Life Science Informatics Publications

Research Journal of Life Sciences, Bioinformatics, Pharmaceutical and Chemical Sciences

Journal Home page http://www.rjlbpcs.com/

RJLBPCS

ISSN 2454-6348

Original Research Article **DOI: 10.26479/2019.0502.19**

WILD EDIBLE MUSHROOMS OF NORTHERN ODISHA, INDIA: DATA ON DISTRIBUTION AND UTILIZATION BY ETHNIC COMMUNITIES

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ABSTRACT: The current study revealed diversity, distribution and utilization of wild edible mushrooms from forest regions of northern Odisha, India. A total of 20 wild edible mushroom species belonging under six orders and nine families. Among them the order Agaricales was dominant, harboring maximum number of species and the genus *Russula* exhibited maximum number of species. The optimum growth period of all studied mushrooms was found in the month of August. Maximum numbers of species were found in forest soil substratum and minimum in decayed paddy straw. Quantitative analysis of the collected wild edible mushrooms revealed that *Russula delica* were denser (5.73) and most frequent species (93.33%) while *Termitomyces* sp. was found to be most abundant species (35). The study revealed that species diversity varied amongst different forest sites. Among the different forest regions, Bhimkund forest showed highest species diversity with Shannon's and Simpson's indices of 1.88 and 0.83 respectively while Bangiriposi forest showed the lowest with Shannon's and Simpson's indices of 1.12 and 0.56. Evenness was also found to be highest in Bhimkund (0.94) and lowest in Bangiriposi (0.82). An assessment of economic value revealed that wild edible mushrooms were sold in rural markets at lower prices in comparison to urban markets. The market value of species belonging to genus *Russula* was cheaper in rural areas (10–30 rupees/kg) as compared to urban markets (60–90 rupees/kg) while that of *Termitomyces* species was found comparatively higher in both rural (30–120 rupees/kg) and urban markets (150–250 rupees/kg).

KEYWORDS: Economic values, Mushroom diversity, Quantitative analysis, Statistical methods, Tribal peoples.

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1. INTRODUCTION

Wild edible mushrooms play an important role in ecological process. Most of them are symbiotically associated with trees and sustains the growth of indigenous and commercial plantations of tropical forests [1]. The saprobic wild edible mushrooms are very crucial in nutrient recycling and also providing economical benefits to rural/tribal people by collecting them from wild and selling in the markets [2]. From ancient times mushrooms have been used as an important dietary supplement with high nutritional and medicinal value [3]. The mushrooms produced more than 100 medicinal functions like antioxidant, anticancer, antidiabetic, antitumor, antiinflamatory, antiallergic, immunomodulating, cardiovascular protector, anticholesterolemic, antiviral, antibacterial, antiparasitic, antifungal, detoxification, and hepatoprotective effects [4,5,6].The number of fungi on Earth is currently estimated about 15,00,000 and only 14,000 were recognized as mushroom species [7,8,9] but the recorded wild edible mushrooms is about 1154, which is only 8.24% of the estimated mushroom species[10]. Therefore, it may conclude that most of the identified mushrooms are either inedible or poisonous. According to [10] incidents of poisoning and deaths are very less as compared to the regular and safe consumption of wild edible species; it may because the number of poisonous mushroom species is relatively small belong to a tiny minority. However, in developed as well as developing countries publicity and cultural attitudes on wild mushrooms poisoning continue to fuel an intrinsic fear which is undoubtedly led to creating potential barriers on global uses and wider marketing as well [10]. While the present study will conclusively shows that, this is simply not true; rural people of northern Odisha are using wild mushrooms extensively as food and increasing their income by selling the mushrooms in different places. Mushrooms are getting significant importance in the present diet conscious era due to their nutritive and medicinal values and income generating venture [11]. In India, 232 genera have been reported out of the 357 genera of Basidiomycetes in the world [12]. The number of mushroom species documented in India is about 1,200, out of which 300–315 species are considered edible [13]. In Odisha the forest area constitutes about 36.73% and most of them are tropical forests, which favor the conditions for mushroom growth and developments, but still there are no considerable explorations on the diversity of mushrooms and their uses. The rural and tribal community of Northern Odisha purely depends on forest resources by hunting, gathering and collecting forest products for their livelihood. They are the traditional collectors and consumers of varieties of wild mushrooms. Even though, wild edible mushrooms contribute towards livelihood and economy of the rural and tribal folks, information on their diversity and demand are very limited in Northern Odisha except some few sporadic studies on their occurrence [14, 15]. It is therefore very important to document the diversity, distribution, abundance and economic value of the edible macro fungi of Northern region of Odisha and to analyze how seasonality and different habitats influence their distribution.

2. MATERIALS AND METHODS

Study area and Observations

The landscape of Northern Odisha (85°11'- 87°29'E longitude and 21°1'- 22°32'N latitude) comprises numerous rolling hills and the vegetation comprises of tropical semi-evergreen forest, tropical moist deciduous forest, dry deciduous hill forest, high level Sal forest, grassland, and savannah. Three distinct seasons are felt during the year. They include the rainy season (mid-June to mid-October), winter (mid-October to February), and summer (March to mid-June). The annual rainfall ranges from 1200 mm to 2000 mm and temperature ranges from 2°C to 46°C. The study area concentrates in and around the deep forest pockets of tribal villages and villages situated in the transitional zone of SBR. Besides, visit to 16 weekly markets in different parts of Mayurbhanj, Keonjhar, and Balasore district were undertaken and interviewed was conducted on sellers of wild mushrooms about their edibility and economic values.

Sampling and collection of mushrooms

Stratified random sampling using quadrate method [16] was employed to collect the information on mushroom species diversity and ecological information. Mushroom diversity was studied during the year 2016 using 3 quadrats (10 × 10 m) at each site. Collection was carried out in 10 different forest areas of Northern odisha namely Bhimkund, Satkosia, Natto, Devkund, Bangiriposi, Bisoi, Joranda of Mayurbhanj district; Kanjipanighati and Barbil of Keonjhar districts and Kuldiha of Balasore districts and their adjoining areas. The fleshy mushrooms were collected from different habitats such as meadows, decaying wood, rotting plant parts, termite nests in the forest areas. Each of the collected samples were wrapped in wax paper and brought to the laboratory for identification purposes.

Identification of samples

Identification of specimens was based on macroscopic and microscopic features. The macroscopic features used were: the pileus size, shape, color, surface texture and surface moisture; gill color, attachment, spacing, the stem size, shape, surface texture and surface moisture, the presence or absence of partial and universal veils, flesh color and texture. The information of the various characters stated was used to identify each specimen by comparison with illustrations in colour field guides and also by the use of descriptions and keys [17, 18, 19]. Microscopic features were carried out using standard microscopic methods [15].

Quantitative analysis

The quantitative analysis such as density, frequency, and abundance of mushroom species were determined as per Curtis & McIntosh [20].

Density: Density was calculated for all the collected species by expressing the numerical strength of each individual.

$$\text{Density} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of quadrats studied}} \times 100$$

Frequency (%): Frequency is the percentage of occurrence of individual species in an area. It was studied by sampling the study area at several places at random and recorded the name of the species that occurred in each sampling units. It is calculated by the equation:

$$\text{Frequency}(\%) = \frac{\text{Number of quadrates in which the species occurred}}{\text{Total number of quadrats studied}} \times 100$$

Abundance: It is the study of the number of individuals of different species in the community per unit area. It is represented by the equation:

$$\text{Abundance} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of quadrates in which the species occurred}} \times 100$$

Species diversity indices

The vegetation data were analyzed for 20 mushroom species. Shannon index and Simpson's index were calculated using the quadrat data and following the methods given by Misra [21].

The Shannon index [22] was calculated as follows:

$$H' = -\Sigma [(ni/N) \ln (ni/N)]$$

Where, H' = Shannon index;

ni = No. of individuals of species in that vegetation type;

N = Total individuals of all species;

Concentration of dominance was measured following Simpson [23].

$$Cd = -\text{S} (ni/N)$$

Where, S = Number of species;

ni and N are the same as in the Shannon information function.

Equitability or evenness refers to the degree of relative dominance of each species in that area. It was calculated according to Pielou [24] as:

$$Equitability\ (e) = H'/Log\ S$$

3. RESULTS AND DISCUSSION

A total of 20 wild edible mushroom species belonging under nine families were recorded during the study period from ten different places of three districts viz. Mayurbhanj, Keonjhar and Balasore of Northern Odisha, India (Fig. 1). The families were grouped under six orders (Table 2) and among them Agaricales were dominated by 10 species followed by the order Russulales with six species and the remaining four orders *viz*. Boletales, Polyporales, Geastrales and Pezizales consisted of one species each. Out of 20 wild edible mushroom species fifteen species were found in forest soil substratum followed by three species from termite nests, two species from decaying wood logs and only one species from the decaying paddy straw. The dominant mushrooms species belonged to genera *Russala* (six species) followed by *Termitomyces* (three species) and *Amanita* (two species)

(Table 2). Species of the genus *Russula* were found abundantly in forest soil substratum during the peak growing periods and *Geastrum* species were rare and found only in Sal forest under decomposed leaves, while *Termitomyces* species were found abundantly in the sandy forest soil around termite nests (Fig. 3).The favorable time for collection of wild edible mushrooms in the study area was found during the onset of rains, the period when the conditions was conducive for the mushroom growth. The wild edible mushroom species started growing on the month of May with the oncoming of rain and the occurrence gradually increases and found to be high in August and then after decreases gradually at the end of October (Fig. 2).

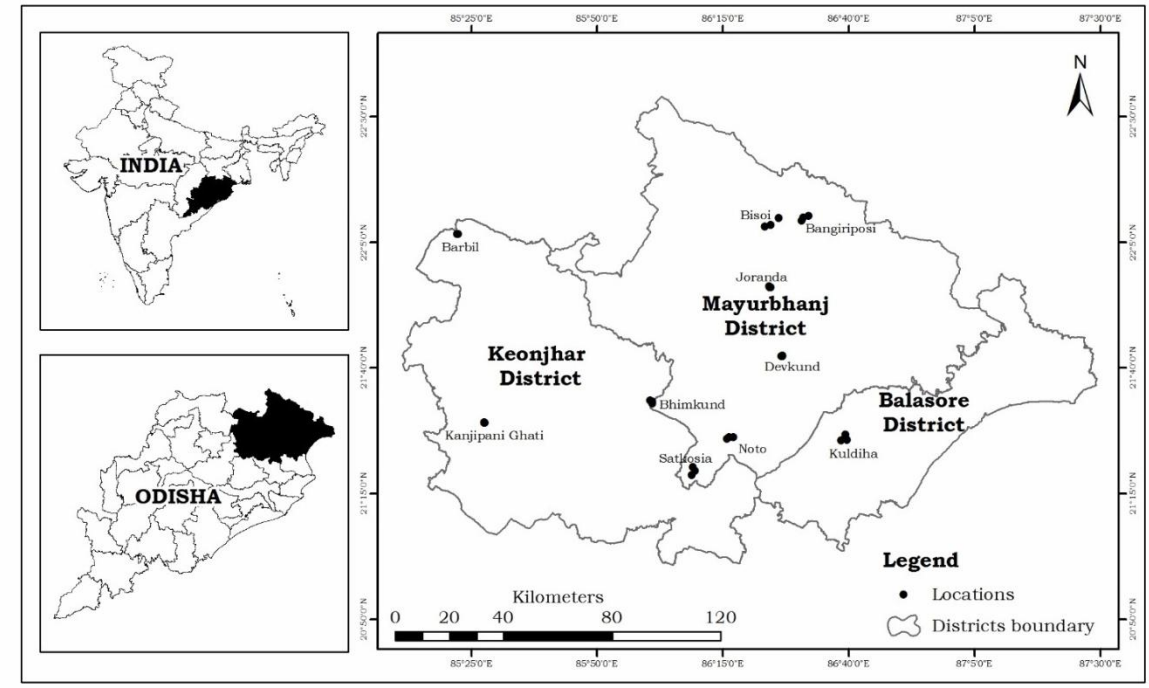

Figure1- Geographical map of Study area

Table1 Geographical position of sampling sites of northern Odisha.

Sl. No	Sampling Area	Sites	Longitude	Latitude	Elevation(m)
1	JORANDA	1	86°24'31.04"	21°56'06.72"	712
		2	86°24'15.81"	21°56'06.95"	672
		3	86°24'11.25"	21°56'18.66"	681
2	BISOI	1	86°24'28.63"	22°08'33.29"	340
		2	86°23'23.67"	22°08'11.54"	420
		3	86°26'08.11"	22°09'56.12"	360
3	NATTO	1	86°16'15.65"	21°26'16.75"	239
		2	86°15'51.69"	21°25'56.11"	256
		3	86°17'04.31"	21°26'14.90"	232
4	SATKOSIA	1	86°08'46.25"	21°18'46.52"	208
		2	86°09'25.66"	21°19'32.62"	216

		3	86°09'00.68"	21°20'18.36"	274
5	BANGIRIPOSI	1	86°30'40.77"	22°09'23.19"	285
		2	86°31'01.71"	22°09'59.02"	205
		3	86°32'01.51"	22°10'17.63"	136
6	DEVKUND	1	86°26'52.80"	21°42'27.98"	359
		2	86°26'40.01"	21°42'21.46"	381
		3	86°26'53.97"	21°42'25.19"	354
7	BHIMKUND	1	86°00'55.44"	21°33'25.91"	282
		2	86°00'55.20"	21°32'57.06"	273
		3	86°00'31.94"	21°33'34.75"	278
8	BARBIL	1	85°22'07.23"	22°06'38.98"	452
		2	85°22'14.51"	22°06'42.62"	461
		3	85°22'23.35"	22°06'38.98"	447
9	KANJIPANI GHATI	1	85°27'33.69"	21°29'12.37"	628
		2	85°27'37.32"	21°29'06.92"	642
		3	85°27'32.48"	21°29'07.53"	650
10	KULDIHA	1	86°38'32.88"	21°25'38.45"	256
		2	86°39'38.99"	21°25'43.89"	216
		3	86°39'20.88"	21°26'48.19"	341

Table 2 Classification of wild edible mushroom from Northern Odisha, India with their isolation source and period of availability.

Order	Family	Genus	Species	Substratum	Period of availability (Fresh)
Agaricales	Agaricaceae	*Lycoperdon*	*Lycoperedon pyriforme* Schaeff.	Grass field Soil	Aug-Sept
		Calvatia	*Calvatia gigantea* (Batsch) Lloyd	Grass field soil	May-Aug
		Volvariella	*Volvariella volvacea*(Bull.)Singer	Paddy straw	June-Sept
	Amanitaceae	*Amanita*	*Amanita egregia* D.A. Reid	Sal forest soil	June-Sept
			Amanita hemibapha (Berk. & Broome) Sacc.	Sal forest soil	June-Sept
	Lyophyllaceae	*Termitomyces*	*Termitomyces microcarpus* (Berk. & Broome) R. Heim	Termite nest soil	June-Sept

			Termitomyces eurhizus(Berk.) R. Heim	Forest sandy soil	June-Sept
			Termitomyces heimii Natarajan	Soil (Underground termite nest)	Aug-Oct
			Termitomyces sp.	Termite nest soil	Aug-Sept
	Pleurotaceae	*Pleurotus*	*Pleurotus florida* Cetto	Decaying Wood	Aug-Oct
Russulales	Russulaceae	*Russula*	*Russula delica* Fr.	Sal forest soil	June-Aug
			Russula rosea Quél.	Sal forest soil	June-Aug
			Russula virescens (Schaeff.) Fr.	Sal forest soil	June-Aug
			Russula cyanoxantha (Schaeff.) Fr.	Sal forest soil	June-Aug
			Russula densifolia (Secr.) Gillet.	Sal forest soil	June-Aug
			Russula violeipes Quel.	Sal forest soil	June-Aug
Boletales	Diplocystaceae	*Astraeus*	*Astraeus hygrometricus* (Pers.) Morgan	Sal forest soil	May-Aug
Polyporales	Polyporaceae	*Lentinus*	*Lentinus sajor-caju* (Fr.) Fr.	Decaying wood	July-Oct
Geastrales	Geastraceae	*Geastrum*	*Geastrum* sp.	Sal forest soil	June-Sept
Pezizales	Tuberaceae	*Tuber*	*Tuber* sp.	Sal forest soil	June-Aug

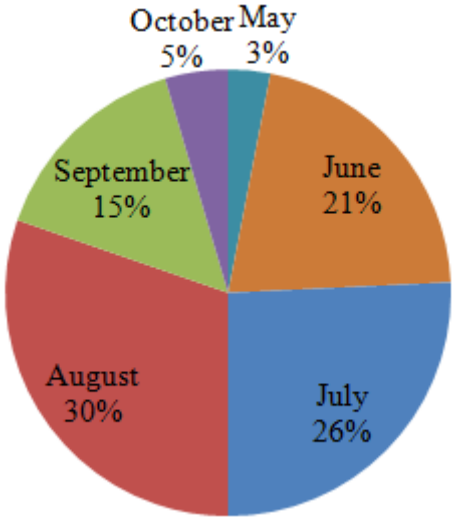

Figure 2 - Occurrence of wild edible mushroom species with respect to months in Northern Odisha

Photography of mushroom samples was taken from the habitat and also after collection (Figure 3). The morphological characters of each species were studied, documented and described in the following.

(a) *Russula rosea* Quél

(b) *Russula delica* Fr.

(c) *Russula densifolia* (Secr.) Gillet.

(d) *Russula violeipes* Quel.

(e) *Russula cyanoxantha* (Schaeff.) Fr.

(f) *Russula virescens* (Schaeff.) Fr.

(g) *Termitomyces heimii* Natarajan

(h) *Termitomyces microcarpus* (Berk. & Broome) R. Heim

(i) *Termitomyces eurhizus* (Berk.) R. Heim

(j) *Termitomyces* sp.

(k) *Amanita hemibapha* (Berk. & Broome) Sacc.

(l) *Amanita egregia* D.A. Reid

(m) *Tubber* sp.

(n) *Geastrum* sp.

(o) *Astraeus hygrometricus* (Pers.) Morgan

(p) *Lycoperdon pyriforme* Schaeff.

(q) *Calvatia gigantea* (Batsch) Lloyd

(r) *Volvariella volvacea* (Bull.)Singer

(s) *Lentinus sajor-caju* (Fr.) Fr.

(t) *Pleurotus florida* Cetto

Figure 3. (a)- (t) Wild edible mushroom species of Northern Odisha

Morphological characteristics of wild edible mushrooms obtained from the study area

NODM-1 *Russula rosea* Quél.

Pileus3-8 cm, beautiful red color, sometimes vermilion and crimson, lighter at edge, rounded then convex, eventually fairly flattened, fleshy, hard, margin curved, regular or slightly undulate, cuticle not detachable. Lamellae gypsum white with cream colored highlights, sometimes pinkish towards pileus edge, crowded, forked anastomosed near stipe, straight. Stipe 3-8 × 1-3 cm, white, fairy speckled with crimson red, especially at base, hard, fragile, club shaped, short and almost cylindrical. Flesh white, pink beneath cuticle, thick, hard, compact, granular when broken. Odor cedar or menthol, flavor similar bitter. Annulus absent and no volva**.** Spores pale cream colored, elliptical, warty, 6-8 × 6-8 microns (fig. 3(a)).

Place of collection: Kuldiha forest (Balasore)

Habitat: Growing solitary on decaying leaf litter of *Shorea robusta*

NODM-2 *Russula delica* Fr.

Pileus: 3-9 cm, whitish, sometimes with rust colored patches, surface dry, rounded then convex, eventually fairly flattened, fleshy, hard, margin thick, regular or slightly undulate, cuticle not detachable. Lamellae: white with cream colored highlights, crowded, forked anastomosed near stipe, regular. Stipe: 3-8 × 1-3 cm, white, hard, fragile, club shaped, short and almost cylindrical. Flesh: white, white beneath cuticle, thick, hard, compact, granular when broken. Annulus: absent. Odor: fruit like, flavor sweet. Annulus: absent and no volva. Spores: creamy white colored, elliptical, warty, 8-11 × 7-8 microns **(**fig. 3(b)).

Place of collection: Kuldiha forest (Balasore)

Habitat: Scattered on the ground in forest and growing in symbiotic association with the roots of *Shorea robusta.*

NODM-3 *Russula densifolia* (Secr.) Gillet.

Pileus: 3-11 cm, whitish turns black with maturity, surface dry, hemispherical then concave, deep depression, fleshy, hard, margin thick, regular or slightly undulate and cuticle not detachable. Lamellae: gypsum-white turns black, crowded, forked inosculated near stipe, regular. Stipe: 3-8 × 1-3 cm, grey to dark, hard, fragile, club shaped, short and almost cylindrical. Flesh: white, white beneath cuticle, thick, hard, compact, granular when broken. Odor: fruit or fish like, flavor bittery. Annulus: absent and no volva. Spores: creamy white colored, elliptical, warty, 8-12 × 7-8 microns (fig.3(c)).

Place of collection: Natto forest (Mayurbhanj)

Habitat: Growing on leaf litter, scattered, moist deciduous black decomposed soil.

NODM-4 *Russula violeipes* Quel.

Pileus: 3-10 cm, light or greenish yellow, planoconvex, umbilicate with depressed center at maturity, fleshy, hard, margin curved, regular or slightly undulate, cuticle detachable. Lamellae: white then cream to light greenish yellow, gills distant when mature, adnate to adnexed, regular. Stipe: 3-8 × 1-3 cm, cylindric, white to pale greenish yellow. Flesh: white, thick, compact. Odor: pleasant, flavor similar bitter. Annulus: absent and no volva. Spores: white cream colored, subglobose to globose, crowded warts, 7-8 × 6.5-8 microns (fig. 3(d)).

Place of collection: Joranda forest (Mayurbhanj)

Habitat: Growing scattered on decaying leaf litter.

NODM-5 *Russula cyanoxantha* (Schaeff.) Fr.

Pileus: 4-12 cm, blackish violet, pale purple at edge and conspicuous green at disc, varying to slate grey with lighter areas, bluish violet or a uniform green when mature, surface dry, rounded then convex, eventually fairly flattened, fleshy, margin curved, regular or slightly undulate, cuticle not detachable. Lamellae: white tinged bluish green, fairly crowded, unequal forked and regular. Stipe: 3-8 × 1-3 cm, white, hard, fragile, club shaped, short and almost cylindrical. Flesh: white, white beneath cuticle, thick, hard, compact, granular when broken. Annulus: absent and no volva. Odor: fish like, flavor sweet. Spores: white colored, elliptical, small isolated warts, 7-10 × 6-7 microns (fig. 3(e)).

Place of collection: Bhimkund forest (Mayurbhanj)

Habitat: Ectomycorrhizal fungus, growing solitary on decaying leaf litter.

NODM-6 *Russula virescens* (Schaeff.) Fr.

Pileus: 4-11 cm, dark gray, pale off white at edge and conspicuous grey and sometimes olive green at disc, , surface dry, rounded then convex , eventually fairly flattened, fleshy, margin curved, regular

or slightly undulate, cuticle not detachable. Lamellae: white tinged bluish grey, fairly crowded, unequal forked, regular. Stipe: 3-8 × 1-3 cm, white, hard, fragile, club shaped, short and almost cylindrical. Flesh: white, white beneath cuticle, thick, compact, granular when broken. Annulus: absent and no volva. Odor: fruit like, flavor sweet. Spores: white colored, elliptical, small warts, 7-10 × 6-7 microns (fig. 3(f)).

Place of collection: Bhimkund forest (Mayurbhanj)

Habitat: Ectomycorrhizal fungus, growing solitary on decaying leaf litter.

NODM-7 ***Termitomyces heimii*** Natarajan

Pileus: 4-10 cm, white, grayish in center when young, dry, rounded then convex, eventually fairly flattened, fleshy, margin thick, regular or slightly undulate, cuticle half peeling. Lamellae: white with cream colored highlights, moderately crowded, regular short gills of 2–3cm lengths. Stipe: 10-20 × 2-5 cm, central, cylindrical, creamish white, fibrillose, solid and smooth. Pseudorrhizea: white in colour, cylindrical, narrowing down to the point of attachment to the termite nest. Flesh: white, white beneath cuticle, thick. Annulus: double and no volva. Odor: fruit like, flavor sweet. Spore: white creamy colored, elliptical, smooth, 6-10 × 5-7 microns (fig. 3(g)).

Place of collection: Bhimkund forest (Mayurbhanj)

Habitat: Epigeous, emerging from termite comb, growing solitary on termite infested soil.

NODM-8 ***Termitomyces microcarpus*** (Berk. & Broome) R. Heim

Pileus: 1-4 cm, whitish, grey in center when young, pale conspicuous grey, irregularly lobed margin, smooth to silky, radially striate and viscid or slimy when wet, otherwise dry, moderately thick and fleshy. Lamellae: white, sparsely crowded, regular. Stipe: 2–4cm × 2-6 mm, central, cylindrical, whitish, fibrillose, smooth and solid, slender, slightly tapering towards the apex. Pseudorrhiza: absent. Flesh: white, white beneath cuticle, thin. Annulus: absent and no volva. Odor: pleasant, taste excellent. Spore: pink in colour, elliptical, smooth, 5.9–6.6 × 4.2-5 microns (fig. 3(h)).

Place of collection: Kuldiha forest (Balasore)

Habitat: Growing scattered or in groups on tropical moist deciduous forest and grassland.

NODM-9 ***Termitomyces eurhizus*** (Berk.) R. Heim

Pileus: 3.0-9.5 cm., grey-brown and then upturned with black, fading to whitish towards margins, thick and fleshy ,first convex later expanded, scales present on the surface, firm, margin regular, smooth, radially slimy when wet, otherwise semi-slimy. Lamellae: crowded, distinctly formed, free to subadnate, pliable and white. Stipe: central, usually long (up to 18.0 cm long and 1.5-2.5 cm thick), white, somewhat tough, solid above ground, hollow below the soil, penetrating to the soil. Pseudorrhizea: white in colour, cylindrical, narrowing down to the point of attachment to the termite nest, its length determined by the depth of the termite comb. Flesh: white, white beneath cuticle, thick. Annalus: absent, without volva. Odor: pleasant, taste excellent. Spores creamy white colored, ellipsoid, smooth, 5.9–9 × 1.3-5.7microns (fig. 3(i)).

Place of collection: Kuldiha forest (Balasore)

Habitat: Growing solitary on tropical moist deciduous forest and grassland.

NODM-10 *Termitomyces* sp.

Pileus: 1–5.9 cm, whitish, grey in center when young, smooth, silky, fibrillose and viscid or slimy when moist, otherwise dry, thick and fleshy. Lamellae: white, free, pliable and crowded. Stipe: 8–20×1-2 cm (epigeal), central, grayish, stuffed and smooth, solid above ground, hollow below the soil. Pseudorrhizea: white in colour. Flesh: white, white beneath cuticle. Annulus: white and persistent and no volva. Odor: pleasant, taste excellent. Spores: creamy white colored, elliptical, smooth 5.3–7.2 × 4.0–4.7 microns (fig. 3(j)).

Place of collection: Kanjipanighati (Keonjhar)

Habitat: Epigeous, growing solitary or in groups on termite infested soil.

NODM-11 *Amanita hemibapha* (Berk. & Broome) Sacc.

Pileus: 6-18 cm, hemispherical to flat, orange washing out to yellow, cuticle separable, margin strait, smooth, slimy, waxy, thick and fleshy. Lamellae: crowded, whitish yellow, free, pliable. Stipe: 6-14 × 2-3 cm, narrowing at top, hollow when mature, central, smooth, cylindrical, slightly swollen at base. Flesh: whitish, whitish beneath cuticle. Annulus: present with yellow falling ring with large white membranous volva. Odor: pleasant, fish like. Spores: white, elliptical, smooth, 8-14×5-8.5 microns (fig. 3(k)).

Place of collection: Bisoi (Mayurbhanj)

Habitat: Ectomycorrhizal fungus, growing solitary on decaying leaf litter of *Shorea robusta.*

NODM-12 *Amanita egregia* D.A. Reid

Pileus: 5-20 cm, whitish, hemispherical to flat, cuticle separable, margin strait, thick, fleshy, smooth, slimy and waxy. Lamellae: free, fairly crowded, regular and white. Stipe: 8-15 × 2-3 cm, narrowing at top, hollow when mature, smooth, cylindrical, central, slightly swollen at base, with large white membranous volva. Flesh: white, whitish beneath cuticle. Annulus: present with yellow falling ring with large white membranous volva. Odor: fruit like, flavor sweet. Spores: white, elliptical, smooth, 8-14×5-8.5 microns (fig. 3(l)).

Place of collection: Bisoi (Mayurbhanj)

Habitat: Ectomycorrhizal fungus, growing solitary on decaying leaf litter of *Shorea robusta.*

NODM-13 *Tuber* sp.

Carpophore: 2-6 cm, globose, irregularly lobate or deformed, peridium smooth, yellow brown, quite spotted, often cracked, almost smooth, hard, ligneous. Gleba: hard, solid, whitish, grayish brown when mature, tough, marbled. Odor: strong garlic, flavour pleasant. Spores: brownish, elliptical, 19-56 × 15- 45 microns (fig. 3(m)).

Place of collection: Satkosia (Mayurbhanj)

Habitat: Hypogeous, scattered and associated with moist deciduous trees.

NODM-14 *Geastrum* sp.

Carpophore: first subglobose, shaped like a tulip bulb. Exoperidium opening into 4-9 triangular lobes, up to 6 cm wide, fairly equal, divided in the middle, often cracked into areolae on the outside, olive-brown in the exoperidium, light brownish inside, with a thick fleshy stratum which breaks up and disappears except for the central part where a sort of cup forms at base of endoperidium, which is globose, 1.5-3.5 cm in diameter, light brown, sessile, membranous, with lighter apical ostiole, conical, fibrillose-fringed, with base not delimited. Gleba: whitish at first, soon olive-ochre, powdery as soon as peridium opens. Odor: pleasant. Spores: brown, globose, 3-5 microns (fig. 3(n)).

Place of collection: Satkosia (Mayurbhanj)

Habitat: Growing solitary on decaying leaf litter of *Shorea robusta.*

NODM-15 *Astraeus hygrometricus* (Pers.) Morgan

Carpophore: 2-5 cm in diameter, without stipe, globose. Peridium 2 layered; outer peridium (exoperidium) ochraceous tan or dark brown, hygroscopic, splitting stellately at maturity, opening in to 6-10 or more arms, star shaped and turning back; inner peridium (endoperidium) light coloured to grayish, opening by an ostiole. Gleba: brown with age. Capillitium threads attached to the side of the endoperidium. Odor: pleasant, flavor excellent. Spores: cinnamon-brown, spherical or globose, warty, 9-11.5 microns (fig. 3(o)).

Place of collection: Bangiriposi (Mayurbhanj)

Habitat: Hypogeous, Growing scattered and associated with moist deciduous trees.

NODM-16 *Lycoperdon pyriforme* Schaeff.

Carpophore: 1-6 cm in diameter, up to 6 cm high, pear shaped, sub globose. Exoperidium, broken up in to plaques of varying shapes and sizes, smooth. Endoperidium smooth, whitish to greyish yellow, opening at the apex where there is a papilla; at the base it has a white mycelial thread. Gleba: white, soft, fleshy at young stage, brown cottony at later stage. Odor: pleasant like fruit, flavor excellent. Spores: olive brown, globose, smooth, 2.5-4.5µm. Edible when young (fig. 3(p)).

Place of collection: Barbil (Keonjhar)

Habitat: Epigeous, growing scattered in sandy loam forest soils and grasslands.

NODM-17 *Calvatia gigantea* (Batsch) Lloyd

Carpophore: 10-30 cm in diameter, globose. Exoperidium, white turns brown with age, thin, smooth, minutely fragmented when mature. Endoperidium smooth, whitish to greyish yellow, becoming fragmented to disintegrated Gleba: white, soft, fleshy at young stage, elastic when mature, brown cottony at later stage. Odor: pleasant like fruit, flavor excellent. Spores: olive brown, globose, smooth, 3-5 micron. Edible when young (fig. 3(q)).

Place of collection: Bangiriposi (Mayurbhanj)

Habitat: Epigeous, growing scattered in sandy loam forest soils and grasslands.

NODM-18 ***Volvariella volvacea*** (Bull.)Singer

Pileus: 4-10 cm, white, velvety, blackish in center when young, dry, rounded then convex, eventually fairly flattened, fleshy, margin thick, regular, cuticle half peeling. Lamellae: distant, white then pinkish, moderately crowded, regular short gills of 2–3cm lengths. Stipe: 6.0-8.0 cm longs, narrowed upward, 2.5-3.0 cm broad at the base, 0.8-1.0 cm at the top, solid, membranous, brown, descending, margin curved, smooth. Annulus: absent and volva present. Odor: pleasant like fruit/fish, flavor excellent. Flesh: white, white beneath cuticle, thick, compact. Spores: pink, elliptical, smooth, 7-9 × 4.0–6.0 microns (fig. 3(r)).

Place of collection: Bisoi (Mayurbhanj)

Habitat: Growing on tropical moist deciduous areas, mostly on grassland or decaying paddy straw.

NODM-19 ***Lentinus sajor-caju*** (Fr.) Fr.

Pileus: 2-10 cm, silvery white colored to brown, irregular, funnel shaped, edge faintly spiraled, imbricate, variegated with small fibrillose scales. Lamellae: distant, white then pinkish moderately crowded. Stipe: 3-8 × 0.6-3.0 cm, pale white then yellowish, extremely tough, stalk central in position, solid and cone shaped normally hollow, narrowing towards base and rooting, elastic. Annulus: absent, volva absent. Odor: pleasant milk like, flavor somewhat acid. Flesh: thin, whitish, tough, elastic. Spores: whitish, globose, smooths, 4-7 microns (fig. 3(s)).

Place of collection: Devkund (Mayurbhanj)

Habitat: Growing on decaying wood, found on soil.

NODM-20 ***Pleurotus florida*** Cetto

Pilus: 3-12 cm, briefly convex, spatulate to kidney shaped, whitish or light grey. Surface smooth, margin incurved. Lamellae: white, yellowish when dry. Stipe: 2.0-6.0 × 0.5-2.0 cm eccentric or lateral, thick, smooth. Annulus: absent, volva absent. Odor: pleasant fruit like, flavor sweet. Flesh: thin, whitish, soft. Spores: whitish, elliptical or cylindrical, smooth, 6-11× 3-5 microns (fig. 3(t)).

Place of collection: Devkund (Mayurbhanj)

Habitat: Growing in clusters on dead tree trunk or branches and rarely on living trees.

Survey on market value of collected wild mushrooms

During the study, it was observed that, the rural tribal peoples in the northern region of Odisha collects mushrooms from the wild and sells in the market for their livelihood. Species belongs to genus *Termitomyces* were found to have the highest market value in rural (30-120 rupees/kg) as well as in urban markets (150-250 rupees/kg). Another wild mushrooms belonging under the genus *Russula* was found to be lower market prices both in rural (10-30 rupees/kg) and Urban markets (60-90 rupees/kg) as compared to other wild edible mushrooms (Table 4). Thus the study revealed that the economic value of wild edible mushrooms varied remarkably from rural to urban markets. This might be because of the ignorance of the rural tribal community about the palatability and health benefits of wild edible mushrooms while urban community were too choosy on those wild

mushrooms, because they have insufficient knowledge about and the edibility as they considered many of the mushroom species to be poisonous. Further, vendors play an important role on the economy of rural tribal people who depends upon the forest product such as mushrooms for their living. They used to purchase the mushrooms at cheaper price from the rural folk and sell in mush higher price in urban markets.

(a) **(b)**

(c) **(d)**

Figure 4(a)-(d) - Wild edible mushrooms of the study area: (**a** and **b**) tribal women selling wild edible mushrooms in road side as well as in local market (**c** and **d**)local vendors selling the wild edible mushrooms in urban market.

Table 4 Market values of some wild edible mushrooms sold in local markets of Northern Odisha

Mushroom species	Local name	Price in rural tribal villages/kg(Rs)	Price in city markets /kg(Rs)	Period of availability
Russula delica Fr.	Patra chatu	10-30	60-90	
Russula rosea Quél.	Kukuda chatu, Nali patra chatu	10-30	60-90	
Russula virescens (Schaeff.) Fr.	Patra chatu, Kali kukuda chatu	10-30	60-90	
Russula cyanoxantha (Schaeff.) Fr.	Jamu chatu	10-30	60-90	

Russula densifolia (Secr.) Gillet.	Angarani, Angar Chatu	10-30	60-90	Fresh sold during the rainy season (June-Aug)
Russula violeipes Quel.	Kukuda chatu	10-30	60-90	
Termitomyces microcarpus (Berk. & Broome) R. Heim	Bada bali chatu	30-60	150-240	
Termitomyces eurhizus(Berk.) R. Heim	Chota bali chatu	30-60	150-240	
Termitomyces heimii Natarajan	Parbana chatu, Ind chatu, Nada chatu	60-120	150-250	
Termitomyces sp.	Bihida chatu	60-100	100- 180	
Amanita egregia D.A. Reid	Mahudhal chatu, Dhala manda chatu	10-30	60-90	
Amanita hemibapha (Berk. & Broome) Sacc.	Haladia Manda	10-30	60-90	
Astrareus hygrometricus (Pers.) Morgan	Rutka chatu	30-80	120-250	
Volvariella volvacea (Bull.)Singer	Kuta chatu	80-120	120-200	

Quantitative analysis

Frequency, density and abundance of individual mushroom species of the study area were studied by comparative analysis. The results revealed that *Russula delica* Fr. showed highest density (5.73) among the mushroom species while *Lycoperedon pyriforme* Schaeff. showed the lowest (0.3). Similarly, the frequency of occurrence of *Russula delica* Fr. was highest (93.33%) whereas four mushroom species namely *Calvatia gigantea* (Batsch) Lloyd., *Termitomyces* sp., *Pleurotus florida* Cetto, and *Lentinus sajor-caju* (Fr.) Fr. showed lower frequency rate (3.33 %). Among the mushrooms *Termitomyces* sp. showed the most abundant species while *Amanita egregia* D.A. Reid and *Amanita hemibapha* (Berk. & Broome) Sacc. were found to be least abundant (Table 5).

Table 5 Density, Frequency and Abundance of Mushroom species of Northern Odisha

Sl. No.	Name of Species	Density	Frequency%	Abundance
1.	*Russula rosea* Quél.	3.1	90	4.96
2.	*Russula delica* Fr.	5.73	93.33	6.14
3.	*Russula densifolia* (Secr.) Gillet.	1.06	30	3.55
4.	*Russula violeipes* Quel.	4.46	90	3.44

5.	*Russula cyanoxantha* (Schaeff.) Fr.	1.36	50	2.73
6.	*Russula virescens* (Schaeff.) Fr.	1.96	40	4.91
7.	*Termitomyces heimii* Natarajan	0.83	10	8.33
8.	*Termitomyces microcarpus* (Berk.& Broome) R. Heim	3.7	26.66	13.87
9.	*Termitomyces eurhizus* (Berk.) R. Heim	1.06	36.66	2.90
10.	*Termitomyces* sp.	1.16	3.33	35
11.	*Amanita hemibapha* (Berk. & Broome) Sacc.	0.6	16.66	3.6
12.	*Amanita egregia* D.A. Reid	0.83	23.33	3.57
13.	*Tuber* sp.	0.4	6.66	6
14.	*Geastrum* sp.	0.26	6.66	4
15.	*Astrareus hygrometricus* (Pers.) Morgan	4.43	53	8.31
16.	*Lycoperdon pyriforme* Schaeff.	0.3	6.66	4.5
17.	*Calvatia gigantea* (Batsch) Lloyd.	0.33	3.33	10
18.	*Volvariella volvacea* (Bull.) Singer	0.46	6.66	7
19.	*Lentinus sajor-caju* (Fr.) Fr.	0.46	3.33	14
20.	*Pleurotus florida* Cetto	0.36	3.33	11

Diversity Indices

Diversity indices provide important basic information about rarity and commonness of species in a community. The analysis of mushrooms diversity among the study sites revealed that Bhimkund forest showed highest diversity indices in term of Simpson's index (0.83) and Shannon's diversity index (1.88). This forest also showed highest value of evenness (0.94) as compared to other study sites. In contrary, Bangiriposi forest showed lowest Shannon's diversity index (1.12), Simpson's index (0.56) and evenness (0.82) among the studied forest area (Table 6).

Table 6 Diversity of wild edible mushrooms from different regions of Northern Odisha

Sampling Area	Taxa	Shannon	Simpson	Evenness
JORANDA	8	1.71	0.78	0.90
BISOI	7	1.66	0.79	0.93
NATTO	7	1.46	0.72	0.88
SATKOSIA	8	1.83	0.81	0.92
BANGIRIPOSI	8	1.12	0.56	0.82
DEVKUND	7	1.65	0.75	0.87
BHIMKUND	8	1.88	0.83	0.94
BARBIL	7	1.28	0.64	0.84
KANJIPANIGHATI	9	1.87	0.80	0.89
KULDIHA	8	1.75	0.79	0.90

The present study documented 20 wild mushroom species to be edible based on the information provided by the tribal forest dwellers of the study area and in consultation with available literatures and mushrooms manual. The local and tribal peoples identify wild mushrooms based on their own perception, knowledge and phenological characters and the naming of the species is done in local dialect to keep memory and transfer the knowledge from one generation to the next. Such observations were also reported by many workers [25, 26]. Out of 20 wild edible mushroom species 15 species were documented from the forest soil substratum during the rainy seasons. Majority of the macro-fungi were collected from large sal tree (*Shorea robusta*) stands where organic matter might have built up in the rhizosphere. Species of *Russula* were dominant and found abundantly in forest soil substratum during the peak growing periods followed by *Termitomyces* and *Amanita* species. Similar observation were made by Sharma [27] who reported *Russula* as one of the most dominant genus inhabiting the all tropical forests of India. Further, Riviere [28] have reported that, the family Russulaceae was dominant ectomycorrhizal fungal populations in two tropical rain forests of Africa (Western Upper Guinea) and Asia (Western Ghats, India). Wild edible mushrooms are predominantly fleshy and gilled fungi that appear with the beginning of rainy seasons and the rate of appearance decreases with the beginning of winter. The reason for this may be attributed to adequate moisture, favorable temperature, relative humidity and sunshine, which aids the macrofungi in the decomposition of dead organic matter. The seasonal monsoon starts in Odisha from late June to late September. In this study all of the edible mushroom species appear in the month of August. Similar observation on appearance of edible mushrooms was reported from Eastern Ghat regions of Odisha by Mohapatra [29] suggested that, August as the peak time for mushroom collection. Macrofungi diversity was found to be higher in the Bhimkund forest. The higher diversity of Bhimkund may be due to less anthropogenic effect of this area as compared to other forest sites. Besides, the evenness of the mushrooms was also found to be highest in Bhimkund forest (0.94) indicating more even distribution of the macrofungi in this forest. Wild mushroom harvesting not only provides healthy food to the rural dwellers, but also it brings economic benefits to unemployed people. Out of 20 wild edible mushrooms 14 species found to be sold in both rural as well as urban markets, this may because of their appealing taste, frequent occurrence and the fact that they are easily identifiable by the locals as safe for consumption. Species belongs to genus *Termitomyces* were found to have highest market value in rural (30-120 rupees/kg) as well as in urban markets(150-250 rupees/kg) (Table 6). Earlier studies of Sanjeev & Yash [30], observed that in Jammu and Kashmir, *Termitomyces* spp. were sold at marginally higher price of rupees 40-50 per kilogram than other studied mushrooms. During survey, it was observed that wild edible fleshy fungi were usually collected by rural/tribal womens in bamboo buckets and sold along the road sides (Fig 4). Also in Punjab and the adjoining border areas of Himachal Pradesh, the local people collected the mushrooms in bulk and further sold these through their sale counters at rupees 60-80/kg [31].

Mushrooms that are sold by traders do not have enough knowledge on the taxa as the tribal or rural peoples. Many peoples in the urban areas are less interested to consume wild edible mushrooms probably due to perception that considered wild mushrooms to be poisonous. Wild edible mushroom species sold by the tribal communities were less demanding and fetched very low price due to ignorance of their edibility and are only purchased by local people having knowledge on the mushrooms. Documentation and dissemination of knowledge on wild edible mushrooms would help the rural tribal communities to fetch a higher price and increase income generation. Further details of nutritional analysis and scientific study on the medicinal properties of the mushrooms should be evaluated to help to develop a proper knowledge base and increase market demand of these mushrooms species. Thus, utility and better marketing of wild mushrooms could contribute to improve the livelihoods and to reduce the poverty of the local communities.

4. CONCLUSION

This study provides the baseline information on wild edible mushroom diversity, distribution of northern region of Odisha and stresses upon the socio-economic importance of the indigenous edible mushroom species among rural/tribal peoples. The study also recommends regular surveys over an extended period in order to assess the patterns of abundance of mushrooms in different seasons. From such information, harvesting strategies and management plans can be formulated and implemented to ensure the lasting presence of these socially and economically important species. In view of the increasing commercialization of the wild edible mushrooms, more studies on the production and cultivation of some of these socio-economically important wild species should be conducted in this region by introducing simple and appropriate low cost technology. Further, it will be worthwhile to gather different views of the local populace about the value of mushrooms, which would pave a way for the introduction of some known wild edible mushrooms in the diet of rural population. In addition wild mushrooms are known to exhibit novel bioactive compounds and bioactivities. Therefore, further studies need to be carried out in order to assess the mushroom diversity of Northern regions of Odisha in a view to highlight their socio-economic importance and ethno-medicinal potentials for discovery of novel compounds for their pharmaceutical applications.

ACKNOWLEDGEMENT

The authors are highly grateful to the village heads and other resource persons from the study area for sharing their invaluable knowledge and experience. We are thankful to the forest staffs of Keonjhar and Mayurbhanj forest divisions for their help and co-operation. Mr. Manish Kumar Bakshi, GIS expert of Palamu tiger reserve Jharkhand is thanked for generating the map of study area. This study is a part of project funded by Department of Science and Technology, Govt. of India (Project No. SB/EMEQ-038/2014).

CONFLICT OF INTEREST

We declare that we have no conflict of interest.

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