WOOD RESEARCH
58 (3): 2013
475-482

MODIFICATION OF WOOD COLOUR OF *FAGUS SYLVATICA* L. TO A BROWN-PINK SHADE CAUSED BY THERMAL TREATMENT

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(Received December 2012)

ABSTRACT

By a process of thermal treatment using water steam, the colour of beech wood changes from light white-yellow with a yellow tint through brown-pink to dark red-brown shade depending on the conditions of the technological process.

The goal of this paper is to determine the colour of beech wood in CIE-L*a*b* colour space after thermal treatment – steaming using saturated water steam with temperature of t = 125–130°C for the duration of τ = 6.5 h.

The colour of surface of seasoned, thermally treated and milled beech wood blanks in CIE-L*a*b* colour space is expressed by coordinates: L* = 58.1 ± 3.8; a* = 15.5 ± 2.2; b* = 24.9 ± 1.3.

KEYWORDS: Colour, CIE-L*a*b* colour space, beech wood, thermal treatment, saturated water steam.

INTRODUCTION

The colour of wood is a basic physical property and a typical feature of sapwood and heartwood of wood species. The colour range of native wood of industrially important wood species used as construction material in cabinetmaking and furniture industry covers a wide range: From light white-grey-yellow shades of wood species *Picea excelsa*, *Abies alba*, *Tilia cordata*, *Carpinus betulus* through red-brown shades of heartwood of wood species *Quercus robur*, *Fraxinus excelsior*, *Juglans regia* as stated by Drapela (1980), Makovíny (2010).

One of the methods to objectively quantify this optical property of wood is to express it in form of coordinates in CIE-L*a*b* colour space. A colour coordination system (according to CIE – Commision Internationale de l'Eclairage) in terms of ISO 7724 (1984) is based on the measurement of three parameters: Lightness L from 100 for white to 0 for black, chromatic coordinate a* for determination of shade between red and green colour and chromatic coordinate b* determining the shade between yellow and blue colour.

Light, white-grey colour with a yellow tint of wood of *Fagus sylvatica* is described in the CIE-L*a*b* colour space, according to Babiak et al. (2004a), with coordinates L* = 75.96; a* = 6.62; b* = 17.63.

Thermal treatment – steaming or hydrothermal treatment – seasoning changes the colour of beech wood from light white-grey with a yellow tint through brown-pink shade to dark red-brown shade according to the conditions of the technological process Deliiski (1991, 2003), Halaj (1999), Molnár and Tolvaj (2004), Dzurenda and Deliiski (2003, 2012), Babiak et al. (2004b), Klement and Marko (2009), Klement et al. (2011).

The goal of this paper is to determine the colour of beech wood in CIE-L*a*b* colour space after thermal treatment – steaming using saturated water steam with temperature of t = 125 – 130°C for the duration of τ = 6.5 h.

MATERIAL AND METHODS

Beech sapwood blanks with measures 27 x 75 x 320 mm and moisture content W_p = 70 ± 3 % were thermally treated using saturated water steam with temperature of t = 125 – 130°C in a pressure autoclave APDZ 240 by LIGNOTHERM Ltd. for the duration of τ = 6.5 h. The regime of pressure steaming of beech blanks is in Fig. 1.

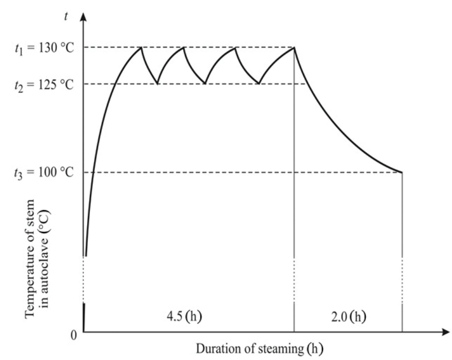

Fig. 1: Regime of thermal treatment of beech wood using saturated water steam.

These beech blanks were subsequently seasoned to moisture content W_p = 12 ± 0.5 % in a conventional wood drying kiln KAD 1x6 by KATRES s.r.o. Seasoned blanks were milled on a horizontal planing milling machine FS 200.

The wood colour of beech blanks in CIE-L*a*b* colour space was determined by a colorimeter Color Reoder CR-10 (Konica Minolta, Japan). The light source used was D65 and the diameter of collecting area was 8 mm.

The coordinates L*, a* and b* of CIE-L*a*b* colour space were measured on 54 blanks. The measurement of colour coordinates on beech wood samples was carried out on the marked side in the middle of width of the blank 160 mm away from the end before the thermal treatment of blanks and after mechanical milling of seasoned steamed blanks on a horizontal planing milling machine FS 200.

The values of colour coordinates are expressed as ; average measured values and a combined standard measurement uncertainty. Combined standard measurement uncertainty consists of type A and type B uncertainty. The calculation of combined standard uncertainty for particular coordinates of the CIE-L*a*b* colour space are expressed by formulas:

$$u_{C_L} = \sqrt{u_{A_L}^2 + u_{B_L}^2} = \sqrt{\frac{\sum_{i=1}^{n}\left(L_i - \bar{L}\right)^2}{n.(n-1)} + u_{B_L}^2} \quad (1)$$

$$u_{C_{a*}} = \sqrt{u_{A_{a*}}^2 + u_{B_{a*}}^2} = \sqrt{\frac{\sum_{i=1}^{n}\left(a_i - \bar{a}\right)^2}{n.(n-1)} + u_{B_{a*}}^2} \quad (2)$$

$$u_{C_{b*}} = \sqrt{u_{A_{b*}}^2 + u_{B_{b*}}^2} = \sqrt{\frac{\sum_{i=1}^{n}\left(b_i - \bar{b}\right)^2}{n.(n-1)} + u_{B_{b*}}^2} \quad (3)$$

where: L_i , a_i, b_i – measured colour range coordinate values,
$\bar{L}, \bar{a}, \bar{b}$ – average colour range coordinate values,
n – number of measurements,
u_{BL}, u_{Ba}, u_{Bb} = 0.1 standard deviation of the measuring device from nominal value.

Variance of determined coordinate values in CIE-L*a*b* colour space of steamed and non-steamed beech sapwood is evaluated using relative standard uncertainty $_{rel}u_C$. Values of relative standard uncertainty for particular colour coordinates are described by formulas:

$$_{rel}u_{C_L} = \frac{u_{C_L}}{\bar{x}_L}.100 \quad (\%) \quad (4)$$

$$_{rel}u_{C_{a*}} = \frac{u_{C_{a*}}}{\bar{x}_{a*}}.100 \quad (\%) \quad (5)$$

$$_{rel}u_{C_{b*}} = \frac{u_{C_{b*}}}{\bar{x}_{b*}}.100 \quad (\%) \quad (6)$$

From the difference of colour range parameters ΔL*, Δa*, Δb*, which were determined by measuring wet beech blanks before thermal treatment and after seasoning and milling of steamed blanks a colour deviation ΔE* was determined, which quantifies the total change in CIE-L*a*b* colour space according to these formulas:

$$\Delta L^* = L_2^* - L_1^* \quad (7)$$

$$\Delta a^* = a_2^* - a_1^* \quad (8)$$

$$\Delta b^* = b_2^* - b_1^* \quad (9)$$

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (10)$$

where: L_1, a_1, b_1 - colour range coordinates of sapwood before thermal treatment of wood, L_2, a_2, b_2 - colour range coordinates of surface of seasoned, milled and thermally treated beech sapwood.

RESULTS AND DISCUSSION

A brown-pink colour shade of seasoned beech sapwood acquired by the thermal treatment using saturated water steam is shown in Fig. 2.

Fig. 2: Surface of seasoned and milled beech sapwood after thermal treatment using saturated water steam with temperature of t = 125–130°C for the duration of τ = 6.5 h.

Statistical data of colour coordinates of surface of beech wood in CIE-L*a*b* colour space before its thermal treatment and of the surface of seasoned, milled and steamed blanks shows Tab. 1.

Tab. 1: Colour range coordinates of beech sapwood before and after thermal treatment using saturated water steam.

Beech blanks		Colour coordinates		
		L*	a*	b*
Non-steamed	Number of measurements (-)	54	54	54
	Average value of coordinates (-)	71.3	9.6	21.8
	Combined standard uncertainty (-)	4.8	3.7	1.9
	Relative standard uncertainty (%)	6.7	38.5	8.7
Steamed	Number of measurements (-)	54	54	54
	Average value of coordinates (-)	58.1	15.5	24.9
	Combined standard uncertainty (-)	3.8	2.2	1.3
	Relative standard uncertainty (%)	6.5	14.2	5.2

The colour shade of surface of seasoned, milled and steamed beech blanks in CIE-L*a*b* colour space described as the average value of colour coordinate and the interval of its variance is shown in the formula:

L* = 58.1 ± 3.8
a* = 15.5 ± 2.2
b* = 24.9 ± 1.3

The changes of particular colour coordinates of beech wood caused by thermal treatment using saturated water steam with temperature of t = 125–130°C for the duration of τ = 6.5 h are in form of a column diagram shown in Fig. 3.

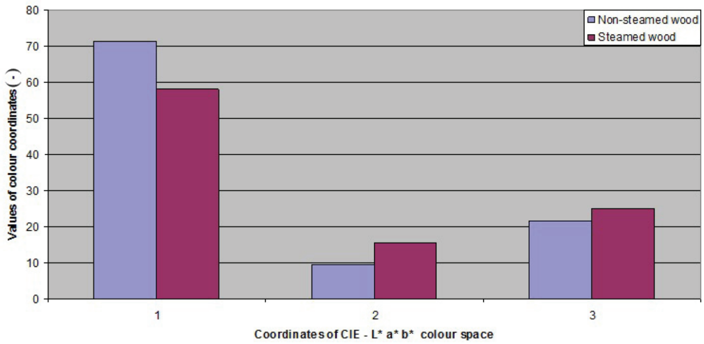

Fig. 3: Changes of colour coordinates of beech wood caused by the thermal treatment using saturated water steam.

Due to the thermal treatment the lightness of beech wood slightly decreased by ΔL* = - 13.2 and also a shift of colours on the chromatic coordinates occurred, which increased the values of red colour by Δa* = + 5.9 and the values of yellow colour by Δb* = + 3.1.

The value of relative standard uncertainty of colour coordinate a* = 14.2 % of surface of seasoned, milled and steamed beech blanks points out a certain variability in changes of colours of beech wood during thermal treatment. It is caused by high variance of colour values in colour range of native beech wood declared by the value of relative standard uncertainty a* = 38.5 % shown in Tab. 1 and values of coefficient of variation v_{x-a^*} = 23.22 % by Hrčka (2010) or v_{x-a^*} = 22.8 % by Klement and Marko (2009).

Total colour deviation of colour changes of beech wood caused by thermal treatment, calculated via formula (10) equals ΔE* = 14.8. Since this value exceeds the limit of significant colour changes ΔE* > 12 (Cividini 2007), the colour change of beech wood caused by steaming belongs into the group of different colours. In terms of categorisation of changes of physical and chemical properties of wood, according to Kollmann and Côté (1968), Trebula (1996), this change of colour of beech wood belongs into the group of irreversible changes. It is caused by a partial hydrolysis of hemicelluloses in lignin-saccharidic matrix of beech wood and the extraction of water-soluble accessory compounds, as stated in works: Bučko (1995), Trebula and Bučko (1996), Dzurenda and Deliiski (2000) Kačík (2001), Laurová et al. (2004), Kačíková and Kačík (2011) due to the presence of monosaccharides, organic acids and elementary building components of lignin with guayacyl and syringyl structure in condensates after pressure steaming of beech wood.

CONCLUSIONS

Change in colour of beech wood in thermal process – steaming with saturated water steam with temperature of t = 125–130°C for a duration of τ = 6.5 h is presented in this paper. The colour of beech wood changes during steaming from light grey-white colour with a yellow tint to a brown-pink colour shade. The surface of seasoned, thermally treated beech sapwood milled by a milling machine is declared in CIE-L*a*b* colour space by coordinates L* = 58.1 ± 3.8; a* = 15.5 ± 2.2; b* = 24.9 ± 1.3.

Due to the thermal treatment, the lightness of beech wood has decreased by ΔL* = - 13.2 and colour coordinates in CIE-L*a*b* colour space shifted by Δa* = + 5.9 for red colour and Δb* = + 3.1 for yellow colour.

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