Quality of particleboard made from rattan waste

L Astari¹, Sudarmanto¹, S S Kusumah¹, F Akbar¹ and K W Prasetiyo¹

¹Research Center for Biomaterials, Indonesian Institute of Sciences, Cibinong Science Center, Cibinong-Bogor 16911, Indonesia

E-mail: astari@biomaterial.lipi.go.id

Abstract. Indonesia as a tropical country has a various source of renewable resources; rattan is one of them. Rattan (Calamus rotang L.) is mainly utilized as raw material for furniture. Several wastes such as core and bark are produced during the process of furniture making. This research was conducted to investigate the properties of particleboard made from core and rattan bark. Rattan particle with moisture content less than 5% was mixed with the adhesive. Phenol formaldehyde (PF) 12% was used as the adhesive. The mixed particle was then hot pressed for 10 minutes at 150 °C with 25 kgf/cm². Board dimension was 25 x 25 x 1 cm. Before testing, boards were conditioned for seven days. Testing was conducted for physical and mechanical properties according to JIS A 5908-2003. Surface roughness testing, as well as wettability, was also conducted to investigate the surface properties of particleboard.

1. Introduction

Global demand on wood-based panel especially particleboard rises each year. Data released by FAO mentioned that in 2015 production growth of particleboard was 0.3 percent and soared to about 8 percent by 2017. Particleboard panels are commonly applied in furniture and decoration [1]. Particleboard as wood-based products performs several advantages, therefore, it still becomes favourite in several applications such as door core, wardrobes, cupboards, veneered panels, furniture, cabinets, home constructions, millwork, case and sporting goods, wall linings, shelving, toys and subflooring [2]. The increase in particleboard demands is not in line with the wood supply, therefore, recent research on wood-panel has concern on seeking new materials as a wood substitution.

Rattan is a cellulosic material that becomes the main commodity in Indonesia for the category of non-wood forest products. Indonesia produces at least 660,000 ton/year. The areas with major rattan production in Indonesia are Kalimantan, Sumatera, Sulawesi and Papua. Rattan is generally used as a material for furniture and craft stuff. During manufacturing of rattan for furniture, around 50% of the harvest is wasted. Rattan waste is generated from some processes such as debarking, cutting, skinnning and coring. The wastes come in chips form or dust. Therefore, the utilization of this material is still low. Since rattan is cellulosic materials and aimed as raw material for particleboard, chemical content is crucial information. The chemical components of rattan fibres are lignin 29%, hemicellulose 30%, cellulose 29% and ash 29% [3]. Besides, Jasni and Krisdianto provide data of chemical content of rattan that comprises as holocellulose (71-76%), cellulose (39-58%), starch (18-23%) and lignin (18-27%) [4]. It is stated that higher amount of cellulose increases the modulus of rupture (MOR) of rattan and higher amount of lignin content gives better bonds among rattan fibers. Based on the information above, it is necessary to provide information regarding the quality of particleboard that is produced from rattan waste.
Investigation on particleboard properties is generally conducted for its physical and mechanical, yet surface roughness information of particleboard is still limited. Information on surface roughness is urgent when particleboards are to be coated using thin overlays: foils, films and melamine impregnated papers for instance [5]. Surface irregularities critically influence the quality of end products. Therefore, investigating the surface roughness properties of particleboard made from rattan is essential.

2. Materials and method

2.1. Materials and equipment
Rattan fibers used in this research were the core part and skin part. Rattan fibers were supplied by PT. Rimba Makmur Utama (RMU) Katingan, East Kalimantan. The adhesive used was urea phenol formaldehyde (PF). The equipment involved was siever to obtain particle size 4-14 mesh, oven, drum mixer, spray gun, moulding mat with size 35cm x 35cm, hot press machine, Teflon sheet, iron bar, balance, desiccator, calliper and moisture meter.

2.2. Particleboard production
Weighing the particles and the adhesive according to formula calculation was the first step during particleboard production. The targeted density of the board was 0.7 g/cm$^3$, and the board dimension was 35cm x 35cm x 1cm. The adhesive percentage was 10% based on dry weight of particles. Particles and adhesive were mixed using drum mixer and spray gun. The mixture was then evenly spread at moulding mat. The mat was pressed manually using a hot press machine. The pressing condition was 150 °C, 10 minutes at 25 Kgf/cm$^2$. Conditioning was conducted for seven days at room temperature. Conditioning aimed to obtain moisture content evenly at all surface area of particleboard.

2.3. Physical properties testing

2.3.1. Density. The dimension of the sample test for density was 5cm x 5cm. To obtain the volume, samples at dry condition were measured for its length, width and thickness. The mass of the samples was also weighed. The density was calculated as follow:

$$D = \frac{m}{V}$$

$D$ = Density (g/cm$^3$)
$m$ = Mass of the sample (g)
$V$ = Volume at dry air condition (cm$^3$)

2.3.2. Moisture content. Sample test for moisture content measurement has a similar dimension with density, 5cm x 5cm. The samples were measured for their initial weight ($w_1$), then oven dried at temperature 103±2 °C for 24 hours. Samples were then placed at desiccator for about 15 minutes. Samples were weighed for their weight ($w_2$). The formula to calculate moisture content is given below:

$$MC = \frac{w_1 - w_2}{w_2} \times 100$$

$MC$ = Moisture content (%)
$w_1$ = initial weight of the samples (g)
$w_2$ = weight after oven (g)

2.3.3. Thickness swelling and water absorption. Thickness swelling and water absorption were measured by calculating the dimensional change. The thickness measurement was taken at the same point on the board. During the immersion, care was given to ensure that the surface of the specimen did not rest against the surface of the container. After two hours immersion, samples test was removed and extra water retained at the surface of the samples was wiped out. Following this, the measurement of dimension and weight was conducted. The procedure was repeated for 24 hours immersion. Thickness swelling (%) was calculated using the equation below:
TS = \frac{T_0 - T_1}{T_1} \times 100 \tag{3}

TS = Thickness Swelling (%)
T_0 = Wet thickness after water immersion (mm)
T_1 = Dried Thickness (mm)

Water absorption was calculated with following equation:

WA = \frac{w_2 - w_1}{w_1} \times 100 \tag{4}

WA = water absorption (%)
W = Weight at dry condition (g)
w_2 = Weight after immersion (g)

2.3.4. Mechanical properties testing. Parameters tested for mechanical properties were flexural strength properties which included testing the modulus of rupture (MOR) and modulus of elasticity (MOE), internal bonding (IB) and screw withdrawal (SW). Flexural strength was determined by three points static bending test using Shimadzu Universal Testing Machine (UTM) with a 50kN load cell. IB and SW measurement was also carried out by the same UTM. The sample dimension for flexural, IB and SW, was 20cm x 5cm, 5cm x 5cm and 10cm x 5cm.

2.3.5. Surface roughness. The surface roughness of the samples was tested by the stylus method using Mitutoyo surface roughness tester type SJ-210. Values of the roughness were measured with 0.5 μm sensitivity. Measuring speed and pin top angle was 0.02 in/s and 90°. The samples were tested for their roughness average.

3. Results and discussion

3.1. Physical properties

3.1.1. Density and moisture content. The density of the particle board was in the range of 0.73-0.78 g/cm³. The average density was 0.75 g/cm³. Moisture content was between 7.3-10.6%. All those values are in the range of JIS A 5908-2003 standard. The result of density and moisture content is depicted in the histogram below:

![Figure 1. Histogram of board density and moisture content.](image)

Board density fulfilled the targeted density which was 0.7 g/cm³. Board density highly depended on the density of raw materials and the pressure occupied during hot pressing. In this research, small variation occurred because the mat moulding was conducted manually during the production process.
JIS A 5908-2003 requires a moisture content of particleboard between 5-13%; the average moisture content of the board was 8.97%, therefore, it was clearly acceptable. The moisture content of the board is significantly affected by natural fibres, in this research is rattan fibre, which is hygroscopic and also due to the liquid adhesive [6]. The graph shows that particleboard from rattan core has the highest moisture content compared to those with rattan skin. It is observed that rattan skin is smoother than rattan core.

3.1.2. Thickness swelling and water absorption. Figure 2 shows that thickness swelling of particleboard after 24 hours immersion was in the range of 20.7 – 28.8% with the average of 24.1%. Those values are not in the acceptable standard value which requires maximal swelling 14%. The highest value given by particleboard from rattan was 28.8%, and the lowest was 20.7% from particleboard with wood waste. Rattan as a cellulosic material has poor absorption resistance. This condition is caused by the presence of polar groups. Polar groups are responsible for attracting water molecule by hydrogen bonding. The presence of water causes a moisture build-up in the cell wall as well as in the interface of fiber-adhesive. This phenomenon is responsible for the shift of dimension on particleboard [7]. In line with thickness swelling result, water absorption of particleboard is higher on rattan particleboard. There is no standard for water absorption.

![Figure 2. Thickness swelling of particleboard.](image)

![Figure 3. Water absorption of particleboard after 2 and 24 hours immersion.](image)

3.2. Mechanical properties

3.2.1. Modulus of Rupture (MOR) and Modulus of Elasticity (MOE). The result shows that the highest modulus of rupture was given by particleboard made from wood waste which was 21.69 MPa. The
Second place was particleboard from rattan core which was slightly below the wood with 21.33 MPa. Particleboard from rattan skin has MOR value of 18.48 MPa. All the MOR values meet the JIS standard for particleboard type 18. Lower MOR value on particleboard from rattan is due to fewer woody cells and short fibres [8].

![MOR and MOE value of particleboard.](image)

Particleboard made with rattan core performed superior mechanical properties compared to rattan skin due to a particle of rattan core was lighter. Particleboard using lighter material could increase mechanical properties of composites due to the increase of compaction ratio [7]. MOR of particleboard was also affected by adhesive characteristics such as adhesion, type, and content of adhesive and the particle size of raw material [9]. The high result of MOR of rattan particleboard is also supported by Zuiraida et al. ; their research resulted in MOR value which was about 48.8 MPa [10].

Figure 4 exhibits that MOE value has a similar trend to MOR though the value was below the JIS standard. It is mentioned that MOE value for type 8 board is 2 GPa. MOE value of particleboard in this research was between 0.19 – 0.87 GPa with an average of 0.51 GPa.

### 3.2.2. Screw Withdrawal (SW) and Internal Bond (IB)

Result for screw withdrawal and internal bond of particleboard is illustrated in figure 5. The highest internal bond was 1.46 MPa given by particleboard from wood waster followed by the board from rattan skin (0.67 MPa) and board from rattan core (0.35 MPa). All those boards are satisfied with the standard which requires 0.15 MPa for particleboard type 8.

![Screw withdrawal and internal bond of particleboard.](image)
Figure 5 depicts that screw withdrawal of particleboard from rattan core is considerably higher than particleboard made with rattan skin. The highest one is still performed by particleboard from wood waste.

3.2.3. Surface roughness. Roughness is a condition of the irregularities that occur on a surface. The surface roughness of particleboard was measured for its roughness average. It is observed that particleboard made with rattan core has the roughest surface (8.19 µm). The smoothest was particleboard from waste which was 3.34 µm.

![Figure 6. Surface roughness of particleboard.](image)

Research conducted by Hiziroglu and Suzuki [11] concluded that an acceptable range of surface roughness for particleboard is 3.67-5.46 µm. Therefore, particleboard from wood waste and rattan skin is in the range. The value of surface roughness is a combination function of raw material properties and several variables during manufacturing [12]. Factors affecting surface characteristics are board density, species of wood/raw material and pressing time. Generally, pressing time positively affects almost all of particleboards properties. In terms of surface roughness, pressing time gives an optimum condition on good hardening of adhesive and effectively evaporates moisture in the mat. It is also argued that due to longer time in pressing, some particles with vertical position may turn to a horizontal position and also the surface part becomes densified [8].

4. Conclusion
Rattan waste from core and skin is suitable as raw material for particleboard; the evidence was the targeted density which reached (0.7 g/cm³), the moisture content which was less than 10%, and all had MOR for Type 18 board. Moisture content, modulus of rupture and internal bond of the boards meet the JIS standard. Particleboard from rattan core has a rougher surface than particleboard from rattan skin and wood waste. The surface roughness of particleboard from rattan was between 5.39-8.19 µm. Particleboard from rattan waste especially core is comparable to those from wood waste.

5. References
[1] Candan, Z., & Akbulut, T. (2013). Developing environmentally friendly wood composite panels by nanotechnology. BioResources, 8(3), 3590–3598
[2] Baharoglu, M., Nemli, G., Sari, B., Bardak, S., & Ayirlimis, N. (2012). The influence of moisture content of raw material on the physical and mechanical properties, surface roughness, wettability, and formaldehyde emission of particleboard composite. Composites: Part B, 43, 2448–2451
[3] Ahmad, Z., Tajuddin, M., Salim, N. F. F., & Halim, Z. (2018). Effect of alkaline treatment on properties of rattan waste and fabricated binderless particleboard. *IIUM Engineering Journal, 19*, 185–196

[4] Jasni, & Krisdianto. (2012). The properties of Indonesian rattan. Retrieved from http://arknfpd.org/index.php/product/%0Adetail/The-Properties-of-Indonesian-rattan#.%0AUYFX2p3v ulU

[5] Buyuksari, U., Avci, E., Ayrlmis, N., & Akkilic, H. (2010). Effect of pine cone ratio on the wettability and surface roughness of particleboard. *BioResources, 5*(3), 1824–1833

[6] Haygreen, J & Bowyer, J (1996). *Forest Products and Wood Sciences: An Introduction (in Indonesian)*. Yogyakarta: Gadjah Mada University Press

[7] Tabarsa, T., Ashori, A., & Gholamzadeh, M. (2011). Composites : Part B Evaluation of surface roughness and mechanical properties of particleboard panels made from bagasse. *Composites Part B, 42*(5), 1330–1335

[8] Nemli, G., Aydin, I., & Zekovic, E. (2007). Evaluation of some of the properties of particleboard as function of manufacturing parameters. *Mater Des, 28*, 1169–1176

[9] Maloney, T. M. (1993). *Modern Particleboard and Dry Process Fiberboard Manufacturing*. San Francisco: Miller Freeman

[10] Zuraida, A., Maisarah, T., & Wan-Shazlin-Maisarah, W. (2017). Mechanical, physical and thermal properties of rattan fibre-based binderless board. *Journal of Tropical Forest Science, 29*(4), 485–492

[11] Hiziroglu, S., & Suzuki, S. (2007). Evaluation of surface roughness of commercially manufactured particleboard and medium density fiberboard in Japan. *Journal of Material Processing Technology, 184*, 436–440

[12] Hiziroglu, S., Jarusombuti, S., & Fueangvivat, V. (2004). Surface characteristics of wood composites manufactures in Thailand. *J Build Environ, 39*, 1359–1364