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Radial variation of the content of cellulose and lignin in selected softwood species

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Abstract: *Radial variation of the content of cellulose and lignin in selected softwood species.* This study determined radial variation of the content of cellulose and lignin on the cross-section of chosen softwood species. Research was carried out on the wood of pine (*Pinus sylvestris* L.), spruce (*Picea abies* (L.) Karst.) and larch (*Larix decidua* Mill.) originating from dominant trees at the age of 104-106 years, growing in the same habitat and climatic conditions. The test material consisted of approximately 30 mm thick discs. 4 cm wide slats, intended for determination of the chemical composition, were cut out from the discs in the north-south direction. The measurements of the content of cellulose and lignin were taken from the 25-year incremental zones, counting from the core to the circumference. Having analysed the radial variation of cellulose content in the zones determined on the cross-section, the authors observed that it demonstrated some fluctuations with an upward trend in the direction from the core to the circumference. On the other hand, the highest lignin content was characteristic of juvenile wood (of close-to-the-core zone) and decreased towards the circumference.

Keywords: chemical composition, cellulose, lignin, pine wood, spruce wood, larch wood

INTRODUCTION

Wood is a very changeable material as regards its properties. Most of its anatomical or physico-chemical features depend on, inter alia, the species, geographic origins, tree age, the biosocial position of the tree within the stand, and also the location on the trunk cross-section or along the tree height. The content of particular chemical components of wood also varies within an individual tree or species, as well as between species. Although the issues connected with the variability of chemical composition in different species was addressed in many publications (Krutul and Kocoń 1983, Prosinski 1984, Wróblewska and Spława-Neyman 1995, Berrocal et al. 2004, Wadenback et al. 2004, Yeh et al. 2005, Diaz-vaz, et al. 2009, Waliszewska et al. 2015), it is difficult to compare those values due to the various ages of trees, habitat and climatic conditions of the tree growth, and also diverse locations on the cross-section from whence the wood for testing was sampled. There is not many publications subject literature which concern the radial variation of chemical composition of different wood species originating from the same geographical region.

This research aimed at determination of the radial variation of basic chemical composition of the wood of pine (*Pinus sylvestris* L.), larch (*Larix decidua* Mill.), and spruce (*Picea abies* (L.) Karst.), originating from trees that were approximately 100 years old and came from the same stand, therefore grew in the same habitat and climatic conditions. The trees were cut in the Forestry Management of Łopuchówko, the commune of Murowana Goślina (52°26'N; 16°43'E).

MATERIALS

Determination of the content of basic chemical composition was carried out on a disc cut out at the breast height. In order to perform the test, a 4 cm wide slat was cut out from the disc in the north-south direction. Previous tests carried out on a disc adjacent to the tested disc (thus carried out on the same test material) allowed determination, based on the length of tracheids, of the number of annual rings making up the juvenile zone. In the case of trees of the analysed species that zone encompassed 25-28 close-to-the-core annual rings; therefore a

detailed analysis of the content of basic chemical components was carried out in 25-year incremental zones, counting from the core to the circumference. For the purposes of this study, those zones were marked as follows: zone I (1^{st}-25^{th} annual ring), zone II (26^{th}-50^{th} annual ring), zone III (51^{st}-75^{th} annual ring), and zone IV (76^{th}-100^{th} annual ring). Determination of basic chemical composition of wood was carried out using a fraction of particles of the dimensions of 0.5-1.0 mm. For the tested wood species the authors determined the content of:

- cellulose by the method of Seifert acc. to PN-92/P-50092,
- non soluble in acids lignin, so-called Klason lignin, acc. to PN-92/P-50092.

The average values of the content of cellulose and lignin determined for pine, spruce and larch for the entire cross-section and calculated from four zones, each encompassing 25 annual rings, were very similar (Fig. 1a and 1b). In the case of cellulose its average content was 47.91% for pine, 48.29% for larch, and 47.57% for spruce, and in the case of lignin it was 26.96%, 27.93%, and 28.01%, respectively. In order to check the significance of the differences in the content of cellulose and lignin in the tested species, the authors carried out an analysis of variance (ANOVA), whose results are presented (Fig. 1a and 1b). The calculated values of the test statistics F at the significance level $p < 0.05$ were lower than the critical values. This proved the insignificance of the interspecies differences in the average values of the entire cross-section of the values of the determined chemical composition. Sjöström (1993) observed almost identical values of the content of cellulose and lignin in the wood of pine (*Pinus sylvestris* L.) and spruce (*Picea glauca)*, i.e. 40% and 39.5%, respectively, for cellulose, and 27.7% and 27.5%, respectively, for lignin.

Having analysed the radial variation of the content of cellulose in the zones determined on the cross-section, each zone encompassing 25 annual rings, the authors observed that it demonstrated some fluctuations with an upward trend in the direction from the core to the circumference (Fig. 2a). In the case of all the tested species lower value were obtained for juvenile wood (zone I) compared to average cellulose content in the mature wood zones (zones II, III, and IV).

Some fluctuations were observed for pine wood in the transition zone between juvenile wood and mature wood (zone II). In the case of that species it was also the outer zone of heartwood. A lower content of cellulose in zone IV of spruce wood, observed in this research, requires some explanation. The analysis of microscope preparations of the cross-section of annual rings in that zone allowed identification of reaction wood. Reaction wood is characterised by an increased content of lignin and a lower content of cellulose compared to normal wood. Similar observations concerning the different of the content of cellulose and lignin in the reaction tissue of softwood species were made by, inter alia, Timell (1986), Tarmian and Azadfallah (2009).

The radial variation of the content of lignin in 25-year-old incremental zones is presented in Fig. 2b. Those values, to some extent, are a mirror image of cellulose content in those zones of the cross-section of the tested species. The highest share of lignin was observed for juvenile wood and the lowest for mature wood. As in the case of cellulose, there is one exception, i.e. the last zone of spruce wood where tracheids of reaction wood were identified.

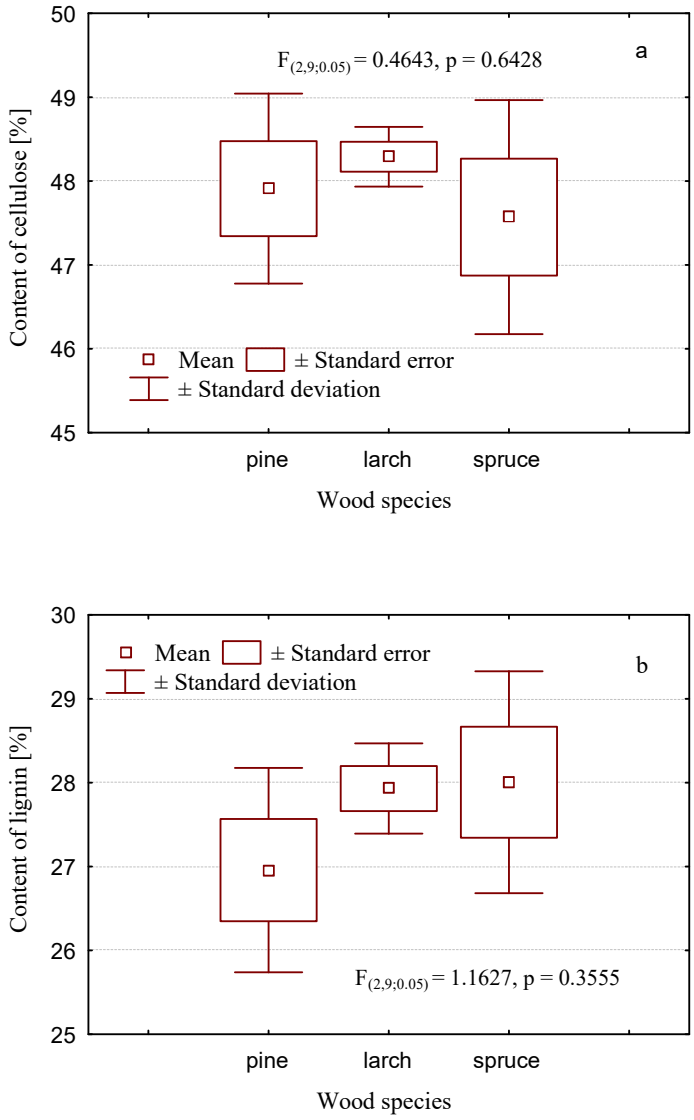

Figure 1. The average content of cellulose (a) and lignin (b) calculated for the entire cross-section in the wood

Wróblewska and Spława-Neyman (1995) observed that the content of cellulose increased and the share of lignin decreased in the direction from the core to the circumference in the case of 40 and 60 years old pines, growing in a standard spacing. Diaz-va et al. (2009) observed similar variation of the content of cellulose and lignin on the cross-section of pine *Pinus radiata*. The cited authors proved that cellulose content was at a level of 43.8% in juvenile wood and 46% in mature wood; whereas lignin content was at a level of 27.2% and 26.2%, respectively. Such variation of the content of cellulose and lignin on the cross-section it typical of softwood species (Timell 1986, Chen 1991, Shupe et al. 1997, Fengel and Wegener 2003).

Gierlinger and Wimmer (2004) observed the increasing lignin content in the direction from the core to the circumference (from approximately 27.8 % to approximately 30%) in 150-years-old larch trees (*Larix decidua* Mill.) originating from Austria. The cited authors also proved that in the case of approximately 200-years-old larch trees, of said species, originating from the French Alps the content of lignin increased from 26.8% to approximately 29% until they reached 130 years of age, and decreased in the following years. Bertaud and

Holmbom (2004) observed insignificant decrease in the share of lignin in spruce wood (from 28.3% to 27.7%) in the direction from the core to the circumference.

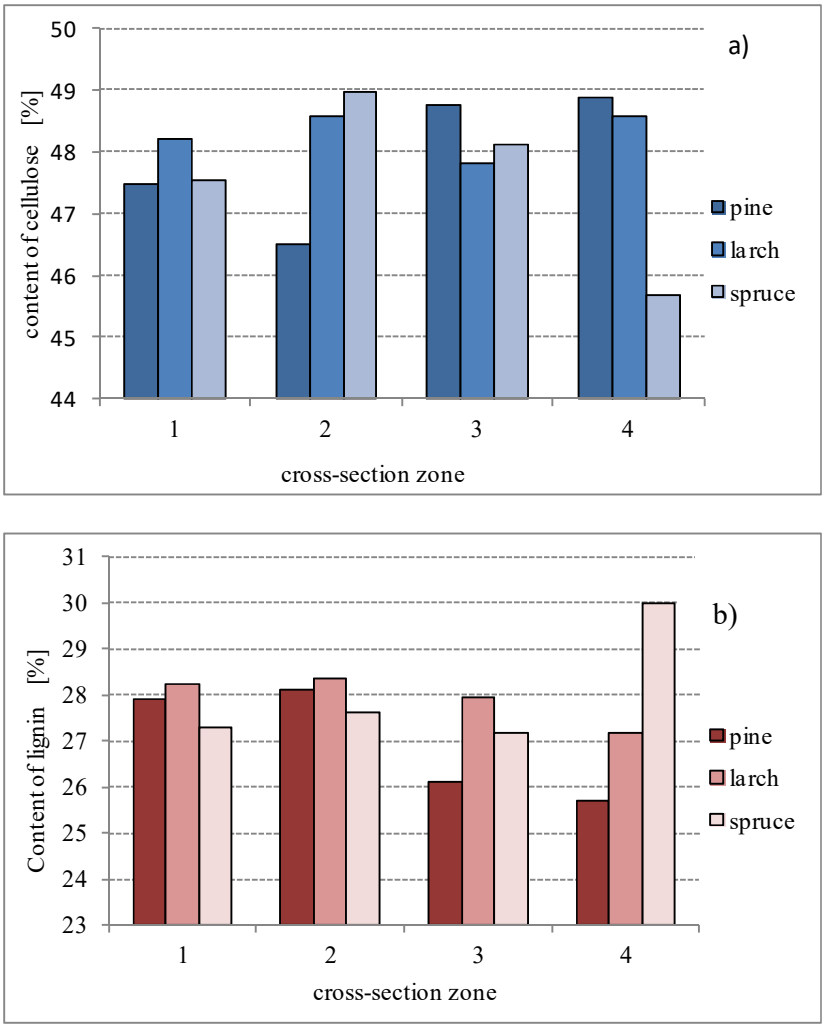

Figure 2. The content of cellulose (a) and lignin (b) in the determined zones of the cross-section in the wood of pine, larch, and spruce

CONCLUSIONS

1. The average values of the content of cellulose and lignin calculated for the entire cross-sections of the wood of pine, spruce and larch were very similar. The interspecies differences for both cellulose and lignin did not exceed 1%, and the average for the tested species was at a level of approximately 47.93% and 27.63%, respectively.
2. The radial variation in the content of cellulose in the zones determined on the cross-section, each zone encompassing 25 annual rings, demonstrated an upward trend and the radial variation in the content of lignin demonstrated a downward trend in the direction from the core to the circumference.
3. For all the tested species lower values of the cellulose share and higher of the lignin share were obtained for the juvenile wood zone compared to the mature wood zone.
4. The decreasing content of cellulose and the increasing of lignin in a dozen or so close-to-the-circumference annual rings in spruce wood was due to the presence of reaction wood tracheids in those annual rings.

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Streszczenie: *Promieniowa zmienność zawartości celulozy i ligniny w wybranych gatunkach iglastych*. W pracy określono promieniową zmienność zawartości celulozy i ligniny na przekroju poprzecznym wybranych gatunków iglastych. Badania przeprowadzono na drewnie sosny (*Pinus sylvestris* L.), świerku (*Picea abies* (L.) Karst.) i modrzewia (*Larix decidua* Mill.) pochodzącym z drzew dominujących w wieku 104-106, rosnących w tych samych warunkach siedliskowych i klimatycznych. Materiałem do badań były krążki o grubości ok. 30 mm z których wycinano listewki w kierunku północ- południe o szerokości 4 cm przeznaczone do oznaczeń składu chemicznego. Pomiary zawartości celulozy i ligniny wykonywano w 25 letnich strefach przyrostowych licząc od rdzenia do obwodu. Analizując promieniową zmienność zawartości celulozy w wydzielonych na przekroju poprzecznym strefach stwierdzono, że wykazuje ona pewne fluktuacje z tendencją wzrostową w kierunku od rdzenia do obwodu z kolei najwyższa zawartość ligniny cechuje drewno młodociane (strefę przyrdzeniową) i maleje w kierunku obwodowym. Wyjątek stanowiło drewno świerku u którego zaobserwowano spadek zawartości celulozy oraz wzrost zawartości ligniny w kilkunastu przyobwodowych przyrostach rocznych w wyniku obecności w tych przyrostach cewek drewna naciskowego.

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