Some Physical and Mechanical Properties of White Poplar (*Populus alba* L.) Wood Grown in Varaždin Region

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**ABSTRACT**

Investigation of physical and mechanical properties of wood is important for application of wood as a raw material. Nowadays, large quantities of wood from fast-growing species, especially from agricultural unusable land, are available on the market. One of them is poplars. The available data on physical and mechanical properties of white poplar wood grown in Croatia is insufficient. In this work, some of this properties were investigated on white poplar (*Populus alba* L.) from the region near Varaždin. Also, the distribution of this properties from pith to bark was investigated. This preliminary study was carried out on five trees, using only segments with north and south orientation in the wood at breast height. This article presents charts of listed properties from pith to bark for trees where the correlation of properties was highest. The average values of results in this preliminary study are: density in absolute dry condition is 0.390 g/cm³, density at 12% of moisture content is 0.422 g/cm³, maximum volume shrinkage is 15.1%, static bending strength is 62.8 MPa, modulus of elasticity at static bending is 12.99 GPa, compression strength parallel to grain is 34.3 MPa. In order to determine the statistical reliability, research must be continued on a larger number of samples.

**Key words:** White poplar (*Populus alba* L.), Physical properties, Mechanical properties, Radial direction, Distribution

1. **INTRODUCTION**

So far, research has been carried out on white poplar in Croatia (Horvat, 1960) on physical and mechanical properties on location in Slavonija. Unfortunately, these studies were carried out in an older way that was appropriate to this time and the possibilities of data processing. Research of anatomic properties was carried out at the same location (Ištok *et al.*, 2017) as this research of physical and mechanical properties. Based on the interesting results of this research, we began to this test research of the physical and mechanical properties of white poplar. Defining the distribution of physical and mechanical properties in the radial direction was the primary goal. The research was conducted on a relatively small number of samples as a pilot study. Defining the distribution of properties in the radial direction contributtes to a better application of white poplar for different types of products: wood for packaging fruits and vegetables, wood as a raw material for the production of heat energy, wooden small products ... Knowing the distribution of properties in the radial direction allows us to determine the most valuable parts of logs to produce products with the highest added value. The advantage of white poplar is fast-growing rate regardless to the type of soil even on soils that are not suitable for agricultural production. The area of Varaždin and Međimurje or north-western part of Croatia has a lot of land that can be used for growing poplar or clones of poplars. In developing clones of poplars (Šefc *et al.*, 2009; Ugrenović, 1950), it is also important to create a database of physical and mechanical properties of white poplar characteristics that will allow comparison of the properties of clones with white poplar. Such comparisons allow us to evaluate new clone of poplar in this area.
2. MATERIAL AND METHODS

The material necessary for researching of white poplar properties was taken from test trunk samples of five trees in Lipovac Forest Administration. From ten selected trees, three were located in the Varaždin Forest Administration, forest area of Varaždinske podravske šume, department 3a (Figure 1).

![Figure 1. Mapp of the location the test trees.](image)

The test trees were selected as the best representatives of their age, size, habitus, dendrometric elements and outer trunk properties. The test trees were healthy, normal, with regular crowns, straight stems, average flawlessness and fullness of bole as well as grain texture (Table 1).

<table>
<thead>
<tr>
<th>number of test trees</th>
<th>height of the tree (m)</th>
<th>height to the first thick branch (m)</th>
<th>diameter on breast height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>16</td>
<td>7,5</td>
<td>50,5</td>
</tr>
<tr>
<td>28</td>
<td>14</td>
<td>6</td>
<td>51</td>
</tr>
<tr>
<td>29</td>
<td>14,3</td>
<td>8</td>
<td>41</td>
</tr>
<tr>
<td>30</td>
<td>14,1</td>
<td>8,2</td>
<td>44,5</td>
</tr>
<tr>
<td>31</td>
<td>13</td>
<td>7,3</td>
<td>39,2</td>
</tr>
</tbody>
</table>

The test trunk samples used for establishing the physical and mechanical properties were taken from the breast height (HRN ISO 3129:2015). The trunk samples were taken immediately upon felling and after that, the heart boards oriented North-South were made out of them. The heart boards were stacked and naturally dried until the water content was around 20%. For testing the physical properties we made samples for testing the density in absolute dry condition, and samples for testing density at 12% of moisture content in accordance with HRN ISO 3130:1999 and HRN ISO 3131:1999. For testing the mechanical properties we made samples for testing compression strength parallel to the grain and samples for testing bending strength and modulus of elasticity at bending strength in accordance with HRN ISO 3787:1976 and HRN ISO 3133:1975.
3. RESULTS AND DISCUSSION

The basic test results of physical and mechanical properties for all test trees are given in Table 2.

Table 2. Basic statistical test results for all test trees.

| PROPERTY | $\rho_o$ | $\rho_{12\%}$ | $\sigma_{c||}$ | $\sigma_B$ | $E_B$ |
|----------|---------|---------------|----------------|-----------|-------|
| UNITS    | [g/cm$^3$] | [g/cm$^3$] | [MPa] | [MPa] | [GPa] |
| COUNT    | 53      | 62            | 62   | 57      | 52    |
| MIN      | 0,254   | 0,319         | 19,6 | 40,8    | 2,2   |
| AVERAGE  | 0,413   | 0,429         | 34,3 | 62,5    | 5,2   |
| MAX      | 0,563   | 0,586         | 46,7 | 81,3    | 12,9  |
| STEDEV   | 0,062498| 0,057368      | 6,243973 | 10,87632 | 2,180905 |
| VAR      | 0,003906| 0,003291      | 38,9872 | 118,2943 | 4,756348 |

Legend: $\rho_o$ - density in absolute dry condition, $\rho_{12\%}$ - density at 12% of moisture content, $\sigma_{c||}$ - compression strength parallel to the grain, $\sigma_B$ - bending strength, $E_B$ - modulus of elasticity at bending strength, COUNT - number of samples, MIN - the minimum value of the tested samples, AVERAGE - the mean value of the tested samples, MAX - maximum value of the tested samples, STEDEV - standard deviation and VAR - variance.

For the purpose of obtaining a radial distribution of physical and mechanical properties in the radial direction, a basic representation was made with the lines of the polynomial second degree and the coefficient of correlation in Excel. The results are shown in Table 3.

Table 3. Results of the correlation coefficient of the distribution of physical and mechanical properties in the radial direction.

| PROPERTY | $\rho_o$ | $\rho_{12\%}$ | $\sigma_{c||}$ | $\sigma_B$ | $E_B$ |
|----------|---------|---------------|----------------|-----------|-------|
| $R^2$    | 0,18    | 0,12          | 0,12           | 0,13      | 0,03  |

Legend: $\rho_o$ - density in absolute dry condition, $\rho_{12\%}$ - density at 12% of moisture content, $\sigma_{c||}$ - compression strength parallel to the grain, $\sigma_B$ - bending strength, $E_B$ - modulus of elasticity at bending strength and $R^2$ - coefficient of correlation.

As an example, the Excel rendering results for density in the absolute dry state are shown in Figure 2.

![Figure 2. Distribution of density in absolute dry condition in radial direction for all test trees.](image-url)
By looking at figure per every tree, it was found that in some trees the dependence of physical and mechanical properties in radial direction gives bigger or very large correlation coefficients. The examples are shown in Table 4 and best results in Figure 3 and 4.

Table 4. Results of the correlation coefficient of the distribution of physical and mechanical properties in the radial direction per tree.

<table>
<thead>
<tr>
<th>NUMBER OF TREE</th>
<th>ρ 12%</th>
<th>σc‖</th>
<th>σB</th>
<th>E_B</th>
</tr>
</thead>
<tbody>
<tr>
<td>R²</td>
<td>0,54</td>
<td>0,53</td>
<td>0,20</td>
<td>0,83</td>
</tr>
<tr>
<td>R²</td>
<td>0,40</td>
<td>0,05</td>
<td>0,44</td>
<td>0,03</td>
</tr>
<tr>
<td>R²</td>
<td>0,51</td>
<td>0,78</td>
<td>0,33</td>
<td>0,06</td>
</tr>
<tr>
<td>R²</td>
<td>0,59</td>
<td>0,24</td>
<td>0,87</td>
<td>0,16</td>
</tr>
<tr>
<td>R²</td>
<td>0,51</td>
<td>0,29</td>
<td>0,31</td>
<td>0,64</td>
</tr>
</tbody>
</table>

Legend: ρ 12% - density at 12% of moisture content, σc‖ - compression strength parallel to the grain, σB - bending strength, E_B - modulus of elasticity at bending strength and R² - coefficient of correlation.

Figure 3. Distribution of compression strength parallel to the grain in radial direction for tree 29.

y = -0,0064x² + 0,7028x + 22,793
R² = 0,7837
The most interesting illustration of the correlation between physical and mechanical properties was the influence of wood density at 12% water content and pressure strength in parallel with fiber. This correlation is shown in Figure 5.

Figure 4. Distribution of bending strength in radial direction for tree 30.

Figure 5. Influence of density at 12% of moisture content on compression strength parallel to the grain for all trees.
4. CONCLUSIONS

1. The number of samples at this preliminary research for density in absolute dry condition, the density at 12% moisture content, compression strength parallel to the grain, static bending strength and modulus of elasticity in bending of white poplar in radial direction were small to give a statistically correct conclusion on their interdependence.

2. The density at 12% of moisture content distribution in the radial direction shows good coefficients of correlation per individual trees and indicating that it would be necessary to conduct research on a large number of samples to get a statistically correct conclusion.

3. Conclusion on the increase in the number of samples also applies to compression strength parallel to the grain, bending strength and modulus of elasticity at bending strength.

4. The most interesting is the dependence of compression strength parallel to the grain and density at 12% of moisture content that shows the strongest evidence of the need to conduct research on a large number of samples to get statistically correct conclusion.

5. REFERENCES

5. Required, used HRN and ISO norms
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A CIP catalogue record for this book is available in the Online Catalogue of the National and University Library in Zagreb as 000979682
Publisher:
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Continuous changes on international market open up new horizons and opportunities, and the new strategies adopted by Europe and the world bring new concepts that need to be adapted and followed. This concept seeks increased social cohesion, striking with the harmful effects of climate change, nature preservation and the creation of a healthy environment. At the same time, creative potentials are open to new knowledge and innovative processes whose primary objective is to adapt to the needs of customers and the environment.

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We hope that this year's conference will contribute to awareness raising about the significance of wood as an irreplaceable natural raw material, and that the application of scientific research has a positive impact on the wood sector as well as any user of wood.

Assistant Professor Ivica Župčić, PhD
## CONTENTS

1. Timothy Young  
INDUSTRY 4.0 – Pragmatic Algorithms, Information Quality and Relational Databases  

2. Tetsuya Inagaki; Moe Kashima; Satoru Tsuchikawa  
Estimation of Wood Density, Moisture Content and Fiber Orientation by THz Time Domain Spectroscopy  

3. Hikaru Kobori; Sakura Ichijo; Naoki Okano; Yoichi Kojima; Shigehiko Suzuki  
The Effect of Dry Thermal Treatment on the Vibrational Characteristics of Wood  

4. V. Sierra Sánchez; M. de Luque Ripoll; M. Álvarez San Millán; S. Pérez Mazarío; P. García Espina; Luis de Luque Ripoll  
NIRWOOD: an EU Innovation Project to Determine Species and Geographical Origin of Timber using NIR Spectrometry  

5. Ahmet Can; İsmail Özlüsoylu; Wojcieszek Grzeskowiak; Eser Sözen  
Improvement of Fire Performance of Impregnated Wood with Copper Based Chemicals  

6. Miłjenko Klarić; Velimir Nikić; Stjepan Pervan  
Subfossil Waterlogged Oak-wood (Abonos) Moisture Content Estimation by Electrical Resistance Method  

7. Hajri Haska; Bajram Kullolli; Hajri Ismaili; Eneida Haska  
Traditional Ways Using of Wood and Forest Products in Housings and in Daily Livelihoods in Albania Populations/Communities  

8. Ivan Zulj; Ivica Župčić; Kristijan Radmanović; Ivica Grbac; Valentino Slivar  
Temperature as an Important Factor in Rotary Welding of Wood  

9. Nikola Španić; Vladimir Jambreković; Kristijan Radmanović; Goran Mihulja; Jaroslav Kljak  
Effect of Tartaric Acid Addition to Catalyst on Curing Behaviour of Urea-Formaldehyde Resin  

10. Ivana Perić, Tomislav Grladinović, Jože Kropivšek, Krešimir Greger  
Relationship between Entrepreneurial Competencies and Firm Performance: A Study on Furniture Manufacturing SMEs in Croatia  

11. Fabiana Chipaia; Claudia Urbinati; Patricia Dos Santos; Alisson Reis  
Identification of Diagnostic Anatomical Features in Ten Species of Sapindales Occurring in the Brazilian Amazon  

12. Ignacio Urbán Martínez; Ernesto Gutiérrez Tejón; Oscar Santaclara Estévez; Esther Merlo Sánchez  
Optimization of Juglans sp. Wood Processing from Sustainable Plantations' thinning, Wood Profitability and Final Product Quality  

13. Branimir Safran; Matija Jug; Kristijan Radmanović; Igor Đukić; Daniel Kramar; Stjepan Risić  
Analysis of the Raw Material Properties in the Agro-wood Pellets Production  

14. Tomislav Sedlar; Tomislav Sinković; Jelena Trajković; Bogoslav Šefc; Branimir Jambreković; Iva Ištok  
Relationship between Strength and Density as an Indicator of Sycamore Maple (Acer pseudoplatanus L.) Wood Quality  

15. Tomislav Sinković; Branimir Jambreković; Bogoslav Šefc; Iva Ištok; Filip Veselčić; Tomislav Sedlar  
Some Physical and Mechanical Properties of White Poplar (Populus alba L.) Wood Grown in Varaždin Region  

16. Anka Ozana Ćavlović; Matija Jug; Andrija Novosel  
The Efficiency of Exhaust System in the Wooden Floor Production: A Case study  

17. Ahmet Can; Cengiz Temiz; Hüseyin Sivrikaya  
Surface Characterization of some Woods Exposed to Accelerated Weathering  

18. Ahmet Can; Hüseyin Sivrikaya  
Effect of Water Repellents on the Surface Characterisation of Scots pine (Pinus sylvestris) Exposed to Accelerated and Outdoor Weathering  

19. Marin Hasan; Adriana Hasan; Gordana Orešković; Branimir Jambreković; Suzana Antolović  
Contribution to the Optimisation of Esterification of Beech Wood by Citric Acid  

20. Milan Gaff; Marián Babiak; František Kačík; Veronika Vondrova; Danijela Domijan  
Bendability of Thermally Modified Oak (Quercus robur F.)
<table>
<thead>
<tr>
<th>No.</th>
<th>Authors</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.</td>
<td>Reza Hosseinpourpia; Stergios Adamopoulos; Carsten Mai; Venla Hemmilä</td>
<td>Effect of Bio-Based Additives on Physico-Mechanical Properties of Medium Density Fibreboards</td>
<td>153</td>
</tr>
<tr>
<td>22.</td>
<td>Sergej Medved; Jože Resnik; Vladimir Jambreković; Nikola Španić; Alan Antonović</td>
<td>Image and FT-IR Analysis of Blended Particles</td>
<td>159</td>
</tr>
<tr>
<td>23.</td>
<td>Marina Jajcinovic; Wolfgang Johann Fischer; Ulrich Hirn; Wolfgang Bauer</td>
<td>Influence of Relative Humidity on the Strength of Hardwood and Softwood Pulp Fibres and Fibre to Fibre Joints</td>
<td>165</td>
</tr>
<tr>
<td>24.</td>
<td>Juraj Stanešič; Tomislav Podvorec; Alan Antonović</td>
<td>Influence of Black Poplar Wood Particle Size (Populus nigra L.) on Content and Properties of Bio-oil</td>
<td>175</td>
</tr>
<tr>
<td>25.</td>
<td>Liubov Kozak; Pavlo Bekhta; Ján Sedlíček; Ján Iždinský</td>
<td>Influence of Veneering on the Properties of Lightweight Particleboards with Expanded Polystyrene</td>
<td>183</td>
</tr>
<tr>
<td>26.</td>
<td>Łukasz Krzyżaniak; Jerzy Smardzewski</td>
<td>Modeling of Externally Invisible Cabinet Furniture Joints</td>
<td>191</td>
</tr>
<tr>
<td>27.</td>
<td>Jiří Tauber; Zdeněk Holouš; Miroslav Kozák; Sarah Szőkeová</td>
<td>Trends in the Production and Design of Upholstered Furniture</td>
<td>199</td>
</tr>
<tr>
<td>28.</td>
<td>Boris Iliev; Danijela Domljan</td>
<td>Comparison between Preschool Tables used in Kindergartens in Croatia, Macedonia and Bulgaria</td>
<td>207</td>
</tr>
<tr>
<td>29.</td>
<td>Zoran Vlaović; Karla Seleš; Ivica Grbac; Ivan Žulj; Danijela Domljan</td>
<td>Comfort of Cervical Pillow with Polyurethane Coil Springs</td>
<td>215</td>
</tr>
<tr>
<td>30.</td>
<td>Alena Sobotková; Milan Šimek; Danijela Domljan</td>
<td>Furniture Design for the Entrance Hall</td>
<td>223</td>
</tr>
<tr>
<td>31.</td>
<td>Sarah Szőkeová; Miroslav Kozák; Milan Šimek</td>
<td>Product Line Safari</td>
<td>229</td>
</tr>
<tr>
<td>32.</td>
<td>Roy Damary; Natalia Pryadilina; Sergey Zalesov; Anton Opletaev</td>
<td>Outdoor Wooden Furniture as a Component of an overall Municipal Project: “Green City</td>
<td>237</td>
</tr>
<tr>
<td>33.</td>
<td>Franciska Klanfar; Jerzy Smardzewski; Danijela Domljan</td>
<td>Management of the Project of Traditional Estate Adaptation into Object of Village Tourism</td>
<td>243</td>
</tr>
<tr>
<td>34.</td>
<td>Marko Dušak</td>
<td>Improvements to the Production Management System of Wood-processing in Small and Medium Enterprises</td>
<td>251</td>
</tr>
</tbody>
</table>