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HUES OF *ACER PLATANOIDES* L. RESULTING FROM PROCESSES OF THERMAL TREATMENT WITH SATURATED STEAM

An analysis was made of the hues of the wood of Norway maple (Acer platanoides L.) resulting from processes of thermal treatment (colour modification) with saturated steam: t_I = 112.5 ±2.5°C for τ = 5.5 hours (mode I), t_{II} = 127.5 ±2.5°C for τ = 6.5 hours (mode II) and t_{III} = 137.5 ±2.5 °C for τ = 7.5 hours (mode III). Mode I produced a darker brown hue of Norway maple wood described with the following coordinates in the CIE-$L^*a^*b^*$colour space: L_I^* = 77.2 ±1.8, a_I^* = 9.1 ±1.7, b_I^* = 18.9 ±1.5. Mode II led to a light brown-pink colour with the coordinates L_{II}^* = 70.9 ±1.5, a_{II}^* = 11.0 ±0.6, b_{II}^* = 18.9 ±0.8. Maple wood thermally modified in mode III acquired a unique brown-red colour with the coordinates L_{III}^* = 63.3 ±1.9, a_{III}^* = 11.1 ±0.5, b_{III}^* = 19.2 ±0.6. When the temperature of the saturated steam used in the thermal treatment process is increased, and the exposure time of the wood is prolonged, the colour of the wood becomes darker. Specific hues are achieved through increases in the values of the red coordinate a^* and yellow coordinate b^* in the CIE-$L^*a^*b^*$colour space. The irreversible changes in the colour of Norway maple wood achieved in some modes of colour modification with saturated steam broaden the possibilities for its use in the fields of construction and carpentry, as well as in art and design.

Keywords: wood, maple, colour, thermal treatment, saturated steam

Introduction

The colour of wood is a fundamental optical property and a characteristic feature of the sapwood or heartwood of individual tree species. The wide range of colours of native wood of commercially important species enhances their use as materials in cabinet and furniture manufacturing: from the light white-grey--yellow colour of the species Norway spruce (*Picea excelsa*), silver fir (*Abies alba* L.), small-leaved linden (*Tilia cordata*) and European hornbeam (*Carpinus betulus* L.), through the red-brown colour of the heartwood of Scots pine (*Pinus sylvestris*), to the dark brown-grey colour of the heartwood of English oak

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(*Quercus robur*), European ash (*Fraxinus excelsior* L.) and Persian walnut (*Juglans regia*) [Drapela et al. 1980; Klement et al. 2010; Makovíny 2010].

Timber placed in an environment of hot water, saturated steam or saturated humid air becomes warmer, and its physical, mechanical and chemical properties change. These facts are exploited in the technologies of steam bending and boiling during the manufacture of veneers and plywood, bent furniture and pressed wood.

Processes of thermal treatment of wood, in addition to specific physico-mechanical and chemical changes, also produce changes in colour [Kollmann and Gote 1968; Nikolov et al. 1980; Trebula 1986; Sergovskij and Rasev 1987; Lawniczak 1995; Deliiski 2003; Dzurenda and Orlowski 2011; Dzurenda and Deliiski 2012]. In the past, the colour changes as wood became darker during the steaming process were used to remove the undesirable colour differences between light-coloured sapwood and dark-coloured heartwood, or to eliminate wood stain colours resulting from mould. In recent times, research into thermally modified wood has been focused on colour changes of specific wood species to more or less bright hues or the imitation of domestic or exotic wood species [Tolvaj et al. 2010; Fan et al. 2010; Dzurenda 2013, 2018; Barcik et al. 2015; Barański et al. 2017].

Use of the coordinates of the CIE-$L^*a^*b^*$colour space is one of the ways of quantifying a given optical property of wood objectively. This colour space (established by the CIE – Commission internationale de l'éclairage) is based, in accordance with the ISO 7724-2:1984 standard, on the measurement of three parameters. The lightness L^* ranges from 0 for the darkest black to 100 for the brightest white. The value of a^* is a measure of the red-green character of the colour, with positive values for red shades ($+a^*$) and negative values for green ($-a^*$). The value of b^* gives the yellow-blue character, with positive values for yellow shades ($+b^*$) and negative for blue ($-b^*$).

The aim of this work was to determine the colour of Norway maple (*Acer platanoides* L.) in the CIE-$L^*a^*b^*$ colour space resulting from processes of thermal treatment – colour modification of wood with saturated steam at the following temperatures: t_{I} = 112.5 ±2.5°C for τ = 5.5 hours (mode I), t_{II} = 127.5 ±2.5°C for τ = 6.5 hours (mode II), and t_{III} = 137.5 ±2.5°C for τ = 7.5 hours (mode III).

Materials and methods

Norway maple wood in the form of woodturning blanks with dimensions of 30 × 55 × 500 mm and moisture content W_p = 58.2 ±3.5% was thermally treated with saturated steam in an APDZ 240 pressure autoclave (Lignotherm Ltd.) at Sundermann s.r.o. Banská Štiavnica. The total number of maple wood blanks was 162. They were taken from 41 logs originating in Krupinská planina. The age of the trees was 50-60 years. One board was taken from each log, and four blanks were made from each board. These blanks were divided into one set which did not undergo thermal treatment, and three sets which underwent thermal treatment in different colour modification modes.

The modes of colour modification of maple wood in the form of woodturning blanks using saturated steam are shown in figure 1. A specification of the optimum conditions of thermal treatment for the particular modes of colour modification is given in table 1.

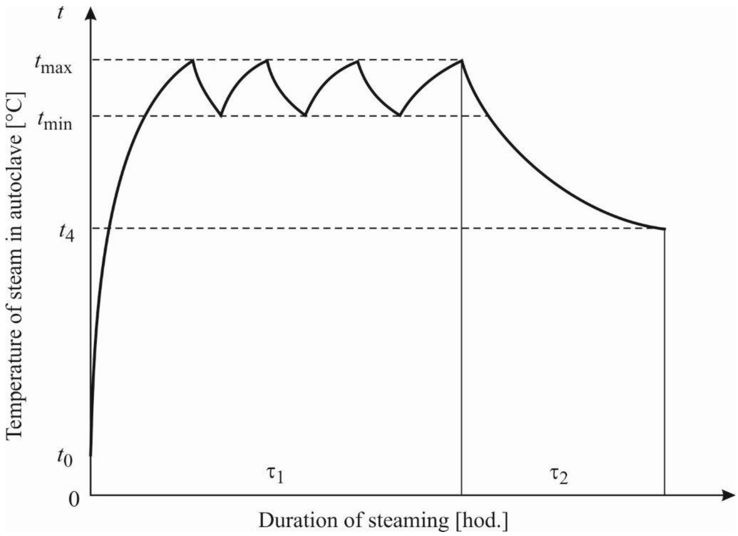

Fig. 1. Modes of colour modification of Norway maple wood with saturated steam

Table 1. Modes of colour modification of Norway maple wood with saturated steam

Thermal treatment regimes – colour modification	Temperature of the saturated water steam, °C			Duration technological process of thermal treatment of wood τ, h		
	t_{min}	t_{max}	t_4	τ_1- stage I.	τ_2-stage II.	total $\tau_1 + \tau_2$
Mode I.	110	115	100	4.5	1.0	5.5
Mode II.	125	130	100	5.0	1.5	6.5
Mode III.	135	140	100	5.5	2.0	7.5

The untreated and thermally treated woodturning blanks of Norway maple wood were dried to a moisture content of W_p = 12 ±0.5% in a conventional wood drying kiln (KAD 1×6, Katres Ltd.). Subsequently, the dried blank surfaces were processed using a Swivel FS 200 spindle milling machine.

The colour of the blanks in the CIE-$L^*a^*b^*$ colour space was determined using a CR-10 colour reader (Konica Minolta, Japan). A D65 light source was used, and the diameter of the collecting area was 8 mm.

The coordinates L^*, a^* and b^* of the CIE-$L^*a^*b^*$ colour space were measured for a control set of n = 35 Norway maple woodturning blanks. A sample set of n = 40 blanks were modified using mode I, n = 42 blanks were thermally treated using mode II, and n = 40 blanks were modified using mode III. Measurement of the L*a*b coordinates using dried and planed woodturning blanks was performed in the centre of the blank width and 250 mm from the face of the processed dried woodturning blanks, using a Swivel FS 200 spindle milling machine.

Colour coordinate values are presented in the form $x = \bar{x} \pm s_x$, i.e. average measured value and standard deviation. The extent of variability of the measured values in the CIE-$L^*a^*b^*$ colour space for untreated Norway maple wood and wood following thermal treatment in various modes is represented by the coefficient of variation.

The total colour difference ΔE^* is determined according to the formula (1), in accordance with the ISO 11 664-4: 2008 standard, based on the differences in the colour coordinates ΔL^*, Δa^*, and Δb^* obtained from measurements of the wood colour of the blanks before and after thermal treatment:

$$\Delta E^* = \sqrt{\left(L_1^* - L^*\right)^2 + \left(a_1^* - a^*\right)^2 + \left(b_1^* - b^*\right)^2} \qquad (1)$$

where L^*, a^*, b^* are the values of the coordinates of the wood in the colour space before the thermal treatment process, and $L_1{}^*$, $a_1{}^*$, $b_1{}^*$ are the values of the coordinates for thermally treated Norway maple wood.

The degree of change in the wood colour and hue during the processes of thermal treatment, based on the total colour difference ΔE^*, is classified according to the chart given in table 2 [Cividini et al. 2007].

Table 2. Classification of ΔE^* values

$\Delta E^* < 0.2$	No visible difference
$0.2 < \Delta E^* < 2$	Small difference
$2 < \Delta E^* < 3$	Colour difference visible with low-quality screen
$3 < \Delta E^* < 6$	Colour difference visible with medium-quality screen
$6 < \Delta E^* < 12$	High colour difference
$\Delta E^* > 12$	Different colours

Results and discussion

The colour of the wood of Norway maple (*Acer platanoides* L.) is light brown--white [Trebula 1986; Makoviny 2010]. It has been reported to have the following coordinate values in the CIE-$L^*a^*b^*$ colour space: L^* = 80.99, a^* = 5.20, b^* = 16.36 [Babiak et al. 2004]. These findings are confirmed by our measurements. We obtained the following coordinate values for the planed surface of dried Norway maple wood: L^* = 80.6 ±2.4, a^* = 6.3 ±1.1, b^* = 16.5 ±1.1. The corresponding coefficients of variation were $v_L{}^*$ = 2.9%, $v_a{}^*$ = 17.6 and $v_b{}^*$ = 6.5.

The values of coordinates in the CIE-$L^*a^*b^*$ colour space of Norway maple woodturning blanks that had undergone colour modification by particular modes of thermal treatment, after drying and on the planed surface, are listed in tables 3-5.

Table 3. Coordinates in the CIE-$L^*a^*b^*$ colour space of thermally treated maple wood with water vapor by mode I. at t = 112.5 ±2.5°C

Parameter	The coordinates of colours		
	L^*	a^*	b^*
Number of measurements [-]	40	40	40
Value of the coordinate [-]	77.2 ±1.8	9.1 ±1.7	19.6 ±1.5
Coefficient of variation [%]	2.3	18.7	7.6

Table 4. Coordinates in the CIE-$L^*a^*b^*$ colour space of thermally treated maple wood with water vapor by mode II. at t = 127.5 ±2.5°C

Parameter	The coordinates of colours		
	L^*	a^*	b^*
Number of measurements [-]	42	42	42
Value of the coordinate [-]	70.9 ±1.5	11.0 ±0.6	18.9 ±0.8
Coefficient of variation [%]	2.1	5.4	4.2

Table 5. Coordinates in the CIE-$L^*a^*b^*$ colour space of thermally treated maple wood with water vapor by III. at t = 137.5 ±2.5°C

Parameter	The coordinates of colours		
	L^*	a^*	b^*
Number of measurements [-]	40	40	40
Value of the coordinate [-]	63.3 ±1.9	11.1 ±0.5	19.2 ±0.6
Coefficient of variation [%]	3.0	4.5	3.1

The changes in values ΔL^*, Δa^*, Δb^* for individual coordinates in the CIE-$L^*a^*b^*$ colour space following thermal treatment of Norway maple wood with saturated steam are shown on the bar graph in figure 2.

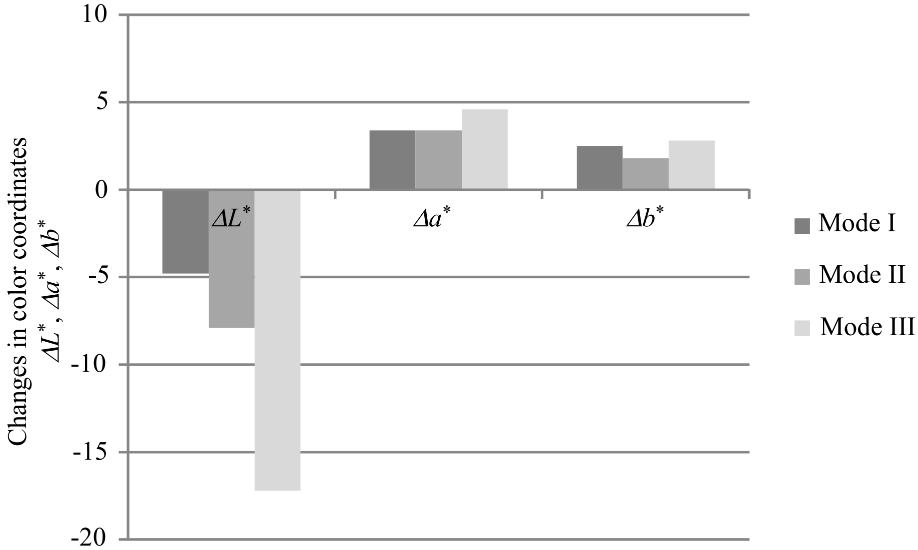

Fig. 2. Changes in values ΔL^*, Δa^*, Δb^* in the CIE-$L^*a^*b^*$ colour space following thermal treatment of maple wood in colour modification modes I, II and III

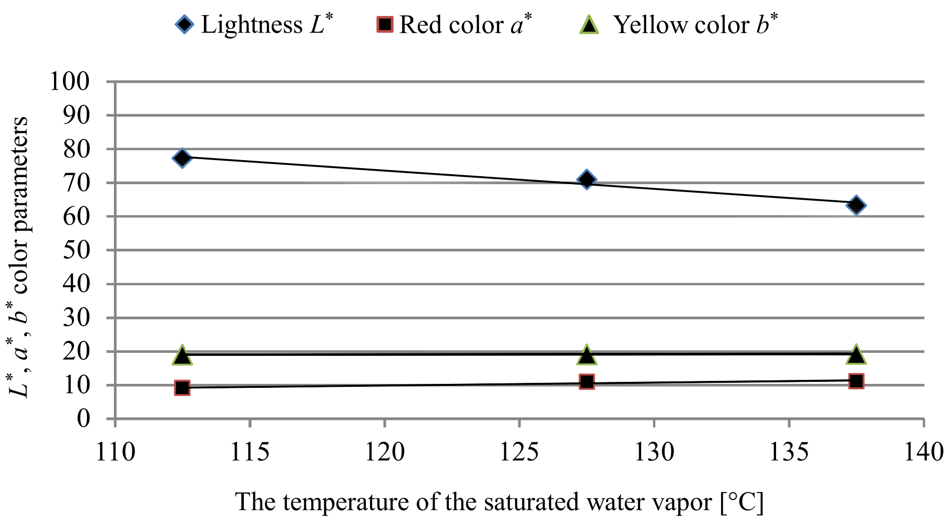

Fig. 3. Correlation of the decrease in lightness and the increase in red and yellow colour values of thermally treated maple wood, measured in the CIE-$L^*a^*b^*$ colour space, with the temperature of the saturated steam

The dependence of the colour coordinates (lightness L^*, red a^* and yellow b^*) of Norway maple wood on the temperature of thermal treatment of woodturning blanks with saturated steam, in the temperature range 112.5-137.5°C, is shown in figure 3. Functional dependences with values of the coefficient of determination are listed in table 6.

Table 6. Functional dependencies in brightness L^*, red a^* and yellow b^* colours of the thermally treated maple wood with saturated water vapor in the interval of temperatures 112.5°C ≤ t ≤ 137.5°C

Colour coordinate	Functional dependencies	Coefficient of determination
L^*	$L^* = -0.5453 \cdot t + 139.08$	$R^2 = 0.9717$
a^*	$a^* = +0.0832 \cdot t - 0.0974$	$R^2 = 0.9024$
b^*	$b^* = +0.0079 \cdot t + 18.107$	$R^2 = 0.9868$

The dependence of the total colour difference ΔE^* of maple wood on the temperature of the particular modes of thermal treatment with saturated steam, in the temperature range 112.5-137.5°C, is illustrated on the graph in figure 4.

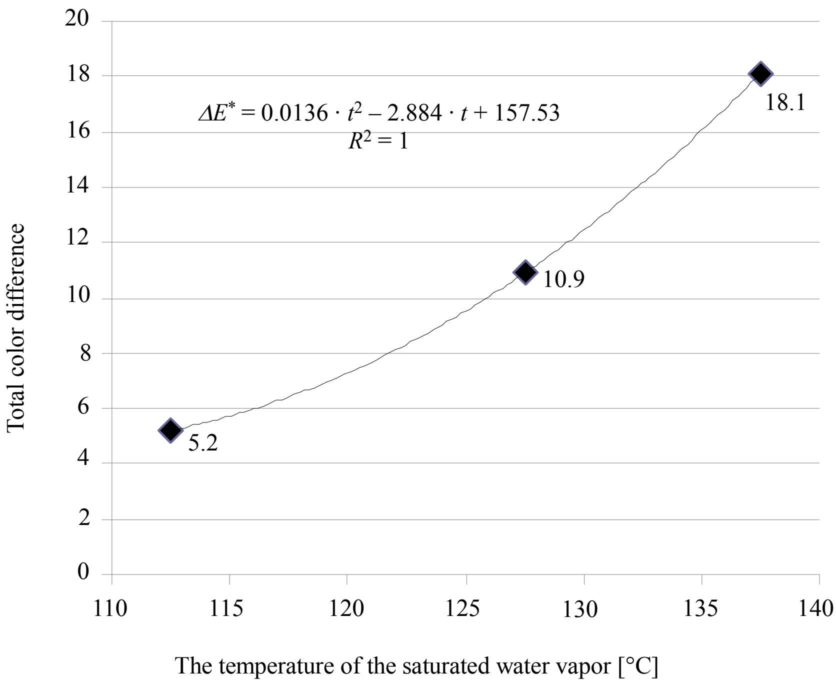

Fig. 4. Functional dependence of the total colour change of colour-modified maple wood, measured in the CIE-$L^*a^*b^*$ colour space, on the temperature of the saturated steam

According to the data obtained, under the applied processes of thermal treatment, the colour of Norway maple wood changes from light white-grey-brownish to brown or brown-reddish and finally to bright brown-red as the temperature of the saturated steam increases.

The thermal treatment of Norway maple wood resulted in the following changes in the values of coordinates in the CIE-$L^*a^*b^*$ colour space. In mode I, the lightness coordinate decreased from $L^* = 80.6 \pm 2.4$ to $L_I^* = 77.2 \pm 1.8$ (a decrease of $\Delta L^* = -3.4$), the red chromatic coordinate increased from $a^* = 6.4 \pm 1.2$ to $a_I^* = 9.1 \pm 1.7$ (an increase of $\Delta a^* = +2.7$), and the yellow chromatic coordinate increased from $b^* = 16.6 \pm 1.1$ to $b_I^* = 19.5 \pm 1.5$ ($\Delta b^* = +2.9$). The combined result of these changes in the colour of Norway maple wood is a total colour difference of $\Delta E_I^* = 5.2$.

More significant changes in the colour of Norway maple wood were recorded in the case of thermal treatment in modes II and III. In the case of mode II, the hue of the Norway maple wood became brown-reddish, with a total colour difference of $\Delta E_{II}^* = 10.9$.

The application of saturated steam with a temperature of $t = 137.5 \pm 2.5$°C for $\tau = 7.5$ hours (mode III) resulted in a decrease in lightness by $\Delta L^* = -17.3$ and increases in the values of the chromatic coordinates by $\Delta a^* = +4.6$ and $\Delta b^* = +2.3$. The unique brown-reddish colour of the Norway maple woodturning blanks is a result of the darkening of the wood.

The fact that the resulting colour is uniform across the full extent of the wood can be considered a positive feature of the applied modes of thermal treatment with saturated steam. It implies that the thermally modified woodturning blanks can be used to produce lamellas for flooring, or for 3D machining of solid wood, without any change in wood colour between the surface and the centre of the blank. The increase in the homogeneity of the obtained hues, confirmed by the low values of the coefficients of variation for the coordinates of lightness, red colour and yellow colour ($v_x \leq 5.4\%$), can be considered another advantage.

The total colour differences ΔE^* of the colour of Norway maple wood resulting from the processes of thermal treatment with saturated steam at temperatures from 112.5°C to 137.5°C lie in the range $\Delta E^* = 5.2$-18.1. According to the colorimetric classification given in table 2, these differences correspond to medium up to significant changes in the wood colour.

The dependence of the total colour difference ΔE^* in the CIE-$L^*a^*b^*$ colour space for thermally treated maple wood on the temperature of the saturated steam is in accordance with existing knowledge concerning wood colour changes during wood treatment processes [Molnar and Tolvaj 2002; Dzurenda 2014], during high-temperature drying in an environment of overheated saturated steam [Klement and Marko 2009; Barański et al. 2017] and in processes of thermal treatment in thermowood production [Barcik et al. 2015].

In terms of changes in physical and chemical properties of wood during the process of thermal treatment, it has been reported [Kollmann and Gote 1968; Trebula 1986] that the colour change of wood belongs to the category of irreversible changes. It is caused by the partial hydrolysis of hemicelluloses in the lignin-saccharine wood matrix and the extraction of water-soluble accessory substances. These findings are confirmed by the differences in ATR-FTIR spectroscopic analyses of untreated and thermally treated wood [Timar et al. 2016; Kučerová et al. 2016; Geffert et al. 2017; Výbohová et al. 2018] and by the presence of monosaccharide, organic acids and basic units of lignin with guaiacyl or syringyl units in the condensate resulting from the pressurised steam treatment of wood [Bučko 1995; Dzurenda and Deliiski 2000; Kačík 2001; Laurova et al. 2004; Kačíková and Kačík 2011].

The irreversible colour change and new light brown and brown-reddish hues of Norway maple wood obtained via the process of thermal treatment with saturated steam broaden the possibilities for the use of maple wood in the fields of construction and carpentry, as well as in art and design.

Conclusions

This study has considered the colours of Norway maple wood resulting from processes of thermal treatment with saturated steam at a temperature of $t_I = 112.5 \pm 2.5°C$ for $\tau = 5.5$ hours (mode I), at $t_{II} = 127.5 \pm 2.5°C$ for $\tau = 6.5$ hours (mode II) and at $t_{III} = 137.5 \pm 2.5°C$ for $\tau = 7.5$ hours (mode III). During the process of colour modification in mode I, the hue of Norway maple changed from light brown-white to light brown, with the following coordinates in the CIE-$L^*a^*b^*$colour space: $L_I^* = 77.2 \pm 1.8$, $a_I^* = 9.1 \pm 1.7$, $b_I^* = 19.6 \pm 1.5$. Treatment in mode II led to a change in hue to brown, with the coordinates $L_{II}^* = 70.9 \pm 1.5$, $a_{II}^* = 11.0 \pm 0.6$, $b_{II}^* = 18.9 \pm 0.8$. Colour modification in mode III resulted in a unique brown-reddish hue, with the coordinates $L_{III}^* = 63.3 \pm 1.9$, $a_{III}^* = 11.1 \pm 0.5$, $b_{III}^* = 19.2 \pm 0.6$.

When the temperature of the saturated steam used in the thermal treatment process is increased, and the exposure time of the wood is prolonged, the colour of the wood becomes darker. Moreover, unique hues – brown to brown-reddish – are achieved as a result of increased values of the red coordinate a^* and the yellow coordinate b^* in the CIE-$L^*a^*b^*$colour space.

The irreversible changes in the colour of Norway maple wood, and the new hues resulting from some of the modes of heat treatment with saturated steam, broaden the possibilities for its use in the fields of construction and carpentry, as well as in art and design.

References

Babiak M., Kubovský I., Mamoňová M. [2004]: Farebný priestor vybraných domácich drevín (Color space of selected domestic woods). In: Interaction of Wood with Various Forms of Energy. TU Zvolen, Zvolen

Barański J., Klement I., Vilkovská, T., Konopka A. [2017]: High Temperature Drying Process of Beech Wood (*Fagus sylvatica* L.) with Different Zones of Sapwood and Red False Heartwood. BioResources 12 [1]: 1861-1870. DOI: 10.15376/biores.12.1.1761--1870

Barcík Š., Gašparík M., Razumov E.Y. [2015]: Effect of thermal modification on the colour changes of oak wood. Wood Research [60] 3: 385-396

Bučko J. [1995]: Hydrolýzne procesy (Hydrolysis processes). TU Zvolen, Zvolen

Cividini R., Travan L., Allegretti O. [2007]: White beech: A tricky problem in drying process. International Scientific Conference on Hardwood Processing. September 24-26, 2007, Quebec City, Canada, NARDI s.r.l. Kiln Dryer, Soave Verona, Italy. Available from: http://www.ivalsa.cnr.it/ISCHP07/CividiniTravanAllegreti.pdf

Deliiski N. [2003]: Modelirane i tekhnologiya za para drveni materiali v avtoklavi (Modelling and technologies for steaming of wood materials in autoclaves). DSc. Dissertation, University of Forestry, Sofia

Drapela J., Humpolec J., Kamenický J., Konečný L., Pavlica J., Ráček V., Zapletal J. [1980]: Výroba nábytku – Technologie (Manufacture of furniture – Technology). SNTL, Praha

Dzurenda L., Deliiski N. [2000]: Analysis of moisture content changes in beech wood in the steaming process with saturated water steam. Wood Research 4 [45]: 1-8

Dzurenda L., Orlowski K. [2011]: The effect of thermal modification of ash wood on granularity and homogeneity of sawdust in the sawing process on a sash gang saw PRW 15-M in view of its technological usefulness. Drewno 54 [186]: 27-37

Dzurenda L., Deliiski N. [2012]: Convective drying of beech lumber without color changes of wood. Drvna Industrija 2 [63]: 95-103

Dzurenda L. [2013]: Modification of wood colour of *Fagus Sylvatica* L to a brown-pink shade caused by thermal treatment. Wood Research 3 [58]: 475-482

Dzurenda L. [2014]: Sfarbenie bukového dreva v procese termickej úpravy sýtou vodnou parou (Modification of the colour of beech sapwood by thermal treatment to a pale brown-pink colour shade). Acta Facultatis Xylologiae Zvolen 1 [56]: 13-22

Dzurenda L. [2018]: The Shades of color of *Quercus robur* L. wood obtained through the processes of thermal treatment with saturated water vapor. BioResources 13 [1]: 1525--1533. DOI: 10.15376/biores.13.1.1525-1533

Geffert A.,Výbohová E., Geffertová J. [2017]: Characterization of the changes of colour and some wood components on the surface of steamed beech wood. Acta Facultatis Xylologiae Zvolen 1 [59]: 49-57. DOI: 10.17423/afx.2017.59.1.05

Fan Y., Gao J., Chen Y. [2010]: Colour responses of black locust (*Robinia pseudoacacia* L.) to solvent extraction and heat treatment. Wood Science and Technology 44: 667-678. DOI: 10.1007/s00226009-0289-7

Kačík F. [2001]: Tvorba a chemické zloženie hydrolyzátov v systéme drevo-voda-teplo (Creation and chemical composition of hydrolysates in wood-water-heat system). TU Zvolen, Zvolen

Kačíková D., Kačík F. [2011]: Chemické a mechanické zmeny dreva pri termickej úprave (Chemical and mechanical changes of wood during thermal treatment). TU Zvolen, Zvolen

Klement I., Marko P. [2009]: Colour changes of beech wood (*Fagus sylvatica* L.) during high temperature drying process. Wood Research 3 [54]: 45-54

Klement I., Réh R., Detvaj J. [2010]: Základné charakteristiky lesných drevín – spracovanie drevnej suroviny v odvetví spracovania dreva (Basic characteristics of forest trees - processing of wood raw material in the wood processing industry). NLC, Zvolen

Kollmann F., Gote W.A. [1968]: Principles of Wood Sciences and Technology, Vol. 1. Solid Wood, Springer Verlag: Berlin–Heidelberg–New York

Kučerová V., Lagaňa R., Výbohová E., Hýrošová T. [2016]: The effect of chemical changes during heat treatment on the color and mechanical properties of fir wood. BioResources 4 [11]: 9079-9094

Lawniczak M. [1995]: Zarys hydrotermicznej i plastycznej obróbki drewna. Część I. – Warzenie i parzenie drewna (Outline of hydrothermal and plastic woodworking. Part I – Cooking and steaming wood). Wydawnictwo XX, Poznań

Laurova M., Mamonova M., Kučerova V. [2004]: Proces parciálnej hydrolýzy bukového dreva (*Fagus sylvatica* L.) parením a varením. (The process of partial hydrolysis of beech wood (*Fagus sylvatica* L.) by steaming and cooking). TU Zvolen, Zvolen

Molnár S., Tolvaj L. [2002]: Colour homogenisation of different wood species by steaming. In: Interaction of Wood with Various Forms of Energy. TU Zvolen, Zvolen

Makovíny I. [2010]: Úžitkové vlastnosti a použitie rôznych druhov dreva (Useful properties and use of different types of wood.). TU Zvolen, Zvolen

Nikolov S., Rajčev A., Deliiski N. [1980]: Proparvane na drevesinata (Steaming wood). Zemizdat, Sofia

Sergovskij P.S., Rasev A.I. [1987]: Gidrotermičeskaja obrabotka i konservirovanije drevesiny (Hydrothermal processing and protection of wood). Lesnaja Promyšlennost, Moskva

Timar M.C., Varodi A.M., Hacibektasoglu M., Campean M. [2016]: Color and FTIR analysis of chemical changes in beech wood (*Fagus sylvatica* L.) after light steaming and heat treatment in two different environments. BioResources 11 [4]: 8325-8343. DOI: 10.15376/biores.11.4.8325-8343

Tolvaj L., Molnar S., Nemeth R., Varga D. [2010]: Color modification of black locust depending on the steaming parameters. Wood Research 2 [55]: 81-88

Trebula P. [1986]: Sušenie a hydrotermická úprava dreva (Drying and hydrothermal treatment of wood). TU Zvolen, Zvolen

Výbohová E., Geffertová J., Geffert A. [2018]: Impact of Steaming on the Chemical Composition of Maple Wood. BioResources. 13 [3]: 5862-5874. DOI: 10.15376/biores.13.3.5862-5874

List of standards

ISO 7724-2:1984 Paints and varnishes – Colorimetry – Part 2: Colour measurement

ISO 11 664-4:2008 Colorimetry – Part 4: CIE 1976 L*a*b* colour space

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