

Comparison of the chemical composition of domestic common hornbeam (*Carpinus betulus* L.) wood and exotic yakal (*Shorea astylosa* Foxw.) wood

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Abstract: Comparison of the chemical composition of domestic common hornbeam (*Carpinus betulus* L.) wood and exotic yakal (*Shorea astylosa* Foxw.) wood. The study was carried out to compare the chemical composition of domestic hornbeam wood with exotic yakal wood, which is an endemic species occurring in the Philippines. Species of similar structural structure occurring in different areas were studied. Extractives, cellulose (including α -cellulose), holocellulose (including hemicelluloses), lignin and ash contents were analyzed. The obtained results indicated lower content of cellulose, α -cellulose, lignin, extractives and ash in hornbeam wood as compared to yakal wood. On the other hand, a much higher amount of hemicelluloses (by 12 percentage points) was found in hornbeam wood.

Keywords: hornbeam wood, yakal wood, chemical composition

INTRODUCTION

Wood is used in many areas of life, from building's structures, toys to paper and other everyday objects. Its widespread use has made it the subject of many studies carried out at universities around the world, and its results have a positive impact on the efficiency of woodworking processes. It is an anisotropic and heterogeneous material, which requires detailed knowledge of its properties in order to make the best use of it.

The mechanical properties are influenced by the anatomical structure of the wood, i.e. the width of the rings or the proportion of late and early wood. Knowing the chemical composition of wood, allows to know in depth the correlation of its properties with the chemical substances of which it is composed, so it is equally eagerly studied. The chemical composition of wood consists mainly of cellulose, hemicelluloses and lignin, which are a structural components. Whereas extractives and mineral substances are a nonstructural components.

Cellulose is a polysaccharide - the main component of wood and plant fibers, which forms the backbone of cell walls, occurs in the form of thin fibers - microfibril. It has a macromolecular structure, is a polymer of β -D-glucopyranose residues combined with 1,4- β -glycoside bonds, with a high degree of polymerization (from 200 to 10 000). The percentage content of cellulose in wood is from 40% to 60% [Krzyśik 1978].

The wood contains also other polysaccharides, which are called hemicelluloses. The hemicelluloses, is a group of substances with a much lower degree of polymerization (100-200) and resistance to various diluted acids and alkalis. The percentage content of hemicelluloses in wood is from 18% to 35% [Krzyśik 1978].

The next an important structural component of wood is lignin, which ensures wood durability [Gierlinger et al. 2004] and provide protection against pathogens, insects and UV radiation [Polle et al. 1997, Whetten et al. 1998]. Lignin is the compound of aliphatic and aromatic properties, constituting in wood from 15% to 36% of the dry mass [Krzyśik 1978].

The nonstructural components are not part of the structure of the wood cell wall and do not affect its mechanical properties. Extractives are compounds that include organic substances such as resins, waxes, fats, dyes, tannins or essential oils. These substances are readily soluble in conventional inert solvents like ether, ethyl alcohol, benzene, chloroform or water. The percentage content of extractives in wood is from 3% to 10% [Prosiński 1984].

Mineral substances, on the other hand, are a group of inorganic compounds that occur in wood in small amounts (usually from 0.3% to 1%) [Prosiński 1984]. These substances are determined in the form of ash, which mainly consists of oxides of magnesium, potassium, calcium and carbonates of potassium, sodium, calcium and carbonates, silicates and phosphates of magnesium and iron.

In this paper, the chemical composition of common hornbeam (*Carpinus betulus* L.) wood and yakal (*Shorea astylosa* Foxw.) wood was compared. Both species belong to hardwood species with diffuse-porous wood, characterized by vessels of similar size and distribution in the whole annual ring and the lack of a clear border in the annual ring between the early and late wood.

The wood of hornbeam is heavy, very hard, very difficult to split, characterized by a wavy course of annual rings with numerous wood rays and very thick fiber walls [Kokociński 2005]. The hornbeam wood is heartless of white-grey color and average density of 790 kg/m³ [Krzysik 1978]. This wood is often used for machine elements, for sledge skids, is excellent for turning, also used for tools production, for chipboards, for firewood (very high calorific value) and for musical instruments such as drumsticks.

Yakal is an endemic species found in the Philippines and also on the islands of Luzon, Mindanao, Negros and Samar. Yakal is a commercial name used for several species that seem to be identical in terms of structure and durability. For the first time this name was used for the wood *Hopea plagata* (Blanco.) Vid. Among them are also used: *Shorea balangeran* (Korth.) Dyer., *S. ciliata* King., *S. astylosa* Foxw., *S. malibato* Foxw., *S. falciferoides* Foxw., *S. scrobiculata* Burck., *H. foxworthyi* Elmer., *H. odorata* Eoxb., *H. malibato* Foxw., *Balanocarpus cagayanensis* Foxw., *B. brachyptera* Foxw., *Isoptera borneensis* Scheff. Yakal is the most valued of the Philippine dipterocarps [Fernando 2009]. The wood of yakal is dark brown in color, the vessels of which are clearly visible and evenly spaced across the cross section. The sapwood is slightly lighter than dark brown heartwood, with a width of 2 cm to 8 cm and an average density of 850 kg/m³ [Jankowska et al. 2012]. This wood is moderately easy to process mechanically and difficult to dry and easy to finish. Yakal wood is used in boatbuilding, parquet flooring production and to bridge construction [Gerard et al. 2017].

The aim of this work was to determine the chemical composition of two structurally similar species, domestic common hornbeam (*Carpinus betulus* L.) wood and exotic yakal (*Shorea astylosa* Foxw.) wood. In the available literature there is a lack information about a studies concerning chemical composition of *Shorea astylosa* Foxw. wood. Hence, in this respect the determination of its chemical composition and comparison with structurally similar domestic species can be interesting and noteworthy. Moreover, by recognizing the chemical composition, it is possible to predict the possible use of wood of a given species.

MATERIALS AND METHODS

Samples were taken from a 22 cm diameter common hornbeam (*Carpinus betulus* L.) trunk obtained from a tree which grew for about 30 years in Mazovia (Forest Inspectorate of Wyszaków). The wood sample of yakal (*Shorea astylosa* Foxw.) came from the southern part of the island of Luzon, in the province of Batangas in Philippines. This material was also obtained from the stem of a similar age (about 30 years) and only part of heartwood was used. The research material was stripped of its bark and the phloem. Before the chemical composition determination, the material was ground in the mill. Dust (fraction below 0.43 mm) was collected for ash analysis, while for the determination of the content of the remaining components, the fraction from 0.43 mm to 1.02 mm was used. The content of the each analyzed substance referred to absolutely dry wood. Before each determination, the ground material was dried to a constant weight in a laboratory dryer at 103±2°C.

The content of extractives was determined using a Soxhlet apparatus with a mixture of chloroform and ethanol at a ratio of 93:7 by weight [Antczak et al. 2006]. Extraction was carried out according the method described by Krutul [2002]. Regardless of the studied species, the extraction time was 10 hours.

The content of ash was determined according to the Sluiter et al. [2008]. The combustion process lasted 6 hours at a gradually increasing temperature to reach 600°C. To the analysis of cellulose, holocellulose and lignin content, the extracted material in a mixture of chloroform and ethanol (93:7)_{w/w} was used.

The cellulose content was determined by Kürschner-Hoffer method detailed described by Saeman et al. [1954] and Krutul [2002]. In this method three 1 hour boiling cycles in a mixture of 5 cm³ of 65% nitric acid and 20 cm³ of 96% ethyl alcohol were used.

The α -cellulose content in the Kürschner-Hoffer cellulose was determined by method described by Krutul [2002]. In this method 0.5 g Kürschner-Hoffer cellulose and 12.5 cm³ of 17.5% NaOH solution were used.

The next analyzed component was lignin and its content was determined according to TAPPI UM 250 [1985] and TAPPI T222 om-02 [2006]. Lignin content was determined as the sum of insoluble and soluble lignin in 72% sulfuric acid VI.

The analysis of holocellulose content was performed with sodium chlorite (NaClO₂) [Wise et al. 1946, Krutul 2002]. In the case of common hornbeam wood four cycles of heating in a mixture of sodium chlorite and glacial acetic acid were performed. Whereas, for yakal wood five cycles were carried out.

The hemicelluloses content was calculated from the difference between the holocellulose and cellulose content.

Each determination of chemical substances content was performed three times in order to obtain the most reliable results and single standard deviation was calculated.

RESULTS AND DISCUSSION

In this work the chemical composition of two structurally similar species, domestic common hornbeam (*Carpinus betulus* L.) wood and exotic yakal (*Shorea astylosa* Foxw.) wood was determined. The results were presented in Figs 1 and 2.

The cellulose content in the native common hornbeam wood species was 48.9% (Fig. 1). According to Fengel and Wegener [2003], hornbeam wood contains from 43.0% to 46.4% of cellulose. Whereas, according to Pettersen [1984] *Carpinus betulus* L. wood contains 47% of cellulose and this result is similar to the value obtained in this paper. In our study, the hemicelluloses content in common hornbeam wood was 35.0% (Fig. 1). This result is almost identical to value (35.5%) presented by Fengel and Wegener [2003]. In the exotic yakal wood, the cellulose content was higher and was 53.6%, while hemicelluloses content was much less compared to hornbeam wood and represented 23.0% (Fig. 1). The average holocellulose content for hardwood trees in the Philippines, according to Pettersen [1984], ranges from 66.3% to 77.3%. The result obtained in this studies (76.5%) presented in Fig. 1, is within this range. A similar species to *Shorea astylosa* Foxw., is *Hopea plagata* (Blanco.) Vidal., which is also included in the yakal group of trees. According to Pettersen [1984] this wood contains 75% of holocellulose.

The results of the α -cellulose content were similar for the compared species and were 48.0% and 50.1% for hornbeam and yakal wood respectively (Fig. 1). According to Pettersen [1984], the α -cellulose content in *Shorea negrosensis* Foxw. wood is 50%, while in *Shorea philippinensis* Brandis wood is 52%. The determined α -cellulose content in this study was very similar to literature data of *Shorea* species, that occur on the Philippine Islands.

The results of lignin content obtained in these studies were 18.9% and 28.5% for *Carpinus betulus* L. wood and *Shorea astylosa* Foxw. wood, respectively. In this case, the

difference in lignin content between these two species was very significant. Fengel and Wegener [2003] point out, that the lignin content in hornbeam wood is in the range from 17.8% to 21.2%. Whereas, according to Pettersen [1984], the average lignin content in hardwood species that occur on the Philippine Islands, is 29.4%. In both cases, the results obtained in this study are consistent with the literature data.

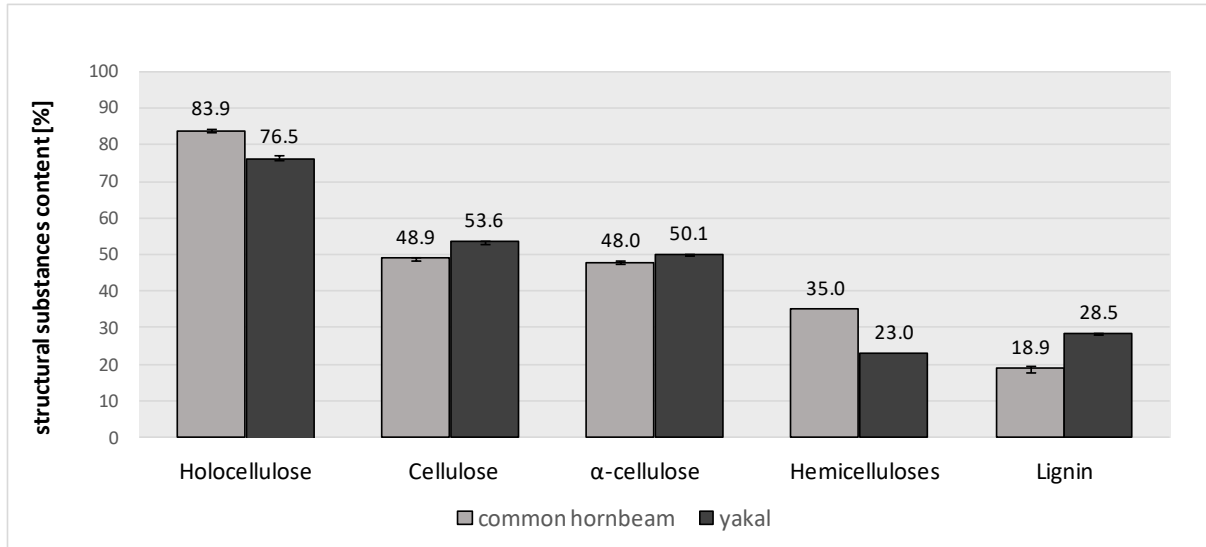


Figure 1. Content of structural substances in common hornbeam (*Carpinus betulus* L.) wood and yakal (*Shorea astylosa* Foxw.) wood

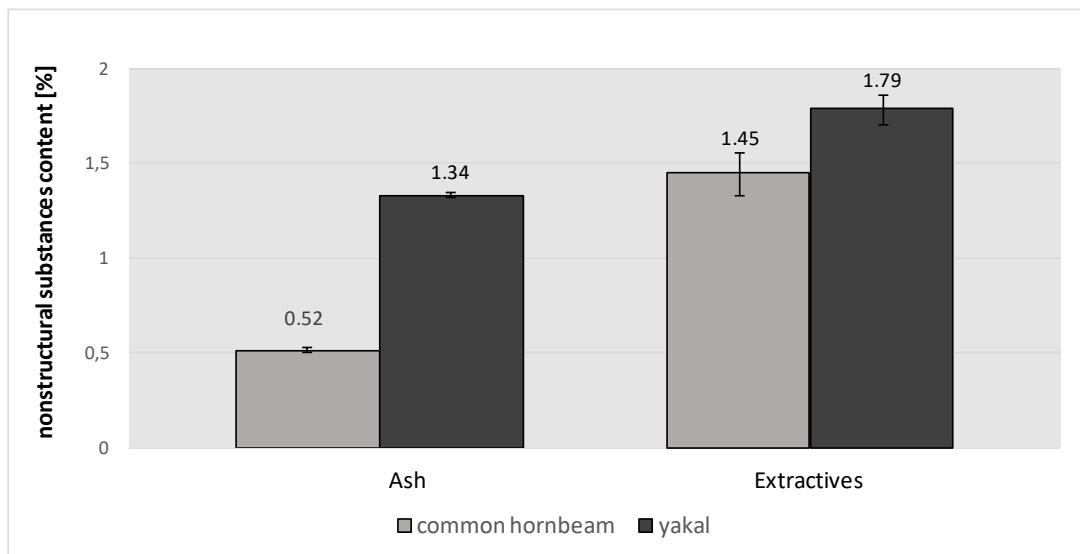


Figure 2. Content of nonstructural substances in common hornbeam (*Carpinus betulus* L.) wood and yakal (*Shorea astylosa* Foxw.) wood

The results presented by Fengel and Wegener [2003] show, that the content of extractives in hornbeam wood (*Carpinus betulus* L.) soluble in the alcohol-benzene mixture is 2.0%, while the ash content oscillates between 0.4% and 0.5%. The results obtained in this work are consistent with literature findings. Our research showed, that the content of extractives soluble in the mixture of chloroform and ethanol was 1.45% and the ash content was 0.52% for common hornbeam wood (Fig 2.).

For yakal wood, the ash content (1.34%) was much higher than for hornbeam wood, but at the same time the extractives content was similar and for yakal wood the value was

1.79%. According to Pettersen [1984], the extractives content in *Shorea negrosensis* Foxw. wood and in *Shorea philippinensis* Brandis wood is 2%. Whereas, the average ash content in hardwood species that occur on the Philippine Islands, is 1.2%. The determined extractives and ash contents in this study are consistent with literature data.

SUMMARY AND CONCLUSIONS

It can be stated that although the two species are structurally similar, their chemical composition is different. Analysis of the chemical composition of *Carpinus betulus* L. and *Shorea astylosa* Foxw. woods showed:

- lower cellulose content (by about 5 percentage points) and α -cellulose content (by about 2 percentage points) in the wood of *Carpinus betulus* L. compared to *Shorea astylosa* Foxw. wood,
- higher hemicelluloses content (by 12 percentage points) in the wood of *Carpinus betulus* L. compared to *Shorea astylosa* Foxw. wood,
- lower lignin content (by about 10 percentage points) in the wood of *Carpinus betulus* L. than *Shorea astylosa* Foxw. wood,
- the wood of *Shorea astylosa* Foxw. contained more than twice as much ash content as *Carpinus betulus* L.,
- an extractives content was similar in these two species, although in *Shorea astylosa* Foxw. wood was slightly more their content.

Probably, the main reason for the differences in the chemical composition of wood were natural differences between species studied.

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Streszczenie: *Porównanie składu chemicznego krajowego drewna grabu pospolitego (Carpinus betulus L.) oraz egzotycznego drewna yakal (Shorea astylosa Foxw.).* Badanie przeprowadzono w celu porównania składu chemicznego rodzimego drewna grabowego z egzotycznym drewnem yakal, który jest endemicznym gatunkiem występującym na Filipinach. Badano gatunki o podobnej budowie strukturalnej, występujące na innych terenach. Analizowano zawartość substancji ekstrakcyjnych, celulozy (w tym alfa celulozy), holocelulozy (w tym hemiceluloz), ligniny i popiołu. Uzyskane wyniki wskazują na mniejszą zawartość celulozy, α -celulozy, ligniny, substancji ekstrakcyjnych oraz popiołu w drewnie grabowym w stosunku do drewna egzotycznego. Z kolei znacznie większą ilość hemiceluloz (o 12 punktów procentowych) stwierdzono w drewnie grabu.

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