NATIVE OAK WOOD PROPERTIES – LIMITATIONS IN WOOD UTILIZATION AND POSSIBILITIES OF QUALITY IMPROVEMENT

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5 Center of Excellence, Batelovská 485, 486, CZ-588 56 Telč/ Czech Republic

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Innovative production technologies and increased wood products recycling and reuse
Brno, Czech Republic, 29-30 September 2016
Introduction

- Scientific exchange
- Visits → Brno →:
  from <-> to
  contacts

1 – 2
3 – 5
> 5
Introduction

- Scientific exchange
- Visits → Brno:
  from <-> to
contacts (V)

1 – 2 (Z)

3 – 5 (S)

> 5 (G)
Introduction

- Scientific exchange
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  from <-> to
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  1 – 2 (Z)
  3 – 5 (S)
  > 5 (G)
Introduction

- Scientific exchange
- Visits → Brno →:
  from     <->   to
  contacts (V)

1 – 2 (Z)
3 – 5 (S)
> 5 (G)
Methods

Screening:

- **Biological investigation**
  - Decay
  - Durability class

- **Structural/optical investigation**
  - Growth
  - Microscopy
  - Color
  - Computer Tomography (CT)

- **Physical investigation**
  - Density
  - Fiber saturation range
  - Swelling/Shrinkage

- **Chemical investigation**
  - Amount of extracts
  - Content of phenolic compounds (heartwood components)
    - Sum (Photo-Spectrometry; UV-microspectrophotometer [UMSP])
    - Single components (HPLC)
Problems:

Fungi decay on sessil oak constructions (Sightseeing-tower project)

Photos: Melcher
Mass loss and durability class (CD) of the test specimens and durability test (SD = standard deviation; n = 30)

<table>
<thead>
<tr>
<th>Wood species</th>
<th>Mean [%]</th>
<th>SD [%]</th>
<th>Min. [%]</th>
<th>Max. [%]</th>
<th>x-value</th>
<th>DC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beech</td>
<td>29.6</td>
<td>4.1</td>
<td>25.2</td>
<td>43.0</td>
<td>1.0</td>
<td>5</td>
</tr>
<tr>
<td>Scots pine sapwood</td>
<td>21.8</td>
<td>8.3</td>
<td>8.6</td>
<td>36.2</td>
<td>1.0</td>
<td>5</td>
</tr>
<tr>
<td>Sessile oak</td>
<td>18.7</td>
<td>1.2</td>
<td>16.8</td>
<td>21.3</td>
<td>0.6</td>
<td>4</td>
</tr>
<tr>
<td>Scots pine heartwood</td>
<td>11.0</td>
<td>8.3</td>
<td>5.1</td>
<td>17.6</td>
<td>0.4</td>
<td>3</td>
</tr>
<tr>
<td>European larch heartwood</td>
<td>10.4</td>
<td>3.1</td>
<td>5.6</td>
<td>16.5</td>
<td>0.5</td>
<td>3</td>
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Investigations on natural durability of important European wood species against wood decay fungi. Part 1: Laboratory tests

K. Plaschkies a,*, K. Jacobs a, W. Scheiding a, E. Melcher b

a Institut für Holztechnologie Dresden gemeinnützige GmbH, Zellescher Weg 24, 01217 Dresden, Germany
b Thünen Institute of Wood Research, Leuschnerstraße 91d, 21031 Hamburg, Germany
Native wood durability (DC I-V)

Durability of natural and modified wood species

Teak - Robinie - Eukalyptus (A) - Western Red Cedar - Pine/heartw - Douglas/heartw - Larch/heartw - Pine/sap - Beech - Poplar - Birch - Ash

I II III IV V

← high - durability classes - low →

Source: A. Krause et al., 2002
Native wood durability (DC I-V)

Durability of natural and modified wood species

OAK acc. EN 350-2:1994 ➔ DC 2

Source: A. Krause et al., 2002
Native wood durability (DC I-V)

Durability of natural and modified wood species

<table>
<thead>
<tr>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eukalyptus (A)</td>
<td>Western Red Cedar</td>
<td>Pine/heartw</td>
<td>Douglas/heartw</td>
<td>Pine/sap</td>
</tr>
<tr>
<td>Eur.Chestnut</td>
<td>Oak</td>
<td>spruce</td>
<td>spruce</td>
<td>spruce</td>
</tr>
<tr>
<td>Teak</td>
<td>Robinie</td>
<td>Dark Red Meranti</td>
<td>Poplar</td>
<td>Ash</td>
</tr>
</tbody>
</table>

← high - durability classes - low →

Correlation Growth/ Ring Width <-> Density (YC1/ Tree5)

15_Ring widths and density

- total annual ring width (mm)
- annual ring width earlywood (mm)
- annual ring width latewood (mm)
- density 0 (kg/m³)

Krüger, Rademacher, Rousek
Correlation Growth/ Ring Width <-> Density (YC4/ Tree2)
Phenolic Compound Concentration (PhCo [mg/l]) Extract Conc. [%]

**PhCo mg/l**

**ExCo %**

**Bark**

**Mark**

YC 1/ Tr 5

YC 4/ Tr 3

Krüger, Rademacher, Rousek
Correlation Ring Width <-> Phenolic Compounds (YC1/ Tree5)
Correlation Growth/ Ring Width <-> Density (YC4/ Tree3))

Krüger, Rademacher, Rousek
Correl. ‘R’ Ring Width <-> Density <-> Phenol.Comp. (all YC/ all Trees)

Correlation coefficients of ring widths and density with phenolic contents

Krüger, Rademacher, Rousek
Correlation Lightness <-> Phenol Content (all YC/ all Trees)

\[ y = -0.1931x + 71.699 \]

\[ R^2 = 0.0516 \]

Krüger, Rademacher, Rousek
Correlation Lightness <-> Shrinkage (all YC/ all Trees)

\[ y = -0.1011x + 15.524 \]

\[ R^2 = 0.1758 \]

Krüger, Rademacher, Rousek
Correlation Phenol Content <-> Shrinkage (all YC / all Trees)

\[ y = -0.0104x + 8.6677 \]

\[ R^2 = 0.0029 \]

Krüger, Varvic, Rademacher, Rousek
### All Correlations

**Correlation matrix (R)**

<table>
<thead>
<tr>
<th></th>
<th>FSR (%)</th>
<th>extractives content (%)</th>
<th>phenolic s. content (mg/l)</th>
<th>density 0 (kg/m³)</th>
<th>density max (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>total anual ring width (mm)</td>
<td>0.31</td>
<td>0.44</td>
<td>0.22</td>
<td>-0.13</td>
<td>-0.04</td>
</tr>
<tr>
<td>annual ring width earlywood (mm)</td>
<td>0.44</td>
<td>0.44</td>
<td>0.22</td>
<td>-0.13</td>
<td>-0.04</td>
</tr>
<tr>
<td>annual ring width latewood (mm)</td>
<td>-0.31</td>
<td>-0.31</td>
<td>-0.31</td>
<td>0.31</td>
<td>0.41</td>
</tr>
<tr>
<td>L*r</td>
<td>1.00</td>
<td>0.67</td>
<td>0.97</td>
<td>0.31</td>
<td>0.16</td>
</tr>
<tr>
<td>a*r</td>
<td>0.67</td>
<td>1.00</td>
<td>0.49</td>
<td>0.06</td>
<td>-0.21</td>
</tr>
<tr>
<td>b*r</td>
<td>0.97</td>
<td>0.49</td>
<td>1.00</td>
<td>-0.39</td>
<td>-0.27</td>
</tr>
<tr>
<td>L*t</td>
<td>-0.31</td>
<td>0.06</td>
<td>-0.19</td>
<td>0.28</td>
<td>-0.24</td>
</tr>
<tr>
<td>a*t</td>
<td>0.16</td>
<td>-0.21</td>
<td>0.27</td>
<td>1.00</td>
<td>-0.83</td>
</tr>
<tr>
<td>b*t</td>
<td>0.28</td>
<td>-0.08</td>
<td>0.36</td>
<td>-0.77</td>
<td>-0.88</td>
</tr>
<tr>
<td>R (%)</td>
<td>0.05</td>
<td>-0.26</td>
<td>0.16</td>
<td>-0.78</td>
<td>0.87</td>
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<tr>
<td>T (%)</td>
<td>0.07</td>
<td>-0.17</td>
<td>0.14</td>
<td>-0.31</td>
<td>0.27</td>
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<tr>
<td>L (%)</td>
<td>0.11</td>
<td>0.11</td>
<td>0.11</td>
<td>0.06</td>
<td>-0.10</td>
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<tr>
<td>L*10 (%)</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.22</td>
<td>-0.21</td>
</tr>
</tbody>
</table>

**Art of wood**

- total anual ring width (mm)
- annual ring width earlywood (mm)
- annual ring width latewood (mm)
- color (radial surface)
- color (tangential surface)
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- color (tangential surface)
All Correlations ‘R’ with Phenolic Compounds

Correlation coefficient of **phenolic contents**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Correlation Coefficient (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total annual ring width (mm)</td>
<td>0.32</td>
</tr>
<tr>
<td>Annual ring width earlywood (mm)</td>
<td>0.29</td>
</tr>
<tr>
<td>Annual ring width latewood (mm)</td>
<td>0.35</td>
</tr>
<tr>
<td>L*r</td>
<td>0.43</td>
</tr>
<tr>
<td>a*r</td>
<td>0.47</td>
</tr>
<tr>
<td>b*r</td>
<td>0.28</td>
</tr>
<tr>
<td>L*t</td>
<td>0.37</td>
</tr>
<tr>
<td>a*t</td>
<td>0.29</td>
</tr>
<tr>
<td>b*t</td>
<td>0.27</td>
</tr>
<tr>
<td>R (%)</td>
<td>0.33</td>
</tr>
<tr>
<td>T (%)</td>
<td>0.30</td>
</tr>
<tr>
<td>L (%)</td>
<td>0.33</td>
</tr>
<tr>
<td>FSR (%)</td>
<td>0.68</td>
</tr>
<tr>
<td>Extractives content (%)</td>
<td></td>
</tr>
<tr>
<td>Density 0 (kg/m³)</td>
<td>0.32</td>
</tr>
<tr>
<td>Density max (kg/m³)</td>
<td>0.31</td>
</tr>
</tbody>
</table>

Krüger, Varvic, Rademacher, Rousek
Computertomography $\rightarrow$ Density, Growth Ring, Early/Late Wood
Computertomography → Density, Growth Ring, Early/Late Wood

Krüger, Varvic, Rademacher, Rousek
Computertomography → Density, Growth Ring, Early/Late Wood

YC 1/ Tree 5

YC 5/ Tree 2

Krüger, Varvic, Rademacher, Rousek
L. Clauder (FH), A. Maschmann-Fehrensen (HIT), F. Seemann (HIT)

Production of thermal modified OAK-Wood
Thermo Wood: Processes

Native behavior of water uptake and delivery

Permanent reduction due to OH-group decay

Effects
(+) Dimensional stability
(+) Fungi resistance

L. Clauder; A. Maschmann-Fehrensen, F. Seemann: Herstellung von thermisch modifiziertem Eichenholz
L. Clauder; A. Maschmann-Fehrensen, F. Seemann: Herstellung von thermisch modifiziertem Eichenholz
Thermo Wood: Processes

Color change relative to temperature

Treatment and utilisation of small dimensioned sessile oak wood

L. Clauder; A. Maschmann-Fehrensen, F. Seemann: Herstellung von thermisch modifiziertem Eichenholz
Color change relative to temperature

Treatment and utilisation of small dimensioned sessile oak wood

Effects

(+) Cross-Sections of up to 60 mm totally modified.

(+) Wood assortments in Furniture and Indoor-Sector as well as Flooring realised!

L. Clauder; A. Maschmann-Fehrensen, F. Seemann: Herstellung von thermisch modifiziertem Eichenholz
Thermo Wood: Processes

Cracking and shortening of strength responsible cellulose chains

Komplex changes and decay of the Wood Material

Effect

(-) Loss of strength due to heat treatment

L. Clauder; A. Maschmann-Fehrensen, F. Seemann: Herstellung von thermisch modifiziertem Eichenholz
Thermo Wood: Processes

Possible disposal due to previous technical drying (species-specific)

Cracks due to retention during high-temperature periods

Effect

(-) Material damage due to drying or heat treatment

L. Clauder; A. Maschmann-Fehrensen, F. Seemann: Herstellung von thermisch modifiziertem Eichenholz
Native Oak Wood: UMSP-Scan

Strong native inclusion of heartwood components in the cell wall
Thermo-Wood: Results

Material strength + hardness

Modification steps (n=40)

<table>
<thead>
<tr>
<th>Modification</th>
<th>Bending strength</th>
<th>Brinell hardness tang</th>
<th>Brinell hardness rad</th>
</tr>
</thead>
<tbody>
<tr>
<td>nativ</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>160 °C</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>180 °C</td>
<td>85</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>190 °C</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>200 °C</td>
<td>75</td>
<td>75</td>
<td>75</td>
</tr>
</tbody>
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L. Clauder; A. Maschmann-Fehrensen, F. Seemann: Herstellung von thermisch modifiziertem Eichenholz
Thermo-Wood: Results

Maximal Swelling

<table>
<thead>
<tr>
<th>Modification steps (n=40)</th>
<th>Absolute maximal swelling (%)</th>
</tr>
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<tbody>
<tr>
<td>nativ</td>
<td>10</td>
</tr>
<tr>
<td>160 C°</td>
<td>9</td>
</tr>
<tr>
<td>180 C°</td>
<td>8</td>
</tr>
<tr>
<td>200 C°</td>
<td>7</td>
</tr>
</tbody>
</table>

L. Clauder; A. Maschmann-Fehrensen, F. Seemann: Herstellung von thermisch modifiziertem Eichenholz
Parquett floor – left: Abrasion test of untreated and different treated samples; right: Makro-Viewe

L. Clauder; A. Maschmann-Fehrensen, F. Seemann: Herstellung von thermisch modifiziertem Eichenholz
Results

Outdoor test of durability untreated and different treated samples; left: Utilization classes 3 (GK 3 Dobble layer test). Right: Samples of Utilisation class 4 (GK 4 Earth contact)

L. Clauder; A. Maschmann-Fehrensen, F. Seemann: Herstellung von thermisch modifiziertem Eichenholz
Ergebnisse

Abb. 5: Gartenbank - Vergleichstest zur Verklebung von unbehandelten gegenüber unterschiedlich stark modifizierten Proben

L. Clauder; A. Maschmann-Fehrensen, F. Seemann: Herstellung von thermisch modifiziertem Eichenholz
• Oak was declassified into DC 2-4
• Strong varying properties
• Correlations/ reasons still unclear on this step of investigation
• Final durability and single phenol content needed
• Heat treatment improves most properties
  • Durability → other investigations
  • Swelling/ shrinkage
  • Hardness + strength up to moderate heating (180°C)