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The Influence of Microwave Treatment On The Characteristics of Randu (*Ceiba pentandra* (L) Gaertn.) Wood

(Pengaruh Perlakuan Microwave terhadap Karakteristik Kayu Randu (Ceiba pentandra (L) Gaertn.*))*

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ABSTRACT

Randu (Ceiba pentandra (L) Gaertn.) *wood is one of the fast-growing species which has low density. Wood modification by microwave (MW) treatment were conducted to improve its quality. The aim of this work was to evaluate the effect of microwave treatment on the characteristics (physical properties, wood discoloration, and wettability) of Randu wood. Microwave treatment for 0.5 and 1 minute were applied for Randu wood. The evaluation of wood discoloration, wettability, and physical properties include moisture content, specific gravity, swelling, and anti-swelling efficiency (ASE) were measured. Wood discoloration and wettability of untreated and treated sample were measured. The results showed that microwave treatment was reduce the swelling, wettability and cause discoloration. Microwave treatment not significantly affected moisture content and specific gravity of treated wood. Microwave treatment increased contact angle than untreated, and 0.5 minutes microwave treatment caused significant discoloration than 1 minutes microwave treatment and untreated sample. The MW treatment indicated to increase the hydrophobicity of Randu wood.*

***Keywords**: discoloration, microwave, randu, wettability.*

ABSTRAK

Kayu randu (Ceiba pentandra (L) Gaertn.) merupakan salah satu jenis kayu cepat tumbuh yang memiliki kerapatan rendah. Modifikasi kayu dengan perlakuan microwave (MW) dilakukan untuk meningkatkan kualitasnya. Tujuan dari penelitian ini adalah untuk mengevaluasi pengaruh perlakuan microwave terhadap karakteristik (sifat fisik, perubahan warna kayu, dan keterbasahan) kayu Randu. Perlakuan microwave selama 0.5 dan 1 menit diaplikasikan pada kayu randu. Pengujian yang dilakukan yaitu perubahan warna kayu, keterbasahan, dan sifat fisis yang meliputi kadar air, berat jenis, pengembangan, dan anti-swelling efficiency (ASE). Hasil penelitian menunjukkan bahwa perlakuan microwave mengurangi pengembangan, keterbasahan dan menyebabkan perubahan warna. Perlakuan microwave tidak berpengaruh nyata terhadap kadar air dan berat jenis kayu. Perlakuan gelombang mikro meningkatkan sudut kontak dibanding kontrol, dan perlakuan microwave 0.5 menit menyebabkan perubahan warna yang signifikan dibanding microwave 1 menit dan tanpa perlakuan. Perlakuan MW dapat meningkatkan hidrofobisitas kayu randu.

***Katakunci**: keterbasahan, microwave, randu, perubahan warna.*

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INTRODUCTION

Randu (*Ceiba pentandra* (L.) Gaertn) can grow up to 60–70 meters in height with wide diameter (up to 3 meters). This species mainly planted at West Java, Central Java, East Java, Bali, East Nusa Tenggara, West Nusa Tenggara, South Sulawesi area. Randu wood has specific gravity 0.28 (0.24-0.49) and categorized as a lowquality wood. It has class of strength: IV – V and class of durability IV-V (Salazar and Dorthe 2001). Wijayatrie (2008) reported that Randu wood have a lower quality in physical and mechanical properties than other wood species. Thus, special treatment were needed to improve its quality, one of improvement treatment is microwave treatment.

Wood modification is one of an effective way to improve physical and mechanical properties of wood (Hill 2006). Various methods for wood dimensional stability improvement have been developed. Wood dimensional stability improvement methods that have been developed include heat treatment, bulking agent, chemical modification, acetylation, impregnation (Esteves et al. 2007; Xu et al. 2009; Islam et al. 2012; Soltani et al. 2013; Cermak et al. 2015).

Another method to improve dimensional stability is microwave treatment. Microwave is electromagnetic wave generated by a magnetron (a microwave generating machine). A very small waves with frequenceies ranged from 300 Mhz to 300 GHz, have negative and positive poles that can penetrate into hollow structure such as wood. This wave are able to induce water molecules in wood cells and caused back and forth movement of negative and positive poles of water molecules, and generate heat (Barnes et al. 1976). Therefore, research on the effect of microwave treatment on the characteristics of Randu wood are needed. Thus, this study aims to evaluate the effect of microwave treatment on the characteristics of Randu (*Ceiba pentandra*) wood.

METHODS

Sample Preparation

Randu wood (±25 years; 40 cm in diameter) were obtained from community forest from Subang District, West Java, Indonesia. Wood sample were cut with the dimension 2 cm x 2 cm x 5 cm in width, thickness, and length.

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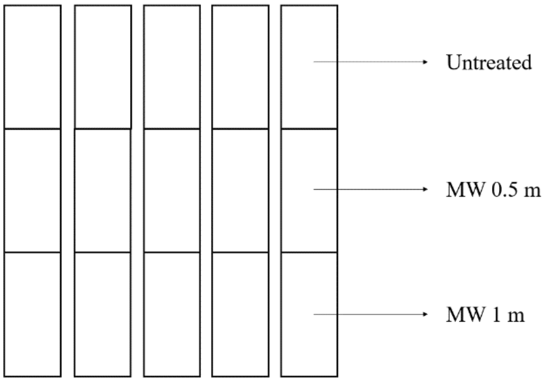

Figure 1 Sample preparation

Aftrer MW treatment, the samples was end-coated with hydrophobic paint on both edge and conditioned in the ± 60°C oven for 1 week. The air dried wood were weighted and measured the dimension. After measuring the dimensions and weight, the samples were immersed for 2 hours for swelling test. The sample also weighted to obtaine the final weight. To get the BKT value, the sample were dried at ± 103°C for 2 x 24 hours.

Microwave Treatment

Wood samples were treated by microwave heating at a constant temperature for 0.5 minute (5 minutes rest) and at a constant temperature for 1 minute (5 minutes rest), each treatment has 3 repetitions. After the sample was treated, the sample was conditioning in an oven at a temperature of ± 60°C for 2 days. The wood sample conditioned for 2 days before discoloration and wettability measurement.

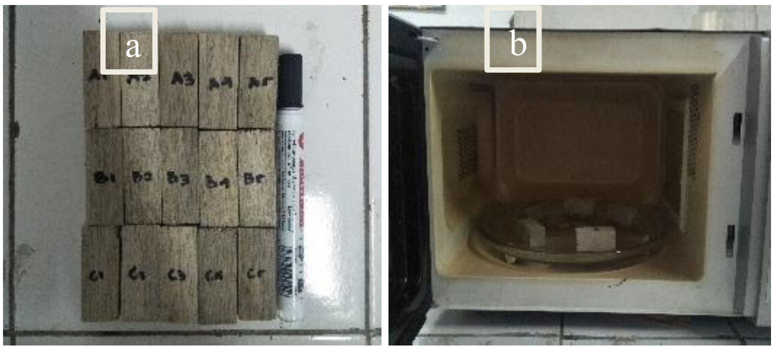

Figure 2 Wood samples (a) and microwave treatment (b) of Randu wood

Physical Properties Test

Moisture content (MC), specific gravity (SG), swelling, and anti swelling efficiency (ASE) of untreated and treated wood were measured. The weight of samples were measured to identify initial weight (W0) and measurement of volume (V0) by measure length, width, and height. The samples the oven dried at 103 ± 2 C for 48 hours to obtain a constant mass. Oven dried weight was measured to identify W1. The MC and SG was measured using formula:

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$$\% \text{ MC} = \frac{W_0 - W_1}{W_1} \times 100 \qquad (1)$$

$$\text{SG} = \frac{W_1/V_0}{\rho_{water}} \times 100 \qquad (2)$$

Dimensional stability of samples were evaluated by swelling and anti-swelling efficiency (ASE) The dimension of sample before (D1) and after (D2) immersion in water for 2 hours were measured. The sample then oven dried at 103±2ºC and weighted. Swelling and ASE value were measured using formulas:

$$\% \text{ S} = \frac{D_2 - D_1}{D_1} \times 100 \qquad (3)$$

$$\%\text{ASE} = \frac{\text{Swell V control- Swell V treatment}}{\text{Swell V control}} \times 100 \qquad (4)$$

Where Abs is absorption, B1 and B2 is initial and final weight, %ASE is anti-swelling efficiency, %S is swelling, D1 is initial dimension (before immersion), and D2 is final dimension (after immersion).

Wood Discoloration Measurement

The measurement of wood discoloration refers to Kleeberger and Bruno (2002) using an image processing scanner and processed with Image-J to obtain L*, a* and b* values. The color difference (ΔE) was calculated based on the CIELab method (Christie 2007):

$$\Delta \mathbf{E} = \sqrt{[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]} \qquad (5)$$

where ΔE is color difference, ΔL* is the brightness change, Δa* is red-green color difference, and Δb* is the yellow-blue color difference.

Contact Angle Measurement

Contact angle measurement were determined according to Yuningsih et al. 2019; Martha et al. 2020; Baiti et al. 2021. The dynamic contact angles of water were performed with video measuring system with hight-resolution CCD camera. Wood specimen was placed on the top of table in front of the CCD camera then drop of water (volume 20 µl) using syringe with a screwing method to obtain the same droplets. The drop shapes were captured and saved for 180 s, then five droplets per sample were captured for contact angle measurements. Contact angle of each droplet were measured both on the left and right side using The Image-J 1.46 software with drop-snakes plugin analysis. The equilibrium contact angle (θe) were determined based on the segmented regression equation between contact angle (y) and time (x) using PROC NLIN program from SAS software (SAS 2004). The contact angle change rate (K-value) on the S/G model (Shi and Gardner 2001) was used to quantitatively evaluate the wettability (Equation 6).

$$\theta = \frac{\theta i . \theta e}{\theta i + (\theta e - \theta i) \exp\left[K\left(\frac{\theta e}{\theta e - \theta i}\right)t\right]} \qquad (6)$$

Where the equilibrium contact angle (θe), the constant of contact angle change rate (K), (θi) is the initial contact angle (t = 0 s). The K-value was calculated using defined functions of non-linear regression model to fit the S/G equation by XLSTAT.

Data Analysis

The experiment was arranged in a completely randomized design with five replications. The factor studied was the effect of microwave treatment (0.5 and 1 minute). Analysis of variance with a 95% confidence level were performed using IBM SPSS 25.0 software. If the results have a significant effect then continue with Duncan's test.

RESULTS AND DISCUSSION

Physical Properties

The physical properties of MW treatment wood were varied between 0.5 and 1 min MW treatment. A low moisture content value will be more beneficial, especially to increase the resistance of wood from microorganisms attack (Hill 2006). According to Coto (2005), drying (microwave heating) to low water content causes a change in some of amorphous regions to become crystalline which results in reduced hydroxyl groups.

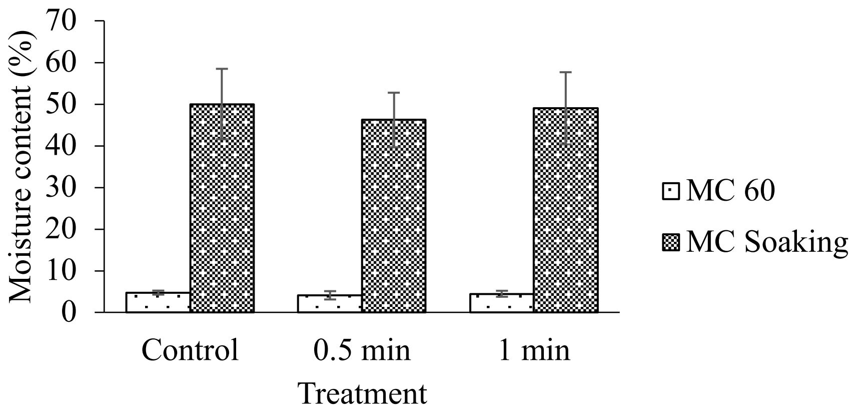

Figure 3 Moisture content of untreated and microwave treated Randu wood

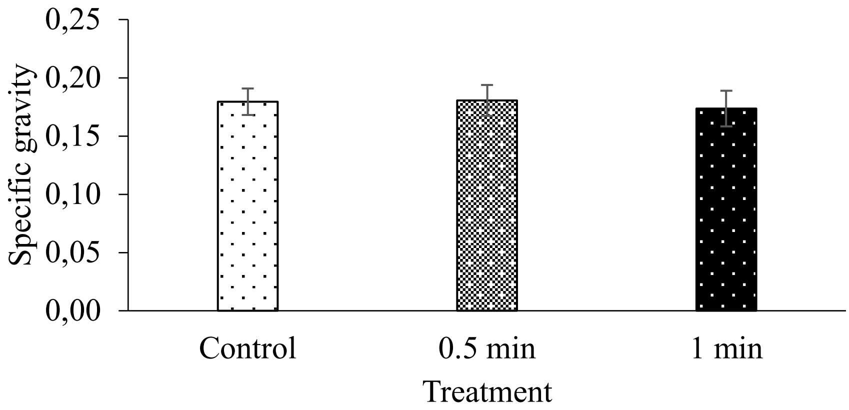

Figure 4 Specific gravity (b) of untreated and microwave treated Randu wood

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Microwave treatment resulted a lower water absorption on Randu wood (Figure 5). A lower water absorption on wood were in line to a lower moisture content. Its caused by volatilization of wood extractive content to the surface. According to Hill (2006), wood is hygroscopic material because it contains reactive hydroxyl groups as cell wall polymers. Thus, wood can absorb water when soaked, resulting in an increase in mass due to the entry of water molecules. Wood swelling is related to dimensional stability. The lower wood dimensional swelling, the better the dimensional stability of wood. This is in accordance with the statement of Bekhta and Niemz (2003) that heated wood will be more stable.

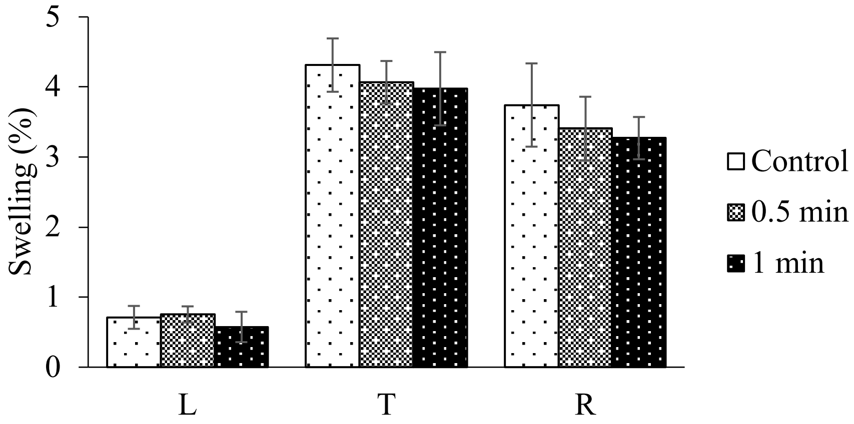

Figure 5 Swelling of Randu wood on the three direction

The ASE value used to evaluate the improvement of dimensional stability treatment. The higher ASE value indicates the ability of material to prevent swelling and become a good-stability material (Barly et al. 2012). The ASE value of Randu wood after 1 minute of MW treatment was higher than 0.5 minute of MW treatment. In addition, 1 minute of MW treatment tended to cause Randu wood to be more stable than 0.5 minute MW treatment. This is supported by Astuti (2016) that the higher the ASE value, the lower swelling dimensions of wood sample. The cross-linking reaction within lignin complex can decrease the hydophylic character of wood that caused increase of dimensional stability (Cai et al. 2018).

The results of the analysis of variance showed that the ASE value was not influenced by MW treatment. The ASE value was higher than 50%, indicates that dimensional stabilization were succeed. ASE value after heat treatment was strongly dependent on climate location, cultivation method, hardwood or softwood, and heartwood or sapwood; and on the technology-related factors (Zhan et al. 2021). The ASE value of 0.5 and 1 minute MW treatment was lower than 50%, so the treatment were not successfully increased ASE value of Randu wood. The longer time of MW treatment may needed to increase the ASE value of wood.

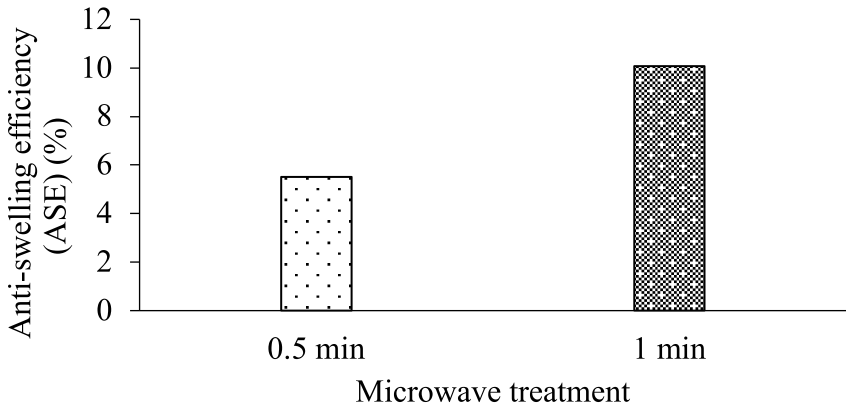

Figure 6 ASE value of untreated and microwave treated Randu wood

Wood Discoloration

Wood colors is one of the important parameters for wood consumen due to its relation for wood utilization. Wood colors for different use also need different colors. Microwave treatments also can modify wood colors. Wood discoloration were measured by CIELAB method (Equation 5) and the results are presented in Table 1. The L*, a*, and b* parameter represent brightness, redness, and blue color of material. A lower brightness value (L*) cause the wood to darken, while an increasing a* value makes the higher red color, and a decrease of b* indicates a higher blue color of wood after treatment.

Wood discoloration caused by MW treatment are caused by several factors. The use of high temperatures can encourage a reaction to the color of the wood (Muflihati 2013). In addition, the color changes that occur are also influenced by the heating temperature and heating time (FPS 2002). Higher heating temperature and longer heating duration may caused the wood to loose its brightness (Huang et al. 2012).

Tabel 1 Color Parameter Analysis of Untreated and Treated Randu Wood

	MW 0.5 m		MW 1 m	
	Before	After	Before	After
L*	77.05	81.91	81.57	83.35
a*	1.84	2.48	2.29	2.06
b*	9.73	8.28	10.35	8.15
∆E	-	6.67	-	5.39

Wettability

The wettability of wood can be characterized by measuring the contact angle. Contact angle value that less than 90° indicates good wettability, while more than 90° indicates poor wettability because the liquid will difficult to wetting the wood surface (Yuan and Lee 2003). In addition, the larger contact angle of treated wood caused by the change of the amorphous region to the crystalline region and the reduction of the hydroxyl group of Randu wood. According to Coto (2005), drying (microwave heating) to low water content

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causes a change in some of the amorphous regions to become crystalline which results in reduced hydroxyl groups.

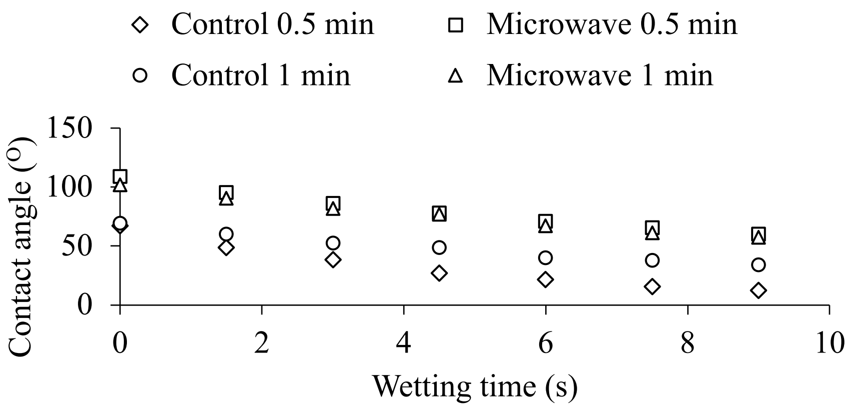

Figure 7 Contact angle as function of time (left) and plot of contact angle versus time for untreated and microwave treated Randu wood (right)

Wettability of liquid were determined by K value. A higher K value indicates better wettability (Shi and Gardner 2001). K value of 0.5 and 1 minute MW treatment wood were decreased from the untreated wood. Thus, MW treatment were decreased the wettability of Randu wood (shown by the decreasing of K value). In other word, the MW treatment indicated to increase the hydrophobicity of Randu wood. Heat treatment will increase the hydrophobicity of wood (Petrissans et al. 2005).

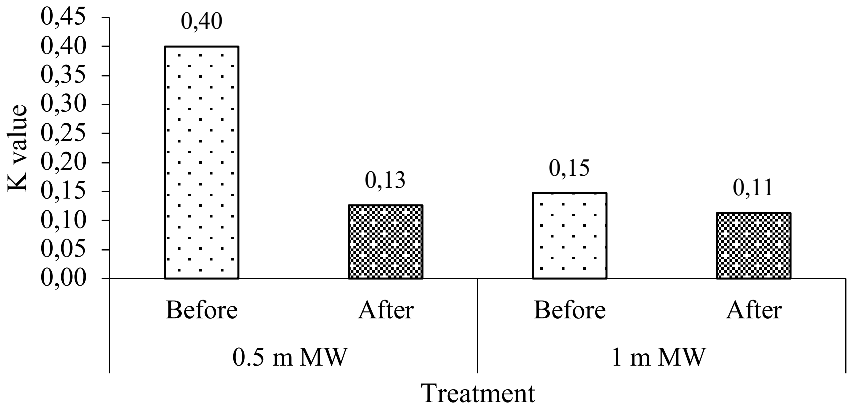

Figure 8 K value of untreated and microwave treated Randu wood

The K value describes how fast the liquid can penetrate the wood surface. A higher K value indicates a faster liquid velocity to spread and penetrate the wood surface (Shi and Gardner 2001). In other words, a higher K value indicates better wettablility. According to Darmawan et al. (2017) a rough wood surface has a high K value and good wettability.

Wetting process were affected by several factors, include the acidity (pH) of wood (Gerardin et al. 2007). The wettability of wood also influenced by macroscopic

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characteristics of wood such as density, surface roughness and moisture content (Unsal et al. 2011). The density of wood is related to the level of absorption. The higher the density, the lower rate of absorption (Panshin and de Zeeuw 1980).

CONCLUSION

Microwave treatment 0.5 and 1 min were reduce swelling of treated wood. Therefore, MW treatment not significantly affected moisture content. The anti-swelling efficiency (ASE) of Randu wood were increased after microwave treatment. Microwave treatment were reduce the wettability and cause discoloration of Randu wood. Microwave treatment increased contact angle than untreated sample. Microwave treatment at 0.5 minute caused significant discoloration than 1 minute microwave treatment and untreated sample. The MW treatment indicated to increase the hydrophobicity of Randu wood.

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