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

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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\textsubscript{end}) was reached. Wood colour was assessed visually and with standard 3-stimulus colorimeter, using CIE \(L^\ast a^\ast b^\ast\) 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 (\(\Delta E^\ast=7.16\)), especially in lightness (\(L^\ast\)) and in hue (\(h^\ast\)) of wood colour, in comparison to the predefined reference. Desired, referent colour of steamed cherrywood has the lowest lightness (\(L^\ast=59.6\)) and hue (\(h^\ast=50\)), and the highest chromaticity (\(C^\ast=25\)). 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, CIEL\(L^\ast a^\ast b^\ast\) 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 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, Wassipaal 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](image-url)
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 CIEL*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).

![CIEL*a*b* colour space (CIE, 1971)](image)

The CIEL*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.

\[
h_{ab} = \arctg\left(\frac{b^*}{a^*}\right)
\]

\[
C^* = \sqrt{(a^*)^2 + (b^*)^2}
\]

\[
\Delta E^* = \sqrt{(\Delta a^*)^2 + (\Delta b^*)^2 + (\Delta L^*)^2}
\]

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

<table>
<thead>
<tr>
<th></th>
<th>$a^*$</th>
<th>$b^*$</th>
<th>$L^*$</th>
<th>$C^*$</th>
<th>$h_{ab}$</th>
<th>$\Delta E^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13.88</td>
<td>20.80</td>
<td>60.22</td>
<td>56.28</td>
<td>2.89</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>13.97</td>
<td>25.42</td>
<td>62.33</td>
<td>29.17</td>
<td>61.49</td>
<td>7.89</td>
</tr>
<tr>
<td>3</td>
<td>11.71</td>
<td>21.86</td>
<td>66.99</td>
<td>24.94</td>
<td>62.12</td>
<td>9.60</td>
</tr>
<tr>
<td>4</td>
<td>11.75</td>
<td>22.13</td>
<td>65.14</td>
<td>25.20</td>
<td>62.29</td>
<td>8.27</td>
</tr>
<tr>
<td>average</td>
<td>12.83</td>
<td>22.55</td>
<td>63.67</td>
<td>26.08</td>
<td>60.55</td>
<td>7.16</td>
</tr>
<tr>
<td>reference</td>
<td>16.20</td>
<td>19.20</td>
<td>59.60</td>
<td>25.12</td>
<td>49.84</td>
<td></td>
</tr>
</tbody>
</table>

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.
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 ($L^* = 60, b_{ab} = 50$).

Instrumentally measured total colour difference ($\Delta E^*$) is useful to classify and compare experimental samples and to verify the visual assessment. Many steamed elements did not reach the reference ($\Delta E^* = 7.16$). 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 $\Delta E^*$ in case of unevenly steamed elements.
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 $\Delta E^*$ was determined between measured and targeted values.

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

<table>
<thead>
<tr>
<th>Difference $\Delta E_{ab}$</th>
<th>Colour variation estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.2</td>
<td>undiscernible</td>
</tr>
<tr>
<td>0.2 – 0.5</td>
<td>very light</td>
</tr>
<tr>
<td>0.5 – 1.5</td>
<td>light</td>
</tr>
<tr>
<td>1.5 – 3.0</td>
<td>clear</td>
</tr>
<tr>
<td>3.0 – 6.0</td>
<td>very clear</td>
</tr>
<tr>
<td>6.0 – 12.0</td>
<td>intensive</td>
</tr>
<tr>
<td>&gt; 12</td>
<td>very intensive</td>
</tr>
</tbody>
</table>

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.

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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

4. DIN 5033, 1979: Farbmessung
5. DIN 6174, 1979: Farbmetrische Bestimmung von Farbabständen bei Körperfarben nach der CIELab Formel
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