical characteristics of composite boards.

The aim of this study was to examine the physical (density, moisture content, and thickness swelling) and mechanical (elastic modulus and collapse) characteristics of composite boards (Bispo *et al*., 2022). This board is made from coconut coir, using modified cassava starch adhesive with 25% citric acid. To evaluate the physical and mechanical characteristics of particle boards according to the SNI 01-4449-2006 standard. The benefit of this research is the utilization of coconut fiber as an alternative non-wood raw material in the fiber composite board industry, as well as utilization of natural adhesives that are affordable, available, safe, and environmentally friendly as raw materials.

2. MATERIALS AND METHODS

2.1. Research Time and Location

This research was conducted from November 2022 to March 2023 at the Biosystems Engineering Laboratory, Faculty of Agriculture. Meanwhile, the mechanical characteristics tests were carried out at the Material Engineering Laboratory, Faculty of Engineering, Sam Ratulangi University, North Sulawesi.

2.2. Materials and Tools

The materials used were coconut fiber obtained from Berkat Abadi Korindo Company in Bitung City, cassava starch, distilled water, Polyester Yukalac 157 BQTN-EX resin, MEKPO catalyst (Methyl Ethyl Ketone Peroxide), and commercially available citric acid. The tools used included a Kern EW 1500-2M digital scale, a mould for producing (30 x 30 x 1)cm boards, a ruler, a hot press machine with a hydraulic jack of 20 tons and a stove, zinc sheets, aluminium foil, spray, saw, NDO-410 type oven, desiccator, digital caliper, mixer, and Universal Testing Machine.

2.3. Research Method

This experimental research produced medium-density fiber composite boards using the hot press method. This research uses descriptive data analysis. The boards had dimensions of (30 x 30 x 1)cm and a target density of 0.6g/cm^3. The hot press method involved applying a pressure of 22 kg/cm^2 and one-side heating at a temperature of 180°C for 20 minutes. In addition, this process was repeated on the other side. A natural adhesive made from cassava starch (tapioca) with a modification of 25% citric acid was used. The adhesive preparation method involved some adjustments (Widyorini *et al*. 2017; Owodunni *et al*. 2020). The fiberboards in this research were produced using the hot-press method. The procedure involved subjecting the boards to a pressure of 22 kg/cm^2 and one-sided heating at a temperature of 180 °C for 20 minutes, then repeating the process on the other side. The adhesive used was cassava starch (tapioca), which was modified by adding 25% citric acid (Owodunni *et al*., 2020). These included using room temperature water for the modification process and ensuring that the time interval for adhesive preparation, raw material mixing, and board molding was kept short by heating during the hot press.

The research focused on examining the variable composition of coconut fiber with cassava starch adhesive alongside a control treatment involving resin adhesive (Handayani 2016). The treatments were listed as follows: P0 (fiber 70% : 30% polyester adhesive); P1 (fiber 80% : 20% starch adhesive); P2 (fiber 70% : 30% starch adhesive); and P3 (fiber 60% : 40% starch adhesive). To ensure accuracy and reliability, each treatment was replicated three times, resulting in a total of 12 test specimens. The data obtained were shown in the form of diagrams and then analyzed descriptively.

2.4. Research Procedure

The research procedure consisted of several steps, starting with preparing coconut fiber. This was followed by the preparation of the adhesive and the mixing of raw materials. Subsequently, the particleboards were molded and underwent testing to evaluate their properties.

2.5. Coconut Fiber Preparation

Meanwhile, the raw coconut fiber material was carefully selected to prepare the fiber and then air-dried until it reached a moisture content of approximately 5%. The fiber was cut to a length of 9cm, which is considered the optimal length for fiberboards (Sawir, 2017).

2.6. Adhesive Preparation

The adhesive preparation process involved the addition of citric acid to cassava starch, with slight adjustments (Owodunni *et al*. 2020). The optimal mixing ratio of citric acid to starch was 75%:25%, yielding the best characteristics for particle boards (Widyorini *et al*., 2017). In order to prepare the adhesive for fiberboard production, the cassava starch, modified with citric acid, was dissolved in distilled water at a mass ratio of 1:2. The mixture was thoroughly stirred using a mixer at room temperature for 20 minutes. In contrast to Owodunni *et al*. (2020), where the acid modification was carried out using 25% citric acid with warm water (70°C ± 2°C), the present research used distilled water at a temperature of 23°C. The intention behind this deviation was to account for the anticipated heating that would occur during the board moulding process. The adhesive made from starch had to be used immediately because it was susceptible to damage when mixed with water and had poor shape stability (Ferdosian *et al*., 2017).

2.7. Raw Material Mixing

The process starts by spraying the adhesive onto the coconut fiber to ensure an even distribution (Nauli, 2021). Once mixed thoroughly, the materials are transferred into a mold that has been lined with aluminum foil. This lining not only prevents sticking but also provides a smooth surface for the mixture. The mold and the mixture were further subjected to cold-pressing for a duration of 20 min. The cold press was performed to adjust the board shape and facilitate molding before the hot press stage.

2.8. Board Molding

The fiberboards were made using the hot press method with the aid of a homemade press and a 20-ton hydraulic jack. The process involved the use of a mold measuring 30cm x 30cm, which generated a pressure of 22 kg/cm^2. In order to facilitate bonding, heating was applied using a stove. The temperature was set at 180 °C for 20 min, and the heating process was repeated on both sides of the fiberboards (Widyorini *et al.* 2018). The boards were intended to have a target thickness and density of 1 cm and 0.6 g/cm^3, respectively (Puspitaningrum *et al*. 2020). Achieving these specifications necessitated a raw material mass of 540 g per board. The composition of the raw materials adhered to the treatments outlined in this research. Subsequently, the boards underwent a conditioning process where they were stored at room temperature for over 1 week before being tested (Nauli, 2021).

2.9. Board Testing

The conditioned fiberboards were then used as the test sample by following the cutting pattern shown in Figure 3. The sampling and testing procedures adhered to the SNI 01-4449-2006 standard for fiberboards (BSN, 2006), which encompassed the evaluation of their physical and mechanical characteristics.

2.9.1. Density

Density (ρ) is the ratio of weight or mass to volume, expressed in g/cm^3. Particle board density greatly influences other physical and mechanical characteristics. A test sample measuring 10 cm x 10 cm is weighed to determine its mass, while the volume is obtained by calculating its dimensions. Density can be calculated using the formula:

$$\rho = \frac{M}{V} \tag{1}$$

where *m* is mass of test sample (g), and *V* is volume of test sample (cm^3)

2.9.2. Moisture Content

Moisture content is one of the physical characteristics that indicate the water content of the board is in equilibrium with its surrounding environment, especially air humidity. Haygreen & Bowyer (1996) stated that particle boards have lower moisture content than solid wood products in a stable environment. This variation in moisture content could be attributed to the distinct temperature conditions that affect each raw material. A test sample measuring 10cm x 10cm is first weighed and then dried in an oven at a temperature of 103±2 °C for 6 hours. Before taking the final weight measurement, the sample is removed from the oven and allowed to cool in a desiccator for 10 minutes. This process is repeated iteratively until the weight of the sample remains constant, indicating that the drying process is complete (BSN, 2006). Moisture content (*MC*) is determined using the formula:

$$\text{Moisture Content (\%)} = \frac{\text{ma} - \text{mb}}{\text{mb}} \times 100\% \tag{2}$$

where *ma* is initial mass before oven (g), and *mb* is final mass after oven (g).

2.9.3. Thickness Swelling

Thickness swelling is a physical characteristic that measures the ability of particle boards to maintain their dimensions when soaked in water (Arliansy, 2021). A higher thickness swelling value indicates lower dimensional stability. In order to ensure accurate observations of thickness development, the test was conducted in a stepwise manner, with measurements gradually taken at 2-hour and 24-hour intervals. This approach allows for a more precise assessment of how the thickness of particle boards develops over time (Owodunni *et al*. 2020).

Furthermore, to assess the thickness swelling of a test sample measuring 5cm x 5cm, measurements are taken before and after soaking at 2-hour and 24-hour intervals. Thickness swelling is determined from initial thickness (*T1*) and final thickness after soaking (*T2*) using the following formula:

$$\text{Thickness Swelling (\%)} = \frac{T2 - T1}{T1} \times 100\% \tag{3}$$

2.9.4. Modulus of Elasticity

Modulus of Elasticity (MOE) is a measure of wood resistance to deformation under a load (Haygreen & Bowyer, 1996). The MOE is determined through the use of a Universal Testing Machine (UTM). However, to obtain the MOE of a test sample with a size of 5 cm x 15 cm, the length, width, and thickness need to be carefully measured. The sample is then positioned horizontally on supports with a distance of 13 cm. The load is applied at the center of the sample at a speed of approximately 1.8cm/min. The deflection value is recorded when the sample reaches its maximum load-bearing capacity. MOE (kg/cm^2) is calculated using the following formula:

$$MOE = \frac{\Delta p \times L^3}{4 \times b \times h^3 \times \Delta y} \tag{4}$$

where Δp is difference between the highest and lowest load limits (kg), L is support distance (cm), b is width of test sample (cm), h is width of test sample (cm), and Δy is deflection change in Δp

2.9.5. Modulus of Rupture

Modulus of Rupture (MOR) is determined by the maximum load that can be supported or withstood by a material per unit area until it ruptures (Bowyer *et al*., 2003). MOR test is conducted simultaneously with the loading process determined in the MOE (kg/cm^2). The loading process is continued until the test sample is damaged or ruptured. MOR was determined from maximum load (P_{max}) using the following formula:

$$MOR = \frac{\Delta p \times P_{max} \times L}{2 \times b \times h^2} \quad (5)$$

3. RESULTS AND DISCUSSION

3.1. Density

Density, expressed in g/cm³, is a crucial factor in the characteristics of fiberboards (Arliansy, 2021). It is determined by the ratio of weight or mass to volume and is influenced by the density of the raw materials used and the level of pressure applied during board moulding. The density of fiberboards plays a fundamental role as it affects all aspects of the material. Furthermore, it serves as a critical basis for determining the suitability and application of fiberboard products (Bowyer *et al*., 2003).

Density is related to porosity, which refers to the proportion of void space volume within the material (Haygreen & Bowyer, 1986). Increased density is also influenced by the compaction of fiber during board manufacturing (Hakim *et al*., 2011). Figure 2 shows a clear trend where the density values of fiberboards increase as the adhesive ratio is increased. The obtained densities for the fiberboards range from 0.46 g/cm³ to 0.57 g/cm³, meeting the requirements outlined in the SNI 01-4449-2006 standard for medium-density fiberboards (0.40 to 0.84 g/cm³). Among the different adhesive ratios, the 60%:40% ratio showed significantly the highest density value of 0.57 g/cm³, which is close to the target density of 0.6 g/cm³ for the boards. Meanwhile, the 80:20 ratio showed the lowest value of 0.46%. The density value in the control sample with polyester resin adhesive which is lower than the other cassava starch adhesive treatments complies with research conducted by Xu *et al.* (2016).

The pressing process of the boards may influence the value of density. The higher the pressure applied during the procedure, the denser the arrangement of the constituent materials (Nurdin *et al*., 2019). Additionally, Saddikin *et al.* (2019) stated that the greater the adhesives used in the boards, the higher the density value.

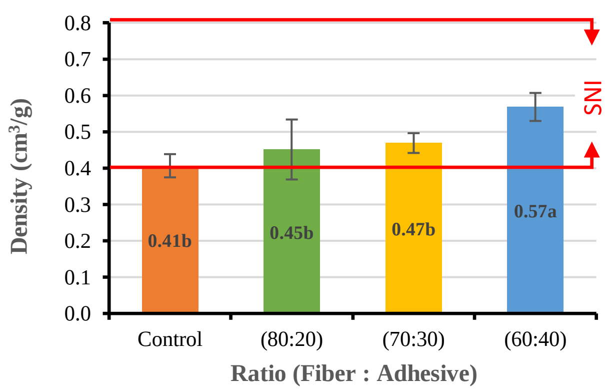

Figure 1. Graph of fiberboard density

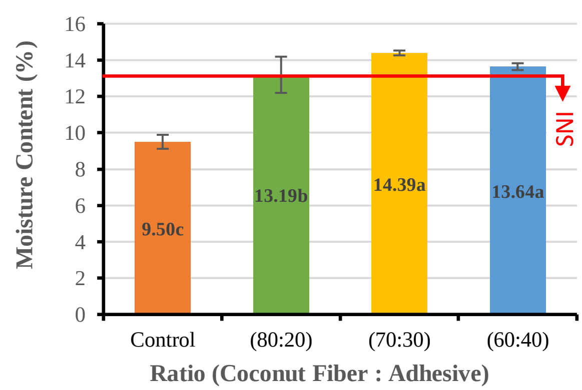

Figure 2. Graph of fiberboard moisture content

3.2. Moisture Content

Moisture content refers to the water content in fiberboards, expressed as a percentage of the oven-dry or moisture-free weight of the boards. It holds utmost importance in preserving the dimensional stability of the boards, as high moisture content can lead to undesirable dimensional changes during usage. Additionally, maintaining a low moisture content is desirable to prevent the growth of fungi and avoid termite infestation, both of which can significantly shorten the lifespan of the boards (Arliansy, 2021). By effectively managing moisture content, the durability and longevity of the boards can be ensured.

The moisture content of the produced boards ranges from 13.18% to 14.39%. Starch adhesive results in fiberboards with significantly higher moisture content as compared to that of using polyester adhesive. Overall, the moisture content value exceeds the SNI 01-4449-2006 standard, which specifies a maximum of 13% (BSN, 2006). The observed moisture content of the boards exceeds the reference standard by 0.18 to 1.39%. In this research, the cassava starch adhesive was modified with citric acid using the hydrolysis method. It is worth mentioning that the hydrolysis method involves the use of water, which consequently leads to an increased moisture content in the raw materials. As a result, the fiberboards made have moisture content values ranging from 13.18% to 14.39%. This moisture content differs from the control variable, which uses polyester resin adhesive and has a value of 9.50%.

Coconut fiber is a lignocellulosic material with hygroscopic characteristics, making it capable of absorbing and releasing water depending on the surrounding temperature. At low and high temperatures, desorption and absorption take place, respectively (Mulyadi, 2001). This phenomenon becomes apparent during the hot press process, especially on one side, where the application of elevated temperature causes water to migrate to the opposite side. It is important to note that even though the hot press is applied to both sides repeatedly, the processes of desorption and absorption also occur repeatedly throughout the process. This dynamic interplay of water migration and moisture content adjustment is intrinsic to the behaviour of coconut fiber fiber during the hot press treatment. Budiadji (2004) stated that larger-sized fillers tend to absorb more water and vice versa. Coconut fiber fiberboards have cavities due to their large size, making them prone to water absorption. Consequently, during the processes of desorption and absorption, water primarily infiltrates the cavities within the boards rather than being absorbed by the surrounding environment.

3.3. Thickness Swelling

Thickness swelling determines the quality of boards and is correlated with porosity. According to Arliansy (2021), it determines the suitability of boards for interior or exterior purposes. Boards exhibiting low thickness swelling, indicating high dimensional stability, are well-suited for exterior uses where resilience against weather conditions and long-term durability are principal. Low-thickness swelling refers to a gradual hindrance in the absorption of water into the structure of boards, specifically through the pores and void spaces between fibers. This hindrance leads to high dimensional changes in the boards, which occur due to an increased amount of absorbed water entering its structure (Arliansy, 2021). After soaking the fiberboards for 2 h, the thickness swelling value ranged between 8.39% and 10.60% and is not different statistically. However, after 24 h of soaking, the thickness swelling value increased to 19.05% – 32.06% and the ratios of fiber to adhesive significantly affect the thickness swelling. These findings indicate that the observed thickness swelling does not meet the maximum requirement of 17% set by SNI 01-4449-2006 (BSN, 2006) for a 24-h soaking period.

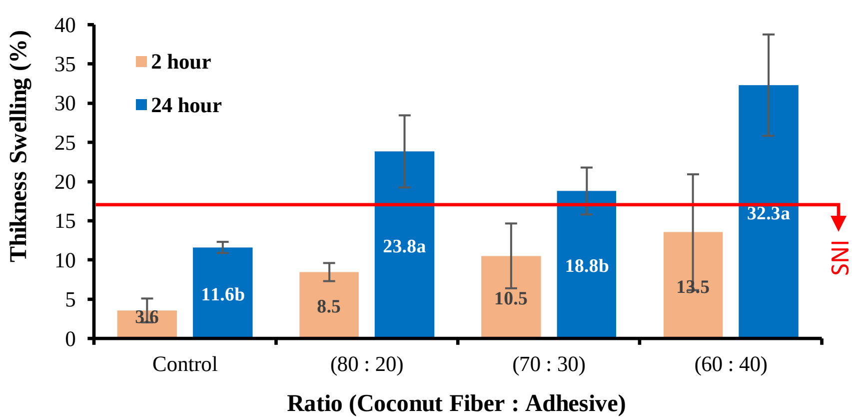

Figure 3. Graph of fiberboard thickness swelling (numbers with different letter in the same color mean significantly differ)

After soaking for 2 hours, the experiment showed that the ratio of 70% water to 30% of another substance yielded the highest thickness swelling value, measured at 10.60%. The outcome could be attributed to the higher moisture content present in this particular treatment. According to Arliansy (2021), maintaining the dimensional stability of boards primarily relies on controlling their moisture content since those with higher moisture content are more susceptible to experiencing dimensional changes. However, after 24 hours of soaking, the 80%:20% and 70%:30% treatments had a thickness swelling value of 24.22% and 19.50%, respectively. The difference in thickness swelling was attributed to the lower density of the 80%:20% treatment, which led to the formation of more cavities within the structure of the board. Maulana (2015) stated that these cavities or void spaces increase water absorption due to the enlarged surface area of the fiber and water penetration into the boards.

During the 24-h soaking period, the highest thickness swelling occurred in the 60%:40% treatment with a value of 32.06%. This remarkable result could be attributed to the greater usage of cassava starch adhesive in comparison to the other treatments. According to Ferdosian *et al*. (2017), cassava starch adhesive is susceptible to water damage, leading to a decrease in adhesive strength over time. Considering the higher water absorbency of the starch adhesive used, the fiberboards produced in this research were recommended as raw materials suitable for interior applications that are indirectly exposed to water and dry environments.

3.4. Modulus of Elasticity (MOE)

The Modulus of Elasticity (MOE) is a measure of the resistance of a material to shape modifications when subjected to an applied load. Bahtiar (2008) stated that higher MOE values indicate increased flexibility or elasticity in composite boards, making them more resistant to shape changes caused by external loads. Furthermore, Meivel *et al*., (2021) reported that the density of constituent particles significantly influences the MOE value, leading to the production of boards with higher flexibility.

Figure 4 shows a clear correlation between the ratio of adhesive used and the corresponding increase in MOE values. The measured MOE values of the produced fiberboards fall within the range of 19,247.33 to 42,740.38 kg/cm^2, satisfying the minimum requirement of 8,200 kg/cm^2 as specified by the SNI 01-4449-2006 standard (BSN, 2006). The control variable, which used polyester resin adhesive, showed a comparatively lower MOE value compared to the ones with cassava starch adhesive. In addition, increasing starch adhesive significantly increase the MOE of the fiberboards. According to Saddikin *et al*. (2019), the greater the adhesive usage, the stronger the strength of the boards. It was reported that increasing the amount of adhesives led to denser bonding between the materials, consequently maximizing the overall strength of the boards.

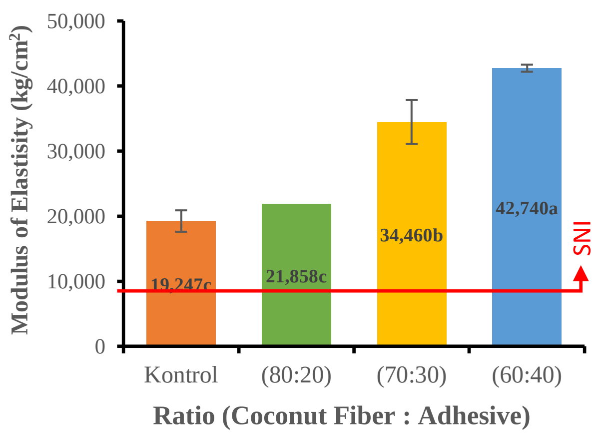

Figure 4. Graph of fiberboard MOE

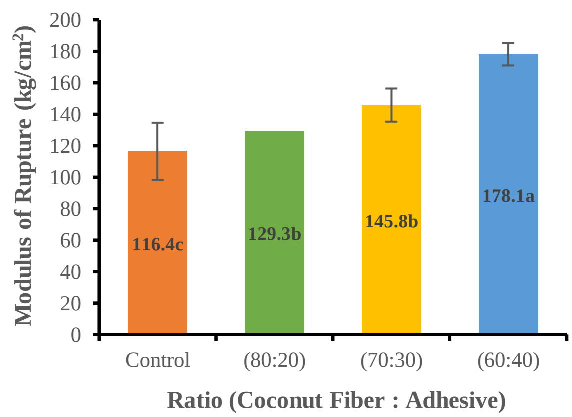

Figure 5. Graph of fiberboard MOR

1. Modulus of Rupture

The Modulus of Rupture (MOR) serves as an indicator of the maximum load a fiberboard can withstand per unit area before rupturing or sustaining damage. Boards with higher MOR values can withstand greater load (Arlyansy, 2021). Additionally, Ariyani (2009) stated the importance of the MOR value in determining the suitability and safety of the boards as structural or non-structural components. MOR value is a critical factor in assessing the load-bearing capacity and reliability of fiberboards.

Based on Figure 5, the test results show that the MOR (Modulus of Rupture) values range from 108.72 to 146.50 kg/cm^2, satisfying the minimum requirement of 50 kg/cm^2 specified by the SNI 01-4449-2006 standard (BSN, 2006). From Figure 5, it can be observed that increasing starch adhesive has resulted in stronger fiberboards with significantly higher MOR values. The ratios 80%:20% and 70%:30% showed the highest and lowest MOR values of 146.50 kg/cm^2 and 110.00 kg/cm^2, respectively. Additionally, the control variable yields a value of 116.36 kg/cm^2. According to Widyorini *et al*. (2017), the composition and quantity of the adhesive used in the boards significantly influence the MOR value. Similar to MOR, the adhesive content is directly proportional to MOE (Ruhendi & Sucipto, 2013). This connection was attributed to the role of the adhesive in establishing strong bonds between the materials.

3.5. Statistical Data of Fiberboard Thickness

In the thickness of composite boards during the 0-24 hour period for each ratio of adhesive mixture, namely the control (0% SSK), 80%:20% ratio, 70%:30% ratio, and 60%:40% ratio. Observations indicate that the control exhibits a consistent increase in thickness, while the 80%:20% and 70%:30% ratios show more significant increases, and the 60%:40% ratio demonstrates more minor variations. Second, the average thickness for each ratio reveals significant differences, with the 80%:20% ratio having the highest average thickness among all ratios. Third, the standard deviation indicates the level of thickness variation, and the results show that the 80%:20% and 70%:30% ratios have higher standard deviations, depicting more significant variations in thickness. The interpretation of the high standard deviation in these ratios is attributed to the complexity of the interaction between the adhesive material and coconut fiber in the composition. Fourth, the hypothesis test suggests no significant influence between the SSK and PTS ratios on the thickness of composite boards. Fifth, these findings provide valuable information for the production process, with variations in the 80%:20% and 70%:30% ratios possibly requiring adjustments in the adhesive formulation to achieve more consistent thickness.

Table 1. Statistical data of fiberboard thickness

Treatment	Initial-Final thickness (cm)								Average	Dev. Standard
	0 hour	2 hour	4 hour	8 hour	12 hour	16 hour	20 hour	24 hour		
Control	1.12	1.16	1.16	1.17	1.18	1.19	1.2	1.25	1.18	0.02
80% : 20%	1.30	1.41	1.42	1.44	1.46	1.48	1.5	1.61	1.46	0.05
70% : 30%	1.33	1.47	1.48	1.5	1.52	1.54	1.56	1.58	1.52	0.05
60% : 40%	0.96	1.09	1.11	1.12	1.11	1.11	1.17	1.27	1.12	0.01

The results of the ANOVA analysis indicate a significant difference in treatments with a confidence level below 0.05. The data encompass the sum of squares for treatment (SSK) and percentage of total sum of squares (PTS) at various treatment ratios. In the control treatment (Dev. Standard 0.02), SSK and PTS both reached 0.02, indicating a significant variation in the control treatment concerning the overall variation. In the treatment with an 80%:20% ratio (Dev. Standard 0.05), SSK and PTS both reached 0.05, indicating a significant impact on the experimental results, with values higher than the control. Similarly, the treatment with a 70%:30% ratio (Dev. Standard 0.05) showed comparable results, with SSK and PTS both at 0.05. The treatment with a 60%:40% ratio (Dev. Standard 0.01) also exhibited a significant impact, with SSK and PTS both reaching 0.01. It is crucial to note that the PTS value reflects the extent to which the variation in the treatment contributes to the overall variation. With these significant differences, it can be inferred that variations in treatment ratios have a substantial impact on experimental outcomes. Therefore, this information can serve as a basis for further development in the production process, including potential modifications to adhesive formulations or adjustments to other process parameters. However, to comprehend the final quality of the produced coconut fiber composite boards, further analysis is required, including mechanical tests and the evaluation of other functional properties. Although there is no significant influence on thickness, these variations can serve as a basis for improving the production process, including modifying adhesive formulations or adjusting other process parameters. However, it is essential to note that this interpretation is statistical. Further analysis, including mechanical tests and other functional properties, is needed to obtain a more comprehensive understanding of the final quality of the produced coconut fiber composite boards.

4. CONCLUSIONS

In conclusion, the coconut fiber-based fiberboards with modified cassava starch adhesive (25% citric acid) had distinct physical and mechanical characteristics. The boards exhibited a density range of 0.46 to 0.57 g/cm3 and a moisture content between 13.18% and 14.39%. Furthermore, the thickness swelling of the boards after 2 hours of soaking ranged from 8.39% to 10.60%, and after 24 hours of soaking, it varied from 19.05% to 32.06%. %. In terms of mechanical properties, the fiberboards obtained an MOE (Modulus of Elasticity) and an MOR (Modulus of Rupture) ranging from 19247.33 to 42740.38 kg/cm^2 and 116.36 to 178.07 kg/cm^2, respectively. Based on the physical characteristics test, it was observed that the density of the coconut fiber-based fiberboards complies with the SNI 01-4449-2006 standard. However, the moisture content and thickness swelling did not meet the standard due to the use of modified cassava starch adhesive with hydrolysis and citric acid, which resulted in elevated moisture content in the raw materials. The mechanical characteristics test showed that both the MOE and MOR values satisfied the requirements of the SNI 01-4449-2006 standard.

SUGGESTIONS

Further research is needed to investigate the use of adhesive with varying moisture content for the modification of starch using the hydrolysis method.

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