

## Enhancing Colour Appearances of Cultivated 15 Year-old *Acacia Hybrid* through Oil Heat Treatment Process

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### Abstract

This study investigated the effect of oil heat treatment process on colour appearance of cultivated *Acacia hybrid*. Parameters such as temperatures and treatment time are taken in account due to their influences in enhancing the colour changes of the natural untreated and oil heat treated of the wood from the sapwood right trough the heartwood. Young, natural and untreated *A. hybrid* would normally have the sapwood having lighter colour than the dark colour heartwood. Turning these timbers into plywood or furniture at this stage will result in uneven colour as the results of the mixture between the sapwood and heartwood. This will decrease the value of the products. Heating the wood at varying temperatures and treatment time would enhance the colour appearance of the young wood. The colour changes in the sapwood and heartwood were measured using Minolta Chroma-meter CR-310 and the results are presented according to the CIE L\*a\*b\* colour co-ordinates system. The results revealed that the rising temperature at certain duration resulted in enhancing and darkening of wood tissues.

**Keywords:** Oil heat treatment, High temperature, Duration, Colour appearance, *Acacia hybrid* and sapwood

## 1. Introduction

*Acacia* species has become one of the major plantation species in the forest plantation project in Malaysia. The project started in 1982, aiming in sustainably supplying of timbers to the local wood-based industry. The wood-based industry is expected to face a shortfall from the natural forests (Shakri, 1995). *Acacia* was chosen as a plantation species based on its quick growth, adaptability to local soil conditions and the quality of wood it produces. *Acacia* is also highly appreciated for its quality in producing exquisite furniture with lasting values at an affordable cost. The furniture is valued mostly based on its strength, durability and aesthetic value such as grain orientation and colours.

However, young *Acacia* has a higher proportion of distinct colour difference between the sapwood and heartwood. The sapwood's colour is lighter than heartwood. These colour differences with definite irregular colour margins reduce the value of wood considerably. A serious marketing problem could occur when matching pair individual pieces with different colour components into final products. In order to achieve a competitive market, the colour appearance of the wood needs to be technically modified for evaluating the quality of the products (Tolvaj *et al.*, 2006). The sapwood of all timber species can be enhanced by using the heating process (Charrier *et al.*, 2002).

Heat treatment seemed to be a suitable treatment for woods because of its advantage to be environment friendly process because of non-toxic and does not require chemicals. Most wood treatments used preservatives, which mostly have heavy metals and discharge toxins to the environment. A lot of effort has been put to develop new wood preservatives. In addition, developed countries have totally banned the use of Chrome-copper Arsenic (CCA) in their woody materials (Berard *et al.*, 2006). In recent years, advanced environmental awareness and the effectiveness of policies which support the use of renewable resources and environment-friendly chemicals have resulted in high interest in non-biocides. Another environment friendly technique is the use of biodegradable substances in wood protection (Hyvonen *et al.*, 2006).

The objective of this study was to investigate how oil heat treatment process enhanced *A. hybrid* wood colour appearance at different temperature treatment time. The result of this study will benefit immensely in terms of improving the technologies in treated wood for the local wood industry in producing uniform and good quality of *Acacia* products.

## 2. Material and Methodology

### 2.1 Wood material

Three defects free of 15 years old *A. hybrid* (*Acacia mangium* x *Acacia auriculiformis*) trees were obtained from a forest plantation at Sabah Forest Development Authority (SAFODA), Kinarut, Kota Kinabalu, Sabah. The logs were harvested from trees selected based on their good physical appearances, diameters of the trees at breast height ranged from 25 to 30 cm., long straight bole and with minimum branches. The logs were cut and segregated into bottom, middle and top portions. Boles of 600 mm long were cut from the middle of each portion and later planed into size of 320 mm x 100 mm x 25 mm (length x width x thickness). After drying, the bolts were cut open in the middle by using chainsaw and planed to size 300 mm x 100 mm x 25 mm (length x width x thickness). The samples were placed in a conditioning chamber at 20±3°C and 65±5% relative humidity to stabilize the moisture content prior to treatment.

### 2.2 Oil-heat Treatment Process

The oil heat treatment on *A. hybrid* wood was performed in a stainless steel tank, complete with the thermocouples and heat generator. The tank size used in this study is 30 cm x 10 cm x 25 cm (length x width x height) and 3 mm thickness. The heat of the tank was generated by an electric power source. Eighty samples were prepared prior to the treatment. Crude cooking oil which is palm oil was used as heating medium. This oil was chosen because it is chemically free and has a high boiling point of 320°C (Rafidah, 2007). Treatment temperatures at 180°C, 200°C and 220°C were applied at durations of 30, 60 and 90 minutes. After each treatment period, the samples were removed out from the tank. The samples were cooled down and then conditioned in a conditioning chamber at 20±3°C and 65±5% relative humidity. Treated samples were tested in accordance to the international standard procedures.

### 2.3 Colour Measurement of Heat Treated Samples

The colour measurements were taken when the wood samples had undergone the oil heat treatment at 180°C, 200°C, 220°C and 30, 60, and 90 minutes respectively. Prior to the colour appearance analysis, the surface to be measured was marked before the heat treatment process. This was done so that the parts of the surface measured were consistent throughout the process. By using pencil, the marked point was done by 2 cm x 2 cm at the cross-sectional surface of each sapwood and heartwood. This section was regarded as the most representative

area for revealing the colour difference of sample (Unsal *et al.*, 2003). The samples were sanded down slightly for about 3mm with P100 sandpaper and brushed cleanly to minimize the risk of variation colour values cause by differences in surface structure.

The measurements of colour were determined according to CIE L\*a\*b\* (1986) system for providing a more accurate and objective colour determination. A colour solid is defined by three rectangular coordinates. This system was sensitive enough to detect small differences in colour parameters to describe between tree and within species' variation (Thulasidas *et al.*, 2006). The principal axis is the lightness level L\* on a 0-100 scale, 0 being total blackness and 100 pure white while intermediate values give grey shades. The hue is specified by the other two chromic characters a\* and b\*. Where, a\* is the red-green axis, with negative values reflecting the dominance of greenness and positive ones redness, and b\* is the yellow-blue axis, with negative values reflecting the dominance of blueness and positive ones yellowness.

Changes in colour of the wood surface due to treatment were done by using a Minolta Chroma Meter CR-10. These measurements were only done on clear wood surfaces as stated before. The sensor head was 8 mm in diameter. The colour reader measures the colour difference on the surface of wood specimens between two colours which that before and after treatment. The results were presented according to the CIE L\*a\*b\* colour co-ordinates system base on the D65 light source with the reflection spectrum was measured in the 400 – 700 nm regions. These values were used to calculate the colour change as a function of heat treatment according to the 1, 2 and 3 respectively.

$$L_t^* = L_t^* - L_s^* \quad \dots\dots\dots (1)$$

$$a_t^* = a_t^* - a_s^* \quad \dots\dots\dots (2)$$

$$b_t^* = b_t^* - b_s^* \quad \dots\dots\dots (3)$$

Where, t = treated sample, s = control sample at tΔ = colour change

### 3. Results and Discussion

#### 3.1 Colour Appearances

Based on the colour measurement of both the sapwood and heartwood, the effect on colour through oil heat treatment can be noticed obviously at different treatment temperature and treatment time, in comparison to the original color of the specimen. Changes in L\*, a\* and b\* were affected by treatment temperature, duration of the time exposed and wood types while the change in colour with sampling height did not show any significant difference. Treatment temperature at 200°C and treatment time of 90 minutes and 220°C at 30 minutes of the sapwood are effective in uniforming the colour of wood to the original colour of the untreated heartwood.

##### 3.1.1 Lightness (L\*) of Wood Colour

In this study, the main involvement of the change in colour of both wood types is the lightness (L\*). As noted by Keey (2004), variation in L\* is more responsive sign of colour change to the human eye that accompanying change in chromic characters a\* and b\*, while Thulasidas *et al.* (2006) reported that the variability in darkness or lightness is the main cause of wood colour variability.

Table 1 presents the colour changed values of treated sapwood and heartwood. From the change in lightness (L\*) values, both sapwood and heartwood show the decreasing lightness at first 30 minutes of every treatment and it becomes progressively decreased with the increase of treatment temperature and duration. However the L\* values of heartwood did not change considerably if compared to L\* values of sapwood. This might be because of the brightness of the wood colour itself which that sapwood of *Acacia* has a brighter colour than heartwood.

Figures 1, 2 and 3, shows the colour of bottom, middle and top of *Acacia* boards treated at different temperatures and durations respectively. From the observation, sapwood becomes slightly darker, while heartwood becomes considerably darker when exposed to vary treatment conditions. From the result obtained from bottom, middle and top portion of sapwood, wood treated at 220°C in 30 minutes showed L\* values almost have similar values with L\* values of untreated heartwood. This also can be observed obviously from the below figure shown (see Figures 4, 5 and 6).

From the result shown, the decrease in L\* values between 200°C-220°C was larger than 180°C in sapwood if compared to heartwood. The L\* values in heartwood slightly changed when the temperature exceeds 200°C. The largest change of treatment duration of both wood types can be found between 60-90 minutes. This indicates the change in L\* values gradually decreased with the increase of treatment temperature and longer duration.

The summary of the correlation coefficient of colour variation with other wood properties of treated acacia is given in Table 2. According to Sundqvist (2004), the differences of chemical composition in wood such as extractive and lignin in sapwood and heartwood can probably be the main reason for dissimilar in colour. This reinforced by the research done by Burtin *et al.* (2000) where during steaming at elevated temperatures, polyphenol compounds found in hybrid walnut heartwood, which conferred the dark color to heartwood, may migrate in the sapwood region and change the sapwood colour from light to dark changes in wood colour.

Mitsui *et al.* (2001) and Bourgios *et al.* (1991) also reported that decreased in lightness was resulting from high temperature of heat treatment due to decrement in a certain chemical component in wood such as hemicellulose and lignin. Changes in wood colour can be an indication of chemical modification or changes in wood (Burtin *et al.* 2000; Bekhta and Niemz, 2003; Sundqvist *et al.* 2006).

### 3.1.2 Chroma Colour, a\* (Reddish Colour)

In the chroma coordinates, a\* and b\* are a combination of red (a\*) and yellow (b\*). Both of the wood type samples showed some differences due to the change in a\* and b\* values. Figures 6 and 7, shows that the change in red a\* values of sapwood and heartwood were totally different with the trends of the chart.

The a\* values of sapwood was increased while a\* values of heartwood decreased through this treatment. This might be because of the original colour of the wood samples itself. Original sapwood colour of *Acacia* hybrid is light yellowish red while heartwood colour is brownish red. Increased in treatment temperature tends to increase a\* values of sapwood. The a\* values reached maximum values after treated at 220°C temperature. Based on the a\* values, the colour of sapwood becomes redder than before while red colour in heartwood becomes lessen. According to Hon *et al.* (1991) the reddish colour and increased saturation substantiated as a decrease in hue and increase in chroma can be due to the formation of secondary condensation or degradation products of the quinone and quinonemethide types. According to Charrier *et al.* (2002) and Grelier *et al.* (1997), wood colours changed toward yellow to brown because of the photo-oxidation of lignin and wood extractives, with the production of coloured quinone component.

### 3.1.3 Chroma Colour, b\* (Yellowish Colour)

Figure 6 presents b\* values of sapwood. b\* values for sapwood begin to decrease with the increase of temperature and duration of treatments. b\* values of sapwood show the greater decreased when treated at 200°C-220°C and 60-90-minute duration. From the observation in Figures 7, 8 and 9 respectively, the yellowish colour of sapwood becomes faded and turns to brownish yellow.

The b\* values of heartwood show the negative change from the start of the treatment (Figure 9). This means that the yellowish colour in heartwood start to decrease from 180°C and it decreases drastically when exposed to 220°C and longer treatment duration.

There was a correlation between b\* and a\* of *A. hybrid* wood (Table 2). Positive correlations were observed between a\* and b\*.

## 3.2 Analysis of Variance on Colour Appearances

The summary of ANOVA of colour appearances of treated *Acacia* is given in Table 2. The change in lightness (L\*) through oil heat treatment were highly significant affected by treatment temperature, duration, wood types and sampling height. This means that L\* play a significant role in the treatment in indicating the changed of wood colour. However for chroma colour (a\* and b\*) only wood types showed the significant difference. This concludes that chroma colour did not influence much in the changed of wood colour through this treatment.

## 4. Conclusion

The sapwood and heartwood of *A. hybrid* colour becomes darker once they are exposed to the high temperature and longer treatment time in oil heat treatment process. The degree of the changes varies between both wood types. The sapwood tends to darken more than the heartwood. The increment in colour of both woods increases with temperature and treatment time.

The lightness (L\*) values, both sapwood and heartwood decrease with the increase in the treatment temperature and treatment time. The L\* values for the heartwood did not changed considerably when compared to L\* values of sapwood. The L\* value are tremendously affected by the treatment where there are changes in a\* and b\* values.

The increase in treatment temperature tends to decrease L\* and drastically increase the a\* values of wood. The decrease of L\* values causes the darkening of the wood surfaces while the increased values in a\* caused the wood colour becomes more red and decreases in b\* values caused the decrease yellow colour of wood turn into

brownish colour. The temperature rather than the treatment time is the most important process variable in controlling the final colour of the treated wood.

Changes in L\*, a\* and b\* were affected by treatment temperature, duration of the time exposed and wood types while the change in colour with sampling height did not show any significant difference. Treatment temperature at 200°C and treatment time of 90 minutes and 220°C at 30 minutes of the sapwood are effective in uniforming the colour of wood to the original colour of the untreated heartwood.

Oil heat treatment induced extensive darkening and reddening of *A. hybrid* wood. This technology can be used to modify acquiring darker tonality of wood to suit the consumers demand.

## References

- Bekhta, P. and Niemz, P. (2003). Effect of High Temperature on the Change in Color, Dimensional Stability and Mechanical Properties of Spruce Wood. *Journal of Holzforschung*, Vol. 57: 539-546.
- Berard, P., Laurent, T. and Dumonceaud, O. (2006). Use of Round Wood of Chestnut Tree Coppices: Crack Risk and Effects of a Hot Oil Bath Treatment. *Journal of Holz als Roh-und Werkstoff*, Vol 64: 287-293. DOI 10.1007/s00107-005-0086-4.
- Bourgeois, P.J., Janin, G. and Guyonnet, R. (1991). La Mesure de Couleur. Une Methode d'Etude et d'Optimisation des Transformations Chimiques du Bois Thermolyse. *Journal of Holzforschung*, Vol 45:377-382.
- Burti, P., Jay-Allemand, C., Charpentier, J. P. and JANIN, G. (1998). Natural Wood Colouring Process in Juglans Spp. (*J.nigra*, *J.regia*, and Hybrid *J. nigra* x *J. regia*) Depends on Native Phenolic Compounds Accumulated in the Transition Zone between Sapwood and Heartwood. *Journal of Trees*. 12:258-264.
- Charrier, B., Charrier, F., Janin, G., Kamdem, D.P., Irmouli, M. and Goncalvez, J. (2002). Study of Industrial Boiling Process on Walnut Colour: Experimental Study Under Industrial Conditions. *Journal of Holz als Roh-und Werkstoff*, Vol 60: 259-264. DOI 10.1007/s00107-005-0082-8.
- Grelier, S., Castellan, A., Desrousseaux, S., Nour, A, Ode, A. and Podgorski, L. (1997). Attempt to Protect Wood Colour Against UV/Visible Light by Using Antioxidants Bearing Isocyanate Groups and Grafted to the Material with Microwave. *Journal of Holzforschung*. 51: 511-518.
- Hon, D. N. S. and Minemura, N. (1991). Color and Discoloration. In Hon, D. N. S. and Shirashi, N. (ed.) *Wood and Cellulosic Chemistry*, pp.395-454. New York: Marcel Dekker Inc.
- Hyvonen, A., Piltonen, P. and Niinimäki, J. (2006). Tall Oil/Water- Emulsions as Water Repellents for Scots Pine Sapwood. *Journal of Holz als Roh-und Werkstoff*, Vol 64: 68-73. DOI 10.1007/s00107-005-0040-5.
- Mitsui, K., Takada, H., Sugiyama, M. and Hasegawa, R. (2001). Changes in the Properties of Light-Irradiated Wood with Heat Treatment. Part 1. Effect of Treatment Conditions on the Change in Color. *Journal of Holzforschung*, Vol 55: 601-605.
- Rafidah, M.D. (2007). Effect of high temperature boiling on properties of *Gigantochloa scortechinii gamble* (Buluh Semantan). Master Thesis. Universiti Putra Malaysia, Malaysia.
- Shakri, M.S. (1995). Finishing Properties of *Acacia mangium*, *Paraserianthes falcataria* and *Gmelina arborea* Timbers: Some Important Parameters. *Journal of Tropical Forest Products*, Vol 1(1): 83-89.
- Stenudd, S. (2003). Colour Response of Silver Birch to Press Drying. *Proceedings of the 8th International IUFRO Wood Drying Conference*. August 24 – 29, 2003. Brasov, Romania. 449-454.
- Sundqvist, B. (2004). Colour changes and acid formation in wood during heating. Ph.D. Thesis. Lulea University of Technology.

Table 1. Average values of colour variation in L\*, a\* and b\* of oil heat-treated *Acacia* hybrid wood

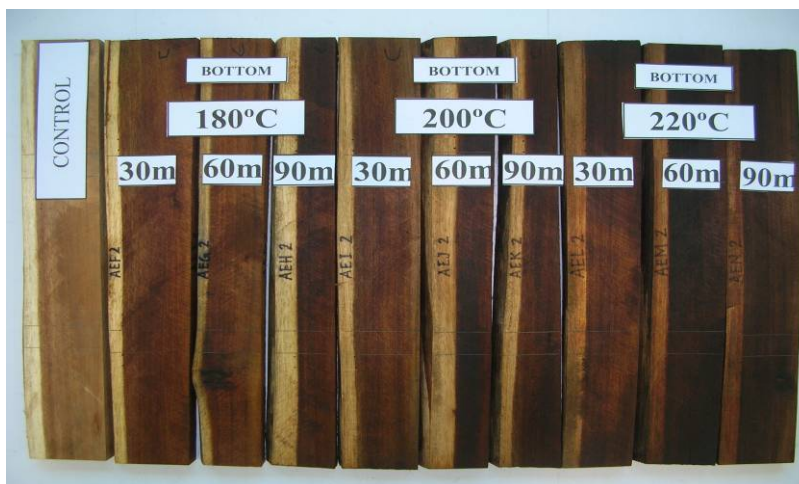
Wood types	Temp. (°C)	Treatment duration (min)	L*			a*			b*			
			B	M	T	B	M	T	B	M	T	
Sapwood	Control	Control	73.6	73.0	71.4	6.9	6.6	7.3	21.2	22.3	21.4	
		180	30	66.7	70.0	65.5	7.4	8.7	8.5	21.9	23.3	23.4
			60	65.4	62.7	63.0	8.8	9.9	9.8	25.7	26.3	24.1
	90		65.6	61.9	62.9	9.3	10.9	10.2	27.3	27.5	26.3	
	200	30	30	63.5	63.5	58.2	9.5	10.0	9.9	26.4	26.1	26.2
			60	56.9	57.2	56.9	11.4	11.9	10.7	27.5	27.1	26.5
			90	50.7	54.6	51.6	12.2	12.4	12.2	27.9	28.9	28.0
		220	30	56.5	53.0	53.4	11.7	10.6	10.3	27.6	26.9	26.7
			60	48.7	47.9	43.2	12.3	12.7	11.2	27.8	27.6	27.8
			90	41.5	40.6	39.2	13.9	13.5	12.6	28.1	29.3	28.9
	heartwood	Control	Control	54.1	54.8	53.5	14.2	15.1	13.9	26.8	26.3	25.2
			180	30	53.6	52.7	52.9	13.4	12.9	12.0	25.0	24.8
60				51.7	51.6	50.7	11.9	11.1	11.5	23.6	23.2	23.5
90		50.4		50.2	48.2	11.2	10.8	10.7	23.0	21.5	22.3	
200		30	30	51.4	52.1	48.6	11.5	10.3	11.3	23.7	24.1	23.9
			60	49.1	50.5	46.9	11.0	9.7	10.7	23.4	21.5	21.9
			90	45.9	46.7	43.5	9.9	8.9	10.2	23.1	21.2	20.9
		220	30	50.7	50.8	46.3	10.0	9.0	10.2	22.6	22.9	21.0
			60	46.6	47.4	38.8	8.3	8.3	8.4	21.1	19.8	17.2
			90	40.0	40.9	33.1	6.7	7.1	7.3	20.5	19.0	15.1

Note: Temp. = temperature  
 min = minutes  
 L\* = lightness  
 a\* = red  
 b\* = yellow  
 B = Bottom  
 M = Middle  
 T = Top

Table 2. ANOVA of colour appearances of treated *Acacia* hybrid

Source of Variance	Dependent Variable	Sum of Squares	Df	Mean Square	F-Ratio
Temperature	L*	9538.60	3	3179.53	110.70**
	a*	9.33	3	3.11	0.42 <sup>ns</sup>
	b*	35.41	3	11.80	1.10 <sup>ns</sup>
Duration	L*	1257.57	2	628.79	21.89**
	a*	1.43	2	0.72	0.10 <sup>ns</sup>
	b*	2.67	2	1.33	0.12 <sup>ns</sup>
Wood Types	L*	6537.30	1	6537.30	227.60**
	a*	94.80	1	94.80	12.82**
	b*	294.70	1	294.70	27.55**
Sampling Height	L*	222.61	2	111.31	3.88*
	a*	0.78	2	0.39	0.05 <sup>ns</sup>
	b*	23.77	2	11.89	1.11 <sup>ns</sup>

Note: \*\* = significant difference at  $p \leq 0.01$ ,  
 \* = significant difference at  $p \leq 0.05$   
 ns = not significant

Figure 1. Colour of treated *Acacia* hybrid (bottom)

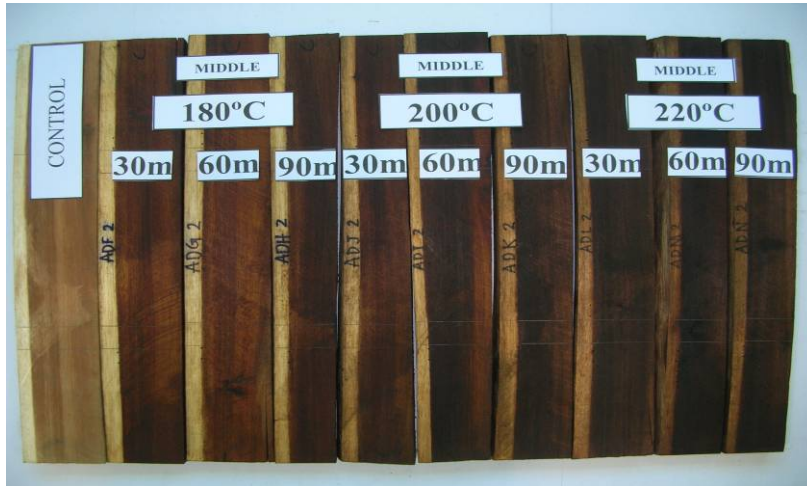


Figure 2. Colour of treated *Acacia* hybrid (middle)



Figure 3. Colour of treated *Acacia* hybrid (top)



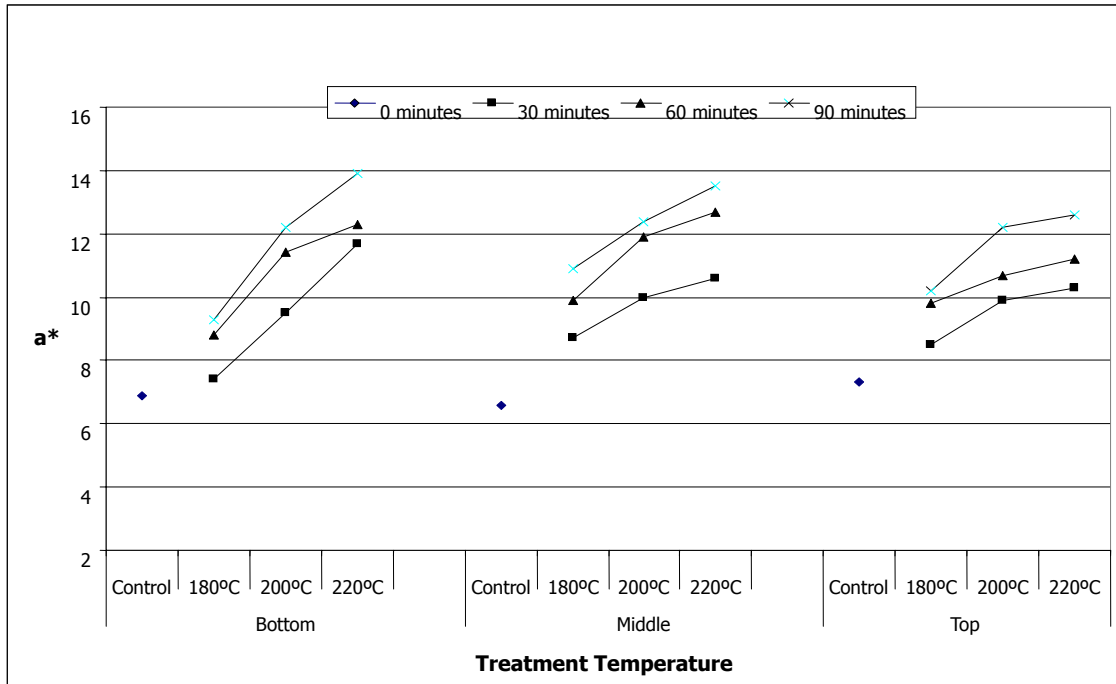


Figure 4. Average values in reddish (a\*) of treated sapwood

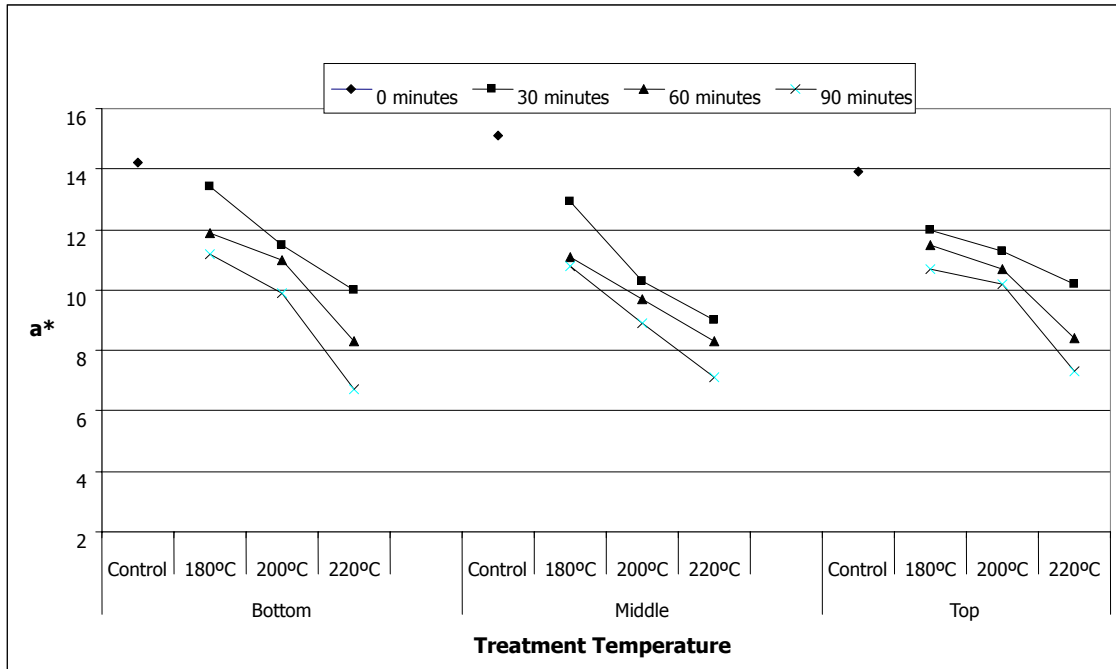


Figure 5. Average values in reddish (a\*) of treated heartwood

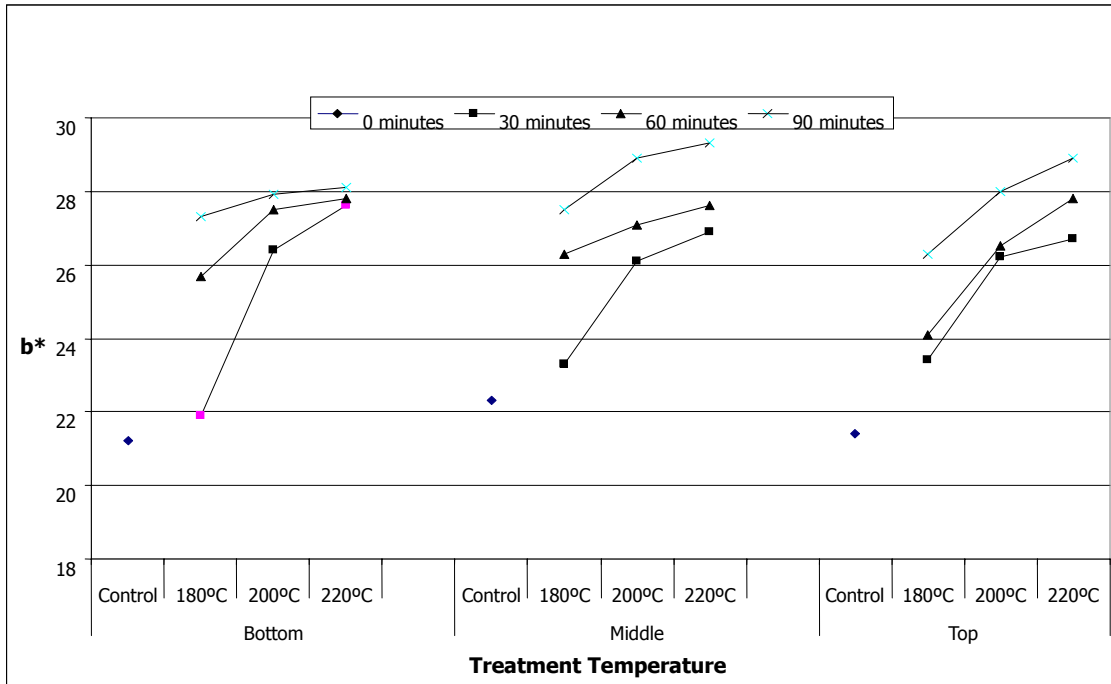


Figure 6. Average values in yellowish (b\*) of treated sapwood

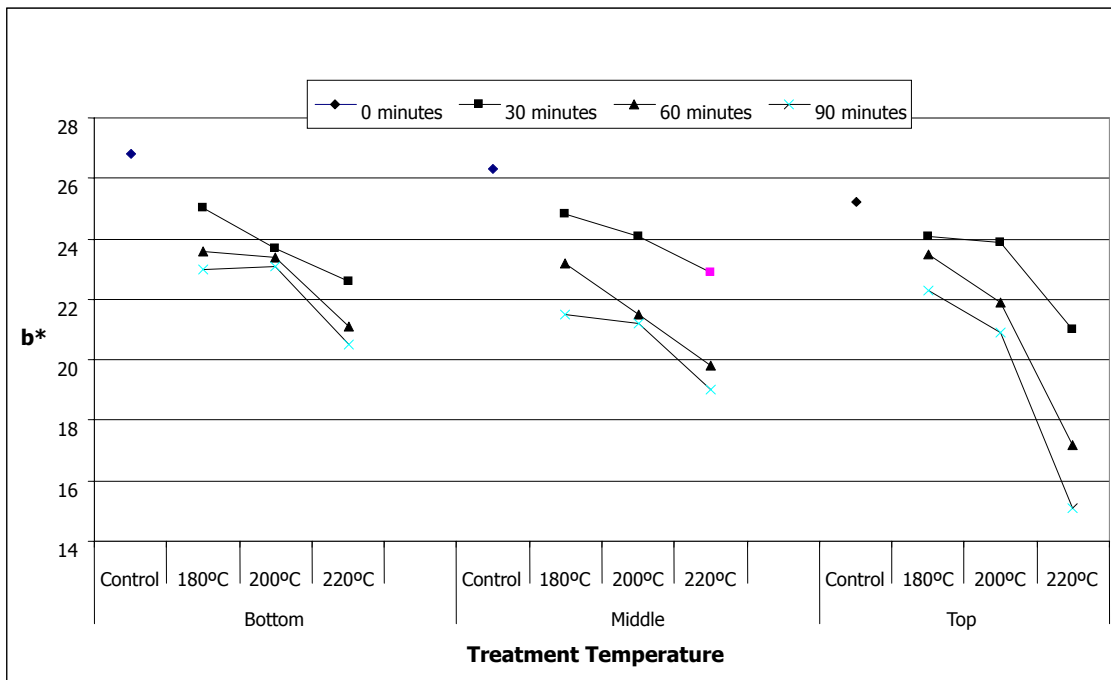


Figure 7. Average values in yellowish (b\*) of treated heartwood

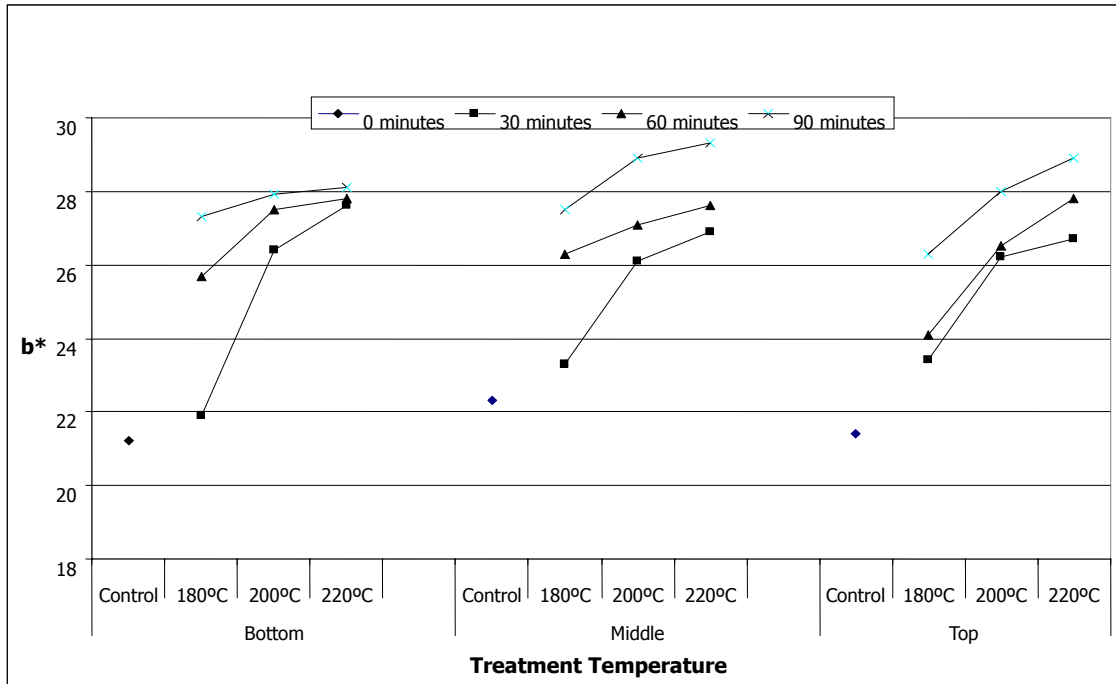


Figure 8. Average values in yellowish (b\*) of treated sapwood

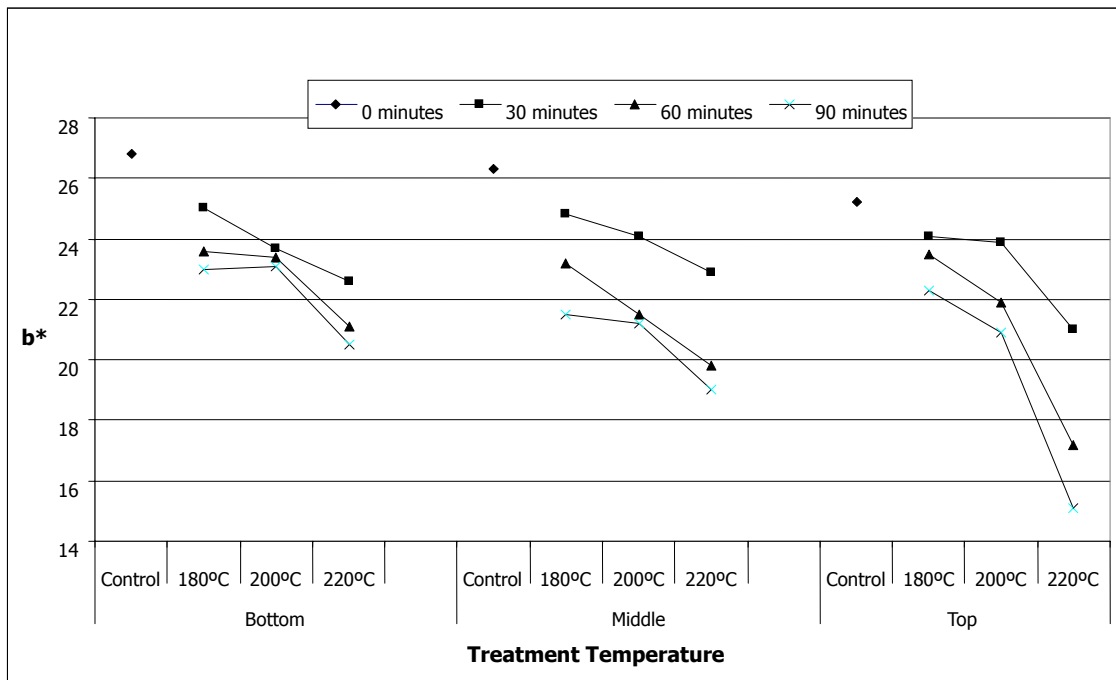


Figure 9. Average values in yellowish (b\*) of treated heartwood