

COLOUR CHARACTERISTICS OF PINE WOOD AFFECTED BY THERMAL COMPRESSING
CARACTERÍSTICAS DA COR DA MADEIRA DE PINUS AFETADA POR COMPRESSÃO
TÉRMICA

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ABSTRACT

The goal of this study was to determine the effects of thermal modification and hot-pressing on the colour characteristics of pine wood as bio-resource. The experimental wood boards with dimensions of 250 mm in width by 500 mm in length by 18 mm in thickness were thermally compressed at a temperature of 120 °C or 150 °C, press pressure of 5 or 7 MPa for 60 min in a hot press. Results obtained in this study showed that the colour characteristics of the pine wood boards were affected by press pressure and temperature. The resin leakages significantly increased the chromacity (a^* - 25.99 and b^* - 43.18) of the treated wood samples. Thermally compressing caused browning of wood colour, which rate increases with pressure at high temperature conditions.

Keywords: heat treatment; thermal compressing; pine wood; wood colour.

RESUMO

O objetivo deste estudo foi determinar os efeitos das modificações térmicas e prensagem a quente sobre as características de cor de madeira de pinus como bio-recursos. As tábuas de madeira com dimensões de 250 mm de largura por 500 mm de comprimento por 18 mm de espessura foram comprimidas termicamente a uma temperatura de 120 °C ou 150 °C, a pressão de 5 ou 7 MPa durante 60 min em uma prensa quente. Os resultados obtidos neste estudo mostraram que as características de cor das amostras de madeira de pinus foram afetadas pela pressão e temperatura da prensa. A exsudação da resina aumentou significativamente as coordenadas cromáticas (a^* - b^* e 25,99 – 43,18) das amostras de madeira tratada. Compressão térmica causa escurecimento na cor da madeira, o que aumenta em condições de pressão e alta temperatura.

Palavras-chave: tratamento térmico; compressão térmica; madeira de pinus; cor da madeira

INTRODUCTION

Physical and mechanical properties of wood materials could be improved by thermal modification process. Thermally compressed wood was called as *Staypak* by SEBORG et al. (1945) and STAMM (1964), however compressed wood materials pre-impregnated with phenol formaldehyde resin was named as *Compreg* (STAMM, 1964, STAMM and HARIS, 1953). TARKOW and

SEBORG (1968) carried out by studying surface densification of wood. After 1980, thermally compressed wood materials which had lower density and costs were produced especially for utilization in some fast growing markets in Asia (NORIMOTO, 1993; NORIMOTO, 1994; WANG et al., 2000). In the presence of heat, the goal of thermally compression of wood is to increase its physical and mechanical properties and this process might be result in a new material depending on the process conditions.

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Specific gravity, vertical density profile, dimensional stability, bending properties, drying characteristics, equilibrium moisture content, decay and termite resistant, surface quality, surface hardness, surface abrasion strength, nail/screw withdrawal strength, and shear modulus of thermal compressed wood are investigated (BLOMBERG et al., 2005; KUBOJIMA et al., 2003; NAVI and GIRARDET, 2000; TABARSA, 1995; TABARSA and CHUI, 1997; UNSAL and CANDAN, 2007; UNSAL and CANDAN, 2008; UNSAL et al., 2009; WANG and COOPER, 2005a; WANG and COOPER, 2005b; WELZBACHER et al., 2008; YOSHIHARA and TSUNEMATSU, 2007).

BOURGOIS et al. (1991) and BEKHTA and NIEMZ (2003) stated that colour of heat treated wood changes to red-brown. Some wood materials have been suggested as an alternative to use of dark-coloured wood products from tropical wood species. Another suggestion is that the colour of wood could be used as an indicator of the degree of its thermal modification. Some colour changes caused by thermal modification could be more appreciated by customers. This is especially the case with the wood species such as pine, beech, poplar, and ash which have clear colours (AYADI et al., 2003).

However, colour properties of heat treated wood were previously investigated by AYADI et al. (2003), AYDIN and COLAKOGLU (2005), ESTEVES et al. (2008), PHUNONG et al. (2007), SUNDQVIST et al. (2006), UNSAL et al. (2003), colour characteristics of thermally compressed wood and its main factors have not been completely studied so far. In this study, colour characteristics of pine wood boards after thermal modification by hot-pressing under different press pressure and temperature were evaluated. Thus, value of pine wood as bio-resource from forest resources might be improved for high quality applications.

MATERIALS AND METHODS

Materials

Scotch pine (*Pinus sylvestris* L.) wood boards with dimensions of 250 mm in width by 500 mm in length by 18 mm in thickness were used in this research. Totally, ten experimental pine wood boards, two for each treatment (5 groups: 4 heat treatment + 1 control), were investigated.

Thermal compressing process by Hot-Pressing

A laboratory type hot-press (500 mm by 500 mm in dimensions) at Wood Composite Panel Manufacturing Laboratory at Department of Forest Products Engineering, Istanbul University was used to press the wood boards. The experimental pine wood boards were compressed at temperatures of 120 °C or 150 °C, under press pressures of 5 or 7 MPa for 60 minute. Experimental design of thermal modification process is given in Table 1. After hot-pressing, the larger specimens were cut into 50 mm in width by 50 mm in length for the determination of colour characteristics.

Determination of colour characteristics

The experimental pine wood boards were conditioned at a climate chamber using 20 ±2 °C and 65 ±5 % of relative humidity (RH) for about 3 weeks before preparing the test specimens. To measure the colour of the treated pine wood of 5 x 5 cm pieces were taken. The cross-sectional surface was regarded as the most representative plane for revealing the colour difference of samples (ATIK, 2006). Surfaces of the treated samples were sanded down (sandpaper roughness: P100) 3 mm and brushed cleanly (MONNONEN et al., 2002).

The colour measurements were performed using an ‘Elrepho 3300’ spectrophotometer at 23 ±1 °C temperature and 50 ±2 % RH. The device was calibrated against a white working standard supplied with the instrument. Measurements were made using D65 illumination, 10° standard observer and SAV aperture (9 mm illuminated and 5 mm measured area) (ATIK, 2006).

The CIE L*, a*, b* (Commission Internationale de l’éclairage) characters were de-

TABLE 1: Decrease in thickness after thermal modification process.

TABELA 1: Diminuição da espessura após o processo de modificação térmica.

Treatment Group	Press Pressure (MPa)	Press Temperature (°C)	Pressing Duration (min)	Decrease in Thickness* (%)
1	5	120	60	3.3
2	5	150	60	4.7
3	7	120	60	7.2
4	7	150	60	38.8
Control	-	-	-	-

*Based on control specimens

terminated and the colour changes as a function of heat and pressure treatments were calculated using the following equation:

$$\Delta E^* = \sqrt{(L_s^* - L_R^*)^2 + (a_s^* - a_R^*)^2 + (b_s^* - b_R^*)^2}$$

Where R = reference (Control sample), S = sample (thermal compressed)

The CIE colour system utilize three coordinates L*, a*, and b* to locate colour in colour space. L* axis represents the lightness, it varies from 100 (white) to zero (black), a* and b* are the chromaticity coordinates, representing red-green and blue-yellow respectively.

Annual ring measurements

The growth ring properties (early wood-late wood ratio) of the samples were determined using Time Series Analysis Program (TSAP-Win) and LINTAB measurement system. The measurements were performed at the area where the colour properties were determined.

RESULTS AND DISCUSSION

Thermal compression of wood changes the colour properties of wood, and it becomes darker. At low temperature pressure the main reason for colour difference is the drop of lightness (L*) properties, and with the increase of temperature to 150°C the increase the role of chromacity on colour difference of samples (Table 2). The temperature conditions influence the colour properties of wood in the same manner at high pressure treatment, while the colour difference is higher at high pressure conditions (Figure 1).

The appearance of cross section of wood is related to its surface topography and chemical characteristics (early and late wood parts of annual rings). Therefore, it will be expected that the annual ring width, early wood and late wood ratio to influence the colour properties of wood. However, there was not determined significant correlation between annual ring properties (Table 3) and colour properties of untreated and treated wood samples. Accordingly, the chemical composition is the main factor influencing its wood colour before and after the thermally compression.

The colour properties of wood defects were also determined. The parts of wood with defects are darker than any other parts of wood samples (Table 4). Meanwhile, the thermally compressing process did not cause such decrease (difference) of colour properties. The resin leakages cause a significant increase of chromacity (a* - 25.99 and b* - 43.18) of treated wood samples.

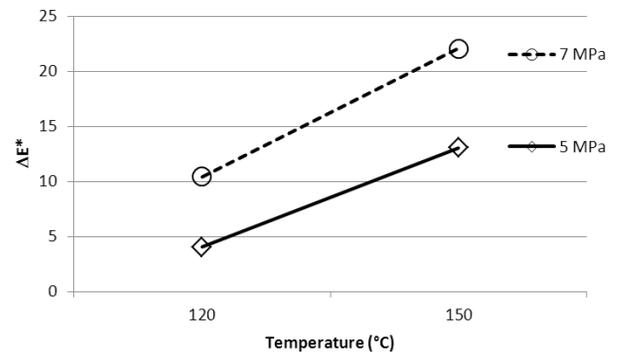


FIGURE 1: Colour changes of thermally compressed wood.

FIGURA 1: Mudanças de cor de madeira tratada por compressão térmica.

TABLE 2: Colour values and colour differences of thermally treated wood.

TABELA 2: Valores e diferenças da cor da madeira tratada termicamente.

Treatment Group	CIE L*	CIE a*	CIE b*	ΔE*
1	73.24	5.70	20.60	4.04
2	64.54	7.16	22.78	13.05
3	66.98	6.88	20.79	10.41
4	55.81	9.77	22.75	22.05
Control	77.11	4.56	20.46	-

TABLE 3: Annual ring properties of samples.

TABELA 3: Propriedades dos anéis de crescimento das amostras.

Treatment Group	Annual Ring Width (mm)	EW ratio	LW ratio
1	0.44	72.28	27.72
2	1.31	74.08	25.92
3	1.28	79.48	20.52
4	0.45	64.44	35.56
Control	0.25	59.67	40.33

TABLE 4: Colour values of wood defects and colour differences from the mean value for treatment group.

TABELA 4: Valores da cor para defeitos da madeira e diferenças de cor a partir do valor médio do grupo de tratamento.

Wood Defect	Section	CIE L*	CIE a*	CIE b*	ΔE^*	Treatment group
Stain	Cross	67.87	1.25	15.79	48.41	0
Knot	Tangential	25.39	4.28	4.36	51.96	0
Stain	Cross	66.99	0.93	13.12	47.05	1
Rosin	Cross	33.59	25.99	43.18	37.80	2
Knot	Cross	57.37	9.18	21.57	35.38	2
Knot	Cross	24.34	1.55	1.95	43.11	3
Knot	Radial	27.35	2.17	2.33	40.43	3

CONCLUSION

The findings obtained in this study showed that the thermally compressing process caused browning of the wood colour, which rate increases with pressure at high temperature conditions. The annual ring properties of the wood samples seem to be an insignificant factor affecting the colour changes during the thermal compressing.

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