Chemical composition and nutritional value of the main cultivated mushrooms in Zhejiang province, China: An inter-species comparative study

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Abstract. Herein, it was reported and compared the chemical composition and nutritional value of the main cultivated mushroom in Zhejiang province, China: *Agaricus bisporus*, *Auricularia auricula*, *Flammulina velutipes* and *Lentinus edodes*. *A. bisporus* revealed the highest levels of protein and fat, while *A. auricula* contained the lowest fiber and fat. The amount of the essential amino acids in *A. bisporus* was highest among the mushrooms used in this study. *L. edodes* had the highest concentrations of S and the other three species had the highest P contents. The four main cultivated mushrooms were also rich in K, the lowest contents of Mg, Ca and Na were measured in *L. edodes*. A 4-fold difference in Zn concentration was found *L. edodes* and *A. auricular*. The highest Cu level was 23.93 mg/g for the *A. bisporus*, and the lowest Cu level was 2.40 mg/g for *A. auricular*. The levels of As in *A. bisporus*, Cd in *L. edodes* and Cr in these four main cultivated mushrooms exceeded the national standard. This study contributes to the elaboration of nutritional databases of the most consumed fungi species worldwide, allowing comparison between them.

1. Introduction

Mushrooms might be used directly in diet and promote health since they have a great nutritional value. More than 3000 mushrooms are said to be “the main edible species”, of which only 100 are commercially cultivated, and only 10 of those on an industrial scale [1]. Production of mushrooms continuously increases over time, being China the biggest producer. The most cultivated mushrooms are *A. bisporus*, *A. auricula*, *F. velutipes* and *L. edodes*. These species require shorter growth time when compared to other edible mushrooms, they demand few environmental controls, and they can be cultivated in a simple and cheap way. Herein, it was intended to provide information about the nutritional value and chemical composition of the main cultivated mushrooms in Zhejiang province.

2. Material and methods

2.1 Mushroom species.

Fresh fruiting bodies of *A. bisporus*, *A. auricular*, *F. velutipes* and *L. edodes* were collected from Zhejiang Agriculture Research Institute, Longquan City, Jiangshan City and Qingyuan County in Zhejiang Province, China, respectively. All of the mushrooms were dried at 65°C for 24 h and grind for further analysis.

2.2 Standards and reagents.

All other chemicals and solvents were of analytical grade and purchased from common sources. Water was treated in a Milli-Q water purification system (TGI Pure Water Systems, USA).

2.3 Nutritional value.

The samples were analysed for chemical composition (ash, proteins, fiber, fat, and carbohydrates) using the AOAC procedures (AOAC, 1995). The ash content was determined by incineration at 600 ± 15°C, the crude protein content (N × 4.38) of the samples was estimated by the macro-Kjeldahl

method; the crude fat was determined by extracting a known weight of powdered sample with petroleum ether, using a Soxhlet apparatus. Total carbohydrates were calculated by difference.

2.4 Free amino acid assay.

Air-dried mushroom powder (500 mg) was shaken with 50 ml of 0.1 N HCl (Union Chemical Co., Hsinchu, Taiwan) for 45 min at ambient temperature and filtered through Whatman No. 4 filter paper. The filtrate was then passed through a filter unit (13 mm, Lida), and filtered using a 0.45-mm CA non-sterile filter (Lida). The purified filtrate was mixed with *o*-phthal-aldehyde reagent (Sigma) in an Eppendorf tube, shaken to facilitate derivatisation and then immediately injected onto the HPLC.

The HPLC system was the same as for sugar analysis but included a Hitachi F-1050 fluorescence detector with fluorescence excitation at 340 nm and emission at 450 nm, and a Prodigy 5 ODS-2 column (4.6×250 mm, 5µ, Phenomenex Inc., Torrance, CA). The mobile phases and gradient conditions were the same as described in Mau et al. (1997). Each amino acid was quantified by the calibration curve of the authentic amino acid.

2.5 Mental analysis.

Collected wheat grain samples were dried at 70°C in a drying cabinet with air circulation until they reached constant weight. Later, about 0.5 g dried and ground sample was digested by using 5 ml of 65% HNO_3 and 2 ml of 35% H_2O_2 in a closed microwave system (Cem-MARS Xpress). The volumes of the digested samples were completed to 20 ml with ultra-deionized water and mineral concentrations were determined by inductively coupled plasma-optical emission spectroscopy (Vista-Pro Axial; Varian Pty Ltd, Australia).

Appropriate quality assurance procedures and precautions were carried out to ensure the reliability of the results. The standard reference material, chicken powder (GBW10018), was obtained from the National Standard Substance Research Center (NSSRC), China and digested with the samples to validate the analytical procedures. The standard solutions used for the calibration procedures were prepared by diluting the stock solution with 1% (v/v) HNO_3.

2.6 Statistical analysis.

All results were expressed as means ± standard deviation (SD) of three replications, and the one-way analysis of variance (ANOVA) was used for the statistical analysis.

3. Results and discussion

The results of the nutritional value obtained for the main cultivated mushrooms in Zhejiang province are shown in Table 1. Ash ranges between 4.00% in *A. auricula* and 7.00% in *A. bisporus*. *A. bisporus* gave the highest level of protein(29.38%). Mushrooms are reported to be a good source of protein, and some investigators have even contended that the amino acid compositions of mushrooms are comparable to animal proteins [2]. *F. velutipes* revealed the highest fiber (14.83%) contents; *A. auricula* gave the lowest fat levels (0.67%). In general, mushrooms are low-calorie foods since they provide low amounts of fat [1]. Carbohydrates, calculated discounting protein, ash and fat levels, were the most abundant macronutrients and the highest levels were also found in *L. edodes* (43.20%). Although, an extraordinarily high level of total fiber was reported for *A. bisporus*, and *L. edodes* gave the highest carbohydrates levels. Carbohydrates content includes also fiber such as the structural polysaccharides β-glucans, chitin, hemicelluloses and pectic substances [3]. *F. velutipes* studied here presented similar ash and fiber level, but lower carbohydrate, fat and protein, while *L. Edodes* herein studied was discribed lower ash, carbohydate and fat, but higher fiber and protein compared to the samples from Taiwan [4]. It is known that the growth compost can influence the chemical composition and, as a comsequence, the nutritional value of the cultivated mushrooms. Mushroom quality is also influenced by other qarameters such as the stage of development and pre and post-harvest conditions. All these interfering factors justify the variability in compositon data published by didderent authers working with even the same species of mushroom [5].

Table 1 Proximate composition of four main cultivated mushrooms in Zhejiang province

Component	*L. edodes*	*A. bisporus*	*F. velutipes*	*A. auricula*
Ash	4.83±0.225	7.00±0.264	6.67±0.153	4.00±0.100
Protein	23.48±0.025	29.38±0.234	15.59±0.345	13.14±0.056
Fiber	7.50±0.108	7.30±0.046	14.83±0.103	5.40±0.121
Fat	2.07±0.042	3.87±0.031	2.12±0.024	0.67±0.006
Carbohydrates	43.20±0.305	37.30±0.296	38.83±0.454	32.27±0.202

Generally, leucine, valine, glutamine, glutamic and aspartic acids are the most abundant amino acids in mushrooms, which were analysed by different techniques such as ionic exchange chromatography coupled to an amino acids analyzer, reaction with ninhydrin using an amino acids analyzer, gas chromatography coupled to mass spectrometry (GC–MS), high performance chromatography (HPLC) with UV-Vis detection and HPLC-fluorescence [6]. The composition and amount of amino acids varied with mushroom species (Table 2). Comparing the total amounts of the essential amino acids in the three mushroom species, the amount of the essential amino acids in *A. bisporus* was highest among the mushrooms used in this study. The fruiting body of *A. bisporus* contained 6.75 g essential amino acids/100 g of edible weight, while *A. auricula* had 3.94 g essential amino acids/100 g of edible weight, respectively. Additionally, methionine was the most abundant components of essential amino acids in *F. velutipes*. (0.94 g/100 g). The most abundant component of essential amino acid was leucine in three mushrooms except *F. velutipes*. *A. auricula* contained 0.83 g leucine/100 g of edible weight, while *L. edodes* and *A. bisporus* contained 1.29 g and 1.28 g leucine/100 g of edible weight, respectively. The major component of non-essential amino acid, glutamate, ranged from 1.51 g to 1.92 g/100 g of *A. auricular* and *F. velutipes*. Moreover, the amount of glutamate was higher in *L. edodes* (4.35 g/100 g) and *A. bisporus* (4.86 g/100 g). These results were similar to the reports that leucine and glutamate were the most abundant component of essential and non-essential amino acids in *P. Ostreatus* [7-8]. Asparagic acid, serine, cysteine, histidine and arginine were more abundant in *L. edodes* than other mushrooms. While, glycine, alanine, prolinewere more abundant in *A. bisporus* than other mushrooms. Additionally, the essential and non-essential amino acids in the main cultivated mushrooms in Zhejiang province were more abundant than three edible mushroom in Korea [6].

Table 2 Amino acid profile of four main cultivated mushrooms in Zhejiang province

Amino acids	*L. edodes*	*A. bisporus*	*F. velutipes*	*A. auricula*
Threonine	0.93±0.035	0.90±0.006	0.57±0.014	0.68±0.008
Valine	0.88±0.034	0.99±0.006	0.61±0.006	0.57±0.008
Methionine	0.73±0.008	0.92±0.009	0.94±0.035	0.29±0.005
Isoleucine	0.67±0.028	0.74±0.003	0.40±0.004	0.37±0.002
Leucine	1.29±0.051	1.28±0.006	0.81±0.011	0.83±0.006
Phenylalanine	0.78±0.031	0.80±0.004	0.62±0.012	0.48±0.005
Lysine	0.98±0.039	0.80±0.003	0.70±0.019	0.56±0.002
Total essential amino acids	6.26	6.43	4.65	3.78
Aspartate	1.63±0.058	1.50±0.005	1.05±0.022	1.09±0.011
Glutamate	4.35±0.161	4.86±0.054	1.92±0.065	1.51±0.017
Serine	0.94±0.033	0.92±0.003	0.56±0.014	0.62±0.006
Glycine	0.85±0.031	0.93±0.003	0.58±0.008	0.54±0.004
Cysteine	0.48±0.013	0.35±0.002	0.29±0.003	0.19±0.009
Histidine	0.39±0.015	0.36±0.002	0.24±0.004	0.32±0.004
Arginine	0.91±0.037	0.90±0.002	0.56±0.009	0.63±0.009
Alanine	1.05±0.040	1.77±0.028	0.75±0.007	0.85±0.010
Proline	0.62±0.032	0.80±0.023	0.33±0.005	0.47±0.004
Tyrosine	0.37±0.007	0.42±0.003	0.55±0.017	0.34±0.004
Total non-essential amino acids	11.59	12.81	6.83	6.56
Total amino acids	17.85	19.24	11.48	10.34

The mean concentrations of macroelement for the main cultivated mushrooms in Zhejiang province are shown in Table 3. Macroelement contents varied among the four species. *L. edodes* had the highest concentrations of S (10298.71 g kg^{-1}, respectively) and the other three species (*A. bisporus*, *F. velutipes*, *A. auricular*) had the highest P contents (12359.35, 6203.29, and 2891.24 g kg^{-1}, respectively). The four main cultivated mushrooms were also rich in K, and the highest K concentration was mesasured in *A. bisporus* (6029.62 g kg^{-1}). A comparatively constant level was noted in Mg, which was from 835.42 g kg^{-1} in *L. edodes to* 1054.18 g kg^{-1} in *F. velutipes*. The highest content of Ca was found in *A. auricular* (2354.50 g kg^{-1}), much higher than other three species. It was worth noting that the lowest contents of Mg, Ca and Na were measured in *L. edodes*.

Table 3 Macroelement level of four main cultivated mushrooms in Zhejiang province

Macroelement	*L. edodes*	*A. bisporus*	*F. velutipes*	*A. auricula*
Ca	168.60±6.151	272.24±9.059	233.45±8.126	2354.50±114.889
K	4594.31±8.932	6029.62±31.174	4937.14±43.310	2802.36±122.702
Mg	835.42±9.832	854.31±5.770	1054.18±15.626	1021.24±15.150
Na	51.81±1.090	363.24±8.190	147.37±5.961	317.69±12.736
P	7246.59±59.133	12359.35±108.449	6203.29±153.154	2891.24±85.896
S	10298.71±17.789	1977.30±15.669	1206.47±11.079	670.64±3.554

The trace elements are of great biochemical interest and they have nutritional and clinical importance. For example, Se and Zn play very important roles in human and animal metabolism, because they are constituents of various enzymes of clinical significance. The mean concentrations of microelements of each individual species were shown in Table 4. Generally, the individual species the concentrations of microelement varied to some extent. There was a 4-fold difference in Zn concentration between *L. edodes* and *A. auricular*. However, the concentration of Co did not vary in the individual species. Fe concentration ranged from 41.15 in *L. edodes* to 107.72 mg kg^{-1} in *F. velutipes*. A more than 3-fold difference in Al concentration was found between *L. edodes* and *A. bisporus*. The highest Cu level was 23.93 mg/g for the *A. bisporus*, and the lowest Cu level was 2.40 mg/g for *A. auricular*. The highest Mn level was found in *A. auricular* (21.53 mg/g) and the lowest was found in *F. velutipes* (5.38 mg/g). The level of Se in *A. bisporus* (5.55 mg/g) was higher than the other three main cultivated mushrooms. According to previous studies, it appears *A. Bisporus* from Zhejiang province had lower Cu and Co, but higher Fe, Mn and Zn levels than sample from Turkey [9].

Table 4 Microelement level of four main cultivated mushrooms in Zhejiang province

Microelement	*L. edodes*	*A. bisporus*	*F. velutipes*	*A. auricula*
Al	20.66±1.045	63.03±2.219	43.43±0.993	56.19±3.860
Co	0.02±0.001	0.02±0.001	0.02±0.002	0.02±0..02
Cu	10.73±0.219	23.93±0.776	4.49±0.077	2.40±0..59
Fe	41.15±0.995	93.37±2.692	107.72±0.605	71.27±4.458
Mn	13.05±0.066	7.10±0.104	5.38±0.050	21.53±1.667
Se	3.13±0.040	5.55±0.072	3.06±0.029	3.10±0.026
Zn	52.88±0.536	36.84±0.429	35.31±0.457	12.36±0.257

The heavy metal contents of 4 mushroom species were shown in Table 5. The highest As level was 2.83 mg/g in *A. bisporus* and lowest in *F. velutipes* (0.27 mg/g). From the table, the highest Cd level was found as 2.11 mg/g for *L. edodes*, whereas the lowest Cd level was 0.08 mg/g in *F. velutipes*. The Cr level was comparatively high, ranging 1.94~2.66 mg/g for this four cultivated mushrooms in Zhejiang province. The heavy metal of As was determined in *A. bisporus* (2.83 mg/g) and *F. velutipes* (0.16 mg/g). Interestingly, Hg was not detected in these four main cultivated mushrooms in Zhejiang province**.** The heavy metal of Pb was tested in *F. velutipes* and *A. auricular*, the higher level was 0.22 mg/g for *A. auricular* and the lowest level was 0.09 mg/g for *F. velutipes*. It should be pointed that the maximum level for certain contaminants in foodstuffs established by the national standard is set at about 1.0, 1.5 and 0.2 mg/kg dry weight for As, Cr and Cd, respectively, in cultivated fungi. Therefore, As in *A. bisporus*, Cd in *L. edodes* and Cr in these four main cultivated mushrooms

exceeded the national standard. Due to the growth compost, *A. bisporus* from Turkey was reported lower As but higher Hg, Pb, Cd than herein studied [9].

Table 5 Heavy metal level of four main cultivated mushrooms in Zhejiang province

Heavy metal	*L. edodes*	*A. bisporus*	*F. velutipes*	*A. auricula*
As	ND	2.83±0.84	0.16±0.28	ND
Cd	2.11±0.42	0.12±0.01	0.08±0.04	0.17±0.09
Cr	1.94±0.18	2.66±0.36	2.34±0.19	2.18±0.50
Hg	ND	ND	ND	ND
Pb	ND	ND	0.09±0.04	0.22±0.38

4. Conclusion

In this study, chemical composition and nutritional value of the main cultivated mushroom in Zhejiang province were compared. The results revealed that these four species contained high protein and low fat. They not only were rich in mineral elements, which were abundant in P, K, S, but also contained varieties of essential amino acids and non-essential amino acids. However, chemical composition and nutritional value in different species mushroom were varied. It should be pointed out that the levels of As in *A. bisporus*, Cd in *L. edodes* and Cr in these four main cultivated mushrooms exceeded the national standard. This study contributes to the elaboration of nutritional databases of the most consumed fungi species worldwide by comparison between them.

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