REVIEW PAPER

Medicinal properties of fungi occurring on *Betula* sp. trees. A reviewJOANNA SMOLIBOWSKA¹, MARCIN SZYMAŃSKI^{*1}, ARKADIUSZ SZYMAŃSKI²

¹Department of Pharmacognosy
Poznan University of Medical Sciences
Święcickiego 4
60–781 Poznań, Poland

²Faculty of Chemistry
Adam Mickiewicz University
Umultowska 89
61-614 Poznań, Poland

*corresponding author: phone: +48618546703, e-mail: mszymanski@ump.edu.pl

S u m m a r y

The article presents the chemical constituents and pharmacological properties of polypore fungi found on birch, namely *Piptoporus betulinus*, *Inonotus obliquus*, *Lenzites betulina*, *Fomes fomentarius*, and *Trametes versicolor*. The *in vitro* and *in vivo* studies on the effect of different extracts from above-mentioned fungi on the human organism shown anti-cancer, anti-inflammatory, antiviral, antibacterial and immunostimulant activity, conditioned by the presence of such compounds as polysaccharides, polyphenols or terpenes. These fungi are commonly found in Poland and may superbly compete with *Ganoderma lucidum* (Reishi) or *Lentinula edodes* (Shitake) used in Asia for medicinal purposes.

Key words: *polypore fungi fruiting bodies, Piptoporus betulinus, Inonotus obliquus, Lenzites betulina, Fomes fomentarius, Trametes versicolor*

INTRODUCTION

The kingdom of fungi is a huge group of organisms which differ in their structure, coloration, nutrition, proliferation, and concentrations of chemical compounds.

Polyporoid fungi are often viewed as harmful through the prism of the damages that they cause in such industries as forestry, fruit-farming, construction, transport or telecommunications. With the use of the enzymes they produce, they decompose cellulose, hemicellulose and lignin, leading to disintegration of wood cells and occurrence of dry rot [1]. On the other hand, however, they constitute a rich source of biologically active compounds, extremely important for humans. Many undervalued species of polyporoid fungi growing mainly on birch that show medicinal properties can be found in Poland. Such compounds as polysaccharides [2-8], polyphenols [6, 9], triterpenes [6, 10, 11] which are contained in them demonstrate positive influence on the human organism; they mainly exhibit anticancer [4, 5, 9, 12-15], anti-inflammatory [16, 17], anti-bacterial [18] and immunostimulant [2, 7, 19] activity.

Numerous studies are being conducted in order to explain their medicinal activity as well as to investigate the active compounds conditioning the activity.

Piptoporus betulinus

Piptoporus betulinus (Bull.) P. Karst. is common in the woods and parks, preferably in wet habitats. It grows on dead or weak trunks of birch tree (*Betula* sp.) [1].

An analysis of the fruiting bodies of *P. betulinus* showed the following composition: fatty acids: lauric (4.8% of the sample), myristic (2.2%), palmitic (13.1%), stearic (4.6%), tetracosanoic (1.7%), palmitoleic (1.8%), oleic (8.2%), linolenic (63.6%), as well as ergosterol peroxide (0.29%) and dehydroergosterol peroxide (0.05%), polyporenic acid C (fig. 1) (0.44%), α,α' -trehalose (4.28%), D-mannitol (2.14%), D-arabinitol (21.18%) [20].

Figure 1.
Polyporenic acid C

The constituents of *P. betulinus* that account for antioxidative properties include: phenolic acids, organics, flavonoids, tocopherols, and vitamins [6, 21]. Phenolic acids include *p*-hydroxybenzoic, protocatechuic, and vanillin acids [6].

The following vitamins and carotenoids were also determined: α -tocopherol, β -tocopherol, γ -tocopherol, δ -tocopherol, ascorbic acid and minor amounts of β -carotene and lycopene. The highest concentrations were found for β -tocopherol (302 $\mu\text{g}/100\text{ g}$) and γ -tocopherol (254 $\mu\text{g}/100\text{ g}$) [21].

Water-soluble polysaccharides with an α -(1 $\rightarrow$ 3)-D linkage, of anti-tumor properties are also present [22].

Ergosterol peroxide (described for *Inonotus obliquus*) shows anti-tumor and immunomodulating effects, fatty acids are able to control lipid management and mannitol is able to protect the colon against cancer [20, 23, 24].

An anti-inflammatory effect is shown by lanostanoids: 3 α -acetylpolyporenic acid A, (25S) - (+) - 12 α - hydroxy - 3 α - methylcarboxyacetate - 24 - methyl- lanosta - 8,24(31) - diene - 26-oic acid, lanostanoid and polyporenic acid C. The above-mentioned compounds show anti-inflammatory effect by affecting hyaluronidase. They also show slight inhibition of the pro-inflammatory COX-1 factor. A comparison of their activity with that of indometacin and its effect on 3 α -hydroxysteroid dehydrogenase, it appears that their anti-inflammatory effect is similar to that of indometacin, if not more pronounced. The value of IC_{50} ($\mu\text{g}/\text{ml}$) of indometacin in the presence of 3 α -HSD is 6.5 and the test compounds have the following IC_{50} : polyporenic acid C 17.5; 3 α -acetylpolyporenic A 8.5; lanostanoid 5.5; (25S) - (+) - 12 α - hydroxy - 3 α - methylcarboxyacetate - 24 - methyl- lanosta - 8,24(31) - diene - 26 - oic acid merely 4.0, which makes it the most effective among the compounds in this comparison. Each of them is of considerable anti-inflammatory effect. In respect of inhibition of the activity of hyaluronidase, the above-mentioned compounds showed a satisfactory inhibitory activity towards bacterial hyaluronidase (from *Streptococcus agalactiae*), the efficacy of (25S) - (+) - 12 α - hydroxy - 3 α - methylcarboxyacetate - 24 - methyl- lanosta - 8,24(31) - diene - 26 - oic acid proved to be the highest of all [17]. Polyporenic acid C also has an anti-tumor effect, combining inflammatory inhibition and inducing apoptosis. After examining its effect on nonsmall lung cancer cells (A549 cells), it appeared to satisfactorily inhibit cell division depending on dosage: 60 μM of the acid reduced cell proliferation by 50%, 200 μM did by as much as 90%. Moreover, it induces apoptotic processes as early as in the caspase-mediated stages [15].

Piptamine (fig. 2) is an antibiotic found in *P. betulinus*. Minimum inhibitory concentration (MIC) tests were performed for its extract in the presence of selected microbial cultures. The values of MIC ($\mu\text{g}/\text{ml}$) were as follows: *Staphylococcus aureus* 134/94 - 6.25; *S. aureus* SG 511 - 0.78; *Enterococcus faecalis* 1528 - 1.56; *Bacillus subtilis* ATCC 6633 - 1.00; *Escherichia coli* SG 458 - 12.5; *Rhodotorula rubra* IMET 25030 - 50.0; *Kluyveromyces marxianus* IMET 25148 - 6.25; *Candida albicans* BMSY 212 - 6.25; *Sporobolomyces salmonicolor* SBUG 549 - 6.25; *Penicillium notatum* JP 36 > 50.0. The findings indicate that the *P. betulinus* extract is useful for microbial control and demonstrate its antibacterial properties; specifically, notable MIC results were obtained for *S. aureus* SG 511 and for *E. faecalis* [18].

Figure 2.

Piptamine

Inonotus obliquus

Inonotus obliquus, widespread in North America, Europe, and Asia, is the most thoroughly investigated [10]. The constituents of the fruiting bodies of *I. obliquus* include lanostane-type triterpenes: inotodiol (fig. 3), trametenolic acid (fig. 4), 3 β -hydroxylanosta-8,24-dien-21-al, 3 β ,22,25-trihydroxylanosta-8,23-diene, 3 β -hydroxylanosta-8,24-diene-21,23-lactone, 21,24-cyclopentalanost-8-ene-3 β ,21,25-triol, and lanost-8-ene-3 β ,22,25-triol, lanosterol, inonotsuoxides A and B, inonotsulides A, B, and C, inonotsutriols A, B, C, D and E [11] and inonotusols A, B, C, D, E, F, G and abietane-type diterpene – inonotusic acid [25].

Figure 3.

Inotodiol

Figure 4.

Trametenolic acid

Low-molecular polyphenolics were isolated from *I. obliquus*, including caffeic acid (3,4-dihydroxycinnamic acid), 3,4-dihydroxybenzalacetone (DBL), protocatechuic acid (3,4-dihydroxybenzoic acid), gallic acid (3,4,5-trihydroxybenzoic acid), syringic acid (4-hydroxy-3,5-dimethoxybenzoic acid), 3,4-dihydroxybenzaldehyde, and 2,5-dihydroxyterephthalic acid. While all of the above-mentioned polyphenolics have an inhibitory effect on topoisomerase II, those showing the highest activity (caffeic acid and 3,4-dihydroxybenzalacetone) inhibit the activity of topoisomerase I as well. Nowadays, compounds used in oncology, such as irinotecan, topotecan, etoposide, as well as amsacrine, doxorubicin, and streptogrin are also inhibitors of topoisomerase I or II. The presence of polyphenol

with a similar mechanism of action indicates anti-tumor properties of the extract of *I. obliquus* [9].

Triterpenes exhibit anti-tumor properties: directly inhibit cancer cell proliferation in two mechanisms: they are responsible for the G0/G1-phase arrest of cancer cells (the cells are unable to diversify or divide) [12] and start the neoplastic cell apoptosis [13]. In *in vitro* assays, inonotusol F and inonotusic acid showed hepatoprotective effect [25].

Xylogalactoglucan – a polysaccharide showing activity towards neoplastic cells, enhancing the activity of NK cells and macrophages – was isolated from *I. obliquus*. The polysaccharide fractions showing the highest activity originate from *mycelium*. The free-radical scavenging effect towards oxygen radicals and non-oxygen radicals was attributed to polysaccharides. High molecular β -glucans with β -(1 $\rightarrow$ 3) and β -(1 $\rightarrow$ 6) links in their chains show activity toward inhibition of tumor growth as well as toward the immunological system, thus inhibiting inflammatory conditions [2].

n-Hexane extracts (where lanosterol is of a specifically strong effect) of *Inonotus* are able to stop the neoplastic process in Walker 256 carcinosarcoma cells [26], MCF – 7 human mammary adenocarcinoma cells [27], P 388 leukemic cells. The components of the anti-tumor effect also include the ability to inhibit the inflammatory process. Inhibition of the effect of nitrogen oxide (NO) and cytokines (TNF- α , IL-1b, IL-6) was caused by the above-mentioned triterpenes (lanosterol, 3-hydroxy-8,24-dien-21-al, inotodiol, trametenolic acid) and steroids: ergosterol and ergosterol peroxide. The strongest anti-inflammatory effect was observed for trametenolic acid and ergosterol peroxide.

A methanolic extract of *Inonotus* (MEIO) has an anti-inflammatory and analgesic effect, reducing the level of NO synthase (iNOS) and COX – 2, thus resulting in suppressed nuclear factor-kappaB (NF-kappaB), which accounts for inflammatory conditions [16, 28]. A water extract from *I. obliquus* is reported to have a virucidal effect towards hepatitis C virus and to reduce its infective properties very fast [29]. After investigating diabetic mouse models, the mice showed much lower glycaemia, elevated insulin levels, and a positive effect on glucose levels (increased insulin capture of glucose) after the administration of *Inonotus* extract (DMCB). The same extract was observed to reduce total cholesterol, triglycerides and the volume of free fatty acids, while contributing to higher HDL levels in the livers of diabetic mice. This shows that *I. obliquus* has hypoglycemic properties and prevents lipid peroxidation; the effect is attributable to the melanin complex it produces [30, 31].

Lenzites betulina

Lenzites betulina (L.) Fr. is a species of fungus growing in deciduous and mixed tree stands. It can be found on trunks and dead stumps (rarely living ones, too),

mainly those of oak, birch, beech and alder. Outside forests, it colonises utility wood, such as fences and posts [1].

Olennikov *et al.* determined the content of fatty acids in the fructification of *L. betulina*. They extracted dried fructification in a Soxhlet extractor at a temperature of 70°C for 10 hours with the use of a mixture of chloroform and methanol (2:1). The solvent was evaporated on a rotary evaporator in order to obtain the lipid fraction, and, subsequently, esterised by saponification with use of 0.5 N methanolic NaOH and transesterification with BF_3 14% (v/v) in methanol. The mixture obtained was analysed by gas chromatography equipped with a mass selective detector. As a result of the analysis the following were determined: C12:0 – 0.2%; C14:0 – 1.0%; C15:0 – 0.8%; C16:0 – 14.4%; C17:0 – 0.5%; C18:0 – 6.3%; C20:0 – 8.0%; C22:0 – 6.3%; C23:0 – 0.3%; C24:0 – 4.0%; C25:0 – 1.0%; C16:1 ω 7 – 0.9%; C18:1 ω 7 – 2.2%; C18:1 ω 9 – 18.7%; C18:2 ω 6 – 34.1%; Σ SFA – 42.8%; Σ UFA – 55.9%; oil yield – 0.98 g/100 g dry fruit body [32].

Betulinans A and B (Fig. 5), isolated from the methanolic extract from the fructification of *L. betulina*, inhibited lipid peroxidation. The IC_{50} values were 0.46 and 2.88 $\mu\text{g/ml}$, respectively. Betulinan A was approximately four times more active than vitamin E [33-37].

Figure 5.

Betulinan A and B

The following were isolated from the ethanol extract from *L. betulina*: 2-methoxy-3,6-diphenyl-4H-pyran-4-one, named betulinan C, along with three already known compounds: 5 α ,8 α -epidioxy-22,E-ergosta-6,22-dien-3 β -ol, β -sitosterol and ergosta-7,22-dien-3-one. Their structures were determined by spectral data analysis [38].

The effect of various doses of the aqueous extract from *L. betulina* on the blood glucose level in ICR mice (*Mus musculus*) was investigated. 16.7 mg/kg of glimepiride was administered to Group A (positive control); distilled water was administered to Group B (negative control); 200 mg/kg of the aqueous extract was administered to Group C (low dose); 400 mg/kg of the aqueous extract was administered to Group D (half the dose) and 800 mg/kg of the aqueous extract was administered to Group E (high doses). All the investigated extracts caused normalisation of the blood glucose level in the mice [39].

In order to assess the antibacterial activity of the ethanol, petroleum ether and aqueous extracts from *L. betulinus*, studies on their influence on certain bacterial strains of *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Proteus vulgaris*, *Klebsiella pneumonia* and *Escherichia coli* were conducted. Thanks to the presence of phenolic compounds, tannins, flavonoids and saponins in the examined extracts, effectiveness of their activity as antimicrobial agents was demonstrated. Therefore, they may be applied also as substitutes of known antibiotics [40].

The ethanol extract from the fructification of *L. betulinus* showed significant antioxidant activity (determined by the method with DPPH). The hydroxyl radical scavenging effect was comparable to that of butylated hydroxytoluene (BHT), which was used as the control sample. Moreover, the extract from the mushroom was able to inhibit growth of the following microorganisms: *Candida albicans* (MIC= 12.5 mg/ml); *Cryptococcus neoformans* (12.5); *Bacillus cereus* (100); *Bacillus subtilis* (50); *Staphylococcus aureus* (100); *Shigella dysenteriae* (100); *Salmonella typhimurium* (50); *Alcaligenes faecalis* (12.5) [41].

Oyetayo *et al.* determined the total content of polyphenols (by the method with the Folin-Ciocalteu reagent), the antioxidant activity (by the following methods: with DPPH, inhibition of the formation of thiobarbituric acid reactive species (TBARS), and the protein-binding dye sulforhodamine B (SRB)) and *in vitro* cytotoxicity (on U251 cell lines (human glioblastoma), PC-3 cell lines (human prostatic adenocarcinoma), K562 cell lines (human chronic myelogenous leukemia), HCT-15 cell lines (human colorectal adenocarcinoma), MCF-7 cell lines (human breast cancer cell line) and SKLU-1 cell lines (human lung adenocarcinoma) of the hexanolic (LHE), ethyl acetate (LEA) and ethanol (LET) extracts from the fructification of *L. betulina* collected in south-western Nigeria.

The ethanol extract containing the most polyphenols exhibited the strongest antioxidant activity. The inhibition of the human cancer cell growth has been presented in table 1 [42].

Table 1.

Cytotoxic effects (%)^a of *L. betulina* extracts on human cancer cell lines [42].

Extracts	U251	PC-3	K562	HCT-15	MCF-7	SKLU-1
LHE	NA	NA	41.85	17.65	37.93	25.15
LEA	NA	23.55	NA	NA	NA	NA
LET	NA	11.65	3.50	22.00	22.31	14.28

^aValues are mean of replicates (n=3). NA: No Activity. U251: human glioblastoma, PC-3: human prostatic adenocarcinoma, K562: human chronic myelogenous leukemia, HCT-15: human colorectal adenocarcinoma, MCF-7: human mammary adenocarcinoma and SKLU-1: human lung adenocarcinoma

Oral administration of ethanol extract from *L. betulina* at doses of 200 and 400 mg/kg body mass had a positive effect on the liver parameters in male Wistar rats, which received paracetamol for 21 days at a dose of 200 mg/kg body mass

in order to destabilise their liver. Significantly lower AspAT, SGPT, ALP and total bilirubin levels were found in them in contrast to individuals in which the treatment with the mushroom extract was not applied [43].

Fomes fomentarius

Fomes fomentarius (L.) J. J. Kickx is the only European representative of the genus *Fomes*. In Poland, it is commonly found in lowlands and in lower mountains: often in the forests, less commonly in parks; it grows on live and dead deciduous trees. It is commonly found on birch (*Betula* sp.) and beech tree trunks (*Fagus* sp.) [1, 44].

F. fomentarius also generates ergostane-type sterols: fomentarol A, B, C, D, cerivisterol ((22E,24R)-ergosta-7,22-dien-3 β ,5 α ,6 β -triol) (Fig. 6), (22E,24R)-ergosta-7,22-dien-3 β ,5 α ,6 α -triol, (22E,24R)-ergosta-7,9(11),22-trien-3 β ,5 α ,6 β -triol, (22E,24R)-ergosta-7,22-dien-3 β ,5 α ,6 β ,9 α -tetraol, 3 β -O-glucopyranosil-5 α ,6 β -dihydroxyergosta-7,22-diene, (22E,24R)-5 α ,8 α -epidioxyergosta-6,22-dien-3 β -ol. The compounds had a cytotoxic effect on selected cancer cell lines (colon, lungs, breasts, stomach), confirming the anti-tumor effect of *F. fomentarius* and indicating a new direction in medical therapy [45].

Figure 6.
Cerevisterol

Reduction of mitochondrial membrane potential, accountable for an elevated number of free radicals, tends to initiate apoptosis leading, eventually, to destruction of tumor cells, as shown for the cells of murine sarcoma S180. In comparison with the presently used medicine cyclophosphamide, the tumor weight was reduced in a similar degree. However, the toxic effect on the organs, shown by the extract of *F. fomentarius* is not as pronounced as that of cyclophosphamide. In addition to ergosterol and ergosta-7,22-dien-3-ol, the analysis included the following fatty acids: n-hexadecanoic acid, hexadecanoic (palmitic) acid ethyl ester, 6-octadecenoic

acid, octadecanoic acid (stearic), and derivatives: 1,2-epoxynonadecane, tetradecanal and hexadecanal. The predominant n-hexadecane and octadecane acids showed cytotoxicity against lung cancer, breast cancer, and oral cancer [14].

A water extract of *F. fomentarius* was prepared and its content of polysaccharides and their monosaccharides: glucose, galactose, mannose and fucose was determined. Separation of the polysaccharide fractions demonstrated the presence of D-mannose, L-fucose, 3-O- α -D-mannopyranosyl-L-fucose, 6-O- β -D-galactopyranozyl-D-galactose, D-glucose, D-galactose. The major polysaccharide was identified to be manno-fuco-galactan, and its major chain component were D-galactoses, linked by the glycoside link β -(1 $\rightarrow$ 6) [3]. Exopolysaccharides (EPS) and intramolecular polysaccharides (IPS) showed an anti-cancerogenic effect on stomach cancer cells. IPS from *F. fomentarius* also have a less harmful effect on healthy liver cells, in comparison with standard medicines – doxorubicin or cisplatin [4]. Treating human lung carcinoma A549 cells with polysaccharides (25–100 μ g/ml) caused fragmentation and decomposition of DNA in lung cancer cells, definitely suggesting apoptosis [5].

Polysaccharides in *F. fomentarius* were also observed to have an inhibitory effect on the tobacco mosaic virus [46]. The *in vitro* antiviral activity of *F. fomentarius* against influenza virus A (H1N1) and herpes simplex virus (HSV-2) were investigated. The effect of both viruses was neutralized to a similar extent: the therapeutic index of the extract of *F. fomentarius* was 40.32 and was defined to be a result of the maximum tolerable concentration and half-maximum effective concentration [47]. It is believed that the antiviral and antifungal effect of *F. fomentarius* are attributable to the melanin-glucan complex, or the pigment-polysaccharide system, in addition to polysaccharides. The water-soluble melanin-glucan complex (MGC, composed of 80% melanin and 20% β -glucan) is believed to show an activity against *Helicobacter pylori* as high as that of erythromycin. It also enhanced the activity of zidovudine (antiretrovirally) and showed the highest effect on *Candida albicans*, completely depressing its development and preventing its growth. Both complex types are safe to use – they do not destroy erythrocytes [48].

The use of methanolic extract of *F. fomentarius* (MEFF) reduced laboratory-induced swelling in mice, suggesting reduced level of prostaglandins and inhibition of inflammatory reaction. MEFF was also observed to extend the duration of sensitivity to pain (this potentially affects the peripheral and central nociceptive pain). The effects of MEFF are attributed to its inhibition of NO synthase (iNOS), COX-2 and the NF- κ B; the most highly-active factors being the polysaccharide fraction and β -glucan [16, 28].

Trametes versicolor

Trametes versicolor (L.) Lloyd is a common fungus, frequently found in deciduous forests and hardly ever in coniferous forests. It commonly grows on tree stumps

and branches, preferably in sunny spots. It is found round the year, its fruiting bodies can even survive the winter [1, 44].

A methanolic extract of the fruiting bodies of *T. versicolor* comprises a number of fatty acids: lauric (4.2% of test sample content), myristic (1.7%), palmitic (11.7%), stearic (4.0%), tetracosanoic (2.5%), palmitoleic (1.8%), oleic (8.7%), linoleic (65.4%), betulin (0.05%) and α,α' -trehalose (54.06%) [20].

Ergosterol derivatives were also isolated: 3β , 5α , 9α -trihydroxyergosta-7,22-dien-6-one and 3β , 5α , 9α -trihydroxy- 6β -metoxyergosta-7,22-diene. The active compounds were isolated by bioassay-guided fractionation using rat hepatoma cells [37, 49].

T. versicolor is rich in polysaccharopeptides. Their monosaccharide components and links are shown in table 2.

Table 2.

Extracts obtained from *Trametes versicolor* and respective polysaccharopeptide components [7]

Source	Main component	Main features	Molecular weight	Component monosaccharides
<i>Trametes versicolor</i> (fruiting body)	PSP*	A -1,4, β -1,3-glucans, 10% peptides	100000	glucose, arabinose, mannose, rhamnose
<i>Trametes versicolor</i> (mycelium)	PSK** (Krestin, polysaccharide K)	B-1,4; 1,3; 1,6-D-glucans, peptides	94000	glucose (74.6%) mannose (15.5%) xylose (4.8%) galactose (2.7%) fucose (2.4%)

*polysaccharopeptide

**polysaccharide-K

The extract of *T. versicolor* prolongs survival of gastric, colon, or colorectal cancer patients, improves immune parameters, including increased secretion of NK cells, leukocyte count, IgG, IgM [7]. Combining β -1,3-glucane with PSP activates immunostimulating and anti-tumor effects. In addition, PSP has an analgesic effect and improves appetite [8]. An extract of *T. versicolor* stimulates lymphocytes T, lymphocytes B, monocytes, and NK cells (natural killers). The extract inhibits the growth of cancer cells and reduces their harmful effect on the immune system. Its anti-tumor effect is attributable to polysaccharopeptides and proteins. Its medicinal effect is documented (*in vitro*, *in vivo* and clinical studies), whereas its active ingredients and mechanisms underlying their action remain unidentified. Nonetheless, a new protein, YZP (Yun-Zhi protein) was isolated. This non-glycosylated protein is composed of 139 amino acids, including an 18-amino acids signal peptide. It specifically stimulated interleukin 10 (IL-10) to produce and activate the subset of lymphocytes B, called B cells (Bregs), resulting in an anti-inflammatory effect. The B cells (Bregs) are able to suppress by approx. 40% the macrophage

production caused by inflammatory cytokines. Owing to its effect on the immune system, the YZP protein is able to suppress inflammation, which is a desirable phenomenon in cancer treatment [50]. An extract of *T. versicolor* was shown to be a safe immunostimulant which can support chemotherapy and improve patient's condition generally [51]. The anti-tumor effect in breast cancer is attributed to the PSP and PSK (Krestin) polysaccharopeptides, which act on the immune system and mediators of inflammation [19].

The *T. versicolor* extract demonstrates a very strong antiviral activity against influenza virus type A (H₁N₁) and herpes simplex (high therapeutic index of 324.67) [47].

CONCLUSIONS

The compounds, found in the composition of fungal fruiting bodies include polyphenolics, such as flavonoids and phenolic acids, fatty acids, polysaccharides, tocopherols, carotenoids, sterols, or even those having an antibiotic effect. The diversified compositions and concentrations of surface active agents are responsible for the diverse pharmacological effects, such as anti-inflammatory, anti-tumor, immunomodulating, anti-diabetic, or cholesterol depressing effects. The above mentioned properties contribute to the growing importance of fungal species in therapy today.

Ethical approval: The conducted research is not related to either human or animal use.

Conflict of interest: Authors declare no conflict of interest.

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WŁAŚCIWOŚCI LECZNICZE GRZYBÓW WYSTĘPUJĄCYCH NA BRZOSIE. PRZEGLĄD

JOANNA SMOLIBOWSKA¹, MARCIN SZYMAŃSKI^{*1}, ARKADIUSZ SZYMAŃSKI²

¹Katedra i Zakład Farmakognozji
Uniwersytet Medyczny im. Karola Marcinkowskiego
ul. Świącickiego 4
60–781 Poznań

²Wydział Chemii
Uniwersytet im. Adama Mickiewicza
ul. Umultowska 89
61-614 Poznań

*autor, do którego należy kierować korespondencję: tel.: +48618546703,
e-mail: mszymanski@ump.edu.pl

Streszczenie

W artykule przedstawiono chemizm i właściwości farmakologiczne owocników grzybów poliporoidalnych występujących na brzozie, mianowicie *Piptoporus betulinus*, *Inonotus obliquus*, *Lenzites betulina*, *Fomes fomentarius* i *Trametes versicolor*. Przeprowadzone badania *in vitro* i *in vivo* wpływu różnych wyciągów z opisanych owocników grzybów na organizm ludzki, wykazały działanie przeciwnowotworowe, przeciwzapalne, przeciwwirusowe, przeciwbakteryjne i immunostymulujące, uwarunkowane obecnością takich związków jak polisacharydy, polifenole czy terpeny. Grzyby te występują powszechnie w Polsce i w znakomity sposób mogą konkurować ze stosowanymi w celach leczniczych w Azji *Ganoderma lucidum* (Reishi) oraz *Lentinula edodes* (Shitake).

Słowa kluczowe: owocniki grzybów poliporoidalnych, *Piptoporus betulinus*, *Inonotus obliquus*, *Lenzites betulina*, *Fomes fomentarius*, *Trametes versicolor*