Asian Journal of Biology

16(2): 21-32, 2022; Article no.AJOB.94252
ISSN: 2456-7124

Temitomyces heimii– A Nutritious and Medicinally Important Wild Edible Mushroom of Similipal Forests, Odisha Boosting Tribal Health and Economy

Supriya Kulkarni [a], Santosh Joshi [b++] and Hrudayanath Thatoi [a*]

[a] Department of Biotechnology, Maharaja Sriram Chandra Bhanja Deo University, Takatpur, Baripada-757003, Odisha, India.
[b] Department of Forest, Environment and Climate Change, Government of Odisha, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJOB/2022/v16i2298

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/94252

Short Communication

Received 27 September 2022
Accepted 29 November 2022
Published 07 December 2022

ABSTRACT

Mushrooms are consumed worldwide because of their nutritional, medicinal values as well as pleasant taste and flavour. Wild edible mushrooms are source of livelihood for poor and landless people which they consume and sell the surplus mushrooms in the nearby market. Many people are not aware about the edibility of wild mushrooms which are generally confined to the tribal areas. However, tribals are aware of the edible mushrooms due to their age-old traditional uses and fond of hunting mushrooms during rainy season. The present paper deals with availability, collection, consumption pattern of wild edible mushrooms by tribals communities, along with preservation and economical contribution of *Termitomyces heimii*, a popular wild edible mushrooms profusely growing during rainy season of the Similipal, state of Odisha, India.

Similipal has a greater diversity of mushrooms throughout the length and breadth due to its varying soil and climate conditions. *T. heimii* collected the tribal people from near forest area in 4-5 different times in huge quantities during July to October. It partly consumed and rest of the mushroom are sold in the market at a price of Rupees 300/- to 400/-. *Termitomyces* were more frequently available

[++] *Divisional Forest Officer, Baripada Forest Division;*
**Corresponding author: E-mail: hnthatoi@gmail.com;*

in Sal (*Shorea robusta*) forests. Many traders visit forest fringe villages and collect this mushroom from local collector's and sell it in the marker with profit. Due to its taste, the mushroom has got very high demand in this locality that, it is sold within 5-6 hours after reaching to market. It is assessed that mushrooms worth 14 lakhs are sold in Baripada alone a nearly town of Similipal. The valuation *T. heimii* alone made by the authors during the field assessment showed that, the entire of Similipal is contributing economically nearly 1.2 crore value of mushrooms as contribution towards livelihood of tribal people. In interior areas tribal people preserve the mushrooms after drying it and consume later during after the season is end. During the study, a survey was conducted in villages adjoining to the forests and local markets to assess the quantities of mushrooms collected from forest and the value of selling valve on the market. Exercise was conducted to know the traditional preservation practice of this mushroom by tribals. From the present investigation, it is concluded that *T. heimii* is an important wild edible mushroom from Similipal which provides, nutrition and economic boost to the tribals in Similipal region. This promising species can be explored for its domestication in view of its preferred food value as well as a livelihood support of the rural poor people.

Keywords: Wild edible mushrooms; Termitomyces; Similipal; tribal economy; preservation of mushrooms.

1. INTRODUCTION

"Mushroom is the fruiting body of macro-fungi (*Ascomycota* and *Basidiomycota*) and represents only a short reproductive stage in their life-cycle" [1]. "Mushrooms have a long association with humankind and provide profound biological and economic impact. There are thousands of mushroom species in the world that grow allows ecosystem in the wild forest and are classified into two groups, namely, the edible mushroom and non-edible mushroom. Many of the wild mushrooms have been traditionally consumed by man with delicacy probably, for their taste and pleasing flavour" [1]. "Wild edible mushrooms have rich nutritional value with high content of proteins, fibbers, minerals, trace elements, vitamins, and low/no calories and cholesterol" [2,3]. "Many of these mushrooms have been used as folk medicine for thousands of years. Mushrooms are their nutraceuticals (natural food by tribe people having potential value in maintaining good health and boosting immune system of the human body) or can produce potent nutraceuticals (compounds that have medicinal and nutritional attributes and are consumed as medicines in the form of capsules or tablets but not as food" [4,5]. "It is estimated that out of approximately 14,000 known species, 2,000 are safe for human consumption and about 650 of these possess medicinal properties" [6]. "Large number of mushrooms are known to be rich sources of various bioactive substances like antibacterial, antifungal, antiviral, antiparasitic, antioxidant, anti-inflammatory, antiproliferative, anticancer, antitumour, cytotoxic, anti-HIV, hypocholesterolemic, antidiabetic, anticoagulant, hepatoprotective compounds, among others" [7,8,9]. "In a biodiversity rich country like India, mushrooms are a boon for the progress in the field of food, medicine and unemployment because of several medicinal mushrooms that have been found to be useful towards human health development" [6,10,3].

The Similipal Biosphere Reserve in Odisha located between (Latitude $20^0$17′ to $22^0$34′ N and Longitude $85^0$40′ to $87^0$10′ E) with an area of 5569 km^2. It is located in the central part of Mayurbhanj district of Odisha. Similipal Biosphere Reserve is surrounded by the states West Bengal and Jharkhand at the North-East and North-West respectively, While its East and South-West borders one linked with Balasore and Keonjhar districts. It falls under the extended portion of Chhotanagpur plateau. Similipal is a hilly and forest terrain whose altitude of the Biosphere Reserve varies from 40 m to 1200 m. While the humidity also varies from 70% to 100% due to the presence of dense forest. It experiences tropical climate with temperatures ranging from 2^0-15^0C in winter and 30^0-45^0C in summer. The annual rainfall is about 2200 mm from south-west monsoon (June to September) and retreats north -east monsoon (November) represents. Similipal represt diverse forest types such as dry deciduous, moist deciduous and semi-evergreen forest harbours rich and endemic flora and faunal diversity. Similipal Biosphere Reserve (SBR) include the entire Similipal Sanctuary, tiger reserve, elephant reserve and the proposed national park. Nato and Satkosia reserve forests and a 10 km belt form the boundaries of Similipal [11]. The Similipal Biosphere Reserve has a well demarcated core area, as well as buffer zone. While core has

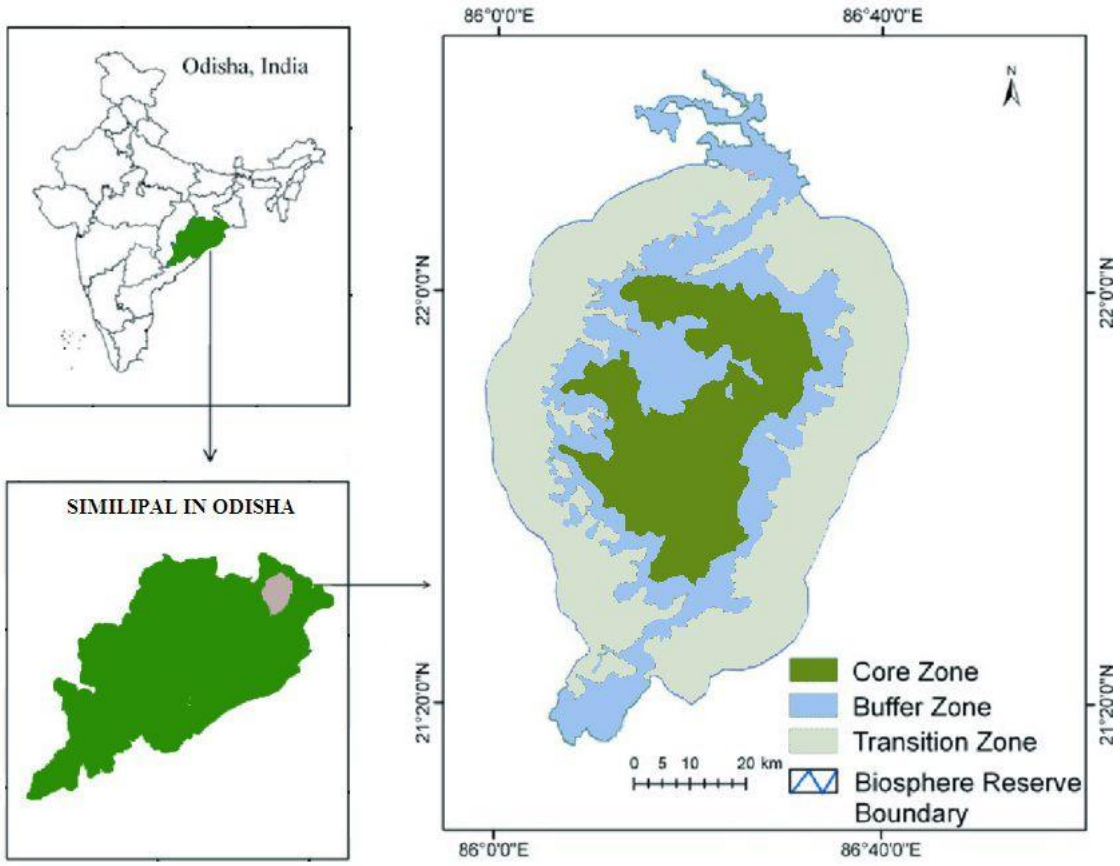

Fig. 1. Similipal Biosphere Reserve, Odisha

seven forest ranges, namely upper Barha Kamda (UBK), Chahala, Jenabil, Nawana (South), Nawna (North), Pithabata and National Park. The buffer zone has twelve ranges falling into three forest divisions, namely Baripada, Karanjia, and Rairangpur. The Similipal is the abode of several tribal communities such as Santal, Ho, Bhomij, Bhuian, Bathudi, Kharia, Gondo, Mankdias, Pouri-Bhuyan, Mahalis, Sounti and Saharas. Some of these tribes, e.g. the Kharia and Mankdias and Saharas, still live in a primitive state. They depend solely on the surrounding forest for most of their requirements-from food to medicine [12]. “Apart from flora and fauna, Similipal is also rich in mushroom diversity. Mushrooms are worldwide appreciated for their taste and flavour and are consumed both in fresh and processed. Apart from being delicacy and tasty foods, they have special biochemical compositions, with significant contents of proteins, carbohydrates, lipids, enzymes, minerals, vitamins and water which attract more attention as functional health promoters. Mushrooms are well known to produce a wide range of secondary active metabolites with high therapeutic value” [13]. To obtained data related to the mushroom its ecology and commercial aspect field study as well as survey in local market and village household were conducted during rainy season in 2022.

2. WILD EDIBLE MUSHROOMS

“For thousand years wild edible mushrooms are one of the important natural sources of food and income for many indigenous communities across the world” [14,15,16]. “These mushrooms are also known as an important source of folk medicines” [17,18]. “Wild mushrooms are considered as valuable non-timber forest resources used by tribals and other indigenous people and their use has been documented in many countries around the world” [5]. They are also sold in traditional markets [5] or commercially exploited as food or medicines. In many parts of the world mushrooms have been used extensively in traditional medicine. Several species of medicinal mushrooms have been identified as potent immunomodulators or bactericide and they are used to treat infections.

"In several studies it was demonstrated that mushrooms of the genus *Termitomyces* possess the immunomodulatory or antibacterial activities" [19].

3. GENUS *Termitomyces*

The genus *Termitomyces* is one of mushrooms genera representing a unique group of edible species which are superior in taste to every other edible mushroom [20,21]. The genus *Termitomyces* belongs to family Lyophyllaceae of order Agaricales (Agaricomycetes). The Genus was established by Heim (1942), a French mycologist. *T. heimii* described as new to science in 1979. *Termitomyces* mushrooms were naturally endowed with high nutritional values, containing a full range of non-replaceable amino acids and minerals at high concentrations [22,23]. All species of the genus are both nutritious and regarded as delicious [24], and have been used for human consumption for many years in many countries [25]. Currently, the genus comprises of 71 taxa. In India, 16 species of *Termitomyces* have been reported so far [26].

"Because of their unique taste and exotic flavour termitophilic mushrooms are frequently gathered by low-income groups in bulk from the forested and roadside stops during rainy season in different parts of the world including India, Tanzania, Nepal, Côte d' Ivoire, Cameroon, etc" [21,27,28,29,30]. Besides edibility, there are also a number of references pertaining to ethnic uses of *Termitomyces. Tibuhwa,* (2012b) has documented the use of *Termitomyces* mushrooms as food and medicine against various gastro-intestinal ailments by different communities of Tanzania [27]. Aryal and Budathoki (2016) while investigating the ethnic aspects highlighted the different cultural practices associated with use of different *Termitomyces* species in Nepal [28]. Ethnomycological uses of different mushrooms including *Termitomyces* species in Cameroon was documented by Teke et al., [29]. Kalaba et al., (2013) reported that "*T. titanicus* was sold by the local tribals at the roadside market in Katanino in Zambia [30]. In India, *Termitomyces* mushrooms are collected for their consumption and selling in different regions such as Punjab, Goa, Chhattisgarh, Karnataka, Kerala, Maharashtra, Gujarat, Tamil Nadu, Nagaland, Madhya Pradesh etc" [31,32,33,34]. These mushrooms are sold alongside village roads and local markets. Atri et al., [35] has reported that the fruitbodies of *T. heimii* and *T. mammiformis* were sold @ Rs 50- 60/-per kg in the local markets of Punjab [35]. At present the population of these mushrooms is reported to be dwindling because of being under constant target of mushroom hunters [35,36]. "The knowledge of use of termitophilic mushrooms is quite high in case of ethnic tribes of Kodagu region in Karnataka" [37]. "While analyzing the Goa's booming illegal wild mushroom trade, it is reported that the trade of wild edible termite hill mushrooms has increased from Rs 5 lakhs per annum in 1980 to Rs 1500 lakhs/annum by 2019. During Nagapanchmi in Panaji (Goa) a single wild mushroom seller is reported to earn Rs. 30,000–50,000/- a day" [37]. There is a great demand for this mushroom in Ponda (Goa) that a person has been reported to sell packets containing 25–30 mushrooms @ Rs 100/ per packet and just in one hour he is reported to earn Rs 50,000/- [38]. In Baripada (Odisha) survey conducted by author reported that around 150kg *T. heimii* was sold per day at price as an average 350 per kg with a total value of approx. Rs. 52000/-.

"Mushrooms in daily life are mostly seen as a food product. These structures of *Termitomyces* have been described by various authors under different names" [39]. Heim.,1977 "proved these structures exclusively as sporodochia which are found on the combs of *Macro-terminae* and represent the anamorph of the genus *Termitomyces"* [40]. "The fruiting bodies of *Termitomyces* are rich in nutritional and medicinal constituents. Many species of *Termitomyces* are used by different ethnic groups with ethnomedicinal knowledge" [41] *Termitomyces* R. Heim, a fungal genus belonging to the family Lyophyllaceae [42,43], "These mushrooms are regularly collected both for home consumption and for sale in local markets or along roadsides" [44,45].

Termitomyces spp. are another popular edible mushroom largely consumed by the people of tribal as well as urban areas of the country [46]. *Termitomyces* is a genus of edible mushroom collected from the wild and commonly consumed in Africa and Asia. Major bioactive components of *Termitomyces* mushrooms include polysaccharides, phenolics, fatty acids and lignocellulolytic enzymes have potential uses as antioxidants, immunomodulators, antitumors, and antimicrobial

4. *Termitomyces heimii*

"Termitomyces heimii is termiophilous fungi, solitary and gregarious, usually growing

symbiotically on the termite nests. The mushroom can be described as follows.

Pileus 3-5 cm in diameter and extends upto 10 cms on full maturity, it has scale fibrous on surface, white to creamy in colour, solid fleshy, margin is incurred, inflexed, no colour change while handling or brushing. Pileus cuticle: filamentous, 6-8 µm thick, hyaline, septate, interwoven, cramp connection present; Hymenophoral trama: sub regular, divergent, hyaline hyphae, septate, clamp connection present; It has a centrally stipe of 10-20cm long, 4cm thick white, surface smooth, viscid when moist, cylindrical tapering downward, not hallow with ring, fibrous surface, annulus. Stipe cuticle: filamentous, regularly arranged, 6-8 µm thick, septate hyaline, cramp connection present. Gills of the mushrooms are crowed, free attached, separable. Basidiospores: 6-8 x 4-6 µm ovate to ellipsoidal, whitish to pinkish or white to grey inamyloid; Basidia: 30-36 x 8-10 µm, claviform, 4 spored, sterigmata upto 4 µm long; Pleurocystidia: 38-42 x 8-10 µm, clavate and hyaline; Cheilocystidia: 30-36 x 6- 8 µm long occasionally present, hyaline" [31].

Fig. 2. *Termitomyces heimii* grown in Sal forest in Similipal

5. *Termitomyces* MUSHROOMS ECOLOGY

Mushrooms are the key entities in the forest ecosystems being saprobic in nature and play a significant role in the environment. The fungi *Termitomyces* are known to have a unique life cycle. Various species of *Termitomyces* are widely dispersed in Africa and Southeast Asia [29,47]. "They live in a medium called the fungus comb, located in a special chamber, fungus garden, inside the nest. The termites collect plant materials from outside the nest to maintain the fungus combs, which they later eat" [48]. *Termitomyces* mushrooms grow as symbionts in the termite nests, produce various enzymes to help termites for the digestion of lignocellulosic substrates from plant materials.

"*Termitomyces* mushrooms production of their fruiting bodies under artificial cultivation has not been successful yet" [49]. These are specially grown on the soil maintaining symbiotic association with termites and therefore, quite difficult to grow artificially. Red soil covers the maximum area among all the soil groups extended to the districts of Koraput, Rayagada, Malkangiri, Nawarangpur, Keonjhar, Ganjam, Kalahandi, Nuapara, Bolangir, Denkanal and Mayurbhanj which are the major areas where *Termitomyces* genus found to be the dominant. Many a times other mushrooms in rainy season resemble to *Termitomyces* spp. cause food poisoning in different localities. Five species of *Termitomyces* namely, *T. microcarpus , T. heimii, T.eurrhizus, T clypeatus*and *T. medius* were found largely on the soil with long pseudorrhiza.*Termitomyces* mushrooms become an important source of nutrients as well as micronutrients including vitamins and minerals [50]. "Several species of *Termitomyces* are commonly used ethnomedicinally for health promotion and treatment of illnesses. *Termitomyces albuminosus* is used in China for improving brain and stomach functions and curing hemorrhoids. In India, *T. heimii* and *T. microcarpus* are used in treatment for fever, cold, and fungal infections" [51]. "*T. heimii* is as blood tonics during wound healing and blood coagulation" [24].

6. COLLECTION OF *Termitomyces heimii* FROM SIMILIPAL

Similipal foothills provide perfect environment and ecological niches for the growth of Termitophilic mushrooms. The mushrooms collected by tribal family are usually 5 to 6 kg per day and 50 to 60 kg per season. The average selling price for a kilogram of mushroom in rurals is about Rs. 350 to 400 per kg. depending upon type of mushroom. Its price varies with different localites. Collection of mushrooms and its consumption is a traditional practice in rural and tribal zones of Odisha in different forests and surrounding areas. In many cases, the collections of mushrooms are for the self-consumption rather than for the commercial purpose except few cases [52]. *Termitomyces heimii* is locally known as "*parban*" mushroom.

However different tribes in different parts of Similipal, identify this mushroom in different names such as Bihuda chhatu, Paraban chhatu, Dasahara chhatu, Bada Chatu etc.Probably because of its fruiting coincides with festivals, like Bihuda, Rath yatra, Dasahara festival these are named differently mushroom fruiting observed during festival etc. This mushroom grows in forest, village land during rainy season. It has a special character, it grows plentily for about a week and then disappears. Again, it appears with a gap of 15-20 days. Nearly 4 to 5 times it grows in forest starting from Ganesh puja (July) to Durgapuja (October). When it grows, mushrooms in quintals are collected by local people. Partly of these are consumed and surplus mushrooms are sold either in nearby towns or markets. *Termitomyces heimii* is most favourite and demanded mushrooms in and around Similipal due to its unique taste. Any quantity of mushroom comes to market, are sold within few hours. During the study period in 2022 mushrooms are sold @ 400/- per kg in market. Mushroom collected in two different stages of growth that is full grown with mature mushroom and young mushroom (pile is not opened). Consumers prefer young mushrooms for their delicacy, and its price is also high compared to mature mushrooms and consumed by people irrespective of their caste, income group, and age. During survey of mushrooms in Baripada town during october (Durga puja), we noticed nearly 15-20 people selling their mushrooms in different location like daily markets, such as Bhaghara road, Station bazar, Murghabadi, Asthia, Takatpur and nearly 100-150kg mushrooms are sold continuously for about one-week period. The sellers comprised with villagers with small quantity (2-5kg), traders who collected from nearly Baripada such as Lulung, Costa, Kuliana, Kathpal, Biudhi khamari, Dantiamuhan, Badjod etc. One interesting fact is that, in forest where these mushrooms grow are found in huge quantities (4-5 kgs) in one place. The financial contributions to rural livelihoods are not known though the widespread sale of these wild edible fungi takes place in and around Similipal. But it clearly demonstrates that substantial amounts of money are earned. Women frequently go on trips in many parts of Odisha and a number of reports confirm the importance of this activity during the three- to four-month season, each year. The distance from collecting sites to potential markets is a crucial factor in selling wild edible mushroom. The roadside markets at villages in Mayurbhanj district are close to the forest areas where wild edible mushrooms are sold. One seller from the villagers informed that there was competition among the people for collecting this mushroom. For this competition, the villagers go to the forest before the sunrise with torch in search of this mushroom. They usually travel within 2-3 km inside the forest to make sufficient collection of this mushroom. The mushrooms were appeared as a white patch which is distinctly visible because they grow in large quantity and large in size (Bada chhatu) as well. There is no shortage of people wanting to collect and sell, and there is an increased competition for mushroom resources. People now have to walk further to collect the mushroom Sales at Dongadhia, Sarat, Poadhia one of Similipal and elsewhere depend on the flow of traffic and buyers. Some traders wait until the end of the day and buy the unsold produce, moving it quickly to more central markets in the bigger town. The prices they offer are low but the alternatives are either to dry the mushroom or discard them. Mushroom are sold on roadside local markets in villages of Odisha, in small-scale but to a greater extent within towns rather than by the roads. From our survey, it is reported by villagers that, sometimes tiger may appear where these mushrooms grow. This may be a myth. However, it has some reality as many wild animals like deer, boar etc eat this mushrooms and tiger may come to catch the prey. During the field survey on wild edible mushrooms, ethnomedicinal uses of this mushrooms were also collected. The powder of this mushroom is applied on body for treatment chicken pox and wound healing [51]. It is not consumed when someone is suffering some serious diseases or the person is very week.

7. CONTRIBUTION OF MUSHROOM TOWARDS ECONOMY

Approximately 150 kg of mushrooms are sold in Baripada town continuously for 7days at a time which means 1000kg are sold for one set. If thousand kg of mushroom is sold in one lot in Baripada, then in 4-5 sets nearly Rs.4000-5000kg or roughly 40-50 quintals of mushrooms are sold in Baripada. It is expected that, more than the same number of mushrooms i.e., 5000kg are consumed by the local people, Thus, roughly 100 quintals of mushrooms are collected from Baripada, adjacent forest near to Similipal forest in a season. This is only status of northern part of the Similipal (Baripada and its adjoining areas). If we consider the southern, western and eastern, into consideration, then the total mushrooms collection would be approximately 4

Table 1. Detailed of quantity and selling of *T. heimii* mushroom in different location of Baripada during rainy season 2022

Sl. no	Name of the market in Baripada town	No. of times mushroom appeared in the market in one season	Average number of days per season appeared in the market	Average quantity sold per day. (kg/day)	Total quantity sold per year (in kg)	Average price Rate/kilo (in Rs)	Total amount of mushroom sold (Rs)
1	Baghara road	4	6	24	576	350	201600
2	Stationbazar	5	7	38	1330	400	532000
3	Stadium Square	5	5	42	1050	350	367500
4	Murghabadi	3	6	17	306	300	91800
5	Asthia	4	5	9	180	300	54000
6	Taktpur	4	4	22	352	350	123200
	Total				3794		**1370100 (say 14 lakhs)**

times (i.e. 400 quintals). If we consider Rs 300/- as an average cost per kg of mushroom, the total cost of the *Termetomyces heimii* mushroom in a season would be approx. 1 Crore 20 lakhs Rupees. This is the contribution of one mushroom variety towards the livelihood support of tribal people in and around Similipal.

8. MUSHROOM PRESERVATION

Mushrooms are a seasonal and highly perishable food that are primarily available in the monsoon season. Value addition requires different preservation techniques that prolong shelf life. Salting, boiling, sun drying, and soaking (in fresh or cold water) are all common techniques for preserving mushrooms. Sun drying and smoking were the two most popular techniques in the research area. However, dried mushrooms have been observed being sold in markets or along the sides of roads despite the fact that preservation is primarily done for domestic use and rarely for commercial purposes. Preservation has the possibility of significantly enhance the nutritive and sensory qualities of wild edible mushrooms. Mushrooms undergo post-harvest procedures to prolong their shelf life and improve their marketability

9. PROCESSING AND PRESERVATION FOR SHORT AND LONG-TIME UTILIZATION

Wild edible mushrooms (WEM) are an important dietary food supplement to many tribal communities around the world. They are used in traditions not just as foods, but also for other purposes, among which medicinal use is the most prominent one.

“Wild mushrooms had been collected and consumed by people from the past. Many edible mushrooms are considered as functional food / nutraceutical, since it supplements diet and used in prevention and treatment of diseases. They provide body with the required amount of vitamins, fats, proteins, carbohydrates, etc., needed for the healthy survival of body” [3]. “The quality of a wild mushroom as functional food is dependent on the nutritional and chemical composition of the fruiting body and may differ according to species on the substratum, atmospheric conditions, age and part of the fructification its food value lies between meat and vegetables” [53]. “The nutritional composition of mushrooms from different countries were reviewed by various workers” [54].

Fig. 3. Preservation of mushrooms (*T. heimii*) through sun drying by tribal people

Fig. 4. Collection and selling of *T. hemii* in local market near Similipal, Odisha (a- *T. hemii* growing in the forest, b- *T. hemii* collected by local villagers, c- *T. hemii* collected by local peoples for own consumption, d- *T. hemii* selling to traders, e- Transportation of *T. hemii* by traders to local market, f- Selling of *T. hemii* by traders in local market)

10. CONCLUSION

Termitomyces heimii is a delicious wild edible mushroom, profusely grows in foot hills of Similipal. Even if this mushroom is sold at a high price, it is purchased and consumed by local people as a favourite food. *T. heimii* also has some medicinal value and used as ethnomedicine. It grows in 4-5 times a season during rainy season and appears in huge quantity in each time having great contribution towards livelihood support. This mushrooms no doubt boosts the economy and health benefit to the tribals and most important mushrooms in Similipal. The mushroom *T. heimii* is also dried and preserved by tribals for its use during lean period. Its commercial use would be very essential for supplement nutritional benefit to the human being and providing economical benefit as well.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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