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RESEARCH ON COLOUR VARIATION OF STEAMED CHERRYWOOD (*PRUNUS AVIUM* L.)

Aleš Straže, Željko Gorišek
Wood Science and Technology Department, Biotechnical Faculty, Ljubljana University, Slovenia

Stjepan Pervan, Silvana Prekrat, Alan Antonović
Wood Technology Department, Faculty of Forestry, Zagreb University, Croatia

ABSTRACT

Hydrothermal treatment of wood, especially steaming, is often used to achieve more intensive and homogenous colour of wood or to vary its hue. On cherrywood (*Prunus avium* L.) influence of steaming and drying on colouring of wood tissue was researched. Green, randomly selected cherrywood boards, 43 mm thick, were conventionally steamed in period of 60 to 72 hours, between 45 to 70°C. Low temperature kiln drying in conventional dryer followed afterwards, by successive rising of temperature from 30°C to 55°C, till 8% end wood moisture content (MC_{end}) was reached. Wood colour was assessed visually and with standard 3-stimulus colorimeter, using CIE$L^*a^*b^*$ system, and compared to natural colour of cherrywood. Wide heterogeneity of hues was found out on specimens at the end of hydrothermal treatment, where only minorities of them reached target level. A huge amount of steamed wooden elements significantly deviated (ΔE^*=7.16), especially in lightness (L^*) and in hue (h_{ab}) of wood colour, in comparison to the predefined reference. Desired, referent colour of steamed cherrywood has the lowest lightness (L^*=59.6) and hue (h_{ab}=50), and the highest chromaticity (C^*=25). Declining linear trend of lightness and hue from sapwood over heartwood and steamed elements to referent specimens was confirmed. There is clear indication of usefulness of colorimetry to asses and control steaming process of wood. There are additional data for first 18 hours of steaming where samples were taken for light microscopy analysis of parenchyma cells which confirmed the decrease of cellular deposits during steaming treatment in sapwood, with complete elimination at the end of the procedure. In the heartwood, additional resin deposits were found out, whereas parenchyma globular deposits were not present in any wood specimen.

KEY WORDS: cherrywood (*Prunus avium* L.), hydrothermal treatment, wood colour, colorimetry, CIE$L^*a^*b^*$ system

INTRODUCTION

Colour of wood is an inherent property and together with texture builds its aesthetic value. Wood is an excellent material to absorb and reflect of lightness, and interaction of its physical properties causes colour heterogeneity. About 30,000 commercial wood species is the greatest source of natural variability of wood colour, with a pronounced influence of wood anatomy (Phelps and McGinnes 1983), growth conditions and genetics (Rink and Phelps 1989). The range of wood colour is really great, from very light sapwood of some species to completely dark colour of ebony, for example.

The complexity of wood colour evaluation can be expressed by the percentage of correct decisions during selection process in praxis (Katuščák et al. 2002). The authors performed discriminant analysis of measured data for two wood species: fir (*Abies alba*) and spruce (*Picea excelsa*). The percentage of correctly identified wood samples has been used as the measure of the acceptance. The measurement of CIE Lab parameters and their probability density curves increased the probability of correct decisions to 60 - 80%.

The „wood-like colour space" has been defined by (Katuščák and Kučera 2000) in the case of 25 temperate wood species, and they have been ordered in the 5 CIE colour sequences according to lightness (L*), redness (+a*), yellowness (+b*), chroma (C*) and hue (H degrees), which is much objective system of colour evaluation than IAWA system of qualitative colour classes from 1989.

On macroscopic level, influence of anatomy on wood colour is often explained with differences of early- and latewood and closely linked with geometry, thickness and orientation of fibres, tracheids, tracheas or parenchyma cells. In these cases significant correlation of anatomy with density and wood colour is used in some densitometric methods.

Detailed analyses confirmed high dependence of wood colour to chemical properties of wood (Hon and Minemura 1991). Cellulose and hemicelluloses weakly absorb visible light (λ = 380 - 710nm). Good absorption of light below wavelength of 500nm, with a peak at 280nm is confirmed at natural lignin, where red colour is reflected (Aulin-Erdtman 1949). Significant changes of wood colour are often explained with presence and variability of aromatic compounds, i.e. wood extractives, like resins, polyphenols, alkaloids or organic salts, present in lumina or in cell wall layers. Some wood species also absorb light of wavelengths above 500nm, having phenolic compounds like stilbens, lignans, tannins or kinons (Hon and Minemura 1991).

Steaming of wood is a common procedure in wood industry for sterilisation, softening of wood in veneer production, for improvement of dimensional stability of wood as well as for intensifying of wood colour (Brauner et al. 1964, Kubinsky et al. 1973). In most wood species darker hues of wood colour are achieved after steaming procedure, which is a result of hydrolysis of accessory compounds and arised condensed polyphenolic products (Chen 1980, Straže 2004). Schwalbe et al. (1934) and Kollmann (1939) accomplished first spectrophotometric measurements of wood colour during hydrothermal treatment. By similar methods Schneider (1973) confirmed the greatest colouring of wood during the first period of steaming procedure. Significant influence of temperature, pressure, and duration of maintained conditions during steaming as well as their interaction were confirmed in many other studies (Kollman et al. 1951, Schmidt 1982). Some authors stress the strong impact of some inherent wood properties, especially wood moisture content, on direction and intensity of colouring process (Brauner et al. 1964, Schmidt 1986, Straže et al. 2001, 2003, Straže and Pervan 2005, Wassipaul et al. 1987, Tolvaj 2000). Cited studies confirmed good possibilities of hydrothermal treatment to stabilise and equalise of wood colour, where further treatments as well as proper end-use of products insignificantly change this wood property.

Cherrywood (*Prunus avium* L.) is decorative, high quality wood species, often used for extra performance wooden products. The solid wood of cherry is easily cut, peeled, bended and sawed. Bonding as well as surface treatment of cherrywood is unpretending. Drying of the timber is not difficult, however warping and colouring of wood is common in practice.

The goal of this study is to establish the basis for research of colouring during hydrothermal treatment of cherrywood (*Prunus avium* L.), and of other, commercially important wood species. Therefore, instrumental analysis of wood colour before and after steaming of cherrywood boards will be performed. The results will be compared to natural colour of cherrywood.

MATERIAL AND METHODS

Sampling and hydrothermal treatment

Four meter long, randomly selected, cherrywood boards (*Prunus avium* L.), 43 mm of thickness, were sawed from lumber in green state. Indirect steaming procedure was carried out just after sawing, applying common steaming schedule having yearly overall temperature range from 45 to 98 °C and average duration 66 hours.

During first 18 hours of steaming the samples were taken, prepared and examined for light microscopy analysis of parenchyma cells for discolouration of wood.

Sticking in standard stacks (1.2 by 1.4 by 4.0m) followed after steaming, using 25mm thick wooden stickers. For drying of steamed boards, usual low temperature kiln drying was used. Drying was performed in industrial kiln dryer by successive rising of temperature (from outside temperature to maximal 60 °C) and equilibrium moisture content ranging from 18 until 5 %, till 8% end wood moisture content was achieved.

Mechanical treatment of steamed and dried boards followed after, with joining of sawed and planned elements into solid wooden boards of different dimensions. A portion of naturally dried boards, stacked in a common stack with 25mm thick stickers was used for control. Control boards were dried after air drying, from achieved 15% end moisture content, to equal 8% end moisture content under same kiln drying procedure.

For purpose of research there were randomly selected samples of production board selected afterwards, having 43 mm thickness. Fig. 1 shows dimension parts on which colour was measured.

Fig. 1: The sample of cherrywood board with dimension parts for colour measurement

Laboratory work

Assessment of cherrywood colour was made visually and instrumentally, where the former was used to locate desired referent specimens and the rest of the elements. The determination of colour parameters of planned and equilibrated cherrywood specimens was performed with colorimeter (Microflash 100d - DATACOLOR), a compact three-stimulus colour analyser for measuring reflective colours of surfaces. The measuring head of the instrument uses wide-area illumination and an 8° viewing angle, and has a 10mm - diameter measuring area to average the reading over the area (DIN 5033, 1979). The CIE*L*a*b** colour system was used to describe the colour space, where *L** is the lightness varying from zero to hundred, and represent lightness scale from completely black to completely white colour (DIN 6174, 1979). The chroma of an area is described with two equivalent parameters (*a**, *b**). The parameter *a** represents the chromaticity on green-red axis and equally, parameter *b** describes the chromaticity of an area on blue-yellow axis (Fig. 2).

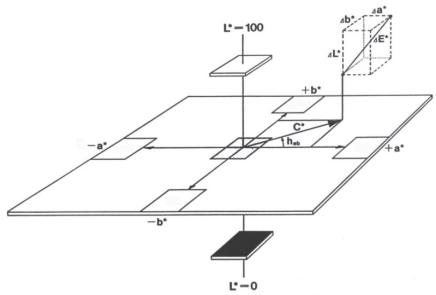

*Fig. 2: CIEL*a*b* colour space (CIE, 1971)*

The CIE*L*a*b** system offers more precise analysis of colour and its changes by additional parameters. The hue of a colour is defined by h_{ab} vector, where its angle and length generally represent the chromaticity of colour in axes of *a** and *b**, as well as in the plane generally (*C**). The total colour difference is a space distance between to colours, and is used to register integral colour differences.

$$h_{ab} = arctg\left(\frac{b^*}{a^*}\right) \tag{1}$$

$$C^* = \sqrt{(a^*)^2 + (b^*)^2} \tag{2}$$

$$\Delta E^* = \sqrt{(\Delta a^*)^2 + (\Delta b^*)^2 + (\Delta L^*)^2} \tag{3}$$

To process the data, standard statistical tests were carried out on the results of colorimetric measurements.

RESULTS AND DISCUSSION

Visual assessment of cherrywood colour

A colour of cherrywood often described as yellow- to gold brown often varies in lightness, especially in transition from sapwood to heartwood. The sapwood possesses lighter colour, with more yellow to white-yellow hue.

In addition to natural colour of cherrywood, steamed cherrywood is commonly darker with more red and brown hues and visually indistinguishable in comparison with steamed sapwood and heartwood. Desired equal colour of steamed cherrywood was achieved on many elements or in their separate regions, whereas great part of specimens exhibit high heterogeneity. Locations of higher lightness and lower chromaticity of wood colour were frequent, and hues varied from yellow to red-brown. Boundaries between differently altered tissues after steaming were visible on many elements. The colour of many steamed specimens significantly deviated from target request.

Colorimetric analysis of cherrywood

Visual assessment of steamed cherrywood colour was in a great part confirmed instrumentally also. Generally, the most distinctive change of steamed wood colour is determined in lightness (L^*) and in chromaticity on green-red axis (a^*) (Tab. 1).

Tab. 1: Means of basic colour parameters (L, a*, b*) of cherrywood (Prunus avium L.) steamed (1, 2, 3, 4, average) and reference*

	a*	b*	L*	C*	h_{ab}	ΔE*
1	13,88	20,80	60,22	25,00	56,28	2,89
2	13,97	25,42	62,33	29,17	61,49	7,89
3	11,71	21,86	66,99	24,94	62,12	9,60
4	11,75	22,13	65,14	25,20	62,29	8,27
average	12,83	22,55	63,67	26,08	60,55	7,16
reference	16,20	19,20	59,60	25,12	49,84	

The lightness (L^*) increased from 1 to 7 units in steamed samples respectively, where likewise a lot of steamed specimens did reach the target value (L^*=60). Opposite, tendency was not confirmed at change of chromaticity (C^*). More or less similar values were determined comparing steamed and reference specimens (C^*≈25-29).

Detailed analysis of chromaticity changes is presented in Fig. 3. A similar chromaticity on blue-yellow axis is found out at weakly as well as at regularly steamed specimens (b^*=19–26). More distinctive changes of chromaticity were established on green-red axis (a^*), where during steaming referring chromaticity could increase up to 10 units.

An attempt for more simple description of complex changes of wood properties during hydrothermal treatment is presented. Evidently, for achievement of the target appearance of wood at the end of hydrothermal treatment, approximately linear decreasing of hue (h_{ab}) and lightness (L^*) of heartwood and sapwood colour is necessary.

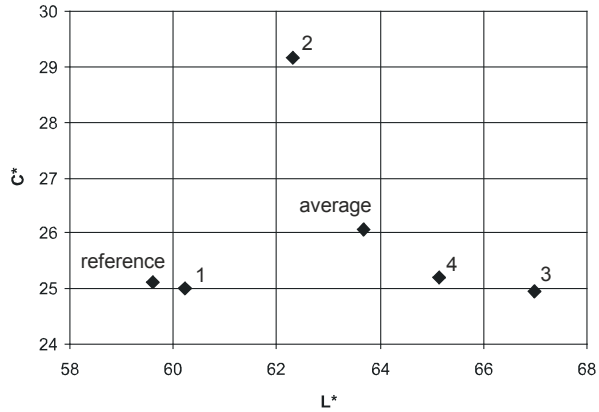

Fig. 3: Lightness (L) and chromaticity (C*) of cherrywood colour reference and measured*

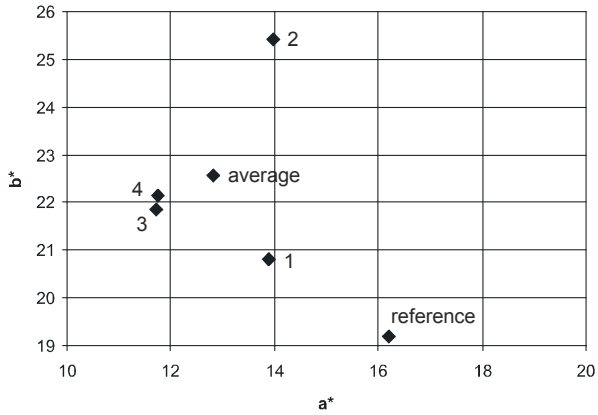

Fig. 4: Chromaticity on green-red axis (a) and on blue-yellow axis (b*) of cherrywood reference and measured*

Analysis of colorimetric results confirms specificity and complexity of the influence of hydrothermal treatment on wood colour. Required trend of colour change from natural sap- and heartwood through unevenly steamed specimens to the steaming reference is visible in Fig. 5. Almost linear decrease of hue and lightness of wood colour is needed to reach the target, minimum value ($L^*\approx60$, $h_{ab}\approx50$).

Instrumentally measured total colour difference (ΔE^*) is useful to classify and compare experimental samples and to verify the visual assessment. Many steamed elements did not reach the reference ($\Delta E^*\approx7.16$). It is evident, that the colour has to be significantly changed during the hydrothermal treatment. Inappropriate control of hydrothermal treatment caused different colour changes, visible in the widest distribution of ΔE^* in case of unevenly steamed elements.

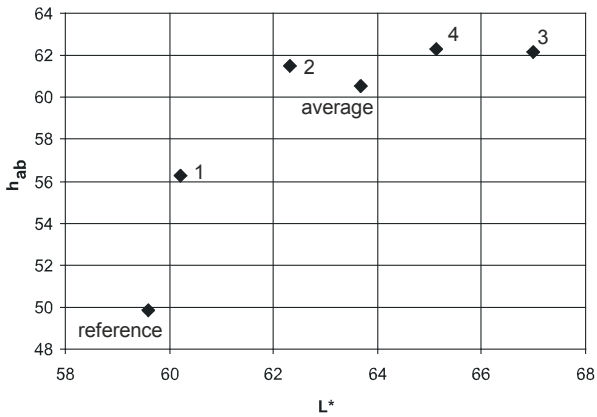

Fig. 5: Lightness (L) and hue (h_{ab}) of cherrywood reference and measured*

Anatomical changes in wood tissue during steaming process

Additionally, anatomic samples were made during first 18 hours of steaming for light microscopy to evaluate anatomical changes of wood tissue (Fig. 6-11).

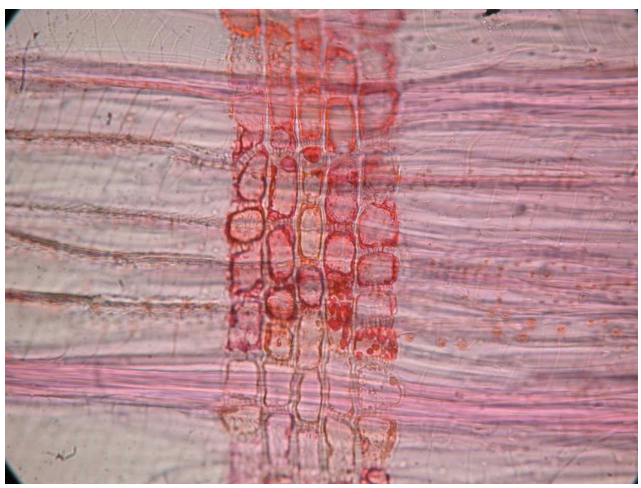

Fig. 6: Sapwood in green condition: deposits and occlusions in parenchyma cells

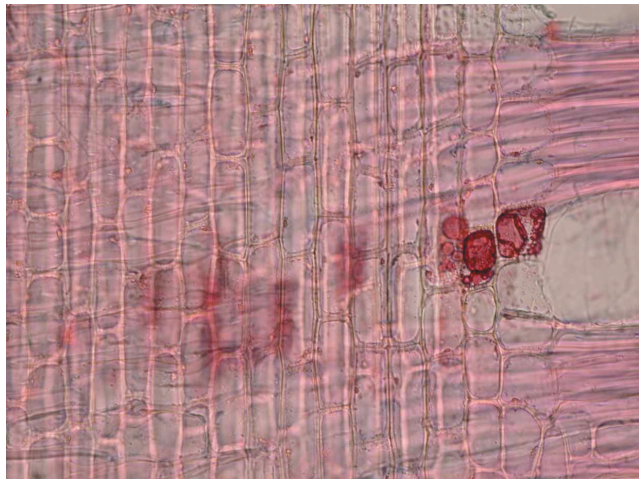

Fig. 7: Sapwood after 6 hours of steaming: decrease of deposits in parenchyma cells

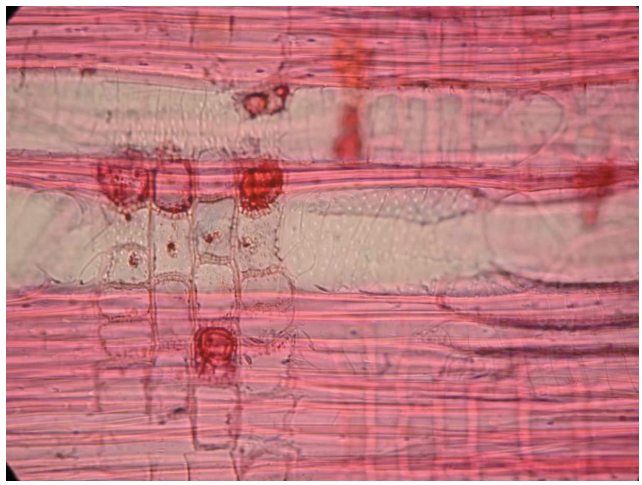

Fig. 8: Sapwood after 15 hours of steaming: deposits are only locally left in some cells

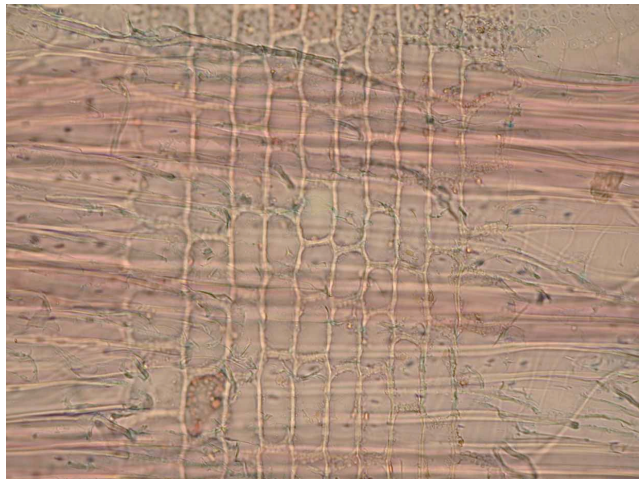

Fig. 9: Sapwood after 18 hours of steaming: there are not deposits left in parenchyma cells

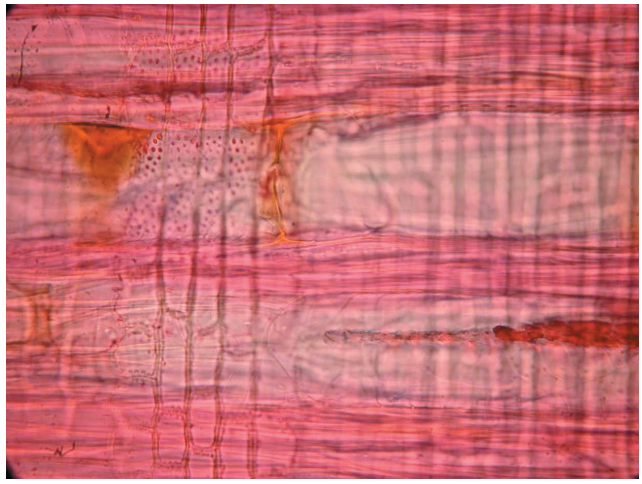

Fig. 10: Heartwood in green condition: resin deposits in vessels, effused, less dispersed

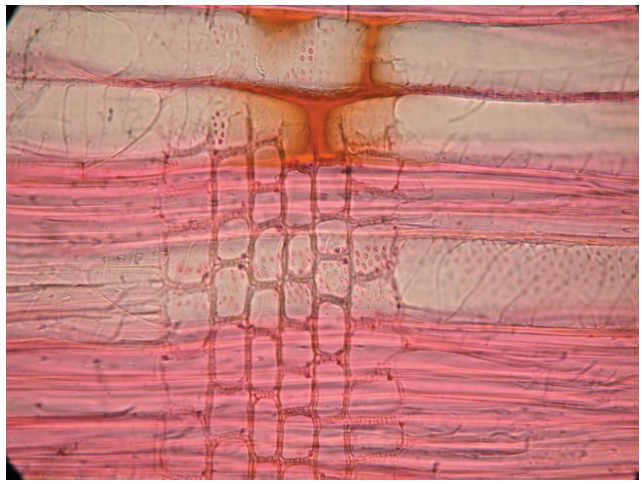

Fig. 11: Heartwood after 18 hours – more resin deposits in vessels

Light microscopy analysis confirmed the decrease of cellular deposits in parenchyma cells during steaming treatment in sapwood, with complete elimination at the end of the procedure. In the heartwood, additional resin deposits were found out, whereas parenchyma globular deposits were not present in any wood specimen.

On the basis of achieved results during instrumental measurements clear and very intensive colour variation ΔE* was determined between measured and targeted values.

Tab. 2: Colour variation range according to Jirouš and Ljuljka (1999)

Difference ΔE^*_{ab}	**Colour variation estimation**
< 0,2	undiscernible
0.2 – 0.5	very light
0.5 – 1.5	light
1.5 – 3.0	clear
3.0 – 6.0	very clear
6.0 – 12.0	intensive
> 12	very intensive

CONCLUSIONS

Experimental analysis confirmed variability of wood colour in the living tree, as a result of ageing and physiological processes, as well as colour changes arising from different treatments.

In common use is the quality and homogeneity the primary demand, where colour of wood has usually no abatement. According to very limited possibility to control the natural wood properties has the successive precise manipulation of lumber very important role. To achieve the desired wood colour, proper storage, hydrothermal treatment and drying of timber have to be carried out.

The study confirmed the possibility to measure the colour of wood as well as the trend of colour changes during steaming. Therefore the results could have practical value, with applying of colour measurement during hydrothermal procedures. Such application in future has feasibility in control, optimisation and reduction of time and costs of such treatments. To the knowledge of the authors the colorimetric measuring together with anatomical sampling is useful in research and quality control and sorting by colour of end products especially from cherrywood.

REFERENCES

1. Aulin-Erdtmann, G., 1949: Ultraviolet spectroscopy of Lignin and Lignin Derivatives. Tappi, 32(4): 161
2. Brauner, A., Conway, E.M., 1964: Steaming walnut for Color. Forest Products Journal, 14(11): 525-527
3. Chen, P., Workman, E.C., 1980: Effect of steaming on some physical and chemical properties of black walnut heartwood. Wood and Fiber, 11(4): 218-227
4. DIN 5033, 1979: Farbmessung
5. DIN 6174, 1979: Farbmetrische Bestimmung von Farbabständen bei Körperfarben nach der CIELab Formel
6. Hon, D.N.S., Minemura, N., 1991: Color and discoloration. Wood and cellulosic chemistry. New York and Basel, Marcel Dekker, 1015 pp.
7. Jirouš, Rajković, V., Ljuljka, B., 1999: Boja drva i njezine promjene prilikom izlaganja atmosferskim utjecajima, Drvna industrija, 50(1): 31-39
8. Katuščák, S., et al., 2002: New Method of Recognition of Wood Species: Increasing of the Effectiveness of Colorimetric Recognition of Picea Excelsa and Abies Alba. Wood Research, 47(1): 1-12
9. Katuščák, S., Kučera, L.J., 2000: CIE Cylindrical and Orthogonal Parameters of the Color Sequences of the Temperate Wood Species. Wood Research, 45(3): 9-21
10. Kollmann, F., 1939: Vorgänge und Änderungen von Holzeigenschaften beim Dämpfen. Holz als Roh- und Werkstoff, 17(2): 15-22
11. Kollmann, F., Keylwerth, R., Kubler, H., 1951: Verfärbungen des Vollholzes und der Furnier bei der künstlichen Holztrocknung. Holz als Roh- und Werkstoff, 9: 385-391
12. Kubinsky, E., Ifju, G., 1973: Influence of steaming on the properties of red oak. Part I. Structural and chemical changes. Wood Science, 6(1): 87-94
13. Phelps, J.E., McGinnes, E.A. Jr., 1983: Growth-quality evaluation of black walnut wood. Part III. An anatomical study of color characteristics of black walnut veneer. Wood and Fiber Science, 15(3): 212 –218
15. Rink, G., Phelps, J.E., 1989: Variation in heartwood and sapwood properties among 10-year old black walnut trees. Wood and Fiber Science, 21(2): 177 –182
16. Schmidt, K., 1982: Auswirkungen verschiedener Parameter beim Dämpfen von Rotbuchenholz. Teil 1. Holzforschung und Holzverwertung, 34(3): 47-51
17. Schmidt, K., 1986: Untersuchungen über die Ursachen der Verfärbungen von Eichenholz bei der technische Trocknung. Holzforschung und Holzverwertung, 38(2): 25-36
18. Schneider, A., 1973: Zur Konvektionstrocknung von Schnittholz bei extrem hohen Temperaturen. Zweite Mitteilung: Trocknungsschaden, Sorptions-, Farb- und Festigkeitsänderungen von Kiefern-Splint und Buchenholz bei Trocknungstemperaturen von 110 bis 180°C. Holz als Roh- und Werkstoff, 31: 198-206

19. Schwalbe, C.G., Ender, W., 1934: Zur Kenntnis des Dämpfens von Buchenholz. Forstarchiv, 10, 33 pp.
20. Straže, A., Gorišek, Ž., 2001: Influence of drying parameters on discolouration in ash-wood (*Fraxinus excelsior* L.). Proceedings of the Fifth International Conference on the Development of Wood Science, Wood Technology and Forestry, ICWSF 2001, Ljubljana, Slovenia, Pp. 273-280
21. Straže, A., Oven, P., Zupančič, M., Gorišek, Ž., 2003: Colour changes of ash-wood (*Fraxinus excelsior* L.) during conventional drying. Proceedings of the 8th International IUFRO wood drying conference, Brasov, Romania, Pp. 465-469
22. Straže, A., Merela, M., Gorišek, Ž., Oven, P., 2004: Occurrence of discolouration of beechwood (*Fagus sylvatica* L.) during conventional drying. Proceedings of International Symposium on Wood Sciences, IAWA, Montpellier, France, Pp. 62
23. Straže, A., Gorišek, Ž., Pervan, S., Brezović, M., Prekrat, S., Kljak, J., 2005: Colour of steamed cherrywood (*Prunus avium* L.) and its variation. Proceedings from International Scientific Conference „Wood in Construction Industry". Zagreb, Pp. 51-59
24. Tolvaj, L., Horvath-Szovati, E., Safar, C., 2000: Colour modification of black locust by steaming. Drevársky Výskum, 45(2): 25-32
25. Wassipaul, F., Vanek, M., Fellner, M., 1987: Verfärbungen von Eichenschnittholz bei der künstlichen Holztrocknung: Holzforschung und Holzverwertung, 39: 1-5
26. Wilkins, A.P., Stamp, C.M., 1990: Relationship between wood color, silvicultural treatment and rate of growth in *Eucalyptus grandis* Hill (Maiden). Wood science and technology, 24(4): 297-304

M. Sc. Aleš Straže
Assistant
Wood Science and Technology Department
Biotechnical Faculty
Rožna dolina
Cesta VIII/34
Ljubljana University
1000 Ljubljana
Slovenia
Phone: ++ 386 1 423 11 61
E-mail: ales.straze@bf.uni-lj.si

Željko Gorišek, PhD
Associate Professor
Wood Science and Technology Department
Biotechnical Faculty
Rožna dolina
Cesta VIII/34
Ljubljana University
1000 Ljubljana
Slovenia
Phone: ++ 386 1 423 11 61
E-mail: zeljko.gorisek@bf.uni-lj.si

Stjepan Pervan, PhD
Assistant Professor
Wood Technology Department
Faculty of Forestry
Svetošimunska 25
Zagreb University
10000 Zagreb
Croatia
Phone: ++385 1 235-2509
E-mail: pervan@sumfak.hr

Silvana Prekrat, PhD
Assistant Professor
Wood Technology Department
Faculty of Forestry
Svetošimunska 25
Zagreb University
10000 Zagreb
Croatia
Phone: ++385 1 235-2408
E-mail: prekrat@sumfak.hr

Alan Antonović, M.Sc.
Assistant
Wood Technology Department
Faculty of Forestry
Svetošimunska 25
Zagreb University
10000 Zagreb
Croatia
Phone: ++385 1 235-2504
E-mail: alan.antonovic@zg.htnet.hr