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Elemental composition and nutritional value of three edible mushrooms from Serbia

ABSTRACT

Nutrition value, as well as macro- and microconstituents of three edible mushrooms (Pleurotus ostreatus, Lentinula edodes, Macrolepiota procera) collected in Serbia were tested. It has been determined that all three mushroom samples were low in energy, fat and carbohydrates, but rich in β -glucans content. The most abundant elements in these three mushrooms were essential macroelements Ca, K and P, but also there is a significant amount of Li, Se and Zn. On the other hand, toxic elements, such as Pb, As and Cd were also detected in level higher than allowed.

Keywords: *Pleurotus ostreatus, Lentinula edodes, Macrolepiota procera, nutrition value, elemental analysis.*

1. INTRODUCTION

Mushrooms have an important role as decomposers in nature, assimilating elements and converting them into simpler substances [1]. Also, fresh and preserved mushrooms are consumed in many countries as a delicacy, particularly for their specific aroma and texture [2]. Knowledge of the composition and nutritional value of culinary mushrooms, particularly of wild-growing ones, was limited until the last decade [2]. Apart from flavor and taste, the fruiting bodies of mushrooms are considered to be the sources of organic nutrients such as digestible proteins, carbohydrates, fibre and certain vitamins, as well as minerals and antioxidants [3]. In fungal cell wall there is a complex network of fibers (β -glucans, chitin, mannoproteins, galactomannan, etc.) that provide structure, protection and rigidity to cell wall. Some of these fibers also possess therapeutic properties. β -glucans are the most important constituents, as they show antitumor, immunomodulatory, antimicrobial, antinociceptive, antiinflammatory, antioxidant, hypoglycemic activity [1].

In this study, we investigated the content of macro- and microconstituents, as well as nutritional value and β -glucan content of three common edible mushrooms: *Pleurotus ostreatus* (Jack.:Fr) Kummer (1871), *Lentinula edodes* (Berk.) Pegler (1976), *Macrolepiota procera* (Scop.:Fr) Singer (1948).

2. EXPERIMENTAL PART

2.1. Mushroom material

Fruiting bodies of three edible mushrooms, *P. ostreatus*, *L. edodes* and *M. procera* were purchased on local market in Belgrade, Serbia in July 2014. Mushrooms were dried at room temperature and pulverized in a laboratory mill. The voucher specimens were deposited at the Faculty of Pharmacy, Department of Pharmacognosy (Nos 26, 27 and 28).

2.2. Determination of nutritional value

The sample of dried material was analyzed for the percentage of moisture, proteins, fats, carbohydrates and ash. All values were calculated on a dry weight (d.w.) of mushroom. Nutritional value was determined by using the procedures described by the Association of Official Analytical Chemists (AOAC 1990) [4]. The moisture and ash contents were estimated using gravimetric methods after drying at 105°C, and incineration at 550°C, respectively. The crude protein content by the Kjeldahl method and the nitrogen factor used for

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protein calculation was 6.25, while the crude fats were determined using the extraction procedure on Soxhlet apparatus, using petroleum ether as a solvent, after the treatment with HCl.

Total carbohydrates were calculated as the residual difference after subtracting protein, ash, moisture, total fibre and crude fat content. Total energy was determined by the calculation of energy values of carbohydrate, fat, protein and fibre. Energy, kcal = 9 (crude fat content, g) + 4 (protein content, g + carbohydrate content, g) + 2 (fibre content, g).

2.3. Determination of β -glucans

Enzymatic assay kit K-YBGL (Megazyme International Ireland) was used in order to determine content of β -glucans in both dried and cooked samples. The assay performed according to the instruction manual of the kit producer. In short, content of β -glucans was calculated indirectly from the difference in total glucans content and α -glucans content. After solubilisation in concentrated (37%; 10 N) HCl, total glucans (1,3:1,6- β -D-glucan, 1,3- β -D-glucans and α -glucans) were extensively hydrolyzed by 1.3 N HCl at 100°C for 2 h. In addition, mixture was incubated with highly purified enzymes *i.e.* exo-1,3- β -glucanase and β -glucosidase. The measurement of α -glucans content was performed after hydrolysis with mixture of amyloglucosidase and invertase. All glucans split into their glucose monomers, and measured spectrophotometrically (510 nm).

2.4. Determination of macro- and microelements

Preparation of the sample for determining heavy metal concentration carried out by wet digestion using nitric acid. The weighed mass of dry sample (0.01 g) topped with 1 ml of concentrated nitric acid and allowed to stand for 24 hours. Thereafter, the mixture heated at the acid boiling temperature until brown vapors of nitrogen oxide stopped forming. After digestion, the sample was filtered and the filtrate transferred to a volumetric flask and filled with distilled water up to 10 ml.

All measurements were done in triplicate on ICP-OES (*Inductively Coupled Plasma - Optical Emission Spectrometry*, ARCOS FHE12, SPECTRO, Germany) according to the instruction for the quantitative analysis given by the manufacturer. Argon 5.0 (purity 99.999%) was used as a carrier gas. Except the sample for the analysis, the solution for the calibration curve construction were prepared using Multistandard IV - multi-element standard solution, which contained Ag, Al, B, Ba, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ga, In, K, Li, Mg, Mn, Na, Ni, Pb, Sr, Se, Ti, V and Zn, and

also specific standard solution of Si, As, P, Mo and Sb in concentration of 1000 ppm.

3. RESULTS AND DISCUSSION

3.1. Nutritional value and β -glucans content

According to recent data, normal medians of crude protein, lipid and ash content of numerous wild-growing mushroom species were 250, 30 and 80 g/kg d.w., respectively [2]. Table 1 presents the nutritional values of mushrooms tested in this study. The content of proteins was lower in samples of *P. ostreatus* and *L. edodes*, while fat content of *L. edodes* and *M. procera* was higher than samples from literature data. The protein content was much higher in *M. procera* than the average content in mushrooms (337.7 g/kg).

Table 1. Nutritional value of dried mushrooms

Tabela 1. Nutritivna vrednost osušenih pečuraka

Parameter	<i>Pleurotus ostreatus</i>	<i>Lentinula edodes</i>	<i>Macrolepiota procera</i>
Moisture (g/kg)	80.9	108.6	62.2
Ash (g/kg)	81.6	32.1	74.0
Fat (g/kg)	39.4	70.4	50.6
Proteins as Nx6.25 (g/kg)	22.6	23.8	337.7
Carbohydrates (g/kg)	304.9	251.8	77.7
Energy (kcal/kg)	1664.6	1736.0	2912.6
Energy (kJ/kg)	7025.3	7290.0	12174.7

β -Glucans are polysaccharides present in fungal cell wall. These biomolecules exhibit important medicinal effects [1]. Lentinan, β -glucan isolated from *L. edodes*, and pleuran, isolated from *P. ostreatus*, showed positive effect on immune system [5][6]. In recent study, the content of β -glucans in 39 commercially cultivated and wild mushrooms was analysed. β -glucan content in *P. ostreatus* (whole mushroom), *L. edodes* (cap and stalk), as well as *Macrolepiota fuliginosa* (cap and stalk) were 24,231 g/100g d.w.; 19,779 g/100g d.w.; 25,309 g/100g d.w., 13,952 g/100g d.w. and 13,118 g/100g d.w., respectively [7]. Culinary treatment have influence on proximate composition of mushrooms [8]. Results of our study indicate that thermal treatment (boiling at 100°C) can drastically decrease the content of β -glucans in mushrooms, approximately 90%. (Table 2).

Table 2: The content of α -, β - and total glucan in dry and cooked mushroom (g/100g)Tabela 2: Sadržaj α -, β - i ukupnih glukana u osušenim i kuvanim pečurkama (g/100g)

Different prepared samples	α -glucan	β -glucan	Total glucan
<i>Pleurotus ostreatus</i>			
Dried	3.27±0.01	47.14±0.61	50.42±0.60
Cooked	0.32±0.01	8.65±0.14	8.97±0.15
<i>Lentinula edodes</i>			
Dried	1.42±0.00	33.98±0.31	35.40±0.31
Cooked	0.22±0.01	3.99±0.08	4.21±0.09
<i>Macrolepiota procera</i>			
Dried	1.30±0.07	11.20±0.57	12.50±0.63
Cooked	0.16±0.01	1.42±0.06	1.58±0.06

3.2. Micro- and macroelements

Mushrooms are very good source of minerals [9], but also could be enriched with selenium and lithium [9,10,11]. The most common macroelements in mushrooms are calcium, potassium, sodium and phosphorus, as well as magnesium, copper and zinc [3]. These metals are among the vital ions to body liquids and tissues and are co-factors of numerous enzymes [9]. The most abundant mineral in all three mushroom samples was calcium, followed by potassium. On the other hand, the concentration of sodium in all three samples is very low. For overall therapy of hypertension Na/K ratio is very important.

Table 3. Micro- and macroelements in mushrooms samples ($\mu\text{g/g}$).Tabela 3. Mikro- i makroelementi u uzorcima pečuraka ($\mu\text{g/g}$).

Element	<i>Pleurotus ostreatus</i>	<i>Lentinula edodes</i>	<i>Macrolepiota procera</i>
Ag	0	0	0
Al	273	141	239
As	20	10	16
B	96	0	26
Ba	118	62	94
Bi	25	24	25
Ca	78031	46678	99126
Cd	0	2	0
Co	0	0	0
Cr	0	0	0
Cu	147	63	109
Fe	88	28	69
Ga	0	0	0
Ge	72	69	71
In	23	22	21

K	26942	7972	12169
Li	5	4	5
Mg	1658	959	1353
Mn	0	0	0
Mo	31	27	26
Na	2609	1936	2316
Ni	0	0	0
P	21634	13251	20137
Pb	0	0	2
Pt	470	443	446
Sb	0	0	0
Si	1165	871	1078
Sr	10	5	15
Tl	0	0	0
Zn	110	125	94
Se	69	67	67

In patients with hypertension, the lower sodium intake, recommended by American Heart Association, should be less than 2.3 g, or maximal 6 g of sodium chloride. Na/K ratio for our samples was also very low 0.190 for *M. procera*, 0.24 for *L. edodes* and 0.09 for *P. ostreatus*. Concerning the effects on blood pressure, the low concentration of sodium and the presence of a great amount of potassium supports the utilization of mushrooms within an antihypertensive diet.

The order of other elements in our samples was: Ca>K>P>Na>Mg>Si>Pt>Al>Zn>Mn>Fe >Ge> >Se>Ba>Cu>Mo>Bi>In>As,B>Sr>Li>Pb. Ag, Cd, Co, Cr, Ga, Ni, Sb and Tl had not been detected. In a review paper by Falandysz and Borovička (2013) the content of the most frequent micro- and macroelements occurring in edible mushrooms was presented [9]. We can conclude that the

concentrations of the majority of elements in our samples (Ca, K, P, Na, Mg, Cu, Se, Zn, etc.) are within the range of concentrations measured by other researchers so far.

M. procera and *P. ostreatus* had the highest amount of Li (5 µg/g). According to Vetter (2005), the highest Li content was found in the sample from Hungary (0.609 mg/kg), but the mushrooms could not be considered as accumulators of Li [10]. The highest quantity of Se 69 µg/g d.w. found in *P. ostreatus*. In general, most of the wild-growing mushrooms are poor in Se, containing less than 1.0 µg/g d.w. [12]. On the other hand, it is not uncommon to detect higher amounts of Se in mushrooms, especially in *P. ostreatus*. The concentrations of Se can reach up to 858.0 mg/kg d.w. when *P. ostreatus* grows on the soil enriched with selenium [13]. That is why, we can conclude that *P. ostreatus* is a very good Se accumulator. The great amount of Zn and Cu was also detected in *P. ostreatus* (110.0 and 147.0 µg/g d.w.) and *M. procera* (94 and 109 µg/g d.w.). The fruit bodies of mushrooms accumulate remarkably high concentrations of Cu and Zn from the soil. Concentrations of these elements found in samples collected in Lugo province in Spain were as high as those in our sample of *M. procera* (Zn: 92.49 mg/kg d.w.; Cu: 217.85 mg/kg d.w.), while the content of minerals in *P. ostreatus* was lower (Zn: 82.77 mg/kg d.w.; Cu: 25.22 mg/kg d.w.). Still, it has been confirmed that mushrooms growing on wood generally contain lower concentrations of heavy metals than fungi growing on soil [14].

Considerable amount of Pb was found in *M. procera* (2.0 µg/g d.w.). According to European Commission (2008) maximum level of Pb in mushrooms is 0.1 mg/kg calculated on wet weight (w.w.), with the exception of *L. edodes* and *P. ostreatus* (0.3 mg/kg w.w) [15]. Considering the fact that fresh mushroom contains approximately 90% of moisture [16], maximum level of Pb in dried mushrooms, including *M. procera*, would then be 1.0 mg/kg d.w. which is still less than the concentration in our sample. Nevertheless, this higher level of Pb (1.4-3.5 µg/g) was found in caps of *M. procera* in different regions in Poland [17]. Cd was detected only in *L. edodes* in the concentration of 2.0 µg/g d.w., which is the maximum level for Cd allowed in European Union (0.2 mg/kg calculated on fresh weight (f.w.), equivalent to 2.0 mg/kg d.w., assuming 90% moisture) [15]. Cadmium accumulation in mushrooms was demonstrated before. Mattila et al. (2001) detected 1.2 µg/g d.w. of Pb in their sample of *L. edodes* collected in Finland [18], while the highest level of Pb in the

same mushroom collected from Henan province, PRC, was 1.9 mg/kg d.w. [19]. Verily, Jain et al. (2013) found the highest amount of Pb in dried fruit body of *L. edodes* (mean 4.52 mg/kg in 2009; mean 4.39 mg/kg in 2010) [20]. In the same paper, the authors concluded that the concentration of Pb in mushrooms depends on the cotamination of the soli mushroom grew on, but there is also an opinion that cadmium could be a growth stimulation factor for mushrooms and that high concentration of this element was not the result of environmental contamination with Cd from the soil [21]. All mushroom samples had considerable amounts of arsenic. The European Commission does not specify the maximum level of As in mushrooms. However, the JEFCA (1988) Provisional Tolerable Daily Intake (PTDI) for inorganic arsenic is 0.002 mg/kg b.w., equivalent to 0.12 mg/day for a 60 kg adult [22]. Also, in Republic of Serbia, the maximum level of As in fresh and processed mushrooms is 0.3 mg/kg [23]. The normal levels of arsenic in wild mushrooms are usually less than 1 mg/kg d.w. [24]. However, it is not the first time that mushrooms accumulate As in such a high concentrations in wild mushrooms. It has been reported that values of As vary between 23 and 77 µg/g d.w. and even up to 1420 mg/kg d.w. in polluted areas of Denmark for *Laccaria amethystine* [25].

In contrast to vascular plants, macrofungi can accumulate extremely high concentrations of macro- and microelements in their fruiting bodies, even when growing above soils with low metal contents. Elements typically accumulated in include Au, Ag, As, Br, Cd, Cl, Cs, Cu, Hg, Rb, Se, V, and Zn, while elements with typically low concentrations in macroungi include Co, Cr, F, I, Ni, Sb, Sn, Th, U, and rare earth elements. The bioaccumulation of trace elements in macrofungi depends on various factors, such as bedrock geochemistry, environmental pollution, fungal lifestyle (distribution of mycelia in soil profiles) [9].

4. CONCLUSIONS

Tested mushrooms have very good nutritional composition, low energy value and favorable sodium/potassium ratio, but unfortunately they have higher content of heavy metals (Pb, As, Cd) than permitted. Since we tested commercial samples, these data are significant, because they indicate that mushrooms were collected in the polluted area. Knowing the importance of the polysaccharide polymers for human health, the tested mushrooms can be a significant source of these compounds.

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Author disclosure statement

The authors confirm that this article content has no conflict of interest.

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IZVOD

SASTAV MIKRO I MAKROELEMENTATA I NUTRITIVNA VREDNOST U TRI JESTIVE PEČURKE IZ SRBIJE

Nutritivna vrednost, kao i sadržaj makro- i mikroelemenata testirana je u uzorcima tri jestive pečurke, sakupljene u Srbiji (Pleurotus ostreatus, Lentinula edodes, Macrolepiota procera). Pokazano je da su sve tri gljive bile siromašne energijom, mastima i ugljenimhidratima, ali bogate β -glukanima. Najzastupljeniji elementi u sva tri uzorka bili su esencijalni makroelementi Ca, K i P, ali je takođe je detektovana značajna količina Li, Se i Zn. Sa druge strane, koncentracija toksičnih metala, Pb, As i Cd, bila je iznad dozvoljenih granica.

Ključne reči: *Pleurotus ostreatus, Lentinula edodes, Macrolepiota procera, nutritivna vrednost, analiza hemijskih elemenata.*

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