İleri Teknoloji Bilimleri Dergisi
Journal of Advanced Technology Sciences
ISSN:2147-3455

EFFECTS OF HEAT-TREATMENT AND VARNISH APPLICATION ON THE COLOUR CHANGE OF PINE AND ASH LAMINATED VENEER LUMBERS

Hamiyet ŞAHİN KOL[1] Sema AYSAL KESKİN[2] Kübra GÜNDÜZ VAYDOĞAN[2]

[1] Karabuk University, Department of Environmental Engineering, 78050, Karabuk, TURKEY
[2] Karabuk University, Department of Forest Industrial Engineering, 78050, Karabuk, TURKEY
semaaysal@karabuk.edu.tr

Abstract- Heat treatment temperatures and varnish effects on colour properties of pine (*Pinus sylvestris* L.) and ash (*Fraxinus americana*) laminated veneer lumbers (LVL) were evaluated. In the first instance the wood lumbers were exposed to heat treatment with the temperatures of 190 and 212 ºC for 1.5 and 2 h, respectively. After heat treatment process, LVLs were manufactured from heat treated pine and ash veneers with polyurethane (PU) and melamine urea –formaldehyde (MUF) adhesives and one surface of them varnished with yacht varnish. A spectrophotometer was employed to determine colour change of heat-treated and varnished specimens. The samples had significant discoloration as a result of heat exposure and varnish application. Colour difference of the specimens increased as a result of all treatment temperatures. Varnish application caused a significant colour change for both tree species.

Key Words- Colour, Heat-treatment, Varnish, ThermoWood.

1. INTRODUCTION

Wood material has been used in many purposes for indoor and outdoor construction/furniture materials. In the outdoor applications the wood condition is exposed many destroying factors which is a combination of factors such as solar irradiation, moisture, wind, heat/cold, oxygen and atmospheric pollutants and these factors degrade the components and changes its colour. The ultraviolet (UV) light which is the dangerous one, depolymerizes lignin in the wood cell walls and after depolymerization reactions, with the water degradation products removes and it results in surface erosion [1-4]. The photochemical degradation begins due to UV, which changes aesthetic appearance of wood materials and wood becomes pale or greyish, yellowish or darkened mostly depending on the extractive compounds [4-6].

To minimize the effects of weathering deterioration, it is necessary to identify the causative factors and to improve wood properties against to weathering deterioration. Heat treatment is a well-known method to develop some physical properties of wood. It gives wood a nice darker colour. However, it improves the dimensional stability of wood and gives a nice darker colour, it makes wood susceptible against to photodegradation. Several investigations have shown that weathering causes poor aesthetics surface for heat-treated wood which are discoloration and surface checking when it exposed to UV radiation [7-9].

To protect wood against to these kinds of deteriorations several methods has been used for many years. The surface of the wood is protected by the surface treatments and besides it is getting aesthetically beautiful appearance. One of the commonly used method is varnishing.

In this study, the effect of heat treatment temperature and varnish application on laminated veneer lumber which produced heat-treated and untreated ash and pine wood species was investigated.

2. MATERIALS AND METHOD

2.1. Wood Species

In this study, Ash (*Fraxinus americana*) and Yellow Pine (*Pinus slyvestris* L.) species, which find a significant use in trade, have been used. Heat treated by ThermoWood method and untreated Ash and Yellow Pine timbers were supplied from the Novawood in Gerede, Bolu. In addition, attention has been paid to the fact that lumber is perfect, that there is no reaction wood, and that it has not been damaged by fungi and insects. Both tree species were heat treated at 190 and 212 °C for 1.5 and 2 hours, respectively.

2.2. Heat Treatment

Heat treatment by ThermoWood method takes place in three stages. Increasing the temperature and drying at high temperature: Using the heat and water vapor, the oven temperature is quickly increased to 100 °C and then raised to 130 °C, during this time the high temperature drying is performed and the moisture in the wood is tried to be reduced to almost zero level. Heat treatment: After high temperature drying, the temperature in the oven is raised from 185 °C to 212 °C. When the desired temperature is reached, this temperature is maintained for 2 - 3 hours depending on the usage of the material. Cooling and conditioning: At the final stage, temperature is lowered by water spraying. When the temperature reaches 80-90 ºC, the wood material is re-moistened to bring the moisture content to a level of 4-7%.

2.3. Lamination

The heat-treated and untreated timbers were cut to lamellas at a measurement of 110x500 mm and a thickness of 5 mm and they kept at room temperature for 30 days. Then the lamella is divided into two groups before the lamination process. In the production of laminated wood material, AkzoNobel brand Melamine-Urea Formaldehyde (MUF) was used for the first group lamellas and Akfix Brand Polyurethane (PU) was used for another group of lamellas as glue types. The properties of the adhesives are in the following table.

Table 1. Adhesive Properties

Adhesive	**Density (20 ˚C) (Kg/m^3)**	**pH (-25 ˚C)**	**Viscosity (20 ˚C) (mPs)**	**Amount of Solid (%)**	**Amount of Application (g/m^2)**
MUF	1270	9,5-10,7	10.000-25.000	65-69	250-450
PU	1100	-	5.000-15.000	-	140-240

2.4. Varnish Application

In varnishing process yacht varnish (one component alkyd-based varnish) which is frequently used in outdoor applications is used. Prior to varnishing, the surface of all samples was sanded and smoothed. The principles specified in ASTM-D 3023 [10] have been respected in the varnishing of the test sample. At the same time, when the varnish had been applying, the manufacturer's recommendations were considered. It was applied on the single surface with the roller as a 2-layer, 125 g / m^2 varnish falls to each layer and waited 24 hours between the layers. There were control samples (non-varnished samples) for each variation. The specimens which were completed varnishing were kept under normal weather conditions for two months. The table showing varnish properties is as follows;

Table 2. Varnish Properties

Varnish Type	Density (20 ˚C) (g/cm^3)	Component	Dust Drying Time	Amount of Solid (%)	Touch Drying Time
Yatch Varnish	0,9-1,00	Single	3-4 hours	40-45	6-8 hours

2.5. Colour Measurement

The colors of samples were measured by an 8 mm in diameter with 10° observer angle using with a spectrophotometer according to the CIE L* a* b* system to express the color change (Figure 1).

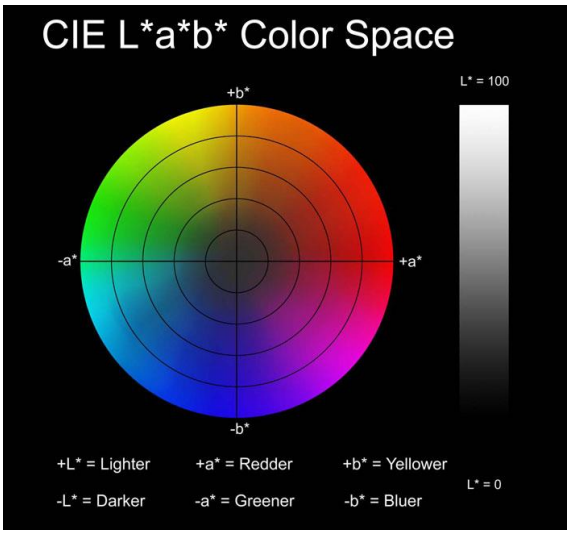

Figure 1. CIE Lab colour space: L is always positive and represents lightness; a> 0 represents red component, a<0 represents green component; b>0 represents yellow component, b<0 represents blue component.

The measurements were recorded at the same points on surface of each sample before and after varnishing. Initially, to determine the effect of heat treatment on colour change, before and after heat treatment the colour of samples was measured. Measurement of the total colour change, the equation 1 was used,

$$\Delta L^* = Lut - Lht \quad (1)$$

Δa^*=aut-aht (2)

Δb^*=but-bht (3)

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

where ΔE^* is total colour change; ΔL^* is lightness difference, Lut/ht is untreated/heat treated lightness; Δa^* is green/red coloration difference; aut/ht is untreated/heat treated green/red coloration; Δb^* is yellow/blue coloration difference; b ut/ht is untreated/heat treated yellow/blue coloration.

3. RESULTS AND DISCUSSION

Heat-treatment at increasing temperature causes a darker and more brownish colour on wood which is desirable for the last user but with heat treatment the wood becomes more susceptible to ultra-violet radiation. To protect of wood surface becomes a necessity with coatings, paints and varnishes. In figure 2 it is obvious that the heat treatment and varnish cause a darker colour on wood samples especially ash wood samples.

Figure 2. The colour change caused by heat treatment process and varnish on wood samples

3.1. Colour Change after Heat Treatment

Table 3 shows the changes of L*, a*, b*, and E* according to the temperature of treatment. While the increase in ΔL^* indicates that the samples become darker, negative values of Δa^* and Δb^* indicate a tendency of wood surface to become red hue and yellow hue.

Table 3. Colour change caused by heat treatment

Wood Species	Heat Treatment Temperature	ΔL	Δa	Δb	Total Color Change ΔE*
Pine	190 ˚C	24,98	-3,30	-5,10	29,06
	212℃	32,68	-3,13	-2,11	35,92
Ash	190 ˚C	20,89	-3,74	-4,90	22,02
	212℃	30,46	-4,12	-3,13	31,06

It is obvious in the figure 3 that with the increasing treatment temperature, total colour change values increased. This means the wood samples were darker than the untreated samples (Figure 2). In literature, there are several studies which obtained similar results [11]. Thermal treatment makes wood more brownish. It is a desirable property by user and industry.

This darkening in the colour may be due to degradation of hemicelluloses therewith an increase in percentage of lignin.

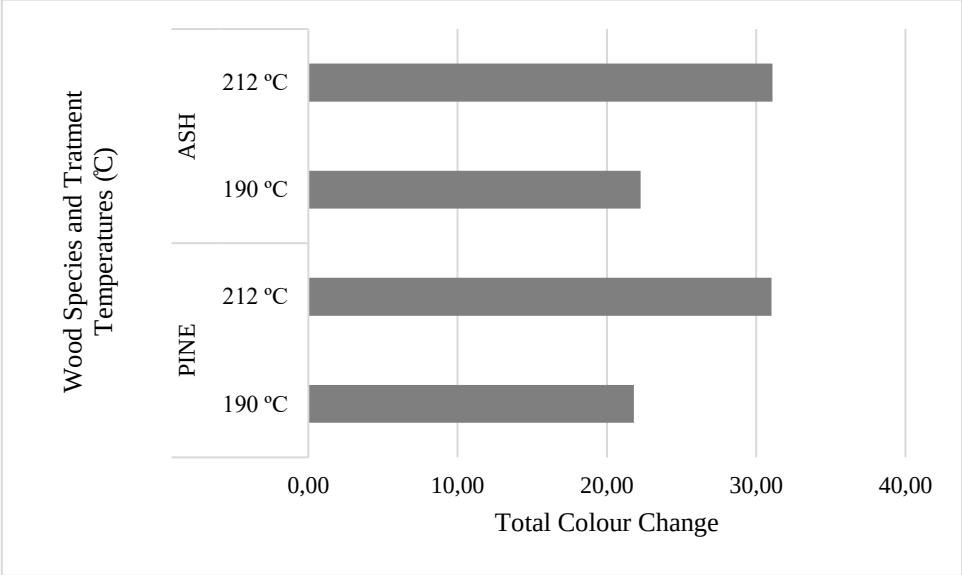

Figure 3. Total colour change caused by heat treatment process

The most total colour change became the samples that heat treated at 212 ˚C for both pine and ash wood species (Figure 3). Intensive heat treatment conditions changed the original colour of wood samples significantly. It is obvious when the positive ΔL* values of samples are examined. Some reactions such as oxidative and/or hydrolytic discolouring reaction causes the colour change during heat treatment [12]. It was indicated that the colour changes occurring after heat treatment most probably become because of the modification of polysaccharide structures, the vaporization of colorant extracts and rapid oxidation of lignin and some chemical elements at high temperature [13].

3.2. Colour Change after Varnish Application

Table 4 shows the changes of L*, a*, b*, and E* according to the temperature of treatment. While the positive values of ΔL* indicates that the samples become darker, decrease of ΔL* indicates that the samples become lighter; negative values of Δa* and Δb* indicate a tendency of wood

surface to become red hue and yellow hue. Lightness (L*) value of all the control and heat-treated samples has decreased after the varnish applications and the samples have darkened (Figure 2). Pelit [14] achieved similar results in a study using different varnishes. When working with four different varieties, the result is that all the varnishes darken the colour of the wood samples. It has seen that in Table 4 ΔL* value has been similar for all pine wood samples (control and heat-treated wood samples) but there is significant difference between untreated (control) and heat-treated ash wood samples.

Table 4. Colour change caused by varnish

Wood Species	Heat Treatment Temperature	ΔL	Δa	Δb	Total Color Change ΔE*
Pine	Control	5,83	-1,45	-10,26	12,06
	190 ˚C	9,83	-4,55	-5,04	12,21
	212 ˚C	12,30	-4,28	1,86	13,48
Ash	Control	6,39	-1,38	-8,72	11,20
	190 ˚C	16,75	-2,65	-0,72	18,09
	212 ˚C	16,56	0,71	4,38	17,64

By the varnishing the positive value of ΔL* indicated that the almost all heat-treated samples at temperature 190 and 212 °C were getting darker. With the effect of varnishing, the total colour change decreased for heat-treated at temperature both 190 °C and 212 when the compared the colour change after heat treatment.

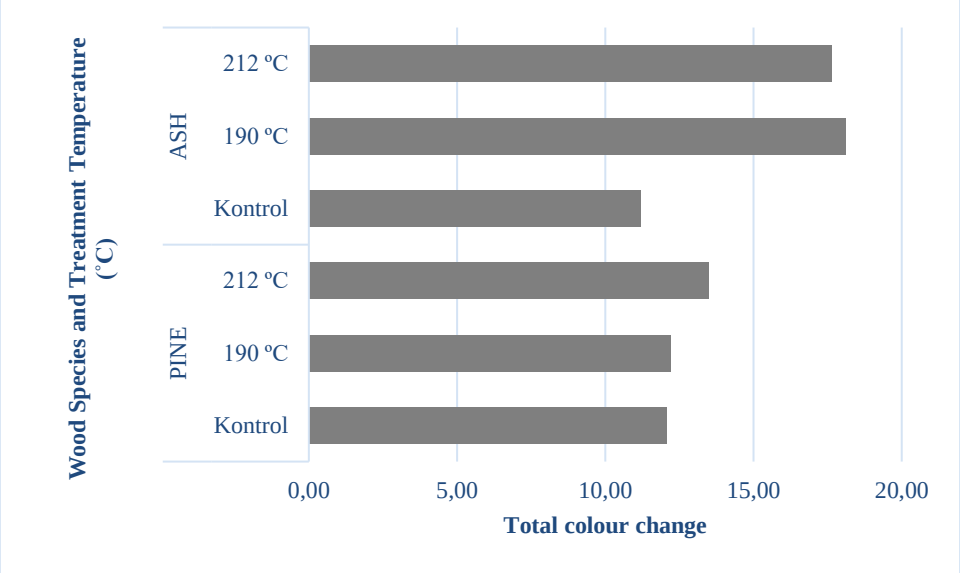

Figure 4. Total colour change caused by varnish apply

The maximum total colour change caused by the varnish took place in ash wood. Total colour changes of ash wood at 190 and 21 °C were visibly more than the total colour change in the heat-treated pine wood samples.

4. CONCLUSIONS

Intensive heat treatment conditions changed the original colour of wood samples significantly. It is apparent that the colour of wood became darker when the positive ΔL* values of samples are examined. Some reactions such as oxidative and/or hydrolytic discolouring reaction causes the colour change during heat treatment. Varnishing is a method to protect wood against to mostly ultra-violet radiation and applying varnish causes dark colour on the wood which is mostly desirable for final user.

5. ACKNOWLEDGEMENTS

Thanks to Scientific Research Project Department of Karabuk University due to the contributions. The project was founded by Scientific Research Project Department of Karabuk University.

6. REFERENCES

[1]. Williams, R.S., (2005). *Weathering of wood.* In: Rowell, R.M. (ed) Handbook of wood chemistry and wood composites. CRC Press, Florida, pp. 139-185.-163.

[2]. Hon, DNS (1991). *Photochemistry of wood.* In: Hon DN-S, Shiraishi N (eds) Wood and cellulosic chemistry. Marcel Decker, New York, pp 525 555.

[3]. Evans, P.D., Michell, A. J. and Schmalzl K.J., (1992). Studies of the degradation and protection of wood surface. *Wood Science Technology*; 126:151.

[4]. Hon, D.,N.,S., (2001). *Weathering and photochemistry of wood.* In: HON, D. N.-S.; SHIRAISHI, N. (eds) Wood and cellulosic chemistry. Marcel Dekker, New York, pp. 513-546.

[5]. Feist, W.C., (1983). Weathering and protection of wood. In: Annual meeting of the American wood-preservers' association. Kansas 79: 195-205.

[6]. Ayadi, N., Lejeune, F., Charrier, F., Charrier, B. and Merlin, A., (2003). Color stability of heat-treated wood during artificial weathering. *Holz als Roh-und Werkstoff*, 61(3), 221-226.

[7]. Sivonen, H., Maunu, S.L., Sundholm, F., Jämsä, S. and Viitaniemi, P., (2002). Magnetic resonance studies of thermally modified wood. *Holzforschung*, 56:648.

[8]. Syrjänen, T. and Kangas, E., (2000). *Heat treated timber in Finland.* The International research group on wood Preservation, IRG/WP 00e40158. IRG Secretariat; SE-100:44.

[9]. Mayes, D. and Oksanen, O., (2002). *Thermo Wood Handbook*; p. 52.

[10]. ASTM D3023-98, (2011). Standard Practice for Determination of Resistance of Factory-Applied Coatings on Wood Products to Stains and Reagents. American Society for Testing and Materials, USA.

[11]. Bekhta, P. and Niemz, P., (2003). Effect of high temperature on the change in color, dimensional stability and mechanical properties of spruce wood. *Holzforschung*, 57(5), 539-546.

[12]. Sundqvist, B., (2002). Color response of Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*) and birch (*Betula pubescens*) subjected to heat treatment in capillary phase. *European Journal of Wood and Wood Products,* 60(2), 106-114.

[13]. Şahin, H.T. and Korkut, S., (2016). Surface colour changes of turkish hazelnut wood caused by heat treatment. *Journal of Advances in Biology & Biotechnology*, 6(1): 1-7.

[14]. Pelit, H., (2017). The effect of different wood varnishes on surface color properties of heat treated wood materials. *İstanbul Üniversitesi Orman Fakültesi Dergisi,* 67(2), 262-274.