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FUNGI-DERIVED β-GLUCANS AS A COMPONENT OF FUNCTIONAL FOOD

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Abstract. Functional food market develops dynamically all over the world although in Poland consumers knowledge in this area is insufficient. An importance of functional food mainly arises from contained bioactive substances. Funcional food includes also mushrooms which contain polisaccharides, especially β-glucans. These compounds differ in structure, water solubility, molecule size and molecular mass which determine their medicinal properties. β-glucans derived from fungi show very wide spectrum of health-supporting activity. Their antitumor, immunomodulating, antibacterial, antiviral and anti-oxidative properties are well documented. They have ability to lower high blood pressure, lower excessive cholesterol synthesis, and decrease blood-glucose level. *Lentinula edodes* and species from genus *Pleurotus* are regarded as main sources of β-glucans. The most important fungi derived β-glucans are lentinan, pleuran, grifolan, crestin and ganoderan.

Key words: polisaccharides, medicinal properties, edible mushrooms

INTRODUCTION

At the end of 20th century requirements concerning food changed significantly [Mollet and Rowland 2002]. Food should not only satisfy hunger and provide human with necessary nutrients but also should assist in achieving and maintaining possible the best physical and psychological condition and also help in disease avoiding [Grajeta 2004]. These changes induced occurrence of idea of functional food, i.e. food that influences human health what has been proved by numerous studies [Bleiel 2010]. Functional food includes inter alia fungi [Barros et al. 2008], that are an abounding source of many bioactive compounds, e.g. β-glucans [Yang and Zhang 2009].

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FUNCTIONAL FOOD

Term "Functional Food" was created in 1980s in Japan [Hardy 2000]. As pointed out by Krygier and Florowska [2008], there is a new, wider term used now in Japan – Food with Health Claims (FHC).

There are a few definitions of functional food. One of them is included in the final document of the research program FUFOSE (Functional Food Science in Europe) financed by the European Commission. According to this definition, food can be recognized as functional if its beneficial influence on one or more organism functions has been proved [Roberfroid 2002]. Saluk-Juszczak [2010] states that lack of uniform and widely accepted definition incurs many problems, e.g. with promotion of such products.

A quality of functional food mainly arises from contained bioactive substances that stimulate metabolism [Jones 2002]. The most important bioactive substances, that determine application of functional food are, polyunsaturated fatty acids, especially omega-3 fatty acids, vitamins and minerals with antioxidative activity, dietary fibre, prebiotics and probiotics, and substances enhancing natural immunity of an organism [Świderski and Waszkiewicz-Robak 2005]. Concerning lack of uniform legal regulations on functional food, it is necessary to control safety of its usage [Olędzka 2007].

Lange [2010] distinguishes three main directions of functional food impact on human organism,

1. inhibition of degenerative changes or healing activity and supporting of treatment in the course of some diseases, e.g. cancers, circulatory system diseases, osteoporosis, diabetes, allergy, dyspepsia and malabsorption;
2. increase of nutrients provision during conditions of higher demand, e.g. during growth period, pregnancy, convalescence, sport activities;
3. improvement of mood and psychophysical efficiency of an organism.

However, majority of functional products influence human organism multidirectionally. Bioactive substances in functional food improve cardiac performance and circulatory system functioning. They also support digestive system activity and help to maintain normal body mass. In many cases they also positively influence lipid metabolism of an organism and regulate organism immune response, being a kind of modulator [Vetvicka 2011].

β-GLUCANS STRUCTURE AND PROPERTIES

Glucans are polysaccharides commonly present in living organisms. They are polymers built of monosaccharides linked by alfa and beta type glycosidic bonds. They have complex chemical structure and perform varied physiological functions. They are also used in many different industrial branches [Laroche and Michaud 2007]. Augustin [1998] states that considering physicochemical properties, glucans can be divided into four groups, branched β-1,3 glucans with high molecular mass [pleuran, lentinan, grifolan and schizophyllan], β-glucans with lower molecular mass [e.g. *carboxymethyl glucan*], glucans with small molecule [e.g. zymosan] and α-glucans. A lot of attention has been put on β-glucans during last years [Laroche and Michaud 2007]. Numerous

researches on impact of these compounds on human health are conducted all over the world [Ramberg et al. 2010].

β-glucans are components of cell walls of plants, algae, bacteria and fungi [Novak and Vetvicka 2009]. They have very wide activity spectrum, depending, inter alia, on their origin [Havrlentova et al. 2011]. They are long-chained, multidimensional polymers of glucose, in which individual molecules of glucopyranose are linked by β- or α-glycosidic bonds [Lowman et al. 1998]. These molecules bind in a line in [1→3] and/or [1→4] configuration or in a branched way using β-[1→6]-glycosidic bonds in order to link side-chains of different length to the backbone [Laroche and Michaud 2007]. As pointed out by Volman et al. [2008], there are distinct differences in polymer structure of β-glucans depending on their origin (fig. 1, tab. 1).

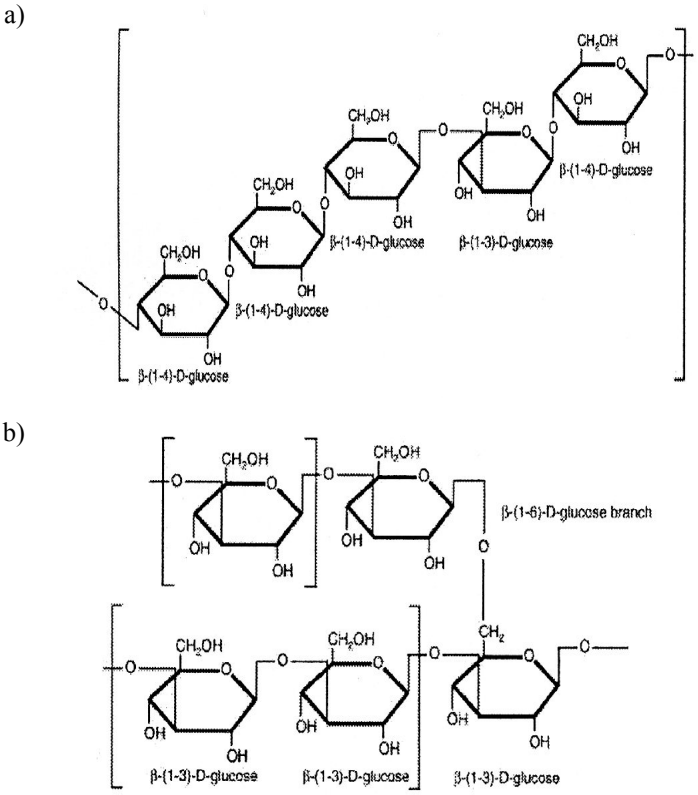

Fig. 1. Structure of cereal (a) and yeast (b) β-glucan [Volman et.al. 2008]
Ryc. 1. Struktura β-glukanu pochodzącego z ziarna (a) i z drożdży (b) [wg Volman i in. 2008]

β-glucans from cell walls of yeasts and other fungi consist of glucopyranose molecules linked by 1,3-β linkages and small number of branches bound by 1,6-β bonds, whereas cereal cell wall consists of not branched β-glucans with glucopyranose mole-

cules linked by 1,3-β and 1,4-β linkages. Bacteria derived β-glucans are not branched and include glucopyranose molecules linked by 1,3-β bonds [Laroche and Michaud 2007].

Table 1. Commonly used β-glucans [Volman et. al 2008]
Tabela 1. Powszechnie stosowane β-glukany [wg Volman i in. 2008]

Name Nazwa	Source Źródło	Source type Typ źródła	Structure Budowa
Glomerellan	*Glomerella cingulata*	Fungus	1,3 1,6 branched
GRN (grifolan)	*Grifola frondosa*	Fungus /mushroom	1,3 1,6 branched
LNT (lentinan)	*Lentinula edodes*	Fungus /mushroom	1,3 1,6 branched
Pneumocytis carinii	*Pneumocytis carinii*	Fungus/protozoan	1,3 1,6 branched
P-SG	*Ganoderma lucidum*	Fungus	1,3 1,6 branched
SPG (sonifilan, schizophyllan)	*Schizophyllum commune*	Fungus	1,3 1,6 branched
SR (skleroglucan)	*Sclerotium rolfsii* or *S.glucanicum*	Fungus	1,3 1,6 single branched
SSG	*Sclerotium sclerotiorum*	Fungus	1,3 1,6 highly branched
CSBG	*Candida albicans*	Yeast	1,3 1,6 branched
GluP (fosforoglucan)	*Saccharomyces cerevisiae*	Synthetic modified	1,3
PGG (betafektin)	*Saccharomyces cerevisiae*	Genetically engineered	1,3 1,6 highly branched
Saccharomyces cerevisiae	*Saccharomyces cerevisiae*	Yeast	1,3 and small numbers of 1,6 branches
WPG-glucan (whole glucan particle)	*Saccharomyces cerevisiae*	Yeast	1,3 1,6
Zymocel	*Saccharomyces cerevisiae*	Yeast	Crude e β-glucan extract
Zymosan	*Saccharomyces cerevisiae*	Yeast	Crude extract with β-glucan and mannan non-uniform branches
Barley, oat, wheat, rye, rice		Cereal	1,3 1,4 mixed linkage, unbranched
Curdlan	*Alcaligenes faecalis*	gram negative bacteria	1,3 unbranched
LAM (laminarin, laminaran)	*Laminaria*	algae e.g. brown seaweeds	1,3 unbranched with some branching of 1,6

In addition to differences in bond types and branching, β-glucans can present different solubility, viscosity, ability to gel formation, molecular mass and tertiary structure. Moreover, β-glucans properties depend also on isolation method and origin [Volman et al. 2008], that influence in turn diversity of their structure and degree of polymerisation and thereby their molecular mass [Rajarathnam et al. 1998]. Bohn and BeMiller [1995] state that β-glucans derived from the same source, but with higher molecular mass have higher activity. Numerous studies reveal that physicochemical properties of β-glucans can be modified [Wang et al. 2010].

The above mentioned factors decide to a large degree about health-supporting properties of β-glucans [Yang and Zhang 2009] and possibility of their use in pharmaceutical industry [Laroche and Michaud 2007], food industry [Lazaridou and Biliaderis 2007] and as dietary supplements [Synytsya et al. 2008].

Healing activity of β-glucans have been known for years. There are used first of all as natural adjuvants – substances that enhance immune system called "biological response modifiers", and antibacterial and antiviral agents [Ramberg et al. 2010]. Many of them also demonstrate antitumour activity [Chan et al. 2009] and give positive results in treatment of AIDS patients [Adotey et al. 2011].

Detailed studies of β-glucans revealed their very wide, beneficial impact on human organism, e.g. lipid balance improvement [Tsiapali et al. 2001], normalization of blood-glucose level in the case of diabetics [Chen and Raymond 2008], decreasing of total blood-cholesterol level [Queenan et al. 2007] and impact on general feeling [Talbott and Talbott 2009]. As pointed out by Szymańska-Czerwińska and Bednarek [2007], (1-3)(1-6)-β-D-glucans, that have long, branched side chains are also good prebiotics, which stimulate growth of beneficial intestinal flora.

β-glucans are commonly used in food technology and, owing to their diverse physicochemical properties, perform in food products different functions, e.g. gelling, stabilising, emulsifying, thickening [Thammakiti et al. 2004]. Especially often they are used for improvement of consistence of food products, e.g. drinks, dressings or ice cream [Worrasinchai et al. 2006]. Szymańska-Czerwińska and Bednarek [2007] point out that β-glucans are used not only as a dietary supplement for humans, but also as a supplement to animal feed. In the market, there are preparations such as Sophy β-glucan and Wellmune WGP®, which are mainly designed to modulate immune system of humans [Feldman et al. 2009] and animals [Hoa et al. 2011]. The uses of β-glucans in animal breeding not only limits infection occurrence but also improves animal growth and development and significantly helps in decreasing of antibiotics usage [Petravic-Tominac et al. 2010]. β-glucans are used also in cosmetic industry, mainly for production of preparations for irritation prevention and for delaying of skin aging effects [Petravic-Tominac et al. 2010]. Numerous researchers point out that considering β-glucans properties, they need to be more commonly used [Vetvicka 2011].

β-GLUCANS SOURCES

Cereal β-glucans demonstrate different properties depending on their origin [Wood 2007] and, as stated by Charalampopoulos et al. [2002], different molecular mass, that is the biggest in oat (about 30×10^5 Da) and barley (about 21×10^5 Da). Wang's et al. researches [2003] revealed that molecular mass of β-glucans can be also influenced by a method of their extraction. Furthermore, it was found that molecular mass influences cereal β-glucans properties and determines their rheological properties [Lazaridou et al. 2003], health-supporting features and usage [Lazaridou and Biliaderis 2007]. Kim et al. [2006] points out numerous clinical trials with cereal β-glucans use.

According to Laroche and Michaud [2007], content of β-glucans in cereal grains depends not only on a species but also on a variety and cultivation conditions and nor-

mally is between 2 and 6% of dry matter. Oat is especially rich in β-glucans [Lange 2010]. As pointed out by Havrlentova et al. [2011] significant amount of β-glucans can be found also in barley grain. In researches by Smith et al. [2004] oat derived β-glucans demonstrated comparable health-supporting properties as β-glucans from barley. Glucans from above mentioned cereals have inter alia an ability to decrease glucose-blood level [Poyhonen 2004]. Study by Biorklund et al. [2005] demonstrated that oat derived β-glucans with high degree of water solubility, decrease glycaemia and insulinaemia in higher degree than barley derived β-glucans, that include lower amount of water soluble components. According to Queenan et al. [2007], β-glucans from oat and barley lower also total level of cholesterol and triglycerides, what, as pointed out by Maki et al. [2007], decreases the probability of cardiac diseases occurrence. Lange [2010] states that lowering of cholesterol level is proportional to the amount of oat derived β-glucans. Moreover, research by Yun et al. [2003] proved that oat derived β-glucans increase immunity to bacterial and parasitic infections. Concerning their properties cereal β-glucans are used not only in medicine but also in food and cosmetic industry [Havrlentova et al. 2011]. There are also valuable component of functional food [Gibiński 2008].

Especially valuable source of β-glucans is cell wall of yeast [*Saccharomyces cerevisiae*], which in 55–60% consists of β-glucans [Saluk-Juszczak and Królewska 2010]. These β-glucans are built of glucose backbone with β-1,3 linkages, from which short side-chains branch off linked by β-1,6 bonds [Lipke and Ovalle 1998]. As pointed out by Bell et al. [1999] yeast have more β-glucans than oat grains, regarded as rich β-glucans source. Content of β-glucans in yeast cell wall fits in quite a wide range, i.e. between 29 and 64% and mainly depends on yeast cultivation conditions

Saluk-Juszczak and Królewska [2010] distinguish three types of glucans present in yeast cell wall, that differ with type of linkage and branching of molecules. Akramiene et al. [2007] point out that in the inner layer of yeast cell wall there is between 30 and 35% of insoluble β-glucans, in the middle layer between 20 and 22% of soluble β-glucans and in the outer one approximately 30% of glycoproteins. However, Jaehrig et al. [2007] state that β-glucans in yeast cell wall are present in two forms, i.e. insoluble in bases and soluble. Yeast derived β-glucans are insoluble in water because of chitin.

Isolated from yeast (1→3)-β-D-glucan has inter alia ability to induce immunity against bacterial, fungal, viral and parasite infections and against tumour cells [Yoon et al. 2008], whereas its soluble form – *carboxymethyl glucan (CMG) shows antioxidative properties* [Sandula et al. 1999]. A valuable β-glucan derived from yeast is zymosan, insoluble polymer of glucose, that demonstrates strong antibacterial properties and by activation of macrophages and induction of cytokines secretion enhances immune system [Brown et al. 2003].

In food industry bacteria derived polysaccharides, often named bacterial exopolysaccharides, are commonly used. These β-glucans are secretions of different microorganisms, such as *Cellulomonas flavigena* strain KU [Kenyon et al. 2005], *Bacillus curdlanolyticus*, *Bacillus kobensis*, *Bacillus* and *Micromonospora* [Obst et al. 2004], *Agrobacterium* sp. ATCC 31749, *Bradyrhizobium*, *Rhizobium* spp., *Sarcina ventriculi*

[Stasinopoulos et al. 1999]. Bacteria derived β-glucans, such as, xanthan, dextran, pollulan and gellan are used on large scale in food industry [Funane et al. 2001]. Glucan, which is widely used as a component with technical importance is also curdlan, isolated from *Alcaligenes faecalis* [McIntosh et al. 2005]. It is a colourless and odourless compound, insoluble in cold water. It has thickening, gelling and texture stabilizing properties owing to forming irreversible gel resistant to wide range of temperature [Williams et al. 2009]. Its molecular mass is $5.3 \times 10^4 – 2.0 \times 10^6$ Da [Nakata et al. 1998].

FUNGI DERIVED β-GLUCANS

Fungi have been appreciated by people for a long time, not only because of their nutritive but also because of healing properties [Guillamon et al. 2010]. They are especially often used in oncological treatment [Zaidman et al. 2005]. As pointed out by Wasser [2002], about 650 fungi species from phylum Basidiomycota demonstrate antitumour properties. According to different authors, there are 10,000–15,000 known mushroom species, 700–2,000 of them are edible, and 200–650 have healing properties [Minato 2010]. Smith et al. [2002] state that 35 mushroom species are cultivated in the world, 20 on them on a mass scale.

Numerous studies on fungi impact on human health are conducted in different research centres in the world [Smith et al. 2002]. Many of them concern polysaccharides contained it fungi, especially glucans [Ferreira et al. 2010]. As stated by Chen and Seviour [2007], β-glucans derived from fungi show very wide spectrum of health-supporting activity. Some of fungi derived β-glucans are used as pharmaceutical preparations e.g. lentinan, schizophyllan, crestin, PSP and Grifron-D [Smith et al. 2002].

Immunological activity of fungi and their antitumour properties have been in the area of interest of researchers for over 50 years [Borchers et al. 2004]. Studies on healing properties of fungi conducted in the world are continually extended by new species [Shamtsyan et al. 2004]. Species, that have been used for many years in a traditional medicine of the Far West, are, *Ganoderma lucidum*, *Lentinula edodes*, *Grifola frondosa*, *Hericium erinaceus*, *Trametes versicolor*, *Schizophyllum commune*, *Phellinus linteus*, *Inonotus obliquus* and *Pleuortus ostreatus* [Wasser 2011]. As pointed out by Wasser [2005] the species that is especially reach in polysaccharides [more than 200] is *Ganoderma lucidum,* and different forms of β-glucans are between 10 and 50% of dry matter of Lingzhi mushroom. Numerous studies reveal β-glucans presence also in other fungi species, e.g. from genus *Boletus*, in which these compounds constitute between 2 and 13% of dry matter [Manzi et al. 2004]. Other representatives of *Basidiomycota* are also rich sources of β-glucans. According to Reverberi et al. [2004], *Hirneola auricula*, *Stropharia aeruginosa*, *Agrocybe aegerita* and *Armillaria mellea* are particularly interesting. Furthermore, β-glucans were also isolated from other species of Basidiomycota e.g. *Lyophyllum decastes* [Ukawa et al. 2000], *Collybia dryophila* [Sanchez-Pacheco et al. 2006], *Inonotus obliquus* [Rhee et al. 2008] and *Calocybe indica* [Mandal et al. 2010]. Very good results in oncological treatments were obtained using β-glucan isolated from *Agaricus blazei* syn. *Agaricus brasiliensis* [Ohno et al. 2011]. There are also conducted numerous studies in the world on *Phellinus linteus*, the species known and

appreciated for thousands years in Asiatic countries [Li et al. 2004]. According to Fan et al. [2006], one should expect intensive development of researches on healing properties of fungi and their usage as dietary supplements.

Lentinula edodes and species from genus *Pleurotus* are regarded now as the most important sources of β-glucans [Rop et al. 2009]. In the researches conducted by Manzi and Pizzoferrato [2000] on few species of *Pleurotus* fungi and shiitake mushroom, concentration of β-glucans was between 0.21 and 0.53 g · 100 g^{-1} of dry matter. The compared species differ also in amount of insoluble fractions (53–83%) and soluble ones (16–46%).

β-glucans contained in fungi differ in structure, water solubility, molecule size and molecular mass. Listed features cause that not all β-glucans contained in fungi show equally strong healing activity [Zhang et al. 2007]. According to Wasser [2002], β-glucans with higher molecular mass are more effective. Ohno [2005] found high healing activity of scleroglucan [fungi from genus *Sclerotium*] with high molecular mass. However, in research by Zhang et al. [2007] higher antitumour activity was demonstrated by lentinan [*Lentinula edodes*] with low molecular mass. Wasser [2011] points out that efficiency of β-glucans is influenced by length of side-chain, number of backbone branches and ratio of (1,4) bonds to (1,6) and (1,3) ones. The effect of β-glucans activity is also determined by their solubility Wasser [2011]. Research by Ishibashi et al. [2001] proved that soluble β-glucans are stronger immunomodulators than insoluble ones.

Interest in β-glucans is closely connected to their antitumour properties [Kidd 2000, Daba and Ezeronye 2003]. As pointed out by Peng et al. [2003] these properties are demonstrated both by fruiting bodies and mycelium. Antitumour activity of β-glucans refers mainly to (1→3)/(1→6)-β form. It is related to their ability to neutralise free radicals, that are vital reason of cancer occurrence [Chen and Seviour 2007]. Antitumour properties of fungi derived β-glucans are widely described in scientific literature [Sanodiya et al. 2009]. They result not from direct cytotoxic activity but from strong enhancement of immunological response of an organism [Enshasy 2010]. It was confirmed by a study by Radic et al. [2010] on β-glucans isolated from over 30 species of fungi. Mechanism of prevention of diseases that result from decreased organism immunity consists in stimulation by β-glucans of cytokines production [Minato 2010].

β-glucans activity was studied mainly in tests on animals. Not many of them were tested on humans [Wasser 2011]. It was revealed in clinical trials that stronger antitumour activity showed β-glucans linked with proteins than free β-glucans [Jeurink et al. 2008].

Fungi-derived β-glucans show also antibacterial, antiviral and antiallergic activities [Kumar et al. 2004]. These compounds have ability to lower excessive cholesterol synthesis, lower high blood pressure and decrease blood-glucose level [Rop et al. 2009]. They also prevent diabetes [Perera and Li 2011]. Fungi derived β-glucans have also strong antioxidative properties [Tsiapali et al. 2001].

Content of active substances in fungi depends inter alia on cultivation conditions, variation, maturation phase of fruiting bodies [Kimmons et al. 2010], storage conditions [Minato et al. 2004, Jiang et al. 2010] and fruiting bodies processing method [Manzi et

al. 2004]. Jagadish et al. [2009] did not confirm influence of thermal treatment on active substances content in fungi.

FUNGI DERIVED β-GLUCANS CHARACTERISTIC

Lentinan was isolated from shiitake mushroom *Lentinula edodes* almost 40 years ago [Zhang et al. 2011]. It is a polysaccharide with a line structure and side-chains with molecular formula $[C_6H_{10}O_5]_n$. very five molecules of glucose in backbone are linked by (1→3)-β type linkages. These five molecules of glucose in backbone are connected to two molecules of glucose linked by (1→6)-β type linkages (fig. 2) [Brauer et al. 2010]. Data about molecular mass of lentinan is quite divergent. Zhang et al. [2011] state that at the beginning, mean mass of lentinan was determined as $9.5 \times 10^5 – 10.5 \times 10^5$, and then as $3 \times 10^5 – 8 \times 10^5$. According to Ooi and Liu [2000], lentinan molecular mass is $400 – 800 \times 10^3$. Laroche and Michaud [2007] determine it as 5×10^5, whereas according to Kidd [2000], it varies between 400,000 and 1,000,000 daltons.

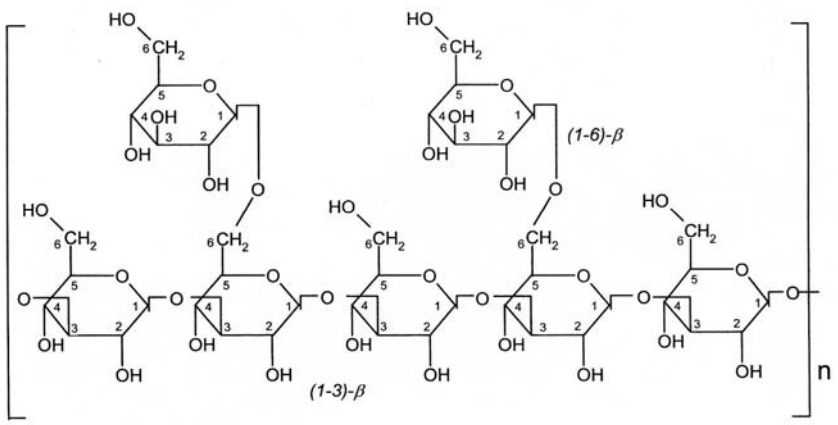

Fig. 2. Chemical structure of lentinan [Borchers et.al 2004]
Ryc. 2. Chemiczna struktura lentinanu [wg Borchers i in. 2004]

Results obtained in many research centres show that lentinan has strong antitumour activity [Wasser 2011], that increases together with its molecular mass [Zhang et al. 2005]. Furthermore, it decreases side effects of chemotherapy [Lull et al. 2005]. Numerous studies revealed also positive impact of lentinan on bacterial infection reduction [Markova et al. 2003]. As pointed out by Adotey et al. [2011] lentinan shows also immunostimulative effect in case of AIDS patients.

Pleuran was isolated from oyster mushroom *Pleurotus ostreatus*. This compound is built of molecules of glucose linked by (1→3)-β bounds (fig. 3). Such backbone with line structure is linked with side-chains built of glucopyranose molecules. Every four molecules of glucose from backbone is connected with 0 to 6 molecules of glu-

copyranose in form of side-chains. Molecules of glucose in side-chains are linked to backbone by (1→4)-β and (1→6)-β linkages [Hozova et al. 2004]. As pointed out by Augustin et al. [2007], molecular mass of pleuran is between 600,000 and 700,000.

Pleuran demonstrates antitumour properties, lowers concentration of lipids in blood and stabilises carbohydrates metabolism. Furthermore, it has antifungal properties [Chu et al. 2005]. It regulates also antioxidative potential of an organism [Bobek and Galbavy 2001]. Zhang et al. [2007] state that pleuran rebuilds epithelium and increases movement of phagocytes and granulocytes to focus of inflammation that results in microorganisms destruction. Detailed studies revealed its antitumour properties [Jose et al. 2002]. Research by Synytsya et al. [2009] confirmed prebiotic properties of pleuran.

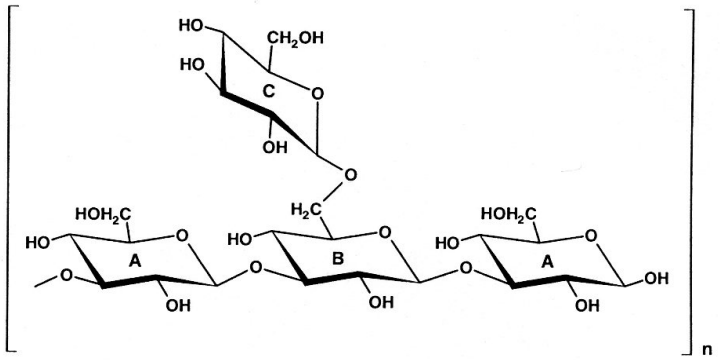

Fig. 3. Chemical structure of pleuran [Carbonero et. al 2006]
Ryc. 3. Chemiczna struktura pleuranu [wg Carbonero i in. 2006]

β-glucans were also isolated from other species of genus *Pleurotus*, inter alia from *P. eryngii* and *P. ostreatoroseus* [Carbonero et al. 2006] and from *P. tuber-regium* [Zhang et al. 2003]. β-glucan derived from *P. pulmonarius* demonstrated analgesic [Baggio et al. 2010] and anti-inflammatory activities [Smiderle et al. 2008].

Extracts isolated from *P. ostreatus* and *P. eryngii* stimulated development of probiotic strains of *Lactobacillus*, whereas extract from *P. eryngii – Bifidobacterium* strains. Work by Lavi et al. [2010] revealed positive impact of β-glucans derived from *P. pulmonarius* on inflammatory states of large intestine. Moreover, in the study by Selegean et al. [2009] extract from *P. ostreatus* limited occurrence of serious viral disease of chicken. As pointed out by Augustin et al. [2007] biological activity of pleuran is probably enhanced by presence in oyster mushroom tissues other health-supporting compounds i.e. chitin and chitosan.

Grifolan is derived from Maitake mushroom – *Grifola frondosa* and commonly named GRN. This glucan includes in its molecule (1→3)-β linkages and its molecular mass is approximately 4.5×10^5 Da [Tada et al. 2009]. Laroche and Michaud [2007] state that molecular mass of grifolan is 5×10^5 Da. It is present both in mycelium and fruiting bodies of *Grifola frondosa* [Minato 2010]. Its structure is similar to schizophyllan and scleroglucan [Mao et al. 2007], whereas triple stranded helix form bears resemblance to other (1→3)-β-glucan – curdlan.

Researches by Minato et al. [2001] revealed that grifolan content in *Grifola frondosa* depends on fungus developmental phase. According to Ishibashi et al. [2001] and Tada et al. [2009], its properties depend on structure and molecular mass. Grifolan is a polysaccharide that demonstrates high biological activity as immunomodulator and antitumour agent [Nie et al. 2006]. Deng et al. [2009] in clinical trials of patients with breast cancer confirmed immunomodulative properties of extract with polysaccharides content from *Grifola frondosa.* Grifolan is also used in treatment of HIV, hyperlipidaemia, hypertension and virus hepatitis [Mayell 2001].

Crestin, named also PSK [polysaccharide-K] was isolated from *Coriolus versicolor* and is a proteoglucan that contains 25–38% of proteins [Ooi and Liu 2000]. It is characterised by diverse molecular mass, that according to Stryer [2003], is between approximately 0.1×10^5 Da and approximately 2×10^6 Da, whereas according to Kidd [2000], between 94 000 and 100 000 Da. Moradali et al. [2007] point out that molecular mass of crestin is 100 KDa. *Coriolus versicolor* is also a source of other proteoglucan – PSP (polysaccharide-P, polysaccharopeptide), with structure similar to crestin and molecular mass approximately 100 000 daltons [Kidd 2000].

Crestin shows antimicrobial activity, inter alia against *Escherichia coli*, *Listeria monocytogenes* and *Candida albicans* [Blondel 2001]. During last years researches have been especially interested in high antitumour activity of crestin [Smith et al. 2002]. Fujimiya et al. [1999] state that antitumour properties of this β-glucan do not depend on its molecular mass. Crestin ability to enhance immune system by induction of IL-6 and TNF was confirmed in research in mouse model [Price et al. 2010].

Ganoderan is derived from *Ganoderma lucidum* and it is also named MW 20K [Ooi and Liu 2000], P-SG [Volman et al. 2008] or Gl-1 [Rop et al. 2009]. It is a proteoglucan similar to crestin. In addition to molecules of (1→3)-β-glucans it consists of 4% of proteins [Ooi and Liu 2000]. As the result, it can be also found in scientific literature as FIMs (fungal immunomodulatory proteins) and GPP (Ganoderma polysaccharides peptide) [Rop et al. 2009]. It was revealed that this compound shows antitumour properties [Zhou et al. 2007].

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β-GLUKANY POZYSKIWANE Z GRZYBÓW JAKO SKŁADNIK ŻYWNOŚCI FUNKCJONALNEJ

Streszczenie. Rynek żywności funkcjonalnej rozwija się dynamicznie na całym świecie, jednak w Polsce świadomość konsumentów w tej dziedzinie jest niewystarczająca. Znaczenie żywności funkcjonalnej wynika głównie z zawartych w niej substancji bioaktywnych. Do żywności funkcjonalnej zalicza się m.in. grzyby, zawierające polisacharydy, w tym β-glukany. β-glukany wyizolowane z grzybów różnią się budową, rozpuszczalnością w wodzie, wielkością cząsteczki oraz masą cząsteczkową, co decyduje o ich właściwościach leczniczych. β-glukany pozyskiwane z grzybów wykazują bardzo szerokie spektrum działania prozdrowotnego. Udowodniono ich właściwości przeciwnowotworowe, immunomodulujące, przeciwbakteryjne, przeciwwirusowe i antyoksydacyjne. Mają również zdolność obniżania ciśnienia krwi oraz poziomu cholesterolu i cukru we krwi. Za główne źródła β-glukanów uznawane są obecnie *Lentinula edodes* oraz gatunki z rodzaju *Pleurotus*. Do najważniejszych β-glukanów pochodzenia grzybowego należą lentinan, pleuran, grifolan, krestin i ganoderan.

Słowa kluczowe: polisacahrydy, właściwości lecznicze, grzyby jadalne

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