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RESEARCH ARTICLE

Diversity and nutritional potential of edible dung loving mushrooms from Northeast India, an Indo-Burma mega biodiversity hotspot

Monidip Boro & Anjan Kumar Sarma*

Faculty of Science, Assam down town University, Sankar Madhab Path, Gandhi Nagar, Panikhaiti, Guwahati 781 026, Assam, India

*Correspondence email - anjankumar.sarma@adtu.in

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Abstract

The study explores the diversity, edibility and nutritional potential of edible coprophilous (dung loving) mushrooms from the biodiversity rich region of Northeast India. Seven macro-fungal species belonging to *Termitomyces*, *Chlorophyllum*, *Macrolepiota* were collected from herbivore dung and identified through morphological and molecular analysis. Nutritional evaluation revealed high protein (up to 53.43 %), carbohydrates (up to 48.5 %) and fiber (up to 17.6 %) indicating their value as functional foods. Mineral analysis showed that these mushrooms are rich in potassium, phosphorus, calcium, iron, zinc while toxic heavy metals such as lead and cadmium were below detectable limits. LC-QTOF-MS analysis confirmed the absence of major mushroom toxins confirming their edibility and safety. The findings highlight the potential of these coprophilous mushrooms as a sustainable nutritional resource and support their use in local diets and rural livelihoods.

Keywords: coprophilous fungi; herbivore dung; macro-fungi; mushroom

Introduction

Mushrooms serve not only as a delicious component of various culinary preparations but also contribute health benefits due to their rich and varied nutritional composition. They are considered an excellent source of essential nutrients, protein, vitamins, minerals and valuable dietary fiber while they are low in fats and calories (1). Worldwide wild mushrooms are documented as an important non timber forest product with significant ecological, nutritional and economic value (2). Wild edible plants and fungi have long contributed to human diets and traditional medicine among the rural and indigenous communities. They are present in diverse ecosystems and agroecosystems and play a vital role in many food systems by providing direct and indirect resources for human nutrition and health (3). In many developing regions, the harvesting and consumption of wild edible plants and mushrooms is still a widespread practice and there is a market for many species with high socio-economic value (4). Despite their significance, wild edible plants and fungi have received limited attention in the literature.

Dung loving mushrooms, commonly known as coprophilous fungi, are unique organisms that thrive on herbivore dung, where they utilize undigested plant material and other nutrients present in it. These fungi play a major role in ecosystem nutrient cycling by decomposing complex organic compound and help to release essential elements such as nitrogen, phosphorous and potassium back into the soil, making them available for plant uptake (5). The term coprophilous fungi are generally used for species that are obligately restricted to dung substrates. In contrast, several macro-fungi may occur on dung opportunistically but also grow on soil and organic matter and these are more considered as facultative dung associated species. Coprophilous fungi have developed unique enzymes and adaptations that allow them to get nutrients from feces. These enzymes break down complex molecules present in the dung into simpler sugars and nutrients. This unique ecological niche allows them to thrive in an environment that many other organisms ignore. Their fruiting bodies commonly found directly on or near dung highlighting their close relationship with their substrate. Due to distinct ecological niche coprophilous fungi are considered bioindicators of ecosystem health and have been widely studied for their enzymatic potential and production of novel bioactive metabolites (6). Recent studies continue to reveal new species and distribution records from diverse habitats, highlighting their rich biodiversity and ecological significance (7).

The Northeastern region of India, an Indo-Burma mega biodiversity hotspot, is rich in diversity of edible and poisonous mushroom. Edible mushrooms are usually collected by local communities for personal consumption and for sale to improve their income. Wild mushrooms play a significant role in biology, ecology and economy and an integral part of our daily life for centuries. In addition to their significance as a vital food supply for local people, several species possess significant bioactive chemicals with therapeutic qualities. Sixteen wild edible mushroom species were documented highlighting their potential role in food security and income generation (8). Mushrooms are mostly classified under Basidiomycota with a few from Ascomycota and to date approximately 40000 species have been identified. These macro-fungi play a significant role in economic activity of human particularly as valuable source of food and medicine (9). The climate of Northeast India is humid which favours the growth of a wide range of macrofungal species. Among these species some of them are consumed as food by the ethnic communities in this region. The edibility of these wild macro-fungi is based on indigenous knowledge system of the people of this region. These wild edible macro-fungi are consumed for their appetizing taste and sweet aroma, nutritionally rich and are good source of proteins, carbohydrates, minerals, trace elements and dietary fiber, while containing low fat (10). However, there is still very limited information is available on the diversity, edibility and nutritional potential of coprophilous macro-fungi of this biodiversity rich region. These dung loving fungi play a vital ecological role in nutrient cycling and organic matter decomposition, yet they remain underexplored compared to another wild edible mushroom (5). Therefore, systematic exploration, documentation and identification of this dung loving macro-fungi are essential, not only to expand the regional biodiversity inventory but also to assess their potential as alternative sources of nutrition, income and bioactive compounds for local communities. In view of the above the present study was undertaken to explore, document and characterize the diversity, edibility and nutritional potential of coprophilous fungi of Northeast region of India.

The findings from this research will provide useful insights into the ecological relevance and potential of alternate nutritional sources, contributing to sustainable usage and enhancement of local livelihoods.

Materials and Methods

Description of the study area

The survey was conducted from January, 2022 to July, 2025 in Udalguri district (BTR) of Assam located between 26.30–26.40° N latitude and 92.15–92.23° E longitude. The average altitude of the study area is 590 feet amsl. The region is characterized by abundant rainfall during the summer with relatively little to scanty precipitation during the winter. The average annual rainfall ranges from 670 to 2318 mm. Climatological parameters of the study area pertaining to relative humidity, average rainfall and mean minimum and maximum temperature during 2022 to 2024 are presented in Fig.1a–c. The predominant vegetation type of the study area is mostly of tropical evergreen type while sub-tropical, deciduous and degraded forests were also observed in some locations.

Sampling of the coprophilous fungi

Macro-fungi growing on the herbivore dung were sampled in different locations of the study area. The information related to their local name, edibility, medicinal and other traditional use of the fungi was also collected from the local communities of the area with structured questionnaire (Table 1). After collection the samples were brought to the laboratory for detail examination and further study.

Molecular identification of the sample

DNA sequencing was carried out by using the Sanger method (11). Genomic DNA was extracted from mushroom sample and amplified using the universal fungal primers ITS1 and ITS4. The targeted region is 18S rRNA - ITS1 - 5.8S - ITS2 - 28S rRNA with an approximate size of 553–689 bp and it was conducted following the method of Romanelli et al (12). In the current study, the sequence length for each species ranges from 637 bp to 654 bp. The bootstrap value used in the phylogenetic tree was 1000. The exact methodology of the phylogenetic tree sample by sample is available as supplementary Table 1.

Estimation of crude protein, crude fat and crude fiber

The percentage of crude protein is ascertained by multiplying the percentage of nitrogen other than ammoniac nitrogen by a factor. The quantity of ammonia nitrogen was separately determined and deducted from total nitrogen. For animal feeds and feeding stuffs the factor to be used will be 6.25, except in case of wheat and its products for which it will be 5.70 (13).

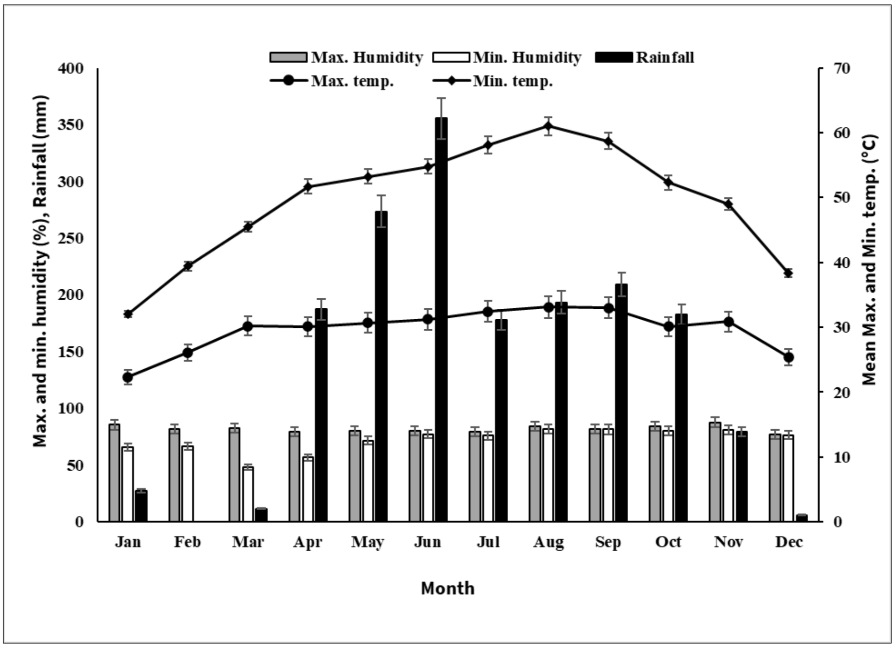


Fig. 1a. Monthly variation in rainfall (mm) and maximin and minimum relative humidity (%), mean minimum and maximum temperatures (°C) of the study area during 2022.

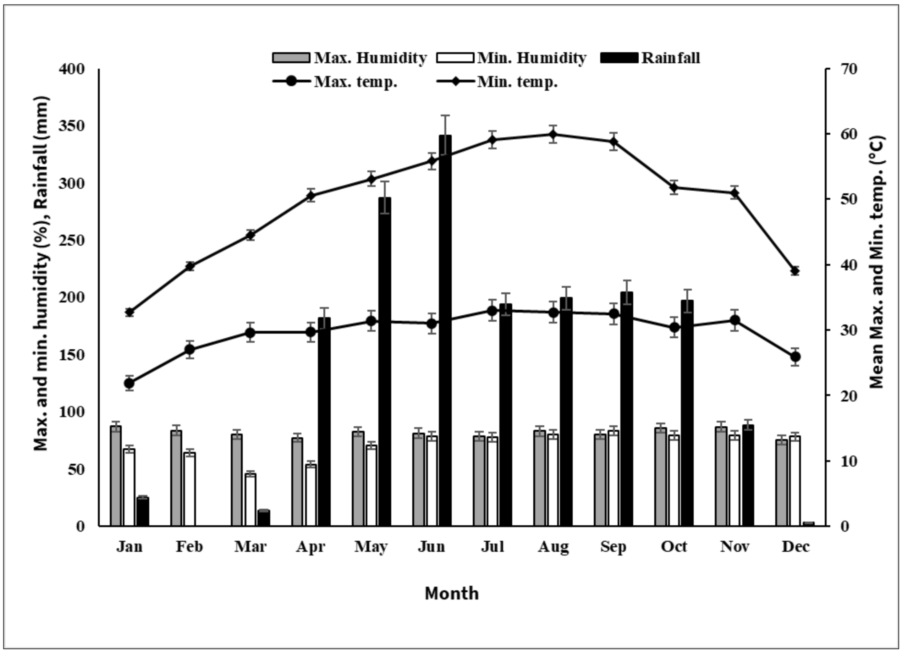


Fig. 1b. Monthly variation in rainfall (mm) and maximin and minimum relative humidity (%), mean minimum and maximum temperatures (°C) of the study area during 2023.

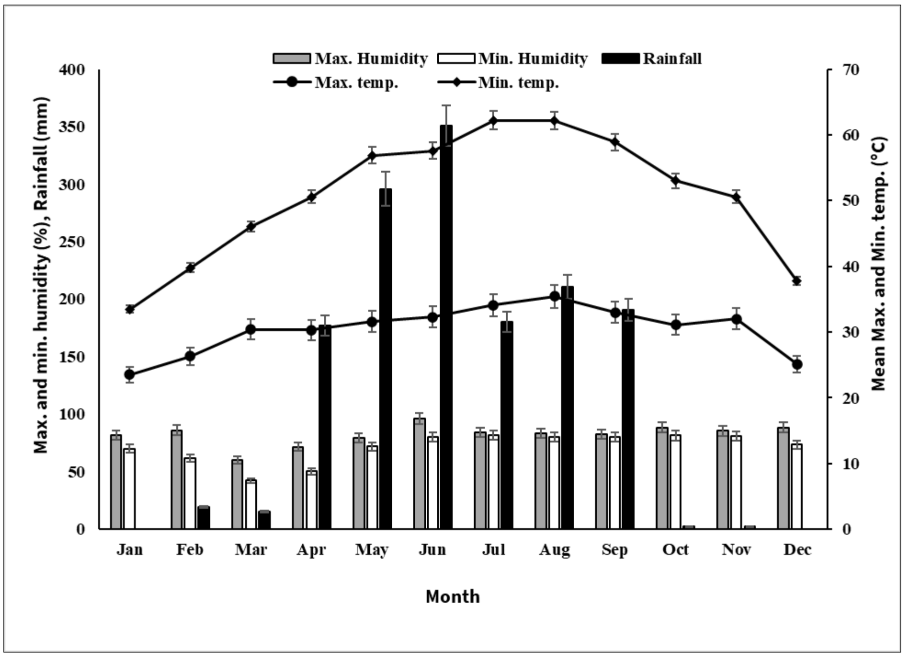


Fig. 1c. Monthly variation in rainfall (mm) and maximin and minimum relative humidity (%), mean minimum and maximum temperatures (°C) of the study area during 2024.

Table 1. Local names, edibility and traditional medicinal uses of collected coprophilous fungi from the study area

Sl. No	Collected sample	Local name	Scientific name	Edibility	Medicinal use	Traditional use
1	SL-1	*Bengsati* (Assamese)	*Termitomyces fuliginosus*		Used to treat urinary disorders	
2	SL-5	*Mwikhun* (Bodo)	*Chlorophyllum rhacodes*		Applied on physical wounds	
3	SL-12		*Chlorophyllum agaricoides*		Relieves constipation, eczema and pneumonia	
4	SL-16	*Cheau* (Nepali)	*Termitomyces striatus*	All are edible	Used for eczema and athlete's foot disease	All the collected samples are used as food
5	SL-18	*Udd* (santal)	*Termitomyces microcarpus*		Treatment of skin blisters	
6	SL-20	*Minuk* (Rabha)	*Macrolepiota clelandii*		Treatment of urinary tract disorders	
7	SL-25		*Macrolepiota procera*		Used for relief from burning and itching	

Crude protein (on moisture-free basis) percent by mass = 6.25(X-Y) where, X = percent by mass of total nitrogen; Y = percent by mass of ammoniacal nitrogen

Crude fat and fiber determined by using the method given by Association of Official Analytical Chemists (14).

Estimation of carbohydrate content

After determination of all the above-mentioned parameters. The carbohydrate content was determined by using the following formula:

Total Carbohydrate (%)

= [100- (Protein + Fat + Moisture + Ash + Fiber) %]

Estimation of mineral elements

The fruiting bodies of collected mushroom species were cleaned, sliced and dried in a hot air drier at 55 °C to a residual moisture of ~5 % and then the dried mushroom samples were powdered to ~1 mm particle size and stored at room temperature in pre-cleaned polyethylene bottles until analysis. One gram of each dry powdered sample was placed in a porcelain crucible and ashed at 450 °C for 5–6 hr and the ash was dissolved in 2 mL concentrated HNO_3 and heated on a low heat for 1 min. It was then cooled and filtered through Whatman No. 42 filter paper to a 50 mL volumetric flask and volume was made with triple distilled water. A blank was also prepared following similar procedure. Three replicates were maintained for each of the sample studied. The mineral contents were determined by using Atomic Absorption Spectrometer (AAS) [Analyst 700 Perkin Elmer, USA] with air-acetylene burner for flame and Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES) [ACTIVIA-M, Horiba Jobin Yvon] with Argon plasma. The ash solution was aspirated to the instrument (AAS/ICP-AES) for the determination of metals/minerals namely Ca, Mg, Na, K, Fe, Zn, Mn, Cu, Ni, Se, Pb and Cd. Phosphorus (P) was estimated by spectrophotometric method wherein P reacts with molybdic acid to form phosphomolybdate complex which was then reduced with amino naphthol sulfonic acid to complex molybdenum blue that was measured spectrophotometrically.

Determination of mushroom toxicity

Extraction of bioactive compounds (Soxhlet method)

To extract bioactive compounds, 5 g of dried mushroom powder was subjected to Soxhlet extraction using 120 mL of methanol as the solvent. The extraction process allowed the solvent to cycle 7–8 times over the sample to dissolve potential toxic and bioactive constituents. The resulting methanolic extract was cooled and filtered and the solvent was evaporated using a rotary evaporator under reduced pressure at 40–50 °C. The concentrated residue was further dried at 40–50 °C and stored at 4 °C until further analysis for phytochemical or bioactivity assessment.

Analysis of chemical constituents (LCHRMS method)

The methanolic extract was analyzed using Liquid Chromatography-Quadrupole Time-of-Flight Mass Spectrometry (LC-QTOF MS) (Agilent G6545B) operated in positive ionization mode with a Dual AJS ESI source. The system was run in MS1 acquisition mode with a scan range of m/z 50–1500 at 5 spectra per second. The method used a binary solvent system (A: 0.1 % formic acid in water, 85 %; B: 0.1 % formic acid in acetonitrile, 15 %) with a flow rate of 0.2 mL/min and a 15 min run. The gradient transitioned from 85:15 to 5:95 (A:B) over 2–10 min and returned to initial conditions by 10.5 min. The column temperature was maintained at 40 °C, with 5 µL of the sample injected using a standard needle wash. Instrument parameters included a gas temperature of 320 °C, capillary voltage of 3500 V, fragmentor voltage of 175 V and sheath gas temperature of 350 °C. The obtained spectra were analyzed to identify and characterize potential toxic compounds present in the mushroom extract.

Results

Sampling and identification of the fungi

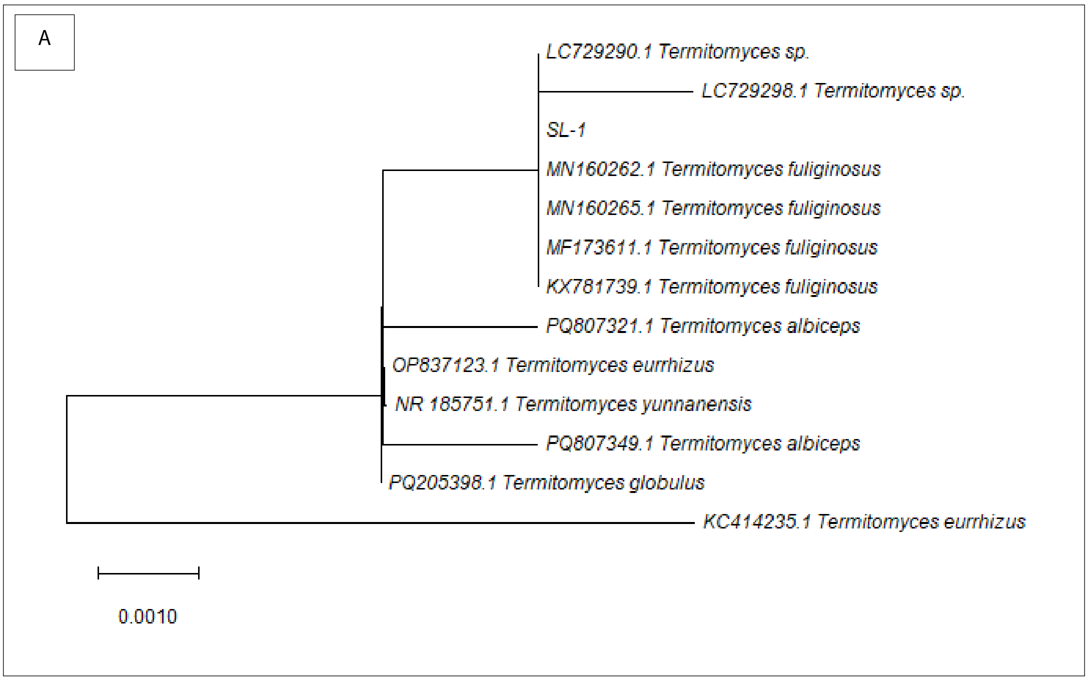
A total of 7 macro-fungi growing on the herbivore dung were collected in different locations of the study area. Data pertaining to their local name, edibility, medicinal and other traditional use of the collected macro-fungi were also collected from the local communities and is presented in Table 1. Based on similarity and evolutionary relationship, the collected macro-fungi matched with the nearest most probable genus as *Termitomyces fuliginosus* (SL-1), *Chlorophyllum rhacodes* (SL-5), *Chlorophyllum agaricoides* (SL-12), *Termitomyces striatus*. (SL-16), *Termitomyces microcarpus* (SL-18), *Macrolepiota clelandii* (SL-20), *Macrolepiota procera* (SL-25). Fig. 2 depicts the phylogenetic relationship with the neighbouring taxa. The photograph of the collected species in presented on Fig. 3. The respective sequences have been deposited in the GenBank database and can be accessed under the accession numbers PX830052–PX830058.

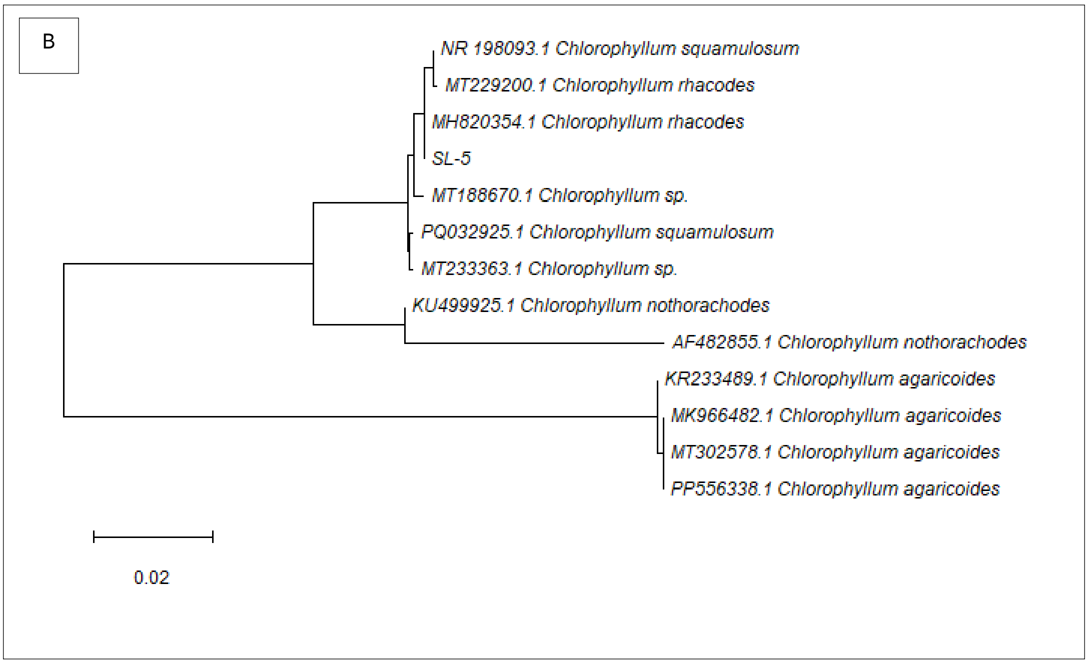
Crude protein, crude fat and crude fiber

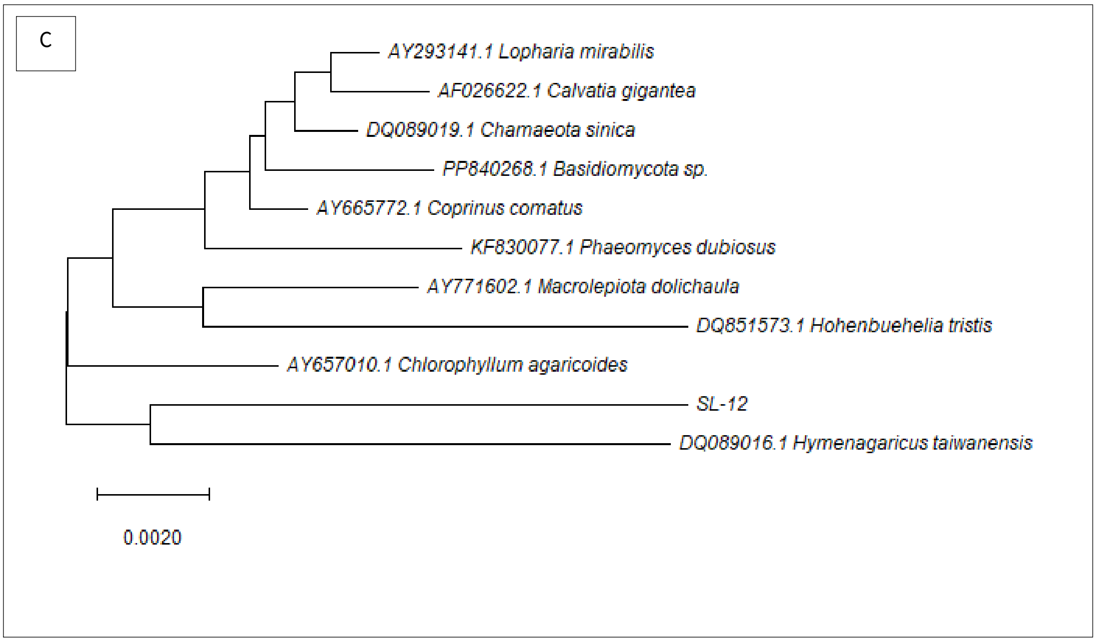
The nutritional analysis of the collected edible coprophilous macro-fungi revealed a significant variation in their macronutrient composition (Table 2). Crude protein content ranged from 24.4 ± 0.45 % in *Termitomyces fuliginosus* to 53.43 ± 0.52 % in *Macrolepiota procera*, indicating their potential as rich protein sources. Crude fiber was highest in *Macrolepiota procera* (17.62 ± 0.15 %) and lowest in *Termitomyces microcarpus* (8.41 ± 0.30 %). Carbohydrate content varied between 31.1 ± 0.44 % (*Termitomyces striatus*) and 48.5 ± 0.39 % (*Termitomyces fuliginosus*). Crude fat content was generally low with the highest value recorded in *Termitomyces microcarpus* (7.90 ± 0.34 %) and the lowest in *Macrolepiota procera* (2.25 ± 0.41 %). This diversity reflects their nutritional significance as functional sources of food.

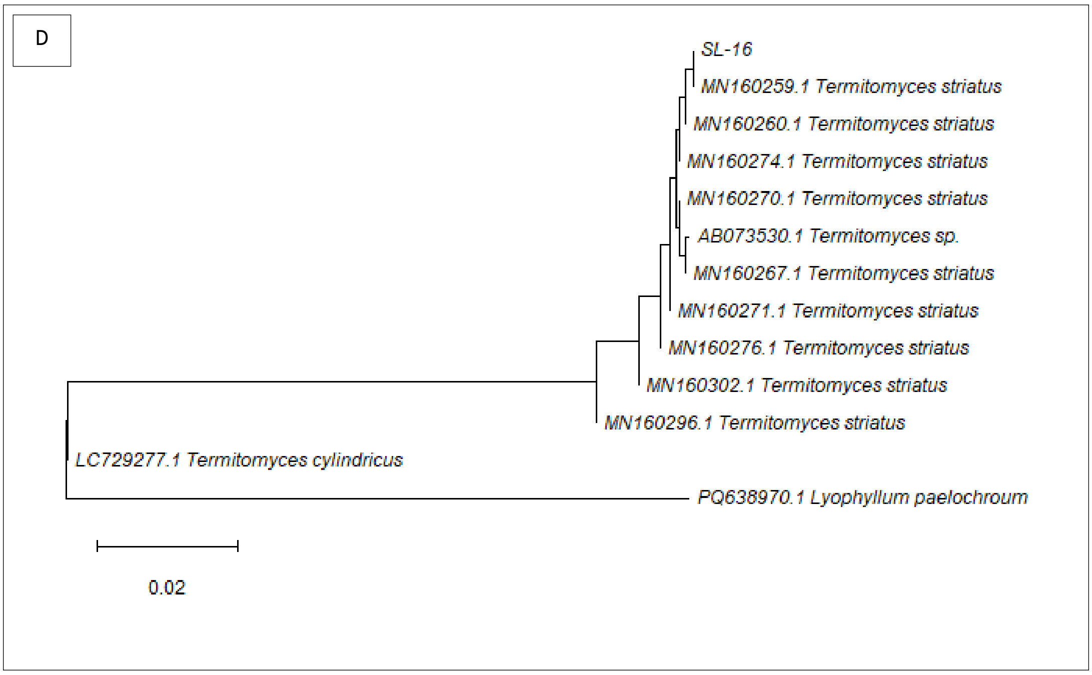
Table 2. Nutritional value of the collected edible coprophilous fungi

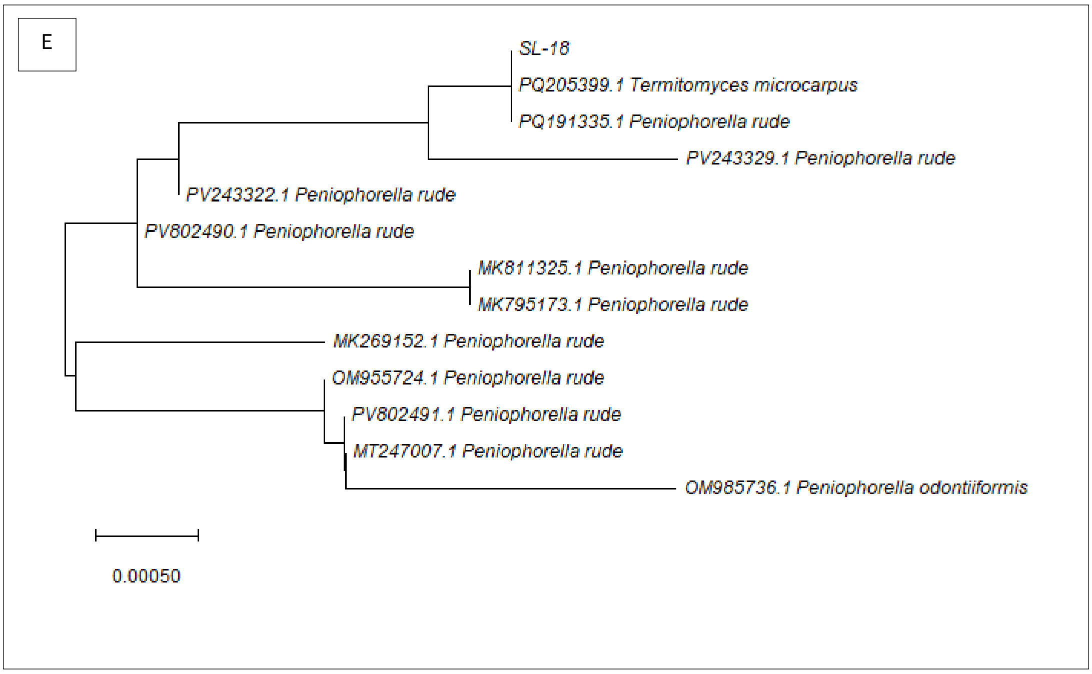
Collected sample	Crude Protein (%)	Crude Fiber (%)	Carbohydrate (%)	Crude Fats (%)
Termitomyces fuliginosus	24.4 ± 0.45	9.54 ± 0.25	48.5 ± 0.39	4.59 ± 0.35
Chlorophyllum rhacodes	31.6 ± 0.40	8.53 ± 0.31	44.5 ± 0.40	5.51 ± 0.31
Chlorophyllum agaricoides	29.5 ± 0.41	9.53 ± 0.26	45.6 ± 0.32	4.50 ± 0.27
Termitomyces striatus	32.3 ± 0.50	16.7 ± 0.22	31.1 ± 0.44	3.65 ± 0.20
Termitomyces microcarpus	31.43 ± 0.40	8.41 ± 0.30	45.49 ± 0.28	7.90 ± 0.334
Macrolepiota clelandii	29.49 ± 0.41	9.53 ± 0.26	45.58 ± 0.32	3.80 ± 0.19
Macrolepiota procera	53.43 ± 0.52	17.62 ± 0.15	40.11 ± 0.33	2.25 ± 0.41

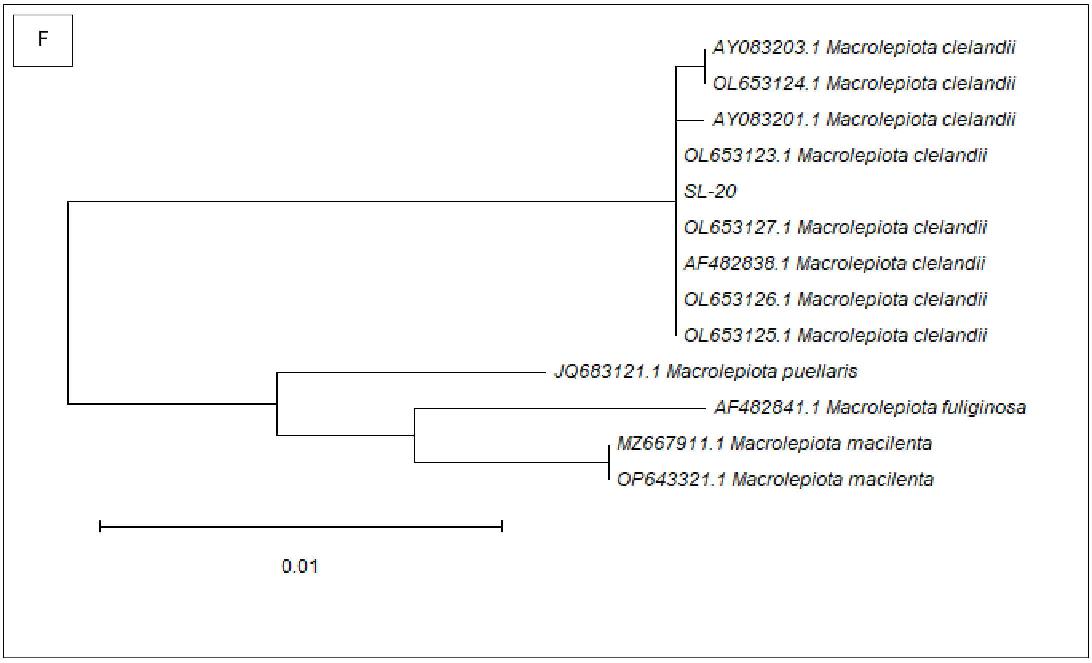

A
LC729290.1 Termitomyces sp.
LC729298.1 Termitomyces sp.
SL-1
MN160262.1 Termitomyces fuliginosus
MN160265.1 Termitomyces fuliginosus
MF173611.1 Termitomyces fuliginosus
KX781739.1 Termitomyces fuliginosus
PQ807321.1 Termitomyces albiceps
OP837123.1 Termitomyces eurrhizus
NR 185751.1 Termitomyces yunnanensis
PQ807349.1 Termitomyces albiceps
PQ205398.1 Termitomyces globulus
KC414235.1 Termitomyces eurrhizus
0.0010


B
NR 198093.1 Chlorophyllum squamulosum
MT229200.1 Chlorophyllum rhacodes
MH820354.1 Chlorophyllum rhacodes
SL-5
MT188670.1 Chlorophyllum sp.
PQ032925.1 Chlorophyllum squamulosum
MT233363.1 Chlorophyllum sp.
KU499925.1 Chlorophyllum nothorachodes
AF482855.1 Chlorophyllum nothorachodes
KR233489.1 Chlorophyllum agaricoides
MK966482.1 Chlorophyllum agaricoides
MT302578.1 Chlorophyllum agaricoides
PP556338.1 Chlorophyllum agaricoides
0.02


C
AY293141.1 Lopharia mirabilis
AF026622.1 Calvatia gigantea
DQ089019.1 Chamaeota sinica
PP840268.1 Basidiomycota sp.
AY665772.1 Coprinus comatus
KF830077.1 Phaeomyces dubiosus
AY771602.1 Macrolepiota dolichaula
DQ851573.1 Hohenbuehelia tristis
AY657010.1 Chlorophyllum agaricoides
SL-12
DQ089016.1 Hymenagaricus taiwanensis
0.0020


D
SL-16
MN160259.1 Termitomyces striatus
MN160260.1 Termitomyces striatus
MN160274.1 Termitomyces striatus
MN160270.1 Termitomyces striatus
AB073530.1 Termitomyces sp.
MN160267.1 Termitomyces striatus
MN160271.1 Termitomyces striatus
MN160276.1 Termitomyces striatus
MN160302.1 Termitomyces striatus
MN160296.1 Termitomyces striatus
LC729277.1 Termitomyces cylindricus
PQ638970.1 Lyophyllum paelochroum
0.02


E
SL-18
PQ205399.1 Termitomyces microcarpus
PQ191335.1 Peniophorella rude
PV243329.1 Peniophorella rude
PV243322.1 Peniophorella rude
PV802490.1 Peniophorella rude
MK811325.1 Peniophorella rude
MK795173.1 Peniophorella rude
MK269152.1 Peniophorella rude
OM955724.1 Peniophorella rude
PV802491.1 Peniophorella rude
MT247007.1 Peniophorella rude
OM985736.1 Peniophorella odontiiformis
0.00050


F
AY083203.1 Macrolepiota clelandii
OL653124.1 Macrolepiota clelandii
AY083201.1 Macrolepiota clelandii
OL653123.1 Macrolepiota clelandii
SL-20
OL653127.1 Macrolepiota clelandii
AF482838.1 Macrolepiota clelandii
OL653126.1 Macrolepiota clelandii
OL653125.1 Macrolepiota clelandii
JQ683121.1 Macrolepiota puellaris
AF482841.1 Macrolepiota fuliginosa
MZ667911.1 Macrolepiota macilenta
OP643321.1 Macrolepiota macilenta
0.01

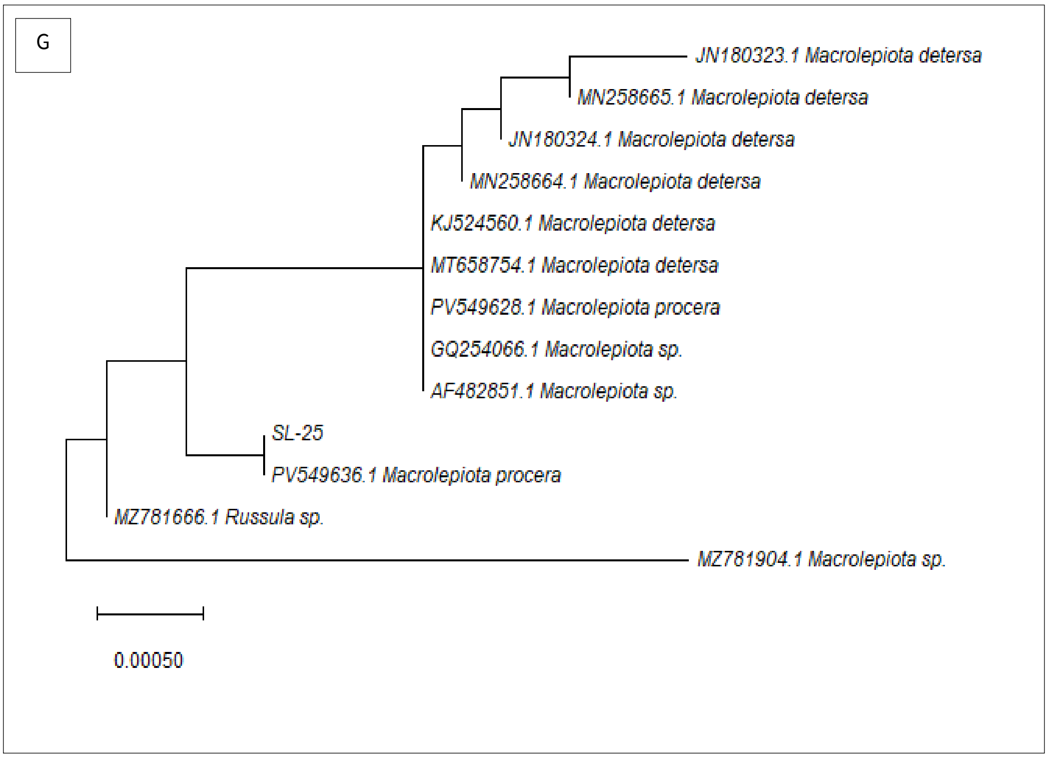


Fig. 2. Phylogenetic tree of the collected samples.
A. *Termitomyces fuliginosus* (SL-1, PX830052), B. *Chlorophyllum rhacodes* (SL-5, PX830053), C. *Chlorophyllum agaricoides* (SL-12, PX830054), D. *Termitomyces striatus* (SL-16, PX830055), E. *Termitomyces microcarpus* (SL-18, PX830056), F. *Macrolepiota clelandii* (SL-20, PX830057), G. *Macrolepiota procera* (SL-25, PX830058).

Fig. 3. Photographs of the wild edible dung associated macro-fungi collected during the study.

Mineral elements

Mineral composition of the collected edible coprophilous macro-fungi showed significant variation among the species. Potassium (K) was the most abundant mineral in most of the collected species with the highest concentration observed in *Termitomyces striatus* (3634 mg/100 g DW) and *Macrolepiota procera* (2527 mg/100 g DW). Phosphorus (P) content ranged from 130.5 mg/100 g in *Termitomyces fuliginosus* to 869.9 mg/100 g in *T. microcarpus*. Calcium (Ca) levels were highest in *T. microcarpus* (184.9 mg/100 g). Magnesium (Mg) was relatively consistent with values between 31.1–96.3 mg/100 g. Among trace elements, zinc (Zn) and iron (Fe) were present in appreciable amounts particularly Fe in *T. fuliginosus* (45.3 mg/100 g) and Zn in *T. microcarpus* (9.74 mg/100 g). Toxic metals such as viz. lead (Pb) and cadmium (Cd) were below detectable levels (BDL) indicating food safety, though minor traces of nickel (Ni) and copper (Cu) were detected in some species (Table 3). The concentration of all minerals was expressed as mg/100 g dry weight of the sample. The detection limit of Pb was 0.01 µg/L and Cd was 0.1 µg/L. Each value is the mean of 3 replicate determination ± standard deviation. Overall, the data revealed that the collected wild edible coprophilous macro-fungi are rich in essential minerals.

Mushroom toxicity

The toxin analysis of the collected mushroom species was conducted using LC-QTOF-MS to detect the presence of known fungal toxins, including amatoxin, orellanine, ibotenic acid, muscarine, psilocybin, coprine, gyromitrin (Table 4). All tested mushroom species showed no detectable levels of these toxic compounds. Therefore, none of the analyzed samples contained measurable quantities of common mushroom toxins indicating that the tested species are non-toxic under the studied conditions.

Discussion

The current research shown that the collected edible coprophilous macro-fungi exhibit considerable nutritional and mineral abundance, underscoring their potential as useful alternative and functional food sources. A total of seven coprophilous macro-fungal species were recorded from herbivore feces, mostly belongs to the genera *Termitomyces*, *Chlorophyllum* and *Macrolepiota*. They are better regarded as facultative dung-associated macro-fungi as they can grow in soil and organic matter but may opportunistically fruit on dung when conditions are favourable. This study corresponds with earlier research that focused on the ecological specialization of coprophilous fungus and their varied presence in herbivore excrement (5, 7). Previous researchers identified three coprophilous fungi, namely *Coprinus miser, C. stercorarius* and *C. radiatus*, which are classified under the Basidiomycetes, from fecal samples of horses (15). The research undertaken in China aimed to examine *Coprinopsis* sect. Niveae from several herbivore dung sources (16). Through 4 loci phylogenetic analysis, they found fourteen phylogenetic species, including six new species: *Coprinopsis furfuracea*, *C. iliensis*, *C. khorqinensis*, *C. sericivia*, *C. subigarashii* and *C. tenuipes*. The existence of many *Termitomyces* and *Macrolepiota* species indicates an environment conducive to these taxa, attributed to the warm, humid climate and the presence of organic-rich soils in northeastern India. The species richness and distribution patterns of *Termitomyces* mushrooms, noting that moderate temperatures,

Table 3. Different mineral elements present in the collected edible coprophilous fungi

Sl. No.	Collected sample	P	K	Ca	Na	Mg	Fe	Zn	Cu	Mn	Se	Ni	Pb	Cd
1	*Termitomyces fuliginosus*	130.5 ± 2.6	56.3 ± 10.5	139.9 ± 6.1	32.2 ± 0.6	31.1 ± 3.57	45.3 ± 3.35	1.76 ± 0.31	0.87 ± 0.02	0.74 ± 0.01	0.15 ± 0.01	0.06 ± 0.06	BDL	BDL
2	*Chlorophyllum rhacodes*	549.9 ± 84.1	1103 ± 103	164.9 ± 44.2	307.4 ± 41.6	90.6 ± 1.26	20.5 ± 2.4	8.54 ± 0.27	1.68 ± 0.04	1.06 ± 0.42	0.142 ± 0.03	0.11 ± 0.01	BDL	BDL
3	*Chlorophyllum agaricoides*	159.9 ±66.1	97.28 ± 0.54	167.4 ± 41.6	80.7 ± 1.44	96.3 ± 10.4	19.74 ± 0.23	9.64 ± 0.21	0.77 ± 0.12	2.22 ± 0.03	0.19 ± 0.41	0.06 ± 0.06	BDL	BDL
4	*Termitomyces striatus*	633.2 ± 39.5	3634 ± 122	44.2 ± 27.9	49.6 ± 7.2	41.6 ± 1.8	20.8 ± 0.71	6.51 ± 0.06	1.54 ± 0.07	1.22 ± 0.04	0.21 ± 0.05	0.12 ± 0.08	0.01 ± 0.052	BDL
5	*Termitomyces microcarpus*	869.9 ±74.1	1402 ± 121	184.9 ± 24.3	367.4 ± 41.6	50.7 ± 1.24	16.8 ± 2.2	9.74 ± 0.26	1.58 ± 0.05	1.05 ± 0.62	0.102 ± 0.01	0.13 ± 0.04	BDL	BDL
6	*Macrolepiota clelandii*	140.5 ±2.5	59.3 ± 10.2	139.5 ± 36.1	32.2 ± 0.7	31.1 ± 3.4	45.3 ± 3.65	1.88 ± 0.28	0.96 ± 0.03	0.64 ± 0.03	0.13 ± 0.02	0.07 ± 0.09	0.062 ± 0.007	BDL
7	*Macrolepiota procera*	770.2 ±8.8	2572 ± 209	7.28 ± 0.5	50.5 ± 6.0	45.9 ± 1.99	7.37 ± 0.61	6.06 ± 0.06	1.08 ± 0.05	0.42 ± 0.01	0.035 ± 0.02	0.05 ± 0.049	BDL	BDL

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

Elements (major/ trace/toxic) concentrations (mg/100 g on dry weight basis)

BDL: Below detectable level

Table 4. Molecular mass of the compounds for fungal toxins

Tested species of mushroom	Compound name	Molecular mass (g/mol)	Result
Termitomyces fuliginosus *Chlorophyllum rhacodes* *Chlorophyllum agaricoides* *Termitomyces striatus* *Termitomyces microcarpus* *Macrolepiota clelandii* *Macrolepiota procera*	Amatoxin	900	ND
	Orellanine	252.17	ND
	Ibotenic acid	158.11	ND
	Muscarine	174.26	ND
	Psilocybin	284.26	ND
	Coprine	202.19	ND
	Gyromitrin	100.12	ND

ND=Not detected

high humidity and monsoon-driven rains facilitate the development and proliferation of this fungus was reported earlier (17).

Macronutrients analysis showed a wide variation among the collected species of mushroom. Present study revealed that *Macrolepiota procera* exhibited the highest crude protein content which is comparable or even superior to the values reported in other wild edible mushrooms. Such high protein levels increase the potentiality of these fungi as plant-based protein supplements especially for rural and vegetarian communities. Eedible macromycetes as an alternative protein source was reported previously (18). Crude fiber content was significantly high in *Macrolepiota procera* indicating its potential role in supporting digestive health and metabolic regulation. Nutritional analysis of 10 species of wild edible mushrooms of Nagaland which are having high protein, carbohydrate, fiber, phenolic, flavonoid contents and strong antioxidant activity was studied earlier (19). The carbohydrate content was substantial in most species, supporting their role as an energy rich food source. The crude fat content was relatively low, consistence with the previous findings on wild edible mushrooms (10), indicating their suitability for low-fat diets. Previous researchers reported three species of wild edible mushrooms from Mizoram viz. *Phallus indusiatus, Schizophyllum commune, Termitomyces heimii* which are rich in protein and carbohydrates, have low in fat and contain substantial amounts of essential minerals (20). These findings emphasized the potentiality of wild edible mushroom for human health and need for their sustainable use.

Analysis of mineral revealed that concentration of potassium (K) was high in *Termitomyces striatus*. Phosphorus (P) and calcium (Ca) were also present in significant quantities further supporting the nutritional importance of these species Trace elements such as iron (Fe) and zinc (Zn) were detected at significant levels, with *Termitomyces fuliginosus* and *Chlorophyllum agaricoides* being the richest sources respectively, indicating their potential to address micronutrient deficiencies. Previous study has reported that macro-fungi have the capability to accumulate the considerable of mineral elements even in soil with low metals concentrations (21). The concentration of mineral content is directly influenced by factors such as species, geographical location of growth, substrate composition, fruiting body developmental stage and proximity to pollution sources (22, 23). The toxic heavy metals such as lead (Pb) and cadmium (Cd) were found below detectable level suggesting these macro-fungi are safe for human consumption. Moreover, detection of nickel (Ni) and copper (Cu) in certain species of wild edible mushroom suggest environmental safety and support their suitability for dietary use. Previous researchers analyzed 24 species of wild edible mushroom and reported that both Cu and Ni were present at levels not typically associated with toxicity indicating their potential as safe dietary sources (24). Coprophilous macro-fungi play a big role in nutrient cycling and decomposition of organic matter which contribute significantly to function the ecosystem (6). The present study not only expand the edible macrofungal diversity of Northeast India but also highlight their nutritional and mineral potential. Rural communities those living in biodiversity rich and economically constrained areas, these macro-fungi can be an alternative nutrient rich food sources which offers opportunities for dietary diversification and livelihood improvement through sustainable harvesting and marketing.

The lack of measurable concentrations of prevalent mushroom toxins in all investigated samples offers compelling evidence for their safe eating under the specified circumstances. Although LC-QTOF-MS analysis did not detect any of the targeted mushroom toxins (amatoxin, orellanine, ibotenic acid, muscarine, psilocybin, coprine and gyromitrin), it is important to note that the screening was limited to this defined toxin panel. Therefore, the findings indicate the absence of these specific toxins only and should not be interpreted as evidence of complete toxicological safety, as other unknown compounds may still be present. The discovery corresponds with recent analytical advancements detailed in the work by previous researchers (25), which used the LC-MS/MS technique to identify several mushroom poisons in food and biological specimens. Furthermore, the literature consistently emphasizes the essential significance of toxin profiling and identification, as detailed in extensive studies on toxic and edible mushrooms (26). Collectively, these statistics substantiate the edible characteristics of the screened species and support their use in the food sector.

Conclusion

This research records the diversity and nutritional content of edible coprophilous fungi from Northeast India, highlighting their ecological and culinary significance. The findings indicated that these mushrooms are rich in vital nutrients and minerals, while also being devoid of detectable toxins, so affirming their safety for human ingestion. Their high protein and mineral content make them a significant food source, especially for rural and indigenous populations. This research further enhances the expanding database of wild edible mushrooms from the Indo-Burma biodiversity hotspot. Additional investigation into their culture, biochemical characteristics and prospective medicinal uses might enhance their sustainable utilization and commercialization for local economic advancement.

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Authors' contributions

Both authors contributed equally to the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

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References

1. Mayirnao HS, Sharma K, Jangir P, Kaur S, Kapoor R. Mushroom-derived nutraceuticals in the 21st century: an appraisal and future perspectives. Journal of Future Foods. 2025;5(4):342-60. https://doi.org/10.1016/j.jfutfo.2024.07.013
2. Boa ER. Wild edible fungi: a global overview of their use and importance to people. Non-Wood Forest Products No. 17. Rome: FAO; 2004.
3. Ferreira ICFR, Morales P, Barros L. Wild plants, mushrooms and nuts: functional properties and food applications. Chichester (UK): John Wiley & Sons; 2017. https://doi.org/10.1002/9781118944653
4. Iwu MM. Food as medicine: functional food plants of Africa. Boca Raton (FL): CRC Press; 2017.
5. Richardson MJ. Diversity and occurrence of coprophilous fungi. Mycological Research. 2001;105(4):387-402. https://doi.org/10.1017/S0953756201003884
6. Bell A. An illustrated guide to coprophilous ascomycetes of Australia. CBS Biodiversity Series; 2005.
7. Krug JC, Benny GL, Keller HW. Coprophilous fungi. In: Biodiversity of fungi. 2004. p. 467-99. https://doi.org/10.1016/B978-012509551-8/50024-6
8. Das K. Diversity and conservation of wild mushrooms in Sikkim with special reference to Barsey Rhododendron Sanctuary. NeBio. 2010;1(2):1-13.
9. Zhao RL. Edible and medicinal macro-fungi. J Fungi (Basel). 2023;9(9):908. https://doi.org/10.3390/jof9090908
10. Gogoi I, Borthakur A, Neog B. Ethnomycological knowledge, nutritional and nutraceutical potential of wild edible macro-fungi of Northeast India. Studies in Fungi. 2023;8:12. https://doi.org/10.48130/SIF-2023-0012
11. Sanger F, Nicklen S, Coulson AR. DNA sequencing with chain-terminating inhibitors. Proceedings of the National Academy of Sciences. 1977;74(12):5463-7. https://doi.org/10.1073/pnas.74.12.5463
12. Romanelli AM, Fu J, Herrera ML, Wickes BL. A universal DNA extraction and PCR amplification method for fungal rDNA sequence-based identification. Mycoses. 2014;57(10):612-22. https://doi.org/10.1111/myc.12208
13. Kassegn HH. Determination of proximate composition and bioactive compounds of the Abyssinian purple wheat. Cogent Food & Agriculture. 2018;4(1). https://doi.org/10.1080/23311932.2017.1421415
14. AOAC. Official methods of analysis of the AOAC. 18th ed. Washington (DC): AOAC; 2000.
15. Pointelli E, Santa-Maria MA, Caretta G. Coprophilous fungi of the horse. Mycopathologia. 1981;74(2):89-105. https://doi.org/10.1007/BF01259464
16. Zhu L, Bau T. Biodiversity of herbivores triggers species differentiation of coprophilous fungi: a case study of snow inkcap (*Coprinopsis* sect. *Niveae*). J Fungi (Basel). 2024;10(12):835. https://doi.org/10.3390/jof10120835
17. Pooja AS, Mary CF, Rashmi CR, Vijayaraghavan R, John KS. Diversity and distribution of *Termitomyces* spp. in central and northern Kerala, India. International Journal of Plant & Soil Science. 2024;36(12):507-18. https://doi.org/10.9734/ijpss/2024/v36i125225
18. Martínez-Burgosa WJ, Ocána D, Manzokia MC, Barrosa RN, Vieiraa R, Soccola CR. Edible macromycetes as an alternative protein source: advances and trends. Biotechnology Research and Innovation. 2024;8(1):e2024002. https://doi.org/10.4322/biori.00022024
19. Ao T, Deb CR. Nutritional and antioxidant potential of some wild edible mushrooms of Nagaland, India. J Food Sci Technol. 2019;56(2):1084-9. https://doi.org/10.1007/s13197-018-03557-w
20. Renthlei L, Zothanzama J, Mishra BP, Chawngthu Z, Thachunglura VL, Khumlianlal J, et al. Nutrient analysis of selected wild edible mushrooms collected from Aizawl, Mizoram, India. Biotech Res Asia. 2024;21(3). https://doi.org/10.13005/bbra/3285
21. Falandysz J, Borovička J. Macro and trace mineral constituents and radionuclides in mushrooms: health benefits and risks. Appl Microbiol Biotechnol. 2013;97(2):477-501. https://doi.org/10.1007/s00253-012-4552-8
22. Gucia M, Jarzyńska G, Rafał E, Roszak M, Kojta AK, Osiej I, et al. Multivariate analysis of mineral constituents of edible parasol mushroom (*Macrolepiota procera*) and soils beneath fruiting bodies collected from northern Poland. Environ Sci Pollut Res. 2012;19:416-31. https://doi.org/10.1007/s11356-011-0574-5
23. Bellettini MB, Fiorda FA, Maieves HA, Teixeira GL, Ávila S, Hornung PS, et al. Factors affecting mushroom *Pleurotus* spp. Saudi J Biol Sci. 2019;26(4):633-46. https://doi.org/10.1016/j.sjbs.2016.12.005
24. Keleş A, Gençcelep H. Wild mushrooms from East Black Sea Region (Turkiye): element concentrations and their health risk assessment. Anatolian Journal of Botany. 2023;7(1):50-9. https://doi.org/10.30616/ajb.1187497
25. Lu J, Zhang J, Li H, Sun C. Simultaneous determination of multi-class mushroom toxins in mushroom and biological liquid samples using LC-MS/MS. Separations. 2024;11:183. https://doi.org/10.3390/separations11060183
26. Jo WS, Hossain MA, Park SC. Toxicological profiles of poisonous, edible and medicinal mushrooms. Mycobiology. 2014;42(3):215-20. https://doi.org/10.5941/MYCO.2014.42.3.215

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