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The effect of oil heat treatment on the color and the community's color preferences of two *Gigantochloa species*

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ABSTRACT
Bamboo is a renewable natural resource with great potential as an environmentally friendly material. Two local Indonesian bamboo species, namely apus bamboo (*Gigantochloa apus*) and ater bamboo (*Gigantochloa atter*), have been widely used in various fields but still face challenges such as fading color and low resistance to moisture. This study aims to investigate the color changes in apus bamboo and ater bamboo after undergoing heat treatment using oil at varying temperatures of 160°C, 180°C, 200°C, and 220°C. Five-year-old bamboo samples were cut into cylindrical shapes with a diameter of 10 cm and a height of 5 cm, then tested for color before and after the heat treatment. The treatment was carried out for 2 hours using oil as a medium, then dried in an oven. Color changes were analyzed using a general colorimeter scanner. Data collection on community preferences for bamboo colors was conducted by distributing questionnaires. The red-green chromaticity changes in apus bamboo exhibit a decreasing trend, whereas ater bamboo shows an increasing trend. The yellow-blue chromaticity changes in both bamboo species show an increasing trend. For the lightness level, both bamboos have decreased. The overall color change in apus bamboo and ater bamboo increases with the increasing temperature. The color preference results revealed that women prefer bright colors in both bamboo species. Men are more selective in their color preferences; some choose bright colors, but many also choose dark colors.
Keyword: Apus Bamboo, Ater Bamboo, Bamboo, Colors, Oil Heat Treatment

1. Introduction

Bamboo is a renewable resource that can be easily cultivated, as it thrives on marginal land. Bamboo also thrives in various soil conditions as long as it receives sufficient water and is exposed to adequate sunlight [1]. Bamboo is a fast-growing plant species, one of the fastest-growing plants in the world. Its strengths are the ease with which it can grow in a wide range of marginal soils, as well as the rapid growth rate of bamboo. In Indonesia, there are around 157 species of endemic bamboo, although not all of them have been utilized optimally [2]. Several bamboo species, such as apus bamboo (*Gigantochloa apus*) and ater bamboo (*Gigantochloa atter*), have been widely used by the community as craft materials, traditional musical instruments, furniture, and even light construction materials [3].

Bamboo is a raw material that has unique properties and characteristics. One of the unique features of bamboo is the natural color variations of its fresh stems [4]. Bamboo comes in various colors, including green, black, and yellow, and some species exhibit distinct patterns that enhance their visual identity. For example, the natural color of apus bamboo is green, and the other is black. According to Aziz et al. [5], the unique color of bamboo provides aesthetic value. It is a special attraction for bamboo-based products, such as furniture, that maintain their natural color. Behind the uniqueness of the color, which is an added value of bamboo, are some disadvantages that are obstacles to utilizing bamboo. The disadvantage of bamboo is that its color can fade, especially in applications exposed to direct sunlight. One of the causes of bamboo color fading is the loss of air content due to prolonged exposure to high temperatures and sunlight [6].

Many consumers prefer the darker bamboo color after heat treatment compared to untreated bamboo. Consumers prefer the darker color change of bamboo resulting from heat treatment, which can add aesthetic value to the product [7]. One way to overcome the shortcomings of bamboo is with oil heat treatment. In oil heat treatment, bamboo is heated to 140–240°C. In this study, the temperature ranges of 160–220°C were based on preliminary trials and literature indicating that these temperatures are more effective at inducing visible discoloration and causing minor structural damage to the bamboo [8]. The effect of oil heat treatment can change the color of bamboo from an initially bright hue to a darker one. [9]. The diversity of bamboo colors resulting from oil heat treatment leads to a diversity of people's bamboo color preferences [10].

The difference in people's preferences for bamboo color is due to their knowledge or personal feelings [11]. Public perception of something can appear objectively or subjectively. Objective assessments arise due to the consistent value of an object [12]. Subjective assessments arise due to the triggering of a person's taste through the five senses received from an object and can be influenced by social factors. The purpose of this study was to determine the color changes that occur in apus bamboo and ater bamboo that were oil heat-treated with a temperature of 160–220°C, and to determine community preferences about the color of apus bamboo and ater bamboo that had been oil heat-treated.

2. Method

2.1. Time and place

The oil heat treatment was conducted at the Forest Product Technology Workshop, Integrated Field Laboratory, University of Lampung. The color inspection was carried out at the Forest Product Technology Laboratory, Department of Forestry, Faculty of Agriculture, University of Lampung. This research was conducted from March to April 2025.

2.2. Sample Preparation

The sample procurement process involved cutting down 5-year-old apus bamboo (*Gigantochloa apus*) and ater bamboo (*Gigantochloa atter*). The bamboo was then cut into cylindrical samples with a diameter of 10 cm and a height of 5 cm. These samples were documented for their initial color before undergoing oil heat treatment. After recording the initial color data, the samples were oven-dried for 24 hours at 100°C [13].

2.3. Research Procedure

The tool used for oil heat treatment was an oil bath (C-WHT-S2; Chang Shin Science, Seoul, Korea). The research material was 4 liters of cooking oil (FILMA, PT. SMART Tbk., Tangerang, Indonesia). The samples were then subjected to oil heat treatment for 2 hours at varying temperatures (160°C, 180°C, 200°C, and 220°C), with each temperature variation repeated three times. The samples used in this research consisted of 30 samples, divided into 15 samples of apus bamboo and 15 samples of ater bamboo. These samples consist of 3 control samples and 12 treatment samples. After the oil heat treatment, the samples were oven-dried for 24 hours at 100°C [14].

2.4. Color Change Analysis

In terms of color change, the surface of the bamboo was documented using a general colorimeter scanner (AMT507, China), and the color change that occurs was evaluated against a predetermined system, the CIE Lab system [15]. The calculation formulas used to determine the color change of bamboo are as follows:

$$\Delta E^* = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1/2} \quad (1)$$

$$\Delta L^* = L_2 * - L_1 * \quad (2)$$

$$\Delta a^* = a_2 * - a_1 * \quad (3)$$

$$\Delta b^* = b_2 * - b_1 * \quad (4)$$

where ΔE* is overall color changes, ΔL* is the difference between the L* values before and after OHT, L1* is lightness level before OHT, L2* is lightness level after OHT, Δa* is the difference between the a* values before and after OHT, a1* is red-green chromaticity before OHT, a2* is red-green chromaticity after OHT, Δb* is the difference between the b* values before and after OHT, b1* is yellow-blue chromaticity before OHT, b2* is yellow-blue chromaticity after OHT. Additionally, the classification of discoloration is

determined by the following: $0.0 < \Delta E^* \leq 0.5$ is negligible, $0.5 < \Delta E^* \leq 1.5$ is slightly perceivable, $1.5 < \Delta E^* \leq 3$ is noticeable, $3 < \Delta E^* \leq 6$ is appreciable, $6 < \Delta E^* \leq 12$, is very appreciable, and >12 is changed.

2.5. Collecting community preference data

Data collection on community preferences for bamboo colors was conducted by distributing questionnaires [16]. The survey was conducted by distributing an online questionnaire containing all treatments for each bamboo species and photos of each bamboo representing each treatment. The questionnaire was distributed through Facebook and WhatsApp. The survey method was used to select respondents who were willing and ready to participate and were students of the University of Lampung. Questionnaires were also distributed to the general public from various backgrounds to determine their preference for bamboo colors. Respondents were asked to fill out a form containing their name, gender, and age, select their preferred color from each of the bamboo images provided, and then explain why they chose that color. The survey involves 110 respondents, consisting of 56 males and 54 females.

3. Results and Discussions

3.1. Visual of apus bamboo and ater bamboo

The color change of the bamboo in Figures 1 and 2 indicates that the higher the temperature used in the oil heat treatment, the darker the bamboo becomes. According to Awandi et al. [17], heat-treated bamboo samples with oil at 180–240°C showed a darker color than the control bamboo samples. In research by Karlinasari et al. [18], heat treatment at temperatures ranging from 120–180°C changed the visual color of jabon wood. At a temperature of 150°C, the color change was already visible. Oil heat treatment can alter the color of bamboo because it involves heating oil to a high temperature. The higher the temperature used, the more noticeable the change in color of the bamboo becomes. The oil penetration during heat treatment causes the bamboo color to darken as the temperature increases.

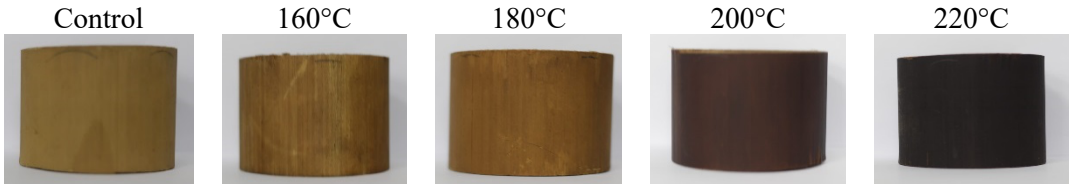

Figure 1. Visual of apus bamboo before (control) and after oil heat treatment

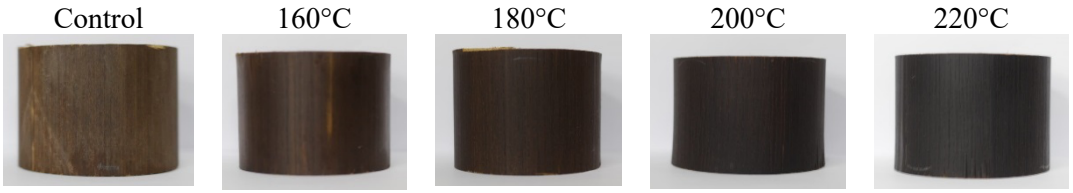

Figure 2. Visual of ater bamboo before (control) and after oil heat treatment

3.2. Changes in lightness value (L) of apus bamboo and ater bamboo*

As shown in Figure 3, the lightness level of apus bamboo and ater bamboo shows that the natural color of apus bamboo is brighter, with a value of 62.74, compared to ater bamboo, which has a value of 47.23, as indicated by the control samples. The color change in apus bamboo samples treated at 160°C had a L* value of 56.08, which then decreased to become darker in the next sample treated at 180°C with a value of 52.78, decreased further in the sample treated at 200°C with a value of 41.33, and continued to decrease in the sample treated at the highest temperature of 220°C with a value of 39.82. In ater bamboo, the L* value in the sample treated at 160°C had a lightness value of 45.97, which then decreased to become darker in the next sample treated at 180°C with a value of 43.96, decreased further in the sample treated at 200°C with a value of 39.31, and decreased again in the sample treated at the highest temperature of 220°C with a value of 38.84. After treatment, the lightness level of both bamboo species decreased, resulting in darker colors as the treatment progressed. Tang et al. [19] reported that the lightness level of bamboo decreases with an increase in the temperature applied during oil heat treatment; initially bright yellow bamboo becomes blackish-brown. According to Nurhanifah et al. [20], after heat treatment, the lightness level of sembilang bamboo was

decreased, resulting in darker colors. High-temperature treatment can cause thermal reactions that alter the color of bamboo, typically involving water evaporation, lignin degradation, and surface carbonization. As a result, the bamboo's color changes from bright to dark [21]. The decreased L* value is due to the degradation of chemical components during heat treatment, such as hemicellulose [22]. Bamboo's chemical components, such as hemicellulose, will be released and reduced when heated at high temperatures, and the reduction of hemicellulose decreases the moisture content of bamboo [23]. The effectiveness of oil heat treatment in reducing moisture content caused by oil heating. This effect leads to an improvement in wood quality due to the intensive degradation of hemicellulose in the silicone oil medium and the higher water repellency of silicone oil compared to rapeseed oil [24].

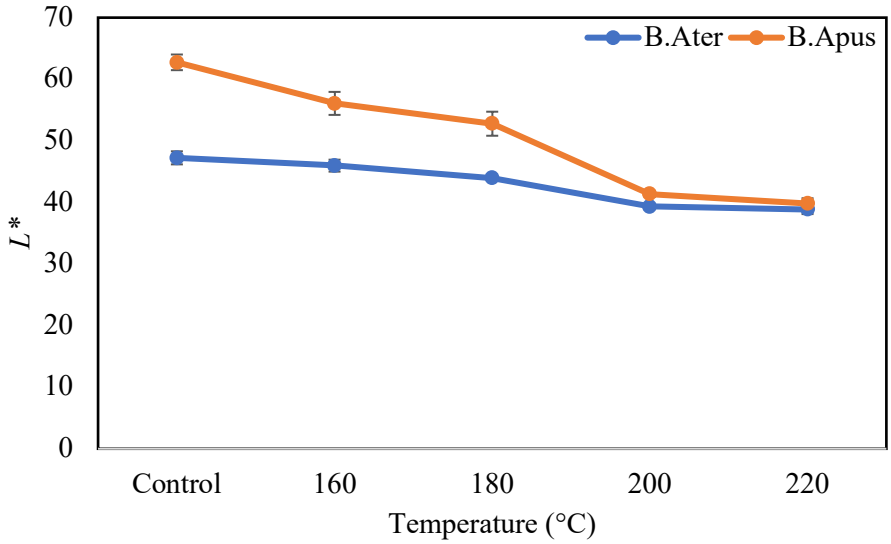

Figure 3. Changes in lightness value (L*) of apus bamboo and ater bamboo

3.3 Changes in red-green chromaticity (a) of apus bamboo and ater bamboo*

The results of the change of a* value of apus bamboo and ater bamboo after oil heat treatment are shown in Figure 4. The a* value of apus bamboo and ater bamboo shows that the natural color of ater bamboo is redder, with a value of 5.94, compared to apus bamboo, which has a value of 7.68, as indicated by the control samples. Bamboo samples subjected to oil heat treatment showed that the higher the temperature used in the oil heat treatment, the greater the likelihood of color changes in the samples. The a* value in apus bamboo samples treated at 160°C had a value of 7.31, which increased in the next sample treated at 180°C with a value of 7.45, then decreased in the sample treated at 200°C with a value of 6.20, and continued to decrease in the sample treated at the highest temperature of 220°C with a value of 5.42. In ater bamboo samples treated at 160°C had a value of 6.32, which increased in the next sample treated at 180°C with a value of 6.51, then decreased in the sample treated at 200°C with a value of 6.20, and increased again in the sample treated at the highest temperature of 220°C with a value of 6.23. These changes suggest that excessively high temperatures in oil heat treatment can cause damage to other chemical structures, which in turn affect the bamboo's color, aside from lignin, cellulose, and hemicellulose [25]. Based on research by Nan et al [26], the higher red-green chromaticity change causes the color of the bamboo to turn greener, while the lower change value causes the color of the bamboo to become redder. The color change caused by the formation of furfural derivative compounds from hemicellulose or the sensitivity of bamboo to thermal degradation, resulting in reddish-brown pigments due to light carbonization processes [27]. The chemical and extractive components of bamboo that are altered by treatment can alter the a* value of the sample [28].

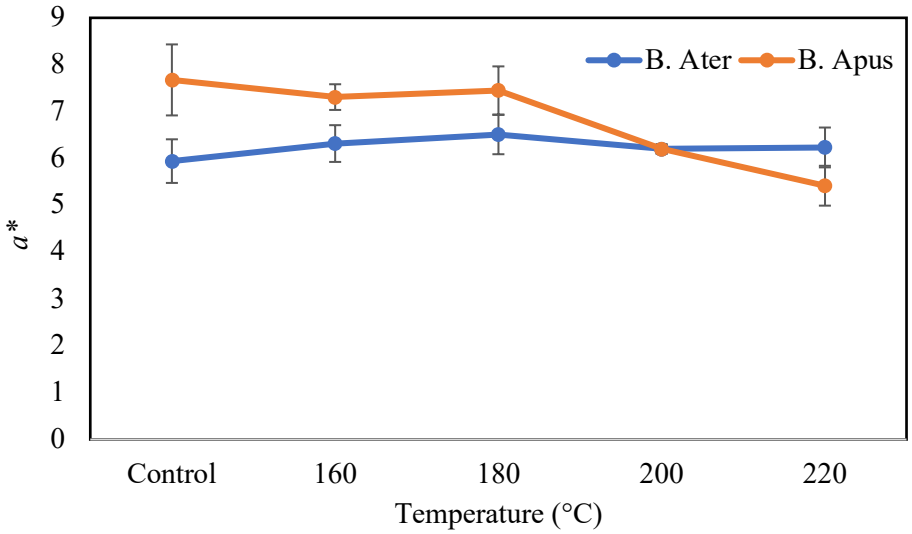

Figure 4. Changes in red-green chromaticity (a*) of apus bamboo and ater bamboo

3.4. Changes in yellow-blue chromaticity (b) of apus bamboo and ater bamboo*

The results of the b* value change of apus bamboo and ater bamboo after oil heat treatment are shown in Figure 5. The b* value of apus bamboo and ater bamboo shows that the natural color of ater bamboo is more yellow, with a value of 10.08, compared to apus bamboo, which has a value of 18.74, as indicated by the control samples. The color change in apus bamboo, the b* value in the sample treated at 160°C had a value of 19.32, which increased in the next sample treated at 180°C with a value of 20.63, then decreased in the sample treated at 200°C with a value of 19.79, and increased again in the sample treated at the highest temperature of 220°C with a value of 20.58. In ater bamboo samples treated at 160°C had a value of 11.68, which then decreased in the next sample treated at 180°C with a value of 11.43, decreased further in the sample treated at 200°C with a value of 11.29, and decreased again in the sample treated at the highest temperature of 220°C with a value of 11.08. The b* value of increased bamboo will change the color to become more yellow, while the color change in the form of a decrease will change the bamboo color to become more blue [29]. According to Huang et al. [30], the b* values of aspen wood decreased as the treatment temperature increased; however, at temperatures of 200°C and below, the b* value of aspen wood increased. The same trend was observed in birch wood; oil heat treatment causes thermal degradation of the primary components of bamboo, including cellulose, hemicellulose, and lignin. When lignin degrades, it can produce dark-colored compounds that influence the visual color of bamboo [31].

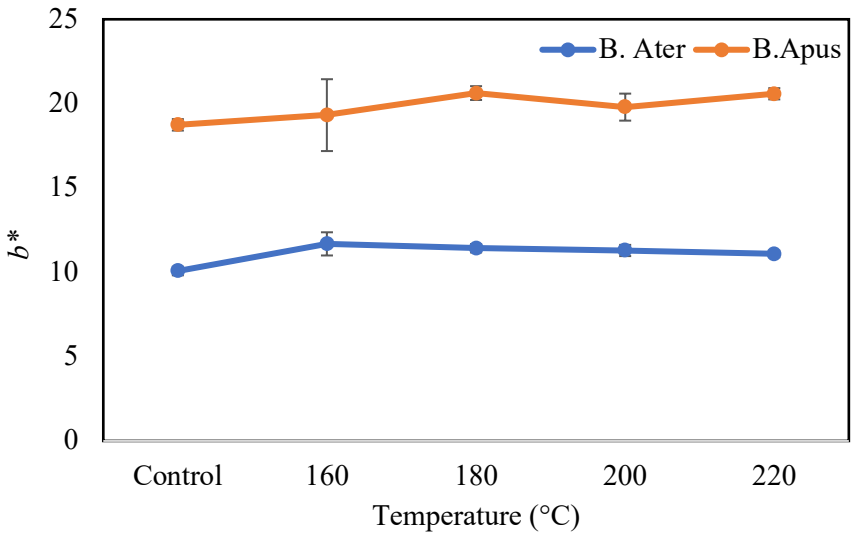

Figure 5. Changes in yellow-blue chromaticity (b*) of apus bamboo and ater bamboo

3.5. Overall color changes (ΔE) of apus bamboo and ater bamboo*

As shown in Figure 6, the overall color change of 160°C oil heat treatment on apus bamboo has a value of 7.6, while ater bamboo has a value of 5.07. Increasing the temperature to 180°C affects the overall color change; apus bamboo has a value of 12.14, while ater bamboo has a value of 6.93. At a temperature of 200°C, the overall color of apus bamboo becomes 27.16, while ater bamboo becomes 12.47. At the highest temperature of 220°C, the overall color change in apus bamboo is 31.22, while ater bamboo is 13.09. Both apus and ater bamboos experience a decrease in lightness, so that the bamboo color becomes darker. According to Hidayat et al. [32], oil-heat-treated wood becomes darker in color, which has aesthetic value because it more closely resembles exotic wood from natural forests, and has a higher economic value. According to Afkar et al. [33], higher treatment temperatures cause the overall color of the sample to change further. Other research also states that the higher the temperature used during oil heat treatment, the greater the overall color change of the bamboo sample [34]. Apus bamboo shows higher color values than the ater bamboo, indicating that apus bamboo is more sensitive to color changes caused by heat or has different chemical compositions that result in a stronger thermal reaction. The natural color and lightness of apus bamboo are brighter, with a green to brass color, compared to ater bamboo, which has a darker natural color and lightness with a blackish-brown color. It greatly affects the color change and change in lightness level of the bamboo [35]. Thermal reactions caused by high temperatures during oil heat treatment cause changes in bamboo color [36]. In this reaction, air evaporation, lignin degradation, and carbonization of the bamboo surface occur; therefore, the initially bright bamboo color can change to a dark one. The lower the moisture content due to high-temperature treatment, the greater the ΔE* value recorded, indicating a more pronounced overall color change [37]. Bamboo comes in various natural colors, depending on its species, including green, yellow, black, and some species with distinctive patterns. The natural color difference of bamboo is influenced by genetic variation, such as chemical composition and physical structure [38]. Lignin, cellulose, and hemicellulose are components in bamboo that form natural color differences [39].

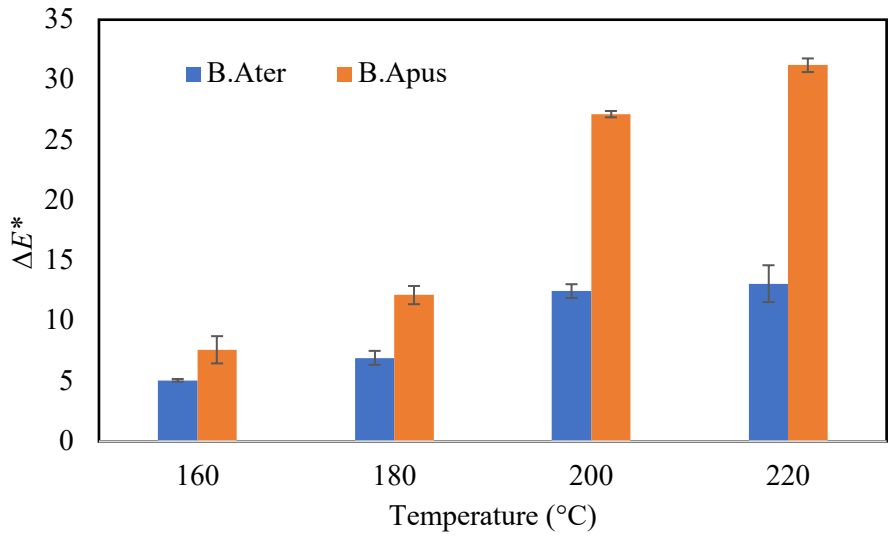

Figure 6. Overall color changes of apus bamboo and ater bamboo

4. Community's Preference

The change in the community's preference for apus bamboo and ater bamboo after oil heat treatment is shown in Figure 7. Women showed the highest preference for the color resulting from the heat treatment at 160°C, with 32 respondents. The preference drastically decreased as the treatment temperature increased, with only 5 respondents choosing apus bamboo heat-treated at 220°C. A similar trend was observed among male respondents, with bamboo heat-treated at 160°C also being the most preferred (28 respondents). However, there was a resurgence in preference at 220°C, with 11 respondents, indicating that men tend to be more tolerant of the darker color produced at higher temperatures. For ater bamboo, women showed relatively balanced preferences at 160°C and 180°C, with 21 and 19 respondents, respectively, but their preference sharply declined at higher temperatures. In addition, male respondents demonstrated relatively stable preferences across the temperature range from 160°C to 220°C, with the highest number of respondents, 13, choosing 220°C. This indicates that men tend to prefer the color of ater bamboo treated at higher temperatures,

which is generally darker and visually stronger. These findings are consistent with the study by Hidayat et al. [40], which showed that male respondents preferred a darker color to the treated Korean white pine wood. Generally, the color of bamboo treated at a lower temperature (160°C) is preferred by women, likely due to its lighter and warmer natural appearance [41]. Conversely, men prefer the color resulting from higher temperature treatment, especially in ater bamboo, which gives a darker and more modern look. These findings are consistent with the study by Yu et al. [42], which showed that bamboo color preferences are influenced by gender, with women tending to choose natural appearances. At the same time, men are more open to the darker colors produced by heat treatment. Other research also suggests that gender influences people's color preferences, with the average woman being more likely to prefer lighter colors, while men tend to prefer darker colors [43].

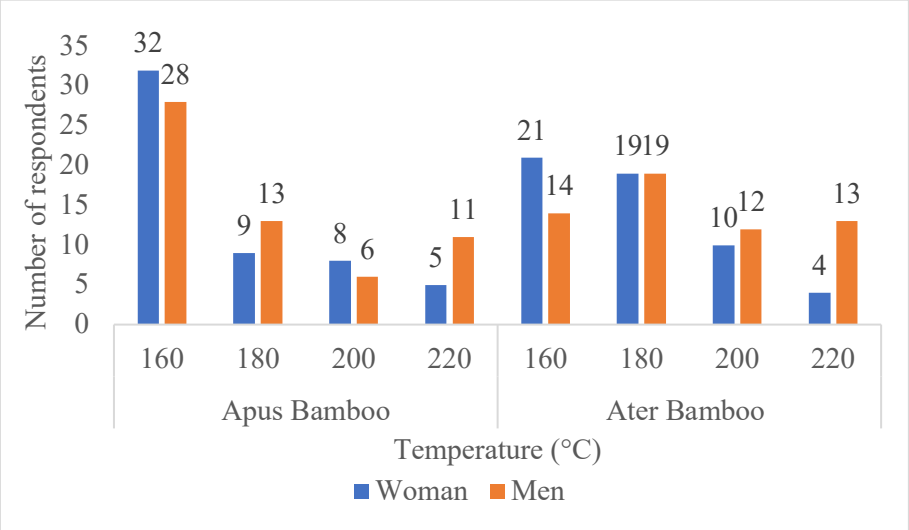

Figure 7. Community Preferences for Bamboo Color Changes

5. Conclusion

The L* values of both ater bamboo and apus bamboo decrease, shifting from bright to dark as the treatment temperature increases. The a* value in apus bamboo and ater bamboo varies at each temperature variation, except at 200°C, where they both have the same value, namely 6.20. The b* value in ater bamboo remains stable at 11 across all temperature variations, while apus bamboo experiences inconsistent changes, as indicated by fluctuating color change values. The ΔE* values for both ater and apus bamboo consistently increase with rising treatment temperatures. Heat-treated apus bamboo undergoes a very significant color change, reaching up to 31.22, whereas the color change in ater bamboo only reaches 13.09 at the highest temperature of 220°C. The most preferred bamboo colors were apus and ater bamboos heat-treated at 160°C and 180°C, whereas the least selected bamboo colors were apus and ater bamboos heat-treated at 200°C and 220°C, respectively. The community perception of the color of bamboo that women like is brighter colors, while the colors that men like are more open to dark colors, but many also like light colors.

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