WOOD COLOUR MODIFICATION OF FRAXINUS EXCELSIOR L. DURING THE PROCESS OF THERMAL TREATMENT WITH SATURATED WATER STEAM

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ABSTRACT

The aim of the paper is to determine the colour of European ash wood (*Fraxinus excelsior* L.) in the CIE-L*a*b* colour space during the thermal treatment with saturated water steam at the temperature of t = 137.5 ± 2.5 °C for the time of τ = 7.5 hours. The colour of European ash wood changes from white with a yellow hue to brown during the process of colour modification. Mentioned hue of thermally modified wood is described with the coordinates of CIE-L*a*b*colour space: L* 65.6 ± 1.4; a* = 10.8 ± 0.5; b* = 21.7 ± 0.9. Irreversible colour change of the European ash wood resulting from the process of thermal modification with saturated water steam widen the possibility for its use in the field of construction and carpentry, design as well as in the field of art.

Key words: wood, European ash (*Fraxinus excelsior* L.), the CIE-L*a*b*colour space, thermal treatment, saturated water steam.

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 technology of steam bending and boiling during veneers and plywood, bent furniture or pressed wood manufacturing processes Kollmann – Gote (1968), Nikolov-Rajčev-Deliiski (1980), Sergovsky – Rasev (1987), Lawnniczak (1995), Trebula (1996), Deliiski (2003).

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), 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).

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 (according to CIE – Commission Internationale de l' Eclairage) in accordance with ISO 7724 is based on the measurement of three parameters: lightness L* represents the darkest black at L* = 0 and the brightest white at L* = 100. The value of 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 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 colour of European ash wood (Fraxinus excelsior L.) in the CIE-L*a*b* colour space

during the thermal treatment with saturated water steam at the temperature of t = 137.5 ± 2.5 °C for the time of τ = 7.5 hours.

MATERIALS AND METHODS

European ash wood in a form of woodturning blanks with dimensions of 32 x 60 x 600 mm and the moisture content of Wp = 56.8 ± 4.3 % was thermally treated with saturated water steam in the pressure autoclave: APDZ 240 (Himmasch AD, Haskovo, Bululharsko) in the company Sundermann Ltd. Banská Štiavnica. Heartwood of European ash was used to prepare woodturning blanks. Mode of colour modification of European ash woodturning blanks with saturated water steam is shown in Fig. 1.

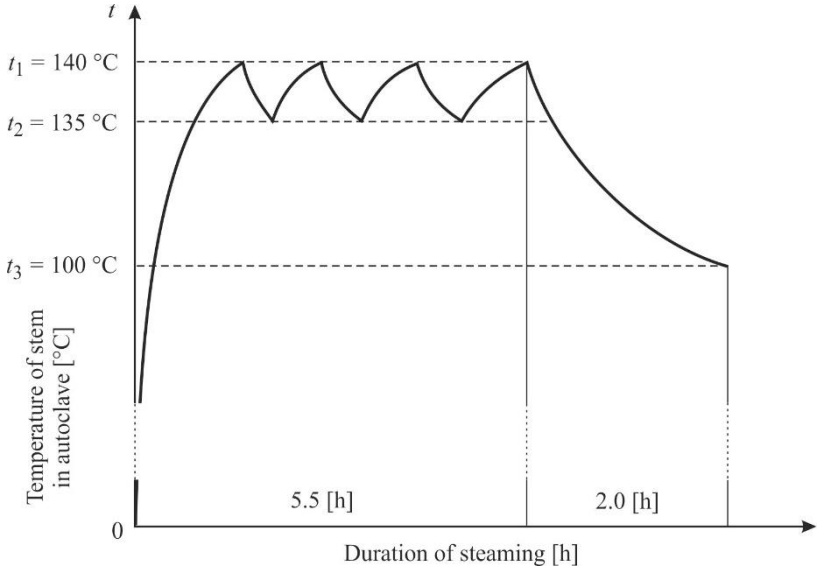

Figure 1: Mode of colour modification of European ash woodturning blanks with saturated water steam

Subsequently, thermally treated and modified European ash woodturning blanks were dried to report the moisture content of Wp = 12 ± 0.5% in a conventional wood drying kiln KAD 1x6 (KATRES Ltd.) Dried woodturning blank surfaces were processed using Swivel spindle milling machine FS 200.

Color Reader CR-10 (Konica Minolta, Japan) was used to assess wood colour of European ash woodturning blanks in the CIE-L*a*b*colour space. The light source D65 with lit area of 8mm was used.

Lightness coordinate L* and coordinates a* and b* of CIE-L*a*b* colour space were measured using a sample unit of n = 178 European ash thermally untreated woodturning blanks after drying and planing and a samle unit of n = 180 of thermally treated woodturning blanks. Measurement of the lightness coordinate L* and coordinates a* and b* using dried and planed samples of thermally modified European ash wood with saturated water steam was carried out in the centre of the blank width and 300 mm far from the face of processed dried woodturning blanks using Swivel spindle milling machine FS 200.

Colour coordinates of thermally untreated as well as treated ash wood are introduced using a formula, it means using the average measured value and standard deviation. The extent of variation of set values in the CIE-L* a* b* colour space of thermally untreated as well as treated European ash wood is determined by the coefficient of variation.

Total colour difference ΔE is determined according to following formula, in accordance with the standard ISO 11 664-4 as the result of the difference in the colour coordinates ΔL*, Δa*, Δb* set following the surface measurements of thermally untreated as

well as treated European ash woodturning blanks:

$$\Delta E^* = \sqrt{\left(L^*_2 - L^*_1\right)^2 + \left(a^*_2 - a^*_1\right)^2 + \left(b^*_2 - b^*_1\right)^2} \qquad (1)$$

where: L^*_1, a^*_1, b^*_1coordinate values in the wood colour space of dried, milled thermally un modified ash wood.

L^*_2, a^*_2, b^*_2coordinate values in the wood colour space of dried, milled thermally modified ash wood.

Rate of change in the wood colour and hues during the processes of thermal 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.

Table 1: Classification of ΔE.

0.2 < ΔE*	Not visible difference
0.2 < ΔE* < 2	Small difference
2 < ΔE* < 3	Colour difference visible with light 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

The colour of wood of *Fraxinus excelsior* L. is according to the authors *Perelygin (1965), Makoviny (2010), Klement – Réh – Detvaj (2010)* light white-yellowish. The authors: *Babiak – Kubovský – Mamoňová (2004),* describe the colour of European ash wood using coordinates in the CIE-L* a* b* colour space: $L^* = 81.80$; $a^* = 4.18$; $b^* = 18.42$. Mentioned statements are confirmed by our measurements as well. According to the results, the coordinates of European ash wood on the planed surface in the CIE-L* a* b* colour space are: $L^* = 84.6 \pm 1.5$; $a^* = 5.9 \pm 0.9$; $b^* = 17.9 \pm 1.2$.

The colour of dried planed, thermally untreated European ash wood and the hue resulting from the thermal treatment with saturated water steam are shown in Fig. 2.

Figure 2: View of the European ash wood before and after thermal treatment

Original light white-yellowish colour changes into brown during the process of thermal treatment. New wood material with physico-mechanical properties of ash wood with unique brown colour is developed by highlighting the ash wood texture using the darker shade of latewood on the brown base of ash wood.

Coordinates in the CIE-L*a*b* colour space describing the colour of wood before and after thermal treatment on dried and planed surface resulting in colour modification are mentioned in Tab. 2.

Table 2: Coordinates in the colour space of ash wood before and after thermal treatment with saturated water steam

European ash		Coordinates		
		L*	a*	b*
Native wood– thermally untreated	number of measurements [-]	178	178	178
	Average coordinate value [-]	84.6	5.9	17.9
	Standard deviation[-]	1.5	0.9	1.2
	Coefficient of variation [%]	1.7	15.2	6.7
Wood after thermal treatment	number of measurements [-]	180	180	180
	Average coordinate value[-]	65.6	10.8	21.7
	Standard deviation[-]	1,4	0.5	0.9
	Coefficient of variation [%]	2.1	4.6	4.1

Changes in individual coordinates – L^*, a^*, b^* of ash wood in the colour space CIE-L*a*b*as a result of thermal treatment with saturated water steam at the temperature of t = 137.5 ± 2.5 °C for the time of τ = 7.5 hours are illustrated in Fig. 3.

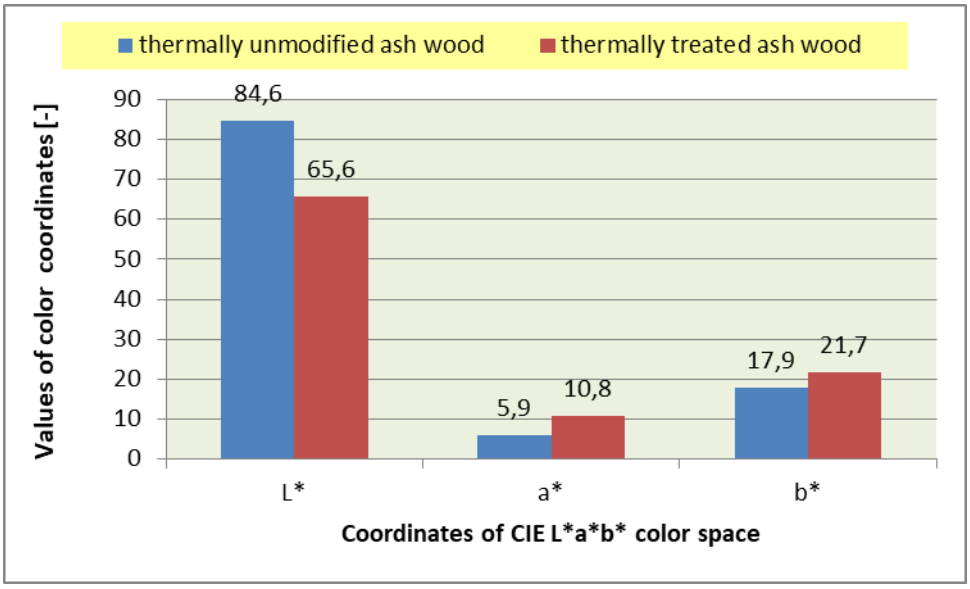

Figure 3: Coordinates of the wood of *Fraxinus excelsior* L. before and after thermal treatment with saturated water steam

Rate of change in coordinates ΔL^*, Δa^*, Δb^* in the colour space of ash wood and the total colour difference ΔE* resulting from thermal modification of colour with saturated water steam at the temperature of t = 1375 ± 2.5 °C for the time of τ = 7.5 hours are illustrated using the bar chart in Fig. 4.

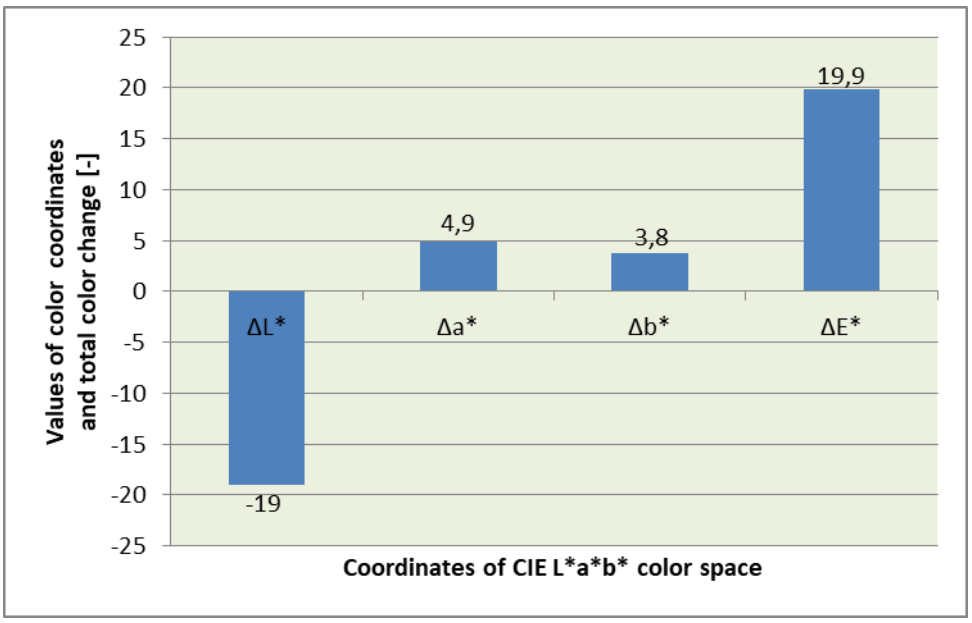

Figure 4: Rate of change in coordinates of ash wood resulting from the process of thermal modification with saturated water steam

Due to thermal treatment, the lightness of ash wood decreased by the value of ΔL* = -19.0 and the shift in chromaticity coordinates was observed. The value of red colour increased by Δa* = + 4.9 and the value of yellow colour by Δb* = + 3.8. Ash wood is getting darker and browner during the process of thermal treatment with saturated water steam. It results in developing unique brown colour of wood with highlighted wood texture on radial as well as tangential face by darker hue of latewood growth ring.

The value of total colour difference of the change in ash wood colour resulting from the thermal treatment process, calculated using the formula (1) is ΔE* = 19.9. Forasmuch as the value is above the limit for distinct colour change: ΔE* > 12 Cividini 2007, presented rate of ash wood colour change resulting from the thermal modification can be classified as a distinctive colour change.

According to the authors: Kollmann – Gote (1968), Trebula (1996) and in terms of classification of physico-mechanical properties of wood, mentioned ash wood colour change can be defined as an irreversible change. It is caused by partial hydrolysis of hemicelluloses in the lignin-saccharide ash wood matrix and by the extraction of water soluble accessory substances. The findings are confirmed not only by the differences in ATR-FTIR spectroscopic analyses of thermally untreated as well as treated wood Timar et all (2016), Kučerová et all. (2016), Geffert – Výbohová – Geffertová (2017) but also by the presence of monosaccharide, organic acids and basic lignin units with guajacyl and syringyl structure in the condensate after pressure steaming of wood presented in the papers: Dzurenda – Bučko (1998), Kačík (2001), Čabalová (2017).

The irreversible colour change and new brown hue of European ash wood achieved during the thermal modification of colour with saturated water steam widen the possibility for the use of ash wood in the field of construction and carpentry, design as well as in the field of art.

CONCLUSION

The colour change of European ash wood (*Fraxinus excelsior* L.) during the ther-

mal treatment – colour modification with saturated water steam at the temperature of t = 137.5 ± 2.5 °C for the time of τ = 7.5 hours is presented in the paper. The colour of European ash wood changes from light white-yellowish to brown hue during the process of thermal treatment. The surface of thermally modified European ash wood is determined with the coordinates in the CIE-L*a*b*colour space: L* 65.6 ± 1.4; a* = 10.8 ± 0.5; b* = 21.7 ± 0.9. Ash wood is getting darker and browner during the process of thermal traeatment with saturated water steam that results in developing unique brown colour of wood with highlighted wood texture on radial as well as tangential face.

Due to thermal treatment, the lightness of ash wood decreased by the value of ΔL* = -19.0 and the shift in coordinates in the CIE-L*a*b*colour space was observed. The value of red colour increased by Δa* = + 4.9 and the value of yellow colour by Δb* = + 3.8.

New hue of European ash wood achieved during the thermal modification of colour with saturated water steam widen the possibility for its use in the field of construction and carpentry, design as well as in the field of art.

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