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EDIBLE MUSHROOMS AS A SOURCE OF VALUABLE NUTRITIVE CONSTITUENTS

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Abstract. An overview of Polish and foreign literature concerning the chemical composition of edible mushrooms both cultivated and harvested in natural sites in Poland and abroad is presented. 100 g of fresh mushrooms contains 5.3-14.8 g dry matter, 1.5-6.7 g of carbohydrates, 1.5-3.0 g of protein and 0.3-0.4 g of fat. Mushrooms are a high valued source of mineral constituents, particularly potassium, phosphorus and magnesium and of vitamins of the B group, chiefly vitamins B_2 and B_3 and also vitamin D. The aroma of the discussed raw materials is based on about 150 aromatic compounds. The mushrooms can be a source of heavy metals and radioactive substances. They are also characterized by the occurrence of numerous enzymes.

Key words: edible mushrooms, nutritious value, largeness of consuming, production

INTRODUCTION

For thousands of years the fructifications of higher fungi has been known as a source of food [Mattila et al. 2001]. For centuries they were gathered in their natural environment, and only in the 17th century was their culture in artificial conditions started in France. The first species obtained in this way was *Agaricus bisporus* (Lange) Sing. [Grzybowski 1978]. This is now the most commonly grown mushroom in Poland. In 2003 production was 140 thousand tons, this constituting about 90% of the total mushroom production in Poland [Szudyga 2004]. In recent years some growers have also undertaken the production of *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. [Kubiak 2001]. In Asia, especially in Japan, the cultivation of various mushroom species has been known for centuries and they are commonly used in traditional Japanese cooking. The most important are *Lentinula edodes* (Berk.) Pegl. (shii-take) and *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. [Miles and Chang 1997, Shah et al. 1997]. In 2003 world production of mushrooms was 3.2 million tons, 46% of which was grown in Asiatic countries, 37% in European countries, and 15% in North America [Smoleński 2004 b].

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The consumption of mushrooms in the world, as well as in Poland, is constantly increasing. In 2003 the annual consumption of fresh mushrooms per capita in Poland was 1.0-1.5 kg; in Holland 2.3-2.8 kg and in Germany over 3 kg [Smoleński 2004 a].

Owing to their taste, flavour, nutritional value and unique texture [Beltran-Garcia et al. 1997, Shah et al. 1997, Manzi et al. 1999 b, Mattila et al. 2001], edible mushrooms are commonly used in home cooking and in catering [Kubiak 2001]. They can be successfully used as appertizers in marinated form and also as an ingredient in soups, sauces, salads, stuffings and meat dishes [Achremowicz et al. 1983]. It is worth adding that mushrooms contain many mineral salts and some vitamins, particularly of the B group [Breene 1990, Vetter 1994, Mattila et al. 2001].

Edible fungi are frequently regarded as a therapeutic food having anticarcinogenic, anticholesterolaemic and antiviral properties, and also prophylactic properties with regard to coronary heart disease and hypertension [Bobek et al. 1995, Bobek and Galbavy 1999, Mattila et al. 2000]. Mushrooms of the genus *Lentinula edodes* (Berk.) Pegl. (shii-take), commonly regarded as functional food, are very popular in Japan [Minato et al. 1999]. Their healthful properties are due to dietary fibre, chiefly chitin [Manzi et al. 1999 a, b]; to polysaccharides building cell walls; and to β-glucans: homo- and heteroglucans with glucoside bonds β (1→3), β (1→4) and β (1→6) [Manzi and Pizzoferrato 2000].

The aim of the work was to present the chemical composition and nutritional value of the most popular species of edible fungi on the basis of the accessible Polish and foreign literature.

CHEMICAL COMPOSITION OF EDIBLE MUSHROOMS

Mushrooms are an old group of heterotrophic organisms classified in *Thallophytae*. Their body is composed of hyphae. A mature hypha forms fructifications most frequently protruding from the surface of the substratum. Mushroom fructifications are composed of two basic parts: the pileus and the stipe. Both the pileus and the stipe can take various shapes, size and colour [Szweykowska and Szweykowski 2003]. The flesh-filled fungal fructifications differ in colour and consistency depending on the species [Deremek and Pilát 1988].

The chemical composition of edible mushrooms determines their nutritional value and sensory properties. It differs according to species but also depends on the substratum, atmospheric conditions, age and part of the fructification [Przybylowicz and Donoghue 1988, Vetter 1994, Shah et al. 1997, Manzi et al. 2001].

Dry matter

The basic indicator characterizing the raw material with respect to the level of chemical constituents is the content of dry matter. It can constitute as much as 20% of the fresh matter of mushrooms, usually about 10%, sometimes slightly less [Źródłowski 1995, Gerhardt 2001]. The content of dry matter in the two mushroom species most commonly grown in Poland, *Agaricus bisporus* (Lange) Sing. and *Pleurotus ostreatus*

(Jacq.: Fr.) Kumm., and also in *Boletus edulis* (Bull.: Fr.), which is the most valued mushroom species gathered in natural sites, are given in Table 1. The data in Table 1 show that in *Agaricus bisporus* (Lange) Sing., *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. and *Boletus edulis* (Bull.: Fr.) the content of dry matter is 7.2-11.2 g, 5.3-14.8 g and 8.3--11.3 g·100 g^{-1} fresh matter, respectively. The available literature does not contain sufficient information about the chemical composition of other cultivated or gathered mushroom species. The mushrooms of the species *Lentinula edodes* (Berk.) Pegl. (shii-take), commonly grown in Japan, contain 8.4-10.0 g dry matter in 100 g fresh matter [Manzi et al. 1999 a, Mattila et al. 2001]. In forest mushrooms such as *Leccinum scabrum* (Fr.: Bull.) Gray (birch boletus), *Suillus luteus* (L.: Fr.) Gray (boletus liteus), *Lactarius deliciosus* (L.: Fr.) Gray (saffron milk cap), *Armillaria mellea* (Vahl.: Fr.) Kumm. (honey fungus), *Cantharellus cibarius* (Fr.: Fr.) Fr. (chanterelle), *Gyromitra esculenta* (Pers.: Fr.) Fr. or *Morchella esculenta* (L.: Fr.) Pers.: St-Am. (morel), the content of dry matter varies from 7-12 g·100 g^{-1} fresh matter [Souci et al. 1989, Grochowski 1990]. The above-given range is consistent with the values of dry matter reported by Woźniak [1990] for *Tricholoma equestre* (L.: Fr.) Kumm. (green night cap) and *Xerocomus badius* (Fr.) Kühn.: Gilb. (boletus scaber).

Table 1. Content of dry matter in selected species of edible mushrooms, g·100 g^{-1} fresh matter
Tabela 1. Zawartość suchej masy w wybranych gatunkach grzybów jadalnych, g·100 g^{-1} świeżej masy

Source Źródło	*Pleurotus ostreatus* (Jacq.: Fr.) Kumm. Boczniak ostrygowaty	*Agaricus bisporus* (Lange) Sing. Pieczarka dwuzarodnikowa	*Boletus edulis* (Bull.: Fr.) Borowik szlachetny
Achremowicz et al. [1983]	9.9	*	*
Souci et al. [1989]	*	9.3	*
Mattila et al. [1994]	7.0	*	8.3
Watanabe et al. [1994]	14.2	*	*
Shah et al. [1997]	9.6	11.2	*
Woźniak and Gapiński [1998]	*	8.2-9.5	*
Manzi et al. [1999 a]	5.3-14.8	*	*
Sapers et al. [1999]	*	7.2	*
Manzi et al. [2001]	8.7	7.2	*
Mattila et al. [2001]	8.0	7.7	*
Jaworska et al. [2003]	*	8.6	*
Vetter [2003]	*	9.4-9.6	*
Nikkarinen and Mertanen [2004]	*	*	10.9-11.3

*Lack of data.
*Brak danych.

Calorific value

Owing to the considerable content of water and low calorific value, at 105-209 J·100 g^{-1} fresh matter, edible mushrooms should be regarded as dietetic food [Młodecki et al. 1967, Elmadfa and Fritzsche 1999, Manzi et al. 1999 b, Manzi et al. 2001]. Cultured species, such as *Agaricus bisporus* (Lange) Sing. and *Pleurotus ostreatus* (Jacq.: Fr.) Kumm., are characterized by a medium calorific value of 125 and 151 J·100 g^{-1} of the edible part respectively [Manzi et al. 2001]. Of forest species, *Suillus luteus* (L.: Fr.) Gray (boletus liteu), *Morchella esculenta* (L.: Fr.) Pers.: St-Am. (morel), *Cantharellus cibarius* (Fr.: Fr.) Fr. (chanterelle), *Lactarius deliciosus* (L.: Fr.) Gray (saffron milk cap) and *Leccinum scabrum* (Fr.: Bull.) Gray (birch boletus) show low calorific values varying from 46 to 59 J·100^{-1} fresh matter; a medium one was found for *Boletus edulis* (Bull.: Fr.) – 71 J; and the highest one for *Tuber melanosporum* (Vitt.)(truffle) – 234 J [Elmadfa and Fritzsche 1999].

Carbohydrates

Of the dry matter constituents of mushrooms, carbohydrates were found in the greatest amounts, constituting 16-85 g·100 g^{-1} dry matter [Blumenthal 1976]. In 100 g of edible parts of *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. and *Agaricus bisporus* (Lange) Sing., the content of these compounds was 3.8-6.7 g and 2.6-5.2 g [Źródłowski 1995, Kunachowicz et al. 1999, Manzi et al. 2001] and in 100 g dry matter 47.9 g [Watanabe et al. 1994] and 53.0 g [Ortíz et al. 1992] respectively. Forest mushrooms differ greatly in carbohydrate content. *Xerocomus badius* (Fr.) Kühn.: Gilb. (boletus scaber) contains 1.5 g carbohydrates in 100 g of edible parts [Woźniak 1990], while in *Armillaria mellea* (Vahl.: Fr.) Kumm. (honey fungus), *Coprinus atramentarius* (Bull.: Fr.) Fr. (coprinus (soil fungus)) and *Tricholoma equestre* (L.: Fr.) Kumm. (green night cap) these compounds constitute 16.4, 24.0 and 37.0 g·100 g^{-1} dry matter [Florczak et al. 2004].

A considerable proportion of the carbohydrate compounds occurs in the form of polysaccharides with particles of different size. Fungal polysaccharides are represented by glycogen and such indigestible forms as dietary fibre, cellulose, chitin, mannans and glucans [Grochowski 1990, Manzi and Pizzoferrato 2000, Pizzoferrato et al. 2000, Manzi et al. 2001], which are important in the proper functioning of the alimentary tract. The content of dietary fibre in 100 g of edible parts ranges from 1.9 g in *Agaricus bisporus* (Lange) Sing. to 7.6 g in *Armillaria mellea* (Vahl.: Fr.) Kumm. (honey fungus) [Souci et al. 1989]. According to Manzi et al. [2001], the content of dietary fibre is 2.0 g in 100 g of fresh *Agaricus bisporus* (Lange) Sing. and 4.1 in 100 g of *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. Glucans (homo- and hetero-glucans) with glycoside bonds β (1→3), β (1→4) and β (1→6) occurring in mushrooms are regarded as healthful constituents. *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. contains considerable amounts of β-glucans in 100 g fresh matter – as much as 139 mg – as opposed to *Agaricus bisporus* (Lange) Sing., where the level of these compounds is only 1.4 mg [Manzi et al. 2001]. According to Manzi and Pizzoferrato [2000] and Ko and Lin [2004], in *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. and *Lentinula edodes* (Berk.) Pegl. (shii-take) the content of β-glucans in 100 g dry matter is 0.24-0.38 and 0.22-0.37 g respectively.

In edible mushrooms the dominant sugar is mannitol [Tseng and Mau 1999, Wannet et al. 2000], whose content varies from 3 to 30 g·100 g^{-1} dry matter in *Agaricus bisporus* (Lange) Sing. [Hammond and Nichols 1979]. Apart from mannitol, mushrooms also contain glucose, galactose, trehalose, mannose and fructose [Tseng and Mau 1999, Wannet et al. 2000].

Protein

Protein is an important component of dry matter of mushrooms. Protein compounds constitute more than half of total nitrogen, and their content depends, among other things, on the composition of the substratum, size of pileus, harvest time and species of mushroom, and varies between 0.8 and 3.5 g·100 g^{-1} fresh matter [Florczak and Lasota 1995, Źródłowski 1995] or between 19.0 and 39.0 g·100 g^{-1} dry matter [Weaver et al. 1977, Breene 1990, Coşkuner and Özdemir 2000]. In *Agaricus bisporus* (Lange) Sing. and *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. the content of protein compounds varies from 1.6 - 3.5 g and 1.6 g·100 g^{-1} fresh matter [Źródłowski 1995, Kunachowicz et al. 1999, Manzi et al. 2001] or 7.0-19.5 g and 11.0 g·100 g^{-1} dry matter [Mendel 1898, Kosson and Bąkowski 1980, Braaksma and Schaap 1996]. Florczak and Lasota [1995] recorded a much smaller content of protein in *Pleurotus ostreatus* (Jacq.: Fr.) Kumm., at a level of only 0.8 g·100 g^{-1} fresh matter i.e., 7.6 g·100 g^{-1} dry matter. *Boletus edulis* (Bull.: Fr.) shows a relatively high content of total protein, reaching about 2.8 g·100 g^{-1} of edible parts [Souci et al. 1989]. According to Młodecki et al. [1968], *Boletus edulis* (Bull.: Fr.) contains about 28.0 g protein in 100 g dry matter. Of the remaining species of forest mushrooms, the highest level of protein is found in *Tuber melanosporum* (Vitt.)(truffles): 5.5 g and the lowest in *Cantharellus cibarius* (Fr.: Fr.) Fr. (chanterelle) and *Morchella esculenta* (L.: Fr.) Pers.: St-Am. (morel): 1.5 g and 1.6 g·100 g^{-1} fresh matter respectively [Souci et al. 1989].

The protein of mushrooms contains all the exogenous amino acids; however, the level of some of them is insufficient. Apart from essential amino acids, considerable amounts of alanine, arginine, glycine, histidine, glutamic acid, aspargic acid, proline and serine can be also found in mushrooms (Table 2). On the basis of the FAO/WHO protein standard [1991], all the authors analysing the level of these substances found methionine and cystine (Table 2) and additionally, according to Shah et al. [1997] and Młodecki et al. [1967], isoleucine as the limiting amino acids of mushrooms. The content of lysine is fairly high in them. Cereal protein is characterized by a low level of this amino acid and in this connection the consumption of mushrooms with cereal products is recommended for balancing the level of essential amino acids in the diet [Shah et al. 1997].

In mushroom fructifications a large amount of nitrogen is contained in the non-protein compounds, hence the conversion factor of total nitrogen into protein is 3.45--4.38 [Braaksma and Schaap 1996, Shah et al. 1997]. In the case of *Agaricus bisporus* (Lange) Sing. this factor is usually 3.45 and in *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. 4.38 [Braaksma and Schaap 1996]. The occurrence of non-protein substances is also associated with the assimilability of fungal protein, which is usually only about 70%; for *Boletus edulis* (Bull.: Fr.) and *Gyromitra esculenta* (Pers.: Fr.) Fr. it is about 66 and 76% respectively [Karkocha and Młodecki 1962].

Table 2. Amino acid composition of selected species of fresh edible mushrooms
Tabela 2. Skład aminokwasowy wybranych gatunków świeżych grzybów jadalnych

Kind of amino acid Rodzaj aminokwasu	*Pleurotus ostreatus* (Jacq.: Fr.) Kumm. Boczniak ostrygowaty			*Agaricus bisporus* (Lange) Sing. Pieczarka dwuzarodnikowa		*Lentinula edodes* (Berk.) Pegl. Shii-take	*Boletus pruinatus* (Fr. and Hok) Borowik aksamitny
	A[b]	A[c]	B[d]	C[a]	A[d]	B[d]	B[e]
Essentials amino acids – Aminokwasy egzogenne							
Lisine – Lizyna	6.7	7.2	5.4-6.4	6.2	8.4	5.0	2.6
Threonine – Treonina	6.8	4.8	4.7-5.3	3.5	5.9	5.6	5.0
Valine – Walina	7.3	5.0	4.3-5.2	3.6	3.6	3.8	6.0
Methionine – Metionina	1.1	1.7	1.5-2.3	1.3	1.0	2.2	1.5
Cystine – Cystyna	1.0	0.8	1.2-1.7	*	1.1	3.4	*
Isoleucine – Izoleucyna	6.7	5.8	3.9-4.7	2.7	5.1	3.3	*
Leucine – Leucyna	7.3	8.2	6.3-7.3	4.8	7.6	6.4	8.4
Tyrosine – Tyrozyna	5.2	3.5	3.6-4.6	2.3	4.2	2.6	3.4
Phenylalanine Fenyloalanina	5.4	4.3	3.8-4.7	5.3	4.7	3.8	*
Tryptophan – Tryptofan	*	1.5	1.1-1.6	*	2.2	1.9	2.9
Selected endogenous amino acids – Wybrane aminokwasy endogenne							
Alanine – Alanina	6.6	6.2	6.0-8.3	4.7	5.8	5.3	11.5
Arginine – Arginina	5.9	6.2	7.0-11.5	3.4	8.0	5.7	0.0
Glycine – Glicyna	5.3	4.6	4.4-4.8	3.4	3.6	4.7	6.1
Histidine – Histydyna	2.7	2.0	3.6-4.3	2.1	2.8	3.0	*
Aspartic acid Kwas asparaginowy	6.5	9.3	9.2-12.1	7.0	8.1	10.2	4.9
Glutamic acid Kwas glutaminowy	5.4	17.7	13.1-16.6	14.5	16.2	20.9	15.4
Proline – Prolina	5.5	6.2	3.6-4.8	4.0	6.1	3.9	*
Serine – Seryna	5.5	4.7	3.5-6.0	3.7	5.2	5.7	7.4

*Lack of data.
A – g·100 g^{-1} total protein.
B – g·100 g^{-1} total amino acids.
C – g·16 g^{-1} N.
[a]Kosson and Bąkowski 1980; [b]Tshinyangu and Hennebert 1996; [c]Shah et al. 1997; [d]Manzi et al. 1999 b; [e]Mdachi et al. 2004.
*Brak danych.
A – g·100 g^{-1} białka ogółem.
B – g·100 g^{-1} aminokwasów ogółem.
C – g·16 g^{-1} N.
[a]Kosson i Bąkowski 1980; [b]Tshinyangu i Hennebert 1996; [c]Shah i in. 1997; [d]Manzi i in. 1999 b; [e]Mdachi i in. 2004.

Apart from protein compounds, free amino acids, chitin, amines, nucleic acids and urea can also be found in mushrooms. The level of chitin varies in different species of mushrooms, reaching 4.7-4.9 g in *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. and 8.2 g·100 g^{-1} dry matter in *Boletus edulis* (Bull.: Fr.) [Yoshida et al. 1986]. Of the biogenous amines, putrescine and cadaverine can be found in edible fungi [Yen 1992, Kalač and Křížek 1997]. According to Kalač and Křížek [1997] fresh fructificaions of *Boletus scaber* (Bull.: Fr.) and *Boletus variegatus* (Sw.) Fr. contain respectively 73.0 and 43.2 mg of putrescine in 100 g fresh matter. Additionally, in *Boletus scaber* (Bull.: Fr.) 6.7 mg of cadaverine was established. These authors postulate that the above-mentioned amines do not occur in *Agaricus bisporus* (Lange) Sing.

Fats

The content of fats in mushrooms is low; however, they contain unsaturated fatty acids, which constitute over 70% of the total content of fatty acids. In 100 g fresh matter of *Agaricus bisporus* (Lange) Sing. and *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. the content of fatty compounds is 0.3 and 0.4 g [Manzi et al. 2001] or in 100 g dry matter 2.0 and 1.8 respectively [Shah et al. 1997]. According to Karkocha and Młodecki [1965], in *Boletus edulis* (Bull.: Fr.) and *Cantharellus cibarius* (Fr.: Fr.) Fr. (chanterelle) the content of these compounds is at the level of 3.6 and 2.6 g·100 g^{-1} dry matter respectively; in the case of *Boletus edulis* (Bull.: Fr.) a greater amount of fats is found in whole fructifications than in the pileus. *Tricholoma equestre* (L.: Fr.) Kumm. (green night cap) and *Armillaria mellea* (Vahl.: Fr.) Kumm. (honey fungus) contain 2.0 and 1.8 g fat in 100 g dry matter [Florczak et al. 2004]. Leticin is a valuable constituent of mushrooms from the point of view of their nutritive value [Grochowski 1990].

Mineral constituents

The fructifications of mushrooms are characterized by a high level of well assimilable mineral constituents [Breene 1990, Vetter 1994, Demirbaş 2001, Falandysz et al. 2001, Mattila et al. 2001] whose level depends, among other things, on the species and age of the mushrooms, the diameter of the pilei and on the substratum [Przybylowicz and Donoghue 1988, Demirbaş 2001]. The distribution of these substances in the fructification varies and their content is usually greater in the pileus than in the stipe. The pilei of *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. have greater contents of copper, iron, potassium, magnesium, phosphorus and zinc [Vetter 1994], and the stipes of sodium [Watanabe et al. 1994]. The content of ash in edible fungi varies from 5 to 13 g·100 g^{-1} dry matter [Varo et al. 1980, Strmisková et al. 1992, Watanabe et al. 1994, Manzi et al. 1999 a]. According to Manzi et al. [2001], in 100 g of edible parts of *Agaricus bisporus* (Lange) Sing. and *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. the content of ash is 0.8 and 0.9 g respectively. A similar amount of ashy substances in *Agaricus bisporus* (Lange) Sing. was reported by Sapers et al. [1999]. *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. contains 7.6-8.8 g of ash in 100 g dry matter [Strmisková et al. 1992, Watanabe et al. 1994]. In a study on *Agaricus bisporus* (Lange) Sing., *Pleurotus ostreatus* (Jacq.: Fr.) Kumm., *Pleurotus sajor-caju* (Fr.) Sing. and *Volvariella volvacea* (Bull.: Fr.) Sing., Shah et al. [1997] found the highest content of ash in *Agaricus bisporus* (Lange) Sing. – 9.2 g –

and the lowest in *Volvariella volvacea* (Bull.: Fr.) Sing. – 5.1 g·100 g^{-1} dry matter. Among forest mushrooms, a high level of ash is typical of the fructifications of *Cantharellus cibarius* (Fr.: Fr.) Fr. (chanterelle) – 10.7 g, while in *Boletus edulis* (Bull.: Fr.) the level of ash was low – 6.7 g·100 g^{-1} dry matter [Karkocha and Młodecki 1965]. Edible fungi contain considerable amounts of base-forming elements and therefore can be utilized as alkalizing products [Źródłowski 1995]. Of the mineral constituents contained in mushrooms given in Table 3, potassium and phosphorus compounds were most abundant, and after the computation into oxides constituted 20-57% and 39% of ash respectively [Karkocha and Młodecki 1965, Strmiskowá et al. 1992, Mattila et al. 2001]. Apart from such elements as calcium, iron, magnesium and sulphur, the presence of iodine, zinc, flourine, copper, mercury and manganese was also recorded in mushrooms [Shah et al. 1997, Falandysz et al. 2001, Mattila et al. 2001]. In general, the level of such macroconstituents as sodium, potassium and phosphorus is constant, while the contents of calcium, magnesium, aluminium, chlorine and sulphur depend on the composition of the substratum [Strmiskowá et al. 1992, Vetter 1994].

Table 3. Content of selected mineral constituents in edible mushrooms, mg·100 g^{-1} dry matter
Tabela 3. Zawartość wybranych składników mineralnych w grzybach jadalnych, mg·100 g^{-1} suchej masy

Mineral constituents Składnik mineralny	*Pleurotus ostreatus* (Jacq.: Fr.) Kumm. Boczniak ostrygowaty	*Agaricus bisporus* (Lange) Sing. Pieczarka dwuzarodnikowa	*Boletus edulis* (Bull: Fr.) Borowik szlachetny	*Cantharellus cibarius* (Fr.: Fr.) Fr. Kurka
Sodium – Sód	44[f]-144[g]	76[f]-86[k]	12[j]-52[i]	4[j]-14[j]
Potassium – Potas	2 722[f]-5 100[i]	3 500[i]-4 520[d]	2 367[i]-3 900[j]	5 400[j]-5 900[j]
Calcium – Wapń	89[f]-150[h]	46[g]-99[f]	46[g]-99[f]	19[j]-57[g]
Phosphorus – Fosfor	618[f]-1 339[i]	969[f]-1 730[d]	1 024[g]-1 730[d]	500[j]-657[g]
Magnesium – Magnez	128[i]-190[f]	91[f]-124[f]	100[j]-120[j]	110[j]-120[j]
Sulfur – Siarka	210[h]	450[d]	450[d]	*
Iron – Żelazo	9[i]-15[f]	5[g]-50[k]	5[g]-50[f]	10[j]-18[j]
Zinc – Cynk	3[i]-12[g]	2[i]-12[d]	12[d]	9[j]-11[j]

*Lack of data.

[a]Karkocha and Młodecki 1965, [b]Młodecki et al. 1967, [c]Młodecki et al. 1968, [d]Strmiskowá et al. 1992, [e]Falandysz et al. 1994 b, [f]Vetter 1994, [g]Watanabe et al. 1994, [h]Shah at al. 1997, [i]Demirbaş 2001, [j]Falandysz et al. 2001, [k]Vetter 2003, [l]Nikkarinen and Mertanen 2004.

*Brak danych.

[a]Karkocha i Młodecki 1965, [b]Młodecki i in. 1967, [c]Młodecki i in. 1968, [d]Strmiskowá i in. 1992, [e]Falandysz i in. 1994 b, [f]Vetter 1994, [g]Watanabe i in. 1994, [h]Shah i in. 1997, [i]Demirbaş 2001, [j]Falandysz i in. 2001, [k]Vetter 2003, [l]Nikkarinen i Mertanen 2004.

Vitamins

Mushrooms are an important source of vitamins. The vitamins of group B are abundant [Breene 1990, Mattila et al. 1994, Źródłowski 1995, Mattila et al. 2000, 2001], particularly thiamine, riboflavine, piridoxine, pantotene acid, nicotinic acid, nicotinamid, folic acid and cobalamin, as well as other vitamins, such as ergosterol, biotin, phytochinon and tocopherols [Karkocha and Młodecki 1965, Elmadfa and Fritzsche 1999, Mattila et al. 2001]. The opinion is that, with respect to thiamine content, mushrooms are a bridge between yeast and other food products of vegetal origin [Karkocha and Młodecki 1965]. A comparison of the most popular species of edible mushrooms (Table 4) shows that *Boletus edulis* (Bull.: Fr.) is the species with the greatest content of vitamins of group B, while *Lentinula edodes* (Berk.) Pegl. (shii-take) has the smallest content. *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. contains more folacine, vitamin B_1 and B_3 but less vitamin B_{12} than *Agaricus bisporus* (Lange) Sing. and *Lentinula edodes* (Berk.) Pegl. (shii-take). Table 4 also shows that the greatest content of vitamin D can be found in *Lentinula edodes* (Berk.) Pegl. (shii-take) and *Boletus edulis* (Bull.: Fr.). A considerable amount of vitamin PP, which protects the skin against pellagra, is noted in mushrooms. In 100 g fresh matter of *Agaricus bisporus* (Lange) Sing. about 5 mg of this vitamin can be found, a level not observed in any other food product [Grochowski 1990]. In general, mushrooms contain small amounts of vitamin C: usually up to 7 $mg \cdot 100\ g^{-1}$ of edible parts [Sapers et al. 1999, Mattila et al. 2001].

Table 4. Content of vitamins in selected species of edible mushrooms, in 100 g of dry matter
Tabela 4. Zawartość witamin w wybranych gatunkach grzybów jadalnych, w 100 g suchej masy

Kind of vitamin Rodzaj witaminy	*Pleurotus ostreatus* (Jacq.: Fr.) Kumm. Boczniak ostrygowaty	*Agaricus bisporus* (Lange) Sing. Pieczarka dwuzarodnikowa	*Lentinula edodes* (Berk.) Pegl. Shii-take	*Boletus edulis* (Bull: Fr.) Borowik szlachetny	*Cantharellus cibarius* (Fr.: Fr.) Fr. Kurka
B_1, mg	0.90[f]-4.25[e]	[a]0.56-0.60[f]	0.60[f]	1.25[a]	0.58[a]
B_2 mg	2.5[f]-2.84[e]	[a]4.39-5.10[f]	1.80[f]	9.36[a]	5.58[a]
B_3, mg	65.0[f]	[a]39.7-43.0[f]	31.0[f]	69.5[a]	47.0[a]
B_{12}, µg	0.6[f]	0.8[f]	0.8[f]	*	*
Folacin, µg Folacyny, µg	640[f]	450[f]	300[f]	*	*
D, µg	0.3[f]	3.0[f]	22.0[c]-110.0[c]	35.0[d]	*
C, mg	20[b, f]	17[f]	25[f]	*	*

*Lack of data.
[a]Karkocha and Młodecki 1965, [b]Lasota and Sylwestrzak 1982, [c]Takamura et al. 1991, [d]Mattila et al. 1994, [e]Watanabe et al. 1994, [f]Mattila et al. 2001.
*Brak danych.
[a]Karkocha i Młodecki 1965, [b]Lasota i Sylwestrzak 1982, [c]Takamura i in. 1991, [d]Mattila i in. 1994, [e]Watanabe i in. 1994, [f]Mattila i in. 2001.

Flavour

Compounds of fungal aroma do not play any essential role in nutrition but they stimulate the appetite and give mushroom dishes a characteristic flavour. The identified flavour compounds in different mushroom species represent a wide range of constituents whose number is today rated at about 150 [Le Loch-Bonazzi and Wolff 1991]. The main substances responsible for the aroma of most edible mushrooms are octavalent carbonate alcohols and carbonyl compounds, among them 1-octanol, 3-octanol, 3--octanon, 1-caprynol-3-ol, 1-octynol-3-ol, 2-octynol-3-ol and 1-caprynol-3-on [Le Loch-

-Bonazzi and Wolff 1991, Mau et al. 1993, 1998, Beltran-Garcia et al. 1997, Breheret et al. 1997, Mau and Hwang 1997]. The compound 1-octynol-3-ol with the typical aroma of fresh *Boletus edulis* (Bull.: Fr.) occurs in greater quantities in young fructifications than in older ones [Mau et al. 1993]. 1-octynol-3-ol also dominates in the fructifications of *Agaricus bisporus* (Lange) Sing. [Man et al. 1992] and *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. [Beltran-Garcia et al. 1997]. The aroma of mushrooms also depends on the content of amino acids, nucleotides, some other elements, such as nitrogen, phosphorus, potassium, sulphur, iron and zinc, and also on the autooxidation of unsaturated fatty acids [Grzybowski 1978].

Other substances

An unfavourable trait of mushrooms is their ability to acumulate heavy metals and radioactive substances [Florczak and Lasota 1995, Skibniewska and Smoczyński 1999, Falandysz et al. 2000, 2001, Falandysz and Wędzisz 2003]. The level of heavy metals depends on the species, place of harvest, part of the fructification, and the concentration of these substances in the substratum and in air [Lasota and Florczak 1991, Kalač and Svoboda 2000, Blanuša et al. 2001, Demirbaş 2001, Falandysz et al. 2001]. Mushrooms growing in natural conditions are more exposed to contamination by heavy metals than cultivated mushrooms, and the concentrations of these substances can sometimes be very high, especially in regions polluted by industry [Falandysz et al. 1994 a, b, Skibniewska and Smoczyński 1999, Falandysz et al. 2000, Kalač and Svoboda 2000]. Mushrooms of the *Agaricus* family have a particularly strong tendency to accumulate of heavy metals, above all cadmium and mercury [Falandysz et al. 1993, Kalač and Svoboda 2000]. In a study on *Agaricus bisporus* (Lange) Sing., *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. and mushrooms of the *Boletus* family, Demirbaş [2001] found that only *Agaricus bisporus* (Lange) Sing. mushrooms are prone to accumulate very large amounts of cadmium and mercury. Moreover, Lasota and Florczak [1991] showed that the accumulation of mercury chiefly occurs in the pileus of *Agaricus bisporus* (Lange) Sing. Mushrooms with large fructifications are classified as food products which maintain radiocaesium contamination for a long time and frequently at a very high level [Mihok et al. 1989, Falandysz and Caboń 1992], the quantity of caesium depending, among other things, on the species and the site of harvest [Skibniewska and Smoczyński 1999, Florczak et al. 2001]. According to Florczak et al. [2001], a high level of radiocaesium was found in boletus harvested in the Lubuskie region and in *Xerocomus badius* (Fr.) Kühn.: Gilb. (boletus scaber) from the forests of the Kujawy-Pomorze region.

Enzymes

A characteristic trait of the composition of mushrooms is the occurrence of various enzymes, which are never or only rarely found in other organisms. In spite of the content of oxidative oxidases, fat splitting lipases, inverting enzymes and proteolytic enzymes [Kohlmünzer et al. 1980, Ratcliffe et al. 1994] in mushrooms, most investigations concentrate on the activity of polyfenoloxidases [Choi and Sapers 1994, Beaulieu et al. 1999, Espín and Wichers 1999 a]. According to Ratcliffe et al. [1994], various species of mushroom manifest different enzymatic activity; e.g. *Agaricus bisporus*

(Lange) Sing. is characterized by a higher activity of polyphenoloxidase compared with *Pleurotus ostre*atus (Jacq.: Fr.) Kumm. and *Lentinula edodes* (Berk.) Pegl. (shii-take). The effect of this enzyme is due to the catalysis of phenol compound oxidation, causing a rapid darkening of harvested mushrooms, which in turn reduces their sensory and nutritive properties [Choi and Sapers 1994, Weemaes et al. 1997, Devece et al. 1999, Espín and Wichers 1999 b]. According to Jiménez and Garcia-Carmona [1997], the darkening of products decreases their keeping quality and hence their market value.

CONCLUSION

The above review of Polish and foreign literature shows that in the global market three mushroom species currently play a significant economic role: *Agaricus bisporus* (Lange) Sing., *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. and *Lentinula edodes* (Berk.) Pegl. In recent years there has been an increase in the consumption of mushrooms. They have an interesting taste and flavour, and can also supply nutritive constituents important in human nutrition, such as dietary fibre, protein, mineral compounds and vitamins of group B.

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Streszczenie. W pracy przedstawiono przegląd piśmiennictwa krajowego i zagranicznego dotyczącego składu chemicznego grzybów jadalnych, zarówno uprawnych, jak i zbieranych ze stanowisk naturalnych. 100 g świeżych grzybów zawiera 5,3-14,8 g suchej masy, 1,5-6,7 g węglowodanów, 1,5-3,0 g białka oraz 0,3-0,4 g tłuszczu. Grzyby są cennym źródłem składników mineralnych, szczególnie potasu, fosforu i magnezu oraz witamin z grupy B, głównie witaminy B_2 i B_3, a także witaminy D. Za aromat omawianych surowców odpowiedzialnych jest około 150 związków zapachowych. Grzyby mogą być źródłem metali ciężkich i substancji promieniotwórczych. Ponadto są w nich obecne liczne enzymy.

Słowa kluczowe: grzyby jadalne, wartość odżywcza, wielkość spożycia, produkcja

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