

DRIED SHIITAKE (*LENTINULA EDODES*) AND OYSTER (*PLEUROTUS OSTREATUS*) MUSHROOMS AS A GOOD SOURCE OF NUTRIENT

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Abstract. Due to presented in literature potential health benefits of shiitake *Lentinula edodes* (Berk.) Pegl. and oyster mushroom *Pleurotus ostreatus* (Jacq.: Fr.) Kumm., chemical composition as well as Fe, Cu and Zn ions sorption (in conditions related to human digestive tract) by dried shiitake and oyster were investigated. Both dried mushrooms had the high content of dietary fiber, Fe, Cu, Mg, K but low of fat, Na and Ca. Relatively low sorption of micronutrients was found in pH = 1.8, while the high sorption of Cu and Fe was observed in pH = 8.7. Dried mushrooms satisfied the maximum permissible level standards concerning toxic metals. The results of the research suggest that dried shiitake and oyster mushrooms can be used as additives in food products.

Key words: mushrooms, oyster, shiitake, chemical composition, metal sorption

INTRODUCTION

Shiitake *Lentinula edodes* (Berk.) Pegl. and oyster mushroom *Pleurotus ostreatus* (Jacq.: Fr.) Kumm., due to their documented probiotic properties [Bobek et al. 1991, Stamets 1993, Lasota and Karmańska 1994, Wasser and Weis 1999, Manzi and Pizzoferrato 2000, Wang et al. 2000, Smith et al. 2002, Rajewska and Bałasińska 2004] and relatively high nutritive value, are recommended in numerous countries as an addition to the daily diet [Lasota et al. 1992, Lasota and Florczak 1996, Kalač and Svoboda 2000, Isiloglu et al. 2001, Florczak et al. 2004, Bernaś et al. 2006].

Shiitake *Lentinula edodes* (Berk.) Pegl. mushrooms have been attributed with many medical properties by both eastern and western medicine. They range from reducing cholesterol, lowering blood pressure, strengthening the immune system against diseases including viral ones, fighting tumors, and improving liver function [Bobek et al. 1991, Wang et al. 2000, Mau et al. 2002, Rajewska and Bałasińska 2004]. Many of the shiitake health benefits come from chemical compounds these mushrooms produce, these

include: lentinan, eritadenine, L-ergothioneine [Lasota and Karmańska 1994, Smith et al. 2002, Rajewska and Bałasińska 2004, Bernaś et al. 2006]. Lentinan has shown some effect on bowel cancer, liver cancer, stomach cancer, ovarian cancer and lung cancer. Lentinan stimulates the production of T lymphocytes and natural killer cells and can potentiate the effect of AZT in the anti-viral treatment of AIDS. Shiitake is rich in several anti-oxidants (selenium, uric acid, vitamin A, E, C) as well as vitamin D [Lasota and Florczak 1996, Mau et al. 2002, Florczak et al. 2004]. Shiitake *Lentinula edodes* (Berk.) Pegl. mushrooms may also lower blood pressure in those with hypertension, lower serum cholesterol levels, stimulate the production of interferon which has anti-viral effects, and has proven effective against Hepatitis in some cases [Lasota et al. 1992, Mau et al. 2002, Smith et al. 2002].

A lectin isolated from the fruiting bodies of *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. demonstrated antitumor activity in mice bearing sarcoma and hepatoma [Wang et al. 2000]. In animal studies, oyster mushrooms significantly enhanced plasma cholesterol turnover by 50% with a corresponding 25% decrease in liver cholesterol levels as compared to controls [Bobek et al. 1995]. Other animal studies have shown significant reductions in serum and liver cholesterol levels when dried and powdered mushrooms were included in the animal diets, even with high-fat diets and in animals with hereditary high cholesterol levels [Bobek et al. 1991].

It is believed that for individuals excluding animal origin products from their diet, dried oyster mushrooms *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. and shiitake *Lentinula edodes* (Berk.) Pegl. mushroom and products with their addition may constitute a good source of iron, zinc and copper [Dwyer 1999, Kalač and Svoboda 2000, Isiloglu et al. 2001]. However, recommending the introduction into the Polish diet of products with added dried shiitake and especially oyster mushroom *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. as sources of minerals requires on the one hand a precise determination of the contents of these elements and on the other hand the microelement binding capacity by the mushrooms themselves. Thus the aim of this study was to assess the chemical composition of dried shiitake and oyster mushrooms and to estimate the Fe, Cu and Zn binding capacity by these materials under pH conditions similar to those found in the human alimentary tract.

MATERIAL AND METHODS

Material consisted of milled dried *Lentinula edodes* (Berk.) Pegl. (shii-take) obtained from fruiting bodies grown on a beech sawdust substrate enriched with 20% crushed wheat grain, spawned with the granular mycelium of Shiitake *Lentinula edodes* (Berk.) Pegl. (shii-take) cv. 'Sylvan 4080'. Incubation was carried out at the temperature of 25°C and relative humidity of 80-85%, whereas after incubation culture was conducted at 17-18°C and relative humidity of 85-90%. The substrate for oyster mushroom *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. consisted of wheat straw spawned with the mycelium of cv. K-22. Culture was conducted in a room with relative humidity of 85-90% and at 13-15°C. Shiitake *Lentinula edodes* (Berk.) Pegl. and oyster mushroom *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. fruiting bodies were dried at 40°C for 8 h and then forced dried at 70°C to constant weight and ground to powder.

Contents of protein, fat and ash were determined using standard analytical methods [Rutkowska 1979]. It was assumed that 2/3 nitrogen contained in mushrooms is a component of proteins and only this amount was converted into protein, using the conversion factor of 6.25. In turn, all the nitrogen compounds, also non-protein in character, were taken into consideration when calculating contents of carbohydrates and energy value.

Soluble dietary fiber (SDF) and insoluble dietary fiber (IDF) were determined enzymatically according to Asp et al. [1983]. Total dietary fiber (TDF) constituted the sum of SDF and IDF. Analytical determinations were conducted in three simultaneous replications and the results are presented in grams per 100 g dry matter.

The analysis of mineral contents were measured by flame atomic absorption spectrometry technique. Results are presented in grams per 100 g dry matter.

In order to determine the capacity of dried mushrooms to bind selected minerals (Cu, Zn and Fe) the method used was based on a study by Stachowiak and Kubiak [1990], which consisted in shaking dried mushrooms at 37°C. The adsorbents were solutions containing CuCl₂, ZnCl₂ and FeCl₃ with the following concentrations of individual elements: Cu 5 µg·ml⁻¹, Zn 25 µg·ml⁻¹ and Fe 30 µg·ml⁻¹. The dispersion mediums were buffer solutions with pH = 1.8, pH = 6.6 and pH = 8.7. Experimental conditions were selected so that they imitated those found in the human alimentary tract: the oral cavity (pH = 6.6, shaking time – 7 min), the stomach (pH = 1.8, shaking time – 2 h 15 min), and the duodenum (pH = 8.7, shaking time – 1 h). Contents of Fe, Cu and Zn were assayed using the AAS method. The volume of sorption was determined as the ratio of the content of an element bound to the product to the total amount of this element introduced to the system.

Statistical analysis was performed using ANOVA for factor systems and the assessment of differences between individual groups was analyzed using the Tukey's HSD test with the application of a Statistica 7.0 statistical software package by StatSoft. Significant differences (p < 0.001) in the contents of macrocomponents and minerals in dried mushrooms were denoted with different letters.

RESULTS

Table 1 and 2 presents the energy value, contents of macrocomponents, dietary fiber and minerals, and toxic metals in dried shiitake *Lentinula edodes* (Berk.) Pegl. and oyster mushrooms *Pleurotus ostreatus* (Jacq.: Fr.) Kumm.

The energy value, contents of fat and water differed significantly (p < 0.001) in both tested dried products, while the higher fat level and higher energy value was found for dried shiitake *Lentinula edodes* (Berk.) Pegl. No significant differences were observed in the contents of protein, carbohydrates and ash. The tested dried mushrooms exhibited high, but diverse contents of total dietary fiber (TDF). Its mean level for dried oyster mushrooms was 41.8 g·100 g⁻¹ dry matter, while for shiitake it was 46.1 g·100 g⁻¹ dry matter, at a lower share of the soluble than the insoluble fraction. The SDF content ranged from 1.95 g·100 g⁻¹ dry matter (shiitake) to 2.01 g·100 g⁻¹ dry matter (oyster mushroom).

Dried oyster mushrooms *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. in comparison to dried shiitake *Lentinula edodes* (Berk.) Pegl. contained 60% more iron, and 20% less

Table 1. The energy value, kcal·100 g⁻¹, and contents of macrocomponents, g·100 g⁻¹ dry matter, of dried *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. and *Lentinula edodes* (Berk.) Pegl. Shiitake
 Tabela 1. Wartość energetyczna, kcal·100 g⁻¹, i zawartość makroskładników, g·100 g⁻¹ suchej masy, w suszach grzybów *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. and *Lentinula edodes* (Berk.) Pegl. shiitake

Energy value and macrocomponents Wartość energetyczna i makroskładniki	Dried <i>Pleurotus ostreatus</i> (Jacq.: Fr.) Kumm. Susz bocznika ostrygowatego	Dried <i>Lentinula edodes</i> (Berk.) Pegl. Shiitake Susz shiitake
Energy value – Wartość kaloryczna	345 ±1.84 ^a	359 ±1.48 ^b
Water – Woda	10.6 ±0.28 ^a	7.14 ±0.06 ^b
Protein – Białko	15.7 ±0.37 ^a	17.2 ±0.87 ^a
Fat – Tłuszcz	2.66 ±0.06 ^a	2.89 ±0.08 ^b
Carbohydrates – Węglowodany	64.1 ±0.01 ^a	66.0 ±0.66 ^a
Ash – Popiół	7.04 ±0.15 ^a	6.73 ±0.35 ^a
Soluble dietary fiber – Błonnik rozpuszczalny	2.01 ±0.33 ^a	1.95 ±0.18 ^a
Insoluble dietary fiber – Błonnik nierozpuszczalny	39.8 ±0.55 ^a	44.2 ±0.39 ^b

Values followed by a difference letter within the same row are significantly different (P < 0.001).
 Wartości oznaczone różnymi literami w tym samym rzędzie różnią się istotnie (P < 0,001).

Table 2. Contents of selected minerals and toxic metals of dried *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. and *Lentinula edodes* (Berk.) Pegl. Shiitake, mg·kg⁻¹ dry matter
 Tabela 2. Zawartość wybranych składników mineralnych i metali toksycznych w suszach grzybów jadalnych *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. and *Lentinula edodes* (Berk.) Pegl. shiitake, mg·kg⁻¹ suchej masy

Mineral constituents and toxic mestas Składniki mineralne i metale toksyczne	Dried <i>Pleurotus ostreatus</i> (Jacq.: Fr.) Kumm. Susz bocznika ostrygowatego	Dried <i>Lentinula edodes</i> (Berk.) Pegl. Shiitake Susz shiitake
Iron – Żelazo	68.6 ±5.50 ^a	39.5 ±0.45 ^b
Coper – Miedź	12.9 ±1.36 ^a	13.7 ±0.74 ^a
Zinc – Cynk	109.6 ±0.89 ^a	125.9 ±13.0 ^a
Magnesium – Magnez	1 289 ±20.4 ^a	1 622 ±5.09 ^b
Calcium – Wapń	27.6 ±0.15 ^a	157.7 ±0.17 ^b
Potassium – Potas	33 120 ±191 ^a	31 551 ±303 ^b
Sodium – Sód	133.7 ±21.4 ^a	135.6 ±1.66 ^a
Lead – Ołów	0.000 ±0.000	0.000 ±0.000
Cadium – Kadm	0.70 ±0.05 ^a	2.40 ±0.13 ^b
Mercury – Rtęć	0.08 ±0.003 ^a	0.046 ±0.001 ^b

Values followed by a difference letter within the same row are significantly different (P < 0.001).
 Wartości oznaczone różnymi literami w tym samym rzędzie różnią się istotnie (P < 0,001).

magnesium and 6 times less calcium. An advantageous sodium to potassium ratio was found in both species of dried mushrooms. Both dried mushroom products met the requirements in terms of admissible contents of toxic metals in mushrooms.

Statistical analysis of testing results on the sorption of Cu, Zn and Fe by dried mushrooms showed that the level of binding for these metals was dependent ($p < 0.001$) on the pH of the medium and the species from which the dried product was obtained. Values of metal sorption were lowest at pH = 1.8, whereas binding Fe and Zn by dried oyster mushrooms and Cu and Zn by dried shiitake at this pH did not exceed 6% (Fig. 1). Along with the increasing pH of the medium the metal binding capacity of both dried products increased. The strongest metal sorption capacity was found for dried shiitake in the medium with pH = 8.7, with the highest value reported for Fe.

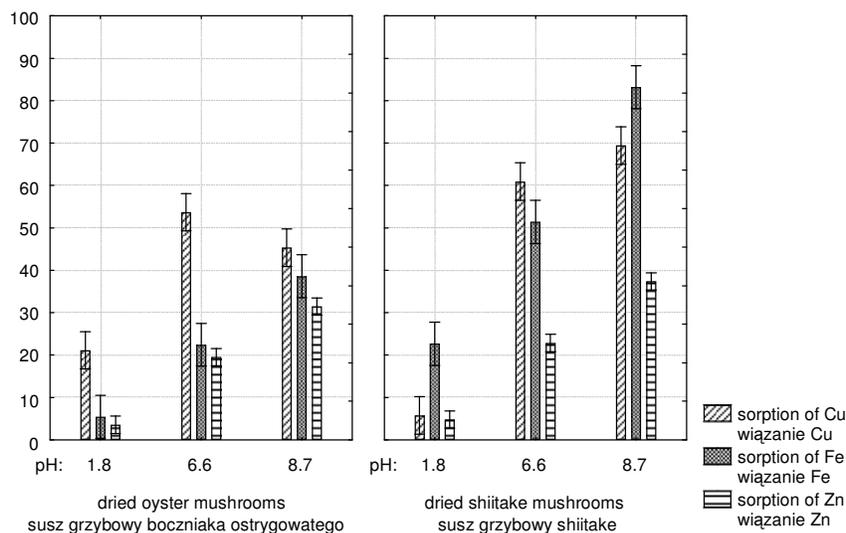


Fig 1. Sorption of iron, copper and zinc by dried mushrooms
Rys. 1. Wiązanie żelaza, miedzi i cynku przez susze grzybowe

DISCUSSION OF RESULTS

In literature on nutrition the studies documenting probiotic of shiitake *Lentinula edodes* (Berk.) Pegl. and oyster mushrooms *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. have been presented for a number of years [Lasota and Karmańska 1994, Manzi and Pizzoferrato 2000, Mau et al. 2002, Bobek et al. 2003, Rajewska and Bałasińska 2004, Bernaś et al. 2006]. The emphasis is put on their high contents of β -glucans (homo- and heteroglucans) and chitosans, exhibiting anticancer action, lowering LDL fraction cholesterol level and arterial blood pressure, having an effect on the immune system [Bobek et al. 1991, Wang et al. 2000, Smith et al. 2002]. According to Manzi and Pizzoferrato [2000] in oyster mushroom and shiitake, in 100 g dry matter there are 0.24 g and 0.38 g β -glucans, respectively. It is believed that these mushrooms may also be a good source

of micro- and macroelements, such as K, Mg, P, Zn, Fe, or Cu [Stamets 1993, Isiloglu et al. 2001]. Both fungal species are relatively easy to grow and their production is cheap. However, there is limited data on the nutritive value of these mushrooms cultured in Poland on cheap native substrates – beech sawdust and wheat straw, as well as their heavy metal contents. Moreover, there is no information on the range of their metal binding capacity (including microelements) by the investigated fungi, which may considerably reduce the availability of microelements by the organism. This study is an attempt to clarify these issues, thus dried shiitake and oyster mushrooms *Pleurotus ostreatus* (Jacq.: Fr.) Kumm., potential additives to certain foodstuffs, were selected for analysis. The tested dried mushrooms exhibited a relatively high nutritive value. Protein content was similar to the level reported in dried vegetables, while numerous authors [Lasota et al. 1992, Lasota and Florczak 1996] suggest that protein in both shiitake *Lentinula edodes* (Berk.) Pegl. and oyster mushroom is relatively well-available and amino acids reducing their nutritive value are valine and phenylalanine in case of oyster mushroom, whereas it is methionine in shiitake. The high dietary fiber content in the tested dried mushrooms needs to be emphasized here, as it considerably exceeds amounts reported in dried vegetables and fruits.

Both dried mushroom products exhibited high contents of ash as well as Fe, K, Mg, P, Zn and Cu. Sorption of selected microelements was high primarily at pH = 8.7, which is consistent with the observations by other authors [Thompson and Weber 1979, Stachowiak and Gawęcki 1989, Stachowiak and Kubiak 1990, Górecka and Stachowiak 2002] that most sorbents of various origin (wheat, maize, soy and rice bran, oat glumes and cellulose) bind metals at pH = 8.7, whereas along with increasing acidity of the solution sorption decreases. However, it needs to be stated that maximum sorption values were found only at pH = 8.7 for Cu and Fe for dried shiitake *Lentinula edodes* (Berk.) Pegl. (69% and 83%, respectively), which is a lower value than those observed by other authors [Stachowiak and Kubiak 1990, Górecka and Stachowiak 2002, Stachowiak and Śmigielska 2004] in high-fiber preparations such as wheat, maize, soy and rice bran or oat glumes. Complete information concerning sorption capacity of both fungi could only be obtained in *in vivo* tests.

Taking into consideration the relatively high nutritive value expressed in the contents of protein, dietary fiber, Mg, K, as well as the probiotic value suggested by other authors [Stamets 1993, Bobek et al. 1995, Manzi and Pizzoferrato 2000, Smith et al. 2002, Bernaś et al. 2006], dried shiitake *Lentinula edodes* (Berk.) Pegl. and oyster mushrooms *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. obtained under conditions of Polish mushroom farming may be recommended as food additives. However, caution must be applied when recommending these dried mushrooms as good sources of macro and microelements.

CONCLUSIONS

1. Dried *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. and *Lentinula edodes* (Berk.) Pegl. mushrooms exhibited high contents of protein, total dietary fiber, K, Mg, Zn, Fe and Cu at low contents of fat, Na and Ca.
2. High sorption values were reported only in case of pH = 8.7 for Cu and Fe by dried shiitake (69% and 83%, respectively).

3. Values of metal sorption were lowest at pH = 1.8, whereas binding of Fe and Zn by dried oyster mushroom and Cu and Zn by dried shiitake at that pH did not exceed 6%.

4. Results of the study suggest that both dried mushroom products might be used as food additives; however, in order to promote them as good sources of microelements it is necessary to determine sorption capacity of dried mushrooms in *in vivo* studies.

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**SUSZ GRZYBOWY SHIITAKE (*LENTINULA EDODES*)
I BOCZNIAKA OSTRYGOWATEGO (*PLEUROTUS OSTREATUS*)
JAKO DOBRE ŹRÓDŁO SKŁADNIKÓW ODŻYWCZYCH**

Streszczenie. Ze względu na przedstawiane w literaturze korzystne właściwości prozdrowotne grzybów shiitake *Lentinula edodes* (Berk.) Pegl. i boczniaka ostrygowatego *Pleurotus ostreatus* (Jacq.: Fr.) Kumm. w suszach z tych grzybów oznaczono skład chemiczny oraz oszacowano zdolności wiązania Fe, Cu i Zn w warunkach *in vitro* (symulowanych dla przewodu pokarmowego). Oba susze charakteryzowały się dużą zawartością Fe, Cu, Mg, K, natomiast małą Na i Ca. Stosunkowo niedużą zdolność wiązania wybranych metali przez badany materiał obserwowano przy pH = 1,8, natomiast wysokie wartości sorpcji zanotowano jedynie, gdy pH = 8,7. Badane susze spełniały wymagania odnośnie dopuszczalnej zawartości metali toksycznych w grzybach. Wyniki badań sugerują, że oba susze mogłyby być stosowane jako dodatek do żywności.

Słowa kluczowe: grzyby, bocznik ostrygowaty, shiitake, wartość odżywcza, sorpcja metali

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