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EXTRACTIVE SUBSTANCES OF SELECTED SPECIES OF EXOTIC WOOD

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SYNOPSIS. The study determined the content of substances soluble in an organic solvent as well as hot and cold water of exotic woods: merbau, wenge, padouk and doussie. In addition, characteristics of these substances in UV and IR were presented.

KEY WORDS: exotic wood, soluble substances, UV, IR

INTRODUCTION

Various species of imported exotic wood have become increasingly popular in Poland in recent years. Exotic wood is a raw material which derives, primarily, from the tropical zone extending between the tropic of Capricorn and Cancer. From among a huge number of tree species, approximately 140 enjoy wider commercial popularity (Kozakiewicz and Szkarłat 2004). Many of them derive from wet equatorial forests which can be found in three regions of the globe: Central and South America, East and Central Africa and Madagascar, as well as South-Eastern Asia, on the Pacific islands and in the state of Queensland in Australia.

Growing conditions of exotic trees differ considerably in relation to those which occur in Poland. There are only slight temperature differences in the tropical zone climate which allow constant growth dependant on the precipitation occurring on a given area. There are no distinct divisions into annual increments in trees growing in rainforests. Most of broad-leaved species, which are dominant among exotic trees, exhibit scattered-vascular structure with large vessels forming a very effective system of water transport and that explains why the sapwood area in these trees is fairly narrow. A different picture emerges in the wood of trees occurring in the monsoon forests where concentric rings of annual increments are quite apparent on the trunk cross section (Kozakiewicz and Szkarłat 2004).

In the case of wood of exotic trees, due to the wide area of their occurrence, one of the serious problems is poorly recognised and described systematics. That is why many confusing names of tree species growing on the territories of many countries inhabited by different ethnic groups are frequently coined. It is not uncommon to find several recognised Latin names for a large number of exotic trees. The most difficult situation occurs when several or even several dozen local and trade names are used for a single species.

Wood of exotic tree species is particularly valuable for its individual and rare aesthetic value and physico-chemical properties unmatched by any Polish tree species allowing much wider application of the exotic wood. It is widely applied in construction and furniture industries, as well as in chemical processing. Species characterised by considerable durability and stability, e.g. iroko, ipe or teak, are used as elements working in changing environmental conditions such as bathroom equipment, garden furniture, gates, fences, flood-gates and port protection facilities. Due to its decorative values, exotic wood is used to manufacture veneers and furniture facings. Some exotic wood species are employed in very narrow, special fields, for example guaiacum is used to manufacture bearings, camshafts and marine screw propellers; zapatero – to make control-measuring equipment, housing of apparatuses, whereas light, porous balsa – to make insulation in refrigerating equipment, floats and flying models (Kozakiewicz and Szkarłat 2004). Many exotic wood species are used to produce plywood, while worse quality wood, offcuts and peeling wastes can be utilised as raw material for chipboard production.

Frequently wood of exotic tree species contain various auxiliary substances in its chemical composition. Some of them provide these woods with impregnation and protect them against fungi and microorganisms. These substances often give wood decorative patterns, e.g. striped structure of the zebrano species.

It is clear from the performed investigations of their physical properties that exotic wood species are characterised by similar, very good mechanical properties.

Table 1. Comparison of some physical and mechanical properties of selected exotic wood species (Kozakiewicz 2006 a, b, 2007, Wagenführ 2007)

Specification	Species			
	Afzelia africana	*Millettia laurentii* De Wild.	*Instsia* sp.	*Pterocarpus soyauxii* Toub.
Green wood density [kg/m^3]	1100-1200	1100-1200	1100-1300	900-1000
Wood density in air-dry state [kg/m^3]	950	860	830	700
Longitudinal shrinkage [%]	–	0.7	0.5	0.45
Radial shrinkage [%]	2.2-3.0	4.1-5.9	2.1-4.0	2.4-3.6
Tangential shrinkage [%]	3.6-4.4	8.6-9.4	4.4-7.4	4.1-5.4

AIM OF THE RESEARCH

The objective of the performed investigations was to examine quantities of substances soluble in organic solvents and water and the character of these compounds found in the selected species of exotic wood.

MATERIAL AND METHODS

Investigations were carried out on exotic wood obtained in the form of sawn timber approximately 80-100 cm long, from the "DLH DREWNO" Company. Investigations were carried out on the heartwood part of the trunk and, in the case of padouk wood, also for sapwood, due to its considerable proportions, as well as very high variability in the colour: sapwood – light, heartwood – dark red. The material intended for experiments was seasoned in an air-conditioned facility with the temperature of 20°C and then cut and ground in a Pulverisette 15 mill and then sieved through sieves with the aim to separate the proper fraction of 0.5-1.0 mm. Assays of substances soluble in hot and cold water, as well as in organic solvents were carried out in accordance with the methodology recommended by Tappi (2007, 2008). In addition, analyses of water solutions were carried out in UV light using a SPECORD M40 spectrophotometer, while dry residues which were left after the extraction with hot water were subjected to Fourier Transform Infrared Spectrometers (FTIR). The filtrate was evaporated in an evaporating dish in a water bath. The dry residue was examined. Infrared spectra were conducted using KBr (1.5 mg extract + 200 mg KBr).

The described investigations were carried out on the following four exotic wood species:

- **Merbau** – *Instsia* sp. – sawn wood of characteristic "earthy" smell and of orange-brown colour heartwood and white-yellow sapwood. This wood is characterised by natural high resistance to the effect of atmospheric factors as well as to destructive actions of fungi and microorganisms and insects.
- **Wenge** – *Millettia laurentii* De Wild. – this wood species is characterised by very narrow sapwood – from 2-4 cm wide – and has white-yellow colour. Its heartwood is brown and darkens under the influence of light and oxygen.
- **Padouk** – *Pterocarpus soyauxii* Toub. – a characteristic feature of this wood is its low pH (below 4) which can change depending on the moisture content and method of drying. The low pH makes this wood difficult to glue and requires smaller quantities of hardener (Kozakiewicz and Szkarłat 2004).
- **Doussie** – *Afzelia africana* – this wood is characterised by whitish sapwood and pink-brown heartwood. Another characteristic feature of this wood is the content of oil substances which makes this wood difficult to glue (Noga 1998).

RESULTS

The content of extractive substances is presented in Table 2. In the case of the examined species of exotic trees, the content of compounds soluble in cold water ranged from 7.47% in heartwood of the padouk wood to almost two times more, i.e. 13.35% – in the wood of doussie. Wood of the wenge species contained 10.23%

Table 2. Quantities of extractive substance [%] in selected species of exotic wood

Specification	Wood species				
	doussie	wenge	merbau	padouk heartwood part	padouk sapwood part
Substances soluble in cold water	13.35	10.23	12.58	7.47	8.74
Substances soluble in hot water	19.07	13.07	25.71	11.39	9.77
Substances soluble in mixture of alcohol : benzene (1:1)	9.54	3.87	9.14	18.51	0.64

of substance extracted by cold water and merbau wood – 12.58% of such substances. Despite distinct differences in the colour of the padouk wood, i.e. very light sapwood and dark-red heartwood indicating a higher content of dyes and resins (Prosiński 1984), slightly more cold-water-soluble substances were determined in the sapwood (8.74%, by 1.27% more) than in the heartwood of this wood species.

The highest level of substances soluble in hot water – 25.71% was determined in the merbau wood and the lowest – 9.77% in the sapwood part of the padouk wood. The heartwood part of the latter wood contained 11.39% of compounds extracted by hot water. High contents of substances soluble in hot water were determined in doussie wood – 19.07%, whereas the wenge wood was found to contain 13.07% of these substances.

Very high discrepancies were determined in the content of substances soluble by the alcohol:benzene mixture. In the padouk wood alone, the content of these compounds ranged from 0.64% in sapwood to nearly 30 times more, i.e. 18.51%, in the heartwood part. The examined wenge wood contained 3.87% of substance extracted by the alcohol:benzene mixture, whereas woods of doussie and merbau were characterised by similar levels of these compounds, namely: 9.54% and 9.14%, respectively.

The water solutions, after the analysis of substances soluble in hot and cold water, were subjected to the analysis in UV light. The character of the spectrum of compounds soluble in hot and cold water for the same wood species followed the same course.

Courses of the UV spectra of aqueous solutions of soluble substances of the examined exotic wood species are presented in Figures 1 to 3. It was found that characteristic inclination of spectra in the form of peaks occurred, in the case of the doussie wood, at approximately 275 nm wave length which could indicate a partially hydrolysing and condensed character of tannins (Botha et al. 1978). In the case of the remaining wood species: merbau, wenge and padouk a distinct peak in the spectral run occurred at 285 nm wave length; the two inclinations – at $\lambda = 250$ and 287 nm – visible on the UV spectral run of the padouk wood heartwood indicate a complex nature of phenolic substances occurring in this species. On the other hand, the gentle run of the spectrum from the softwood part of the padouk wood shows a partially hydrolysing character of tannins.

The shift of the peak in the direction of long waves indicates the presence of tannins of condensed character.

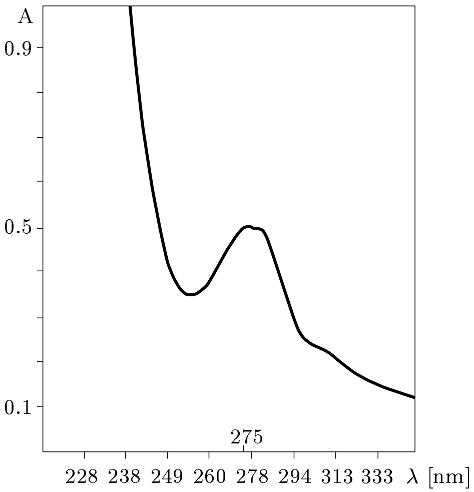

Fig. 1. Course of the UV spectrum of substances from the doussie wood soluble in hot water (dilution: 1:20)

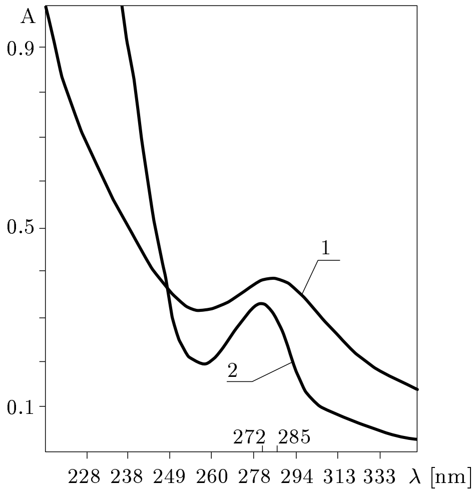

Fig. 2. Course of the UV spectrum of substances from wood soluble in cold water: 1 – the wenge wood (dilution 1:4), 2 – the merbau wood (dilution 1:10)

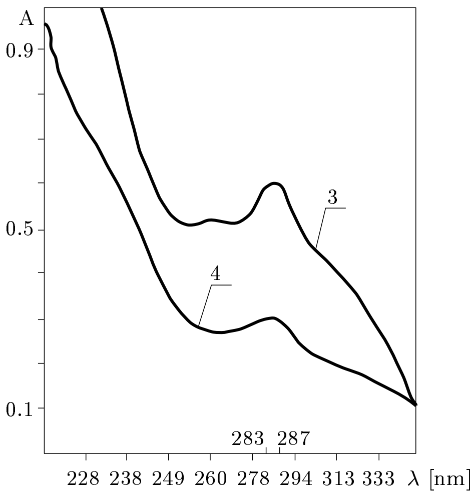

Fig. 3. Course of the UV spectrum of substances from the padouk wood soluble in hot water: 3 – heartwood (dilution 1:20), 4 – softwood (dilution 1:20)

Dry residue which remained after substances soluble in hot water from the examined exotic wood species was subjected to IR light analysis. Courses of these spectra are presented in Figures 4 to 8. It is visible on the presented spectrograms that all species have a characteristic peak at the wave number of about 3300 cm^{-1}. This is a wide, intensive band of valent vibrations of hydroxyl groups participating in intermolecular hydrogen bonds indicating water presence. At the wave number of about 2950 and 2850 cm^{-1}, C-H valent vibrations occur. This is typical for methylene and methyl groups. These groups were found to occur both in the heartwood and softwood parts of the padouk wood, as well as in doussie wood and small quantities in the wenge wood. On the other hand, the course in this spectral area from the merbau wood is very gentle which may indicate lack of these groups or their negligible quantities.

At the wave number of approximately 1710 cm^{-1}, valent vibrations of carbonyl groups occur. Runs of spectra without inclinations at this wave number indicate lack of compounds which have these functional groups which was observed in all the examined wood species.

A very large number of bands occur in the dactyloscopic region in the range from 1500-500 cm^{-1}. The most intensive bands can be found at the following wave numbers: 1380 cm^{-1}, 1270 cm^{-1}, 1237 cm^{-1}, 1220 cm^{-1}, 1115 cm^{-1}, 1030 cm^{-1}, 854 cm^{-1} and 630 cm^{-1}. In this region, individual bands are characteristic for water soluble substances, among others: tannins, dyes, some carbohydrates, pectins etc. (Baeza and Freer 2001). In this respect, the spectrum of the heartwood part of the padouk wood appears most diverse (Fig. 7). Much smaller variability of these groups was determined in the sapwood part of the wood of the above species, as well as in the wenge wood (Figs. 8 and 5).

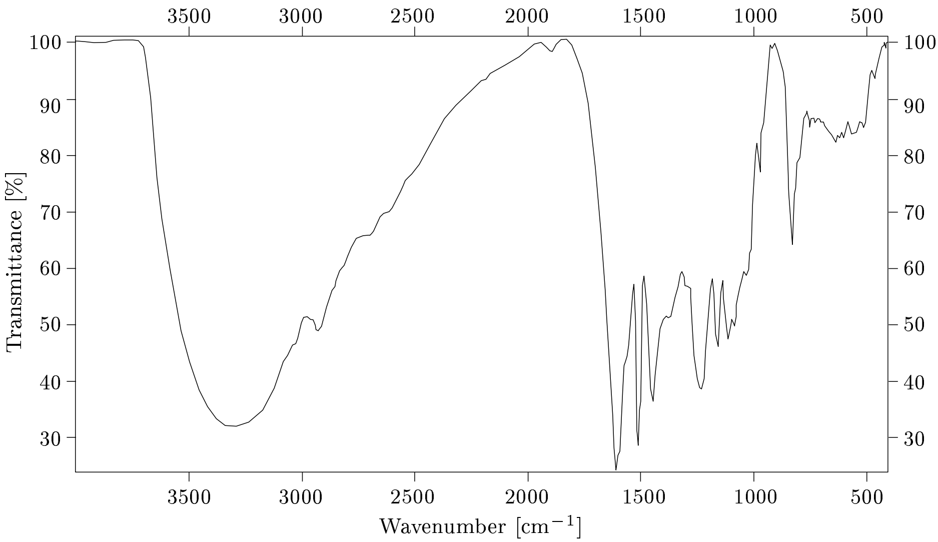

Fig. 4. IR spectrum of the dry residue of substances from the doussie wood soluble in hot water

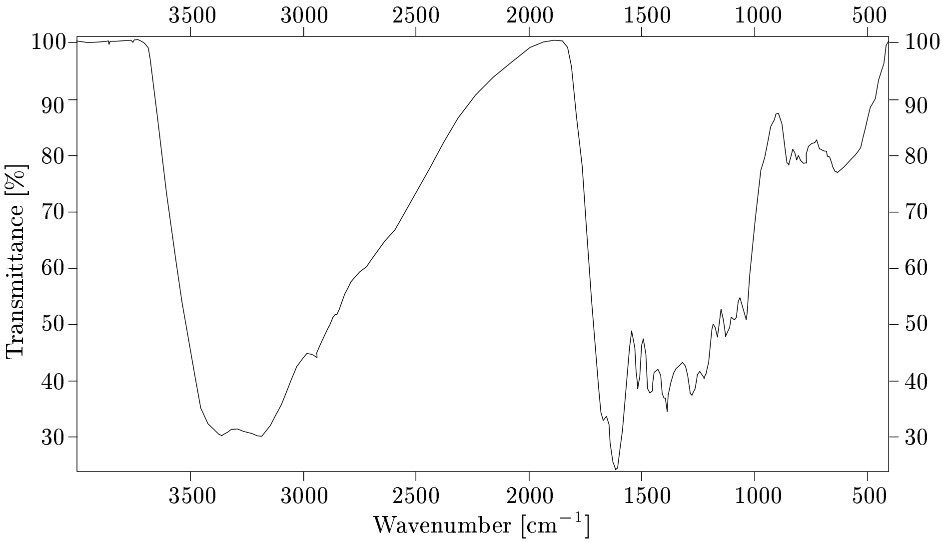

Fig. 5. IR spectrum of the dry residue of substances from the wenge wood soluble in hot water

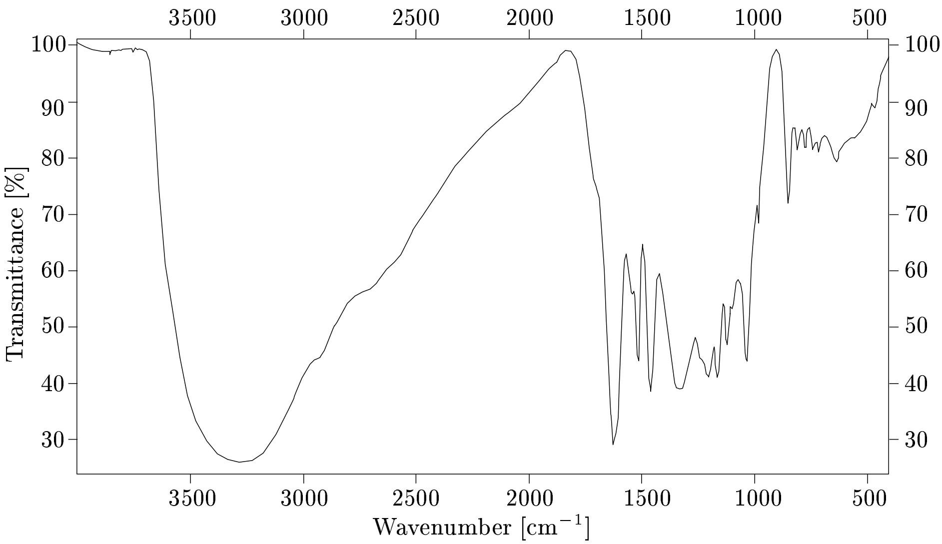

Fig. 6. IR spectrum of the dry residue of substances from the merbau wood soluble in hot water

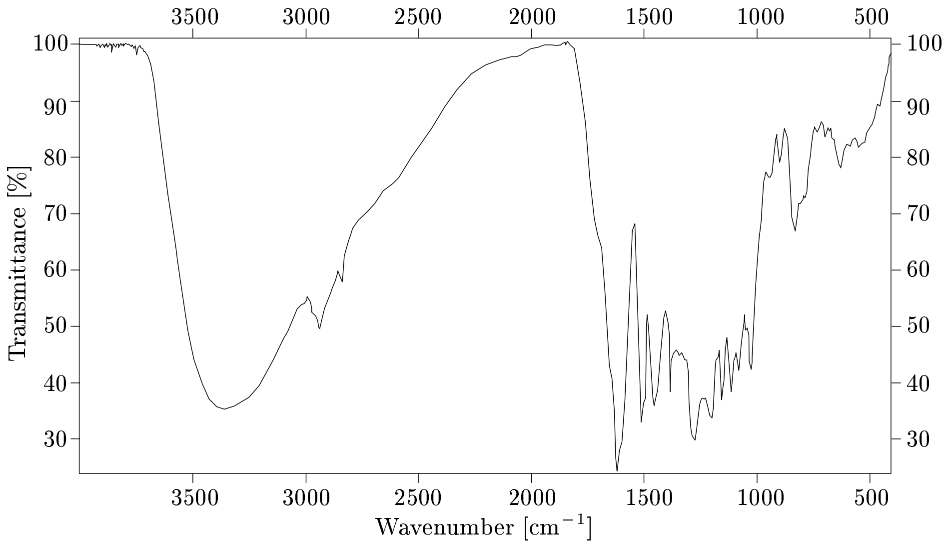

Fig. 7. IR spectrum of the dry residue of substances from the padouk heartwood soluble in hot water

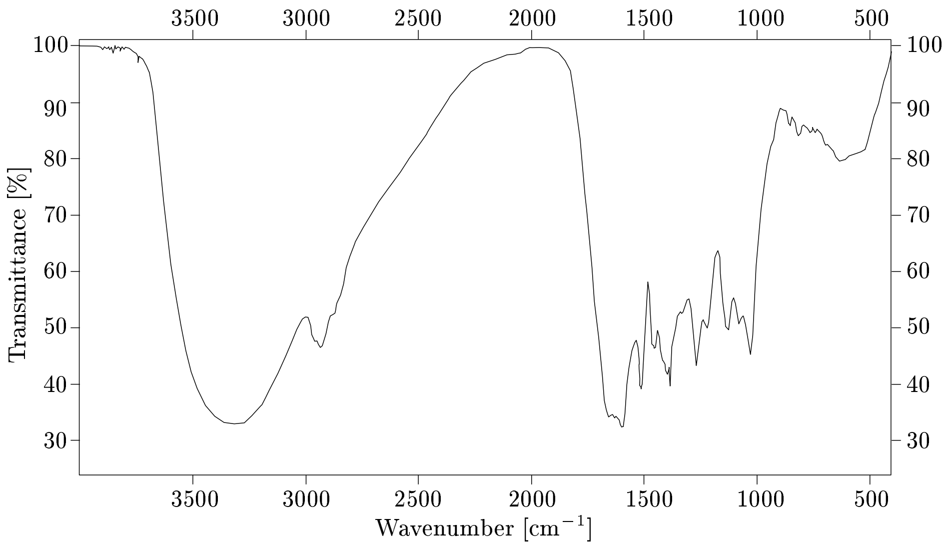

Fig. 8. IR spectrum of the dry residue of substances from the sapwood soluble in hot water

IR spectra of all the examined wood species revealed characteristic absorption bands indicating the presence of aromatic C-H bonds (1511 cm^{-1}), whereas absorption bands ascribed to C-H bending vibrations (1384 cm^{-1}) were found in the case of padouk and wenge species. Additionally, the absorption band at the 774 cm^{-1} wave number, observed only in the wenge wood species can indicate the presence of aromatic, bending C-H vibrations which possess three neighbouring hydrogen atoms.

CONCLUSIONS

1. The amount of substances soluble in cold water found in the examined exotic wood species ranged from 7.47% to 13.35% and of those soluble in hot water – from 9.77% to 25.71%.
2. A very high variation, ranging from 3.87% to 18.51%, was determined in the examined heartwood species in the content of substances extracted by the applied mixture of alcohol-benzene.
3. The shift of the spectrum observed in the UV analysis towards long waves indicates the presence of tannins of condensed nature. The spectral inclination in the form of peaks characteristic for phenolic compounds observed in the majority of the examined wood species occurred at the wave length of about 285 nm.
4. The performed IR spectra analysis in the area from 1500 cm^{-1} to 500 cm^{-1} indicates significant variability and intensity of occurrence of compounds passing to the solution of hot water. Detailed identification requires specialised investigations.

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