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Effect of Heat Treatment on Color Change and The Physical Properties of Sembilang Bamboo (*Dendrocalamus giganteus* Munro)

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ABSTRACT

Timber as a raw material for making furniture is still lacking. One alternative to overcome this problem is bamboo. The potential for bamboo in Indonesia is quite large. Sembilang bamboo is a species of bamboo that has not been widely used. Research related to the effect of heat treatment on color change and the physical properties of bamboo needs to be carried out to determine color change and the dimensional stability of bamboo. This research was carried out by giving heat at 180°C for various durations (control, 3 hours, and 6 hours). The color change, moisture content, absorption, and specific gravity of heat-treated sembilang bamboo were researched. The results showed that the color of sembilang bamboo after heat treatment became darker than the control. The moisture content and absorption values of sembilang bamboo with heat treatment at 180°C for 6 hours were higher than the control and 3 hours. The specific gravity value of the bamboo control was higher than 3 hours and 6 hours for sembilang bamboo. Heat treatment at 180°C for 6 hours had an adverse effect on the physical properties of sembilang bamboo. Heat-treated sembilang bamboo at 180°C for 3 hours was recommended in this research.

Keyword: Bamboo Modifications, *Dendrocalamus giganteus* Munro, Heat Treatment, Physical Properties, Sembilang Bamboo

1. Introduction

One of the obstacles to the development of the furniture industry in Indonesia is the need for round wood raw materials for making furniture. According to Industrial Data Center of Ministry of Industry (*Pusat Data Industri Kementerian Perindustrian*) [18], to achieve the 2024 export target, at least 42.5 million m^3 of logs per year are needed. Logwood production in Indonesia in 2022 will reach 64.65 million m^3 [4]. However, more than this amount is needed to meet the production of furniture industry, bearing in mind that other industries also need supplies of logs. Therefore, alternative raw materials are needed to overcome this problem. Utilization of raw material efficiency needs to be done by looking for raw materials that have properties similar to wood. One of the materials that can be used as a substitute for wood is bamboo.

Bamboo is a plant that is well known to many Indonesian. Bamboo production in Indonesia in 2022 will be around 258.76 tons [10]. The potential for bamboo in Indonesia is quite large. Bamboo production in Indonesia in 2022 will reach 66.92 million stems per year [4]. Bamboo is a non-timber forest product that has many benefits for humans. Bamboo can be used as a construction material for construction, furniture, flooring,

textiles, fiber, food, utensils, and musical instruments due to its quality and versatility [25]. Bamboo is a fast-growing plant and can be harvested in 3-5 years [11]. According to Phimmachanh et al. [23], bamboo has potential as a substitute not only for solid wood raw materials but also for plastics, steel, cement, and composite materials in structural and product applications. Bamboo is a renewable resource and is versatile and easy to work with, using simple tools to make products [13].

One species of bamboo found in Indonesia but rarely utilized is sembilang bamboo (*Dendrocalamus giganteus*). Sembilang bamboo is bamboo with large reeds and clumps [21]. Research related to sembilang bamboo has been carried out regarding its taxonomy [21], specific gravity [26], mechanical properties [1], and growth [2]. Research related to the physical properties of bamboo is important to determine bamboo's dimensional stability [19]. Efforts that can be made to overcome this are through heat modification.

Research related to heat modification has been carried out on wood [5,14,22]. The general result is that temperature and heating time have a significant influence on wood discoloration (making the wood darker), and the hardness of the wood increases. Hill and Boonstra found that one of the factors that can affect the results of heat modification is temperature and heating time [6,16]. Heat modification is claimed to be an environmentally friendly method because it can improve dimensional stability with limited use of chemicals. However, there is an important parameter, especially if bamboo will be used as furniture, which is the appearance of the bamboo. Therefore, this research was conducted to study the effect of heat treatment on color change and the physical properties of sembilang bamboo.

2. Method

Sembilang bamboo at the base section was used in this research. The size of the research sample was 5 x 2 cm (length x width), with the thickness following the thickness of the bamboo. The cut samples were heat treated at 180°C. Before being heat treated, the samples were marked A (control), B (3 hours), and C (6 hours) with 5 repetitions each. The marked sample is then scanned for an initial color test. After that, samples B and C are put into the oven at a temperature of 180°C. After heat treatment, the conditioning process was carried out on the sample by putting it in an oven at 60°C for 1 day. After the conditioning process was completed, the sample was tested again for color changes. The test was conducted using a scanner machine (CanoScan 4400F) and Adobe Photoshop 7 software to determine the L*a*b value. The color change value (ΔE) was calculated based on the CIELab method [9] with the equation.

$$\Delta E=\sqrt{[(\Delta L)^2+(\Delta a)^2+(\Delta b)^2]} \qquad (1)$$

Description:
ΔE : Discoloration
ΔL : Difference in brightness
Δa : Red or green color difference
Δb : Yellow or blue color difference

Table 1. Color Change Assessment of Color Differences [15]

No	Color Differences	Influence
1	ΔE < 0,2	not visible
2	0,2 < ΔE < 2	very small
3	2,0 < ΔE <3,0	small (changes visible with high-quality filters)
4	3,0 < ΔE < 6,0	medium (changes visible with medium quality filters)
5	6,0 < ΔE < 12,0	large (color change are clearly visible)
6	ΔE > 12,0	Color differences occur

After the heat treatment was completed, the sample was given an end coating on both ends with no drop. Then the samples were dried in the oven at 60°C for 7 days for conditioning. After conditioning, the samples were weighed, immersed in water for 2 hours, and then weighed again. The sample was then put into the oven at a temperature of 103 ± 2°C for 2 days until the dry weight of the kiln was measured, and its mass and dimensions were measured again.

A simple completely randomized design was used for data analysis. It is used to analyze the effect of heat treatment on all responses (i.e., color change, moisture content, absorption, and specific gravity). The data uderwent analysis using Microsoft Excel and IBM SPSS Statistics version 26, an acronym for Statistical Product and Service Solution. The study's duration was segmented into three categories: control. 3 hours, and 6 hours, forming the basis of the analysis. Duncan's multiple range tests were conducted for further analysis in cases where a factor exhibited significant differences with at $p \leq 0.05$.

3. Result and Discussion

3.1 Color Change

After heat treatment, the L, a, and b values were lower than the controls (Table 2). L, a, and b values on sembilang bamboo with heat treatment for 3 hours decreased from the control by 26.97, 0.07, and 11.20, respectively. In heat treatment for 6 hours, L, a, and b values decreased by 31.70, 2.67, and 16.50, respectively. In this study, heat-treated bamboo had a darker color than before treatment (Figure 1). The L value indicates the brightness of the wood, with a number range of 100 (white) to 0 (black) [20]. This is in line with research by Zanuncio *et al.* and Lukmandaru *et al.* [3,12], which states that one of the effects of heat treatment is that it can make the color of wood darker.

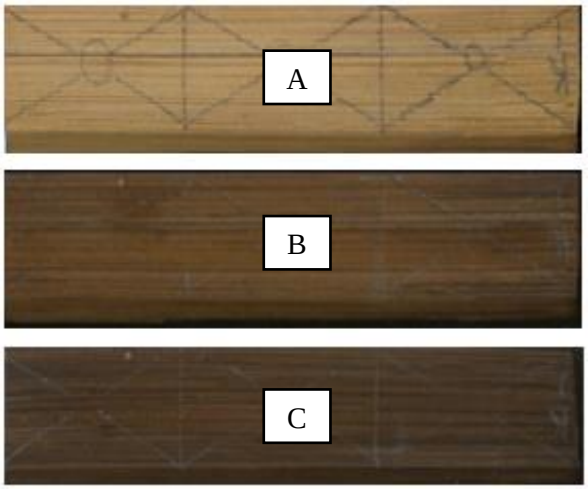

Figure 1. Discoloration sample of Sembilang Bamboo (A: control; B: 3 hours; C: 6 hours)

Table 2. The Color Change Value of Sembilang Bamboo

Duration	L	a	b	ΔE
Control	57,47±1,27[a]	7,67±0,40[a]	28,47±0,29[a]	tb
3 hours	30,50±3,05[b]	7,60±1,25[a]	17,27±3,45[b]	29,56±2,75[a]
6 hours	25,77±1,0[c]	5,00±0,46[b]	11,97±0,8[c]	36,23±0,90[b]

Note: tb: unchanged. Based on Duncan's follow-up test, the same letters in the table 2 showed no difference at α=95%.

According to Nurhanifah [17], the color change that occurs can be seen from the ΔE value. Three and six hours of heat treatment caused the color changes in sembilang bamboo. This is because the color change has a value exceeding 12.0. The ΔE value of the 6 hours heat treatment was higher compared to the 3 hours heat treatment. According to the color change phenomenon, control bamboo has a dark moderate orange color, bamboo with heat treatment for 3 hours has a very dark desaturated orange color, and bamboo with heat treatment for 6 hours has a very dark desaturated orange color.

The statistical analysis showed that the heat treatment for 3 and 6 hours significantly affected the value of the wood color change. Duncan's test showed that colors treated with heat for 6 hours had a higher color change value than those treated with heat for 3 hours. In line with the research of [14], the time factor of heat treatment significantly influences the value of color change. This can happen because the color change of wood depends on temperature and heating time [6]. Widyorini *et al.* [22] stated that the formation of colored substances of phenolic compounds oxidized with air and dark matter (extractive compounds) from hemicellulose hydrolysis is considered the cause of color change.

3.2 Physical Properties

Moisture content is the percentage of water that can be absorbed by a material. The water content value in this study ranged from 2.95 to 3.56% (Table 3). The results of the statistical analysis showed that the control water content had significantly different values than at 3 hours and 6 hours, but the results of Duncan's further test stated that the differences were not significant. In addition, the heat treatment for 6 hours was significantly different from the 3 hours.

Table 3. Physical Properties of Sembilang Bamboo

Duration	Moisture Content (%)	Absorption (%)	Specific Gravity
Control	2.95^{ab}	25.60^{a}	0.37^{a}
180°C 3 hours	2.42^{a}	25.65^{a}	0.34^{a}
180°C 6 hours	3.56^{b}	93.79^{b}	0.34^{a}

Note: values followed by the same letter in a column are not statistically different.

Absorption is the ability of a material to absorb water during testing. Absorption was tested after immersion for 3 hours in water. The absorption value in this study was 25.60-93.79% with the highest value at 6 hours of treatment. According to Sahin [8], the smaller the absorption of water, the better the dimensional stability. The results of the statistical analysis showed that the heat treatment for 6 hours had a significant effect on the absorption value.

According to Karlinasari [14], heat treatment can affect the ability of wood to absorb water due to a decrease in the number of hydroxyl groups. This can make it difficult for a material to absorb water. However, in this study, the values of moisture content and absorption at 180°C heat treatment for 6 hours had higher values than the control and 3 hours. This can occur due to damage to the bamboo due to excessive drying speed. Listyanto [24] states that over-drying can cause differences in the degree of dryness between the surface and the inside, which can cause drying defects such as cracking or even splitting.

Specific gravity in this study was measured when the heavy bamboo was kiln dried. The specific gravity value in this study was 0.34-0.37. The specific gravity value after heat treatment is lower than the control. That can occur due to partial hemicellulose decomposing into acetic acid when the temperature reaches 120°C and then the acetic acid decomposes [7]. The results of the statistical analysis showed that the temperature treatment of 180°C did not have a significant effect on the specific gravity value of sembilang bamboo.

4. Conclusion

Heat treatment at a temperature of 180°C significantly influenced the color change of sembilang bamboo. The color of sembilang bamboo after heat treatment became darker than the control. The longer the heating time, the greater the color change value. Heat treatment at 180°C for 6 hours resulted in the highest moisture content and absorption values compared to the control and the 3 hours treatment. In addition, the specific gravity value of sembilang bamboo after heat treatment decreased compared to the control. In this study, heat treatment at 180°C had an unfavorable effect on the physical properties of the sembilang bamboo.

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