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Research Article

Nutritional Composition, Mineral Contents, and Antioxidant Activities of Eight Common Wild Edible Mushrooms from Champhai District, Mizoram, India

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Abstract

Eight common wild edible mushrooms from Champhai district located in the eastern part of Mizoram state, India, were selected for their nutritional composition, mineral contents and antioxidant activities using standard protocols. The nutritional values were evaluated on a dry weight basis, and the mushrooms showed high total protein (19.53 ± 0.20-64.01 ± 0.10g/100g) and total carbohydrate (6.17 ± 0.22-53.53 ± 0.15g/100g) contents, but low fat contents (2.24 ± 0.14-5.83 ± 0.15g/100g). The most abundant mineral in all the wild edible mushrooms was potassium, which ranges from 2411.59 ± 3.70-1033.29 ± 9.57 mg/100g. In the principal component analysis between multivariate data information (nutrients and minerals), 95.8% of the variance was retained by the first four principal components. The first and second principal components were related to most of the nutrient and mineral contents. The methanolic extracts on selected mushrooms revealed that they all have good antioxidant capacity with DPPH (IC50 = 31 ± 0.29-144 ± 0.25 µg/ml) and ABTS (IC50 = 42.2 ± 0.36-86.55 ± 0.30 µg/ml). Strong DPPH and ABTS radical scavenging activity was observed in mushroom extracts containing more phenols than flavonoid, which suggested that phenolic compounds might be the main antioxidant components present in mushroom extracts, which contributed to their high antioxidant activity. The current study revealed that wild edible mushrooms could be a good source of nutritional and antioxidant components. The results of this study can therefore be used to promote local consumption of mushrooms as functional foods and for commercial purposes while also promoting their habitat preservation. It is worth noting that this was the first study on the nutritional composition, mineral content and antioxidant properties of Mizoram's wild edible mushrooms.

Keywords: Wild Edible Mushrooms; Nutritional Values; Mineral Contents; Antioxidant Activities; Principal Component Analysis; Champhai District; Mizoram

Abbreviations

WEMs: Wild Edible Mushrooms; DPPH: 2,2-Diphenyl-1-Picryl Hydrazyl; ABTS: 2,2'-Azino-Bis(3-Ethylbenzothiazoline) 6-Sulphonic Acid; BHT: Butylated Hydroxyl Toluene; GAE: Gallic Acid Equivalent; QE: Quercetin Equivalent; AOAC: Association of Official Analytical Chemists; AAS: Atomic Absorption Spectrophotometer; PCA: Principal Component Analysis; dw: Dry Weight; fw: Fresh Weight

Introduction

In many cultures, mushrooms are referred to as "vegetable meat" and are highly regarded as culinary delights [14]. They are thought to be the most underutilized source of nutrient-rich meals, nonetheless [37]. The focus of research into the nutritional value of mushrooms has recently switched to the study of the physiologically active chemicals that are found in mushrooms because these substances also have medical implications for consumer health [36]. Protein, sugar, glycogens, lipids, vitamins, amino acids, and crude fibers are all essential elements that the body needs to function normally. It can be used as food to combat malnutrition in developing countries such as India [30].

Antioxidants are essential to our health because they act as our first line of defense against free radical damage. They are chemical compounds that protect cells from free radical damage and are produced exogenously or obtained from food to slow the progression of chronic diseases [7]. Antioxidant activity in common wild edible mushrooms has recently been discovered, and it is closely related to their total phenolic and polyphenol content [29].

Among the bioactive molecules, phenolic acids have received special attention because they have been reported to be the primary antioxidant properties of mushrooms [5]. Several in-vitro

studies on various mushrooms revealed that mushrooms with high phenolic content had a high antioxidant effect [4]. In addition to phenols, flavonoids are also anticarcinogenic, anti - mutagenic, and cardioprotective, as well as having antioxidant properties [6].

There are currently 17 wild edible mushroom species listed in the Champhai district of Mizoram, India, [32]. however, despite being a highly prized state delicacy, there have been no reports of the antioxidant and nutritional value. The objective of this study was to determine the nutritional value, mineral content, and antioxidant activity of eight common wild edible mushrooms found in Champhai District, Mizoram, India *viz., Lactarius piperatus*, *Lactfluus corrugis*, *Lentinus polychrous, Macrolepiota dolichaula*, *Russula adusta, Russula subfragiliformis, Schizophyllum commune* and *Termitocytes heimii* (Table 1).

Sl. No	Scientific Name	Family	Habitats	Source forests	Growth stages
1	*Lactarius piperatus* (L.) Roussel	Russulaceae	Soil	Zote, Tlangsam, Ngur, Mualkawi, Vangchhia	Fruiting
2	*Lactifluus corrugis* (Peck) Kuntze	Russulaceae	Soil	Zote, Ngur, Tlangsam, Mualkawi, Vangchhia	Fruiting
3	*Lentinus polychrous* Lév.	Polyporaceae	Dead & decaying wood	Ngur, Zote, Tlangsam, Mualkawi	Fruiting
4	*Macrolepiota dolichaula* (Berk. & Broome)	Agaricaceae	Soil	Zote, Vangchhia, Khuangleng, Ngur	Fruiting
5	*Russula adusta* (Pers.) Fr.	Russulaceae	Soil	Vangchhia, Khuangleng, Ngur	Fruiting
6	*Russula subfragilliformis* Murrill	Russulaceae	Soil	Zote, Ngur, Tlangsam, Mualkawi	Fruiting
7	*Schizophyllum commune* Fr.	Schizophyllaceae	Dead & decaying wood	Zote, Ngur, Tlangsam, vangchhia	Fruiting
8	*Termitomyces heimii* Natarajan	Lypophyllaceae	Termite mound	Mualkawi	Fruiting

Table 1: General information about the collected wild edible mushrooms from Champhai District, Mizoram, India.

Materials and Methods

Study area

The fruiting bodies of mushrooms specimen was collected from Champhai district, located 196 kilometers (23.4454 ^{0}N and 93.1780 ^{0}E) from Aizawl, Mizoram, India. The district occupies an area of 3,185.83 km^{2}. For this study, five different forests (Zote, Tlangsam, Ngur, Khuangleng and Vangchhia forests) were selected for the collection of wild edible mushrooms (Figure 1).

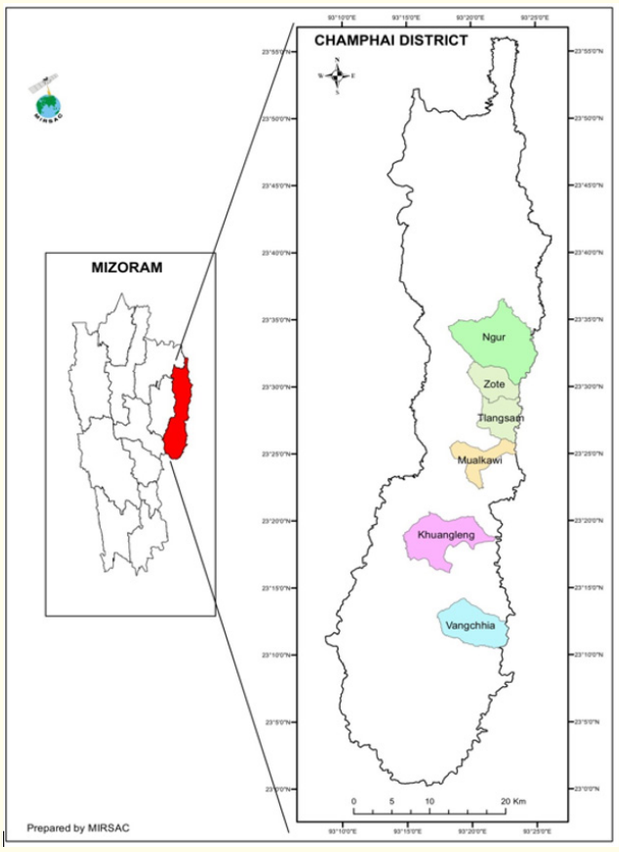

Figure 1: Study sites of Champhai District, Mizoram, India.egory.

Sample collection, preparation and identification

Vishniac., *et al.* (1978) recommendations were followed when collecting mushrooms [39]. After drying in a hot air oven (40-50 0C), it was grounded with mortar and pastel which was used for further testing. The specimens were identified using standard mushroom identification manuals such as www.mushroomexpert.com, www.mycokey.com, mycobank.org, and www.fungusid.com, as well as relevant literature and anatomical aspects [38].

Sample extract preparation

Each 5g sample of finely dried powdered mushrooms was extracted with 50 mL of 80% methanol at 150 rpm using a magnetic

stirrer for 24 h at 25 ^{0}C before being filtered through Whatman No. 1 filter paper. Filtrates were collected and the residue was re-extracted with 50 mL of methanol, centrifuged at 5000 rpm for 10 minutes, and evaporated before being stored at -20 °C until needed.

Nutritional composition

The Association of Official Analytical Chemists methods (AOAC 2005) were followed to determine the nutritional value of the investigated wild edible mushrooms [3]. To determined moisture content, the samples were dried in an oven at 70 0C until constant weight were obtained. Crude fiber and ash content was determined by weighing the residue after burning at 550 0C for 3 h in muffle furnace. Total carbohydrate was determined following Anthrone method [31]. Total protein was determined according to the method of Lowry., *et al*. (1951) [22]. Crude fat content was determined using Soxhlet apparatus by extracting known weight of mushrooms powdered sample with petroleum ether. The total energy content was determined by the value obtained for protein, carbohydrates, and fats multiplied by 4.00, 4.00, and 9.00 respectively, and adding up the values (AOAC 2005).

DPPH free radical scavenging activity

The DPPH free radical scavenging activities of mushroom samples were determined using the method of Muthoni Guchu., *et al*. (2020) with slight modification [26]. In brief, 0.1 mM DPPH solution in methanol was prepared, and 1 mL of this solution was added to 2 mL of different concentrations of mushroom extracts (10-100 µg/mL). The mixture was vigorously shaken and allowed to stand in the dark at room temperature for 30 minutes. The absorbance was then measured in a UV-vis spectrophotometer at 517 nm. The following equation was used to calculate the ability to scavenge the DPPH free radical: DPPH scavenge (%) = $(A_0 - A_1)/A_0 \times 100\%$, where A_1 is the absorbance value of the solution with different samples and A_0 is the absorbance value of the DPPH solution without samples.

ABTS radical scavenging activity

The ABTS activity of each mushroom extract was determined using a modified method of Seal (2014) [35]. For the formation of green-colored ABTS, an equal proportion (1_v:1_v) of ABTS (7 mM) mixed with K_2S_2O (2.45 mM) was left in the dark for 16-18 h. The ABTS solution was further diluted with methanol (1_v:1_v) to produce a working solution with the absorbance of 0.700 ± 0.005 at 745 nm. The resulting ABTS solution was then mixed with 1mL of plant extract or standard (BHT) at varying concentrations (10 -100 µg/mL) and allowed to stand in the dark for 7 min and the absorbance was measured at 745 nm. The following equation was used to calculate the percentage inhibition of samples and standards: ABTS scavenge (%) = $(A_0 - A_1)/A_0 \times 100\%$, where A_1 is the absorbance value of the solution with different samples and A_0 is the absorbance value of the ABTS solution without samples.

Determination of total phenolic content

The total phenolic content (TPC) of the mushroom sample was determined by Folin-ciocalteau method with slight modification [21]. Briefly, 1 mL of the sample, 0.5 mL of Folin-ciocalteau (1:10) reagent was added. After 5 min, 1.5mL of sodium carbonate (20%) was added and incubated at room temperature for 60 min. The absorbance was measured at 765 nm. Different concentrations of Gallic acid (20-100 µg/mL) were used in the same manner for calibration of the standard curve, and quantification was done in terms of mg equivalent of Gallic Acid (mg GAE/g dw).

Determination of total Flavonoid content

Using quercetin as a standard, the total flavonoid concentration was assessed using aluminium chloride ($AlCl_3$) with a small modification [34]. To that 4 mL of distilled water was combined with 1 mL of standard quercetin solution (20-100 µg/mL), then 0.03 mL of $NaNO_2$ (5%) was added. 0.03 mL of $AlCl_3$ (10%) was added after five minutes at 25 °C. 0.2 mL (1 mM) NaOH was added after 5 min intervals. The final volume was made to 10 mL with distilled water, and the absorbance was measured at 510 nm. A quercetin standard curve was used to calculate the flavonoid contents and distilled water was used as blank. Results of total flavonoid contents were expressed in quercetin equivalent (mg QE/g dw) and calculated from the prepared standard curve.

Determination of mineral content

Determination of mineral elements in the dry samples were done following the wet digestion extraction method [40]. The powdered samples (0.2g) were digested using 5 mL nitric acid (HNO_3) and 2 mL perchloric acid ($HClO_4$). The solution was filtered after adding 15 mL of distilled water into a 50 mL volumetric flask and the volume was made up to mark with distilled water. The minerals in the digested samples were then determined by AAS following the development of colour with ammonium molybdate.

Statistical analysis

All the results were expressed in means of five replicates (mean ± SD) and analyzed by one-way analysis of variance (ANOVA) followed by a post hoc test using Duncan's multiple range tests for comparison of statistical significance ($P < 0.05$). Pearson's correlation coefficients were calculated in order to measure the linear correlation between variables. All statistical calculations were performed using R-Studio (V.4.1.2) and SPSS (V.16) statistical software. The packages 'ggplot2', 'factoextra' and 'FactoMineR' were used for plotting graphs using R-Studio (V.4.1.2).

Results and Discussion

Investigated wild edible mushrooms

Eight common wild edible mushrooms harvested by the local people of Champhai district, belonging to 7genera and 5 families

were sampled to determined their nutritional composition, mineral content and antioxidant activities. Among the selected mushrooms five species were soil growing (*L. corrugis*, *L. piperatus*, *R. subfragiliformis*, *R. adusta* and *M. dolichaula*), two species from dead and decaying wood (*S. commune* and *L. polychrous*) and one species from termite mound (*T. heimii*) (Table 1).

Nutritional composition

The nutritional composition of the mushroom samples was shown in table 2, with values expressed on dry weight (dw) basis. But the moisture content was determined on fresh weight (fw) basis. The range of variance for several parameters is as follows: 85.37- 93.19% for moisture content, of 5.67 to 15.33% for ash, 33.16- 9.16% for fiber, 19.53- 64.01g/100g dw for protein, 53.53-6.17g/100g dw for carbohydrates; and 5.83-2.24g/100g dw for fat.

Sl.No	Scientific Name	Moisture content (%)	Total Ash (%)	Crude Fiber (%)	Total Protein (g/100g)	Total Carbohydrates (g/100g)	Fat(g/100g)	Energy (Kcal/100g)
1	*L.corrugis*	91.3 ± 0.27^{b}	15.33 ± 0.24^{a}	33.16 ± 0.06^{a}	34.46 ± 0.19^{b}	45.47 ± 0.22^{b}	3.56 ± 0.23^{c}	351.96
2	*L.piperatus*	88.82 ± 0.25^{c}	6.89 ± 0.07^{f}	12.07 ± 0.05^{g}	19.53 ± 0.20^{g}	10.47 ± 0.21^{f}	5.14 ± 0.16^{b}	166.64
3	*L.polychrous*	86.19 ± 1.90^{e}	14.93 ± 0.06^{a}	28.39 ± 0.15^{c}	25.83 ± 0.14^{e}	7.88 ± 0.15^{g}	2.46 ± 0.23^{d}	157.54
4	*M.dolichaula*	89.36 ± 0.31^{c}	14.35 ± 0.24^{b}	29.57 ± 0.10^{b}	22.63 ± 0.30^{f}	53.53 ± 0.15^{a}	3.27 ± 0.25^{c}	333.62
5	*R. adusta*	93.19 ± 0.31^{a}	11.13 ± 0.15^{d}	16.83 ± 0.11^{e}	29.40 ± 0.27^{d}	34.21 ± 0.21^{d}	5.83 ± 0.15^{a}	307.59
6	*R.subfragiliformis*	90.34 ± 0.49^{b}	13.62 ± 0.14^{c}	20.43 ± 0.19^{d}	31.25 ± 0.26^{c}	37.54 ± 0.22^{c}	6.21 ± 0.24^{a}	330.28
7	*S.commune*	85.37 ± 0.29^{e}	7.84 ± 0.05^{e}	13.55 ± 0.02^{f}	26.38 ± 0.28^{e}	6.17 ± 0.22^{h}	2.24 ± 0.14^{d}	150.9
8	*T. heimii*	87.19 ± 0.23^{d}	5.67 ± 0.03^{g}	9.16 ± 0.11^{h}	64.01 ± 0.10^{a}	20.86 ± 0.20^{e}	3.35 ± 0.23^{c}	369.57

Table 2: Nutritional composition of selected Wild Edible Mushrooms.

*Means followed by different letters within same column are significantly different according to Duncan's multiple range comparisons (DMRTs) ($P < 0.05$).

**Means followed by same letter are not significantly different. Each value was represented as means ± SD (n = 5).

The total moisture content of WEMs was found to be highest in *R. adusta* (93.19%) and lowest in *S. commune* (85.37%) in the current study. Our findings are nearly identical to those of recent studies that reported moisture content greater than 80% [19]. Many edible mushrooms benefit from moisture content in terms of texture, palatability, and shelf life [33]. As a result, the nutritional value of edible mushrooms was concerned with their dry matter content and specific composition, which can range from 3-15% in fresh mushroom [29]. Our study revealed that the dry matter contents ranged from 6.81% in *R. adusta* to 14.63% in *S. commune*, indicating that they have a high nutritional value.

The total ash content of selected WEMs was in the range of 5.67% to 15.33%, which was higher than the finding of Ouzouni., *et al.* (2009) [28]. The highest ash content (%) was observed in *L. corrugis* (15.33%), followed by *L. polychrous* (14.93%), *M. dolichaula* (14.35%), *R. subfragiliformis* (13.62%), *R. adusta* (11.3%), *S. commune* (7.84%), *L. piperatus* (6.89%), and the lowest ash content was observed in *T. heimii* (5.67%). The primary components of mushroom ash are potassium and phosphorus [25]. *T. heimii* had a total ash content of 5.67%, which was significantly lower than the finding of Johnsy., *et al*. (2011) [20]. In contrast, (Barros., *et al*. 2008) reported that the ash content of wild and cultivated mushrooms ranged from 7.07 to 16.48%, which agrees with the findings in our study.

Evaluation of crude fiber revealed that *L. corrugis* (33.16%) had the highest percentage, followed by *M. dolichaula* (29.57%), *L. polychrous* (28.39%), *R. subfragiliformis* (20.43%), *R. adusta* (16.83%), *S. commune* (13.55%), *L. piperatus* (12.07%), and the least content of crude fiber was observed in *T. heimii* (9.16%), significant difference was observed among the species. Fresh mushrooms had a high amount of fiber, which may account for their relatively high ash content [12]. The crude fiber content of selected mushrooms ranged from 9.16 to 33.16%, which was nearly similar to the finding of Ache., *et al*. (2020)[1]. and Chittaragi., *et al*. (2014) [13].

Protein are the most abundant macronutrients and was highest in *L. piperatus* (64.01g/100g dw), while, *T. heimii* recorded the lowest content (19.53g/100g dw). High level of protein was also observed in *L. corrugis* (34.46g/100g dw), *R. subfragiliformis* (31.25g/100g dw), *R. adusta* (29.40g/100g dw) and *S. commune* (26.38g/100g dw). However, no significant difference ($p \leq 0.05$) were found in protein content of *L. polychrous* and *S. commune* (both of which are wood growing). The protein content of wild edi-

ble mushrooms is significantly higher than that of commercial leafy vegetables such as cabbage (1.8g/100g), cauliflower (2.6g/100g), potato (1.62g/100g), and spinach (2.00g/100g) [18]. This demonstrated that mushrooms are higher in protein than green vegetables. The total protein content of the WEMs was found to be higher than the carbohydrate content previously studied [24].

Carbohydrates content of the eight WEMs varies from 6.17g/100g dw (*S. commune*) to 53.53g/100g dw (*M. dolichaula*) with significant difference among the species ($p > 0.05$). The results are in accordance with both bioavailable (sugars, glycogen, and starch) and non-bioavailable (chitin, hemicellulose, pectic materials, -glucans, and mannans) carbohydrates. Almost all the studied species had similar range of carbohydrate content to other studies on edible mushrooms [2].

The evaluation of total fat content from selected WEMs revealed that *R. adusta* had the highest fat content (5.83g/100g dw) and the lowest fat content was observed in *S.commune* (2.24g/100g dw), which was nearly identical to the results reported by (Ouzouni., *et al.* 2009). The genus *Lactifluus, Macrolepiota* and *Termitomyces* had no significant difference in fat content ($p \leq 0.05$). Since edible mushrooms have a low-fat content, a high biological value, and the ability to improve people's health, they are regarded as a healthy food source [15].

The highest energy content/calorific value was observed in *T. heimii* 369.57 (Kcal/100g dw), while *S. commune* showed the lowest calorific value 150.9 (Kcal/100g dw). Total energy in *T. heimii* was 369.57 Kcal/100g dw, which was higher than the reported value from three different *Termitomyces* species (255.57 to 263.08 Kcal/100g dw) [27]. The low energy content of *L. polychrous* (157.54 Kcal/100g dw) and *S. commune* (150.9 Kcal/100g dw) could be attributed to their low-fat contents.

Our findings revealed that among the eight edible mushrooms studied, protein and carbohydrate were the main components, while fat and ash contents were the lowest, implying that the mushrooms studied are a good source of protein, carbohydrates, and low fat. As a result, they have high nutritional significance and are ideal for low-calorie diets.

Mineral contents

The metal concentrations were all calculated on a dry weight basis. Potassium was found to be the most abundant mineral among the eight wild edible mushrooms, with concentrations ranging from 2411.59 mg/100g in *L. polychrous* to 1033.29 mg/100g in *T. heimii*. Phosphorus levels in *R. adusta* and *T. heimii* ranged from 185.29 mg/100g to 834.3 mg/100g, respectively. Mangesium levels in *L. polychrous* were found to be highest (328.51 mg/100g) and lowest (136.71 mg/100g).

In *T. heimii*. Significant differences among the species were observed in phosphorous, potassium and mangesium. Among the eight edible mushrooms, *M. dolichaula* had the highest calcium content (126.46 mg/100g) and *L. piperatus* had the lowest calcium content (32.34 mg/100g). Iron was found to be in the range of 12.04 to 74.70 (mg/100g) in *T. heimii* and *L. corrugis*, while zinc was found to be in the range of 2.83 to 10.8 (mg/100g) in *T. heimii* and *L. polychrous*. The lowest mineral found was copper, with *M. dolichaula* 5.78 (mg/100g) having the highest copper concentration and *T. heimii* 1.06 (mg/100g) having the lowest content (Table 3).

Sl. No	Scientific Name	Iron (Fe)	Calcium (Ca)	Zinc (Zn)	Copper (Cu)	Potassium (K)	Magnesium (Mg)	Phosphorus(P)
1	*L.corrugis*	74.7 ± 1.85^{a}	101.03 ± 6.03^{c}	8.99 ± 1.89^{ab}	3.09 ± 0.54^{bc}	1870.45 ± 8.90^{d}	200.50 ± 2.50^{b}	237.44 ± 1.29^{f}
2	*L.piperatus*	16.5 ± 0.35^{f}	32.34 ± 2.64^{e}	4.41 ± 1.76^{bc}	1.95 ± 0.37^{cd}	2261.84 ± 6.35^{b}	152.09 ± 1.88^{d}	312.07 ± 1.48^{c}
3	*L.polychrous*	65.6 ± 1.27^{b}	126.46 ± 3.01^{a}	10.8 ± 1.67^{a}	4.41 ± 0.41^{ab}	2411.59 ± 3.70^{a}	328.51 ± 2.50^{a}	332.39 ± 2.06^{b}
4	*M.dolichaula*	54.8 ± 2.86^{c}	130.16 ± 2.86^{a}	7.82 ± 1.78^{bc}	5.78 ± 0.66^{a}	1613.88 ± 5.82^{e}	139.04 ± 1.88^{e}	264.28 ± 0.76^{e}
5	*R. adusta*	24.02 ± 0.83^{e}	88.65 ± 1.70^{d}	5.42 ± 1.82^{bc}	1.45 ± 0.19^{d}	1274.29 ± 7.27^{g}	142.11 ± 1.88^{e}	185.29 ± 0.87^{h}
6	*R.subfragiliformis*	31.54 ± 2.01^{d}	112.14 ± 2.13^{b}	6.41 ± 2.11^{bc}	2.06 ± 0.55^{cd}	1417.66 ± 5.46^{f}	175.42 ± 1.56^{c}	211.85 ± 2.27^{g}
7	*S.commune*	14.56 ± 1.43^{f}	38.54 ± 2.25^{e}	5.07 ± 1.46^{bc}	2.00 ± 0.52^{cd}	2214.04 ± 9.82^{c}	157.84 ± 3.44^{d}	302.32 ± 1.39^{d}
8	*T. heimii*	12.04 ± 1.38^{f}	34.37 ± 3.02^{e}	2.83 ± 1.01^{c}	1.06 ± 0.25^{d}	1033.29 ± 9.57^{h}	136.71 ± 1.69^{e}	834.30 ± 1.28^{a}

Table 3: Major and Trace elements concentrations (mg/100g in dry weight) in selected Wild Edible Mushrooms.

*Means followed by different letters within same column are significantly different according to Duncan's multiple range comparisons (DMRTs) ($P < 0.05$).

**Means followed by same letter are not significantly different. Each value was represented as means ± SD ($n = 5$).

Potassium, phosphorous, and magnesium had been reported to be the most abundant minerals in edible mushrooms, but iron and zinc are scarce [10]. The most abundant minerals in all of the studied WEMs were potassium, phosphorous, and magnesium; a similar finding was reported by [17]. Iron, zinc and copper were the traced elements and their concentrations in wild edible mushrooms were similar to the finding of Mallikarjuna., *et al*. (2013) [23].

Principal component analysis

The multivariate data information (nutrients and minerals) contained in the studied WEMs was analysed using Principal Component Analysis (PCA). The Eigenvalues were observed to be 6.58, 3.92, 2.09 and 0.82 for the first four principal components which measure the variation retained by the principal components. To determine how much principal components was to be considered, the percentage of variance from screeplot (Figure 2d) was evaluated. The first four major components accounted for 95.8% of the variance. In PC1(47%), the variables like ash, crude fiber, zinc, calcium, Iron, copper and magnesium were positively correlated whereas protein and phosphorous were negatively correlated. The second, PC2 (28%) showed positive correlation between moisture, carbohydrate and energy, and negative correlation with potassium and magnesium. PC3(14.9%) depicted positive correlation between protein and phosphorous but negatively with fat and moisture. The fourth principal component, PC4 (5.9%), correlated positively with magnesium and fat while negatively with copper and carbohydrate (Figure 2c). The biplot of individuals and variables in PC1 and PC2 (Figure 2a) depicted that *L. polychrous* had high content of K, Mg and Zn. Whereas, *T. heimii* had high content of P and protein. Similarly, in PC3 and PC4 (Figure 2b), *M. dolichaula* showed high Cu and Carbohydrate contents.

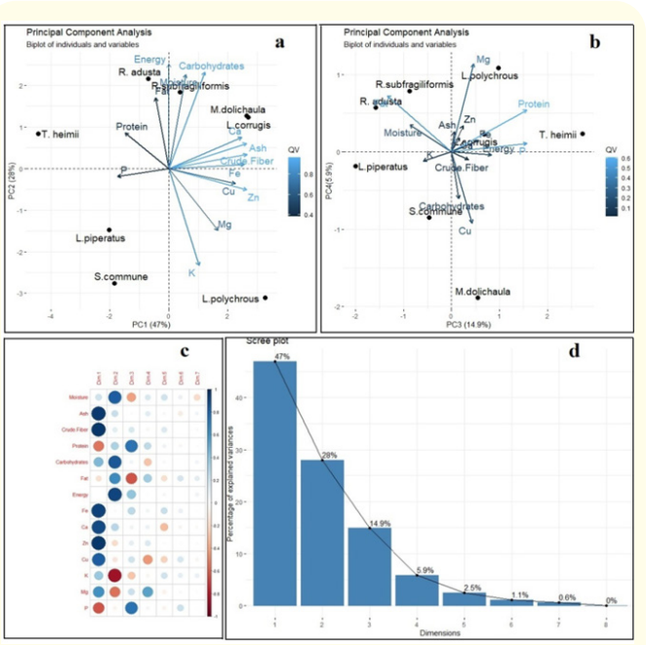

Figure 2: (a-d) Principal Component Analysis (PCA) of WEMs with nutrients and minerals composition, (a) Biplot of individuals and variables (PC1 and PC2), (b) Biplot of individuals and variables (PC3 and PC4), (c) Principal components and their relation with variables, (d) Contribution of each principal component to total variance.

Determination of DPPH and ABTS free radical scavenging activities

The result of the DPPH radical scavenging activity of the eight edible mushroom extracts and BHT was concentrations dependent. The result indicated that *S. commune* had the strongest DPPH radical scavenging activity (69.45%) with an IC_{50} value of 31.12 ± 0.29 µg/mL and R. adusta had the weakest DPPH radical scaveng-

Sl. No.	Mushroom Species	DPPH IC_{50} ± SD(µg/ml)	ABTS IC_{50} ± SD(µg/ml)	TPC (Mg GAE/g ± SD)	TFC (Mg QE/g ± SD)
1	BHT	12.55 ± 0.24^{i}	22.86 ± 0.13^{h}	-	-
2	*L. corrugis*	77.01 ± 0.20^{g}	50.14 ± 0.25^{f}	17.5 ± 0.45^{b}	4.83 ± 0.56^{b}
3	*L. piperatus*	125.2 ± 0.25^{c}	63.84 ± 0.23^{c}	6.83 ± 0.69^{d}	0.67 ± 0.20^{d}
4	*L. polychrous*	103.8 ± 0.45^{d}	55.02 ± 0.22^{e}	13.17 ± 0.55^{c}	0.97 ± 0.20^{d}
5	*M. dolichaula*	80.11 ± 0.29^{f}	54.74 ± 0.36^{e}	16.21 ± 0.81^{b}	2.13 ± 0.41^{c}
6	*R. adusta*	144.5 ± 0.25^{a}	86.55 ± 0.30^{a}	3.07 ± 0.28^{e}	0.09 ± 0.03^{d}
7	*R. subfragiliformis*	83.06 ± 0.23^{e}	58.63 ± 0.25^{d}	15.74 ± 0.74^{b}	1.07 ± 0.12^{d}
8	*S. commune*	31.12 ± 0.29^{h}	42.2 ± 0.36^{g}	19.55 ± 0.85^{a}	7.17 ± 0.40^{a}
9	*T. heimii*	141.5 ± 0.51^{b}	77.22 ± 0.36^{b}	4.78 ± 0.55^{e}	0.35 ± 0.14^{d}

Table 4: Evaluation of antioxidant activities (DPPH and ABTS), total phenol and total flavonoid contents of selected Wild Edible Mushrooms.

*Means followed by different letters within same column are significantly different according to Duncan's multiple range comparisons (DMRTs) ($P < 0.05$).

**Means followed by same letter are not significantly different. Each value was represented as means ± SD (n = 5).

ing activity (35.14%) with an IC_{50} value of 144.51 ± 0.25 µg/mL as compared to standard Butylated Hydroxy Toluene (91.52%) with an IC_{50} of 12.55 µg/mL as shown in table 4 and figure 3a.

The percentage of ABTS free radical scavenging activity was highest in *S. commune* (87.23%) at a concentration of 100 µg/mL with an IC_{50} value of 42.2 µg/mL and *R. adusta* showed the weakest scavenging activity (52.12%) with an IC_{50} value of 86.55 µg/mL. The standard BHT was 95.2% with IC_{50} of 22.86 µg/mL (Table 4 and Figure 3b).

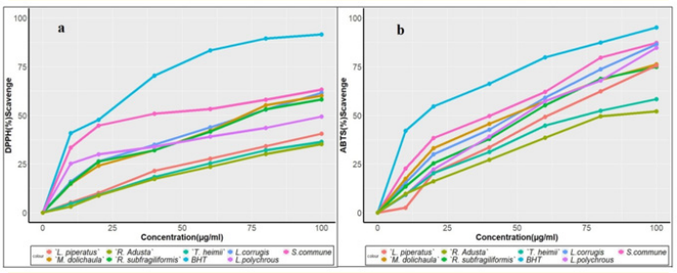

Figure 3: (a, b). Comparisons between the percentages of radical scavenging activity of WEMs extract with positive control BHT, (a) DPPH scavenging activity, (b) ABTS scavenging activity.

Total phenolic and flavonoid content

Numerous studies have reported that the antioxidant activity of mushrooms and plants extracts are directly correlated to their phenolic and flavonoid content [9]. Total phenolic contents in different mushroom extracts were shown in table 4 and were expressed as mg Gallic acid equivalents/g extract. The total phenol content of the eight WEMs varies from 19.55 mg GAE/g in *S. commune*, and lowest 3.07 mg GAE/g extract in *R. adusta*. The species belonging to the genera *Schizophyllum, Lentinus* and *Lactarius* showed significant difference between their species, but no significant difference was observed among the species of the genus *Lactifluus* and *Macrolepiota*, also between *Russula* and *Termitomyces*.

The total flavonoid from methanolic extract of the eight samples was determined from the linear regression curve of standard Quercetin acid. *S. commune* (7.17 mg QE/g extract) had the highest total flavonoid and the least was *R. adusta* (0.09 mg GAE/g extract) as shown in table 4. Significant difference was observed between the species of the genus *Schizophyllum, Lactifluus* and *Macrolepiota*. But no significant difference was observed among the genus *Lactarius, Russula* and *Termitomyces*.

The results of the DPPH and ABTS radical scavenging activity showed that all of the mushroom's extracts were able to scavenge the free radical in a dose-response manner, which was consistent with the findings of Cheung., *et al*. (2003) [11]. Strong DPPH and ABTS radical scavenging activity was observed in mushroom extracts containing more phenols than flavonoid, as phenols had a greater capacity to donate hydrogen to scavenge DPPH radicals. This suggested that phenolic compounds were the main antioxidant components present in mushroom extracts, which contributed to their high antioxidant activity [8]. It can also be stated that climatic condition, geographical location and time of collection can influence total phenolic, flavonoid and nutritional composition of wild edible mushrooms.

Pearson's correlation coefficient between antioxidant activity with total phenol and flavonoid contents

The correlation coefficient was used to measure the degree or strength between the total phenolic content (TPC), total flavonoid content (TFC) of mushroom extracts with DPPH, ABTS. Correlations were divided into categories based on the value of the strength to which the two variables are related: very strong (1.0 - 0.80), strong (0.79 - 0.60), moderate (0.59 - 0.40), weak (0.39 - 0.20), and very weak (0.19 - 0.00) suggested by Evans (1996) [16]. Very strong correlation was observed between phenol with DPPH (R = 0.990) and ABTS (R = 0.862), while TFC and DPPH (R = 0.761) showed strong correlation and a moderate correlation was observed between flavonoid and ABTS (R = 0.687).

Conclusion

The present study contributes to the nutritional characterization and antioxidant properties of wild edible mushrooms from Champhai district, Mizoram, India. The high level of biological activity displayed by the extracts would suggest the presence of a wide range of bioactive molecules, igniting the hunt for new bioactive substances that might be useful in many applications. Since time immemorial, different varieties of wild mushrooms have been a traditional food for the Mizo people. These mushrooms were collected in the wild, with no attempt made to cultivate them for commercial purposes. As a result, a nutritional database for these mushrooms has been created. The study of eight wild edible mushrooms revealed that they had good antioxidant properties as well as an adequate amount of various nutrients and minerals. Wild edible mushroom products, in the form of pure compounds or extracts with antioxidant activity, may help the endogenous defense system of the body. The results of this study can therefore be used to promote local consumption of mushrooms as functional foods and for commercial purposes, which could generate large employment opportunities for the locals to alleviate poverty and fight against malnutrition while also promoting their habitat preservation. It is worth noting that this is the first report on the nutritional composition and antioxidant properties of wild edible mushrooms from Mizoram, India.

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Conflict of Interest

All authors declare that there are no conflicts of interests among the authors.

Bibliography

1. Ache NT., *et al*. "Nutrient and Mineral Contents of Wild Edible Mushrooms from the Kilum-Ijim Forest, Cameroon". *Nutrition And Food Science Journal* 3 (2020): 128.

2. Ao T and Deb CR. "Nutritional and antioxidant potential of some wild edible mushrooms of Nagaland, India". *Journal of Food Science and Technology* 56 (2019): 1084-1089.

3. AOAC. "Official Methods of Analysis, 18th edition". Association of Official Analytical Chemists International, Maryland, USA (2005).

4. Bach F., *et al*. "Bio compounds of edible mushrooms: in vitro antioxidant and antimicrobial activities". *LWT* 107 (2019): 214-220.

5. Barros L., *et al*. "Fatty acid and sugar compositions, and nutritional value of five wild edible mushrooms from Northeast Portugal". *Food Chemistry* 105 (2007): 140-145.

6. Barros L., *et al*. "Wild and commercial mushrooms as source of nutrients and nutraceuticals". Food and Chemical Toxicology. 46 (2008): 2742-2747.

7. Bellettini MB., *et al*. "Factors affecting mushroom Pleurotus spp". *Saudi Journal of Biological Sciences* 26 (2019): 633-646.

8. Butkhup L., *et al*. "Evaluation of bioactivities and phenolic contents of wild edible mushrooms from northeastern Thailand". *Food Science and Biotechnology* 27 (2018): 193-202.

9. Caprioli G., *et al*. "Comparison of chemical composition and antioxidant activities of two Winter savory subspecies (*Satureja montana* subsp. *variegata* and *Satureja montana* subsp. *montana*) cultivated in Northern Italy". *Natural Product Research* 33 (2019): 3143-3147.

10. Chang ST and Hayes WA. "The Biology and Cultivation of Edible Mushrooms". Elsevier (1978).

11. Cheung LM., *et al*. "Antioxidant activity and total phenolics of edible mushroom extracts". Food Chem. 81 (2003): 249-255.

12. Cheung PCK. "The nutritional and health benefits of mushrooms". *Nutrition Bulletin* 35 (2010): 292-299.

13. Chittaragi A., *et al*. "Nutritive value of few wild mushrooms from the western ghats of Shivamogga district, Karnataka, India". *Asian Journal of Pharmaceutical and Clinical Research* 7 (2014): 50-53.

14. Das AK., *et al*. "Edible Mushrooms as Functional Ingredients for Development of Healthier and More Sustainable Muscle Foods: A Flexitarian Approach". *Molecules* 26 (2021): 2463.

15. Dimitrijevic M V., *et al*. "First Report about Mineral Content, Fatty Acids Composition and Biological Activities of Four Wild Edible Mushrooms". *Chemistry and Biodiversity* 16 (2019): e1800492.

16. Evans RH. "An Analysis of Criterion Variable Reliability in Conjoint Analysis". *Perceptual and Motor Skills* 82 (1996): 988-990.

17. Gençcelep H., *et al*. "Determination of mineral contents of wild-grown edible mushrooms". *Food Chemistry* 113 (2009): 1033-1036.

18. Gopalan C., *et al*. "Nutritive value of Indian Foods". National Institute of Nutrition (2014).

19. Jacinto-Azevedo B., *et al*. "Nutritional value and biological properties of Chilean wild and commercial edible mushrooms". *Food Chemistry* 356 (2021): 129651.

20. Johnsy G., *et al*. "Nutritive value of edible wild mushrooms collected from the Western Ghats of Kanyakumari District". *Botany Research International* 4 (2011): 69-74.

21. Kujala TS., *et al*. "Phenolics and Betacyanins in Red Beetroot (*Beta vulgaris*) Root: Distribution and Effect of Cold Storage on the Content of Total Phenolics and Three Individual Compounds". *Journal of Agricultural and Food Chemistry* 48 (2000): 5338-5342.

22. Lowry OH., *et al*. "Protein measurement with the folin phenol reagent". *Journal of Biological Chemistry* 193 (1951): 265-275.

23. Mallikarjuna SE., *et al*. "Mineral Composition of Four Edible Mushrooms". *Journal of Chemistry* 2013 (2013): 1-5.

24. Manzi P., *et al*. "Nutritional value of mushrooms widely consumed in Italy". *Food Chemistry* 73 (2001): 321-325.

25. Mattila P., *et al*. "Contents of Vitamins, Mineral Elements, and Some Phenolic Compounds in Cultivated Mushrooms". *Journal of Agricultural and Food Chemistry* 49 (2001): 2343-2348.

26. Muthoni GB., *et al*. "*In Vitro* Antioxidant Activities of Methanolic Extracts of *Caesalpinia volkensii* Harms., *Vernonia lasiopus* O. Hoffm., and *Acacia hockii* De Wild". *Evidence-Based Complementary and Alternative Medicine* 2020 (2020): 1-10.

27. Nakalembe I., *et al*. "Comparative nutrient composition of selected wild edible mushrooms from two agro-ecological zones, Uganda". *Springerplus* 4 (2015): 433.

28. Ouzouni PK., *et al*. "Nutritional value and metal content of wild edible mushrooms collected from West Macedonia and Epirus, Greece". *Food Chemistry* 115 (2009): 1575-1580.

29. Palacios I., *et al*. "Antioxidant properties of phenolic compounds occurring in edible mushrooms". *Food Chemistry* 128 (2011): 674-678.

30. Pandey VV., *et al*. "Mushroom cultivation: Substantial key to food security". *Journal of Applied and Natural Science* 10 (2018): 1325-1331.

31. Plummer DT. "An introduction to practical biochemistry, 3rd edition". Tata McGraw Hill (1990).

32. Ralte Z, *et al*. "Survey of Wild Edible Mushrooms in Champhai District, Mizoram, India". *International Journal of Current Microbiology and Applied Sciences* 9 (2020): 2159-2166.

33. Reis FS., *et al*. "Chemical composition and nutritional value of the most widely appreciated cultivated mushrooms: An interspecies comparative study". *Food and Chemical Toxicology* 50 (2012): 191-197.

34. Saeed N., *et al*. "Antioxidant activity, total phenolic and total flavonoid contents of whole plant extracts Torilis leptophylla L". *BMC Complementary and Alternative Medicine* 12 (2012): 221.

35. Seal T. "Antioxidant activities of some wild vegetables of northeastern region in india and effect of solvent extraction system". *International Journal of Pharmacy and Pharmaceutical Sciences* 6.5 (2014): 315-319.

36. Stojanova M., *et al*. "Antioxidant potential of extracts of three mushroom species collected from the Republic of North Macedonia". *Journal of Food Processing and Preservation* 45 (2021).

37. Tibuhwa DD. "Wild mushroom- an underutilized healthy food resource and income generator: experience from Tanzania rural areas". *Journal of Ethnobiology and Ethnomedicine* 9 (2013): 49.

38. Verma BN., *et al*. "Mushrooms: Edible and Medicinal: Cultivation, Conservation, Strain Improvement with Their Marketing". *Daya Publishing House* (2013).

39. Vishniac HS., *et al*. "How to Identify Mushrooms to Genus. I: Macroscopic Features". *Bulletin of the Torrey Botanical Club* 105 (1978): 240.

40. William S. "Official Methods of Analysis of the Association of Official Analytical Chemists". Association of Official Analytical Chemists, Inc. (1984).