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Chemical Composition and Nutritional Value of the Mushroom Auricularia *auricula-judae*

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Abstract Chemical composition of *Auricularia auricula-judae* fungus, used as a raw material for producing therapeutic and medicinal agents and as a food material has not been reported yet. Main components of this cultivated fungus (ash, protein, fat, total carbohydrate), water-soluble polysaccharide, cellulose, chitin, pectin, uronic acids, amino acid and mineral element contents, as well as neutral sugar composition were determined. This fungus contains 3.6% of ash, 12.5% of protein, 1.7% of fat and a large amount of carbohydrates (66.1%) per dry matter. Gas-liquid chromatography demonstrated the following monosaccharide composition of dry biomass: glucose (15.0%), mannose (10.7%), xylose (1.5%), galactose (0.6%). *A. auricula-judae* was shown to be a good source of almost all essential amino acids (34.7% of total) as compared to plant proteins, with the umami taste aminoacids present in content typical of mushrooms (25%). Its average calorific value is 327.7 kcal/100 g of dry matter. Results showed this fungus is a good source of healthy nutrients.

Keywords: *amino acids, calorific value, mineral elements, polysaccharides, soluble sugars*

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1. Introduction

Biological value of mushrooms, as a food product containing a unique complex of biologically active substances, has been proved in recent decades [1,2,3,4]. Edible fungi grown on plant residues contain 35% of proteins, all essential aminoacids, unsaturated fatty acids, vitamins, macro and micro elements, polysaccharides and melanin. Fungi are valued as a dietary product due to low calories and absence of cholesterol [5,6,7].

Cultivated edible fungi are used not only as foodstuff but also as a raw material for producing therapeutic and medicinal agents in many countries (Japan, Korea, China, USA and France). Among these is *Auricularia auricula-judae,* the most popular for cultivation in the countries of East Asia. In Japan, this fungus is called “tree jellyfish”, in China it is called “wood ear”, and in Russia it is called “black fungus”. In Asia, this fungus is valued for its flavor and medicinal properties, considered to be a source of antitumor compounds in the Chinese traditional medicine, being used for topical treatment of sore throat, ophthalmia, staphyloncus, tonsillitis and laryngocele by applying fresh fungus to the sore body part [8,9]. Latest research showed this fungus contains substances preventing thrombosis [10] and reduces cytotoxicity [11].

This fungus has been subject of several studies but to the authors’ knowledge its composition has not been published. The objective of this research was to study the chemical composition and nutrition value of edible fungus *Auricularia auricula-judae* as a functional ingredient and a source of biologically active substances.

2. Methods and Materials

2.1. Materials

Dry *Auricularia auricular-judae* samples were purchased at a local supermarket in Kharbin, China.

2.2. General Chemical Analysis

Moisture content in dry mushroom was determined after drying at 105°C for 24 h. Proximate composition of mushroom, including dry matter, ash and crude protein were determined according to the methods of [12], respectively AOAC 950.46, AOAC 942.05 and AOAC 981.10. Crude protein was determined by the Kjeldahl method on the nitrogen analyzer Kjeltec auto 1030 Tecator using nitrogen conversion factor of 6.25 [13]; crude fat, gravimetrically determined after extraction with $CHCl_3/C_2H_5OH$ (2:1, v/v) mixture [14]; uronic acids, determined by titration [15]; pectin, gravimetrically determined after extraction of 1% ammonium oxalate solution and precipitation of ethanol [16]; cellulose, after fungus hydrolysis with 70% mixture of HNO_3/ 80% CH_3COOH (1:10, v/v) [17]; chitin was determined according to [18].

Water-soluble polysaccharides were determined according to the following procedure: 20 g of a powdered sample were extracted with 1200 ml of boiling water during 3–4 h; extract was evaporated under vacuum up to 400 ml, and then 400 ml of absolute alcohol were added to precipitate water-soluble polysaccharides. Precipitated polysaccharides were collected by centrifugation at 5000 rpm during 10 min and subsequently dried at 60°C to remove residual ethanol. Total carbohydrates concentration was determined by the phenol-sulphuric acid method according to [19].

All analyzes were done in triplicate.

2.3. Mineral Elements Analyzes

Approximately 200 mg of the ground fungus sample were accurately weighed in a glass vessel, then 10 ml of nitric acid (70%, v/v) and 5 ml of deionized water were added, left overnight at room temperature and then heated at the temperature of 90 °C to the condition of dry salt. Residues were dissolved in 25 ml of deionized water. Concentration of mineral elements (Ca, Na, K, Mg, Fe, Zn, Cu, Co, Ni, Cr, Mn) were determined using the atomic absorption spectrophotometer Shimadzu AA-6800 (Kyoto, Japan) [20]. Contents of Pb, As, Cd were determined using a graphite tube [20].

2.4. Neutral Sugar Composition

Monosaccharide content was determined as aldononitrile acetate derivatives after a complete reductive hydrolysis of fungal biomass by GLC. Approximately 10 mg of a ground fungus sample was accurately weighed in a glass vessel and 40–50 mg of boran-4-metil-morfoline complex were added. Hydrolysis was performed with 1 ml 2 M TFA (8 h, 100 °C). Sugars were conventionally converted into aldononitrile acetate derivatives by the Guerrant method [21].

Gas-liquid chromatography was performed on Shimadzu GC-9A (Kyoto, Japan) fitted with flame ionization detector (FID) using capillary column CBP5 (Shimadzu 50 m x 0.32 mm I.D., 0.5 µm film thickness). Helium was used as a carrier gas at a flow rate of 1ml/min. Injector and detector temperature were set up at 250 and 280 °C, respectively. Chromatography was carried out at a gradient temperature from 180 to 280 °C, at 5 °C/ min. Capillary column was calibrated against monosaccharide standards. The monosaccharide standartes D-mannose (Man), D-glucose (Glc), D-galactose (Gal), D-xylose (Xyl) were purchased from Sigma-Aldrich (St. Louis, MO, USA).

2.5. Amino Acid Analysis

About 2 mg of fungus powder was hydrolyzed in 2 ml of 6 N HCI under vacuum in an ampoule tube at the temperature of 110 °C during 24 h. Resulting suspension was evaporated in a vacuum evaporator. Solid residue was dissolved in 2 ml of deionized water and evaporated twice again, successively. Final residue was dissolved in 2 ml of 0.01 N HCI and filtered by a 0.45 µm filter membrane. Filtrate was used for amino acids quantification.

Amino acids content in the filtrate were determined by using the amino acid analyzer HITACHI-L-8800 (Kyoto, Japan), equipped with a #2622 ion-exchange column (4.6 × 60 mm, 3 µm of particle size) and a UV-detector (570 nm, 440 nm for proline). Temperature of the separation column was 57℃. Buffer flow rate was 0.35 ml/min and the buffer pump pressure was 7–8 MPa. Ninhydrin flow rate was 0.30 ml/min and the ninhydrin pump pressure was 0.6–0.8 MPa.

2.6. Energy Value

Total energy values were calculated by multiplying the contents of protein and carbohydrate by the factor of 16.7 kJ/g and the content of lipid by the factor of 37.6 kJ/g [22].

2.7. Statistical Analysis

Three samples of the fungus were analyzed to determine their components. All experiments were done in triplicate, and mean values are presented. Results were expressed as mean ± SD (standard deviation).

3. Results and Discussion

3.1. General Chemical Composition

Nutritional value and organoleptic properties of edible black fungus are attributed to its chemical composition. Fungus chemical composition depends upon the species as well as upon the substrate, age and fructification [23,24,25].

Moisture content of dry mushrooms is 12.3%. Contents of the black fungus main components, per 100 g of dry matter, are shown in Table 1. This species contains 3.6 g of ash, 12.5 g of protein and 1.7 g of fat per 100 g of dry matter.

Of the dry matter main components of *A. auricula-judae*, carbohydrates were found to be the major nutrient, constituting 66.1 g/100 g of its dry matter. A considerable proportion of the carbohydrate compounds is in the form of polysaccharides. Fungus polysaccharides are represented by indigestible forms such as: 38.8% of uronic acids, 10.2% of water-soluble polysaccharides (mannans and glucans), 7.4% of pectin, 5.4% of chitin and 4.3% of cellulose, which are important for proper functioning of gastrointestinal tract.

It was found *A. auricula-judae* didn't differ from other edible mushrooms in its qualitative chemical composition [26,27,28,29]. Comparative analysis showed *A. auricula-judae* was very close to wood-destroying fungus (*Armillariella mellea*) in relation to the content of its main components (Table 1). Its ash and carbohydrate contents are similar to that of *A. mellea* *[26]* and *Sarcodon aspratus* [30], and its fat and protein content was similar to that of *A. bisporus* [27,29]. Cellulose content is as much as by 2.6–4.1 times less than the cellulose content of *A. bisporus* and *P. ferulae* [28].

3.2. Neutral Sugars Composition

Polysaccharides in edible fungi are highly valued as biologically or medically active compounds and are used as functional food ingredients or biologically active additives. Fungi neutral monosaccharides were determined for more in-depth analysis of its biomass polysaccharide composition. Monosaccharide composition of *A. auricula* biomass is presented in Table 2. Contents of glucose, mannose, xylose and galactose were determined in the fungus biomass. Glucose and mannose are the major components (15.0 and 10.7 g /100 g of dry matter, respectively) typical of black fungi polysaccharides, but xylose content is lower and mannose content is higher than those ranging in *A. auricular* reported by [31].

Table 1. General chemical composition of *Auricularia auricula-judae* and other edible fungus (g/100 g of dry matter)[a]

Component	*A. auricular-judae*	[b]*Armillariella mellea*	[c,d]*Agaricus bisporus*	[e]*Pleurotus ferula*
ash	3.6±1.0	3.2±0.3	8.7±1,0	5.0±0.4
protein	12.5±0.4	21.1±0.1	13.3±6.0	30.3±1.5
fat	1.7±0.2	6.1±0.1	1.7±0.3	5.7±0.6
total carbohydrate	66.1±4.0	70.0±5.0	44.5±8.5	47.8±1.0
water-soluble polysaccharide	10.2±1.3	-	-	15.9±0.2
cellulose	4.3±1.1	-	17.6±1.0	11.2±0.2
chitin	5.4±0.5	-	-	-
pectin	7.4±0.4	-	-	-
uronic acids	38.8±0.2	-	-	-

[a] Values represent average ± standard derivations for triplicate experiments.
[b][26]; [c] [27]; [d] [29]; [e] [28].

Table 2. Monosaccharide composition of *Auricularia auricula-judae* (g/100 g of dry matter).

Galactose	Xylose	Mannose	Glucose
0.6±0.1	1.5±0.2	10.7±0.5	15.0±0.5

3.3. Mineral Elements Content

Mushrooms are characterized by a high level of well digestible mineral components [32], which depends on the species, mushrooms age and on the substrate [33].

Mineral substances in the *A. auricula-judae* biomass constituted 3.6% (Table 1) which is as much as 1.4 times less than those in *Volvariella volvacea*, *Boletus edulis* [34], but more than those found in *Pleurotus ostreatus* [25].

Table 3. Mineral element content of *Auricularia auricula-judae* (mg/kg of dry matter)

Macro elements		Microelements	
element	content	element	content
Ca	1.6×10^4	Fe	200
Na	0.8×10^4	Zn	60
K	1.2×10^4	Cu	≤ 20
Mg	0.2×10^4	Co	≤ 20
		Ni	≤ 20
		Cr	≤ 20
		Mn	≤ 20

Mushroom mineral composition is presented in Table 3, presenting levels of 11 main macro and microelements. It should be noted that 4 macro elements (Ca, K, Na, and Mg) and 7 microelements were found among the biogenic elements. High content of calcium was found in *A. auricula-judae* as compared to that of *Pleurotus* mushrooms. Calcium concentration in *Auricularia* is twice higher than sodium level and as much as 8 times higher than the magnesium content. Content of sodium and magnesium in *Auricularia* conforms to those microelements levels in *Pleurotus djamor*, *P. ostreatus*, *Lentinula edodes* [13]. These differences makes *A. auricula-judae* macro element composition considerably discrepant from composition of other representatives of edible fungi, such as *A. bisporus*, *B. edulis*, and *L. edodes*, in which potassium content is higher than calcium content. *A. auricula-judae* accumulates more potassium and calcium than magnesium and sodium, what is likely to depend upon the substrate chemical composition [23].

Iron and zinc are predominant microelements in *A. auricula-judae* tissues. As for the uptake level in *A. auricula-judae* tissues. Auricularia is closer to *Lactarius volemus* and *Cantharellus cibarius* (154–250.0 mg/kg) for iron content, and is closer to *Hydnum repandum*, *Lycoperdon perlatum*, *Sarcodon imbricatus* (47 mg/kg, 55 mg/kg and 80 mg/kg, respectively) for zinc content [26].

Content of copper and manganese in *A. auricula-judae* is in agreement with data on those elements of other representatives of edible mushrooms *Ramaria flava* (17.6–22.8 mg/kg) and *Hydrum repandum* (20.0–23.5 mg/kg), respectively [35].

Therefore, metal concentration of *Auricularia* fungi decreased in the following order: Ca> K > Na > Mg> Fe> Zn >Co/Ni/Cu/Mn.

Table 4. Toxic elements content of *Auricularia auricula-judae* compared to maximum content by Russian standards (mg/kg of fresh matter) [37] and Commission Regulation (EC) No 1881/2006 (mg/kg of dry matter) [41]

Toxic elements	*Auricularia auricula-judae* (mg/kg f.m / mg/kg d.m.)	Maximum content in Russian Federation (mg/kg f.m)	Maximum content in EU (mg/kg d.m.)
Pb	0.1 / 0.01	0.5	0.1
Cd	0.01 / 0.001	0.1	0.05
As	0.2 / 0. 02	0.5	-

According to FAO/WHO [36], permissible weekly dose of cadmium, lead and arsenic is, respectively, 0.007, 0.025 and 0.003 mg per kg of a human body weight. Cadmium, lead and arsenic levels in the fungus studied are very low and make up 0.01, 0.1 and 0.2 mg/kg of the fresh matter (Table 4), values considerably lower than the standard parameters stipulated for edible mushrooms in the Russian Federation [37]. Therefore, *A. auricula-judae* can be considered safe for consumption.

3.4. Aminoacids Content

Protein is an important component of fungi dry matter. Protein compounds constitute more than half of the total nitrogen. Protein of *A. auricula-judae* contains all exogenous amino acids; however, the level of some of them is insufficient (Table 5). *A. auricula-judae* essential amino acids content constitutes 34.7% of total amino acids content which is comparable to their content in proteins of *P. djamor* and *P. ferulae* [28]. In addition to essential amino acids, considerable amounts of alanine, glycine, glutamic acid, aspargic acid, proline and serine were discovered in *A. auricula-judae*. Comparison of essential amino acids contents in the standard protein stipulated by the FAO/WHO [36], shows methionine, cystine, and isoleucine are limiting amino acids of *A. auricula-judae* protein.

Table 5. Amino acid (AA) content of edible mushrooms (mg/ g of dry matter)[a]

Amino acid	*Auricularia auricula*	[b]*Pleurotus djamor*	[b]*Pleurotus ferulae*
Asp	8.80±0.13	8.64±0.16	21.11±1.42
Thr	4.89±0.58	3.73±0.64	8.06±0.55
Ser	9.75± 0.50	6.01±0.43	8.61±1.16
Glu	10.30±0.92	7.11±1.07	32.5±2.28
Gly	7.30±0.60	5.53±0.78	9.53±0.24
Ala	7.49±0.91	5.50±0.92	12.9±1.33
Val	3.53±0.65	5.57±0.71	11.8±1.31
Cys	0.50±0.23	5.86±0.11	2.51±0.07
Met	0.29±0.03	1.23±0.04	3.62±0.13
Ile	1.89±0.24	4.33±0.33	11.38±1.24
Leu	4.89±0.71	4.14±0.69	22.31±1.90
Tyr	3.56±0.65	3.35±0.67	3.29±0.53
Phe	2.76±0.15	2.69±0.15	8.68±0.29
Lys	4.04±0.63	3.65±0.66	12.96±1.44
His	2.16±0.22	1.84±0.21	4.47±0.52
Arg	3.68±0.71	7.36±0.71	12.6±1.04
Pro	5.80±1.0	4.66±1.05	5.66±0.77
Try	not determined	not available	not available
Total	75.83±0.52	84.4±1.66	192.0±3.11
Total Essential AA	26.35	24.8	71.5
Essential AA/Total AA, %	34.7	29.4	37.2

[a] -Values represent average ± standard derivations for triplicate experiments.
b [28].

Typical mushroom taste, umami taste or palatable taste, is given by aspartic and glutamic acids [38]. Ratio of umami amino acids to total amino acids is 0.25, a value in the middle of the range (0.21–0.32) found for mushrooms [39].

3.5. Energy Value

Mushrooms are low-calorie food and their energy value varies from 113 to 125 kJ/100 g of fresh matter [40] or from 1442 to 1881 kJ/100 g of dry matter [12,26]. *A. auricula-judae* is characterized by an intermediate calorific value of 1370 kJ/100 g of dry matter and is comparable to *Pleurotus ostreatus* (1442 kJ/100 g) [13].

Due to the high content of polysaccharides, low fat and an intermediate calorific value, this species of edible fungi should be considered as dietetic food.

4. Conclusion

A. auricula-judae chemical content proved this fungus is a valuable raw material to produce low-calorie dietary food, as well as a good source of biologically active polysaccharides and essential aminoacids. This species of edible fungi contained minerals required in the human diet, such as Ca, K, Mg, Fe, Zn. The level of toxic elements Pb, Cd, As was lower than in the Russian standards and Commission Regulation (EC) No 1881/2006 and therefore recommendable for human consumption.

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Conflict of interest

The Authors declare that there is no conflict of interest.

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