Changes in the density, specific gravity and dimensional stability of candlenut wood (*Aleurites moluccanus* (L.) Willd.) from several variation temperatures with oil-heat treatment

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Abstract. Quality of inferior woods can be improved with wood modification technology. There are some wood modification technologies available, one of them is oil-heat treatment. Candlenut wood (*Aleurites moluccanus* (L.) Willd.) is one of low-quality wood species with limited utilization. Efforts to improve the properties of wood are needed for more optimal utilization. This research was conducted to improve physical properties of candlenut wood namely density, specific gravity, and dimensional stability by applying oil-heating treatment at various temperatures (160, 180 and 200°C) for one hour. Physical properties of wood were tested according to ASTM D143-94. The result showed candlenut wood in oil-heat treatment as better than control. Density and specific gravity of wood increased by 25.13% and 26.97%, respectively, and the dimensional stability also increased as well, shown by the reduction of hygroscopic properties of wood at tangential and radial directions by 22%. The best treatment selected for candlenut wood with temperature of 160°C.

1. Introduction

The main use of candlenut plant is as a fruit-producing [1], and if it is no longer productive in producing fruit, the wood will be utilized. However, this species is known as low-quality wood both in terms of strength and durability. Candlenut wood is included in the strength class IV-V and durability class IV and V against wood rot and termite attack, respectively [2].

In order to optimize the candlenut wood utilization, the wood strength and durability should be increased. One way is through heat modification. Heat modification is a technology that is quite commercially developed compared to chemical modification and impregnation technology, especially in European countries [3]. A method in heat treatment is oil-heat treatment. This method is able to increase the durability of wood and is effective in improving the stability of wood dimensions [4].

Modification of wood with oil heat treatment has been studied recently and it is proven can improve the properties of wood, especially by giving heat temperatures higher than 140°C. Several studies have shown an increase and decrease in properties of wood after heating with oil. This shows that a wood species has different responses to the temperature and heating time, thus experiment is needed to obtain optimal results. Therefore, this study was conducted to find out the response of candlenut wood to oil
heat treatment at several variations in temperature and time. Changes in physical properties of wood can be used as a reference response of treatment.

2. Materials and Methods
This research used candlenut wood that was collected from Limam Poccoe Village, Maros Regency. Bulk oil was obtained from traditional market in Maros. Small clear specimens were prepared based on modified ASTM D143-94 [5]: 2 x 2 x 2 cm for specific gravity, and 2 x 2 x 8 cm for shrinkage. The samples were then conditioned to reach at 65±5% relative humidity and temperature of 20±2°C.

There were three heat-oil treatments, namely 160º, 180º, 200ºC, and control (untreated). Firstly, the weight and dimensions of all samples were measured. The treated-samples were gradually heated at 60º and 90°C in oven. The samples were then oil-heated for one hour, and conditioned for one month before measuring the weights and dimensions after treatment. The density, specific gravity, and shrinkage were then calculated.

The data were analyzed using randomized completely design with four treatments and five replications. Tukey’s Honestly Significant Difference (HSD) test at a significance level p>0.05 was used to compare significant differences in the means.

3. Results and Discussion
3.1. Density and specific gravity
Density of candlenut wood after heating treatment with oil showed different results compared to control in Figure 1. The average density of controls was 0.38 g/cm³. The density of wood with oil-heat showed high increase compared to controls ranging from 18.85 to 25.13%. The highest density obtained at 160ºC heating temperature of 0.48 g/cm³. Increased wood density generally occurs due to penetration of a substance in an anatomical structure of wood and remains inside even drained and storage for long time. The density can increase because mass of oil-heated specimens increase that oil filled in the wood cells, while volume of wood just remains or only slightly changed.

The increase of heat temperature affected to the decrease of wood density. High temperatures allow for an increase density due to extractive migration that occurs on surface of wood was not dissolved [6]. In addition, a longer heating time will cause more oil to fill in wood cells, thereby increasing the density of wood [7]. However, the decrease occurred in high temperatures can degrade chemical components of wood, especially hemicellulose [8]. Each characteristic is different for main components of wood. The degradation temperature in wood cellulose ranges from 275 to 350°C, hemicellulose by 150 to 300°C, and lignin by 250-500°C [9]. A decrease in hemicellulose content during heating with oil starting from 180°C [10].
The average specific gravity of controls was 0.36. The range was between 0.31 to 0.44, thus it fell to the strength class IV-V [2]. Specific gravity of wood with oil-heat treatment increased as much as 26.98%. Changes in value of specific gravity are closely related to the changes in wood density.

3.2. Dimensional stability

The dimension changes of wood in tangential direction were greater than at radial direction. This generally occurs even without treatment. Changes in tangential ranged from 1.5 to 3 times higher than radial direction. Oil-heat treatment at 160°C did not show significant differences in wood. This is because only secondary components of volatile and soluble wood were affected.

Figure 2 showed heat treatment with oil has a significant influence on decrease in dimensional stability of wood. Oil can be a good heating media for wood compared to water as oil can transfer the heat into the wood more quickly and evenly. Additionally, the oil can prevent oxygen penetrating the wood during treatment process. Oil absorption during treatment form a protective layer in surface of wood, thus it can maintain the wood stability [6].

![Figure 2. Shrinkage of candlenut wood after heat treatment from air-dry to oven-dry condition](image)

The decrease in dimension by 0.96 to 22.19% occurred when the temperature increase by 200°C. Heat treatment in three species of Philippine bamboo (Bambusa blumeana, B. vulgaris and Dendrocalamus asper) decrease up to 80% compared to the control [11].

Wood have good stability in high temperature than lower. Heat treatments greater than 150°C can clearly decrease the shrinkage and change equilibrium moisture content (EMC) of wood [12]. The heating treatment can reduce water absorption in wood due to reduced hydroxyl groups (-OH). A large number of hydrophilic groups change to hydrophobic oxygen-acetyl (O-Acetyl) groups causing reduced -OH hands to bond with water molecules and wood hygroscopic decreases, resulting the increase in dimensional stability [8,13]. The heat treatment improves the quality of the timber for furniture industry, as well as improves the decorative property. The wood appearance is more attractive, apart from the resistance from fungi.

The ratio of tangential and radial direction (T/R ratio) of candlenut wood after heat treatment ranged below the value of 2. The T/R ratio more than 2 shows poor dimensional stability of wood because it can cause deformation in wood [14].
**Table 1.** Result of Tukey Honestly Significant Difference test for physical properties of candlenut wood

| Variables          | Treatments       | Mean   | St. Dev. | R%     |
|--------------------|------------------|--------|----------|--------|
| Density (g/cm³)    | Control          | 0.38a  | 0.008    | -      |
|                    | Oil Heat-160°C   | 0.48c  | 0.008    | +25.13 |
|                    | Oil Heat-180°C   | 0.46b  | 0.008    | +19.90 |
|                    | Oil Heat-200°C   | 0.45b  | 0.005    | +18.85 |
| Specific Gravity   | Control          | 0.36a  | 0.005    | -      |
|                    | Oil Heat-160°C   | 0.45c  | 0.011    | +26.97 |
|                    | Oil Heat-180°C   | 0.45c  | 0.004    | +25.84 |
|                    | Oil Heat-200°C   | 0.41b  | 0.005    | +16.29 |
| Shrinkage (Tangential) | Control       | 2.37c  | 0.008    | -      |
|                    | Oil Heat-160°C   | 2.32b  | 0.012    | -2.11  |
|                    | Oil Heat-180°C   | 2.29b  | 0.029    | -3.44  |
|                    | Oil Heat-200°C   | 1.84a  | 0.030    | -22.19 |
| Shrinkage (Radial) | Control          | 1.32b  | 0.016    | -      |
|                    | Oil Heat-160°C   | 1.31b  | 0.018    | -0.96  |
|                    | Oil Heat-180°C   | 1.24a  | 0.025    | -5.99  |
|                    | Oil Heat-200°C   | 1.21a  | 0.013    | -8.35  |
| T/R Ratio          | Control          | 1.79bc | 0.019    | -      |
|                    | Oil Heat-160°C   | 1.78b  | 0.028    | -0.78  |
|                    | Oil Heat-180°C   | 1.84c  | 0.044    | +2.79  |
|                    | Oil Heat-200°C   | 1.52a  | 0.022    | -14.96 |

Notes: SD : Standard deviation  
R% : Percentage change in variable after heat treatment from control  
Positive mark (+) : Increase change variable from control  
Negative mark (-) : Decrease change variable from control

4. Conclusion

In this study, oil heat-treatment improved the physical properties of candlenut wood. Heating with oil increased the wood density and specific gravity up to 25.13% and 26.97%, respectively. The increase of dimensional stability was indicated by the reduced hygroscopic properties of wood in tangential and radial directions by 0.96 to 22.19%, respectively. The use of 160°C was best treatment for improve the physical properties of candlenut wood, but better dimensional stability of wood was obtained in higher temperature (200°C).

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