Colour changes of Walnutwood (Juglans regia L.) during steaming process

Stjepan Pervan, Željko Gorišek, Aleš Straže, Silvana Prekrat, Miha Humar
The influence of steaming on:

• chemical
• anatomical
• colour changes of wood tissue was researched
Researches of walnutwood colour change

- Brauner and Conway 1964
- Chen and Workman 1980
- Charier et al. 1998
- Andary et al. 1999
- Burtin et al. 1998, 2000
Charier *et al.* 1998

- boiling process of walnutwood

Brauner and Conway 1964

- colour of sapwood was fast changing during first 10 hours temperature of 100 to 120° C
- decrease of lightness was evenly distributed throughout the width and thickness of wood, but at the same time it is strongly dependant on wood moisture content
Chen and Workman 1980

- steaming of walnutwood darkening of sapwood and extraction of benzole from steamed wood

Andary et al. 1999

- chemical composition of walnutwood - accumulation of flavonoids in secondary xylem, and hydrojuglone glucoside in sapwood cells
Burtin 1998, 2000

- first results of correlation of thermal treatment and colour (accumulation of natural phenolic compounds in transition zone different conditions during steaming process

- satisfactory change of sapwood colour was achieved at temperature of 125 °C after 16 hours of steaming.

- chemical constituents were hydrojuglone and quercetine (neutral bioflavonoide; plant pigment)

- hydrojuglone as chromophore is considered precursor for sapwood colour achieved during hydrolysis, oxidation and polymerisation

- polyphenolic compounds were found during steaming process (the compounds responsible for lightness of wood colour) penetrating in sapwood and changing its colour from lighter to darker, in that way directly inducing chemical changes
• radial distribution of phenolic extractives - influence on colour of walnutwood

• phenolic extractives in thermally modified wood can contribute to discoloration, as long as they are products of degradation of hemicellulose and lignin

• more pronounced change of colour of heartwood than in sapwood because of higher quantity of phenolic compounds
Presence of deposits in parenchyma cells
walnutwood processing problem
Research objectives

To investigate, how:

steaming conditions affect colour change, anatomy and chemistry of walnutwood
Material

- 43 mm thick randomly selected walnutwood boards
- indirectly steamed in period of 16 hours between 45 to 70°C
Methods

instrumental colour evaluation
*CIEL*a*b* system

$L^*$ …colour lightness (0 to 100)
*a* …chromaticity on green-red axis
*b* … chromaticity on blue-yellow axis
Colour parameters ($L^*$, $a^*$, $b^*$, $h_{ab}$, $C$) of walnutwood (*Juglans regia* L.) unsteamed and steamed from start to 16 hours.

<table>
<thead>
<tr>
<th>time (hours)</th>
<th>sapwood</th>
<th>heartwood</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$L^*$</td>
<td>$a^*$</td>
</tr>
<tr>
<td>1</td>
<td>55.92</td>
<td>9.19</td>
</tr>
<tr>
<td>2</td>
<td>48.13</td>
<td>8.51</td>
</tr>
<tr>
<td>3</td>
<td>47.73</td>
<td>7.49</td>
</tr>
<tr>
<td>4</td>
<td>48.41</td>
<td>6.86</td>
</tr>
<tr>
<td>5</td>
<td>45.55</td>
<td>7.11</td>
</tr>
<tr>
<td>6</td>
<td>45.32</td>
<td>7.90</td>
</tr>
<tr>
<td>7</td>
<td>44.78</td>
<td>7.42</td>
</tr>
<tr>
<td>8</td>
<td>42.62</td>
<td>7.71</td>
</tr>
<tr>
<td>9</td>
<td>40.04</td>
<td>6.76</td>
</tr>
</tbody>
</table>

**Summary statistics**

<table>
<thead>
<tr>
<th></th>
<th>sapwood</th>
<th>heartwood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>46.50</td>
<td>18.16</td>
</tr>
<tr>
<td>standard deviation</td>
<td>4.45</td>
<td>2.44</td>
</tr>
<tr>
<td>minimal value</td>
<td>40.04</td>
<td>14.72</td>
</tr>
<tr>
<td>maximal value</td>
<td>55.92</td>
<td>23.23</td>
</tr>
</tbody>
</table>
Chromaticity ($C^*$) and hue ($h_{ab}$) of walnut heartwood during steaming process
Chromaticity ($C^*$) and hue ($h_{ab}$) of walnut sapwood during steaming process.
Lightness (L*) of walnut heartwood and sapwood during steaming process

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Generally, the most distinctive change of steamed wood colour is determined in lightness ($L^*$) and in chromaticity on blue-yellow axis ($b^*$)
Light microscopy

Intensive redistribution of cellular deposits during steaming treatment both in sapwood and heartwood
Sapwood after 16 hours of steaming (40X)
Parenchyma is mostly homogeneously filled with carbohydrates
and present polyphenol deposits
Heartwood control sample (KS 2, 40X)

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Heartwood steamed (S9 sample 2, 40X)
Spectra of the non-steamed and steamed sapwood of Juglans regia L. after different periods of steaming

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Details of the spectra of the non-steamed (black) and steamed sapwood of Juglans regia L. after 9 cycles (red).

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Spectra of the condensates from heartwood after 2 hours (black) and 16 hours (blue) cycles of steaming

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Spectra of the condensates from sapwood after 2 hours (red) and 16 hours (black) cycles of steaming

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Spectra of the condensates from sapwood (red) and heartwood (black) after 16 hours cycles of steaming

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Chemical analysis showed that all FT-IR spectra of the steamed *Juglans regia* L. sapwood samples looks similar to each other.
Some peaks indicated that there were two groups of components leached from wood

- aromatic extractives and non-polymerised lignin fragments
- fragments of hemicellulose and cellulose

It was presumed that hemicelluloses changes were the most important ones, as this change reflects from FT-IR spectra of wood itself, as well of condense.

Comparison of peak surfaces does not reveal any significant change as a result of steaming, so it was concluded that the main chemical structure of wood does not change after steaming.
Time of steaming did not influence on chemical composition of condenses.
<table>
<thead>
<tr>
<th>Sapwood 0 h</th>
<th>Sapwood 2 h</th>
<th>Sapwood 4 h</th>
<th>Sapwood 6 h</th>
<th>Sapwood 8 h</th>
<th>Sapwood 10 h</th>
<th>Sapwood 12 h</th>
<th>Sapwood 14 h</th>
<th>Sapwood 16 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 h</td>
<td>2 h</td>
<td>4 h</td>
<td>6 h</td>
<td>8 h</td>
<td>10 h</td>
<td>12 h</td>
<td>14 h</td>
<td>16 h</td>
</tr>
<tr>
<td>Heartwood 0 h</td>
<td>Heartwood 2 h</td>
<td>Heartwood 4 h</td>
<td>Heartwood 6 h</td>
<td>Heartwood 8 h</td>
<td>Heartwood 10 h</td>
<td>Heartwood 12 h</td>
<td>Heartwood 14 h</td>
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Inappropriate control of hydrothermal treatment can cause different colour changes, visible in the widest distribution of colour parameters especially in case of unevenly steamed elements.
Costs

Walnutwood

- conversion: log 60 % - board (500 Eur) - dimension part (800 Eur)

- solid wood panel (edge glued or finger joint)

- production price 2000 Eur

- final price 2500 Eur

- two classes A and B - requirements - uniform colour dark or light
Walnut (steamed): finger jointed (A/B)

WALNUT (steamed) – finger-jointed, A/B quality:

A-side:

* lamellas (staves) matched by wood structure (the same grain pattern on the whole side of the panel)
* lamellas (staves) matched by the colour (but since the walnut is a very colourfull wood specie, some colour differences are still allowed);
  * little sound pin knots, that are not going through to the opposite side, are allowed (up to max. 5 mm in diameter; 1 knot/m² allowed);
  * without wood cracks, end splits, rot, wormholes or other defects (natural or developed by bad drying);
  * no technical defects allowed

B-side:

* lamellas (staves) matched by wood structure (the same grain pattern on the whole side of the panel);
* light discoloration allowed;
* little sound knots, that are not going through to the opposite side, are allowed (up to max. 5 mm in diameter; 3 knots/m² allowed);
* without wood cracks, end splits, rot, wormholes or other defects (natural or developed by bad drying);
* no technical defects allowed
Thank you very much for your attention.

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