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CHEMICAL COMPOSITION OF THE MUSHROOM *LAETIPORUS SULPHUREUS* (BULL.) MURILL.

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Laetiporus sulphureus (chicken of the woods) is a wood decaying mushroom with positive medicinal and biological effects. The aim of this study was to determine its chemical composition including the main organic components (protein, fat, fibre, and ash contents, different protein fractions, the free amino acid level, soluble oligo- and polysaccharides, phenolics), the *in vitro* digestibility, the free radical scavenging activity, and twenty mineral elements.

Our data demonstrate the characteristic in general valuable chemical composition of the mushroom *Laetiporus sulphureus*. Protein content in fruiting bodies is not too high (10.6% d.m.), but the biological value (in vitro digestibility, rate of protein fractions, free amino acid content, etc.) is good (including fat and energy levels). Occurrence of “bioactive” components (phenolics, soluble oligo- and polysaccharides) and the measured free radical scavenging activity are similar to these parameters in *Pleurotus* (oyster) species. Potassium and phosphorus contents are remarkable (28 940 mg kg^{-1} d.m. and 4890 mg kg^{-1} d.m., respectively); levels of some poisonous microelements (As, Cd, Cr) are very low or undetectable. Chicken of the woods *(Laetiporus sulphureus)* is not only a suitable species for human consumption, but can be a new cultivable mushroom of valuable bioactive substances.

Keywords: chicken of the woods, fruit body, chemical constituents

The mushroom species *Laetiporus sulphureus* (Bull.) Murill. (Chicken of the woods, sulphur tuft) is not only an edible member of mushroom populations of deciduous forests but a perspective species for cultivation. The genus *Laetiporus* was created by the American mycologist W.A. Murill, and the species *Polyporus sulphureus* was moved into the *Laetiporus* genus (Zjawiony, 2004). It is widely distributed across Europe, North America, and in Siberia (Agafonova et al., 2007) and related but distinct species are living in East Asia (Ota el al., 2009). Biochemical, morphological, and ecological studies demonstrated for North America that *L. sulphureus* is a complex of four taxa (Banik & Burdsall, 2000; Lindner & Banik, 2008).

It is most commonly found on oak tree, but it is frequent species on other trees and shrubs (Lindner & Banik, 2008; Ota et al., 2009). In Hungary (in Europe) it is a common mushroom in washland tree communities, or on false acacia. It belongs to the brown (red) decaying fungi. Production of fruit bodies (fructification) occurs from May till October.

The mushroom is brightly coloured (yellow, sulphur yellow to orange), large, and it is typically found in clusters. It grows in a semi circular form around trunks. Fruit bodies of *L. sulphureus* can be extremely large (some have been found with weight over 45 kg and the diameter can be 5–60 cm). The mushroom has no gills, the surface has tiny pores.

Investigations on classical chemical components of *L. sulphureus* are relatively rare. Amino acid composition, lipid content, and some mineral elements were analysed from

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Siberian mushroom samples (Agafonova et al., 2007). *Laetiporus sulphureus* samples derived from South Italy were studied for crude protein, fat, and free fatty acids as well as for some minerals (Ca, Fe, Mg, K, Na, and P_2O_5) and vitamins (Palazzolo et al., 2011). Detailed analyses were done on different carbohydrate fractions of this species (Olennikov et al., 2009a; 2009b). The main fraction of the alkali-soluble polysaccharide, with a yield of 42.7%, was named latiglucan I: it is a β-(1→3)-D-glucan of 1.8×10^5 kDa (Olennikov et al., 2009b). Biological activity of α-(1→3)-D-glucans, isolated from the fruit bodies, was tested on human tumour and normal cells (Wiater et al., 2011). The main pigment of the mushroom (laetiporic acid) is a polyene of non-isoprenoid character, has an unprecedented decaene skeleton, and contains double bonds with a stable *cis* configuration (Weber et al., 2004; Davoli et al., 2005). Twenty-six volatile components were identified from their fruiting bodies (Rapior et al., 2000).

The aim of our studies was to evaluate the nutritional value of *L. sulphureus*, based on a wide chemical survey including the common organic and inorganic components as well as some parameters of antioxidant character.

1. Materials and methods

1.1. Samples

Fruiting bodies (sporocarps, basidiomes) of *L. sulphureus* (Bull.) Murill. were collected from two different habitats from the Hungarian Middle-Mountain (sample 1. from *Fagus sylvatica* (beech) tree (08.05.2005), sample 2. from *Robinia pseudo-acacia* (false acacia) trees (15.05. 2012). The fruiting bodies were cleaned, sliced, carefully dried (at 35 °C), and pulverized. The voucher samples were deposited in the laboratory of the Department of Botany, Faculty of Veterinary Science, Szent István University (Hungary). All analyses were performed from these mushroom powders in triplicate.

1.2. Methods of analyses

Crude protein (conversion factor: 4.39), fibre, fat, and ash contents were determined according to the A.O.A.C. official methods (Palazzolo et al., 2011); the carbohydrate content and the energy level were calculated (Mattila et al., 2002). Digestible protein and non-protein nitrogen (NPN) contents were evaluated after our earlier described method (Vetter & Rimóczi, 1993). Free amino acids were measured from ethanolic (70%) extraction, with ninhydrin reaction (Chen et al., 2009), the fractionation of proteins were carried out according to the modified Osborne method (Petrovska, 2001). The soluble oligo- and polysaccharide fractions were produced by methanol:water (80:20) extraction (for oligosaccharides) and by the following boiling water extraction (for polysaccharides), and were evaluated with anthrone reactions (Saltarelli et al., 2008). Molecules with phenolic character were extracted with ethanol (80%) and determined with Folin reagent (Dubost et al., 2007). Extraction for flavonoids was made in methanol; the concentrations were measured with $AlCl_3$ reagent (Sarikurkcu et al., 2008). The antioxidant activity of mushrooms was evaluated by the free radical scavenging activity on DPPH (Sarikurkcu et al., 2008) and was calibrated with (±)-α-tocopherol.

Quantities of twenty mineral elements were established according to our earlier published methods (Vetter, 1994). All chemical parameters were characterised with the arithmetical mean (n=3) and with standard deviation (SD) of three independent measurements.

2. Results and discussion

Data on nutritional value are given in Tables 1–5. According to basic nutrient contents (Table 1) the crude protein level (10.8% d.m.) is in the lower range compared to values of other edible mushroom species, mainly wood decaying species (for *Pleurotus* species: MANZI et al., 1999; LEAL et al., 2010). Crude fat level is low (2.96% d.m.), which has a determining role in the calculated low energy level (1427 kJ/100 g). The crude fibre content is moderate (5.55% d.m.), the average ash content is 6.39% d.m. The calculated "total" carbohydrate content is remarkable; it is the highest organic component (77.5% d.m.).

Table 1. Macrocomponents (crude protein, fibre, fat, ash contents, calculated carbohydrate concentration, organic ingredients, and the energy level) of *Laetiporus sulphureus* (arithmetical mean±SD)

Components	*Laetiporus sulphureus* No. 1.	*Laetiporus sulphureus* No. 2.	*Laetiporus sulphureus* average
Crude protein (% d.m.)	12.84±0.07	8.38±0.11	10.61±3.15
Crude fat (% d.m.)	2.85±0.21	3.07±0.17	2.96±0.15
Crude fibre (% d.m.)	5.40±0.12	5.70±0.17	5.55±0.21
Crude ash (% d.m.)	7.27±0.18	5.51±0.04	6.39±1.24
Carbohydrate (% d.m.)	71.6±0.58	77.34±0.49	74.47±4.05
Organic ingredients (% d.m.)	92.73±0.94	94.49±0.94	93.61±1.24
Energy (kJ/100 g d.m.)	152	134	143±12.9

Results demonstrate 86% digestibility for proteins (Table 2), the NPN (non-protein nitrogen) value is 13.9%. These results are totally comparable with our earlier data given for *Stropharia rugosoannulata* and *Pleurotus ostreatus* mushroom species (VETTER & RIMÓCZI, 1993).

Table 2. Digestible protein, non-protein nitrogen (NPN), and free amino acid contents of *Laetiporus sulphureus* (arithmetical mean±SD)

Components	*Laetiporus sulphureus* No. 1.	*Laetiporus sulphureus* No. 2.	*Laetiporus sulphureus* average
Digestible protein (% d.m.)	11.05±0.07	7.22±0.11	9.13±2.70
Digestible protein (in % of crude protein)	86.04±0.06	86.12±0.24	86.08±0.05
NPN (% d.m.)	0.41±0.002	0.26±0.001	0.33±0.10
NPN (in % of crude protein)	13.96	13.88	13.92±0.05
Free amino acids (mg g^{-1} d.m.)	20.60±2.0	13.65±1.0	17.12±4.91
Free amino acids (in % of crude protein)	16.04	16.28	16.15±0.16

The extractable (free) amino acid contents are 13 and 20 mg g^{-1} d.m. for *L. sulphurous* No.1. and No.2., respectively, or calculated for crude protein content: 16% of it belongs to this fraction, which is useful to the later digestion process.

The main protein fractions were analysed according to the classical fractionation of Osborne (Table 3). We found the absolute dominant character of albumins (in average 50.4% of total protein content); globulines give 11.2% of total protein content. Quantity of prolamines (and of prolamine-like substances) is low (4.4 and 2.9%, together 7.31%), whereas the glutelins (and gluteline like substances) have remarkable values (17.1% and 13.2%, respectively). Distribution of protein fractions is similar in character to data of Petrovska (2001), but it is absolutely different from the plant protein types. The high or very high rates of water- and salt-soluble protein types (i.e. albumins and globulines) seem to be the most characteristic property of these proteins. The high albumin+globuline levels of *L. sulphureus* have a positive role in digestion because of their good solubility. It is a fact, however, that the rate of glutelins (and gluteline like substances) is relatively high (37.1% of total protein content), higher than in studies of Petrovska (2001).

Table 3. Different protein fractions of *Laetiporus sulphureus* (arithmetical mean±SD), and in percent of raw protein content (%)

Protein fractions	*Laetiporus sulphureus* No. 1.	*Laetiporus sulphureus* No. 2.	*Laetiporus sulphureus* average
Albumins	80.12±3.0 60.16	45.50±3.25 40.68	62.81±24.0 51.3
Globulins	13.56±0.69 10.18	13.62±0.44 12.18	13.59±0.04 11.1
Prolamines	5.93±0.49 4.45	4.87±0.25 4.36	5.40±0.74 4.4
Prolamine-like substances	3.99±0.37 2.99	3.18±0.31 2.84	3.58±0.57 2.9
Glutelines	9.81±1.20 7.36	32.0±2.5 28.61	20.90±15.60 17.1
Gluteline-like substances	19.75±1.75 14.83	12.68±0.75 11.34	16.21±4.99 13.2

Table 4. Soluble oligo- and polysaccharides, total phenolic and flavonoid contents, and free radical scavenging activity of *Laetiporus sulphureus* (arithmetical mean±SD)

Components (mg g^{-1} d.m.)	*Laetiporus sulphureus* No. 1.	*Laetiporus sulphureus* No. 2.	*Laetiporus sulphureus* average
Soluble oligosaccharides	37.8±2.63	26.42±1.16	32.11±8.04
Soluble polysaccharides	24.93±1.15	25.35±4.27	25.14±0.29
Total soluble saccharides	62.73±3.74	51.77±5.43	57.25±7.74
Phenolic content	6.07±0.50	2.23±0.13	4.15±2.71
Flavonoid content	0.312±0.018	0.078±0.003	0.19±0.16
Free radical scavenging activity (IU (±)-α-tocopherol g^{-1} d.m.)	159.8±6.94	48.61±2.48	104.2±78.6

We analysed the soluble oligo-, as well as the polysaccharides of the mushroom (Table 4). The numerical values are not too high (32.1 mg g^{-1} d.m. and 25.2 mg g^{-1} d.m., respectively), but the medicinal value seems to be probable (Radic et al., 2009). The concentration of total phenolics (4.15 mg g^{-1} d.m.) is remarkably higher than the flavonoid level (0.19 mg g^{-1} d.m.), both components can have role(s) in the biological value of this mushroom species. Scavenging capacity is remarkable.

Mineral composition of *L. sulphureus* (Table 5) demonstrates the specificities of a wood decaying mushroom. Potassium is the highest mineral component (28 942 mg kg^{-1} d.m.), the second element is the phosphorus (4891 mg kg^{-1} d.m.). This situation is similar to mineral composition of other wood decaying species. Levels of Ca and Mg are similar (765 and 1001 mg kg^{-1} d.m., respectively). The aforementioned four elements (K, P, Ca, and Mg) give about 99% of the total mineral composition. Regarding the microelements, middle or low levels were determined for Zn, Fe, Cu, and Mn (56.5, 50.9, 9.7, and 5.2 mg kg^{-1} d.m., respectively). Contents of As, B, Co, Mo, Se, and Ti were under the detectable limits (in general: under 0.1–0.3 mg kg^{-1} d.m.).

Table 5. Mineral components of *Laetiporus sulphureus* (arithmetical mean: mg kg^{-1}±SD)

Elements	*Laetiporus sulphureus* No. 1.	*Laetiporus sulphureus* No. 2.	*Laetiporus sulphureus* average
Al	18.25±1.68	50.9±4.0	34.57±23
As	n.d.	n.d.	n.d.
B	1.59±0.35	n.d.	
Ba	1.70 ±0.11	4.38±0.59	3.04±1.89
Ca	804± 18.9	726±133	765±55.1
Cd	3.21±0.24	0.38±0.05	1.79±2.0
Co	0.50±0.09	0.19±0.15	0.33±0.13
Cr	0.50±0.07	0.60±0.13	0.55±0.07
Cu	13.22±1.60	6.22±0.57	9.72±4.90
Fe	38.58±2.6	63±5.5	50.9±17.3
K	30 500±1050	27 400±1435	28 940±2174
Mg	990±46.2	1012±69	1001±15.5
Mn	5.96±0.37	4.40±0.44	5.18±1.10
Mo	n.d.	n.d.	n.d.
Na	109.8±3.2	310±31	209.9±141
Ni	1.85±0.36	0.87±0.27	1.36±0.69
P	5300±265	4480±299	4890±575
Se	n.d.	n.d.	n.d.
Sr	6.95±0.62	6.48±1.03	6.71±0.33
Ti	n.d.	n.d.	n.d.
Zn	60.8±2.7	52.2±4.13	56.5±6.10

n.d.: under detection limit (0.5 mg kg^{-1})

The mushroom chicken of the wood (sulphur tuft) is not only a wood decaying, edible mushroom, but it is a novelty for the cultivation (AGAFONOVA et al., 2007), and is a considerable member of the medicinal mushroom group (RADIC et al., 2009).

3. Conclusions

Main conclusions of our study were:

Laetiporus sulphureus, being a wood decaying mushroom, has – in average – a middle-low protein level (10.6% d.m.) and low crude fat and crude fibre contents. The calculated energy value is low and beneficial.

Biological value of its proteins is good (their in vitro digestibility is about 86%). Rates of different protein fractions (albumins, globulins, prolamins, and glutelins) are 50.4%, 11.2%, 7.31%, and 3.1%, respectively (in per cent of crude protein content). The high rate of albumins+globulins (61.6%) is a very positive character because these fractions have the best solubility, which fact is useful for later digestion.

Rate of free amino acids (16% of crude protein) is a favourable property, too.

The analyzed "bioactive components" and effects of *L. sulphureus* (phenolics, the free radical scavenging capacity) have different contents but are remarkable constituents, and their distribution is similar to composition of *Pleurotus* species (*P. ostreatus, P. eryngii*). These components are perspective for medicinal use.

Mineral composition of the mushroom is similar to other edible wood decomposer fungi. Four elements (K, P, Ca, and Mg) represent the 99% of the total mineral composition. Contents of K and P are high; some microelements (Fe, Zn, Cu) can be important and essential for the human body. Occurrence of some so called "poisonous" elements (as As, Cr, and Ni) is unimportant, their content is very low or is under the detection limits.

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