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Micronutrient status of cultivated mushrooms of India

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ABSTRACT

The present study evaluated the micronutrients, vitamins and minerals of five cultivated mushrooms of India viz., *Agaricus bisporus* (button mushroom), *Calocybe indica* (milky mushroom), *Flammulina velutipes* (winter mushroom), *Pleurotus florida* (oyster mushroom) and *Volvariella volvacea* (paddy straw mushroom). The vitamins detected in 100g dry weight of cultivated mushrooms were Vitamin A (2.44-3.94 mg), Vitamin B_1 (0.003-0.018mg),Vitamin B_2 (0.189-1.625), Vitamin B_3 (42.62-98.16 mg), Vitamin B_5 (0.059-0.405 mg), Vitamin B_6 (15.1 mg in *A. bisporus*),Vitamin B_9 (0.121-0.214 mg),Vitamin B_{12} (0.96-1.68 µg), Vitamin C (24.2-81.1mg), Vitamin D (0.339-0.747 mg), and Vitamin E (24.8 mg in *A. bisporus*, 38.1 mg in *V. volacea* and 56.6 mg in *P. florida*). The mineral contents found in 100g dry weight were K (3.7-6.2 g), Mg (0.11-0.24 g), P (0.58-1.42 g), Ca (31.3-88.3 mg), Na (27.38-101.4 mg), Mn (0.55-1.49 mg), Fe (6.45-29.4 mg), Se (0.036 mg in *V. volvacea* and 0.426 mg in *A. bisporus*), Mo (0.012-0.062 mg), Zn (2.39-8.725 mg), Cu (0.7-7.17 mg) and Cr (0.02-0.159 mg). It is evident from the results that the cultivated mushrooms are valuable source of vitamins and minerals and they can contribute significantly to our fight against malnutrition.

Keywords: Mushroom, vitamins, minerals, *Agaricus, Pleurotus, Volvariella*

Cultivated mushrooms are an excellent biological tool that convert the waste agricultural materials into delicious, nutritious and digestible food ingredients. Mushrooms are the most attractive and high-profit earning non-green cash crop grown indoors. The nutritional composition, taste and flavour of mushrooms make them important component of human diet. The production of cultivated mushrooms in the world was 43 million tonnes, in which India's share was only 2.25 lac tonnes. **(Singh *et al.*, 2021).** The recent mushroom production data of India reveals that Button mushroom has the highest production with a share of 73% followed by Oyster (16%), Paddy straw mushroom (7%), Milky mushroom (3%) and others with only 1% (Sharma *et al*., 2017).

Mushroom recipes have become elegance in the menu of restaurants or meals during celebrations due to their taste, flavour and texture. Cultivated mushrooms are rich in proteins, dietary fibers, and poor in calories and fats (Ahlawat *et al*., 2016; Sharma *et al*., 2020; Roy and Isaac, 2019; Kumar and Sagar, 2023). Mushrooms also serve as a good source of micronutrients like vitamins, e.g. vitamins A, B, C, D and E, and minerals, e.g. phosphorus, calcium, magnesium, selenium, copper, and potassium (Mattila *et al*., 2001; Mallikarjuna *et al*., 2013; Zacharia *et al*., 2017; Jose and Geetha, 2018). The mushrooms have higher mineral content than the most common cereals, vegetables, fruits and nuts (Pandey *et al*., 2022). Vitamins and minerals are the essential nutrients required in our body to perform some important

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functions of growth, development, maintenance and repair. Micronutrients like Zn, Cu, Mn, Fe, and Se function as key components of enzymes involved in antioxidant functions (Kozarski *et al.*, 2015). Mushrooms also contain Vitamin B_9 and B_{12} that are not synthesized in our body and are essentially required in diet. Mushrooms are one of the sources of vitamin D among very limited vegetarian foods (Ahlawat *et al*., 2016). The nutritive properties of mushrooms make them a complete health food and suitable for all age groups. Besides nutritional values, mushrooms are also acknowledged to have many therapeutic activities like antibacterial, antidiabetic, anticancer, immunomodulation, hepatoprotective and hypolipidemic activity (Wasser, 2002; Sagar *et al.*, 2022).

The mushroom production in India is very low in comparison to other parts of the world and so is the knowledge of the nutritional, economic, medicinal and ecological importance of mushrooms grown here. The macronutrient analysis of mushrooms has been investigated comprehensively in different parts of the world but there is not sufficient information available regarding the vitamin and mineral contents of cultivated mushrooms of India. The objective of the present study was to evaluate the vitamin and mineral contents of five cultivated mushrooms in India.

MATERIALS AND METHODS

The sporocarps of white button mushroom (*Agaricus bisporus*, NBS-5), milky mushroom (*Calocybe indica*, DMRO-302), winter mushroom (*Flammulina velutipes*, DMRO-253), oyster mushroom (*Pleurotus florida*, DMRP-136) and paddy straw mushroom (*Volvariella volvacea*, DMRO-484) were obtained in 2020-21 from ICAR-Directorate of Mushroom Research, Solan, Himachal Pradesh, India. Average-sized fresh sporocarps of the first flush of all five mushroom species were dried in a dryer for four days at an ambient temperature (40-45°C). The dried sporocarps were ground in a mixer grinder and sealed. The samples were coded to maintain unbiasness at the analysis level. The samples were got analyzed for vitamins [Vitamin A, Vitamin B (1,2,3,5,6,9&12), Vitamin C, Vitamin D, and Vitamin E and 12 different minerals (Mg, Mn, Fe, Na, K, Se, Mo, Zn, Ca, P, Cu and Cr) from Punjab Biotechnology Incubator, Mohali, India (a NABL accredited Agriculture and Food Testing Laboratory, Govt. of Punjab, India). Standard procedures of AOAC were used for the analysis of mineral and vitamin contents. Minerals: AOAC 999.10 by ICPMS; Vitamin-A: PBTI/SOP/129/TP-91-HPLC; Vitamin-B1: PBTI/SOP/82/TP-51-HPLC; Vitamin-B2: PBTI/SOP/80/TP-49-HPLC; Vitamin-B3: PBTI/SOP/81/TP-50-HPLC; Vitamin-B5: PBTI/SOP/81/TP-50-HPLC; Vitamin-B6: PBTI/SOP/83/TP-52-LCMS-MS; Vitamin-B9: PBTI/SOP/132/TP-94; Vitamin-B12: PBTI/SOP/133/TP-95; Vitamin-C: IS 5838:1970; Vitamin-D: PBTI/SOP/11/TP-05-HPLC and Vitamin-E: PBTI/SOP/74/TP-47-HPLC.

RESULTS AND DISCUSSION

The results of the vitamins and minerals analysis are presented in Tables 1 and 2.

Vitamins

Mushrooms are one of the best sources of vitamins and have almost all vitamins which is also revealed by the results of the present study. Vitamin A (Retinol) content of the studied mushrooms varied from 2.444 mg to 3.940 mg/100g dry weight. The present results showed much lesser values from the reports of Afiukwa Celestine *et al*. (2013) and Alam *et al*. (2008) but higher than Sumathy *et al*. (2015). Vitamin A is a vital micronutrient for vision, growth and development, reproduction and immune function (WHO/FAO, 2004). Vitamin B_1 (Thiamine) was revealed in a very small amount (0.003 - 0.018 mg/100g) in the present study, while previous studies reported much higher amounts (Mattila *et al*., 2001; Stamets, 2005; Rajeshbabu *et al*., 2012; Butkevych *et al*., 2018). Vitamin B_1 acts as a coenzyme for

Table 1. Vitamin contents of cultivated mushroom species on dry weight basis

Sr. No.	Vitamins	Units	*Agaricus bisporus*	*Calocybe indica*	*Flammulina velutipes*	*Pleurotus florida*	*Volvariella volvacea*
1	Vitamin A	mg/100g DW	3.683	3.940	2.827	2.552	2.444
2	Vitamin B_1	mg/100g DW	0.006	0.006	0.003	0.007	0.018
3	Vitamin B_2	mg/100g DW	1.5	0.646	0.189	0.551	1.625
4	Vitamin B_3	mg/100g DW	49.68	96.99	78.14	42.62	98.16
5	Vitamin B_5	mg/100g DW	0.405	0.059	0.141	0.1	0.084
6	Vitamin B_6	mg/100g DW	15.1	BDL	BDL	BDL	BDL
7	Vitamin B_9	mg/100g DW	0.148	0.145	0.121	0.214	0.172
8	Vitamin B_{12}	µg/100g DW	1.09	0.96	1.27	1.68	1.42
9	Vitamin C	mg/100g DW	34.6	24.2	60.0	67.7	81.1
10	Vitamin D	mg/100g DW	0.339	0.379	0.747	0.482	0.512
11	Vitamin E	mg/100g DW	24.8	BDL(MDL:0.3)	BDL(MDL:0.3)	56.6	38.1

BDL: Below Detection Limit; MDL: Method Detection Limit (0.05 mg/100g). All vitamins measured in mg/100g DW except vitamin B_{12} (µg/100mg DW) DW: Dry weight

Table 2. Mineral components of cultivated mushroom species based on dry weight basis

Sr. No.	Mineral element	Units	*Agaricus bisporus*	*Calocybe indica*	*Flammulina velutipes*	*Pleurotus florida*	*Volvariella volvacea*
1	Potassium (K)	g/100g DW	5.6	4.1	3.7	6.2	5.3
2	Phosphorus (P)	g/100g DW	1.42	0.58	0.61	1.22	1.40
3	Magnesium (Mg)	g/100g DW	0.13	0.11	0.24	0.17	0.13
4	Calcium (Ca)	mg/100g DW	31.3	40.0	88.3	72.0	39.3
5	Sodium (Na)	mg/100g DW	87.6	101.4	27.38	53.9	69.8
6	Manganese (Mn)	mg/100g WD	0.66	0.82	0.55	0.96	1.49
7	Iron (Fe)	mg/100g DW	6.45	13.7	6.58	29.4	28.2
8	Selenium (Se)	mg/100g DW	0.426	BDL	BDL	BDL	0.036
9	Molybdenum (Mo)	mg/100g DW	0.024	0.026	0.012	0.015	0.062
10	Zinc (Zn)	mg/100g DW	5.272	2.39	4.786	8.725	8.307
11	Copper (Cu)	mg/100g DW	4.04	3.24	0.7	2.981	7.17
12	Chromium (Cr)	mg/100g DW	0.043	0.159	0.020	0.101	0.026

BDL: Below detection limit

enzymes associated with carbohydrate and amino acid metabolism (WHO/FAO, 2004). Vitamin B_2 (Riboflavin) content was found 0.189 mg to 1.62 mg/100g dry weight in the present study was supported by the earlier reports of USDA (2021), Eguchi *et al.* (2015) but it differs from the reports of Stamets (2005), Mattila *et al.* (2001) Rajeshbabu *et al.* (2012) and Usman *et al.* (2021). Vitamin B_2 acts as a coenzyme for various oxidation and reduction reactions in our body (WHO/FAO, 2004).

Vitamin B_3 (Niacin) component of studied mushrooms varied from 42.62 mg to 98.16 mg/100g dry weight and was comparable with previous studies of Usman *et al*. (2021) but varied from reports of Eguchi *et al*. (2015) and Rajeshbabu *et al*. (2012). Vitamin B_3 lowers LDL cholesterol, risk of cardiovascular disorders and eases arthritis (Lule *et al*., 2016). Vitamin B_5 (Patothenic acid) content was found 0.059 mg to 0.405 mg/100g which is very low from the previous reports of Stamets (2005). Pantothenic acid is a component of Coenzyme-A, a cofactor that carries acyl groups for many enzymatic processes (Kelly, 2011). Vitamin B_6 (Pyridoxine) was only detected in *A. bisporus* (15.1 mg/100 g). USDA (2021) reported vitamin B_6 in *A. bisporus* (0.077 mg/100g) *F. velutipes* (0.119 mg/100g) and *Pleurotus* (0.11 mg/100g). Pyridoxine acts as a coenzyme for the metabolism of glycogen, amino acids and sphingoid bases (WHO/FAO, 2004).

Vitamin B_9 (Folic acid) content of cultivated mushrooms varied from 0.121mg to 0.214 mg/100g dry weight. Mattila *et al*. (2001) reported vitamin B_9 in *A. bisporus* and *Pleurotus ostreatus;* Usman *et al*. (2021) also reported vitamin B_9 in *A. bisporus*. Folic acid is an essential micronutrient required for DNA replication, amino acid metabolism, and cell division and to reduce the risk of neural tube defects in neonates during early pregnancy (WHO/FAO, 2004). Vitamin B_{12} (Cyanocobalamin) content was observed in small quantities ranging from 0.96 - 1.68 µg/100g dry weight. Mattila *et al*. (2001) reported similar contents of vitamin B_{12} in *A. bisporus* and *P. ostreatus*. Vitamin B_{12} is an essential micronutrient involved in red blood cell synthesis, nervous system functions and DNA synthesis (Judit, 2020).

Vitamin C (Ascorbic acid) content of cultivated mushrooms varied from 24.2 mg to 81.1 mg/100g dry weight. The results of the present investigation are comparable to previous reports of Mattila *et al*. (2001), Sumathy *et al*. (2015) and Roy and Isaac (2019) but much higher to the report of Rajeshbabu *et al*. (2012). Vitamin C helps in enzyme activation, oxidative stress reduction, and immune function (Sudha and Raveendran, 2017). Vitamin D (Calciferol) content of analyzed mushrooms varied from 0.339 mg to 0.747mg/100g dry weight. The results of the present study were comparable to Stamets (2005) but much lower than the reports of Ahlawat *et al*. (2016) and Punitha and Rajasekaran (2015). Vitamin D is involved in strengthening of bones, nerve conduction muscle, contraction and general cellular function in all cells of the body (WHO/FAO, 2004). Vitamin E (á-tocopherol) content was found only in *A. bisporus*, *P. florida* and *V. volvacea*. The result showed 24.8 mg to 56.6 mg/100g (dry weight) vitamin E content. Tsai *et al*. (2008) have reported vitamin E in *A. bisporus* while Sumathy *et al*. (2015) reported in *C. indica*. In the cellular antioxidant system, vitamin E is the major lipid-soluble antioxidant, and diet is the exclusively source of it. (WHO/FAO, 2004).

Minerals

Mushrooms generally absorb and accumulate mineral elements from substratum and then become their source in the food chain. It is evident from the present and previous studies that mushrooms are the good source of macro and microelements such as potassium, phosphorus, magnesium, calcium, sodium, iron selenium and copper. Ahlawat *et al*.(2016) reported that *A. bisporus* is a good source of K, Fe, Zn, Na, Se and Mn. Sumathy *et al*. (2015) recorded the presence of mineral elements like Ca, P, Fe, Zn, Mn, Mg, K, Na and Se from dried fruiting bodies of *C. indica*. Sharma *et al*. (2020) analyzed dry fruit bodies of *F. velutipes* (DMRO-253) for mineral nutrients and reported Na, K, Fe, Mn, Zn and Cu. Zacharia *et al*. (2017) studied mineral content of *P. florida* grown on different substrates and reported the presence of Na, K, Ca, Mg, Fe, Mo, Se and Zn. Eguchi *et al*., 2015 studied the mineral components (Ca, P, Fe, Na, and K) of *V. volvacea* during different stages of fruiting body development.

In the current study potassium (K) was found in the highest amount among all minerals and it varied from 3.7 to 6.2 g/100 g DW. These results were the confirmation of the earlier studies and reports of Stamets (2005), Eguchi *et al*. (2015), Ahlawat *et al*.(2016) and Sankaranarayanan and Kumari (2021) but more than the reports of Jose and Geetha (2018) and Rajeshbabu *et al*. (2012). Potassium ions are essential for acid-base balance, osmotic pressure regulation, intracellular fluid, conduction of nerve impulses, and prevention of Addison's disease (Murray *et al*., 2020). Phosphorus (P) amount of mushroom studied varied from 0.58 to 1.42 g/100 g DW, which was in accordance with Mattila *et al*. (2001), Rajeshbabu *et al*. (2012), Ali *et al*. (2017) and Sankaranarayanan and Kumari (2021) but less than Eguchi *et al*. (2015) reported 3.17% phosphorus in *V. volvacea* and higher than the Jose and Geetha (2018) reported 0.225% in *P. florida*. Phosphorus is directly involved in all energy-producing metabolic reactions and is an essential component of nucleic acids and bio-membranes (Knochel *et al*., 2006).

Magnesium (Mg) content varied from 0.11 to 0.24g/100g DW, which was supported by Mattila *et al*. (2001), Smiderle *et al*. (2008) and Sankaranarayanan and Kumari (2021) but from reports of Jose and Geetha (2018), Punitha and Rajasekaran (2015) and Ali *et al*. (2017). Magnesium functions as a cofactor for many enzymes involved in protein synthesis, nucleic acid synthesis, energy metabolism and maintenance of nervous impulses (WHO/FAO, 2004). Calcium (Ca) content of *A. bisporus* (31.1 mg/100g) agreed with previous reports of Mattila *et al*. (2001); Stamets (2005) and *C. indica* (40 mg/100g) was comparable with Sankaranarayanan and Kumari (2021) but significantly differed from Rajeshbabu *et al*. (2012) and Sumathy *et al*. (2015). Ca content of *F. velutipes* (88.3 mg/ 100g), *P. florida* (72.0 mg/100g and *V. volvacea* (39.3 mg/100g) was also different from the previous reports of Smiderle *et al*. (2008), Alam *et al*. (2008) and Ali *et al*. (2017). Calcium is essentially for the development of bones and teeth in our body development (Brody, 1994).

Sodium (Na) content of *A. bisporus* (87.6 mg/ 100g) was more than the reported in the literature (Ahlawat *et al*., 2016; Mattila *et al*., 2001); *C. indica* (101.4 mg/100g) was comparable with Sumathy *et al*. (2015) but very high from the reports of Rajeshbabu *et al*. (2012); Sankaranarayanan and Kumari (2021); *V. volvacea* (69.8 mg/100g) was comparable with Ahlawat *et al*. (2016) and *F. velutipes* (27.38 mg/ 100g) was much less from the study of Smiderle *et al*. (2008). The present study reported higher Na content in *P. florida* (53.0 mg/100g) than in Zahid *et al*. (2010). Sodium in our body maintains the acid-base balance, osmotic pressure, transport of metabolites and Na/K ratio is an important factor in the prevention of hypertension arteriosclerosis. (Saupi *et al*., 2009). Manganese (Mn) content of mushrooms ranged from 0.55 m to 1.49 mg/100g dry weight was comparable with the earlier studies (Mattila *et al*., 2001; Smiderle *et al*., 2008; Ahlawat *et al*., 2016; Sankaranarayanan and Kumari, 2021).

Manganese is an essential micronutrient that functions as a cofactor for a variety of enzymes.

Iron (Fe) content of *A. bisporus* (6.45 mg/100g) was in accordance with Ahlawat *et al*. (2016); Mattila *et al*. (2001); *C. indica* (13.7 mg/100g) was less than Rajeshbabu *et al*. (2012) but very high than Sankaranarayanan and Kumari (2021); *F. velutipes* (6.58 mg/100g) was comparable with Smiderle *et al*. (2008); *P. florida* (29.4 mg/100g) was very higher than Bashir *et al*. (2010) but lower than Mattila *et al*. (2001) and *V. volvacea* (28.2 mg/100g) was significantly higher than Eguchi *et al*. (2015) and Ahlawat *et al*. (2016). Iron is essential for the formation of oxygen-carrying haemoglobin in red blood cells (Punitha and Rajasekaran (2015). Selenium (Se) was detected only in *A. bisporus* (0.426 mg/100g) and *V. volvacea* (0.036 mg/100g). The presence of

Se in mushrooms was reported by Stamets (2005), Kalaè (2013), Alam *et al*. (2008) and Sumathy *et al*. (2015). Selenium (Se), in the form of selenoproteins act as an antioxidant to reduce the cytotoxic effects of ROS (Falandysz and Borovicka, 2013).

A small concentration (0.012-0.062 mg/100g) of Molybdenum (Mo) was detected in all mushroom species. Similar studies conducted by Zacharia *et al*. (2017) had not detected Se and Mo in *C. indica* and *P. florida*. Molybdenum is a trace element that functions as a cofactor for enzymes that help break down proteins, alcohol, drugs, and toxins (Novotny, 2011). The Zinc (Zn) content was found 2.39 mg to 8.725 mg/100g dry weight which was comparable with earlier reports (Mattila *et al*., 2001; Stamets, 2005; Smiderle *et al*., 2008; Zacharia *et al*., 2017; Sankaranarayanan and Kumari, 2021). Ahlawat *et al*. (2016) reported that 0.796 mg/100g Zinc (Zn) in *A. bisporus* was much below the present study. Zinc is a trace element required for protein synthesis and is a co-factor of the enzymes (Punitha and Rajasekaran, 2015).

Copper (Cu) content of *A. bisporus* (4.04 mg/100g) was comparable with Mattila *et al*. (2001) and Stamets (2005). *V. volvacea* (7.17 mg/100g) was in accordance with Ali *et al*. (2017). Rajeshbabu *et al*. (2012) reported very high Cu contents in caps of *C. indica*. The results of *P. florida* (2.98 mg/100g), *C. indica* (3.24 mg/100g) and *F. velutipes* (0.7 mg/100g) regarding Cu were considerably below earlier reported (Alam *et al*., 2008; Zahid *et al*., 2010; Punitha and Rajasekaran, 2015). Cu is an important constituent of enzyme systems like cytochrome oxidase, lysyl oxidase and ceruloplasmin (Mills, 1981). Chromium (Cr) content of cultivated mushrooms ranged 0.02 mg to 0.159 mg/100g dry weight. Kalaè (2013) reported 0.05-0.5 mg/100g Chromium (Cr) content in the wild growing mushrooms. Rajeshbabu *et al*. (2012) reported 0.92 mg/100g Cr in cap and 7.09 mg/100g in stipe of *C. indica*. Chromium is an essential trace element associated with normal carbohydrate, lipid and protein metabolism (Pechova and Pavlata, 2007). Trace elements like Fe, Zn, Cu, and Mn function as cofactors for different antioxidant enzymes and are designated as antioxidant micronutrients (Bhattacharyya *et al*., 2014).

CONCLUSION

The results of present study reveal inter-generic variation in micronutrient content of cultivated mushrooms. In spite of the variation in their micronutrient content, the overall nutrient account of these mushrooms appears to be quite good. The study showed the presence of Vitamin A, Vitamin B[1,2,3,5,6,9&12], Vitamin C, Vitamin D, Vitamin E and twelve minerals including Mg, Mn, Fe, Na, K, Se, Mo, Zn, Ca, P, Cu and Cr. There is wide variation in results reported by different workers. The variations may be due to differnce in the techniques, cultural conditions an genetic factors. The inclusion of mushrooms in routine diet may contribute significantly to overcome the malnutrition problem in our people.

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