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WOOD COLOUR OF RING-POROUS BROAD-LEAVED TREE SPECIES RESULTING FROM THE PROCESS OF THERMAL TREATMENT WITH SATURATED WATER STEAM

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Abstract

*Changes in wood colour of woodturning blanks with dimensions of 32 x 55 x 600 mm of ring-porous broad-leaved tree species: European ash, black locust, sessile oak resulting from the thermal treatment with saturated water steam with the temperature of $t = 137.5 \pm 2.5°C$ for the time $\tau = 7.5$ hours are presented in the paper. Natural wood colour of individual wood species as well as the hues resulting from the thermal treatment are in the CIE-L*a*b*colour space defined by the coordinate of lightness L* and the chromaticity coordinates a*, b*. The wood of ring-porous broad-leaved tree species darkens in the process of thermal treatment and due to changes in chromaticity coordinates of red and yellow colours it achieves brown hue. Mentioned changes in colour of thermally modified woodturning blanks by given mode are irreversible. Change in wood colour is uniform across the full extent and thus, the possibility for its use in the field of construction and carpentry, design as well as in the field of art is widened.*

Key words: *wood, saturated water steam wood colour, thermal treatment*

INTRODUCTION

Timber placed in the environment of hot water, saturated water steam or saturated humid air is getting warmer and its physical, mechanical and chemical properties changes. Mentioned facts are used in the technology of steam bending and boiling during veneer and plywood, bent furniture or pressed wood manufacturing processes. *Kollmann – Gote (1968), Sergovsky – Rasev (1987), Trebula (1996), Dzurenda – Deliiski (2010).*

Thermal treatment processes of wood with saturated water steam, in addition to specific physico-mechanical changes of wood, are accompanied by chemical reactions such as partial hydrolysis and extraction leading to a colour change as well *Bučko (1995), Trebula – Bučko (1996), Dzurenda – Bučko (1998), Kačík (2001), Laurova – Mamonova – Kučerova (2004), Kačíková – Kačík (2011)*. In the past, colour modification, especially wood darkening, was used to remove undesirable differences in colour of lighter sapwood and darker heartwood, or to remove wood stains resulting from steaming or moulding. Recently, the research has been aimed at the colour change of specific wood species to more or less distinctive hues or imitation of the exotic wood species *Tolvaj – Nemet – Varga – Molnar (2009), Fan, Y.- Gao, J. - Chen, Y. (2010), Dzurenda (2014,2018), Barcik – Gašparík –Razumov (2015), Baranski – Klement – Vilkovská – Konopka (2017).*

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Using the coordinates of CIE-L*a*b*colour space is one of the ways to quantify the given optical wood property objectively. Lab colour space CIE-L*a*b* in accordance with ISO 7724 is based on the measurement of three parameters: lightness L* represents the brightest white at L* = 100 and the darkest black at L* = 0. The value of a chromaticity coordinate a* is a measure of the red-green character of the colour, with positive values (+a*) for red shades and negative values (-a*) for green. The value of a chromaticity coordinate b* gives the yellow-blue character with positive values (+b*) for yellow shades and negative (-b*) for blue.

The aim of the paper is to determine the hue of woodturning blanks with dimensions of 32 x 55 x 600 mm of ring-porous broad-leaved tree species: European ash, black locust, sessile oak in the CIE-L*a*b*colour space resulting from the mode of thermal treatment – colour modification of wood with saturated water steam with the temperature of $t = 137.5 \pm 2.5$ °C for the time $\tau = 7.5$ hours in the pressure autoclave APDZ 240.

MATERIAL AND METHODS

The mode of colour modification of woodturning blanks with saturated water steam in the pressure autoclave APDZ 240 for ring-porous broad-leaved tree species: European ash, black locust, sessile oak is illustrated in Fig.1.

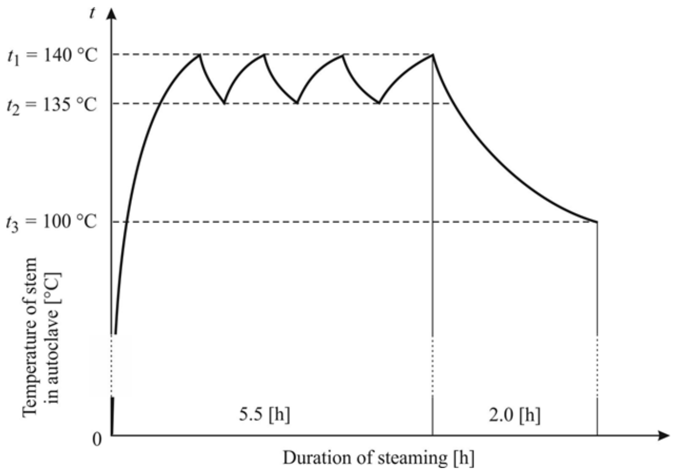

Fig.1. *Description of conditions for the process of thermal treatment of woodturning blanks of ring-porous broad-leaved tree species.*

The moisture content of woodturning blanks of the sapwood of European ash and of the heartwood of black locust, sessile oak was $W_p = 60.3 \pm 3.8$ %. Some of the woodturning blanks were thermally modified in the above-mentioned mode with saturated water steam in the pressure autoclave APDZ 240 (Himmasch AD, Haskovo, Bulharsko) in the company Sundermann Ltd. Banská Štiavnica.

Thermally treated as well as untreated woodturning blanks were dried to report the moisture content of $Wp = 12 \pm 0.5\%$ in a conventional wood drying kiln KAD 1x6 (KATRES Ltd.). Consequently, dried woodturning blank surfaces were processed using Swivel spindle milling machine FS 200.

Color Reader CR-10 (Konica Minolta, Japan) was used to assess the wood colour of woodturning blanks in the CIE-L*a*b*colour space. The light source D65 with lit area of 8mm was used.
Colour coordinates of thermally untreated woodturning blanks after drying and planing are introduced using a formula x = $x \pm s_x$, it means using the average measured value and standard deviation.
Total colour difference ΔE is determined in accordance with the standard *ISO 11 664-4:2008* as the result of the difference in the colour coordinates of thermally untreated as well as treated woodturning blanks of individual tree species using the following formula (4):

$$\Delta E^* = \sqrt{\left(L_2^* - L_1^*\right)^2 + \left(a_2^* - a_1^*\right)^2 + \left(b_2^* - b_1^*\right)^2} \tag{4}$$

where: L^*_1, a^*_1, b^*_1 coordinate values in the CIE-L*a*b* colour space of the surface of dried, milled thermally untreated wood,
L^*_2, a^*_2, b^*_2 coordinate values in the CIE-L*a*b* colour space of the surface of dried, milled thermally treated wood.

The rate of change in the wood colour and hues during the processes of thermal and hydrothermal treatment following the total colour difference ΔE* can be classified according to the chart mentioned by the authors: *Cividini et all (2007)* shown in Tab.1.

Tab. 1 *Classification of ΔE*

0.2 < ΔE*	Not visible difference
0.2 < ΔE* < 2	Small difference
2 < ΔE* < 3	Colour difference visible with low quality screen
3 < ΔE* < 6	Colour difference visible with medium quality screen
6 < ΔE* < 12	High colour difference
ΔE* > 12	Different colours

RESULTS AND DISCUSSION

Colour of the sapwood of European ash is, according to the authors: *Perelygin (1965), Makoviny (2010), Klement – Réh – Detvaj (2010)* white with light-yellow hue. The colour of sessile oak heartwood is light brown-yellowish in comparison to the wood colour of black locust heartwood that is light yellow-green and brown. According to the authors: *Babiak – Kubovský – Mamoňová (2004)* the colour of European ash wood is described with the coordinate values in the CIE-L*a*b*colour space: L* = 81.80; a* = 4.18; b* = 18.45, the coordinates of the colour of sessile oak are L* = 69.9; a* = 6.5; b* = 20.6. The colour of black locust wood is described by the coordinate values: L^* = 71.8; a^* = 5.3; b^* = 25.0. The results of our measurements are similar to the mentioned values and are shown in Tab. 1

Natural colour of the surface of dried, planed native – thermally untreated ash, oak and acacia wood and the hues of mentioned tree species after thermal treatment with saturated water steam are illustrated in Fig. 2.

Light white-yellowish colour of European ash sapwood was changed to brown with the darker hue of latewood of growth ring on tangential and radial section in the process of thermal treatment with saturated water steam – by the mode of colour modification.

Original light white-yellowish colour of heartwood of sessile oak became brown-grey in the process of thermal treatment accompanied with hydrolysis and extraction. Light yellow-green and brown colour of the heartwood of black locust changed to unique dark brown-grey hue in the process of thermal modification.

Sessile oak (Quercus robur L.)

European ash (Fraxinus excelsior L.)

Black locust (Robinia pseudoacacia L.)

Fig. 2 *The colour of the surface of dried and planed wood thermally untreated and treated with saturated water steam.*

Values of the colour coordinates in the CIE-$L^*a^*b^*$ colour space describing the wood colour resulting from the thermal treatment and drying of planed surface are mentioned in Tab. 2.

Tab. 2 *Values of colour coordinates in the CIE-$L^*a^*b^*$ colour space describing thermally untreated and treated wood with the saturated water steam*

Tree species	Woodturning blanks	Number of samples	Colour coordinates		
			L*	a*	b*
European ash	thermally untreated	178	84.6 ± 1.5	6.7± 0.6	19.8± 0.9
	thermally treated	180	65.6 ± 1.4	10.8 ± 0.5	21.7 ± 0.9
Sessile oak	thermally untreated	245	69.4 ± 2.5	8.8 ± 0.6	20.7 ± 0.8
	thermally treated	245	47.5 ± 2.1	5.9 ± 0.9	17.9 ± 1.2
Black locust	thermally untreated	183	69.2 ± 2.9	4.7 ± 0.8;	28.7 ± 2.4
	thermally treated	180	44.3 ± 1.6	8.9 ± 0.4	15.1 ± 0.9

The changes in coordinate values of ΔL* and in chromaticity coordinates of Δa^* and Δb^*, the changes in red and yellow shades in the CIE-L*a*b*colour space of European ash, of sessile oak and black locust wood resulting from the processes of partial hydrolysis and extraction of water soluble accessory substances during the thermal treatment with saturated water steam are illustrated in Fig. 3.

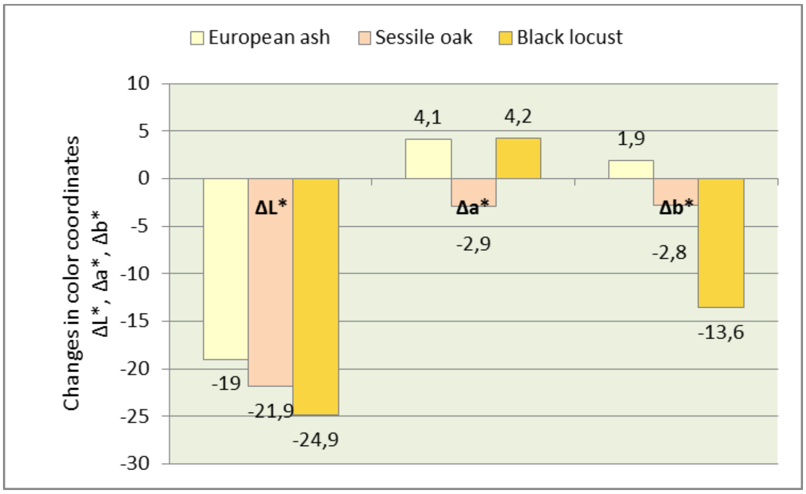

Fig.3 *The rate of change in the coordinate of lightness L* and chromaticity coordinates a* and b* in the CIE-L^*a^*b colour space of individual ring-porous broad-leaved tree species resulting from the process of thermal treatment with saturated water steam.*

Total colour differences ΔE* of colour modified woodturning blanks of individual tree species achieved by the individual thermal treatment modes calculated using the formula (1) are shown in Fig. 4.

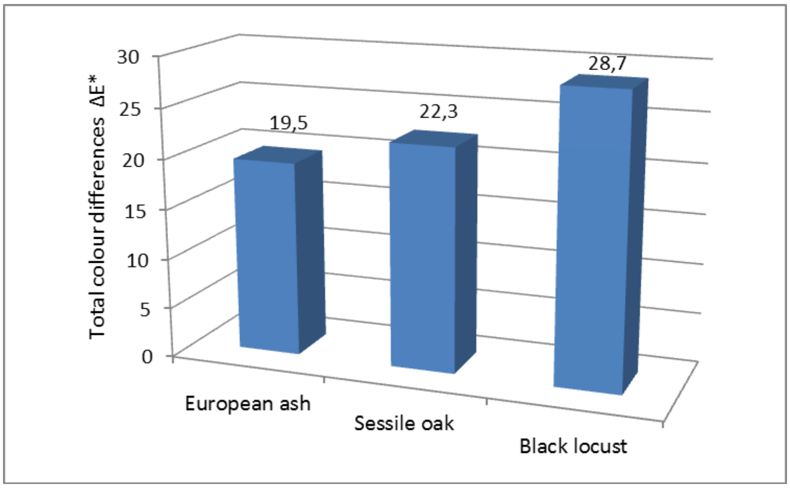

Fig.4. *Total colour differences of woodturning blanks of individual tree species resulting from the process of thermal treatment with saturated water steam*

Chromophore system of lignin-polysaccharide matrix of the heartwood of tree species: sessile oak and black locust contains, in comparison to the sapwood of European ash, more components with chromophore structure of tannin and dyestuff. Due to wide variety of ways to convert new chromophore structures in the processes of partial hydrolysis and extraction, the heartwood of sessile oak becomes darker and changes markedly to dark brown or dark brown-grey hue. On the other hand, more homogenous sapwood of European ash changes to less saturated hue of brown colour.

According to the authors: *Kollmann – Gote (1968), Trebula (1996)*,colour changes in individual thermally modified tree species are, in accordance with the classification of changes in physical and mechanical properties of wood resulting from the process of thermal treatment, irreversible (permanent).

Since the total colour difference ΔE^* of thermally treated woodturning blanks of European ash, sessile oak and black locust is higher than $\Delta E^* = 12$, the colour change can be defined as significant resulting in different colour according to the classification of colours in Tab. 2 *Cividini et all (2007).*

The fact that achieved colour is uniform across the full extent of wood can be considered another positive feature of the mode of thermal treatment with saturated water steam with the temperature of $t = 137.5 \pm 2.5$ °C for the time $\tau = 7.5$ hours in the pressure autoclave APDZ 240. Following the finding, the thermally modified woodturning blanks can be used to produce lamellas for flooring, or 3D machining of solid wood without any change in wood colour between the surface and the centre of woodturning blank.

New hues of European ash, sessile oak and black locust woodturning blanks resulting from the process of thermal treatment with saturated water steam widen the possibility for the use of mentioned tree species of in the field of construction and carpentry, design as well as in the field of art.

CONCLUSION

The colours of European ash, sessile oak and black locust woodturning blanks resulting from the process of thermal treatment with saturated water steam with the temperature of t = 137.5 ± 2.5 °C for the time τ = 7.5 hours are presented in the paper. Original light white-yellowish colour of the sapwood of European ash was changed to brown hue with the coordinates: L^* = 65.6± 1.4; a^* = 10.8± 0.5; b^* = 21.7± 0.9. Light brown-yellowish colour of the heartwood of sessile oak became brown-grey with the coordinates in the CIE-L*a*b* colour space: L^* = 47.5± 2.1; a^* = 5.9± 0.9; b^* = 17.9± 1.2 during the process of hydrolysis and extraction. The most significant change resulting from the mentioned mode of thermal treatment with saturated water steam occurred in black locust wood. Light yellow-green and brown colour changes to unique dark brown-grey hue with the coordinates in the CIE-$L^*a^*b^*$ colour space: L* = 44.3 ± 1.6; a* = 8.9 ± 0.4; b* = 15.1 ± 1.6.

New colours and hues of European ash, sessile oak and black locust woodturning blanks resulting from the process of thermal treatment with saturated water steam widen the possibility for the use of ring-porous tree species use in the field of construction and carpentry, design as well as in the field of art.

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