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Association of *Termitomyces* spp. with fungus growing termites

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Abstract. Among 5 species of *Termitomyces* spp. associated with *Odontotermes* spp., *Termitomyces microcarpus* was the most dominant on the mound surface of *Odontotermes redemanni* during the rainy season. This species was found to grow on the fungal comb fragments brought out by termites as the substrate for its growth. As a result, decrease in cellulose (5·9%), lignin (3·5%) nitrogen (0·54%), carbon (11·2%), C:N ratio (1·37), crude fat (0·48%), moisture (17·02%) and increase in ash content (20·15%) were observed. It was also observed that *Termitomyces microcarpus* was rich in protein (39·16–43·37%) and mineral content.

Keywords. *Odontotermes*; *Termitomyces*; mushrooms; fungus combs.

1. Introduction

Termites cultivate basidiomycete fungi *Termitomyces* in their nests. Certain species of *Termitomyces* are known to grow on the mound surface and also on other surrounding ground during the rainy season in the form of fruiting bodies as mushrooms. These mushrooms are highly priced for their delicacy and nutritive value as human food (Mukiibi 1973). Heim (1941) was the first to establish the genus *Termitomyces* from the fungal gardens of termites. Since then several species have been reported in symbiotic association with termites from different parts of the world (Alasoadura 1966; Oteino 1979; Purkayastha and Andrilla 1985). Literature on the chemical composition of fungal combs before and after growth of *Termitomyces* is scanty, except for the observations of Batra and Batra (1979) who reported low cellulose content on the newly emerged *Termitomyces* compared to the well developed combs/mushrooms. Therefore an attempt has been made to know the different species of *Termitomyces* associated with mound building termites, their chemical composition and nutritive value.

2. Materials and methods

Surveys were conducted during the rainy seasons of 1986 and 1987 at Bangalore, Tumkur and Chikkamagalur districts. Different species of *Termitomyces* mushrooms grown on the mounds of *Odontotermes* spp. and surrounding soil were observed. While collecting the different species of mushrooms, soil was excavated 2 cm away from mushrooms to find out its origin arising as the stipe from the fungal fragment. Freshly collected mushrooms were identified, using the keys given by Purkayastha and Andrilla (1985) and Natarajan (1975, 1979). Morphological descriptions of different species of mushrooms under field condition are given. During the same period several mounds of *Odontotermes redemanni* (Wasmann) were marked in the grassland and on these the growth of *Termitomyces microcarpus* Berk and Broom was observed for a period of 3 days invariably after rains. Samples of fungal combs before and after growth of *Termitomyces* were collected and analysed for cellulose (Updegraff 1969), lignin (Mukhopadhya and Nandi 1979), ash, nitrogen (Jackson 1973) and crude fat (Allen *et al* 1974) contents. Similarly, mushrooms were analysed for nitrogen, mineral matter Ca, Mg (Jackson 1973) and crude fat (Allen *et al* 1974). Micronutrients such as Cu, Zn, Mn and Fe were determined using Spg atomic absorption spectrophotometer as outlined by Lindsay and Norvell (1978).

3. Results and discussion

The present investigation has revealed that 9 species of mushrooms were associated with 4 species of fungus growing termites viz. *Odontotermes obesus* (Rambur), *O. redemanni*, *O. wallonensis* (Wasmann) and *Macrotermes estherae* (Desneaux). The mushrooms belong to 5 genera of Agaricales (table 1).

The genus *Termitomyces* was closely associated with termites as its species were found growing on the mound and surrounding soil. Apart from this genus, *Cantharellus* sp. and *Collybia familia* were observed to grow in the galleries of *O. wallonensis* and on the surface of *O. redemanni* mounds respectively. Species of *Rusella* were also found to grow in the foraging areas of termite *M. estherae.*

More than one species of mushrooms were associated with certain termite species, as in the case of *O. redemanni* (5 species of mushrooms) followed by *O. wallonensis* (4 species). Based on the occurrence and distribution of mushrooms, *T. microcarpus* (86·11%) was most dominant followed by *T. clypeatus* (51·72%). *C. familia* and *Cantharellus* sp. were distributed on only 2·5% of the mounds observed. In the present study these species were reported for the first time along with their host association from this region. However, Natarajan (1975, 1979) and Purkayastha and Andrilla (1985) observed these species growing from an unspecified termite mounds. Likewise, Batra and Batra (1979) observed *T. albuminosus* and *T. microcarpus* associated with *O. obesus* and *O. gurudaspurensis* Holm. mounds respectively. Similarly, *T. microcarpus*, *T. indicus* and *T. badius* Oteino were found associated with *O. redemanni* and *T. clypeatus* and *T. indicus* with *O. wallonensis* in the present study (table 1).

Table 1. Association of mushroom species with fungus growing termites.

Mushroom species	Dominance (%)			
	Odontotermes obesus	*O. wallonensis*	*O. redemanni*	*Macrotermes estherae*
T. albuminosa	37·5	17·24	38·96	—
T. clypeatus	—	51·72	—	—
T. microcarpus	—	—	86·11	—
T. indicus	—	5·17	0·09	—
T. badius	—	—	3·17	—
C. familia	—	—	2·50	—
Cantharellus sp.	—	2·50	—	—
Rusella sp.	—	—	—	44·44
Lepiota sp.	—	—	—	11·11

The morphological characters of the mushrooms are given in table 2. *T. albuminosus* was the larger mushroom compared to other species. The mean length of the stipe (11·4 cm) and diameter of pileus (9·6 cm) were highest in the case of *T. albuminosus* and lowest in the case of *T. indicus* (3·26 cm) and *T. badius* (1·46 cm). The gills were adnexed to free in all the species observed.

3.1 *Observations on the growth of T. microcarpus*

Field observations during rainy season from July to October on the cultivation of mushrooms revealed that *T. microcarpus* was the common mushroom growing regularly on the mounds of *O. redemanni*. The mode of mushroom cultivation by the termites was almost similar in all the mounds observed. The reason for cultivating mushrooms by the termites themselves on the mound surface is not clearly understood. Generally, fresh fungal comb fragments along with the basidiocarps are harvested from the fungal combs inside the mound and deposited usually between the conical growth of the mound (Batra and Batra 1979; Natarajan 1975). After deposition, the mycelium strands grow through the comb fragments, fruiting bodies or the mushrooms begin to appear as very small knobs with enlargements on those strands, and they appeared to be button like structures in the beginning. They were enlarged and elongated, made their way towards the surface of the comb fragments. They appeared very small and grown from the size of pinhead to pea size. Further, they were divided into two main parts, viz. stipe and pileus. At this stage gills appeared on the under surface of the pileus. Later the cap grew in size (1·5 cm), the gills elongated and the stipe also increased in length (3·5 cm). About 90–135 mushrooms were recorded from each place, with 6 mushrooms per square inch. The total development took 36 h from deposition of comb fragments to full growth of the mushroom on the mound surface. These observations are in agreement with the findings of Atkinson (1961) in respect of the edible mushroom *Agaricus bisporus* from USA.

3.2 *Chemical composition of fungal combs during growth of T. microcarpus*

An analysis was made to determine the changes in cellulose, lignin, carbon,

Table 2. Morphology of *Termitomyces*.

Mushrooms	Mean length of the stipe (cm)	Mean diameter of pileus (cm)	Arrangement of gills	Gregarious or solitary growth on mounds
T. albuminosus	11·4 (10–15)	9·6 (9–10)	Adnexed	Solitary
T. badius	4·24 (4·0–4·5)	1·46 (0·8–2·5)	Adnexed to free	Gregarious
T. clypeatus	9·4 (7·0–10)	6·4 (5·5–7)	Free	Solitary
T. indicus	3·26 (3·0–3·5)	3·30 (3·0–3·5)	Free	Gregarious
T. microcarpus	3·72 (3·5–4·0)	1·76 (1·5–2·0)	Adnexed	Gregarious

Values in parentheses are ranges.

nitrogen, C:N ratio, ash and moisture content of fungal comb before and after the growth of *T. microcarpus* (table 3).

There was a significant decrease in cellulose (5·9%) and lignin (3·5%) content of the comb, indicating their direct impact on the growth and development of *T. microcarpus*. Similarly, Batra and Batra (1979) observed decrease in cellulose content of fungal comb in which a species of *Termitomyces* was grown. Likewise, PrabhuDessai (1982) observed a decrease in cellulose and lignin content in paddy straws and maize cob substrate on which *Pleurotus sajor-cuju* (Fr), the edible mushroom was grown.

Significant decrease in carbon (11·2%) and nitrogen (2·34%) contents was observed due to degradation of substrates by mushrooms and nitrogen utilized in the form of fruiting bodies. During decomposition of substrate, the carbon that is lost reflects upon the C:N ratio. Thus, a gradual reduction in C:N ratio (1·37%) was observed in the fungal comb fragment after the growth of *T. microcarpus*.

Similarly, decrease in moisture content of 17·02% was observed in the substrate after the growth of *T. microcarpus*. Contrary to these results PrabhuDessai (1982) observed an increase in moisture content of paddy straw and maize cob after the growth of button mushroom *P. sajor-cuju*. The decrease was attributed to the effect of atmospheric temperature (28·5°C) on the substrate which was exposed to sunlight. Increase in ash content (20·15%) and decrease in fat content (0·48%) of substrate was due to the utilisation of carbon and fat during growth and development of *T. microcarpus*.

3.3 *Nutritional value of T. microcarpus*

These results have indicated that the mushroom (*T. microcarpus*) has been found to be a best source of protein and mineral content. The protein content ranged from 39·16–43·37%. In addition to high nitrogen content (9·68%), it was also rich in crude fat (4·98%), mineral matter (15·14%) and micronutrients such as calcium (155 meq.), magnesium (55 meq.), copper (101·92 ppm), iron (1254·20 ppm), manganese

Table 3. Chemical composition of fungal comb before and after growth of *T. microcarpus*.

Chemical composition	Growth (%) Before growth	After growth	Decrease/ increase (%)	Student 't' value
Moisture	45·00	27·98	17·02	11·57**
Cellulose	26·60	20·70	5·90	6·936**
Lignin	17·20	13·70	3·50	6·932**
Nitrogen	2·88	2·34	0·54	5·280**
Carbon	42·62	31·42	11·20	15·100**
C:N ratio	14·84	13·47	1·37	2·297[NS]
Crude fat	5·42	4·94	0·48	4·800**
Ash	23·28	43·43	20·15	15·104**

't' at 0·05 = 2·300; 0·01 = 3·355.
Significant at **1%.
[NS]Not significant.

(54·60 ppm) and zinc (137 ppm). Similarly, Mukiibi (1973) observed high protein (27·4%), fat (4·3%) and ash (14·1%) content in the same species. Adriano and Cruz (1933) observed a high calcium and iron content, with 217 and 52 mg per 100 g respectively, in *T. albuminosus*.

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