Specific gravity, Extractive Content, and Natural Durability of Balsa (Ochroma pyramidale) Wood at 3 and 4 years old

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Abstract. The aim was to investigate the specific gravity, extractive content, and natural durability of balsa (Ochroma pyramidale) wood. A total of six trees of balsa at 3 and 4 years old were harvested and cut into the sample of specific gravity, extractive content, and natural durability test. Natural durability was tested according to SNI 01-7207-2006 against dry wood termites (Cryptotermes cinocephalus Light.). Specific gravity, extractive content, mass losses, and termite mortality were measured. Variance analysis was used to find the differences. The results showed that age influenced significantly on specific gravity and mass losses, while axial direction/position influenced significantly on extractive content and mass losses. Variance analysis also showed that radial direction influenced significantly on specific gravity and extractive content. The specific gravity of three years balsa wood is 0.14, which is lower than that of four years old three, which is 0.19. Extractive content in the bottom part (3.95%) is higher than that of in the middle (2.87%) and top (2.74%). Mortality in the bottom part (33.83%) is higher than that of in the middle (10.5%) and top part (5.8%) of the stem. In general, balsa wood is classified into durability class II-III.

1. Introduction

The market of balsa (Ochroma pyramidale) wood has been growing positively due to its light specific gravity and numerous application such as a model for aircraft, plywood, the core of structural sandwich panel, and wind turbine components. Balsa wood also shows outstanding vibration, heat, and sound insulation properties. Even light, balsa wood tends to have higher mechanical properties compared to its specific gravity [1]. In addition, the balsa wood market is boosted by the increase of wind energy demand as part of renewable energy and growing weight-saving composite.

Balsa is fast-growing species that is widely planted in the forest plantation industry and private forests in Indonesia. The tree can grow fast in various conditions of soil and perform straight stem [2]. Harvesting rotation of balsa is faster than other fast-growing species in Indonesia such as sengon (Falcataria molucana) and jabon (Anthocephalus cadamba Miq.) [3, 4, 5]. Balsa is normally harvested at 4-5 years old. Due to finding lower specific gravity, there is an effort to cut balsa tree less than four years old. The price per unit volume of balsa wood is also higher than that of sengon and jabon wood.

One of the challenging factors to utilize balsa wood is its natural durability. The durability of wood depends on the natural durability of wood and the condition of the surrounding environment. Natural durability can be defined as the inherent resistance of wood against biological degradation [6]. Natural durability varies according to wood species, geographic territories, and environmental disclosure conditions of growing trees, individual trees, and different parts/sections within individual trees [7]. Understanding the natural durability class is important for lumber manufacturers to produce high-quality products of balsa wood.

This study aimed to determine the effect of axial and radial position on specific gravity, extractive content, and the natural durability of balsa wood at three and four years old. This study also investigates...
the relationship between extractive content, specific gravity, and natural durability. This information is important for basis future recommendations and proper treatment to have its optimal utilization and long-term performance of balsa wood.

2. Methods
Samples were taken from a total of six trees of fast-growing balsa grown in a private forest in Lumajang, East Java. From each tree, three-section logs with a length of 120 cm were taken from the bottom, middle, and top of the trees. The logs were cut into 30 cm in length and sawn into the sample for moisture content, specific gravity, extractive content, and durability test. The detailed collecting sample can be seen in Figure 1. The collecting sample was also reflecting radial positions which are near pith and near bark. Sample for moisture content and specific gravity were measured based on British Standard no 373 [8]. Samples for determining natural durability were conducted against dry wood termites in accordance with Indonesian Standard SNI 01-7207-2006. The mass losses of the sample are then classified based on Table 1 to classify durability class. Analysis of variance was used to determine the effect of axial and radial position in the stem and age on moisture content, specific gravity, extractive content, and the natural durability of balsa wood. To determine the differences, a Tukey post hoc test was conducted.

![Sample preparation](image)

**Figure 1. Sample preparation**

| Table 1. Durability class classification based on mass losses against dry wood termites. (SNI 01-7207-2006) |
|-----------------------------------------------|
| **Class** | **Durability** | **Mass Losses (%)** |
| I | Very Durable | < 2,0 |
| II | Durable | 2,0 – 4,4 |
| III | Moderately Durable | 4,4 – 8,2 |
| IV | Slightly Durable | 8,2 – 28,1 |
| V | Not durable | > 28,1 |

3. Result and Discussion
3.1. Moisture Content and Specific Gravity
Understanding the characteristics of moisture content and the specific gravity of the wood is important. Biological degradation can be easily influenced by moisture content. Wood condition with high moisture content is subject to be attacked by organisms. After conditioning, the moisture content of the
sample is in the range of 10.47% and 13.08% (Table 2). This range of air-dry moisture content indicates slight variation among the different position of the sample at 3 and 4 years old.

| Age (year) | Axial Position | Radial Position | Moisture Content (%) |
|------------|----------------|-----------------|----------------------|
| 3          | Bottom         | Near Bark       | 10.92                |
|            |                | Near Pith       | 11.68                |
|            | Middle         | Near Bark       | 10.90                |
|            |                | Near Pith       | 11.42                |
|            | Top            | Near Bark       | 10.67                |
|            |                | Near Pith       | 11.22                |
| 4          | Bottom         | Near Bark       | 13.08                |
|            |                | Near Pith       | 12.89                |
|            | Middle         | Near Bark       | 10.82                |
|            |                | Near Pith       | 11.78                |
|            | Top            | Near Bark       | 10.47                |
|            |                | Near Pith       | 11.02                |

Specific gravity is in the range of 0.06 and 0.36. According to an analysis of variance, the specific gravity of four years old is significantly (F=9.37, α 0.05) higher than that of three years old. The specific gravity of four years old balsa wood is 0.14, which is higher than that of three years old, which is 0.19. This indicates that balsa wood has different specific gravity when harvested at three and four years old. The result of the study is similar to Midgley et al. [9], who stated that commercial balsa wood usually has specific gravity ranging from 0.1-0.17 or can range between 0.05-0.41 based on differences in age and geographical location (Figure 2). Geographical location can affect specific gravity due to differences in soil type, nutrient content, and climate [10]. The variation of specific gravity is caused mainly by the variation of the fibers, which wide variation in wall thickness [1]. The cellular structure of balsa wood contains fibers 66–76% [1]. Therefore, products like wind turbine blades and aero model may prefer balsa wood from three years old, which show light specific gravity. Meanwhile, plywood company production or sandwich panels prefer using the older one to obtain higher density. A significant difference (F=15.21, α 0.05) of specific gravity was also found between the near pith and near bark (Figure 3). The specific gravity of the near pith is slightly higher than that of near the bark. The information of variation in specific gravity is important during drying process to select proper drying schedule to obtain high quality wood products [11].

![Figure 2](image_url)  
**Figure 2.** Specific gravity of balsa wood at 3 and 4 years old. (Different codes above the data label show significant difference at HSD=0.06).
3.2. Extractive content
In this study, the extractive content of balsa wood ranged from 1.66 to 4.86%. The result of this study is slightly higher than the results of \[1\] who states that the extractive content of balsa wood ranges between 1 and 3%. The higher extractive content may contribute to increase natural durability. Analysis of variance shows that position in the axial direction significantly (F:5.46, \(\alpha\) 0.05) had a significant effect on the extractive content. Extractive content in the bottom part (3.95%) is higher than that of in the middle (2.87%) and top (2.74%). Extractive content also contributes to specific gravity (Figure 4 and 5). The increase of extractive content will raise specific gravity (\(r^2= 0.79\)).

Figure 3. Specific gravity of balsa wood in the radial direction. (Different codes above the data label show significant difference at HSD=0.04).

Figure 4. Extractive content of balsa in the axial direction. (Different code above the data label show significant difference at HSD=0.6).

Figure 5. Correlation between extractive content and specific gravity of balsa wood

\[ y = 0.0494x \]
\[ R^2 = 0.7878 \]
3.3. Natural Durability

Natural durability in this study is indicated by percentage of termite mortality and mass losses of balsa wood against dry wood termite. The termite mortality on balsa wood varies from 0-66%. According to an analysis of variance there is a significant difference in mortality of the sample among axial directions. Mortality in the bottom part (33.83%) is higher than that of in the middle (10.5%) and top part (5.8%) of the stem (Figure 6). The termite mortality is corresponded to the extractive content, which extractive content in the bottom part is higher compared to the other ones. In addition, there is positive correlation between extractive content and termite mortality (Figure 7). Correlation between extractive content and mortality is showed by coefficients determination, which is 0.56. This value is moderate.

**Figure 6.** Mortality of balsa wood in the axial direction.

**Figure 7.** Correlation between extractive content and mortality of balsa wood.

Mass losses were used to classify the durability class of balsa wood-based Table 3, which is developed in SNI 01-7207-2006. Balsa wood is classified into durability class II-III. Durability class II was found in the bottom part near pith at three and four years. In general, the durability class of balsa wood in this study is better than other results such as study by Borrega et al. [1].

**Table 3.** Durability Class of Balsa Wood

| Age (year) | Axial Position | Radial Position | Mass Losses (%) | Durability Class | Durability |
|------------|----------------|-----------------|-----------------|------------------|------------|
| 3          | Bottom         | Near Bark       | 5.03            | III              | Moderate   |
|            | Middle         | Near Bark       | 6.07            | III              | Moderate   |
|            | Top            | Near Bark       | 6.06            | III              | Moderate   |
| 4          | Bottom         | Near Bark       | 4.93            | III              | Moderate   |
|            | Middle         | Near Bark       | 5.96            | III              | Moderate   |
|            | Top            | Near Pith       | 4.49            | III              | Moderate   |

\[ y = 6.0132x \]
\[ R^2 = 0.5564 \]
4. Conclusion

Variance analysis showed that age influenced significantly on specific gravity and mass losses, while axial direction/position influenced significantly on extractive content and mass losses. Variance analysis also showed that radial direction influenced significantly on specific gravity and extractive content. Specific gravity of balsa wood in this study is in the range of 0.06 and 0.36. The specific gravity of three years balsa wood is 0.14, which is lower than that of four years old three, which is 0.19. The extractive content of balsa wood ranged from 1.66 to 4.86%. Position of the sample in the axial direction significantly influences the extractive content. Extractive content in the bottom part (3.95%) is higher than that of in the middle (2.87%) and top (2.74%). Mortality in the bottom part (33.83%) is higher than that of in the middle (10.5%) and top part (5,8%) of the stem. In general, balsa wood is classified into durability class II-III. Durability class II was found in the bottom part near pith at three and four years.

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