The effect of heat treatment to the colour of Pauh Kijang (Irvingia Malayana)

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Abstract. As timber with natural durability and excellence properties is limited and high in price, there is a need to make use of the timber with low durability and properties. In order to use this kind of timber, the timber needs to be treated to improvise its properties and durability. The well-known treatment used worldwide is by using chemical preservative; however, this kind of treatment is bad to the environment. Therefore, there is a need to find an alternative way to replace this treatment with an environmentally friendly way of treatment. Heat treatment is one of the treatments which may equip the timber with new properties without using any chemical or preservative but heat where the heat is used to achieve new material properties rather than to dry the wood. Heat treatment generally causes an apparent decrease in wood mechanical properties due to the material losses in the cell wall, hemicelluloses degradation and the modification of long chain molecules. Therefore, this study investigated the effect of heat treatment on the colour of one of the Malaysian hardwood timbers; Pauh Kijang which located in Strength Group 3 of timber (SG3) after had been treated by heat. The size of the timber beam for each sample is 50mm x 90mm x 1800mm. The total numbers of the sample are 90 which 15 numbers of sample allocated for control, kiln dried and four levels of heat treatment. There are four different levels of temperatures namely 150°C, 170°C, 190°C and 210°C were applied on the timber beam samples within 1 hour. Control and kiln dried samples been used as comparisons to each test conducted to identify the changes that occur on the colour after heated. The colour turned darker as the temperatures increased for these four species of heat-treated timber which had been analysed by CIE-Lab system.

1. Introduction
Timber is one of the oldest building materials been used to build man’s shelters [1]. However, there is a limit on timber usage based on its properties and characteristics. This limit has defined timbers as a material that not under all conditions is an appropriate building material [2]. Due to this problem, the use of timber with natural durability has been decreasing and an alternative to encounter this problem has been found out which is by using timber species with non-natural durability [3]. However, this timber needs to be modified or treated to help improve its durability properties. The most common method of treatment for timber is by using chemical preservatives known as Copper Chromium Arsenic (CCA) [4]. Due to the usage of chemical preservatives that are toxic, there are many issues arise related to CCA. One of the issues is related to human where CCA can give a threat to their health. EC Scientific
Committee on Toxicity, Eco-toxicity, and the Environment (CSTEE) had announced that CCA is both genotoxic and carcinogenic. CCA may give a risk of cancer especially in lung, bladder, kidney and liver. In light of this issue, an alternative treatment method needs to be explored and made available in Malaysia. One of the possible methods of treatment is heat treatment which using heat rather than chemicals. Heat treatment is the most environmentally friendly way to treat a timber species that will be an alternative way to replace CCA. This method of treatment will alter the substrate of a timber species by using a high level of temperature, not by using chemical preservatives. The objective of this paper is to assess the effect on the colour of Pauh Kijang treated by heat at the temperature level of 150°C, 170°C, 190°C and 210°C. Color is related to esthetic value because it is related to the appearance of the timber. So, the changes or differences of color between control and treated samples are important to be analysed.

2. Experimental works
This study utilized the solid hardwood timber namely Pauh Kijang. The temperature of 150°C, 170°C, 190°C and 210°C were determined for the heat treatment. 15 samples of green (wet) timbers with moisture content (MC) more than 20% and size of 50x90x1800mm were prepared respectively for the mentioned heat treatment temperatures. All samples were weighted prior to the test. Those samples were stored in the conditioning room for 2 weeks prior to the heat treatment process. The conditioning room has 65% of relative humidity with temperature level of 24°C. A special electrical furnace acted as an oven was designed and prepared according to the size and numbers of the samples as shown in Figure 1.

15 samples were put into the electrical furnace in an arrangement of what shown in Figure 2. The heat treatment was performed within one-hour duration under steam and atmospheric pressure in an oven which will provide 16 different treatment conditions.
Figure 2. Arrangement of samples inside the electrical furnace.

The Konica Minolta Spectrophotometer CM-5 is the apparatus used to run this test as shown in Figure 3.

Figure 3. Konica Minolta Spectrophotometer CM-5.

The block samples in size of 5mm x 5mm x 5mm were cut from the control and treated beam samples that have been tested for bending test. Calibration had been done on this machine before the test started. The target mask has been used is in size of φ3mm. This is the smallest target mask equipped with this machine. The target mask is important because it will determine the illumination area or the color area of samples to be measured. One by one block sample has been put on the target mask before then a flash light been shoot out from the target mask and slowly touched the surface of the sample. Then, the data will automatically feature on the screen of this machine. The data of this test read in term of L*, a* and b* known as CIELAB system as presented in Figure 4.
To measure the changes of the colour, \( \Delta E \) between the controls and treated timber samples, the displayed data recorded from spectrophotometer need to be used. The data recorded been used to determine \( \Delta L^* \), \( \Delta a^* \) and \( \Delta b^* \) to measure \( \Delta E^* \) as shown in Equation 1, 2, 3 and 4.

\[
\Delta L^* = L_2^* - L_1^* \quad (1)
\]

where,
\( \Delta L^* \) = the difference value of \( L^* \)
\( L_1^* \) = the value of \( L^* \) for reference sample
\( L_2^* \) = the value of \( L^* \) for analysis sample

\[
\Delta a^* = a_2^* - a_1^* \quad (2)
\]

where,
\( \Delta a^* \) = the difference value of \( a^* \)
\( a_1^* \) = the value of \( a^* \) for reference sample
\( a_2^* \) = the value of \( a^* \) for analysis sample

\[
\Delta b^* = b_2^* - b_1^* \quad (3)
\]

where,
\( \Delta b^* \) = the difference value of \( b^* \)
\( b_1^* \) = the value of \( b^* \) for reference sample
\( b_2^* \) = the value of \( b^* \) for analysis sample

\[
\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (4)
\]

where,
\( \Delta E^* \) = the value of color changes
\( \Delta L^* \) = the difference value of \( L^* \)
\( \Delta a^* \) = the difference value of \( a^* \)
\( \Delta b^* \) = the difference value of \( b^* \)
3. Results and discussion

Fig. 5, Fig. 6, Fig. 7 and Fig. 8 are generated in an effort to show the established relationship between the chromatic variation which occurred due to heat treatment process at four different level of temperatures applied and the total color differences (ΔE) for Pauh Kijang by applying CIE-L*a*b* system.

*a* value is an indicator of red/green color where in CIE-L*a*b* system. The decrement of *a* value is an indicator that the timber that been analyze has a tendency to become greener while the increment of this value will be an indicator that the timber has a tendency to become redder in colour. As for Pauh Kijang, the *a* value shown in Figure 5 is increasing from the sample treated at the lowest temperature which is 150°C to the highest temperature which is 210°C. The increment of *a* value is an indicator that this species has a tendency to become reddish after been treated by heat. The increment of *a* value for Pauh Kijang is increasing with the increment of the temperature applied during heat treatment. It means, the maximum value of *a* for Pauh Kijang had occurred at temperature of 210°C which is 5.87.

![Figure 5. a* Value vs Temperatures of Heat Treatment.](image)

In Figure 6, it represents the *b* value for Pauh Kijang at each level of temperature applied during the treatment. The decrement of *b* value is an indicator that the timber has a tendency to become bluer and the increment of this value is an indicator that the timber has a tendency to become yellower after been treated compared to the control sample. Through this figure, it can be seen that the *b* value for Pauh Kijang had been decreasing with the increment of the heat-treated applied temperature. At 150°C, the *b* value for this species is 9.78 and it keeps decreasing until the highest temperature applied which is 210°C. At this temperature level, the *b* value shown is 8.70. This data is an indicator that the heat treated Pauh Kijang had a tendency to become bluer with the increment of temperature applied during heat treatment process.

![Figure 6. b* Value vs Temperatures of Heat Treatment.](image)

*L* value is a value used in CIE-L*a*b* system to show the modification of lightening and darkening.
of timber surface. Figure 7 shows the plotted value of L* for Pauh Kijang for each temperature level applied during heat treatment. The timber surface quality after treated by heat can be visualized by this L* value as it is the most sensitive value in this system. The increment of this value shows that the timber had increased its lightness while the decrement of this value shows that the timber had lost its lightness. The decrement of L* value is accordingly with the increment of temperature value applied on Pauh Kijang. It shows that this timber has lost its lightness with the application of heat treatment and become darker with the increment of heat treatment temperature applied. The degradation of hemicelluloses content in the timber with the increment content of lignin after been treated by heat is lead to the lightness changes of the timber. Since the beginning of the heat treatment process, the timber had become darker in colour. The decrement of Lightness (L*) for heat treated Pauh Kijang indicated that the color of this timber changes to black or darker tone direction.

![Figure 7. L* Value vs Temperatures of Heat Treatment.](image)

In the CIE-L*a*b* system, the total colour changes or different is shown by the ∆E value as form in Figure 8. The total colour differences for heat treated Pauh Kijang is increasing with the increment of temperature level applied. At 210°C, the ∆E value for heat treated Pauh Kijang is 11.78 which is the high value of colour changes compared to the other lower temperature level. It shows that the heat treatment process had caused the Pauh Kijang changes its original colour the different tone of colour which is in darker tone. The higher the temperature applied during the treatment, the darker the colour of Pauh Kijang. The colour of control sample was light brown before the treatment. The colour then changed from light brown, brown to dark brown.

![Figure 8. ∆E* Value vs Temperatures of Heat Treatment.](image)

[5] found that the high temperature level during the thermal treatment will lead to timber browning.
The decrement value of L* and ∆E on heat treated timber were cause by degradation of the hemicelluloses content in a timber. The darker toner of colour of heat treated timber is due to the loss products from the hemicelluloses. The darkening of timber colour due to the heat treatment is depending on the process of heat treatment and the species of timber. The degradation of hemicelluloses content is consequently with the increment of lignin content for heat treated timber. Hence, the reduction of lightness value (L*) due to the heat treatment process is mainly caused by the degradation of the hemicelluloses value. The degradation of hemicelluloses content of heat treated timber is increasing with the increment of temperature level applied during the treatment process. The reading of CIE-L*a*b* system is well correlated with the actual colour changes in Pauh Kijang as the temperatures increases as shown in Figure 9.

![Figure 9. The Changes of Colour of Heat Treated Pauh Kijang.](image)

As wood is heated, acetic acid is formed from acetylated hemicelluloses by hydrolysis. The released acid serves as a catalyst in the hydrolysis of hemicelluloses to soluble sugars [6]. The heat caramelizes the sugar to a brown colour that affects the colour of the wood. As the degradation of hemicelluloses accelerates with temperature the colour will become darker with increased treatment temperature.

4. Conclusion
This study was conducted to determine the effect of heat treatment on one of the physical properties of timber which is colour. In general, as the temperature increases the colours of the timber become darker due to caramelization of the sugar or carbohydrates. The changes of colour may be related to changes of its chemical constituents as well due to the heat.

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