

Bioactive compounds and medicinal properties of Oyster mushrooms (*Pleurotus* sp.)

Iwona Golak-Siwulska, Alina Kałużewicz, Tomasz Spiżewski,
Marek Siwulski, Krzysztof Sobieralski*

Department of Vegetable Crops
Faculty of Horticulture and Landscape Architecture, Poznań University of Life Sciences
Dąbrowskiego 159, Poznań, Poland

ABSTRACT

There are about 40 species in the *Pleurotus* genus, including those with high economic significance, i.e. *P. ostreatus* and *P. pulmonarius*. The fruiting bodies of oyster mushrooms are of high nutritional and health-promoting value. In addition, many species belonging to the *Pleurotus* genus have been used as sources of substances with documented medicinal properties, such as high-molecular weight bioactive compounds (polysaccharides, peptides and proteins) and low-molecular weight compounds (terpenoids, fatty acid esters and polyphenols). The bioactive substances contained in the mycelium and fruiting bodies of *Pleurotus* species exhibit immunostimulatory, anti-neoplastic, anti-diabetic, anti-atherosclerotic, anti-inflammatory, antibacterial and anti-oxidative properties. Their multidirectional positive influence on the human organism is the result of interaction of bioactive substances. Extracts from individual *Pleurotus* species can be used for the production of dietary supplements increasing the organism's immunity. They are also used for the production of cosmetics. They can be added to functional foods as probiotics, or used as natural preservatives or ingredients of special foodstuffs for patients with specific diseases.

Key words: fruiting bodies, functional food, health-promoting activities, oyster mushrooms

INTRODUCTION

Mushrooms have been used in folk medicine all over the world since ancient times (Wasser and Weis, 1999). They have been chiefly used in traditional medicine in China and other Asian countries. Mushrooms have antineoplastic, antibacterial, antiviral, hypoglycaemic, hypocholesterolemic, anti-inflammatory and anti-oxidative properties (Guillamon et al., 2010; Wasser, 2011, 2014). *Ganoderma lucidum* and *Lentinula edodes* are the best-known species with therapeutic properties. An increasing number of studies from different centres confirm the fact that mushroom species

of the *Pleurotus* genus exhibit multidirectional health-promoting effects (Khan and Tania, 2012; Stachowiak and Reguła, 2012; Deepalakshmi and Mirunalini, 2014; Correa et al., 2016). Many authors indicate that oyster mushrooms could be classified as functional food due to their positive effect on the human organism (Synytsya et al., 2008; Patel et al., 2012).

There are about 40 species in the *Pleurotus* genus (Kues and Liu, 2000). These mushrooms grow on various lignocellulosic substrates and form shell-shaped fruiting bodies of high nutritional value as they are rich in proteins, vitamins and minerals.

*Corresponding author.
e-mail: alina.kaluzewicz@up.poznan.pl (A. Kałużewicz).

At present, oyster mushrooms are the world's third most common species of cultivated mushrooms after button mushrooms and shiitake mushrooms (Fernandes et al., 2015). Poland is a leading producer of oyster mushrooms in Europe – the yearly volume of production exceeds 80,000 tonnes. *P. ostreatus* and *P. pulmonarius* are the most economically significant species of oyster mushrooms (dos Santos Bazanella et al., 2013).

Research on the therapeutic properties of oyster mushrooms started in the late 20th century. First, their hypotensive properties were confirmed (Bajaj et al., 1997). Next, studies proved the anti-neoplastic properties of the mushrooms (Wang et al., 2000). Research became intensified in the early 21st century (Cohen et al., 2002; Lavi et al., 2006; Lee et al., 2007; Li et al., 2008; Jedinak and Sliva, 2008). Studies confirmed the health-promoting and therapeutic properties of various oyster mushroom species, such as *P. ostreatus* (Fr.) Kumm., *P. pulmonarius* (Fr.) Quel., *P. ostreatus* f. *florida* Cetto, *P. cornucopiae* (Pers.) Roland, *P. eryngii* (Fr.) Kumm., *P. sajor-caju* (Fr.) Sing., *P. citrinopileatus* Sing. and *P. tuberregium* (Fr.) Sing.

The multidirectional health-promoting and therapeutic effects of mushrooms of the *Pleurotus* genus result from the presence of secondary metabolites, which have been isolated from both oyster mushroom fruiting bodies and mycelia (Morris et al., 2017). The bioactive compounds identified in *Pleurotus* mushrooms can be divided into those with a high and those with a low molecular weight. High-molecular weight bioactive compounds chiefly encompass polysaccharides, including β -glucans, peptides and proteins. Low-molecular weight bioactive compounds include terpenes, fatty acid esters and polyphenols (Patel and Goyal, 2012). Bioactive substances exhibit immunostimulatory, anti-neoplastic, anti-diabetic, anti-atherosclerotic, anti-inflammatory, hepatoprotective and anti-oxidative properties (Lindequist et al., 2005; Alam et al., 2009; Jayakumar et al., 2011; Wasser, 2014).

BIOACTIVE COMPOUNDS AND THEIR ACTIVITY

Polysaccharides

The polysaccharides contained in the mushroom cell wall include β -glucans and α -glucans. These compounds are composed of glucopyranose molecules linked with glycosidic bonds of the type (1 \rightarrow 3)- β , (1 \rightarrow 6)- β - or (1 \rightarrow 3)- α . β -glucans are a group of polysaccharides which has been researched well.

β -glucans acquired from mushrooms differ in their structure, water solubility, size of the molecule and molecular weight. They exhibit a very wide spectrum of health-promoting effects (Zhu et al., 2015; Friedman, 2016). β -glucans of higher molecular weight are more effective (Wasser, 2002). The effectiveness of β -glucans also depends on their solubility (Wasser, 2011). The physicochemical modification of polysaccharides by changing the degree of their branching or by adding substituent groups (sulphates, selenates) influences their bioactivity (Li and Shah, 2014; Witkowska, 2014).

According to Rop et al. (2009), oyster mushrooms are one of the most important sources of β -glucans. Individual oyster mushroom species differ in the concentration of total glucans, α - and β -glucans. According to Sari et al. (2017), total glucans range from 18.260 g 100 g⁻¹ D.M. (dry mass) in *P. citrinopileatus* to 25.636 g 100 g⁻¹ D.M. in *P. ostreatus*. The concentration of β -glucans ranges from 15.321 g 100 g⁻¹ D.M. in *P. eryngii* to 24.230 g 100 g⁻¹ D.M. in *P. ostreatus*. β -glucans can also be found in the mycelium of oyster mushrooms. The total concentration of β -glucans in *P. ostreatus* fruiting bodies reaches 9 g 100 g⁻¹ D.M. The concentration of β -glucans in the oyster mushroom mycelium ranges from 2.5 g 100 g⁻¹ D.M. in *P. pulmonarius* to 4.6 g 100 g⁻¹ D.M. in *P. ostreatus* (Nitschke et al., 2011). According to Synytsya et al. (2009), the concentration of β -glucans in the stem of *P. ostreatus* fruiting bodies amounts to 32.5-50% D.M. and is higher than in the cap (27.4-39.2% D.M.). The concentration of β -glucans in the fruiting bodies of *P. eryngii* amounts to 39.1 D.M. in the stem and 20.4% D.M. in the cap.

Pleuran is the best-known β -glucan extracted from oyster mushrooms. It is composed of D-glucose molecules linked with bonds of the type (13)- β - and (1 \rightarrow 6)- β -. Extraction with hot water is the most common method of acquiring pleuran from fruiting bodies. It can also be obtained from liquid cultures (Maftoun et al., 2013). The compound exhibits anti-neoplastic properties against various cells, including colorectal cancer cells HT-29 (Lavi et al., 2006), prostate cancer cells PC-3 (Gu and Sivan, 2006) and breast cancer cells MCF-7 (Martin and Brophy, 2010). In addition, it has anti-oxidative and antiviral properties (Selegan et al., 2009).

A group of polysaccharides which has not been investigated so well is that of α -(1 \rightarrow 3)-glucans. They can be found in the deepest layer of the mushroom cell wall. They have structural and supportive functions, and serve as a reserve

material. α -glucans have been found to exhibit anti-neoplastic, immunostimulatory and anti-oxidative properties (Wiater et al., 2012). The total concentration of α -(1 \rightarrow 3)-glucans in the fruiting bodies of various oyster mushroom species ranges from 2.0% D.M. in *P. eryngii* to 4.0% D.M. in *P. citrinopileatus* (Sari et al., 2017). Investigations have proved that the fraction of α -glucans from *P. ostreatus* fruiting bodies exhibit an anti-neoplastic effect against colorectal cancer cell lines (Augustin et al., 2007).

The bioactivity of α -(1 \rightarrow 3)-glucans depends on their solubility, structure and concentration. The activity of linear insoluble α -glucans can be increased by chemical modification. Investigations have proved that the derivatives produced by carboxymethylation of α -(1 \rightarrow 3)-glucans from *P. ostreatus* exhibit high cytotoxic activity towards HeLa cell lines. The carboxymethylated α -(1 \rightarrow 3)-glucan isolated from *P. citrinopileatus* exhibits cytotoxic activity to cervical cancer cells but it is not toxic to normal cells (Wiater et al., 2011, 2015).

The fruiting bodies and mycelia of different oyster mushroom species have provided a wide range of polysaccharides of diversified activity. Zhang et al. (2012) isolated two fractions of polysaccharides from *P. ostreatus* and proved their strong anti-oxidative properties. Facchini et al. (2014) proved that polysaccharides extracted from the *P. ostreatus* mycelium successfully inhibited the development of neoplastic cells of Ehrlich tumour and sarcoma 180. Two substances with anti-inflammatory properties have been isolated from the *P. sajor-caju* species: (1 \rightarrow 3)- β -D-glucan and mannogalactan (Silveira et al., 2014, 2015). Cui et al. (2015) isolated the PN-S polysaccharide from *P. nebrodensis* and proved that it was capable of stimulating the activity of macrophages. Another fraction of polysaccharides (PNPA) has also been acquired from the same species. The fraction has been proved to prevent myocardial ischaemia (Yan et al., 2015). Another polysaccharide (PAP) has been acquired from *P. abalonus*. It exhibits anti-proliferative properties against human colorectal cancer cells LoVo (Ren et al., 2015). Li and Shah (2014) conducted sulphatation of polysaccharides obtained from *P. eryngii* cells. The researchers proved that this fraction of polysaccharides had stronger anti-oxidative and antibacterial properties (Li and Shah, 2015). The polysaccharides isolated from the *P. ostreatus*, *P. ostreatoroseus* and *P. florida* species exhibit anti-inflammatory effects (Ghazanfari et al., 2010; Gunawardana et al., 2014;

Correa et al., 2015). Investigations have proved the anti-oxidative properties of polysaccharides obtained from *P. tuber-regium* (Wu et al., 2014). A β -glucan obtained from *P. pulmonarius* has been found to exhibit analgesic and anti-inflammatory effects (Baggio et al., 2012).

Proteins, peptides and lectins

Proteins, peptides and lectins are other high-molecular weight substances acquired from mushrooms of the *Pleurotus* genus which exhibit medicinal properties. Nebrodeolysin is a haemolytic protein isolated from *P. nebrodensis*, which induces apoptosis of neoplastic cells L929 and HeLa (Lv et al., 2009). The substance also exhibits an antiviral effect against HIV-1. A protein derived from *P. ostreatus* has a structure similar to ubiquitin and inhibits HIV-1 reverse transcriptase (Wang and Ng, 2000). A protein extract obtained from *P. ostreatus* exhibited a therapeutic effect towards the colorectal cancer cell line SW 480 and monocytic leukaemia THP-1 by inducing their apoptosis (Wu et al., 2011). In addition, eryngin and pleurostrin – the proteins isolated from the *P. eryngii* and *P. ostreatus* species exhibit antifungal and antibacterial properties (Erjavec et al., 2012). The *P. cornucopiae* species has provided two oligopeptides which exhibit antihypertensive properties (Jang et al., 2011). Moreover, the mycelium and fruiting bodies of *P. citrinopileatus* contain large amounts of ergothioneine, a water-soluble amino acid, which is considered an excellent antioxidant (Lin et al., 2016).

Enzymes isolated from oyster mushrooms also exhibit health-promoting effects. Ribonuclease from *P. djamor* inhibits the proliferation of hepatic cancer and breast cancer cells (Wu et al., 2010). Research has also confirmed the antiviral effect of laccase isolated from *P. ostreatus* against the hepatitis C virus (El-Fakharana et al., 2010).

Lectins are another group of mushroom compounds with multidirectional health-promoting effects (Wang and Ng, 2000; Hassan et al., 2015). Lectins include polysaccharide-protein and polysaccharide-peptide complexes. Research has proved that the polysaccharide-peptide complex from *P. abalonus* reduces the blood glucose level in mice (Chen et al., 2015). Lectins from *Pleurotus citrinopileatus* exhibit antineoplastic and antiviral effects (Li et al., 2008).

Other compounds

Mono- and sesquiterpenoids, ergosterol and fatty acid esters are low-molecular weight bioactive

compounds identified in oyster mushrooms. Terpenoids exhibiting cytotoxicity towards HeLa and HepG2 cancer cells have been isolated from the *P. cornucopiae* mycelium (Wang et al., 2013). Menikpurage et al. (2009) researched the antifungal activity of different fractions isolated from *P. cystidiosus*. They found that the fraction containing ergosterol – $3\beta,5\alpha,6\beta$ -trihydroxyergosta-7,22-diene was the most effective against *Colletotrichum gloeosporioides* fungi that cause anthracnose. Fatty acid esters in an extract from *P. eous* have been found to exhibit a strong antibacterial effect – they inhibit the growth of Gram-positive and Gram-negative bacteria (Suseem and Saral, 2013).

The fruiting bodies of mushrooms of the *Pleurotus* genus contain lovastatin, which belongs to the group of statins affecting the metabolism of cholesterol. These compounds inhibit LDL cholesterol oxidation and positively affect the coagulation system and fibrinolysis. They have anti-inflammatory, anticoagulation and anti-oxidative properties. According to Alarcon et al. (2003), the average lovastatin content in the dry matter of oyster mushrooms amounts to 0.7-2.8%. The concentration of lovastatin in oyster mushroom species varies, ranging from 101 mg kg⁻¹ D.M. in *P. cystidiosus* to 216 mg kg⁻¹ D.M. in *P. ostreatus* fruiting bodies (Chen et al., 2012). Alam et al. (2009) conducted a study on animals and proved that the lovastatin contained in powdered fruiting bodies of *P. osteratus* and *P. sajor-caju* positively affected the lipid profile as well as the hepatic and renal functions. The total cholesterol and triglyceride levels in the rats' blood decreased.

Many authors have indicated that oyster mushrooms contain phenolic compounds with anti-oxidative effects (Palacios et al., 2011; Muszyńska et al., 2013; Piska et al., 2017). Aqueous and ethanol extracts exhibiting high anti-oxidative activity have been isolated from *P. citrinopileatus* fruiting bodies and mycelium. The highest activity has been shown by ethanol extracts from the fruiting bodies of this species due to the high total concentration of phenolic compounds (Lee et al., 2007). Investigations conducted by Jaworska et al. (2015) found that the total phenolic content in *P. ostreatus* fruiting bodies amounted to 708 mg 100 g⁻¹ D.M., in which the flavonoid content amounted to 170 mg 100 g⁻¹ D.M. According to Gąsecka et al. (2016), ferulic acid and *p*-coumaric acid are the chief phenolic acids in oyster mushrooms. Their concentrations in the fruiting bodies amount to, respectively, 30.00

and 10.54 µg g⁻¹ D.M. in *P. ostreatus* and to 29.00 and 13.49 µg g⁻¹ D.M. in *P. eryngii*.

Medicinal activities and the bioactive substances found in some *Pleurotus* species are presented in Table 1.

APPLICATION OF *PLEUROTUS* MUSHROOMS IN THE PHARMACEUTICAL, FOOD AND COSMETICS INDUSTRIES

According to studies conducted so far, mushrooms of the *Pleurotus* genus exhibit numerous potentially therapeutic properties. Medicinal substances can be found in the mycelium, the fruiting bodies, and extracts from them. A therapeutic effect can be achieved by consuming fresh oyster mushroom fruiting bodies, foodstuffs containing dried oyster mushrooms or supplements with such content. The market offers a preparation based on -glucan from the fruiting bodies of *P. ostreatus*. It is used for immunotherapy when the immunity of the organism is low and there are frequent infections and allergies. Research has proved the positive influence of pleuran, which exhibits immunomodulatory properties in children with respiratory infections and allergies (Jesenak et al., 2013, 2014; Pasnik et al., 2017). Studies have also proved the positive effect of pleuran on the function of the immune system in people doing intense physical exercises (Bergendiova et al., 2011). Pleuran can be applied in antibiotic therapy and can be used in chemotherapy and radiotherapy as an adjunctive therapeutic. It also positively affects people exposed to long-lasting stress.

Oyster mushrooms can be used for the production of functional food with significant influence on human health (Wakchaure et al., 2010; Carrasco-Gonzalez et al., 2017; Piska et al., 2017). *Pleurotus* meal is used as an additive to products made from cereals, such as: breads, pastries, noodles, tortillas, etc., because it increases the protein and fibre content (Aishah and Wan Rosli, 2013). Research has proved that when the oyster mushroom additive did not exceed 10%, it did not have a negative effect on the sensory evaluation of products (Adebayo-Oyetoro et al., 2010). Researchers have conducted studies on dried oyster mushrooms used as an additive to cereal products to increase their health-promoting value. Their investigations showed that dried oyster mushrooms added to maize bread and wheat bread reduced the glycaemic index of these products (Reguła and Gramza-Michałowska, 2013). The lipid profile of patients with hypercholesterolemia

Table 1. Medicinal effects of *Pleurotus* mushrooms

Activity	Bioactive compounds	Species	References
Anti-cancer	β -glucans	<i>P. ostreatus</i>	Jedinak et al., 2010 Jedinak and Sliva, 2008
	α -glucan	<i>P. ostreatus</i>	Lavi et al., 2006 Wu et al., 2011
	proteins	<i>P. ostreatus</i>	Wang and Ng, 2000
		<i>P. nebrodensis</i>	Lv et al., 2009
Antitumour	polysaccharides	<i>P. ostreatus</i>	Tong et al., 2009
	proteoglycans	<i>P. ostreatus</i>	Sarangi et al., 2006
	lectin	<i>P. citrinopileatus</i>	Li et al., 2008
		<i>P. ostreatus</i>	Wang et al., 2000
Immunomodulatory	polysaccharides	<i>P. ostreatus</i>	Shamtsyan et al., 2004
		<i>P. cornucopiae</i>	
	heteroglycan	<i>P. ostreatus</i>	Devi et al., 2013
Antihypercholesterolemic	lovastatin	<i>P. ostreatus</i>	Alam et al., 2009
		<i>P. sajor-caju</i>	Khan et al., 2011
		<i>P. florida</i>	
	ergosterol	<i>P. ostreatus</i>	Dissanayake et al., 2009
Antihypertensive	D-mannitol	<i>P. cornucopiae</i>	Hagiwara et al., 2005
	peptides	<i>P. cornucopiae</i>	Jang et al., 2011
Anti-atherogenic	angiotensin converting enzyme inhibitor peptide	<i>P. cornucopiae</i>	Abidin et al., 2017
		<i>P. eryngii</i>	
		<i>P. ostreatus</i>	
		<i>P. ostreatus</i>	
Antiviral	proteins	<i>P. ostreatus</i>	Wang and Ng, 2000
		<i>P. nebrodensis</i>	Lv et al., 2009
	polysaccharides	<i>P. abalonus</i>	Wang et al., 2011
	lectins	<i>P. citrinopileatus</i>	Hassan et al., 2015
Antibacterial	β -glucans	<i>P. ostreatus</i>	Iwalokun et al., 2007 Karaman et al., 2010 Mirunalini et al., 2012
	fatty acids esters	<i>P. eous</i>	Suseem and Saral, 2013
Antifungal	ergosterol	<i>P. cystidiosus</i>	Menikpurage et al., 2009
	proteins	<i>P. ostreatus</i>	Erjavec et al., 2012
		<i>P. eryngii</i>	
Anti-oxidative	phenols	<i>P. citrinopileatus</i>	Lee et al., 2007
	lectins	<i>P. florida</i>	Bera et al., 2011
	polysaccharides	<i>P. ostreatus</i>	Mitra et al., 2013 Jayakumar et al., 2011
		<i>P. tuber-regium</i>	Wu et al., 2014
Hypoglycemic	unspecified	<i>P. ostreatus</i>	Ravi et al., 2013
	β -glucans	<i>P. sajor-caju</i>	Kanagasabapathy et al., 2012
	polysaccharide-peptide	<i>P. abalonus</i>	Chen et al., 2015
Anti-inflammatory	polysaccharides	<i>P. ostreatus</i>	Gunawardena et al., 2014
		<i>P. ostreatoroseus</i>	Correa et al., 2015
		<i>P. florida</i>	Ghazanfari et al., 2010
Anti-arthritis	β -glucans	<i>P. sajor-caju</i>	Patel et al., 2012
		<i>P. ostreatus</i>	Rovensky et al., 2011
Anti-atopic dermatitis	pleuran	<i>P. ostreatus</i>	Park et al., 2016
Anticataractogenic	unspecified	<i>P. ostreatus</i>	Isai et al., 2009
Antinociceptive	β -glucans	<i>P. eous</i>	Suseem et al., 2011
		<i>P. pulmonarius</i>	Baggio et al., 2010, 2012

improved when they consumed bread with dried oyster mushrooms rather than traditional wheat bread. The level of total cholesterol and its LDL fraction in the plasma of all the patients decreased. The people who consumed soup with dried oyster mushrooms every day for 21 days had a lower level of triglycerides and a lower total blood cholesterol level (Schneider et al., 2011).

Oyster mushrooms can also be used for the production of fermented milk beverages. Extracts from *Pleurotus* are a good source of prebiotics due to the high soluble fibre content (Aida et al., 2009; Synytsya et al., 2009). Research has proved that when an aqueous extract from *P. ostreatus* is added to yoghurt, it stimulates the growth of useful microorganisms *Streptococcus thermophilus* and *Lactobacillus bulgaricus* (Pelaes Vital et al., 2015). Studies have also proved that an extract from *P. eous* can be added to foodstuffs as a natural source of antibacterial substances (Suseem and Saral, 2013). The study by Li and Shah (2015) proved that an extract from *P. eryngii* (PEPS) could be added to fermented milk beverages as a natural preservative.

The use of oyster mushrooms in cosmetology and dermatology is another issue. Due to the presence of antioxidants, anti-ageing, anti-wrinkle, whitening and moisturising components oyster mushroom extracts can be used for the production of various cosmetics and cosmeceuticals. A line of cosmetics containing β -glucans has been produced from a few mushroom species, including *P. nebrodensis* (Hyde et al., 2010). Extracts from *P. cornucopiae* var. *citrinopileatus* applied to mice have given positive effects against atopic dermatitis (Tomiyama et al., 2008). Research has confirmed the usefulness of *P. citrinopileatus* as a source of ingredients for the production of skin care cosmetics (Meng et al., 2011). A *P. nebrodensis* extract has proven to be a very effective skin whitener and it could be used for the production of preparations against skin discoloration (Dangre et al., 2012).

Cosmetics containing mushroom extracts are very popular in Asia. They have appeared in Europe only recently. Some countries sell hand-made soap with a *P. ostreatus* extract, which regenerates the skin. Application of a pleuran-based cream as an adjunctive therapeutic to patients with atopic dermatitis has produced good results. The latest scientific reports confirm the usefulness of different oyster mushroom species as a raw material for the cosmetics industry (Taofiq et al., 2016; Wu et al., 2016; Morris et al., 2017).

CONCLUSIONS

According to the current state of knowledge, *Pleurotus* mushrooms are a good source of bioactive substances. Although in recent years the number of studies on the health-promoting effects of *Pleurotus* mushrooms has increased rapidly, most of them have involved *in vitro* or *in vivo* experiments on animals. So far, there have been relatively few clinical trials on humans. At the same time, it is necessary to stress the fact that not all mechanisms of action of bioactive substances in oyster mushrooms have been fully investigated. At present, state-of-the-art techniques are being applied in intense research to extract new metabolites from oyster mushrooms. It will be necessary to verify their pharmacological effects *in vitro* and in clinical trials. The identification of the synergic effect of these substances in the human organism would give a possibility to take full advantage of the health-promoting and therapeutic potential of oyster mushrooms.

AUTHOR CONTRIBUTIONS

I.G.S – reviewed the relevant literature and wrote the manuscript; A.K – co-wrote the manuscript and prepared it for submission; M.S. – revised the text; T.S. and K.S. – contributed to such aspects of this manuscript as development of the idea, review of available literature and writing. All the authors are equally responsible for the content.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

REFERENCES

- ABIDIN M.H.Z., ABDULLAH N., ABIDIN N.Z., 2017. Therapeutic properties of *Pleurotus* species (Oyster mushrooms) for Atherosclerosis: a review. *Int. J. Food Prop.* 20, 1251-1261.
- ADEBAYO-OYETORO A., OLATIDOYE O., OGUNDIPE O., BALAGUN I., ARO F., 2010. Quality characteristics of cookies produced from composite flours of wheat and mushrooms. *J. Sci. Multidiscip. Res.* 2, 25-31.
- AIDA F.M.N.A., SHUHAIMI M., YAZID M., MAARUF A.G., 2009. Mushrooms as a potential source of prebiotics, a review. *Trends Food Sci. Technol.* 20, 567-575.
- AISHAH M.S., WAN ROSLI W.I., 2013. The effect of addition of oyster mushroom (*Pleurotus sajor-caju*) on nutrient composition and sensory acceptance of selected wheat-and rice-based products. *Intern. Food Res. J.* 20(1), 183-188.
- ALAM N., AMIN R., KHAN A., ARA I., SHIM M.J., LEE M.W., 2009. Comparative effects of oyster mushroom

- on lipid profile, liver and kidney function in hypercholesterolemic rats. *Mycobiology* 37, 37-42.
- ALARCON J., AGUILA S., ARANCIBIA-AVILA P., FUENTES O., ZAMORANO-PONCE E., HERNANDEZ M., 2003. Production and purification of statins from *Pleurotus ostreatus* (Basidiomycetes) strains. *Z. Naturforsch. C* 58(1-2), 62-64.
- AUGUSTÍN J., JAWORSKA G., DANDÁR A., CEJPEK K., 2007. Bocznik ostrygowaty (*Pleurotus ostreatus*) jako źródło β -D-glukanów. *Żywn. Nauka. Technol. Jakość* 6(55), 170-176.
- BAGGIO C.H., FREITAS C.S. MARTINS D.F., MAZZARDO L., SMIDERLE F.R., SASSAKI G.L., ET AL., 2010. Antinociceptive effects of (1 \rightarrow 3), (1 \rightarrow 6)-linked -glucan isolated from *Pleurotus pulmonarius* in models of acute and neuropathic pain in mice: evidence for a role for glutamatergic receptors and cytokine pathways. *J. Pain* 11, 965-971.
- BAGGIO C.H., FREITAS C.S., MARCON R., WERNER M.F.P., RAE G.A., SMIDERLE F.R., ET AL., 2012. Antinociception of β -D-glucan from *Pleurotus pulmonarius* is possibly related to protein kinase C inhibition. *Int. J. Biol. Macromol.* 50, 872-877.
- BAJAJ M., VADHERA S., BRAR A., SONI G., 1997. Role of oyster mushroom (*Pleurotus florida*) as hypocholesterolemic/antiatherogenic agent. *Indian J. Exp. Biol.* 35(10), 1070-1075.
- DOS SANTOS BAZANELLA G.C., DE SOUZA D.F., CASTOLDI R., OLIVEIRA R.F., BRACHT A., PERALTA R.M., 2013. Production of laccase and manganese peroxidase by *Pleurotus pulmonarius* in solid-state cultures and application in dye decolorization. *Folia Microbiol.* 58, 641-647.
- BERA A.K., RANA T., DAS S., BHATTACHARYA D., PAN D., BANDYOPADHYAY S., ET AL., 2011. Mitigation of arsenic-mediated renal oxidative stress in rat by *Pleurotus florida* lectin. *Hum. Exp. Toxicol.* 30(8), 940-951.
- BERGENDIOVA K., TIBENSKA E., MAJTAN J., 2011. Pleuran (β -glucan from *Pleurotus ostreatus*) supplementation, cellular immune response and respiratory tract infections in athletes. *Eur. J. Appl. Physiol* 111, 2033-2040.
- CARRASCO-GONZALEZ J.A., SERNA-SALDIVAR S.O., GUTIERREZ-URIBE J.A., 2017. Nutritional composition and nutraceutical properties of the *Pleurotus* fruiting bodies: Potential use as food ingredient. *J. Food Comp. Anal.* 58, 69-81.
- CHEN R.-R., LIU Z.-K., LIU F., NG T.B., 2015. Antihyperglycemic mechanism of an acetoside polymer from rose flowers and a polysaccharide-protein complex from abalone mushroom. *Nat. Prod. Res.* 29, 558-561.
- CHEN S.-Y., HO K.-J., HSIEH Y.-J., WANG L.-T., MAU J.-L., 2012. Contents of lovastatin, γ -aminobutyric acid and ergothioneine in mushroom fruiting bodies and mycelia. *LWT – Food Sci. Technol.* 47(2), 274-278.
- COHEN R., PERSKY L., HADAR Y., 2002. Biotechnological applications and potential of wood-grading mushrooms of the genus *Pleurotus*. *Appl. Microbiol. Biotechnol.* 58, 582-594.
- CORREA R.G.G., BRUGNARI T., BRACHT A., PERALTA R.M., FERREIRA I.C.F.R., 2016. Biotechnological, nutritional and therapeutic uses of *Pleurotus* spp. (Oyster mushrooms) related with its chemical composition: A review on the past decade findings. *Trends Food Sci. Technol.* 50, 103-117.
- CUI H.-Y., WANG C.-L., WANG Y.-R., LI Z.-J., ZHANG Y.-N., 2015. The polysaccharide isolated from *Pleurotus nebrodensis* (PN-S) shows immune-stimulating activity in RAW264.7 macrophages. *Chin. J. Nat. Med.* 13, 355-360.
- DANGRE D.M., DAFNE L.P., BHAGAT R.P., CHANDEKAR C.J., 2012. Effect of *Pleurotus nebrodensis* extract on melanin synthesis: a natural alternative for cosmetics. *Int. J. Med. Arom. Plants* 2(4), 579-588.
- DEEPALAKSHMI K., MIRUNALINI S., 2014. *Pleurotus ostreatus*: an oyster mushroom with nutritional and medicinal properties. *J. Biochem. Tech.* 5(2), 718-726.
- DEVI K.S.P., ROY B., PATRA P., SAHOO B., ISLAM S.S., MAITI T.K., 2013. Characterization and lectin microarray of an immunomodulatory heteroglycan from *Pleurotus osteratus* mycelia. *Carbohydr. Polym.* 94(2), 857-865.
- DISSANAYAKE D.P., ABEYTUNGA D.T.U., VASUDEWA N.S., RATNASOORIYA W.D., 2009. Inhibition of lipid peroxidation by extracts of *Pleurotus ostreatus*. *Pharmacogn. Mag.* 5(19), 266-271.
- EL-FAKHARANY E.M., HAROUN B.M., NG T.B., REDWAN E.R., 2010. Oyster mushroom laccase inhibits hepatitis C virus entry into peripheral blood cells and hepatoma cells. *Protein Pept. Lett.* 17, 1031-1039.
- ERJAVEC J., KOS J., RAVNIKAR M., DREO T., SABOTIC J., 2012. Proteins of higher fungi – from forest to application. *Trends Biotechnol.* 30, 259-273.
- FACCHINI J.M., ALVES E.P., AGUILERA C., GERN R.M.M., SILVEIRA M.L.L., WISBECK E., ET AL., 2014. Antitumor activity of *Pleurotus ostreatus* polysaccharide fractions on Ehrlich tumor and Sarcoma 180. *Int. J. Biol. Macromol.* 68, 72-77.
- FERNANDES A., BARROS L., MARTINS A., HERBERT P., FERREIRA I.C.F.R., 2015. Nutritional characterization of *Pleurotus ostreatus* (Jacq. ex Fr.) P. Kumm. produced using paper scraps as substrate. *Food Chem.* 169, 396-400.
- FRIEDMAN M., 2016. Mushroom polysaccharides: chemistry and antiobesity, antidiabetes, anticancer, and antibiotic properties in cells, rodents, and humans. *Foods* 5(4): 80, doi:10.3390/foods5040080.
- GAŚECKA M., MLECZEK M., SIWULSKI M., NIEDZIELSKI P., 2016. Phenolic composition and antioxidant properties of *Pleurotus ostreatus* and *Pleurotus eryngii* enriched with selenium and zinc. *Eur. Food Res. Technol.* 242, 723-732.

- GHAZANFARI T., YARAEI R., FARAHNEJAD Z., RAHMATI B., HAKIMZADEH H., 2010. Macrophages activation and nitric oxide alterations in mice treated with *Pleurotus florida*. *Immunopharmacol. Immunotoxicol.* 31, 47-50.
- CORREA R.C.G., DE SOUZA A.H.P., CALHELHA R.C., BARROS L., GLAMOCLIJAJ., SOKOVIC M., ET AL., 2015. Bioactive formulations prepared from fruiting bodies and submerged culture mycelia of the Brazilian edible mushroom *Pleurotus ostreatoroseus* Singer. *Food Funct.* 6, 2155-2164.
- GU Y.-H., SIVAM G., 2006. Cytotoxic effect of oyster mushroom *Pleurotus ostreatus* on human androgen-independent prostate cancer PC-3 cells. *J. Med. Food* 9, 196-204.
- GUILLAMON E., GARCIA-LAFUENTE A., LOZANO M., D'ARRIGO M., ROSTAGNO M.A., VILLARES A., ET AL., 2010. Edible mushrooms: role in the prevention of cardiovascular diseases. *Fitoterapia* 81, 715-723.
- GUNAWARDENA D., BENNETT L., SHANMUGAN K., KING K., WILLIAMS R., ZABARASA D., ET AL., 2014. Anti-inflammatory effects of five commercially available mushroom species determined in lipopolysaccharide and interferon- γ activated murine macrophages. *Food Chem.* 148, 92-96.
- HAGIWARA S.-Y., TAKAHASHI M., SHEN Y., KAIHOU S., TOMIYAMA T., YAZAWA M. ET AL., 2005. A phytochemical in the edible tamogi-take mushroom (*Pleurotus cornucopiae*), D-mannitol, inhibits ACE activity and lowers the blood pressure of spontaneously hypertensive rats. *Biosci. Biotechnol. Biochem.* 69, 1603-605.
- HASSAN M., ROUF R., TIRALONGO E., MAY T., TIRALONGO J., 2015. Mushroom lectins: specificity, structure and bioactivity relevant to human disease. *Int. J. Mol. Sci.* 16, 7802-7838.
- HYDE K.D., BAHKALI A.H., MOSLEM M.A., 2010. Fungi – an unusual source for cosmetics. *Fungal Divers.* 43, 1-9.
- ISAI M., ELANCHEZHIAN R., SAKTHIVEL M., CHINNAKKARUPPAN A., RAJAMOHAN M., JESUDASAN C.N., ET AL., 2009. Anticataractogenic effect of an extract of the oyster mushroom, *Pleurotus ostreatus*, in an experimental animal model. *Curr. Eye Res.* 34, 264-273.
- IWALOKUN B.A., USEN U.A., OTUNBA A.A., OLUKOYA D.K., 2007. Comparative phytochemical evaluation, antimicrobial and antioxidant properties of *Pleurotus ostreatus*. *Afr. J. Biotechnol.* 6(15), 1732-1739.
- JANG J.-H., JEONG S.-C., KIM J.-H., LEE Y.-H., JU Y.-C., LEE J.-S., 2011. Characterization of a new antihypertensive angiotensin I-converting enzyme inhibitory peptide from *Pleurotus cornucopiae*. *Food Chem.* 127, 412-418.
- JAWORSKA G., POGOŃ K., BERNAŚ E., DUDA-CHODAK A., 2015. Nutraceuticals and antioxidant activity of prepared for consumption commercial mushrooms *Agaricus bisporus* and *Pleurotus ostreatus*. *J. Food Qual.* 38(2), 111-122.
- JAYAKUMAR T., THOMAS P.A., SHEU J.R., GERALDINE P., 2011. *In-vitro* and *in-vivo* antioxidant effects of the oyster mushrooms *P. ostreatus*. *Food Res. Int.* 44, 851-861.
- JEDINAK A., DUDHGAONKAR S., JIANG J., SANDUSKY G., SLIVA D., 2010. *Pleurotus ostreatus* inhibits colitis-related colon carcinogenesis in mice. *Int. J. Mol. Med.* 26, 643-650.
- JEDINAK A., SLIVA D., 2008. *Pleurotus ostreatus* inhibits proliferation of human breast and colon cancer cells through p53-dependent pathway. *Int. J. Oncol.* 33, 1307-1313.
- JESENAK M., HRUBISKO M., MAJTAN J., RENNEROVA Z., BANOVCIN P., 2014. Anti-allergic effect of pleuran (β -glucan from *Pleurotus ostreatus*) in children with recurrent respiratory tract infections. *Phytother. Res.* 28, 471-474.
- JESENAK M., MAJTAN J., RENNEROVA Z., KYSELOVIC J., BANOVCIN P., HRUBISKO M., 2013. Immunomodulatory effect of pleuran (β -glucan from *Pleurotus ostreatus*) in children with recurrent respiratory tract infections. *Int. Immunopharmacol.* 15, 395-399.
- KANAGASABAPATHY G., KUPPUSAMY U.R., MALEK S.N.A., ABDULLA M.A., CHUA K.-H., SABARATNAM V., 2012. Glucan-rich polysaccharides from *Pleurotus sajor-caju* (Fr.) Singer prevents glucose intolerance, insulin resistance and inflammation in C57BL/6J mice fed a high-fat diet. *BMC Complement. Altern. Med.* 12: 261, doi:10.1186/1472-6882-12-261.
- KARAMAN M., JOVIN E., MALBASA R., MATAVULY M., POPOVIC M., 2010. Medicinal and edible lignicolous fungi as natural source of antioxidative and antibacterial agents. *Phytother. Res.* 24, 1473-1481.
- KHAN M.A., RAHMAN M.M., TANIA M., UDDIN M.N., AHMED S., 2011. *Pleurotus sajor-caju* and *Pleurotus florida* mushrooms improve some extent of the antioxidant systems in the liver of hypercholesterolemic rats. *Open Nutraceuticals J.* 4, 20-24.
- KHAN M.A., TANIA M., 2012. Nutritional and medicinal importance of *Pleurotus* mushrooms: an overview. *Food Rev. Int.* 28, 313-329.
- KUES U., LIU Y., 2000. Fruiting body production in basidiomycetes. *Appl. Microbiol. Biotechnol.* 54, 141-152.
- LAVI I., FRIESEM D., GERESH S., HADAR Y., SCHWARTZ B., 2006. An aqueous polysaccharide extract from the edible mushroom *Pleurotus ostreatus* induces anti-proliferative and pro-apoptotic effect on HT-29 colon cancer cells. *Cancer Lett.* 244, 61-70.
- LEE Y.-L., HUANG G.-W., LIANG Z.-C., MAU J.-L., 2007. Antioxidant properties of three extracts from *Pleurotus citrinopileatus*. *LWT – Food Sci. Technol.* 40, 823-833.
- LI S., SHAH N.P., 2014. Antioxidant and antibacterial activities of sulphated polysaccharides from *Pleurotus*

- eryngii* and *Streptococcus thermophilus* ASCC 1275. Food Chem. 165, 262-270.
- LI S., SHAH N.P., 2015. Effect of *Pleurotus eryngii* polysaccharides on bacterial growth, texture properties, proteolytic capacity, and angiotensin-I-converting enzyme-inhibitory activities of fermented milk. J. Dairy Sci. 98, 2949-2961.
- LI Y.R., LIU Q.H., WANG H.X., NG T.B., 2008. A novel lectin with potent antitumor, mitogenic and HIV-1 reverse transcriptase inhibitor activities from the edible mushroom *Pleurotus citrinopileatus*. Biochim. Biophys. Acta Gen. Sub. 1780, 51-57.
- LIN S.-Y., CHIEN S.-C., WANG S.-Y., MAU J.-L., 2016. Nonvolatile taste components and antioxidant properties of fruiting body and mycelium with high ergothioneine content from the culinary-medicinal golden oyster mushroom *Pleurotus citrinopileatus* (Agaricomycetes). Int. J. Med. Mushr. 18(8), 689-698.
- LINDEQUIST U., NIEDERMAYER T.H.J., JULICH W.-D., 2005. The pharmacological potentials of mushrooms. Evid-Based Complement. Alternat. Med. 2, 285-299.
- LV H., KONG Y., YAO Q., ZHANG B., LENG F.-W., BIAN H.-J., ET AL., 2009. Nebrodeolysin, a novel hemolytic protein from mushroom *Pleurotus nebrodensis* with apoptosis-inducing and anti-HIV-1 effects. Phytomed. 16, 198-205.
- MAFTOUN P., MALEK R., ABDEL-SADEK M., AZIZ R., EL ENSHASY H., 2013. Bioprocess for semi-industrial production of immunomodulator polysaccharide Pleuran by *Pleurotus ostreatus* in submerged culture. J. Sci. Industrial Res. 72, 655-662.
- MARTIN K.R., BROPHY S.K., 2010. Commonly consumed and specialty dietary mushrooms reduce cellular proliferation in MCF-7 human breast cancer cells. Exp. Biol. Med. 235, 1306-1314.
- MENG T.-X., FURUTA S., FUKAMIZU S., YAMAMOTO R., ISHIKAWA H., ARUNG E.T., ET AL., 2011. Evaluation of biological activities of extracts from the fruiting body of *Pleurotus citrinopileatus* for skin cosmetics. J. Wood Sci. 57, 452-458.
- MENIKPURAGE I.P., ABEYTINGA D.T.U., JACOBSEN N.E., WIJESUNDARA R.L.C., 2009. An oxidize ergosterol from *Pleurotus cystidiosus* active against anthracnose causing *Colletotrichum gloeosporioides*. Mycopathologia 167, 155-162.
- MIRUNALINI S., ARULMOZHI V., DEEPALAKSHMI K., KRISHNAVENI M., 2012. Intracellular biosynthesis and antibacterial activity of silver nanoparticles using edible mushrooms. Not. Sic. Biol. 4 (4), 55-61.
- MITRA P., KHATUA S., ACHARYA K., 2013. Free radical scavenging and NOS activation properties of water soluble crude polysaccharides from *Pleurotus ostreatus*. Asian J. Pharm. Clin. Res. 6 (3), 67-70.
- MORRIS H.J., BELTRAN Y., LLAURADO G., BATISTA P.L., PERRAUD-GAIME I., GARCIA N., ET AL., 2017. Mycelia from *Pleurotus* sp. (oyster mushroom): a new wave of antimicrobials, anticancer and antioxidant bio-ingredients. Int. J. Phytocosc. Nat. Ingrid. 2, 14, doi: 10.15171/ijpni.2017.14.
- MUSZYŃSKA B., SUŁKOWSKA-ZIAJA K., EKIERT H., 2013. Phenolic acids in selected edible basidiomycota species: *Armillaria mellea*, *Boletus badius*, *Boletus edulis*, *Cantharellus cibarius*, *Lactarius deliciosus* and *Pleurotus ostreatus*. Acta Sci. Pol., Hortorum Cultus 12, 107-116.
- NITSCHKE J., MODICK H., BUSCH E., VON REKOWSKI R.W., ALTENBACH H.-J., MÖLLEKEN H., 2011. A new colorimetric method to quantify β -1,3-1,6-glucans in comparison with total β -1,3-glucans in edible mushrooms. Food Chem. 127(2), 791-796.
- PALACIOS I., LOZANO M., MORO C., D'ARRIGO M., ROSTAGNO M.A., MARTÍNEZ J.A., ET AL., 2011. Antioxidant properties of phenolic compounds occurring in edible mushrooms. Food Chem. 128, 674-678.
- PARK K.H., LEE E.S., JIN Y.I., MYUNG K.S., PARK H.W., PARK C.G. ET AL. 2016. Inhibitory effect of *Panax ginseng* and *Pleurotus osteratus* complex on expression of cytokine genes induced by extract of *Dermatophagoides pteronissinus* in human monocytic THP-1 and EoL-1 cells. J. Mushroom Sci. Prod. 14 (4), 155-161.
- PASNIK J., ŚLEMP A., CYWINSKA-BERNAS A., ZEMAN K., JESENAK M., 2017. Preventive effect of pleuran (β -glucan from *Pleurotus ostreatus*) in children with recurrent respiratory tract infections-open-label prospective study. Curr. Pediatr. Res. 21(1), 99-104.
- PATEL S., GOYAL A., 2012. Recent developments in mushroom as anti-cancer therapeutics: a review. 3 Biotech.. 2, 1-15.
- PATEL Y., NARAIAAN R., SINGH V.K., 2012. Medicinal properties of *Pleurotus* species (Oyster mushrooms): a review. World J. Fungal Plant Biol. 3(1), 1-12.
- PELAES VITAL A.C., GOTO P.A., HANAI L.N., GOMES-DA-COSTA S.M., DE ABREU FILHO B.A., NAKAMURA C.V., ET AL., 2015. Microbiological, functional and rheological properties of low fat yogurt supplemented with *Pleurotus ostreatus* aqueous extract. LWT – Food Sci. Technol. 64, 1028-1035.
- PISKA K., SUŁKOWSKA-ZIAJA K., MUSZYŃSKA B., 2017. Edible mushroom *Pleurotus ostreatus* (oyster mushroom) – its dietary significance and biological activity. Acta Sci. Pol., Hortorum Cultus 16(1), 151-161.
- RAVI B., RENITTA R.E., PRABHA M.L., ISSAC R., NAIDU S., 2013. Evaluation of antidiabetic potential of oyster mushroom (*Pleurotus ostreatus*) in alloxan-induced diabetic mice. Immunopharmacol. Immunotoxicol. 35(1), 101-109.
- REGULA J., GRAMZA-MICHAŁOWSKA A., 2013. Nutritional value and glycemic index of cereal products with dried oyster mushroom (*Pleurotus ostreatus*) added. Żywn. Nauka Technol. Jakość 5, 119-128.
- REN D., JIAO Y., YANG X., YUAN L., GUO J., ZHAO Y., 2015. Antioxidant and antitumor effects of

- polysaccharides from the fungus *Pleurotus abalonus*. Chem.-Biol. Interact. 237, 166-174.
- ROP O., MLCEK J., JURIKOVA T., 2009. Beta-glucans in higher fungi and their health effects. Nutr. Rev. 67, 624-631.
- ROVENSKY J., STANCIKOVA M., SVIK K., BAUEROVA K., JURCOVICOVA J., 2011. The effects of β -glucan isolated from *Pleurotus ostreatus* on methotrexate treatment in rats with adjuvant arthritis. Rheumatol. Int. 31: 507-511.
- SARANGI I., GHOSH D., BHUTIA S.K., MALLICK S.K., MAITI T.K., 2006. Anti-tumor and immunomodulating effects of *Pleurotus ostreatus* mycelia-derived proteoglycans. Int. Immunopharmacol. 6, 1287-1297.
- SARI M., PRANGE A., LELLEY J.I., HAMBITZER R., 2017. Screening of beta-glucan contents in commercially cultivated and wild growing mushrooms. Food Chem. 216, 45-51.
- SCHNEIDER I., KRESSEL G., MEYER A., KRINGS U., BERGER R. G., HAHN A., 2011. Lipid lowering effects of oyster mushroom (*Pleurotus ostreatus*) in humans. J. Funct. Foods 3, 17-24.
- SELEGEAN M., PUTZ M.V., RUGEA T., 2009. Effect of the polysaccharide extract from the edible mushroom *Pleurotus ostreatus* against infectious bursal disease virus. Int. J. Mol. Sci. 10: 3616-3634.
- SHAMTSYAN M.M., KONUSOVA V.G., GOLOSHCHEV A.M., MAKSIMOWVA Y.O., PANCHENKO A.V., PETRISHCHEV N.N., ET AL. 2004. Immunomodulating and antitumor effects of basidiomycetes *Pleurotus ostreatus* (Jacq.: Fr.) P. Kumm. and *P. cornucopiae* (Pau. Ex Pers.) Rollan. J. Biol. Phys. Chem. 4 (3), 157-161.
- SILVEIRA M.L.L., SMIDERLE F.R., AGOSTINI F., PEREIRA E.M., BONATTI-CHAVES M., WISBECK E., ET AL., 2015. Exopolysaccharide produced by *Pleurotus sajor-caju*: its chemical structure and anti-inflammatory activity. Int. J. Biol. Macromol. 75, 90-96.
- SILVEIRA M.L.L., SMIDERLE F.R., MORAES C.P., BORATO D.G., BAGGIO C.H., RUTHES A.C., 2014. Structural characterization and anti-inflammatory activity of a linear β -D-glucan isolated from *Pleurotus sajor-caju*. Carbohydr. Polym. 113, 588-596.
- STACHOWIAK B., REGUŁA J., 2012. Health-promoting potential of edible macromycetes under special consideration of polysaccharides: a review. Eur. Foods Res. Technol. 234, 369-380.
- SUSEEM S.R., SARAL A.M., REDDY P.N., MARSLIN G., 2011. Evaluation of analgesic activity of ethyl acetate, methanol and aqueous extracts of *Pleurotus eous* mushroom. Asian Pac. J. Trop. Med. 4, 117-120.
- SUSEEM S.R., SARAL A.M., 2013. Analysis on essential fatty acid esters of mushrooms *Pleurotus eous* and its antibacterial activity. Asian J. Pharmaceut. Clin. Res. 6, 188-191.
- SYNYTSYA A., MICKOVA K., JABLONSKY I., SLUKOVA M., COPIKOVA J., 2008. Mushrooms of genus *Pleurotus* as a source of dietary fibres and glucans for food supplements. Czech J. Food Sci. 26(6), 441-446.
- SYNYTSYA A., MICKOVA K., SYNYTSYA A., JABLONSKY I., SPEVACEK J., ERBAN V. ET AL., 2009. Glucans from fruit bodies of cultivated mushroom *Pleurotus ostreatus* and *Pleurotus eryngii*: Structure and potential prebiotic activity. Carbohydr. Polym. 76, 548-556.
- TAOFIQ O., GONZALEZ-PARAMAS A.M., MARTINS A., BARREIRO M.F., FERREIRA I.C.F.R., 2016. Mushroom extracts and compounds in cosmetics, cosmeceuticals and nutricosmetics – a review. Indust. Crops Prod. 90, 38-48.
- TOMIYAMA T., KAIHOU S., ISHIDA M., NISHIKAWA H., YAMAZAKI N., TSUJI K. ET AL., 2008. The water retention effects and action for atopic dermatitis-like symptoms of ethyl alcohol extract (from tamogitake [*Pleurotus cornucopiae* var. *citrinopileatus*] mushroom) on animal model of atopic dermatitis. J. Japan Soc. Nutr. Food. Sci. 61, 21-26.
- TONG H., XIA F., FENG K., SUN G., GAO X., SUN L. ET AL., 2009. Structural characterization and *in vitro* antitumor activity of a novel polysaccharide isolated from the fruiting bodies of *Pleurotus ostreatus*. Bioresour. Technol. 100, 1682-1686.
- WAKCHAURE G.C., SHIRUR M., MANIKANDAN K., RANA L., 2010. Development and evaluation of oyster mushroom value added products. Mushroom Res. 19(1), 40-44.
- WANG C.R., NG T.B., LI L., FANG J.C., JIANG Y., WEN T.Y. ET AL., 2011. Isolation of a polysaccharide with antiproliferative, hypoglycemic, antioxidant and HIV-1 reverse transcriptase inhibitory activities from the fruiting bodies of the abalone mushroom *Pleurotus abalonus*. J. Pharm. Pharmacol. 63, 825-832.
- WANG H., GAO J., NG T.B., 2000. A new lactin with highly potent antihepatoma and antisarcoma activities from the oyster mushroom *Pleurotus ostreatus*. Biochem. Biophys. Res. Commun. 275, 810-816.
- WANG H.X., NG T.B., 2000. Isolation of a novel ubiquitin-like protein from *Pleurotus ostreatus* mushroom with ant-human immunodeficiency virus, translation-inhibitory and ribonuclease activities. Biochem. Biophys. Res. Commun. 276, 587-593.
- WANG S., BAO L., ZHAO F., WANG Q., LI S., REN J., ET AL., 2013. Isolation, identification and bioactivity of monoterpenoids and sesquiterpenoids from the mycelia of edible mushroom *Pleurotus cornucopiae*. J. Agric. Food Chem. 61, 5122-5129.
- WASSER S.P., 2002. Medicinal mushrooms as a source of antitumor and immunomodulating polysaccharides. Appl. Microbiol. Biotechnol. 60, 258-274.
- WASSER S.P., 2011. Current finding, future trends, and unsolved problems in studies of medicinal mushrooms. Appl. Microbiol. Biotechnol. 89, 1323-1332.
- WASSER S.P., 2014. Medicinal mushroom science: current perspectives, advances, evidences and challenges. Biomed. J. 37, 345-356.

- WASSER S.P., WEIS A.L., 1999. Medicinal properties of substances occurring in higher Basidiomycetes mushrooms: current perspectives (Review). *Int. J. Med. Mushroom* 1, 31-62.
- WIATER A., PADUCH R., CHOMA A., PLESZCZYŃSKA M., SIWULSKI M., DOMINIK J. ET AL., 2012. Biological study on carboxymethylated (1→3)- α -D-glucans from fruiting bodies of *Ganoderma lucidum*. *Int. J. Biol. Macromol.* 51, 1014-1023.
- WIATER A., PADUCH R., PLESZCZYŃSKA M., PRÓCHNIAK K., CHOMA A., KANDEFER-SZERSZEŃ M., ET AL., 2011. α -(1→3)-D-Glucans from fruiting bodies of selected macromycetes fungi and the biological activity of their carboxymethylated products. *Biotechnol. Lett.* 33, 787-795.
- WIATER A., PADUCH R., PRÓCHNIAK K., PLESZCZYŃSKA M., SIWULSKI M., BIALAS W., ET AL., 2015. Assessing biological activity of carboxymethylated derivatives of α -(1→3)-glucans isolated from fruiting bodies of cultivated *Pleurotus* species. *Żywn. Nauka Technol. Jakość* 1(98), 193-206.
- WITKOWSKA A.M., 2014. Selenium-fortified mushrooms – candidates for nutraceuticals? *Austin Ther.* 1, 1-4.
- WU G.-H., HU T., LI Z.-Y., HUANG Z.-L., JIANG J.-G., 2014. *In vitro* antioxidant activities of the polysaccharides from *Pleurotus tuber-regium* (Fr.) Sing. *Food Chem.* 148, 351-356.
- WU J.-Y., CHEN C.-H., CHANG W.-H., CHUNG K.-T., LIU Y.-W., LU F.-J., ET AL., 2011. Anti-cancer effects of protein extracts from *Calvatia lilacina*, *Pleurotus ostreatus* and *Volvariella volvacea*. *Evid.-Based Complement. Alternat. Med.*, doi:10.1093/ecam/neq057.
- WU X., ZHENG S., CUI L., WANG H., NG T.B., 2010. Isolation and characterization of a novel ribonuclease from the pink oyster mushroom *Pleurotus djamor*. *J. Gen. Appl. Microbiol.* 56, 231-239.
- WU Y., CHOI M.-H., LI J., YANG H., SHIN H.-J., 2016. Mushroom cosmetics: the present and future. *Cosmetics* 3(3), 22, doi:10.3390/cosmetics3030022.
- YAN B., JING L., WANG J., 2015. A polysaccharide (PNPA) from *Pleurotus nebrodensis* offers cardiac protection against ischemia-reperfusion injury in rats. *Carbohydr. Polym.* 133, 1-7.
- ZHANG Y., DAI L., KONG X., CHEN L., 2012. Characterization and *in vitro* antioxidant activities of polysaccharides from *Pleurotus ostreatus*. *Int. J. Biol. Macromol.* 51(3), 259-265.
- ZHU F., DU B., BIAN Z., XU B., 2015. Beta-glucans from edible and medicinal mushrooms: characteristics, physicochemical and biological activities. *J. Food Comp. Anal.* 41, 165-173.

Received November 4, 2017; accepted February 19, 2018