PLANT SCIENCE TODAY
Vol x(x): xx-xx
https://doi.org/10.14719/pst.7464

eISSN 2348-1900

RESEARCH ARTICLE

Comparative biochemical compositions and antioxidant properties of commercially grown and wild edible mushroom species from Bangladesh

Md Shamsuzzaman[1*], Debu Kumar Bhattacharjya[1*], Sharmin Sultana[1], Akhter Jahan Kakon[2], Md Abdus Satter Miah[3], Tasnim Farzana[3], Anupoma Sen[1] & Md Mahfuzur Rob[4]

[1]Department of Biochemistry and Molecular Biology, Sher-e-Bangla Agricultural University, Dhaka 1207, Bangladesh
[2]Department of Agricultural Extension, Mushroom Development Institute, Savar, Dhaka 1340, Bangladesh
[3]Institute of Food Science and Technology, Bangladesh Council of Scientific and Industrial Research, Dhaka 1205, Bangladesh
[4]Department of Horticulture, Sylhet Agricultural University, Sylhet 3100, Bangladesh

*Correspondence email - zaman_sau@yahoo.com; debu.sau13@gmail.com

Received: 27 January 2025; Accepted: 21 July 2025; Available online: Version 1.0: 17 October 2025

Cite this article: Md Shamsuzzaman, Debu KB, Sharmin S, Akhter JK, Md Abdus SM, Tasnim F, Anupoma S, Md Mahfuzur R. Comparative biochemical compositions and antioxidant properties of commercially grown and wild edible mushroom species from Bangladesh. Plant Science Today (Early Access). https:/doi.org/10.14719/pst.7464

Abstract

The study compared the biochemical compositions and antioxidant properties of ten edible mushroom species in Bangladesh, including five cultivated and five wild species. The proximate composition, minerals, heavy metals and antioxidant capacity were analysed using standard procedures. The proximate composition of the mushroom was found to be in the range from 13.22 to 23.42 % for moisture content, 1.42 to 17.22 % for protein, 1.91 to 10.50 % for lipids, 3.12 to 30.11 % for fibre, 1.28 to 14.28 % for ash and 25.62 to 61.49 % for carbohydrate. The cultivated species contained higher amounts of moisture, ash and fibre, while carbohydrates, protein and lipids were higher in the wild species. In addition, eight mineral elements were analysed: Na, K, Ca, Mg, Fe, Cu, Zn and Mn with respective concentrations of 50.96-128.54, 719.7-1586.9, 194.6-683.3, 96.2-204.5, 0.79-180.07, 0.22-4.08, 1.18-5.58 and 0.61-6.98 mg/100 g. Most minerals were found in higher concentrations in cultivated species, except for Guratta woul, which had the highest concentrations of Fe and Mn. Aflatoxins (B1, B2, G1 and G2) were not detected in any of the samples tested. On the other hand, heavy metals (Pb, As, Cd, Cr) were present in negligible amounts, but below the WHO and FAO suggested range. The highest levels of phenolic (507.3 mg/100 g), flavonoid (132.57 mg/100 g) and total antioxidant content (1197 mg/100 g) were detected in the Guratta woul. Therefore, it can be suggested that both cultivated and wild edible mushrooms could be an excellent source of nutrition and antioxidants.

Keywords: heavy metals; nutrient composition; proximate analysis; wild and cultivated mushrooms

Introduction

Mushrooms, a unique and diverse group of macrofungi, are in a short-lived reproductive stage in their life cycle (1-3). Mushrooms primarily belong to the class Basidiomycetes, but certain Ascomycetes are responsible for mushroom formation from a taxonomic point of view (1, 2). Mushrooms have a rich historical connection with human culture and offer significant biological and economic contributions (4-6).

Mushrooms represent a nutritionally significant dietary component with low caloric and fat content. Substrate, organic supplementation and other additives used affect the nutritional quality of mushrooms (7, 8). Furthermore, mushrooms exhibit a substantial richness in various essential minerals, including, but not limited to, calcium, potassium, iron, manganese, magnesium, zinc, phosphorus and selenium (1, 9, 10). Mushrooms are a notable source of dietary fibre, protein, indispensable amino acids, unsaturated fatty acids, vitamins and minerals while offering a low caloric content (10, 11). The nutritional profile of mushrooms positions them as a valuable dietary resource endowed with diverse health advantages (1, 12). In addition to being an excellent source of various macronutrients, mushrooms contain essential micronutrients such as vitamins (including vitamin C and vitamin D) (2, 12, 13). Furthermore, specific mushroom species contain bioactive components, such as beta-glucans, with immunomodulatory effects and antioxidants that fight oxidative stress (14-16). On the other hand, numerous scientists agree that certain mushrooms tend to accumulate elevated levels of specific metals, particularly heavy metals, compared to grains, vegetables and fruits (17-19).

The mushroom industry comprises three primary segments: cultivated edible, medicinal and wild mushrooms (20, 21). The distinction between edible and medicinal mushrooms is not clear-cut, as many common edible species also have therapeutic properties (2, 20, 22). Edible mushrooms are gathered from natural habitats or grown through cultivation on a global scale (1, 7). There are at least 12000 known species of mushrooms worldwide. Of these, 2000 species are edible and 35 edible

species are commercially cultivated (23, 24). The most cultivated mushroom species is *Agaricus bisporus*, followed by *Lentinus edodes* and *Pleurotus spp* (23, 25).

Wild mushrooms are a popular seasonal food in many countries around the world, especially among several ethnic groups, due to their unique flavour and texture (3, 24, 26). They are also used for medicinal purposes, with nearly 200 species known to be used this way (23, 24, 27). Furthermore, a significant portion of these wild mushrooms is supposedly used for dietary, medicinal and cultural purposes and to a certain extent to generate income (3, 24, 28, 29). Approximately 20 species of wild mushrooms grow in Bangladesh, of which 5-6 are poisonous (9). Therefore, before consuming wild mushrooms, a toxicity test is recommended.

While cultivated mushrooms such as *Agaricus bisporus* and *Pleurotus ostreatus* have been studied extensively for their nutritional content and antioxidant properties (30), many species of wild mushrooms remain unexplored in this context. Comparative studies are of paramount importance, as wild mushrooms frequently exhibit elevated levels of antioxidant and phenolic content. In contrast, cultivated varieties offer consistent quality and safety within controlled environment settings. Investigating and comparing the' chemical composition, nutritional profile and antioxidant activities of cultivated and unreported wild mushrooms will offer valuable insight into their potential applications in nutrition, functional foods and nutraceuticals. Considering the aforementioned information and background, this research endeavour strives to attain the subsequent goals to characterize the biochemical composition of cultivated and unreported wild mushroom species as well as to compare cultivated and wild mushrooms to identify differences and similarities in composition, nutrition and antioxidant properties.

Materials and Methods

Experimental location and year

The present study was conducted at the Laboratory of the Department of Biochemistry and Molecular Biology at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, from March, 2022 to July, 2023 along with the Laboratory of Institute of Food Science and Technology, BCSIR, Dhaka and at the Quality Control and Quality Assurance laboratory of the Mushroom Development Institute (MDI), Savar, Dhaka, Bangladesh.

Sample collection and identification

The study consists of five commonly cultivated mushrooms and five wild edible mushrooms in Bangladesh (Table 1). In pursuit of this study, cultivated mushroom species, including *Pleurotus djmore, Pleurotus ostreatus, Auricularia auricula-judae, Calocybe indica* and *Ganoderma lucidum*, were collected from the MDI, located in Savar, Dhaka, Bangladesh and the collection period spanned from December 2022 to March 2023, with the selection of these species based on their availability, existing scientific data and popularity among local consumers. On the other hand, wild edible mushroom species such as Samo woul (*Flammulina sp.*), Undorhan woul (*Auricularia sp.*), Gach woul (*Pleurotus sp.),* Hakken woul (*Lentinus sp.) and* Guratta woul (*Bulgaria sp.)* were collected from the local market in Khagrachari district of Bangladesh according to their availability in the market during the study period. These mushrooms are highly popular and commonly consumed among local communities in the Khagrachari district. Dr Akhter Jahan Kakon (Project Director, Improvement of nutrition and reduction of poverty through mushroom cultivation project; Department of Agricultural Extension, Ministry of Agriculture), a mushroom specialist at MDI, Savar, Bangladesh, identified and authenticated these mushroom species based on their morphological and taxonomical studies.

Proximate analysis

The proximate composition analysis of the mushrooms studied aimed to determine moisture, carbohydrate, fat, protein content, total ash and crude fibre. The moisture and fat levels in the mushrooms were determined following the protocol outlined by the Association of Official Analytical Chemists (31). The total nitrogen content of the harvested edible mushroom was evaluated using the micro Kjeldahl method and then the crude protein content was calculated using the formula N × 6.25, where N represents the nitrogen content (32). Additionally, total ash and crude fibre were evaluated using standard procedures, while total carbohydrate was calculated by subtracting the combined moisture, ash, total protein, fat and fibre contents from the sample weights. Furthermore, dietary fibre was quantified using the AOAC method (33).

Mineral element analysis

The mineral analysis of calcium and iron in the dried mushroom sample was carried out using an Atomic Absorption Spectrophotometer (AAS) (34). After digestion in an HNO_3/HCl acid mixture, the samples underwent analysis through the AAS system utilising different lamps and calibration with standards of varying

Table 1. Specifications of cultivated and wild edible mushroom species studied

Scientific Name	Local name (In Bengali)	*Price/Kg		Edibility	Habitat
		BDT	USD		
Pleurotus djmore	POP	400	3.5	Excellent	Cultivated
Pleurotus ostreatus	PO2 (Oyster)	250-300	2.5	Excellent	Cultivated
Auricularia auricula-judae	Ear	200-300	2.5	Good	Cultivated
Calocybe indica	Milky	300-350	3	Good	Cultivated
Ganoderma lucidum	Reishi	8000	68	Medicinal	Cultivated
Flammulina sp.	Samo woul	1000	8	Excellent	Wild growing
Auricularia sp.	Underhan woul	1200	10	Good	Wild growing
Pleurotus sp.	Gach woul	1000	8	Excellent	Wild growing
Lentinus sp.	Hakken woul	1300	11.5	Excellent	Wild growing
Bulgaria sp.	Guratta woul	2000	17	Good	Wild growing

***** Price was based on the market rate during 2022-2023

concentrations specific to the minerals under investigation. Ca, Mg, Cu, Fe, Mn and Zn were determined by atomic absorption spectrophotometer (AA-7000, SHIMADZU), P and S were determined by spectrophotometer (UV-1900, SHIMADZU) and Na and K were determined by a flame photometer (PFP7 flame photometer, JENWAY). As, Pb, Cd and Cr were determined by an atomic absorption spectrophotometer (AA-7000, SHIMADZU).

Aflatoxins detection

Detection and quantification of aflatoxins were performed with a High-Performance Liquid Chromatography (HPLC) (Agilent 1200 G1316A ColCom, Germany). The experimental procedure was carried out (35). Briefly, dried and finely crushed samples were mixed with acetone and distilled water and then shaken for 30 min. The mixtures were centrifuged at 6000 rpm for 30 min. The supernatants, consisting of extracted aflatoxins, were concentrated with a concentrator (Techne, DB-3, UK) under nitrogen gas. Finally, the extracts were diluted with 300 µL (0.3 mL) mobile phase (methanol 22.5 % +acetonitrile 22.5 % + 55 % deionised water) as injecting solution.

Determination of antioxidant components (total phenol, flavonoid and antioxidant capacity)

Total phenolic content of mushroom extracts was determined using the Folin-Ciocalteu reagent method with pyrocatechol serving as the standard phenolic compound (36). The absorbance was measured at 760 nm and the total phenolic content was expressed as mg of gallic acid equivalent per 100 g of mushroom. The linear equation obtained from the standard gallic acid calibration curve was used to calculate the phenolic content. For the analysis of the total flavonoid content, the Dowd method was employed (37), where the absorbance was measured at 415 nm. The total flavonoid concentration was calculated using a Quercetin standard calibration curve and expressed as micrograms of rutin equivalent per mg of dry extracts. To determine the total antioxidant capacity, the mushrooms were evaluated using the ammonium molybdate reduction method with modifications (38). The absorbance was measured at 695 nm and the half-minimal inhibitory concentration (IC50) value was calculated using ascorbic acid as a positive control.

Statistical analysis

The recorded data for each parameter from the experiments were analysed statistically with a one-way analysis of variance (ANOVA) to find out the variation resulting from experimental treatments using the Statistix 10 program. Three samples were used for each preparation and all assays were carried out in triplicate. The results are expressed as mean values and standard deviation (SD). Differences between the means of individual groups were assessed using a one-way ANOVA with Duncan's multiple range tests. The mean differences were evaluated by the Least Significant Difference (LSD) test (39). Principal Component Analysis (PCA) was conducted using R Studio (Version 4.3.1).

Results and Discussion

Proximate composition of the mushroom species studied and aflatoxin test of wild mushrooms

The proximate composition of mushrooms is a key area of study because of their significant nutritional, economic and medicinal benefits. By analysing their basic nutritional components, researchers and food scientists can better understand and utilize mushrooms to improve human health, enhance food security and develop sustainable agricultural practices.

The proximate results of the analysis for the investigated mushroom species revealed significant variability in the ash content ranging from 1.28 % to 14.28 % among the mushroom species studied (Fig. 1). POP had the highest ash content at 14.28 % among cultivated mushrooms, while PO2 mushrooms had the lowest at 1.28 %. Among wild mushrooms, Guratta woul exhibited the highest ash content at 11.88 %, while Gach woul had the lowest at 3.013 %. These results align with previous research (40, 41), which reported varying ash content in different mushroom species. Variability in ash content can be influenced by factors such as species diversity, geographical location and environmental conditions during cultivation or harvesting. Understanding these variations is essential for the nutritional assessment and culinary applications of mushrooms. Further research could delve into the factors influencing ash content

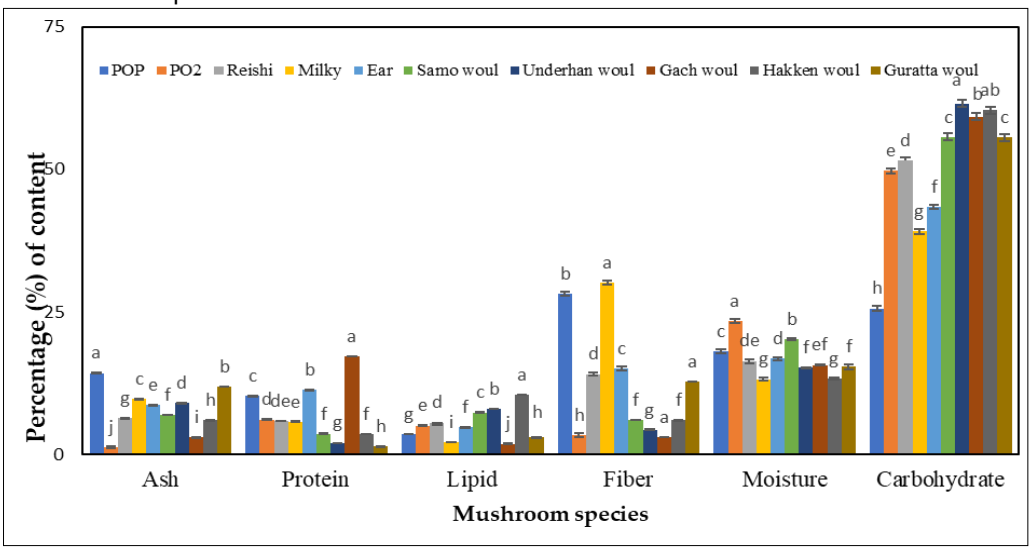

Fig. 1. Proximate composition of selected cultivated and wild mushrooms from Bangladesh.

(The components of Ash, Protein, Lipid, Fibre and Moisture were demonstrated through triplicate analyses of three samples. The Carbohydrate content is calculated by summing the percentages of crude protein, ash, fat and crude fibre and subsequently subtracting this sum from 100. The distinct lowercase superscript characters (a-j) associated with a single component indicate a statistically significant difference at a significance level of $p < 0.05$, as determined through analysis of variance).

variations and their broader implications for mushroom utilization in various contexts.

Analysis of protein content among mushroom species revealed a significant range, from 1.42 % to 17.22 % (Fig. 1). Gach woul exhibited the highest protein content at 17.22 %, while Guratto woul had the lowest at 1.42 %. In cultivated mushrooms, Ear mushrooms had the highest protein content at 11.367 %, while milky mushrooms and Reishi showed the lowest protein content at 5.7 % and 5.93 %, respectively. In particular, the protein content of the milky mushrooms was statistically like that of Reishi. Among wild mushrooms, Gach woul stood out with the highest protein content at 17.22 %, while Guratto woul had the lowest at 1.42 %. These findings highlight the substantial variability in protein content among different mushroom species, whether cultivated or wild. Previous studies also reported wide variations in protein content in mushrooms, aligning with the results of the current study (42, 43). However, substantially higher protein content of 41.06 % was reported (44), indicating notable variability in protein composition between different studies. The early studies further emphasized the diversity in protein levels across various mushroom species (45).

The analysis of lipid content among the mushroom species revealed significant variations, ranging from 1.91 % to 10.5 % (Fig. 1). Hakken woul exhibited the highest lipid content at 10.5 % among wild mushrooms, while Gach woul had the lowest at 1.91 %. In cultivated mushrooms, Reishi showed the highest lipid content at 5.62 %, while milky mushrooms had the lowest at 2.24 %. These findings underscore the substantial differences in lipid content between wild and cultivated mushroom varieties, highlighting the nutritional and culinary implications of such variations. The observed variations in lipid content in our study are consistent with previous research in the field. Studies have reported ranges of lipid content in edible mushrooms that align with the findings of our study (46-49). This consistency among studies reinforces the understanding of the observations of lipid content in edible mushrooms and supports the reliability of our results within the established range.

Mushrooms serve as valuable sources of dietary fibre, primarily composed of chitin and polysaccharides. This dietary fibre is resistant to human enzymes and offers various nutritional and physiological benefits (50). Among the mushroom species studied, milky mushrooms exhibited the highest fibre content at 30.11 %, closely followed by POP at 28.21 % (Fig. 1). Conversely, Gach woul exhibited the lowest fiber content at 3.12 %. When considering cultivated mushrooms, milky mushrooms had the highest fibre content at 30.11 %, while PO2 mushrooms showed the lowest at 13.41 %. In the case of wild mushrooms, Guratta woul contained the highest fibre content at 12.82 %, whereas Gach woul had the lowest fibre content. The results of this study align with and support of prevoius findings (51, 52). Fibre is known for its role in promoting digestive health and overall well-being. Our results show that these health benefits can vary significantly depending on the mushroom variety consumed.

In terms of moisture content, our study observed notable variations, ranging from 13.22 % for milky mushrooms to 23.42 % for PO2 mushrooms (Fig. 1). Milky mushroom and Hakken woul exhibited similar moisture content, as did Reishi and Ear mushroom. Among the cultivated mushrooms, PO2 mushrooms had the highest moisture content, while Milky mushrooms had the lowest. For wild edible mushrooms, Samo woul had the highest moisture content, Hakken woul had the lowest and the rest showed similar moisture levels. The moisture content of mushrooms is a crucial parameter that can impact their nutritional composition and shelf stability. The observed variability in moisture content between different mushroom species may be influenced by factors such as water retention abilities and growth conditions. The findings align with previous studies and highlight the need for further investigation into the factors affecting moisture content in mushrooms. These results align with previous works who reported around 13 % moisture content (29). This similarity in moisture content suggests that these mushrooms might share certain characteristics concerning their water retention abilities or growth conditions, warranting further investigation into the underlying factors influencing their moisture content (24, 53).

The analysis of carbohydrate content among the various mushroom species studied revealed significant variations. Undorhan woul exhibited the highest percentage of carbohydrates at 61.49 %, a value statistically like Hakken woul (Fig. 1). Conversely, the lowest carbohydrate content was found in POP, registering at 25.62 %. When looking at cultivated mushrooms, Reishi displayed the highest carbohydrate content at 51.623 %, while POP demonstrated the lowest carbohydrate content in this category. Among the wild edible mushrooms, Undorhan woul had the highest carbohydrate content at 61.49 %, whereas Guratto woul had the lowest at 55.59 %. These results align with previous studies and which reported similar outcomes for carbohydrate content in mushrooms (40, 54). The variability in carbohydrate content across different mushroom species, whether cultivated or wild, underscores the dietary implications of selecting specific mushroom varieties.

Several factors may contribute to the observed variations in carbohydrate content, including environmental conditions, substrate composition and genetic factors. Further research could delve into these factors to determine whether similar variations exist across different geographical regions and cultivation practices.

The results of the aflatoxin test conducted on wild mushroom samples revealed that none of the tested samples showed detectable levels of aflatoxins (Aflatoxin B1, B2, G1 and G2) (Appendix 1). This indicates that the wild mushrooms analyzed in this study were free from aflatoxin contamination, highlighting their safety in terms of aflatoxin exposure. The absence of aflatoxins in the analyzed wild mushrooms aligns with previous research findings that also reported low or undetectable levels of aflatoxins in similar mushroom species. These results are consistent with early studies (55, 56) further supporting the safety of wild mushrooms in terms of aflatoxin contamination. However, it is crucial to recognize that while the absence of aflatoxins is reassuring, it does not guarantee the absence of other potential contaminants or mycotoxins in wild mushrooms. Environmental factors and growing conditions can lead to the accumulation of various toxins, heavy metals and pollutants in mushrooms. Therefore, continuous monitoring and analysis of wild mushrooms for a broader range of contaminants are essential to ensure food safety and human health.

Appendix 1. Levels of aflatoxins in wild edible mushrooms

SL No.	Sample Name	Test parameter				Amount (µg/kg)
		Aflatoxin				
		B1	B2	G1	G2	
W1	Samo woul	ND	ND	ND	ND	--
W2	Undorhan woul	ND	ND	ND	ND	--
W3	Gach woul	ND	ND	ND	ND	--
W4	Hakken woul	ND	ND	ND	ND	--
W5	Guratta woul	ND	ND	ND	ND	--

ND: Not Detected

Mineral elements determination

Mushroom fruiting bodies are rich in well-absorbed minerals. By providing essential minerals, mushrooms support various body functions, contribute to disease prevention and offer a sustainable dietary option for obtaining vital nutrients. The main mineral constituents of mushrooms are sodium, potassium, calcium, magnesium, phosphorus and sulphur. The sodium (Na) content in the mushrooms studied exhibited a wide range, from 50.955 mg/100 g in Gach woul to 128.54 mg/100 g in Milky mushrooms (Table 2). Most mushrooms showed statistically significant differences in sodium concentrations, except for Reishi, Ear and Samo woul. Notably, Reishi and Ear mushrooms had statistically similar sodium levels, as did Ear mushrooms and Samo woul. Among cultivated samples, Milky mushrooms had the highest sodium concentration, while POP had the lowest. In wild mushrooms, Guratta woul had the highest sodium content and Gach woul had the lowest. Studies reported varying levels of sodium content in edible mushrooms, highlighting the variability in sodium concentrations across different species and studies (57-59).

On the other hand, potassium (K) content in mushrooms varied significantly, with the lowest concentration in Reishi mushrooms (719.67 mg/100 g) and the highest in PO2 mushrooms (1604.7 mg/100g) (Table 2). Among wild edible mushrooms, potassium levels ranged from 826.83 mg/100 g in the Gach woul to 1335.0 mg/100 g in the Guratta woul. Our findings align with previous studies (29, 57, 60, 61) reported significantly higher potassium concentrations. Variations in potassium content may be influenced by factors such as species-specific differences, geographic variations and analytical methodologies used in different studies.

The calcium (Ca) content in mushrooms ranged from 194.64 mg/100 g in PO2 mushrooms to 683.34 mg/100 g in Ear mushrooms (Table 2). Most mushrooms exhibited statistically different calcium concentrations, with exceptions such as Samo woul, Undorhan woul and Gach woul, which had similar calcium levels. Among cultivated mushrooms, Ear mushrooms had the highest calcium content, while PO2 mushrooms had the lowest. In wild mushrooms, Guratta woul had the highest calcium concentration. Our results align with studies (57, 62, 63), although variability in calcium content is evident in different studies.

The magnesium (Mg) content in mushrooms ranged from 96.157 mg/100 g in PO2 mushrooms to 204.45 mg/100 g in Undorhan woul (Table 2). POP and Reishi exhibited statistically similar Mg content, as did Ear mushrooms, Hakken woul and Gach woul. Among cultivated mushrooms, magnesium concentrations varied, with milky mushrooms having the lowest and ear mushrooms the highest. In wild mushrooms, Undorhan woul had the highest magnesium content. Our findings align with early works but differ from studies reporting lower magnesium levels (63). The mushrooms studied showed richness in potassium, calcium and magnesium, with a comparatively lower sodium content, consistent with previous research by various authors. The observed variations in mineral content among the mushrooms can be attributed to factors such as species differences, substrate variability, environmental influences and analytical methods employed in different studies.

The analysis of iron (Fe) content in the studied mushrooms revealed significant variability, with Guratta woul displaying the highest Fe concentration at 180.07 mg/100 g and Reishi exhibiting the lowest at 0.79 mg/100 g, a level comparable to Milky and Ear mushrooms (Table 3). Interestingly, wild edible mushrooms generally exhibited a higher Fe content than cultivated varieties, with Guratta woul showing significantly higher Fe levels compared to other species. Among cultivated mushrooms, Fe concentrations ranged from 0.7867 mg/100 g in Reishi to 4.2867 mg/100 g in POP. In contrast, wild mushrooms showed a wider range of Fe concentrations, ranging from 7.2667 mg/100 g in Gach woul to 180.07 mg/100 g in Guratta woul. These findings are consistent with previous studies (58, 60, 61, 64), highlighting the diversity of iron concentrations between different mushroom species and cultivation conditions.

Table 2. Major mineral composition of selected cultivated and wild edible mushrooms from Bangladesh

Mushroom species	Na (mg/100g)	K (mg/100g)	Ca (mg/100g)	Mg (mg/100g)
POP	$77.72^{c} \pm 0.53$	$1522.4^{b} \pm 9.03$	$223.7^{g} \pm 2.45$	$116.6^{e} \pm 1.18$
PO2	$39.33^{i} \pm 1.01$	$1604.7^{a} \pm 5.90$	$194.6^{h} \pm 3.00$	$96.2^{f} \pm 1.18$
Reishi	$54.17^{g} \pm 0.43$	$719.7^{h} \pm 11.32$	$298.4^{f} \pm 5.22$	$115.9^{e} \pm 1.18$
Milky	$128.54^{a} \pm 0.43$	1586.9a ± 7.68	$350.4^{e} \pm 2.93$	$89.5^{g} \pm 1.18$
Ear	$55.10^{fg} \pm 0.43$	$1008.8^{e} \pm 6.51$	$683.3^{a} \pm 2.48$	$132.4^{c} \pm 1.18$
Samo Woul	$56.23^{f} \pm 0.65$	$1111.8^{d} \pm 2.90$	$385.6^{d} \pm 2.90$	$126.1^{d} \pm 1.45$
Undorhan Woul	$62.86^{e} \pm 0.65$	$938.5^{f} \pm 4.76$	$376.6^{d} \pm 3.49$	$204.5^{a} \pm 1.45$
Gach Woul	$50.96^{h} \pm 0.65$	$826.8^{g} \pm 8.64$	$382.6^{d} \pm 1.18$	$133.7^{c} \pm 1.45$
Hakken Woul	$103.83^{b} \pm 0.65$	$955.5^{f} \pm 8.67$	$435.2^{c} \pm 8.68$	$132.6^{c} \pm 1.45$
Guratta Woul	$66.95^{d} \pm 0.65$	$1335.0^{c} \pm 8.67$	$585.4^{b} \pm 2.92$	$143.3^{b} \pm 1.45$
LSD (0.05)	0.89	11.0	5.7	1.9
CV %	1.57	1.2	1.8	1.8

(Data are presented as the mean ± SD of triplicate analysis of three samples. The distinct lowercase superscript characters (a-g) within a single column denotes a statistically significant difference at a significance level of $p < 0.05$, as determined by analysis of variance).

Table 3. Minor mineral composition of selected cultivated and wild edible mushrooms from Bangladesh

Mushroom species	Fe (mg/100g)	Cu (mg/100g)	Zn (mg/100g)	Mn (mg/100g)
POP	$4.29^{e} \pm 0.01$	$1.90^{b} \pm 0.05$	$5.58^{a} \pm 0.05$	$0.90^{g} \pm 0.01$
PO2	$3.70^{e} \pm 0.03$	$0.77^{e} \pm 0.02$	$3.51^{b} \pm 0.05$	$0.47^{i} \pm 0.01$
Reishi	$0.79^{f} \pm 0.03$	$1.22^{c} \pm 0.02$	$1.27^{f} \pm 0.05$	$1.02^{f} \pm 0.01$
Milky	$1.02^{f} \pm 0.04$	$4.08^{a} \pm 0.01$	$2.86^{d} \pm 0.05$	$0.61^{h} \pm 0.01$
Ear	$1.86^{f} \pm 0.03$	$0.22^{h} \pm 0.02$	$1.18^{f} \pm 0.05$	$0.87^{g} \pm 0.01$
Samo Woul	$17.16^{c} \pm 0.01$	$1.95^{b} \pm 0.05$	$3.21^{c} \pm 0.05$	$3.28^{b} \pm 0.01$
Undorhan Woul	$46.34^{b} \pm 0.03$	$0.32^{g} \pm 0.02$	$1.21^{f} \pm 0.05$	$2.33^{c} \pm 0.01$
Gach Woul	$7.27^{d} \pm 0.03$	$0.87^{d} \pm 0.02$	$2.23^{e} \pm 0.05$	$1.40^{e} \pm 0.01$
Hakken Woul	$45.24^{b} \pm 0.04$	$0.42^{f} \pm 0.01$	$3.18^{c} \pm 0.05$	$1.53^{d} \pm 0.01$
Guratta Woul	$180.07^{a} \pm 0.03$	$0.28^{g} \pm 0.02$	$2.87^{d} \pm 0.05$	$6.98^{a} \pm 0.01$
LSD (0.05)	0.55	0.03	0.06	0.02
CV%	2.20	2.77	2.75	1.47

(Data are presented as the mean ± SD of triplicate analysis of three samples. The distinct lowercase superscript characters (a-g) within a single column denote a statistically significant difference at a significance level of $p < 0.05$, as determined by analysis of variance).

Moreover, Copper (Cu) concentrations in mushrooms exhibited wide variability, ranging from 0.22 mg/100 g in Ear mushrooms to 4.08 mg/100 g in Milky mushrooms (Table 3). Although POP mushrooms and Samo mushrooms had statistically similar copper concentrations, Guratta woul and Undorhan woul also showed comparable levels. The range of copper concentrations was narrower in wild mushrooms compared to cultivated ones. Studies reported varying copper levels in mushrooms, emphasizing the diversity of copper concentrations across different species and experimental conditions (57, 58, 61).

Zinc (Zn) content varied significantly among the mushrooms studied, ranging from 1.18 mg/100 g in Ear and Reishi mushrooms to 5.5767 mg/100 g in POP (Table 3). Undorhan woul was statistically comparable to Reishi in terms of Zn content. POP had the highest concentration among cultivated mushrooms, while ear mushrooms exhibited the lowest. In wild mushrooms, the Zn content ranged from 1.21 mg/100 g in Undorhan woul to 3.21 mg/100 g in Samo woul. These findings align with (40, 58, 61), illustrating the range of zinc concentrations observed in different studies.

The manganese (Mn) content varied notably among the studied mushrooms, with Guratta woul displaying the highest Mn concentration at 6.98 mg/100 g, significantly higher than milky mushrooms, which had the lowest at 0.61 mg/100 g (Table 3). Among cultivated mushrooms, Mn concentrations ranged from 0.4667 mg/100 g in PO2 to 1.015 mg/100 g in Reishi. In contrast, wild mushrooms exhibited a wider range of Mn concentrations, from 1.40 mg/100 g in Undorhan woul to 6.98 mg/100 g in Guratta woul. These findings are in line with studies highlighting the diversity of manganese levels in different mushroom species and experimental conditions (57, 61, 62, 65).

The observed variations in the iron, copper, zinc and manganese content between mushrooms underscore the influence of species-specific differences, cultivation methods and environmental factors on the mineral composition of mushrooms. The wide range of mineral concentrations reflects the complexity of mushroom nutrition and emphasizes the importance of considering these factors in dietary assessments and food studies.

Heavy metal analysis

Mushrooms, while known for their nutritional value, can also accumulate heavy metals that can pose health risks if consumed in excess. Essential heavy metals like iron, copper and zinc are crucial for physiological functions, but toxic heavy metals such as lead, arsenic, cadmium and chromium can be harmful (17, 66, 67). The accumulation of heavy metals in mushrooms is species-specific and is influenced by factors such as mushroom physiology, pollution levels in the sampling area (proximity to human settlement or industrial activities) and the mineral composition of the soil (18, 19). In our study, we investigated the levels of these heavy metals in various cultivated and wild mushroom species.

Lead concentrations in the mushrooms studied ranged from 0.25 ppm in Samo woul to 0.53 ppm in Reishi mushrooms (Table 4). The lead content varied among different varieties, with Reishi mushrooms showing the highest concentration and milky mushrooms the lowest. These levels were well below the permissible maximum limit of 3 ppm set by the World Health Organization for dried vegetables (68). Our findings aligned with previous studies indicate that the mushrooms analyzed are safe for consumption. Whilst Arsenic was not detectable in any wild mushrooms but was found in three cultivated species: milky, ear and Reishi mushrooms, with concentrations ranging from 0.07 ppm to 0.11 ppm (Table 4). Our results are consistent with previous research and suggest that arsenic levels in the studied mushrooms are within safe limits for consumption.

Table 4. Heavy metal content of selected cultivated and wild edible mushrooms from Bangladesh

Mushroom species	Lead (mg/kg)	Arsenic (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)
POP	0.3367^{e}	BDL	BDL	0.2867^{f}
PO2	0.41^{c}	BDL	BDL	0.2433^{g}
Reishi	0.53^{a}	0.09	BDL	0.46^{b}
Milky	0.2533^{g}	0.11	BDL	0.5267^{a}
Ear	0.45^{b}	0.07	BDL	0.3467^{d}
Samo Woul	0.25^{g}	BDL	BDL	0.3233^{e}
Undorhan Woul	0.3233^{e}	BDL	BDL	0.1433^{j}
Gach Woul	0.2967^{f}	BDL	BDL	0.4233^{c}
Hakken Woul	0.3567^{d}	BDL	BDL	0.22^{h}
Guratta Woul	0.4633^{b}	BDL	BDL	0.1767^{i}
LSD (0.05)	0.01			0.02
CV%	2.17			1.7

(Data are presented as the mean ± SD of triplicate analysis of three samples. The distinct lowercase superscript characters (a-g) within a single column denote a statistically significant difference at a significance level of $p < 0.05$, as determined by analysis of variance. Again, BDL stands for 'Below Detection Level).

None of the mushroom species tested in our study exceeded the detection limit for cadmium, set at 0.10 ppm (Table 4). This finding is in line with previous studies and indicates that the mushrooms analyzed do not pose a risk of cadmium exposure. Chromium concentrations varied among the different mushroom species, with milky mushrooms exhibiting the highest (0.5267 ppm) levels and Undorhan woul the lowest (0.1433 ppm) (Table 4). The chromium content of the mushrooms studied fell within safe limits for consumption, consistent with previous research findings. The low concentrations of heavy metals observed in mushrooms suggest that the collection areas are not significantly polluted, indicating that the edible mushroom species studied are safe for consumption. The ability of mushrooms to accumulate nutrients and minerals from their environment underscores the importance of considering environmental factors in assessing the safety and nutritional value of mushrooms.

Antioxidant activity analysis

Antioxidants play a crucial role in protecting the body from oxidative stress and related diseases. In our study, we assessed the antioxidant properties of various cultivated and wild mushroom species by measuring their total phenolic content (TPC), total flavonoid content (TFC) and total antioxidant capacity (TAC) in milligrams per 100 g (mg/100 g) of the mushroom samples.

The total phenolic content varied significantly among the mushrooms analyzed, with values ranging from 57.17 mg/100 g to 507.3 mg/100 g (Fig. 2). Guratta woul exhibited the highest phenolic content, while Undorhan woul displayed the lowest among the wild mushrooms. In cultivated mushrooms, the phenolic content ranged from 66.67 mg/100 g to 149.77 mg/100 g. Our findings align with the results reported on *P. ostreatus* and *A. bisporus* (69, 70). Previously an elevated phenolic content was reported in PO2 mushrooms, with phenolic levels falling within the range of 10.50-83.50 mg GAE/g (70). Furthermore, (70, 71, 72) found a variable total phenol content in *Pleurotus djamor* var. *roseus* and other species ranging from 6.75±0.29 to 1.48±0.23 mg/g.

Guratta woul showed the highest flavonoid content (132.57 mg/100 g), while PO2 mushrooms had the lowest (15.21 mg/100 g) among the studied mushrooms (Fig. 2). Cultivated and wild mushrooms showed varying levels of flavonoid content, with wild mushrooms generally containing higher amounts compared to cultivated varieties. Flavonoid content is an important indicator of antioxidant potential and our results suggest that wild mushrooms may offer greater antioxidant benefits in terms of flavonoid content. Findings reported are consistent with the current study in Pleurotus species (73). However, it is noteworthy that two Malaysian mushroom samples belonging to the Pleurotus genus displayed a total flavonoid content of approximately 14 mg QE/g of dry extract (74). This substantial difference may be attributed to several factors, including variations in the cultivated medium, the climate of the cultivation country and differences in the extraction procedures employed.

The total antioxidant activity ranged from 358.2 mg/100 g in Undorhan woul to 1197 mg/100 g in Guratta woul, indicating significant variability in antioxidant activity among the mushrooms analyzed (Fig. 2). Milky mushrooms exhibited the highest TAC among cultivated varieties, while ear mushrooms had the lowest. Wild mushrooms displayed a broader range of TAC values, highlighting their diverse antioxidant capacity. Our results are in line with previous research findings and emphasize the importance of considering the antioxidant potential of mushrooms in dietary choices. The previous study noted that white PO2 mushrooms exhibited a substantial total antioxidant capacity (TAC) of 114.708 mg/g to 368.78 mg/g (75). Another study found that *Pleurotus ostreatus* demonstrated the highest TAC, measured at 35.36±0.10 µM (76).

In summary, the antioxidant properties of edible mushrooms, as demonstrated by their phenolic, flavonoid and total antioxidant content, make them valuable additions to a healthy diet. The significant antioxidant activity observed in the studied mushroom species suggests they can contribute to overall health and well-being by combating oxidative stress and promoting cellular health.

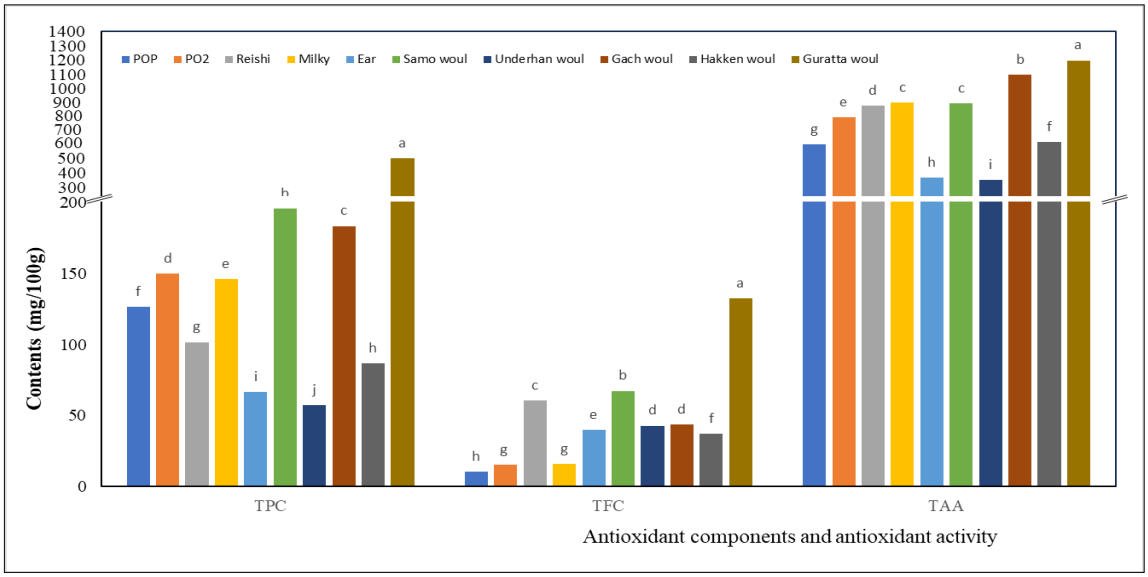

Fig. 2. The composition of antioxidant components and the overall antioxidant activity of chosen cultivated and wild edible mushrooms originating from Bangladesh.

Here, TPC stands for Total Phenolic Content, TFC for Total flavonoid content and TAA for Total antioxidant activity. TPC, TFC and TAA were calculated from a triplicate analysis of three samples. The distinct lowercase superscript characters (a-j) within a single component indicate a statistically significant difference at a significance level of $p < 0.05$, as determined by ANOVA.

PCA analysis

The PCA plot is a visual representation of the differentiation of various samples based on two principal components, PC1, which accounts for 30.85 % of the variance and PC2, which accounts for 21.64 % (Fig. 3). Together, these components explain ~52 % of the total variance. The plot uses red dots for the samples and blue vectors for the variables. Samples like 'Milky', 'POP' and 'PO2' are grouped on the left, indicating shared characteristics influenced by variables such as K, Zn and Cr. 'Guratta woul' is on the right, characterized by high values for the variables like TPC, Fe, Mn, TFC, Ca and Carbohydrate. 'Samo woul' and 'Gach woul' in the centre suggest balanced profiles. The quadrants of the plot represent different characteristics of the sample: high minerals and low carbohydrates on the upper left and the opposite on the right. 'Underhan woul' in the lower right quadrant has high levels of Ca and carbohydrates but lower levels of protein and moisture. 'Reshi' and 'Gach woul' near the origin have average profiles. The plot provides insight into compositional differences and underlying patterns within the dataset, which is crucial for future research and decision-making processes.

Conclusion

The findings of this investigation highlighted the diverse nutrient profiles and antioxidant capacities of both cultivated and wild mushrooms, highlighting their potential health benefits. Cultivated mushrooms exhibited a higher moisture, ash and fibre content, while wild species had a higher protein and lipid content. Essential mineral elements crucial for human nutrition were also found in significant quantities, with milky mushrooms, ear mushrooms and Undorhan woul showing notable levels of sodium, potassium, calcium and magnesium. The absence of toxic elements such as arsenic and cadmium in wild mushrooms and the presence of minerals in both wild and cultivated mushrooms indicated their safety for consumption. The antioxidant assays carried out in this study underscored the potential health benefits of consuming these mushrooms, which are rich in antioxidants that may contribute to overall well-being. These findings underscore the nutritional value of wild mushrooms as potential dietary supplements and functional food ingredients, owing to their rich biochemical and antioxidant profiles. Future research should concentrate on toxicity and safety assessments of wild species to ensure their suitability for regular human consumption and to support their integration into sustainable food systems.

Acknowledgements

The authors express their gratitude to the Mushroom Development Institute (MDI) of Bangladesh for providing mushroom species for this research. The authors are also grateful to the University Grants Commission of the People's Republic of Bangladesh for funding.

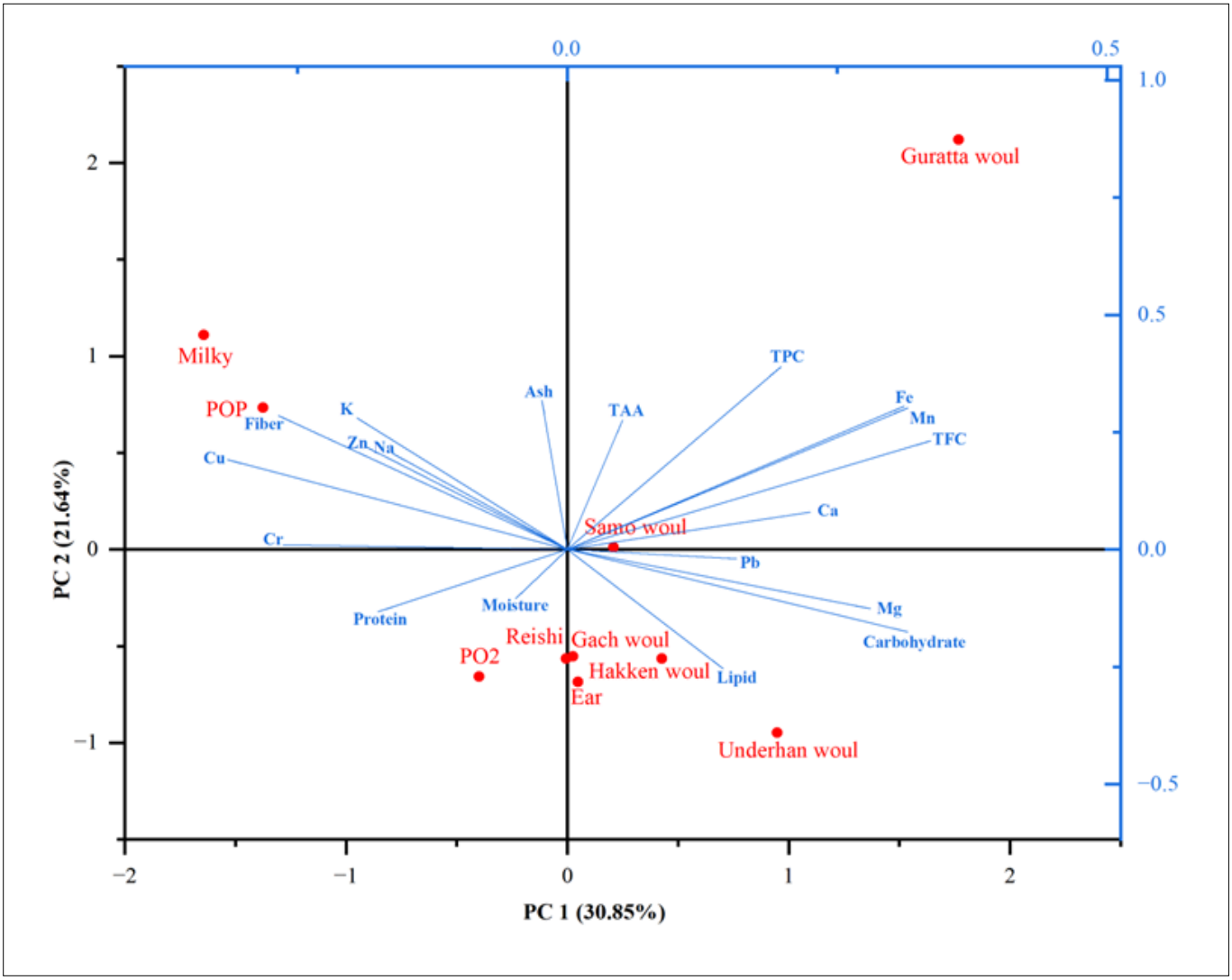

Fig. 3. Principal Component Analysis (PCA) plot of cultivated edible and wild mushrooms under investigation.

Authors' contributions

MS and DKB designed the experiment. MS conducted the experiment, analyzed the data and prepared the manuscripts. SS and AS assisted in performing the experiment. MASM, AJK and TF supervised different parts of the experiments. MMR assisted in the data analysis and editing of the manuscript. DKB coordinated and supervised the overall experiment.

Compliance with ethical standards

Conflict of interest: The authors declare no conflicts of interest.

Ethical issues: None

References

1. Assemie A, Abaya G. The effect of edible mushroom on health and their biochemistry. Int J Microbiol. 2022;(1):8744788. https://doi.org/10.1155/2022/8744788
2. Mwangi RW, Macharia JM, Wagara IN, Bence RL. The antioxidant potential of different edible and medicinal mushrooms. Biomed Pharmacother. 2022;147:112621. https://doi.org/10.1016/j.biopha.2022.112621
3. Zhou Y, Chu M, Ahmadi F, Agar OT, Barrow CJ, Dunshea FR, Suleria HA. A comprehensive review on phytochemical profiling in mushrooms: occurrence, biological activities, applications and future prospective. Food Rev Int. 2024;40(3):924-51. https://doi.org/10.1080/87559129.2023.2202738
4. Gyar SD, Owaku G. Estimation of some metal elements and proximate properties of *Boletus edulis* (Fr), a wild mushroom species in the Nigerian Savannah. Trakia J Sci. 2011;19(2). https://www.cabidigitallibrary.org/doi/full/10.5555/20113201684
5. Lu H, Lou H, Hu J, Liu Z, Chen Q. Macrofungi: A review of cultivation strategies, bioactivity and application of mushrooms. Compr Rev Food Sci Food Saf. 2020;19(5):2333-56. https://doi.org/10.1111/1541-4337.12602
6. Uzziel RG, Carrera-Martínez A, Martínez-Reyes M, Hernández-Santiago F, Evangelista FR, Irma DA, et al. Traditional knowledge and use of wild mushrooms with biocultural importance in the Mazatec culture in Oaxaca, Mexico, cradle of the ethnomycology. For Syst. 2023;32(1):e007. https://doi.org/10.5424/fs/2023321-19884
7. Sahoo S, Gayakwad T, Shahi S. Medicinal value of edible mushrooms: A review. Int J Health Sci. 2022;6:8760-7. http://doi.org/10.53730/ijhs.v6nS2.7263
8. Subbiah KA, Balan V. A comprehensive review of tropical milky white mushroom (*Calocybe indica* P&C). Mycobiology. 2015;43(3):184-94. https://doi.org/10.5941/myco.2015.43.3.184
9. Ferdousi J, Riyadh ZA, Hossain MI, Saha SR, Zakaria M. Mushroom production benefits, status, challenges and opportunities in Bangladesh: A review. Annu Res Rev Biol. 2020;34(6):1-3. https://doi.org/10.9734/arrb/2019/v34i630169
10. Usman M, Murtaza G, Ditta A. Nutritional, medicinal and cosmetic value of bioactive compounds in button mushroom (*Agaricus bisporus*): a review. Appl Sci. 2021;11(13):5943. https://doi.org/10.3390/app11135943
11. Ao T, Deb CR. Nutritional and antioxidant potential of some wild edible mushrooms of Nagaland, India. Food Sci Technol. 2019;56(2):1084-9. https://doi.org/10.1007/s13197-018-03557-w
12. Navarro-Simarro P, Gómez-Gómez L, Ahrazem O, Rubio-Moraga Á. Food and human health applications of edible mushroom by-products. N Biotechnol. 2024;81:43-56. https://doi.org/10.1016/j.nbt.2024.03.003
13. Upadhyaya J, Raut JK, Koirala N. Analysis of nutritional and nutraceutical properties of wild-grown mushrooms of Nepal. EC Microbiol. 2017;12(3):136-45.
14. Valverde ME, Hernández-Pérez T, Paredes-López O. Edible mushrooms: improving human health and promoting quality life. Int J Microbiol. 2015;2015:376387. https://doi.org/10.1155/2015/376387
15. Varghese R, Dalvi YB, Lamrood PY, Shinde BP, Nair CK. Historical and current perspectives on therapeutic potential of higher basidiomycetes: an overview. 3 Biotech. 2019;9:1886-92. https://doi.org/10.1007/s13205-019-1886-2
16. Chaudhary P, Panth N, Raut BK, Pokhrel N, Shrestha N, Shakya S, et al. Biochemical, antimicrobial and antioxidant activities of some wild mushrooms from Nepal. BIBECHANA. 2023;20(2):161-74. https://doi.org/10.3126/bibechana.v20i2.54887
17. Gebrelibanos M, Megersa N, Taddesse AM. Levels of essential and non-essential metals in edible mushrooms cultivated in Haramaya, Ethiopia. Int J Food Contam. 2016;3:2. https://doi.org/10.1186/s40550-016-0025-7
18. Keskin F, Sarikurkcu C, Akata I, Tepe B. Metal concentrations of wild mushroom species collected from Belgrad forest (Istanbul, Turkey) with their health risk assessments. Environ Sci Pollut Res. 2021;27:36193-202. https://doi.org/10.1007/s11356-021-13235-8
19. Sarikurkcu C, Yildiz D, Akata I, Tepe B. Evaluation of the metal concentrations of wild mushroom species with their health risk assessments. Environ Sci Pollut Res. 2021;28:21437-54. https://doi.org/10.1007/s11356-020-11685-0
20. Kozarski M, Klaus A, Jakovljevic D, Todorovic N, Vunduk J, Petrović P, et al. Antioxidants of edible mushrooms. Molecules. 2015;20(10):19489-525. https://doi.org/10.3390/molecules201019489
21. Royse DJ, Baars J, Tan Q. Current overview of mushroom production in the world. In: Edible and medicinal mushrooms: technology and applications. 2017. p. 5-13. https://doi.org/10.1002/9781119149446.ch2
22. Sun M, Zhuang Y, Gu Y, Zhang G, Fan X, Ding Y. A comprehensive review of the application of ultrasonication in the production and processing of edible mushrooms: drying, extraction of bioactive compounds and post-harvest preservation. Ultrason Sonochem. 2024;9:106763. https://doi.org/10.1016/j.ultsonch.2024.106763
23. Rathore H, Prasad S, Sharma S. Mushroom nutraceuticals for improved nutrition and better human health: A review. PharmaNutrition. 2017;5:35-46. https://doi.org/10.1016/j.phanu.2017.02.001
24. Jacinto-Azevedo B, Valderrama N, Henríquez K, Aranda M, Aqueveque P. Nutritional value and biological properties of Chilean wild and commercial edible mushrooms. Food Chem. 2021;356:129651. https://doi.org/10.1016/j.foodchem.2021.129651
25. Hamza A, Mylarapu A, Krishna KV, Kumar DS. An insight into the nutritional and medicinal value of edible mushrooms: A natural treasury for human health. J Biotechnol. 2024;381:86-99. https://doi.org/10.1016/j.jbiotec.2023.12.014
26. Adhikari M, Bhusal S, Pandey M, Raut J, Bhatt LM. Nutritional analysis of selected wild mushrooms from Gaurishankar Conservation Area. Int J Pharmacogn Chin Med. 2019;3:169. https://doi.org/10.23880/ipcm-16000169
27. Procházka P, Soukupová J, Mullen KJ, Tomšík K Jr, Čábelková I. Wild mushrooms as a source of protein: A case study from central Europe, especially the Czech Republic. Foods. 2023;12(5):934. https://doi.org/10.3390/foods12050934
28. Nakalembe I, Kabasa JD, Olila D. Indigenous knowledge and usage of wild mushrooms in Mid-Western Uganda. Afr J Anim Biomed Sci. 2009;4(1). https://www.scirp.org/reference/referencespapers?referenceid=1074918
29. Nakalembe I, Kabasa JD, Olila D. Comparative nutrient composition of selected wild edible mushrooms from two agro-

ecological zones, Uganda. Springerplus. 2015;4:1-5. https://doi.org/10.1186/s40064-015-1188-z

30. Khan MA, Khan LA, Hossain MS, Tania M, Uddin MN. Investigation on the nutritional composition of the common edible and medicinal mushrooms cultivated in Bangladesh. Bangladesh J Mushroom. 2009;3(1):21-8.
31. Amin SR. Performance of different oyster mushroom (*Pleurotus* spp.) varieties [thesis]. Gazipur: Bangabundhu Sheikh Mujibur Rahman Agricultural University; 2002.
32. Cunniff P, Washington D. Official methods of analysis of AOAC International. J AOAC Int. 1997;80(6):127A.
33. AOAC. Official methods of analysis. Washington DC: Association of Official Analytical Chemists; 1995.
34. Kadnikova IA, Costa R, Kalenik TK, Guruleva ON, Yanguo S. Chemical composition and nutritional value of the mushroom *Auricularia auricula-judae*. J Food Nutr Res. 2015;3(8):478-82.
35. Islam MF, Ahsan A, Linkon MR, Sarkar AK, Satter MA, Farhana JA, et al. Comparative assessment of nutritive values and safety characteristics of bread sold in Bangladesh. Food Res. 2021;5:417-25. http://doi.org/10.26656/fr.2017.5(1).450
36. Slinkard K, Singleton VL. Total phenol analysis: Automation and comparison with manual methods. Am J Enol Vitic. 1977;28 (1):49-55.
37. Meda A, Lamien CE, Romito M, Millogo J, Nacoulma OG. Determination of the total phenolic, flavonoid and proline contents in Burkina Fasan honey, as well as their radical scavenging activity. Food Chem. 2005;91(3):571-7.
38. Yang J, Chen C, Zhao S, Ge F, Liu D. Effect of solvents on the antioxidant activity of walnut (*Juglans regia* L.) shell extracts. J Food Nutr Res. 2014;2(9):621-6. http://doi.org/10.12691/jfnr-2-9-15
39. Gomez KA, Gomez AA. Statistical procedures for agricultural research. New York: John Wiley & Sons; 1984. p. 139-53.
40. Bhattacharjya DK, Shamsuzzaman M, Sen A, Mafi AH, Kakon AJ, et al. Evaluation of the nutritive value and metal content of prevalent edible mushrooms in Bangladesh. Res Crops. 2023;24 (3):536-43. https://doi.org/10.31830/2348-7542.2023.ROC-974
41. Chelladurai G, Yadav TK, Pathak RK. Chemical composition and nutritional value of paddy straw milky mushroom (*Calocybe indica*). Nat Environ Pollut Technol. 2021;20(3):1157-64. https://doi.org/10.46488/NEPT.2021.v20i03.023
42. Regula J, Sulibursk J, Siwulski M. Bioavailability and digestibility of nutrients from the dried oyster culinary-medicinal mushroom, *Pleurotus ostreatus* (Agaricomycetes): *In vivo* experiments. Int J Med Mushrooms. 2016;18(8). https://doi.org/10.1615/intjmedmushrooms.v18.i8.40
43. Roy AM, Isaac BR. Nutrient composition and consumer acceptability of cultivated edible mushrooms. Food Sci Indian J Res Food Sci Nutr. 2019;6:19-23. https://doi.org/10.15613/fijrfn/2019/v6i2/190523
44. Pushpa H, Purshothoma KB. Nutritional analysis of wild and cultivated edible medicinal mushrooms. World J Dairy Food Sci. 2010;5:140-4. Available from: https://www.scirp.org/reference/referencespapers?referenceid=1863312
45. Masamba KG, Kazombo-Mwale R. Determination and comparison of nutrient and mineral. Afr J Food Sci. 2010;4:176-9. https://doi.org/10.5897/AJFS.9000070
46. Lavelli V, Proserpio C, Gallotti F, Laureati M, Pagliarini E. Circular reuse of bio-resources: The role of *Pleurotus* spp. in the development of functional foods. Food Funct. 2018;9:1353-72. https://doi.org/10.1039/C7FO01747B
47. Khan MA, Tania M. Nutritional and medicinal importance of *Pleurotus* mushrooms: An overview. Food Rev Int. 2012;28:313-29. https://doi.org/10.1080/87559129.2011.637267
48. Deepalakshmi K, Sankaran M. *Pleurotus ostreatus*: An oyster mushroom with nutritional and medicinal properties. J Biochem Technol. 2014;5:718-26.
49. Reis GC, Guidi LR, Fernandes C, Godoy HT, Gloria MBA. UPLC-UV method for the quantification of free amino acids, bioactive amines and ammonia in fresh, cooked and canned mushrooms. Food Anal Methods. 2020;13:1613-26. https://doi.org/10.1007/s12161-020-01777-5
50. Raman J, Jang KY, Oh YL, Oh M, Im JH, Lakshmanan H, et al. Cultivation and nutritional value of prominent *Pleurotus* spp.: An overview. Mycobiology. 2021;49:1-14. https://doi.org/10.1080/12298093.2020.1835142
51. Alam N, Amin R, Khair A, Lee TS. Influence of different supplements on the commercial cultivation of milky white mushroom. Mycobiology. 2010;38:184-8. https://doi.org/10.4489/MYCO.2010.38.3.184
52. Bach F, Helm CV, Bellettini MB, Maciel GM, Haminiuk CWI. Edible mushrooms: a potential source of essential amino acids, glucans and minerals. Int J Food Sci. 2017;52:2382-92. https://doi.org/10.1111/ijfs.13522
53. Uju NL, Obiakor-Okeke PN. Nutritional profile of three different mushroom varieties consumed in Amaifeke, Orlu Local Government Area, Imo State, Nigeria. Food Sci Qual Manag. 2014;31:70-8.
54. Yang JH, Lin HC, Mau JL. Non-volatile taste components of several commercial mushrooms. Food Chem. 2001;72:46. https://doi.org/10.1016/S0308-8146(00)00262-4
55. Debnath G, Das P, Sah AK. Screening of toxicity test and extracellular laccase enzyme of some wild edible mushrooms of Tripura, Northeast India. Res J Life Sci Bioinform Pharm Chem Sci. 2018;4:586-93. https://doi.org/10.26479/2018.0404.52
56. Jonathan SG, Esho EO. Fungi and aflatoxin detection in two stored oyster mushrooms (*Pleurotus ostreatus* and *Pleurotus pulmonarius*) from Nigeria. Elec J Env Agricult Food Chem. 2010;9:1722-30.
57. Olayinka AA. Evaluation of the nutritional status of two edible mushroom species in Ekiti State, Nigeria. Evaluation. 2016;51:32-6.
58. Mukhopadhyay R, Guha AK. A comprehensive analysis of the nutritional quality of edible mushroom *Pleurotus sajor-caju* grown in deproteinized whey medium. LWT-Food Sci Technol. 2015;61:339-45. https://doi.org/10.1016/j.lwt.2014.12.055
59. Akpoghelie JO, Irerhievwie GO. Nutritional and metal composition of *Lepiota procera*, *Boletus edulis* and *Boletus badius* mushroom species in Owhelogbo, Isoko North Local Government Area of Delta State, Nigeria. Int J Sci Res. 2015;4:1182-5. https://www.ijsr.net/articlerating.php?paperid=SUB157356
60. Sarker NC, Hossain MM, Sultana N, Mian H, Karim AJMS, Amin SMR. Performance of different substrates on the growth and yield of *Pleurotus ostreatus* (Jacquin ex Fr.) Kummer. Bangladesh J Mushroom. 2007;1:9-20.
61. Deepalakshmi K, Mirunalini S. *Pleurotus ostreatus*: an oyster mushroom with nutritional and medicinal properties. J Biochem Technol. 2014;5:718-26.
62. Adejumo TO, Awosanya OB. Proximate and mineral composition of four edible mushroom species from South Western Nigeria. Afr J Biotechnol. 2005;4:1084-8. https://www.ajol.info/index.php/ajb/article/view/71255
63. Shbeeb DA, Farahat MF, Ismail HM. Macronutrients analysis of fresh and canned *Agaricus bisporus* and *Pleurotus ostreatus* mushroom species sold in Alexandria markets, Egypt. Prog Nutr. 2019;21:203-9. http://doi.org/10.23751/pn.v21i2-S.6453
64. Alam N, Amin R, Khan A, Ara I, Shim MJ, Lee MW, et al. Nutritional analysis of cultivated mushrooms in Bangladesh-*Pleurotus ostreatus*, *Pleurotus sajor-caju*, *Pleurotus florida* and *Calocybe*

indica. Mycobiology. 2008;36:228-32. https://doi.org/10.4489/MYCO.2008.36.4.228

65. Mirończuk-Chodakowska I, Socha K, Zujko ME, Terlikowska KM, Borawska MH, Witkowska AM. Copper, manganese, selenium and zinc in wild-growing edible mushrooms from the eastern territory of "Green Lungs of Poland": nutritional and toxicological implications. Int J Environ Res Public Health. 2019;16:3614. https://doi.org/10.3390/ijerph16193614
66. Obodai M, Ferreira ICFR, Fernandes A, Barros L, Mensah DLN, Dzomeku M, Urben, et al. Evaluation of the chemical and antioxidant properties of wild and cultivated mushrooms of Ghana. Molecules. 2014;19:19532-48. https://doi.org/10.3390/molecules191219532
67. Dowlati M, Sobhi HR, Esrafili A, FarzadKia M, Yegane M. Heavy metals content in edible mushrooms: a systematic review, meta-analysis and health risk assessment. Trends Food Sci Technol. 2021;109:527-35. https://doi.org/10.1016/j.tifs.2021.01.064
68. Ahmed S, Mahd MM, Nurnabi M, Alam MZ, Choudhury TR. Health risk assessment for heavy metal accumulation in leafy vegetables grown on tannery effluent contaminated soil. Toxicol Rep. 2022;9:346-55. https://doi.org/10.1016/j.toxrep.2022.03.009
69. Woldegiorgis AZ, Abate D, Haki GD, Ziegler GR. Antioxidant property of edible mushrooms collected from Ethiopia. Food Chem. 2014;157:30-6. http:// doi.org/10.1016/S0308-8146(00)00262-4
70. Smolskaitė L, Venskutonis PR, Talou T. Comprehensive evaluation of antioxidant and antimicrobial properties of different mushroom species. LWT-Food Sci Technol. 2015;60:462-71. https://doi.org/10.1016/j.lwt.2014.08.007
71. Sifat N, Lovely F, Zihad SNK, Hossain MG, Shilpi JA, Grice ID, et al. Investigation of the nutritional value and antioxidant activities of common Bangladeshi edible mushrooms. Clin Phytosci. 2020;6:1-10.
72. Medeiros RL, Andrade GM, Crispim RB, Silva NN, Silva SA, Souza HAN, et al. Nutritional and antioxidant potential of *Pleurotus djamor* (Rumph. ex Fr.) Boedijn produced on agronomic wastes banana leaves and sugarcane bagasse substrates. Braz J Microbiol. 2024;55:1117-29. https://doi.org/10.1007/s42770-024-01336-8
73. Raman J, Lakshmanan H, Jang KY, Oh YL, Im JH. Nutritional composition and antioxidant activity of pink oyster mushrooms (*Pleurotus djamor var. roseus*) grown on a paddy straw substrate. J Mushrooms. 2020;18:189-200. http://doi.org/10.14480/JM.2020.18.3.189
74. Chowdhury MMH, Kubra K, Ahmed SR. Screening of antimicrobial, antioxidant properties and bioactive compounds of some edible mushrooms cultivated in Bangladesh. Ann Clin Microb Antimicrob. 2015;14:1-6. https://doi.org/10.1186/s12941-015-0067-3
75. Egra S, Kusuma IW, Arung ET, Kuspradini H. The potential of white -oyster mushroom (*Pleurotus ostreatus*) as antimicrobial and natural antioxidant. Biofarmasi J Nat Prod Biochem. 2019;17:14-20. https://doi.org/10.13057/biofar/f170102
76. Okafor DC, Onuegbu NC, Odimegwu NE, Ibeabuchi JC, Njoku NE, Agunwa IM, et al. Antioxidant and antimicrobial activities of oyster mushroom. Am J Food Sci Technol. 2017;5:64-9. http://doi.org/10.31989/ffhd.v10i11.751

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

Publisher information: Plant Science Today is published by HORIZON e-Publishing Group with support from Empirion Publishers Private Limited, Thiruvananthapuram, India.