# Effect of natural rubber latex adhesive content on the physical and mechanical properties of agriboard from cassava stem wastes

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# Effect of Natural Rubber Latex Adhesive Content on the Physical and Mechanical Properties of Agriboard from Cassava Stem Wastes

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**Abstract.** Indonesia is one of the largest cassava producers globally, where the cassava wastes have not been optimally utilized yet. Cassava stems are lignocellulosic materials that are potential as raw materials for composite boards. This study aims to determine the effect of the adhesive content of Natural Rubber Latex (NRL) adhesive on the physical and mechanical properties of particleboard from the waste of cassava stems (agriboard). The NRL-based adhesives were formulated from natural rubber, poly(vinyl) alcohol, and isocyanate. The levels of NRL adhesive used were 10%, 15%, and 20%. The agriboard panels were prepared with a size of 400 mm × 400 mm × 10 mm and a target density of 0.7 g/cm$^3$. The board was hot-pressed at 60°C under 10 MPa of pressure for 30 minutes. Evaluation of physical and mechanical properties was done according to JIS 5908-2003 standard. The results showed that the density of agriboard ranged from 0.65–0.74 g/cm$^3$, and the moisture content was around 4.51–5.34%. Water absorption and thickness swelling of agriboard panel ranged from 61.84–70.84% and 23.67–28.77%, respectively. The results revealed that the dimensional stability of agriboard increased with the higher adhesive content, indicating that the urethane linkages produced from the reaction between –NCO of isocyanate and –OH of cassava stems enhanced the adhesion strength of the panel. The MOE and MOR values of agriboard were in the range of 229.20-331.38 MPa and 2.49-3.13 MPa, respectively. The mechanical properties of the panel also increased with higher adhesive content, and the optimum result was obtained by using 20% of adhesive content. In addition, the NRL-bonded panel did not emit formaldehyde, as the panel did not bond with formaldehyde-based adhesives. The results showed that cassava stems and NRL adhesive could be used as an alternative composite product that is renewable and environmentally friendly, particularly for non-structural and interior applications. Keywords: cassava stem, composite board, natural rubber latex, adhesive content, bio-based adhesive.

## INTRODUCTION

Indonesia is the third-largest producer of cassava in the world after Nigeria and Thailand [1]. The largest cassava producer in Indonesia is Lampung Province, with a cassava land area of 342,100 ha and total production of 8.45 million tons, or 35.33% of all cassava production in Indonesia [2]. Cassava harvesting produces the main product in the form of cassava tubers and harvesting waste in the form of cassava stems. The weight of cassava stem waste

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reaches 50% of the weight of cassava tubers per harvest [3]. A small portion of cassava stem waste (± 10%) is used for replanting needs, while the remaining 90% becomes waste that has not been utilized optimally [4].

Cassava stem waste in Lampung Province is estimated at 1.37 million tons/year [1]. In general, cassava stem biomass waste is only disposed of or burned in the fields [4]. However, the presence of cassava stem waste on land can become a nesting place for rats, pests, and diseases that harm the growth of cassava plants [1]. Therefore, the utilization cassava stem wastes are important. One of the potential utilizations of cassava stem waste is as material for composite board. Compared to solid wood boards, composite boards have several advantages: defect-free, dimension and density can be adjusted, uniform thickness and density, and easy to work with [5, 6]. The manufacture of composite boards requires adhesive to bind the particles [7−9].

The adhesive used in this research is an environmentally friendly alternative adhesive, namely natural rubber latex (NRL). NRL-based adhesives have good adhesion properties at room temperature and good resistance to warm or boiling water [10−12]. Therefore, research on composite boards from agricultural waste, called agriboard, from cassava stems using NRL-based adhesives is important. In addition, the development of cassava stem waste as raw material for agriboard is expected to increase the added value of agricultural waste and support efforts to conserve forest resources. This study aims to determine the effect of NRL adhesive content on the physical and mechanical properties of agriboard from cassava stem waste.

## MATERIALS AND METHODS

This research was conducted at the Laboratory of Power and Agricultural Machinery Tools, Department of Agricultural Engineering, Faculty of Agriculture, University of Lampung. The production of agriboard and testing of physical and mechanical properties was conducted at Forest Product Technology at the Integrated Field Laboratory of the Faculty of Agriculture, University of Lampung. The research was conducted in September-March.

### Materials

The main ingredients of the study were cassava stem waste (*Manihot esculenta*). The type of adhesive used was natural latex rubber (NRL) adhesive (Research Center for Biomaterials, Cibinong, Indonesia). The NRL adhesive has viscosity of 457.5 mPa.s, solids content of 31.5%, and pH of 10.2 [12]. The equipment used includes cassava stem chopper machine (Rabakong), screener, oven dryer, digital scale, adhesive mixer, board forming box measuring 400 mm × 400 mm × 10 mm, hot pressing machine, camera, and Universal Testing Machine (Testometer, UK).

### Agriboard Production

The cassava stem particles were manufactured using a cassava stem chopper machine (Rabakong). First, cassava stems were sieved through a 20-mesh sieve. Then, the selected particles were dried utilizing gradual drying, i.e., with the air for a few days followed by drying in an oven drier until the moisture content of the particles reached less than 5%.

The NRL adhesive were applied at different levels such as 10%, 15%, and 20%. The target density is 0.7 g/cm$^3$ with panel size of 400 mm × 400 mm × 10 mm. The calculated amount of particles was arranged in a wooden box, and then hot-pressed at temperature of 60°C for 30 minutes under 10 MPa of pressure. The agriboard panels were then conditioned at room temperature (25-30°C) with relative humidity between 65%or 2 weeks until reaching equilibrium moisture content.

### Board Evaluation

Agriboard properties were evaluated according to the Japanese Industrial Standard (JIS) A 5908:2003 [13] standard for particleboard. Parameters of physical properties tested were density, moisture content (MC), water absorption (WA), and thickness swelling (TS). The parameters of the mechanical properties tested included the modulus of rupture (MOE) and the modulus of elasticity (MOE). The board cutting pattern is shown in Figure. 1.

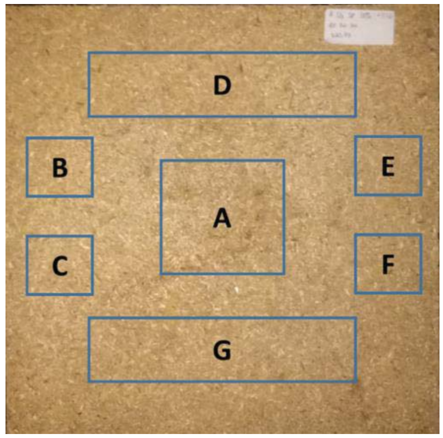


**FIGURE 1**. Illustration of cutting pattern for agriboard panel. A is Density and moisture content test sample, B is water absorption test sample and thickness expander, D is MOE and MOR test sample, C, E, F, G are the reserve samples.

## Data analysis

The mean values of physical and mechanical properties of agriboard were compared using analysis of variance (ANOVA), and Duncan Multiple Range test at $\alpha = 0.05$ was performed to determine optimum adhesive content for agriboard manufacturing. SPSS 25 software (SPSS Inc., Chicago, United States) was used for the statistical analysis.

# RESULTS AND DISCUSSION

## Physical Properties

*Density*

Density is the ratio between the weight of the test sample board and its volume. The higher the overall density of the board of a particular material, the higher its strength [14]. The value of particleboard density at the target density of 0.7 gr/cm$^3$ based on the results of this study ranged from 0.65–0.74 g/cm$^3$ with an average value of 0.71 g/cm$^3$ (Figure 2). The results showed that the resulting density was above the target density of 0.7 g/cm$^3$. The JIS A 5908:2003 standard requires 0.4-0.9 g/cm$^3$ of density for particleboard [13]. The results of this study indicate that the average density of the resulting agriboard meets the standard requirement [13].

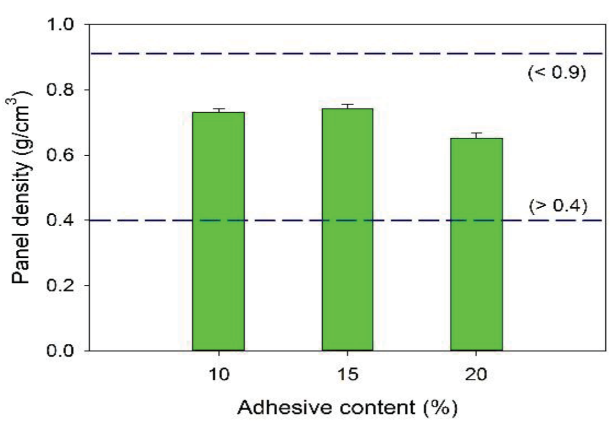


**FIGURE 2**. The density of agriboard panel bonded with NRL adhesive

*Moisture Content*

Moisture content is the amount of water contained in the particleboard in a state of equilibrium with the surrounding environment. The moisture content of agriboard manufactured is shown in Figure 3. The results showed that the moisture content (MC) of the agriboard was between 4.51–5.34%, with an average value of 4.81%. The MC of the resulting agriboard is lower than the JIS A 5908:2003 standard [13], which is 5-13%. The adhesive content of 15% results in 5.34% of MC which met the standard compared to the adhesive content of 10% and 20%. Higher adhesive content generally increased the MC of particleboard.

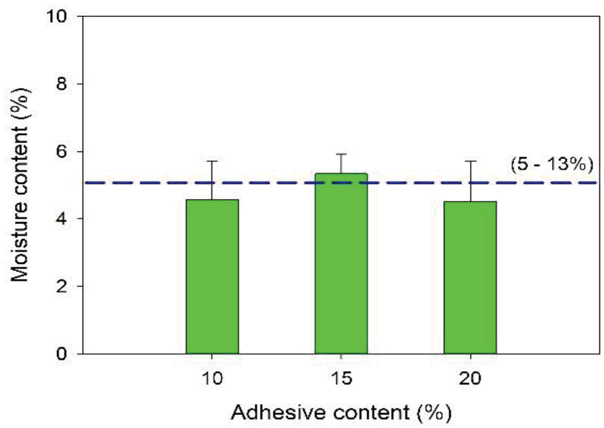


**FIGURE 3**. The moisture content of the agriboard panel at different NRL adhesive contents

*Water Absorption*

Water absorption (WA) is the ability of particle board to absorb water during 24 h immersion. The water fills the empty space on the board. The results of the WA test are presented in Figure 4. The results show that the WA of agriboard manufactured was 61.84-70.84%, with an average value of 67.32%. The results indicated that the type of raw material and adhesive content affected the water absorption of the resulting agriboard [15]. This result is in agreement with the published work that used NRL to produce particleboard, reporting that higher NRL adhesive content in particleboard created a binder protection against the WA [15]. This results revealed that the dimensional stability of agriboard increased with the higher adhesive content, indicating that the urethane linkages produced from the reaction between –NCO of isocyanate and –OH of cassava stems enhanced the adhesion strength of the panel [12].

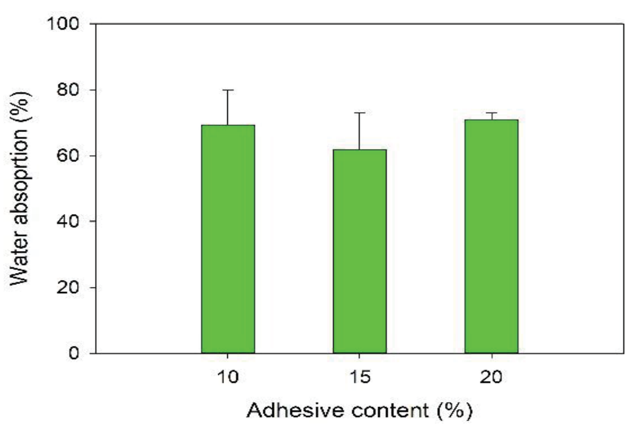


**FIGURE 4**. The water absorption of the agriboard panel at different adhesive contents

*Thickness Swelling*

Thickness swelling is an increase in the dimensions of the thickness of the board due to water filling the cavity in the board after being soaked for 24 hours. The results of the thickness swelling test are presented in Figure 5. The thickness swelling (TS) of agriboard after 24 h immersion was in the range of 23.67–28.77%, with an average value of 26.59%. The lowest TS value was obtained with NRL adhesive content of 20%, which is 23.67%. Meanwhile, the highest TS value was obtained with adhesive content of 10% with a value of 28.77%. This result is in agreement with the published work that used NRL to produce particleboard, reporting that increasing NRL adhesive content could reduce the TS value [16]. This results revealed that the dimensional stability of agriboard increased with the higher adhesive content, indicating that the urethane linkages produced from the reaction between –NCO of isocyanate and –OH of cassava stems enhanced the adhesion strength of the panel [12]. However, the TS value of all agriboard did not meet the JIS A 5908:2003 standard of maximum 12% TS.

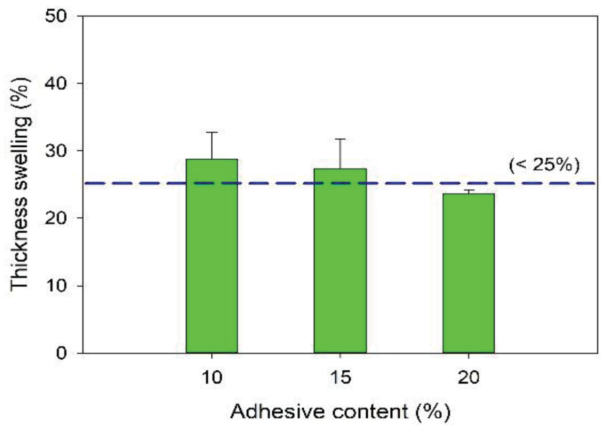


**FIGURE 5.** The thickness swelling of agriboard panel bonded with different levels of NRL adhesive

## Mechanical Properties

*Modulus of Rupture (MOR)*

Modulus of rupture (MOR) is a measure of the maximum load that can be accepted by wood [17]. MOR is determined from the maximum load times of the support distance divided by the cross-sectional area. The maximum load is obtained from testing the test sample until the test sample is damaged/broken. The results of MOR tests are presented in Figure 6. The MOR of particleboard was ranging between 2.49–3.13 MPa with an average value of 2.83 MPa (Figure 6). The highest MOR value was at 20% adhesive roughness. This result is in agreement with the published work that used NRL to produce particleboard [16]. The 2003 JIS A 5908 standard requires a minimum MOR value of 7.84 MPa. The results show that it is below the standard JIS A 5908:2003.

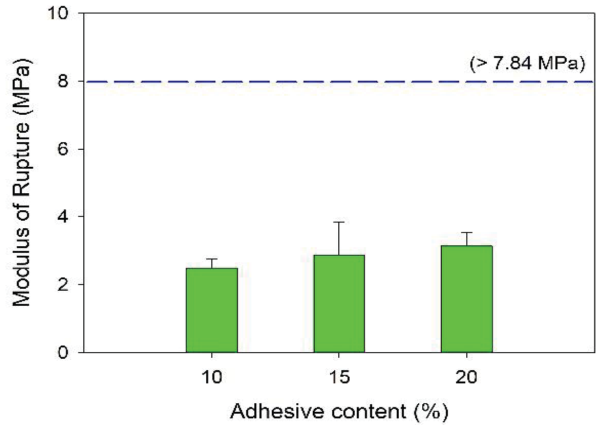


**FIGURE 6.** The MOR values of agriboard panel bonded with NRL adhesive

MOE is a measure of the wood's resistance in maintaining deformation due to loads and in direct contact with wood. The higher the MOE value, the more elastic. The MOE of the agriboard is presented in Figure 7. The results showed that the MOE value of particleboard was between 229.20–331.38 MPa with an average value of 267.67 MPa. This result is in agreement with the published work that used NRL to produce particleboard [16]. But, the MOE results show that the resulting agriboard panel does not meet the minimum JIS A 5908:2003 standard of 2000 MPa.

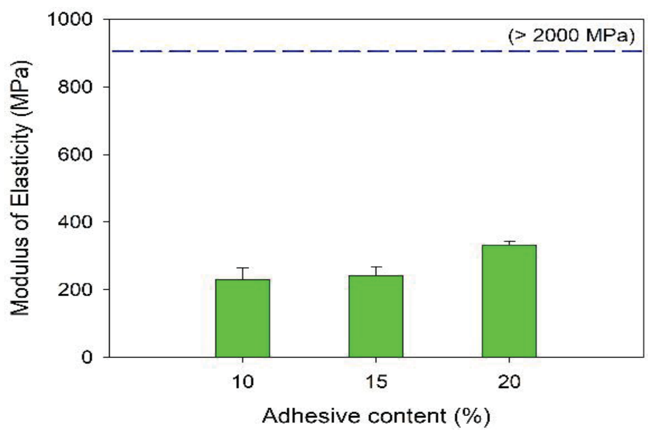


**FIGURE 7.** The MOE value of agriboard panel at different levels of NRL adhesive

**TABLE 1.** Analysis of variance (ANOVA) of agriboard properties bonded with NRL adhesive

| Properties | Mean square | F-value | P-value |
|---|---|---|---|
| Density | 0.007 | 37.471 | 0.001* |
| MC | 0.636 | 0.624 | 0.567 |
| WA | 69.437 | 0.876 | 0.464 |
| TS | 20.718 | 0.276 | 0.768 |
| MOR | 0.310 | 0.758 | 0.509 |
| MOE | 9264.07 | 12.664 | 0.007* |

**Properties with p-value lower than 0.05 are significantly influenced by NRL adhesive content*

Table 1 presents the ANOVA of agriboard properties. The result showed that only density and MOE values were significantly influenced by NRL adhesive content. The low physical and mechanical properties of agriboard bonded with NRL adhesive probably due to the use of fine particles and low adhesion between NRL and cassava particles [18]. However, the mechanical properties of the board increased with greater adhesive content, showing better adhesion could be obtained by increasing the adhesive content. As can be seen in Table 2, the optimal improvement of physical and mechanical properties of agriboard was obtained by using 20% of NRL adhesive content.

**TABLE 2.** Post-hoc test of agriboard properties using Duncan multiple range test

| **Properties** | **NRL adhesive content (%)** | | |
|---|---|---|---|
| | **10** | **15** | **20** |
| Density ($g/cm^3$) | 0.73 (b) | 0.74 (b) | 0.65 (a)* |
| MOE (MPa) | 229.20 (b) | 242.44 (b) | 331.38 (a) |

**The values with similar letters are not significantly different at p-value of 0.05*

## CONCLUSION

Cassava stem waste and NRL adhesive have the potential to be used as an environmentally friendly and sustainable substitute for wood composite products, particularly for non-structural and interior applications. The results revealed that the agriboard with an adhesive content of 15% could produce board with the best properties. The future challenge is to improve the physical and mechanical properties of agriboard using NRL based adhesive as the polymeric binder to be used as a structural particleboard.

## ACKNOWLEDGMENTS

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