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Research Article

Mineral Composition of Four Edible Mushrooms

S. E. Mallikarjuna,[1] A. Ranjini,[2] Devendra J. Haware,[2] M. R. Vijayalakshmi,[1] M. N. Shashirekha,[1] and S. Rajarathnam[1]

[1] *Department of Fruit and Vegetable Technology, Central Food Technological Research Institute, CSIR, Mysore 570020, India*
[2] *Department of Food Safety and Analytical Quality Control Laboratory, Central Food Technological Research Institute, CSIR, Mysore 570020, India*

Correspondence should be addressed to S. Rajarathnam; rajarathnams@yahoo.com

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Two cultivated mushroom species, namely, *Lentinula edodes and Pleurotus florida* and two wild growing species *Lentinus cladopus* and *Pleurotus djamor* were studied for their mineral contents such as Ca, Mg, Na, K, Fe, Zn, Mn, Cu, Ni, Se, Pb, and Cd by Inductive Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) and also Atomic Absorption Spectroscopy, (AAS). Phosphorus was estimated by spectrophotometric method. K, Ca, Na, and P were in higher concentrations ranging from 59.3 mg to 3634 mg, 8.27 mg–174.9 mg, 22.2 mg–327.4 mg, and 100.5 mg–769.9 mg/100 g dry weight respectively in the four mushroom species studied. Fe, Zn, Mg and Se were ranging from 6.27 mg to 35.3 mg, 1.58 mg–9.44 mg, 21.1 mg–40.7 mg and 0.048 mg–0.182 mg/100 g dry weight, respectively, amongst the mushroom species analyzed. However, Ni, Cu, and Mn contents showed relatively lower concentrations, whereas Pb and Cd were below detectable level. The mushrooms were safe for consumption, in accordance with the permissible tolerance limits of the estimated toxic metals. Implications of the mineral contents on mushroom nutritional value are highlighted.

1. Introduction

Mushrooms are important in the ecosystem because they are able to biodegrade the substrate and therefore use the wastes of agricultural production. Fruiting bodies of mushrooms are appreciated, not only for texture and flavor [1–6] but also for their chemical [7–9] and nutritional properties [10–16]. Mushrooms have also been reported as therapeutic foods, useful in preventing diseases such as hypertension, hypercholesterolemia, and cancer. These functional characteristics are mainly due to their chemical composition [11, 17].

Organisms require trace amounts of some heavy metals, including iron, cobalt, copper, manganese, chromium, and zinc. Excessive levels of these metals, however, can be detrimental to organisms. Other heavy metals such as cadmium and lead have no known beneficial effect on organisms [1]. The ability of mushroom species to bioaccumulate the minerals from the growth medium into the fruiting body is well documented [18, 19]. Because of ecological and genetic but known factors, the fruiting bodies of higher mushrooms often are relatively rich in mineral constituents [20–22]. Environmental factors such as species of mushrooms, morphological part of fruiting body, developmental stages and age of mycelium, biochemical composition, and interval between the fructifications affect mineral accumulation in macro fungi [23, 24]. Iron, copper, manganese, zinc (trace elements), lead, cadmium, and nickel (toxic metals) were chosen as representatives, whose levels in the environment represent a reliable index of environmental pollution [24]. Minerals such as iron, copper, zinc and manganese are essential metals since they play an important role in biological systems, whereas lead and cadmium are nonessential metals as they are toxic, even in traces [25]. The essential metals can also produce toxic effects when the metals intake is excessively elevated [24].

In this context, it is worthwhile to evaluate (a) the metal content in mushrooms grown on any substrate, (artificially/natural occurrence), (b) to assess the contribution of

mushrooms to the daily intake of several toxic elements, and (c) to compare the results with the norms for these toxic elements in food stuff, so that it would help to adjudicate the mushrooms for their nutritional value in terms of minerals and also to define the limits of safety [24, 26].

Thus, the present paper is focused on the analysis of four species of mushrooms namely *Lentinus cladopus, Lentinula edodes, Pleurotus djamor,* and *Pleurotus florida* for their mineral contents and to discuss the results generated on essential and trace elements in edible mushrooms, along with the limits of toxic metals. In the perspective that mushrooms do significantly contribute to the minerals in the human diet, the data derived would serve as an useful basis to define the nutritional value of a given mushroom species, along with any warnings for toxic minerals, depending on the concentration(s).

2. Experimental

2.1. Mushroom Samples. Fruiting bodies (3 kg fresh or equivalent) of *Lentinus cladopus* Leveille and *Pleurotus djamor* Sacc were collected from forest areas of Shimla in Himachal Pradesh, while the fruiting bodies of *Lentinula edodes* (Berk.) Pegler grown on saw dust composite substrate in laboratory was received from Maharana Prathap University of Agriculture and Technology (MPUAT), Udaipur. *Pleurotus florida* (Block & Tsao) was cultivated on rice straw in laboratory at Central Food Technological Research Institute, (CFTRI) Mysore. The fruiting bodies (3 kg fresh or equivalent) were cleaned, sliced, and dried in hot air drier at 55°C to a residual moisture of ~5% and then the dried mushroom samples were powdered to ~1 mm particle size and stored at room temperature in precleaned polyethylene bottles until analysis.

2.2. Preparation of Ash Solution. One gram of dry powdered sample was placed in a porcelain crucible and ashed at 450°C for 5-6 h; then the ash was dissolved in 2 mL concentrated HNO_3 (Merck), and heated on a low heat for 1 min. Then, it was cooled and filtered through Whatman No. 42 filter paper to a 50 mL volumetric flask and was made to volume with triple distilled water. A blank was also prepared using similar experimental procedure [33]. Three such replicates were maintained for each of the mushroom species studied.

2.3. Instrumentation. The mineral contents were determined employing Atomic Absorption Spectrometer (AAS), [Analyst 700 Perkin Elmer, USA] with air-acetylene burner for flame and Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES) [ACTIVIA-M, Horiba Jobin yvon] with Argon plasma.

2.4. Mineral Analysis. Aliquot of the ash solution was aspirated to the instrument (AAS/ICP-AES) for the determination of metals/minerals *namely*., Ca, Mg, Na, K, Fe, Zn, Mn, Cu, Ni, Se, Pb, and Cd.

Calibration of AAS was done using the working standard prepared from commercially available metal/mineral standard solutions (1000 μg/mL, Merck, Germany). The most appropriate wavelength, hallow cathode lamp current, gas mixture flow rate, slit width, and other AAS instrument parameters for metals/minerals were selected as given in the instrument user's manual, and background correction was used during determination of metals/minerals. Measurements were made within the linear range of working standards used for calibration [33].

Working conditions of AAS were as follows:

instrument: AAS (Perkin Elmer A Analyst 700),

flame temperature: 2800°C,

acetylene pressure: 0.9–1.0 bar,

air pressure: 4.5–5 bar,

reading time: 1–10 sec (max 60 sec),

flow time: 3-4 sec (max 10 sec).

Calibration of ICP-AES was done using the working standard prepared from commercially available multielement standard solution (100 mg/L, Merck, Germany). The most appropriate wave length, Argon gas flow, Plasma stabilization, and other ICP-AES instrument parameters for metals/minerals were selected, and measurements were made within linear range of working standards used for calibration [33].

Working conditions of ICP-AES were as follows:

instrument: ICP-AES (ACTIVIA-M, Horiba Jobin-yvon),

power: 1000 W–1200 W,

plasma gas flow: 12–16 L/min,

auxillary gas flow: 0.8 L/min,

plasma burning height: 5–22 mm,

reading time: 1–10 sec (max 60 s),

flow time: 2-3 sec (max 10 s).

Phosphorus was determined by spectrophotometric method, wherein phosphorus reacts with molybdic acid to form phosphomolybdate complex, which was then reduced with amino naphthol sulfonic acid to complex molybdenum blue that was measured spectrophotometrically [35].

The concentrations of all the minerals were expressed as mg/100 g dry weight of the sample. The limit of detection for Pb was 0.05 mg/100 g and for Cd was 0.01 mg/100 g on dry weight basis. Each value is the mean of three replicate determination ± standard deviation.

3. Results and Discussion

Minerals represent the ash left behind after complete incineration of the dry mushroom. The mineral composition reflects on the growth conditions of the mushroom. Minerals such as potassium, calcium are said to be major because they are in high concentrations of the mushroom, as well as phosphorus and magnesium. However, sodium is relatively less in mushroom species; thus, mushrooms are said to be good for patients with hypertension [18]. Similar observations were made in the present study too.

Table 1: Major element concentrations (mg/100 g on dry weight basis) in four species of mushrooms.

Elements	*Lentinula edodes*	*Lentinus cladopus*	*Pleurotus florida*	*Pleurotus djamor*
Potassium	1302 ± 101	59.3 ± 10.2	2472 ± 207	3634 ± 122
Phosphorus	769.9 ± 64.1	100.5 ± 2.3	640.2 ± 8.0	743.2 ± 29.8
Calcium	174.9 ± 34.3	129.9 ± 26.1	8.27 ± 0.2	34.2 ± 29.9
Sodium	327.4 ± 51.6	22.2 ± 0.6	30.5 ± 8.0	61.6 ± 8.2
Magnesium	40.7 ± 1.2	21.1 ± 3.5	35.9 ± 1.9	31.6 ± 1.7

Each value is the mean of three replicate determinations ± standard deviation.

Table 2: Trace element concentrations (mg/100 g on dry weight basis) in four species of mushrooms.

Elements	*Lentinula edodes*	*Lentinus cladopus*	*Pleurotus florida*	*Pleurotus djamor*
Iron	14.8 ± 2.3	35.3 ± 3.55	6.27 ± 0.41	14.8 ± 0.91
Zinc	9.44 ± 0.24	1.58 ± 0.21	5.06 ± 0.04	9.21 ± 0.03
Copper	1.48 ± 0.03	0.97 ± 0.01	1.06 ± 0.06	1.45 ± 0.08
Manganese	1.00 ± 0.32	0.54 ± 0.01	0.62 ± 0.03	1.12 ± 0.03
Selenium	0.182 ± 0.01	0.19 ± 0.01	0.048 ± 0.02	0.11 ± 0.04

Each value is the mean of three replicate determinations ± standard deviation.

To overcome the inaccuracies borne in differences in moisture contents from different authors from different parts of the world, on fresh weight basis, and to ensure universal comparison of data, all the values obtained were expressed here on moisture free basis. Amongst the four mushroom species studied (*Lentinus cladopus,* and *Pleurotus djamor* growing wild, and *Lentinula edodes, Pleurotus florida cultivated*), potassium ranged from 59.3 to 3634 mg/100 g dry weight (Table 1). Phosphorous also recorded relatively higher contents, followed by calcium. However, levels of sodium were less except *Lentinula edodes.* Magnesium ranged from 23.1 to 40.7 mg/100 g dry weight and thus emphasizing mushroom as a good source of magnesium.

Iron, zinc, copper, manganese, and selenium are dealt with under minor/trace elements. *L. cladopus* showed high value for iron (35.3 mg/100 g dry wt). Zinc was higher in *L. edodes* and mushrooms are said to be good biological accumulators of zinc, and zinc is biologically very vital to the human body [36]. Copper and manganese were in a relatively low concentration in all the four species analyzed (Table 2). Selenium was in fairly good concentrations, and selenium is known for fighting against cancer [37]. This is organic selenium as found in the mushroom fruiting body, and mushrooms are known for bioconversion of such minerals from the growth substrate from inorganic form to organic form [38]. Concentration of nickel in the studied mushroom species is very low. Lead and cadmium were below detection levels (Table 3). The occurrence and distribution of different toxic components in certain mushrooms is not only a theoretical mycological problem but also has practical environmental and toxicological aspects [39]. According to FAO/WHO [19] tolerable weekly intake of cadmium and lead are 0.007 and 0.025 mg/kg body weight, respectively. The lead and cadmium levels in all studied species are very low and thus, these mushroom species are safe for consumption.

Thus, the minerals analyzed in the four mushroom species were quite comparable with reported literature values (Table 4). Based on the minerals of these mushroom species converted on a scale for 100 g fresh (based on the 90% moisture content), eventually signifies the minerals available in 100 g fresh mushrooms that can be consumed per day. The situation becomes quite practical when considered consumption of 100 g fresh at least five times a week. Recommended minerals intake for trace and permissible limits of the toxic metals along with references are presented in Table 5.

4. Conclusions

The four mushroom species analyzed for their mineral contents conform as sources of calcium, potassium, iron, and zinc and less in sodium.

Accordingly, these species are good supplementary health foods from the angle of human nutrition. More importantly, it is vital to always relate the mushroom mineral contents with specificities of growth substrates on which the species under study is grown, further based on their nonstarchy carbohydrates [5], sugar alcohols [18], and vitamin contents [7]. The present mineral values add to the safe consumption of mushrooms as supplementary foods to the populations preponderantly dependent on cereal diet.

Abbreviations

AAS: Atomic Absorption Spectra
ICP-AES: Inductively Coupled Plasma Atomic Emission Spectrometer.

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Table 3: Toxic metal concentrations (mg/100 g on dry weight basis) in four species of mushrooms.

Metals	*Lentinula edodes*	*Lentinus cladopus*	*Pleurotus florida*	*Pleurotus djamor*
Nickel	0.15 ± 0.03	0.09 ± 0.03	0.07 ± 0.04	0.15 ± 0.04
Lead	BDL[a]	BDL[a]	0.092 ± 0.002	0.12 ± 0.07
Cadmium	BDL[a]	BDL[a]	BDL[a]	BDL[a]

Each value is the mean of three replicate determinations ± standard deviation.
[a]BDL: Below detectable level.

Table 4: Range of reported literature values (mg/100 g dry weight basis) in mushroom.

Mineral elements	Range of literature value (mg/100 g dry wt)	Reference
Potassium	2500–4100	[27]
Phosphorus	120.0–2000	[28]
Calcium	1.8–59.0	[28]
Sodium	6.0–92	[28]
Magnesium	60–250	[27]
Iron	1.46–83.5	[29]
Zinc	2.98–15.8	[30]
Copper	7.1–9.5	[29]
Manganese	1.81–10.3	[31]
Selenium	1–5	[32]
Nickel	0.118–0.514	[29]
Lead	0.286–0.688	[30]
Cadmium	0.271–0.75	[30]

Table 5: Recommended Daily Intake (RDI) of trace elements.

Element	RDI	Reference
Cu	2.2 mg/day	[34]
Fe	28–30 mg/day	[34]
Zn	15.5 mg/day	[34]
Mn	5.5 mg/day	[34]

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