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CHEMICAL ANALYSIS OF KING OYSTER MUSHROOM (*PLEUROTUS ERYNGII*) FRUITBODIES

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King oyster mushroom (*Pleurotus eryngii*) is a worldwide cultivated mushroom of appreciated nutritional and medicinal quality. Aims of these investigations were to give new comparative data for the better evaluation of *P. eryngii*. Results of our investigations can be summarized as follows:

P. eryngii has higher (crude protein, crude fat) or at least the same concentrations (chitin and total carbohydrate) of organic nutritive components than the common cultivated *Pleurotus* hybrid ('HK-35'). Regarding the classical protein fractions: albumins are the highest content in both mushrooms, but the quantity and the proportion in *P. eryngii* is better than in 'HK-35' hybrid. Occurrence and proportion of protein fractions is more valuable in *P. eryngii*, while the NPN contents of both mushrooms are the same.

The investigated soluble oligo- and polysaccharides were present in high amounts in both mushrooms, but the free radical scavenging activity seems to be markedly higher in king oyster mushroom, making it more valuable. Mineral compositions of both species are similarly beneficial, but *P. eryngii* has basically higher P and lower K levels. More intensive cultivation and use of *P. eryngii* is clearly recommended.

Keywords: *Pleurotus eryngii,* cap, stipe, proximate analysis, proteins fractions, phenolics, polysaccharides, minerals

The king oyster mushroom (*Pleurotus eryngii* (DC.) Quél.) belongs to a basidiomycetous fungus family (*Pleurotaceae)*. It is a typical fungus of subtropics and steppes, and is widespread in South- and partly in West- and Central-Europe and in different habitats of Central Asia and North Africa (Zervakis et al., 2014).

The cap (pileus) is reddish or greyish brown (to yellow) slightly squamulose, 4–5 cm; lamellae are white, greyish, stipe is whitish, 3–10 cm long. *Pleurotus eryngii* is actually a species complex (De Gioia et al., 2005) with three varieties (var. eryngii /it is living mostly on roots of *Eryngium campestre* plant/; var. ferulae /on root system of *Ferula* plant species/; var. nebrodensis /living on *Cachrys ferulaceae* plant/). All these "host" plants (this life type is a weak parasitism) are members of the *Apiaceae* (parsley) plant family. Certain investigations were conducted on its proximate general composition (Manzi et al., 1999; Michael et al., 2011). Other works were performed for some constituents, for example for polysaccharides (including glucans: Liu et al., 2010), sterols (Yaoita et al., 2002), fatty acids, and vitamins (Akyuz et al., 2011). Antioxidant character of this mushroom seems to be doubtless (Alam et al., 2011). Intracellular β-glucan molecules can affect the immune system (Carbonero et al., 2006), extracellular glucan molecules (produced by mycelium culture) have anti-angiogenetic properties against tumours (Shenbhgaraman et al., 2012). *P. eryngii*

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could be recommended as a cholesterol decreasing component (Alam et al., 2011) and can improve insulin-sensitivity. Aims of our investigations were:

– to analyse the nutritive components of caps and stipes of *P. eryngii* (organic and inorganic components);

– to compare these parameters of caps and stipes to common *Pleurotus* 'HK-35' hybrid cultivated mushroom.

1. Materials and methods

1.1. Samples

Fruiting bodies of both mushrooms (*Pleurotus eryngii* 'PEF' strain and *Pleurotus* 'HK-35' hybrid) were produced on wheat straw substrate according to Szarvas (2011). Three-three kg of fully developed fruit bodies from first flushes were cleaned, separated into caps and stipes, sliced carefully, dried (at 40 °C), and pulverized. The voucher samples were deposited in the laboratory of our Department. All analyses were performed from this mushroom powder in triplicate (three extractions, later three-three measurements).

1.2. Methods of analysis

Crude protein, crude fibre, crude fat, and ash contents were determined according to the AOAC official methods (Palazzolo et al., 2011), but for crude protein determinations a 4.38 factor was used. Determination of chitin content was conducted according to our earlier method (Vetter, 2007). Total carbohydrate content was calculated according to the following equation: Carbohydrate=100–(g moisture+g crude protein+g crude fat+g ash) (Manzi et al., 2004). Energy values of mushrooms were counted by the equation: 4×(g protein+g carbohydrate)+9×(g lipid) (Manzi et al., 2001). Fractionation of proteins was carried out with the modified Osborne method (Bauer-Petrovska, 2001). Soluble oligo- and polysaccharide fractions were produced by methanol:water (80:20) extraction (for oligosaccharides) followed by boiling water extraction (for polysaccharides) and were evaluated with anthrone reactions (Saltarelli et al., 2008). The phenolics were extracted with ethanol (80%) and determined with Folin reagent (Dubost et al., 2007). Flavonoids were extracted with methanol; the concentrations were measured with $AlCl_3$ reagent; the free radical scavenging activity was evaluated on DPPH (Sarikurkcu et al., 2008). All photometric measurements from the previous methods were carried out by Metertech SP-880 Spectrophotometer. Amounts of 22 mineral elements were measured by ICP analysis (acidic digestion in HNO_3 and H_2O_2 in closed Teflon bombs, measurements by Thermo-Jarrel-Ash ICAP-9000 instrument) by our earlier published method (Vetter, 1994).

1.3. Statistical evaluation

All determinations were carried out in independent triplicate (for example: three extractions and from all extractions three-three measurements) and data were given as arithmetical mean ±SD. The mean values were analysed by one-way ANOVA and Tukey's pairwise means comparison test was used (by Origin 8.5 program) to control significant difference ($P < 0.05$).

2. Results and discussion

Results of our chemical investigations are summarized in Tables 1–4. Levels of the so-called "classical" components (Table 1) are given in comparison with data of *P.* hybrid ('HK-35'). *P. eryngii* has greater caps and stipes in general but these differences are not significant. Dry matter (DM) content of king oyster mushroom is relatively high (10.0%) for caps and very high (19.4%) for stipes. Rate of dry matter contents in caps and stipes of 'HK-35' is similar but the numerical data are lower (7.3% and 10.9% DM, respectively). Crude protein levels are significantly higher in *P. eryngii* (18.9% DM for caps and 11.3% DM for stipe) and we documented markedly different rates between caps and stipes, 1.7 for *P. eryngii* and 3.7 for 'HK-35' hybrid. Crude fat values are significantly different in all samples; *P. eryngii* caps have remarkable higher quantities than stipes, and these values are higher than those of 'HK-35' hybrid. These data confirm the results of Dundar and co-workers, (2008), but they are lower than the data of Manzi and co-workers, (1999). King oyster mushroom has significantly lower crude fibre level than HK-35' hybrid. Fibre contents of caps are significantly higher than of stipes for both mushrooms. Our data for *P. eryngii* are slightly higher than the data of Ulziijargal and Mau (2011), but lower than those of Dundar and co-workers, (2008).

Table 1. Mass (FM) and the contents (for DM) of proximate chemical components of fruit body parts of *Pleurotus eryngii* and of 'HK-35' hybrid mushrooms, and proportions of contents in caps and stipes (means ± SD)

	P. eryngii cap	*P. eryngii* stipe	Cap/ stipe	'HK-35' hybrid cap	'HK-35' hybrid stipe	Cap/ stipe
Mass of fruit bodies (g FM)	38.96a*±15.3	21.9b ±26.6	1.78	24.56b±11.53	13.68c ±4.28	1.80
Dry matter (% DM)	10.03a ±0.28	19.36b ±0.79	0.53	7.31c±0.28	10.94a ±1.60	0.67
Crude protein (% DM)	18.91a ±0.17	11.34b ±0.09	1.67	16.83c ±0.12	4.60d ±0.06	3.66
Crude fat (% DM)	3.84a±0.01	1.30b ±0.04	2.95	1.66c ±0.03	0.75d ±0.02	2.21
Crude fibre (% DM)	8.23a ±0.43	4.47b ±0.28	1.84	10.64c ±0.18	11.01d ±0.11	0.97
Crude ash (% DM)	6.25a ±0.01	4.53b ±0.02	1.37	7.90c ±0.20	4.87b ±0.12	1.61
Chitin (% DM)	6.76a ±0.33	5.61b ±0.60	1.20	6.84a ±0.28	5.34b ±0.25	1.28
Carbohydrates (% DM)	62.77	78.36	0.80	63.03	78.77	0.80
Organic components (% DM)	93.75	95.47	0.98	92.16	95.13	0.96
Energy value kJ/100 g DM	1512	1552	0.97	1399	1426	0.98

*Values in the table with different letters (a–d) differ significantly ($P<0.05$)

Crude ash quantities in caps of both species do not differ significantly in accordance with result of Dundar and co-workers, (2008). Total carbohydrate contents are higher in stipes but the two species have practically the same parameters (62–63% for caps and 78% for stipes).

Comparison of different protein fractions is given in Table 2 (in mg N/g DM). The albumins are dominant in both fruit body parts and in both mushrooms. Caps of king oyster mushroom have significantly higher albumin level (36.3 mg N/g DM) than caps of the 'HK-

35' hybrid (30.4 mg N/g). This is also true for stipes but the differences are more pronounced (21.8 mg N/g for *P. eryngii*, and 7.84 mg N/g only for 'HK-35' hybrid). Globulins have relatively low quantities and rates but caps of *P. eryngii* have significantly higher concentration (1.6 mg N/g DM) than the caps of the hybrid (0.9 mg N/g DM). Prolamin contents are similar, without significant differences. Contents of prolamin-like substances differ significantly for both caps (1.8 mg N/g DM for *P. eryngii*; 8.5 mg N/g DM for 'HK-35' hybrid) and stipes (0.6 mg N/g DM and 1.5 mg N/g DM, respectively). Glutelin fractions show interesting difference; the "control" hybrid has similar values (4.6–4.7 mg N/g DM) for both fruit body parts; *P. eryngii*, however, has higher content in cap (6.9 mg N/g DM) and significantly lower (2.9 mg N/g DM) in stipe. The glutelin-like substances have relatively low quantities but caps have in both species significantly higher levels than in stipes (Table 2). The non-protein nitrogen (NPN) fraction has similar contents and tendency in both mushrooms (i.e. caps have always higher levels).

Table 2. Concentration of different protein fractions for caps and stipes of *P. eryngii* and of 'HK-35' hybrid (means ± SD), and proportions of contents in caps and stipes

	P. eryngii cap	*P. eryngii* stipe	Cap/stipe	'HK-35' hybrid cap	'HK-35' hybrid stipe	Cap/stipe
Albumins (mg g^{-1} DM)	36.33a* ±2.5	21.84b ±2.5	1.66	30.43c ±0.91	7.84d ±0.65	3.88
Globulins (mg g^{-1} DM)	1.64a ±0.1	0.85b ±0.011	1.92	0.95b ±0.03	0.52c ±0.01	1.82
Prolamins (mg g^{-1} DM)	0.77a ±0.02	0.43b ±0.05	1.79	0.70a ±0.01	0.314b ±0.066	2.22
Prolamin-like substances (mg g^{-1} DM)	1.76a ±0.28	0.58b ±0.04	3.03	8.47c ±0.07	1.52a ±0.12	5.57
Glutelins (mg g^{-1} DM)	6.99a ±0.47	2.94b ±0.41	2.37	4.75c ±0.29	4.61c ±1.86	1.03
Glutelin-like substances (mg g^{-1} DM)	0.89a ±0.08	0.112b ±0.01	7.94	0.43c ±0.05	0.138b ±0.018	3.11
Non-protein Nitrogen (mg g^{-1} DM)	2.24a ±0.01	1.59b ±0.09	1.40	2.20a ±0.10	1.85c ±0.11	1.18

*Values in the table with different letters (a–d) differ significantly ($P<0.05$)

Data of Bauer-Petrovska on mushroom protein fractions (2001) are available for comparison but her Macedonian facts are for the whole fruit bodies of certain mushrooms; our data concern caps and stipes, separately. The mean percent distribution of protein fractions (derived from fruit bodies of 25 Macedonian species) is: 24.8% (albumins), 12.1% (globulins), 10.9% (prolamins), 18.9% (glutelins), and 33% (NPN fraction). The distribution of protein fraction for *P. eryngii* has absolute different character: albumin fraction has very high proportion (71.7%), globulins and prolamins have low occurrence (3.2% and 5.0% respectively), the glutelin fraction is about 15.5 % (for Macedonian mushrooms: 18.9%). It is a positive and beneficial fact that the NPN fraction is very low (4.4 for caps and 5.6% for stipes of king oyster mushrooms). The protein character of 'HK-35' hybrid is different: lower albumin (caps: 63.5% and stipes: 46%) and globulin (caps: 1.9%; stipes: 3.1%) fractions

occur; but the prolamin fraction is threefold higher (caps: 19.1%; stipes 10.9%). Other interesting fact is: distribution of protein fractions in cap and stipe is very different, the stipe has lower albumin, higher prolamin, glutelin, and NPN proportions, i.e.: the king oyster mushroom seems to be more valuable and beneficial than the frequently used (cultivated) 'HK-35' *Pleurotus* hybrid.

Data of analysed bioactive components are presented in Table 3. *P. eryngii* has significantly higher soluble oligosaccharide content than 'HK-35' hybrid (197.9; 257.9 mg g^{-1} DM vs. 163.0 and 143.0 mg g^{-1} DM for cap and stipe, respectively). Same situation can be established for total phenolic contents (4.7 mg g^{-1} DM /cap/; 2.9 mg g^{-1} DM /stipe/ for *P. eryngii* and 3.7 mg g^{-1} DM /cap/; 1.3 mg g^{-1} DM /stipe/ for 'HK-35' hybrid). Regarding the flavonoids: differences between the mushrooms are low, but caps have 2–3-fold higher contents than stipes. Free radical scavenging activities for both species are significantly different, king oyster mushroom (both caps and stipes) has about threefold higher activity than 'HK-35' hybrid (Table 3).

Table 3. Soluble oligo- and polysaccharides, total phenolics and flavonoid contents, and free radical scavenging activity of examined mushroom parts (means ±SD)

	P. eryngii cap	*P. eryngii* stipe	Cap/stipe	'HK-35' hybrid cap	'HK-35' hybrid stipe	Cap/stipe
Soluble oligosaccharides (mg g^{-1} DM)	197.9a ±2.01	257.9b ±12.9	0.76	163.0c ±8.24	143.4d ±4.10	1.13
Soluble polysaccharides (mg g^{-1} DM)	15.05a ±3.54	48.51b ±6.1	0.40	23.91c ±1.00	34.17d ±2.35	0.69
Total soluble saccharides (mg g^{-1} DM)	212.9	294.9	0.72	186.91	177.53	1.05
Phenolics (mg g^{-1} DM)	4.67a ±0.24	2.89b ±0.14	1.61	3.73c ±0.17	1.29d ±0.09	2.89
Flavonoids (mg g^{-1} DM)	0.094a ±0.011	0.034b ±0.002	2.76	0.115c ±0.002	0.037d ±0.004	3.10
Flavonoids/phenolics	0.020	0.011	1.81	0.030	0.028	1.07
Free radical scavenging activity (RSA %)	94.12a ±0.93	92.7a ±1.05	1.01	29.6b ±0.78	2.74c ±0.35	10.8

* Values in the table with different letters (a–d) differ significantly ($P<0.05$)

Data on twenty-two mineral elements are presented in Table 4 (in mg kg^{-1} DM units). Four macro elements (K, P, Mg, and Ca) give 97.7–99.0 per cents of total mineral composition. The main element is in all samples the potassium (16 000–32 000 mg kg^{-1} DM). Its contents in caps are remarkably and significantly higher than in stipes; and 'HK-35' hybrid parts have significantly higher levels than those of *P. eryngii*. Phosphorus level is very high in *P. eryngii* but lower in hybrid. Magnesium as third element has higher levels in *P. eryngii*; the caps have significantly higher content than the stipes. Our data are in accordance with the literature (Manzi et al., 1999; Akyuz & Kirbag, 2010), but not all elements were investigated by the cited authors.

Table 4. Minerals (mg kg^{-1} DM) in caps and stipes of *P. eryngii* and 'HK-35' hybrid (means ±SD)

	P. eryngii cap	*P. eryngii* stipe	Cap/stipe	'HK-35' hybrid cap	'HK-35' hybrid stipe	Cap/stipe
Al	11.9a ±2.47	14.23a ±3.23	0.77	15.21a ±0.91	15.58**a** ±0.15	0.98
As	<d.l.	<d.l.		<d.l.	<d.l.	
B	6.71a ±0.36	8.71b ±0.07	0.77	3.08c ±0.12	5.46d ±0.25	0.56
Ba	1.36a ±0.27	1.44a ±0.21	0.94	1.58a ±0.15	2.10b ±0.02	0.75
Ca	882.3a ±183	1008a ±58	0.90	766a ±88.4	1048a ±50	0.73
Cd	<d.l.**	<d.l.		<d.l.	<d.l.	
Co	<d.l.	<d.l.		<d.l.	<d.l.	
Cr	<d.l.	<d.l.		<d.l.	<d.l.	
Cu	11.54a ±0.67	8.86b ±0.67	1.30	9.35b ±0.77	6.80c ±0.98	1.38
Fe	37.24a ±3.53	32.30a ±2.51	1.15	117.6b ±5.39	37.5a ±0.84	3.14
K	22303a ±171	16659b ±29	1.34	32018c ±111	20342d ±12	1.55
Mg	1530a ±75.8	1264b ±2	1.21	1259b ±22.7	763c ±19.6	1.65
Mn	9.93a ±0.22	5.33b ±0.21	1.21	9.37a ±0.11	3.77c ±0.07	2.43
Mo	<d.l.	<d.l.		<d.l.	<d.l.	
Na	792a ±53.6	721b ±7.6	1.10	149c ±11.0	199d ±13.1	0.75
Ni	0.81a ±0.06	0.93a ±0.32	0.89	1.31a ±0.42	1.18a ±0.24	1.11
P	9961a ±378	6562b ±29	1.52	5904c ±108	1446d ±47	4.04
Se	<d.l.	<d.l.		<d.l.	<d.l.	
Sr	6.13a ±1.42	6.6a ±0.84	0.93	6.57a ±0.92	7.89a ±0.29	0.83
Ti	<d.l.	<d.l.		<d.l.	<d.l.	
V	<d.l.	<d.l.		<d.l.	<d.l.	
Zn	68.2a ±2.8	40.2b ±0.95	1.72	66.3a ±1.96	32.04c ±0.05	2.05
Total	35630	26315	1.35	40343	24273	1.66

*Values in the table with different letters (a–d) differ significantly (P<0.05); **<d.l.: under detection limit

3. Conclusions

Comparisons were absolved between the chemical composition of fruit bodies (separately for caps and stipes) of king oyster mushroom (*P. eryngii*) and 'HK-35' hybrid, the following conclusions were drawn:

King oyster mushroom fruit bodies have significantly higher levels of dry matter (both for caps and stipes), crude protein and crude fat, but significantly lower levels of crude fibre, crude ash, and chitin. The calculated "crude" carbohydrate levels and the energy values in both species are practically the same.

Caps have significantly higher levels of crude protein, crude fat-, crude fibre, ash, and chitin, but lower levels of dry matter and total carbohydrate contents than stipes.

Distribution (and comparison) of the protein fractions (produced by the classical Osborne's fractionation) indicates the more valuable character of *P. eryngii* (compared to 'HK-35' hybrid) and the better value of caps (higher concentration of albumins and globulins, lower level of prolamine like substances) compared to stipes for both mushrooms.

Specific, bioactive components: king oyster mushroom has significantly higher contents of total soluble saccharides and phenolics, also its free radical scavenging activity (as a parameter for antioxidant capacity) is higher.

Distribution of mineral spectrum of both species is roughly the same: four macro elements (K, P, Ca, and Mg) present 97–99% of the total mineral content in both species. Level of K is lower in king oyster mushroom, but its phosphorus content is remarkably greater than of 'HK-35' hybrid. The majority of determined elements has higher levels in caps than in stipes (exceptions: Al, B, and Ba), and no differences were found between the examined mushrooms.

A renewed cultivation and use of the king oyster mushroom is clearly recommended for human consumption based on benefits of its chemical composition.

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