

THE RELATIONSHIP BETWEEN TREE HEALTH AND CHEMICAL COMPOSITION OF BEECH (*FAGUS SYLVATICA* L.) AND OAK (*QUERCUS ROBUR* L.) WOOD OF POLISH PROVENANCES*

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Abstract. Analyses of chemical composition of beech (*Fagus sylvatica* L.) and oak (*Quercus robur* L.) wood from healthy and damaged trees have been conducted. Infrared spectra of lignin isolated from the investigated wood have been recorded and analysed. Tree health was determined on the basis of ramification structure of the upper part of the crown according to the Roloff [1989] classification. Beech wood obtained from trees of the ages 80-145 years came from Pomerania and the Carpathians. Oak wood from trees of 84-147 years old came from the Podlasie and Wielkopolska region. The tested wood was cut from the butt-end parts of logs. The chemical composition of the wood, both beech and oak, obtained from trees differing in health levels was very similar. No influence of geographical provenance of beech and oak wood on its chemical composition was observed. The analysis of infrared spectra of lignin samples from oak wood relative to tree health and geographical provenance did not show significant differences. On the other hand, in the case of beech wood, some differentiation in IR spectra of lignin relative to tree health was observed.

Key words: European beech, decline, forest decline, IR spectra, lignin, pedunculate oak, Poland, vitality, wood chemistry

INTRODUCTION

In Poland, pedunculate oak (*Quercus robur* L.) and European beech (*Fagus sylvatica* L.) belong to the most economically and ecologically important species of forest trees. Oak stands cover an area of ca. 500.000 ha, i.e. about 7% of forest area. The share

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of oak in the timber volume of our wood resources amounts to about 6.5% and is smaller only than that of pine and spruce. Forest stands with a share of beech cover an area of ca. 350.000 ha, i.e. about 5% of national forest area. Beech share in the timber volume of our wood resources amounts to 5.6% and is smaller only than that of pine, spruce and oak. Both species cover about 50% of the area of hardwood stands [Budna et al. 2006].

The persistent high level of excessive tree mortality in recent years among hardwood species, especially oak, implies a growth in supply of wood from damaged stands. Results of various research carried out on properties and quality of wood coming from forest damaged areas are ambiguous and sometimes contradictory. However, the opinion prevails that industrial air pollution, regarded as one of the main factors of the weakening health condition of forests in the second half of the 20th century, have no significant influence on the technical properties of the raw material [Liese 1987, Schulz et al. 1988]. On the other hand, Szczepkowski et al. [2004] have proved a significant differentiation in density and compression strength parallel to the grain of beechwood from healthy and damaged trees. They did not find such a relationship in the case of oak wood.

The chemical composition of wood depends not only on tree species but also on many other factors, such as: tree part, age, site conditions, geographical provenance, season of cutting etc. [Prosiński 1984, Samková and Nagyová 1987]. When examining the chemical composition of wood, mainly of coniferous species, coming from forests of industrial regions, usually no influence of industrial air pollution on the content of main wood components was proved [Puls and Rademacher 1986, Fengel and Schulz 1986]. The stress situation of a damaged tree is reflected in the changing content of extractive substances [Liese et al. 1975, Fengel 1987]. Much less extensively the influence of long-term weakening of hardwood trees was investigated, in that oak and beech, in the chemical composition of their wood. Recognition of the chemical composition of wood obtained from hardwood stands of lowered health can be useful for practical utilisation as well as for explanation of differences in the degree of resistance to decline between single trees.

The objective of the research was the determination of the long-term influence of lowered tree crown health on the chemical composition of oak and beech wood obtained from different geographical regions of Poland. This influence was determined by examination and comparison of the chemical composition of wood from trees both healthy and damaged, cut in the same stand or in two different stands but of similar forest characteristics.

MATERIALS AND METHODS

Beech wood (Table 1) was obtained from trees 80-145 years old. The trees represented lowland provenance of beech from Pomerania (Świerzyna Forest District) and a mountain provenance from the Carpathians (Wetlina Forest District). Oak wood (Table 1) was obtained from trees of age 84-147 years. The trees came from the Wielkopolska (Western Poland, Krotoszyn Forest District) and Podlasie regions (North-eastern part of the country, Czarna Białostocka Forest District). From every stand, there were selected two trees of average diameter belonging to the 1st or 2nd Kraft class, of straight stem,

Table 1. Characteristics of beech and oak trees used in the research into the relationship between health and chemical composition of their wood

Tabela 1. Charakterystyka drzew buka i dębu użytych do badań zależności między żywotnością a składem chemicznym ich drewna

Geographical region Kraina geograficzna	Species Gatunek	Forest site type Siedliskowy typ lasu	Mean diameter D_{sr} cm	Age, years Wiek, lata
Pomerania	<i>Fagus sylvatica</i>	Lśw	46.7 ^a , 65.2 ^b	110 ^a , 145 ^b
Carpathians	<i>Fagus sylvatica</i>	LG	38.8	80
Wielkopolska	<i>Quercus robur</i>	Lśw	42.9	147
Podlasie	<i>Quercus robur</i>	Lśw	36.0	105 ^a , 84 ^b

^aHealthy tree, ^bdamaged tree, Lśw – fresh deciduous forest, LG – mountain deciduous forest.^aDrzewo żywotne, ^bdrzewo uszkodzone, Lśw – las świeży, LG – las górski.

without macroscopically visible signs of lowered wood quality (canker, injury and fruiting body). The trees represented two health categories according to the classifications of Roloff [1989] and Dmyterko [1998, 1999]: a healthy tree (degree 0 or 0/1) and a damaged tree (degree 3 or 2/3). The trees were felled in the second half of the vegetation season. From each sample tree there were cut from the butt-end part two 50-cm long bolts, one below, the other above the height of 1.3 m. The bolts were barked and split. Then samples for tests were cut out. Beech wood (without false heartwood) cut out from the middle part of log cross-section was used for the tests. The samples contained 5-7 annual rings per 1 cm. Samples of oak wood were made of outer heartwood. Those from Czarna Białostocka contained 5-7 annual rings per 1 cm while those from Krotoszyn: 3-5 rings per cm. Wood of a relative humidity of 8.5% was divided into small pieces by means of pruning scissors and ground in a grinder Ultra Centrifugal Mill ZM1 produced by the Retsch company to the form of sawdust. After sorting, determination was conducted on the fraction which passed through a sieve of mesh diameter 1 mm and was stopped by a sieve of 0.5 mm.

In the examined material, there were determined:

- extractive substances in Soxhlet apparatus in two stages: by hexane and ethanol
- Klason lignin
- substances soluble in 1% NaOH
- Seifert cellulose
- mineral substances by combustion of organic substances at 600°C.

Analyses b-d were conducted on extracted samples; the relative humidity was determined in the initial material and on the samples after extraction by the oven-dry method.

Transmittance spectra in infrared (FT-IR) of the tested samples were recorded in the range 4000-400 cm^{-1} by the transmission technique. The resolution amounted to 2 cm^{-1} . Powdered samples dried to a constant mass were mixed with powdered KBr of chemical degree of purity in the weight relation 300 mg KBr : 1 mg of sample. Then tablets were produced. A spectrophotometer System 2000 of the Perkin Elmer company was used for the measurements.

RESULTS AND DISCUSSION

The chemical composition of beech wood from trees both healthy and damaged obtained from Pomerania and the Carpathians (Table 2) was very similar and did not differ significantly from the chemical composition of *Fagus sylvatica* L. reported by various authors (Table 3).

In the samples from Pomerania there were found significantly fewer (2-3 times) substances soluble in hexane than in the Carpathian samples. However, based on these results, it is difficult to conclude that there are significant differences in wood composition, and even in extractive substances, as the quantity of them in all of the samples was small (0.4-1.5%) and the total content of extractive substances (sum of those soluble in hexane and ethanol) amounted to 2.6 to 3.5%. Less extractive substances were found in the wood from Pomerania in comparison with those from the Carpathians, but in each case more of such substances were found in wood of damaged trees than in those of healthy ones. Wood of damaged trees contained 6-7% more extractive substances than wood of healthy trees. Growth of the content of those components in trees undergoing stress is confirmed by the results of Liese et al. [1975] researches. The obtained values of extractive substances differ from the literature data (Table 3), but it should be emphasized that in the research different solvents were used than those mentioned in the literature and the extraction was conducted in two stages, thereby taking about twice as much time. Other components of the examined wood: cellulose, lignin and substances soluble in 1% NaOH, were on a similar level in all samples and it is difficult to find any differences.

Table 2. Chemical composition of wood of healthy and damaged beech trees from Pomerania and the Carpathians, %

Tabela 2. Skład chemiczny drewna buka żywotnego i obumierającego pochodzących z Pomorza i Karpat, %

Specification Wyszczególnienie	Pomerania – Pomorze		Carpathians – Karpaty	
	tree vitality grade – stopień żywotności drzew			
	healthy żywotne	damaged uszkodzone	healthy żywotne	damaged uszkodzone
Substances washed out by hexane Substancje wymyte heksanem	0.4	0.5	1.5	1.2
Substances washed out by alcohol Substancje wymyte alkoholem	2.2	2.3	1.7	2.3
Total extractive substances Razem substancje ekstrakcyjne	2.6	2.8	3.3	3.5
Seifert cellulose Celuloza Seiferta	49.5	48.6	49.4	46.0
Klason lignin Lignina Klasona	23.3	22.4	21.7	23.8
Substances dissolved in 1% NaOH Substancje rozpuszczone w 1% NaOH	20.7	19.3	19.3	19.6
Mineral substances Substancje mineralne	0.1	1.1	1.1	1.2

Table 3. Chemical composition of beech and oak wood according to various authors
Tabela 3. Skład chemiczny drewna bukowego i dębowego według różnych autorów

Specification Wyszczególnienie	Nečasny 1958		Olszewski 1975	Prosiński 1984	Fengel, Wegener 1989	Prosiński 1984	Fengel, Wegener 1989	
Species or genus Gatunek lub rodzaj	<i>Fagus sylvatica</i>				<i>Quercus</i>	<i>Quercus</i>		
Zone Strefa	sapwood biel	heart- wood twardziel		without division bez podziału			sapwood biel	heart- wood twardziel
Cellulose Celuloza	56.8	55.8	50.6	40.0-53,4	49.1	46.6	40.5	37.6**
Pentosanes Pentozany	8.2	15.9	16.7	21.1-29.3	22.0	22.6-22.8	17.5	–
Lignin Lignina	22.9	24.9	19.8	20.8-23.8	23.8	23.5-23.8	22.2	24.5
Extractive substances* Substancje ekstrakcyjne*	–	–	–	0.3-0.5	0.8	5.9	2.4	4.4
Mineral substances Substancje mineralne	–	–	0.3-1.0	0.3-1.0	0.3	0.2-0.7	0.5	0.3

*Substances dissolved in alcohol-benzene 1.4%, **Kürschner-Hoffer cellulose.

*Substancje rozpuszczone w alkoholu-benzenie 1,4%, **celuloza Kürschner-Hoffer.

Substances dissolved in 1% NaOH are mainly hemicelluloses. Their quantity determined in the tested samples amounted to 19.3-20.7%. Prosiński [1984] reports that beech wood contains 22.1% of hemicelluloses. As can be seen, these values are comparable. On the other hand, Fengel and Wegener [1989] report that wood of *Fagus sylvatica* contains 22% of pentosanes (Table 3). To hemicelluloses belong not only pentosanes but also hexosanes. However, the share of hexosanes in relation to pentosanes is not great. According to Surewicz [1971], in hardwood hemicelluloses constitute 23-28%, hexosanes 2-5% and pentosanes 21-25%.

The contents of the basic components of oak wood from healthy and damaged trees from the Podlasie and Wielkopolska regions (Table 4) differ neither between each other nor in relation to the literature data (Table 3). Similarly as in beech wood, also in oak wood some differences were observed in quantities of extractive substances contained in wood of healthy and damaged trees. These differences in absolute values are rather small – only about 2%, but the content of extractive substances in wood is usually on a level of several percent. If we assume the content of these substances in healthy wood as 100%, then in the wood of damaged tree from the Wielkopolska region there is about 60% more of them. Meanwhile in the wood of damaged tree from the Podlasie region

Table 4. Chemical composition of wood of healthy and damaged oak trees from the Podlasie and Wielkopolska regions, %

Tabela 4. Skład chemiczny drewna dębu żywotnego i obumierającego pochodzących z Podlasia i Wielkopolski, %

Specification Wyszczególnienie	Podlasie region Podlasie		Wielkopolska region Wielkopolska	
	tree vitality grade – stopień żywotności drzew			
	healthy żywotne	damaged uszkodzone	healthy żywotne	damaged uszkodzone
Substances washed out by hexane Substancje wymyte heksanem	0.3	1.0	0.4	0.9
Substances washed out by alcohol Substancje wymyte alkoholem	4.5	2.0	2.7	4.1
Total extractive substances Razem substancje ekstrakcyjne	4.8	3.0	3.1	5.0
Seifert cellulose Celuloza Seiferta	41.4	45.5	42.1	39.5
Klason lignin Lignina Klasona	22.2	22.2	22.8	25.5
Substances dissolved in 1% NaOH Substancje rozpuszczone w 1% NaOH	23.0	22.2	24.2	25.3
Mineral substances Substancje mineralne	0.4	1.0	1.7	0.5

there was about 60% less of them than in the wood of a healthy tree. A hypothetical reason for such a situation can be the age differentiation of these two provenances and resulting from it a different length of decay period: long in the Wielkopolska region and relatively short in the Podlasie region. Similarly as in beech wood, the content of extractive substances in the tested samples differed from the content given in the literature, but it probably results from the fact that the literature gives substances dissolved in alcohol-benzene and in the tested samples they were dissolved in hexane and ethyl alcohol to avoid harmful benzene in analysis. Other components in particular samples are at similar levels (differences did not exceed several percent) and they do not allow us to conclude that there is an influence of external factors on the chemical composition of the wood. The only exception is the content of mineral substances (1.7%) in wood of healthy tree from the Wielkopolska region. When assuming that usually there is about 1% of mineral substances in wood, it must be admitted that in this wood there was more of them. Probably this result could have been affected by the local site conditions in which the tree grew. This result does not justify drawing more general conclusions; the content of mineral substances in wood of damaged tree from the same stand amounted to 0.5%.

As no differences in the basic composition of the analysed wood were found, it was decided to conduct a more detailed analysis of some components. Phenol substances determine the resistance of wood to external factors. These compounds enter into the composition of extractive substances but they also constitute lignin, the main compo-

ment of every wood [Sjöström 1981, Fengel and Wegener 1989]. Therefore a search for differences in lignin structure was undertaken. Infrared spectra of these samples were recorded. This method is used, among other things, to recognize the structure of compounds, and to prove the presence of bonds and functional groups. The presented spectra can be used mainly in a qualitative comparison of lignin coming from healthy and damaged trees from different regions of the country because the optical distance passed by a falling beam depended on the tablet thickness and this was not determined. However, comparison of corresponding intensities of the same bands provides information on quantitative differences in particular samples.

IR spectra of lignin from healthy and damaged beech trees coming both from Pomerania (Fig. 1) and the Carpathians (Fig. 2) have similar characteristics. In these spectra, there are visible bands typical of lignin, but there occur also atypical bands. The atypical bands can testify to an admixture of other wood components in lignin samples, e.g. hemicelluloses. It is also possible that the lignin underwent some chemical transformations during its extraction from the wood.

In the range $3700\text{--}3000\text{ cm}^{-1}$ there occurs a wide band responsible for O-H stretching. These bands come from vibration of water particles and other OH groups contained in the tested samples. Generally speaking, O-H stretching of hydroxide groups attached to aliphatic chains have higher wave numbers than those of -OH groups attached directly to a ring (phenol). In a similar range (about $2800\text{--}3100\text{ cm}^{-1}$), there occur sharp bands characteristic of C-H stretching. They are present in all spectra and appear against a background of wide bands of O-H vibrations. These are bands 2940 cm^{-1} and 2833 cm^{-1} responsible for -CH stretching of methyl and methylene groups in guaiacyl-syringyl units [Hergert 1971, Fengel and Wegener 1989]. The band 2832 cm^{-1} is visible in lignin samples from Pomerania and is similar 2936 cm^{-1} and 2069 cm^{-1} in samples

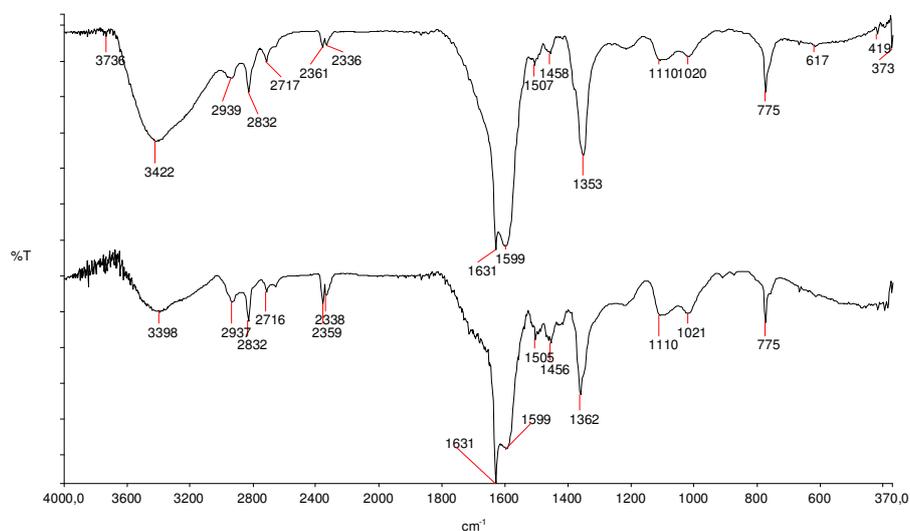


Fig. 1. IR spectra of lignin from beech trees from Pomerania: the upper spectrum from wood of a healthy tree, the lower spectrum from wood of a damaged tree

Rys. 1. Widma IR ligniny drewna buka pochodzącego z Pomorza: górne widmo z drewna drzewa witalnego, dolne widmo z drewna drzewa obumierającego

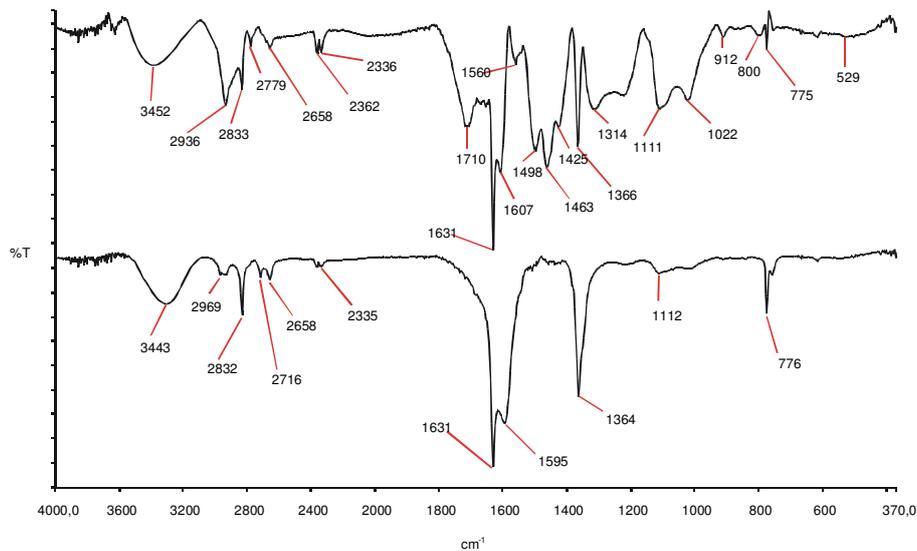


Fig. 2. IR spectra of lignin from beech trees from the Carpathians: the upper spectrum from wood of a healthy tree, the lower spectrum from wood of a damaged tree

Rys. 2. Widma IR ligniny drewna buka pochodzącego z Karpat: górne widmo z drewna drzewa witalnego, dolne widmo z drewna drzewa obumierającego

from the Carpathians. The band 2832 cm^{-1} occurs in all spectra. The band 1631 cm^{-1} visible in all spectra comes from vibrations of C=O groups and is not a band typical of lignin. Fengel and Wegener [1989] report that the bands most characteristic of lignin isolated from wood in acid medium are located in the ranges 1600 cm^{-1} and 1510 cm^{-1} ; these are vibrations of aromatic rings. Hergert [1971] makes this information more precise by stating that bands 1605 cm^{-1} and $1515\text{--}1510\text{ cm}^{-1}$ are generated from guaiacyl units while 1595 and 1505 cm^{-1} – by guaiacyl-syringyl ones. Bands of wavenumber 1600 cm^{-1} , even though with slight shifts, were found in all the investigated samples. However, these shifts do not allow us to determine the lignin structures. The band 1505 cm^{-1} is visible in samples from Pomerania (Fig. 1) both in the lignin of the healthy and damaged trees. This can testify to the existence of guaiacyl-syringyl units. Such a band was not found in lignin coming from the Carpathians. The band situated the closest to this wavenumber, both in the lignin from healthy and damaged trees, was the band 1498 cm^{-1} . The bands in the range $1450\text{--}1420\text{ cm}^{-1}$ are possible to recognize also as vibrations of aromatic rings (skeleton vibrations) [Hergert 1971]. The band 1425 cm^{-1} visible in all spectra, even though with shifts, is probably generated by guaiacyl-syringyl units. The next band present in the spectra of all tested lignin (except for the sample from a damaged tree from the Carpathians) is the band 1458 cm^{-1} which is generated as an effect of C-H asymmetric deformations which can occur both in guaiacylpropane and guaiacyl-syringyl units. The band 1366 cm^{-1} created by C-H symmetric deformation is visible in both samples from the Carpathians while in the samples from Pomerania they are slightly shifted (1362 and 1353 cm^{-1}). Bands 1110 and 1020 cm^{-1} even though not described in the literature concerning lignin are visible in all tested samples except for the

sample from damaged trees from the Carpathians. Uncoupled p-hydroxyphenylpropane, guaiacyl and syringyl units generate a series of two or three bands in the range 900-750 cm^{-1} . These bands are generated from out of plane deformation of C-H groups of aromatic compounds. In all tested samples the band 775 cm^{-1} is distinct, while the band 800 cm^{-1} is visible only in lignin from the Carpathians. Overlaying of the four above-presented IR spectra of lignin samples (from wood of healthy and damaged beech trees both from Pomerania and the Carpathians) has shown that the IR spectrum of lignin from healthy beech tree from the Carpathians in the range 1400-1550 cm^{-1} contains three intensive bands (1498, 1463, 1425 cm^{-1}) which distinguish this sample from three others in which the same bands have a very low intensity. It indicates the presence of the same atom groups but in the case of the lignin sample from a healthy beech tree from the Carpathians there are many more of them. This observation requires confirmation by recording next IR spectra of other samples of lignin from healthy beech trees from the Carpathians.

IR spectra of lignin isolated from wood of healthy and damaged oak trees are shown in Figure 3 (from the Wielkopolska region) and Figure 4 (from the Podlasie region). In all spectra, wavenumbers and intensities of band occurrence are very similar, which testifies to a similar structure of the examined lignin. The band 3436 cm^{-1} in lignin from a healthy tree from the Wielkopolska region and 3412 cm^{-1} in lignin from a damaged tree arose probably as a result of stretching -OH in guaiacyl-syringyl units [Hergert 1971]. In the sample of lignin obtained from a healthy tree from the Podlasie region it is somewhat shifted (3317 cm^{-1}). The next band 2938 cm^{-1} visible in all four spectra is generated from stretching -OH in the methyl and methylene groups. Vibrations of the same groups caused the occurrence of band 2840 cm^{-1} which also is present in all spectra. The band 1721 cm^{-1} (present in all spectra as well) corresponds to stretching of

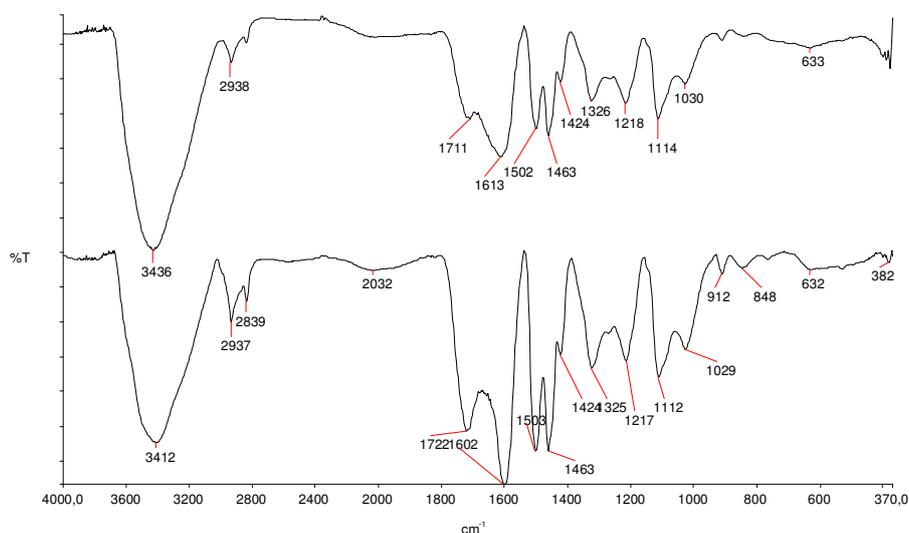


Fig. 3. IR spectra of lignin from oak trees from the Wielkopolska region: the upper spectrum from wood of a healthy tree, the lower spectrum from wood of a damaged tree

Rys. 3. Widma IR ligniny drewna dębu z Wielkopolski: górne widmo z drewna drzewa witalnego, dolne widmo z drewna drzewa obumierającego

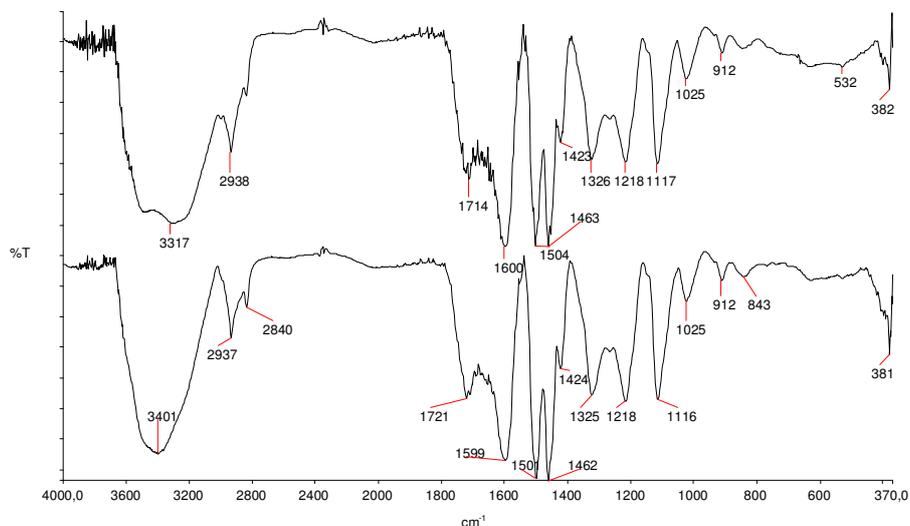


Fig. 4. IR spectra of lignin of oak trees from the Podlasie region: the upper spectrum from wood of a healthy tree, the lower spectrum from wood of a damaged tree

Rys. 4. Widma IR ligniny drewna dębu z Podlasia: górne widmo z drewna drzewa vitalnego, dolne widmo z drewna drzewa obumierającego

uncoupled carbonyl groups in ketones and carboxyl groups. The band 1598 cm^{-1} visible in both lignin from the Podlasie region is attributed to vibrations of aromatic rings; in the samples from the Wielkopolska region, especially in lignin from the healthy tree, it is shifted. The same rings of guaiacyl-syringyl units generated the band 1501 cm^{-1} which can be seen in all spectra. At the same time the band 1463 cm^{-1} is generated from C-H asymmetric deformation, but in guaiacyl units; this band also occurs in all spectra. The band 1325 cm^{-1} , also visible in four spectra, generated from skeleton vibrations of syringylpropane units. The bands: 1217 and 1218 cm^{-1} as well as 1112 - 1117 cm^{-1} and 1025 - 1030 cm^{-1} in corresponding spectra are not typical of lignin. At the same time the bands 900 - 750 cm^{-1} are generated from C-H out of plane deformations of aromatic compounds. In all the tested samples they have similar characteristics. A comparison of IR spectra of lignin samples from healthy and damaged oak trees from the Podlasie and Wielkopolska regions did not show significant differences.

CONCLUSIONS

The obtained results of the research into the chemical composition of beech and oak wood from healthy and damaged trees have not unequivocally proved an influence of geographical provenance or tree health on the content of particular components.

The fact that in the beech wood from the damaged trees there were found more extractive substances than in the wood from the healthy trees seems logical, as these substances influence in a decisive way the durability and resistance of the wood. Thus damaged trees protected from disadvantageous external conditions produce more extrac-

tive substances than healthy ones. However, in the case of oak wood, this relationship occurred only in the samples from the Wielkopolska region. At the same time, wood from the Podlasie region showed a reverse relationship, i.e. there was proved a higher content of extractive substances in wood from a healthy tree than in that from a damaged one.

On the basis of IR spectra analysis of lignin from healthy and damaged trees, both *Fagus sylvatica* and *Quercus robur*, it can be stated that the identified structures are typical of lignin from hardwoods. One cannot however draw a conclusion on this basis about differences in structure caused by the factors such as lowered tree health in the case of samples from oak. On the other hand, such a differentiation can be observed in the case of samples representing beech.

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ZALEŻNOŚĆ MIĘDZY ŻYWOTNOŚCIĄ POLSKICH PROWENIENCJI BUKA (*FAGUS SYLVATICA* L.) I DĘBU (*QUERCUS ROBUR* L.) A SKŁADEM CHEMICZNYM ICH DREWNA

Streszczenie. Przeprowadzono badania składu chemicznego drewna bukowego (*Fagus sylvatica* L.) i dębowego (*Quercus robur* L.) z drzew witalnych i uszkodzonych. Zarejestrowano i przeanalizowano widma IR ligniny wyodrębnionej z próbek badanego drewna. Żywotność drzew określono na podstawie struktury ugałęzienia górnej części korony według klasyfikacji Roloffa [1989]. Drewno bukowe pozyskane z drzew w wieku 80-145 lat pochodziło z Pomorza i Karpat. Drewno dębowe z drzew w wieku 84-147 lat pochodziło z Podlasia i Wielkopolski. Badane drewno wyrobiono z odziomkowej części kłód. Skład chemiczny drewna, zarówno bukowego, jak i dębowego, pochodzącego z drzew różniących się stopniem żywotności był bardzo zbliżony. Nie zauważono wpływu pochodzenia geograficznego drewna bukowego i dębowego na jego skład chemiczny. Analiza widm IR ligniny z próbek drewna dębowego w zależności od witalności drzew i pochodzenia geograficznego nie wykazała istotnych różnic. Zauważono pewne zróżnicowanie widm IR ligniny w próbkach drewna bukowego w zależności od witalności drzew.

Słowa kluczowe: buk zwyczajny, dąb szypułkowy, lignina, Polska, widma IR, skład chemiczny drewna, witalność drzew, zamieranie

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