



# Nutritional and antioxidant potential of some wild edible mushrooms of Nagaland, India

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**Abstract** Mushrooms are known to mankind since early human civilization and are gaining importance because of their nutritional and medicinal properties. Till date 37 wild edible mushrooms are reported from Nagaland. In this study, nutritional analysis including total phenolics, flavonoids and antioxidant activity was done for ten popular WEM species. Total protein content was found to be high which ranged from 62.27 g/100 g (*Lentinus sajor-caju*) to 18.77 g/100 g (*Lentinus squarrosulus* var. *squarrosulus*); total carbohydrate content ranged from 38.44 g/100 g (*Lentinula edodes*) to 5.31 g/100 g (*Schizophyllum commune*); reducing sugar content ranged from 7.81 g/100 g (*Termitomyces heimii*) to 2.33 g/100 g (*S. commune*). Crude fiber ranged from 11.1% (*A. auricula-judae*) to 1.71% (*L. squarrosulus*) and ash content ranged from 10.66% (*L. squarrosulus*) to 3.12% (*L. squarrosulus* var. *squarrosulus*). The highest phenolic content was observed in *L. squarrosulus* (18.7 g/100 g) and highest flavonoid content was observed in *L. sulphureus* (9.3 g/100 g). All the ten mushroom species exhibited antioxidant activity against DPPH free radical, but highest activity was recorded in *L. tigrinus* (47.5 µg/ml, IC50). Hence, mushrooms are valuable natural resource to mankind and should be exploited judiciously for the betterment of society.

**Keywords** Antioxidant properties · Nagaland · Nutritional value · Wild edible mushrooms

## Introduction

Mushrooms have long been known for nutritional and medicinal values and considered to be nutraceuticals due to its antioxidant, antitumor and antimicrobial properties (Barros et al. 2007; Ferreira et al. 2007). Edible mushrooms are considered to be health food as they are rich in proteins, minerals, vitamins, fibers, low/no calories and cholesterol lowering properties (Wani et al. 2010). Barros et al. (2008) considered wild mushrooms to be richer source of proteins and low fat content as compared to commercial mushrooms. The presence of secondary metabolites in mushrooms like polyphenols, terpenes, steroids and polyketides which have antioxidant properties and pharmacological applications play important role in maintaining the health of consumers (Barros et al. 2007). Patel and Goyal (2013) reported that mushrooms act as anti-cancer compounds, plays crucial role as reactive oxygen species inducer, mitotic kinase inhibitor, anti-mitotic, angiogenesis inhibitor, topoisomerase inhibitor, leading to apoptosis and also checking cancer proliferation. Most organisms possess antioxidant defense and repair systems for protection against free radical damage by oxidative enzymes like superoxide dismutase (SOD) and catalase (CAT) and by chemical compounds like ascorbic acid, carotenoids,  $\alpha$ -tocopherol, glutathione and polyphenolic compounds (Mau et al. 2001), yet these systems are not sufficient. Natural sources of antioxidants are extensively studied for their properties to protect organisms and cells from damage brought about by oxidative stress (Cazzi et al. 1997).

Nagaland lies in the North Eastern part of India with 16,579 sq km geographical area. In Nagaland, WEMs are considered as traditionally important nutritious food which forms a vital part of the food culture of all the ethnic tribes. Recently, it is reported that Nagaland is home for 37 WEM

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species and the number is likely to increase as study progresses (Ao et al. 2016). In this study, the local markets were surveyed to gather information on the wild edible varieties consumed by the locals. During the mushrooming season, *A. auricula-judae*, *A. polytricha*, *L. edodes*, *L. squarrosulus*, *L. sajor-caju*, *L. tigrinus*, *S. commune* and *T. heimii* are some of the popularly sold WEM species at the local markets. Presently, the world is dominated by those edible mushrooms which have medicinal properties. The objective of the present work was to evaluate the nutritional compositions and antioxidant properties of ten popular WEM from Nagaland viz., *Auricularia auricula-judae*, *A. polytricha*, *Lactifluus piperatus*, *Laetiporus sulphureus*, *Lentinula edodes*, *Lentinus squarrosulus*, *L. squarrosulus* var. *squarrosulus*, *L. sajor-caju*, *L. tigrinus*, *Schizophyllum commune*, *Termitomyces heimii* and also to set up a nutritional database of these mushrooms with the aim to retain the information which will be unique for each species as the climatic factors play a major role in the biochemical composition of mushrooms.

## Materials and method

### Sample collection and extraction

The mushroom samples were collected from local markets and forest areas during the season of availability. Oven dried samples at 70 °C for 6–12 h was used for biochemical and antioxidant analysis. The samples were extracted according to the methods and procedure followed for each estimation.

### Biochemical analysis

#### Moisture content

For calculation of moisture content, pre-weighed mushrooms were maintained in over (100 ± 5 °C) and weighed till a constant weight was achieved.

#### Dry matter content

Dry matter content was taken as the final weight obtained after the sample have been dried in the oven at 100 ± 5 °C for 12–48 h.

#### Total protein

Total protein content was determined following Lowry's protocol (Lowry et al. 1951).

#### Total carbohydrate

Total carbohydrate was determined following Phenol Sulphuric Acid method of Dubois et al. (1956).

#### Reducing sugar

Reducing sugar was determined following DNS method (Miller 1972).

#### Crude fiber and ash content

Crude fiber and ash content was determined following the methods of AOAC (2000).

#### 2, 2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay

The DPPH stable free radical method of Aoshima et al. (2004) was used to determine the antioxidant activity. Inhibition of free radical by DPPH was calculated by the following equation:

$$\text{DPPH scavenging effect (\%)} = [(A_0 - A_1/A_0) \times 100]$$

where  $A_0$  is the absorbance of control reaction and  $A_1$  is the absorbance in the presence of sample.

#### Total phenolic content

Total phenolic content was determined by Folin–Ciocalteu method (Singleton and Rossi 1965).

#### Total flavonoid content

Total flavonoid content was estimated by colorimetric method of Sahreen et al. (2010).

### Statistical analysis

All the experimental results were the mean of three replicates and the data expressed as Mean ± standard deviation.

## Results and discussion

The biochemical composition of the ten WEM species is presented in Table 1. It has been reported by past workers that the nutritional values of mushrooms are directly related to moisture and environmental conditions (Colak et al. 2009; Kalac 2009). In this study, the highest moisture content was observed in *A. auricula-judae* (88.9%) followed by *L. squarrosulus* (87.3%), *L. squarrosulus* var.

**Table 1** Biochemical composition of the ten popular wild edible mushrooms from Nagaland, India

Mushroom species	Moisture (%)	Dry matter (%)	Total protein (g/100 g DW)	Total carbohydrate (g/100 g DW)	Reducing sugar (g/100 g DW)	Non-reducing sugar (g/100 g DW)	Crude fiber (%)	Ash (%)
<i>Auricularia auricula-judae</i>	88.9 ± .02	11.1 ± .02	56.92 ± .01	18.67 ± .01	2.51 ± .01	16.16 ± .01	11.1 ± .08	3.15 ± .3
<i>Auricularia polytricha</i>	82.01 ± .04	17.9 ± .04	42 ± .02	16.03 ± .02	4.82 ± .02	11.21 ± .02	10.45 ± .3	8.44 ± .8
<i>Lactifluus piperatus</i>	80.03 ± .02	19.97 ± .02	19.33 ± .02	9.2 ± .07	3.12 ± .02	6.08 ± .05	5.09 ± .1	5.38 ± .6
<i>Laetiporus sulphureus</i>	49.8 ± .02	50.2 ± .02	22.73 ± .01	7.65 ± .01	4.32 ± .01	3.33 ± .01	6.09 ± .08	4.81 ± .5
<i>Lentinula edodes</i>	82.8 ± .01	17.2 ± .01	43.81 ± .02	38.44 ± .01	6.19 ± .06	32.25 ± .07	3.6 ± .07	5.59 ± .3
<i>Lentinus sajor-caju</i>	85.1 ± .02	14.9 ± .02	62.27 ± .02	6.81 ± .01	5.08 ± .03	1.73 ± .02	7.02 ± .05	8.41 ± .2
<i>Lentinus squarrosulus</i>	87.3 ± .02	12.7 ± .02	27.86 ± .01	9.32 ± .01	6.05 ± .02	3.27 ± .02	1.71 ± .2	10.66 ± .4
<i>Lentinus squarrosulus</i> var. <i>squarrosulus</i>	86.2 ± .01	13.8 ± .01	18.77 ± .02	19.14 ± .01	5.39 ± .08	13.75 ± .06	6.1 ± .1	3.12 ± .2
<i>Lentinus tigrinus</i>	73.7 ± .04	26.3 ± .04	31.85 ± .03	16.09 ± .3	5.76 ± .02	10.33 ± .2	7.09 ± .08	3.41 ± .2
<i>Schizophyllum commune</i>	69.8 ± .02	30.2 ± .02	24.42 ± .02	5.31 ± .01	2.33 ± .02	2.98 ± .02	11.01 ± .08	6.02 ± .6
<i>Termitomyces heimii</i>	81.1 ± .02	18.9 ± .02	60.53 ± .01	22.74 ± .01	7.81 ± .04	14.93 ± .03	8.11 ± .04	5.66 ± .02

DW dry weight

*squarrosulus* (86.2%), *L. sajor-caju* (85.1%), *L. edodes* (82.8%), *A. polytricha* (82.01%), *T. heimii* (81.1%), *L. piperatus* (80.03%), *L. tigrinus* (73.7%), *S. commune* (69.8%) and *L. sulphureus* (49.8%). The dry matter content was determined from the final weight obtained after the WEM samples have been dried in the oven at 100 ± 5 °C for 12–48 h. The dry matter content ranged from 50.2% in *L. sulphureus* to 11.1% in *A. auricula-judae*.

Protein is an essential component of dry matter of mushrooms. In this study, the protein content of dried mushrooms was observed to be richer than carbohydrate which is similar to previous reports (Manzi et al. 1999). The total protein content ranged from 62.27 g/100 g (DW) in *L. sajor-caju* to 18.77 g/100 g in *L. squarrosulus* var. *squarrosulus*. The protein content of mushrooms is generally regarded to be higher than green vegetables (Jonathan 2002). Bioactive proteins or fungal immuno-modulatory proteins are a new class of bioactive compounds isolated from mushrooms which has shown potential application in suppressing tumor invasion and metastasis (Lin et al. 2010).

A considerable part of carbohydrates occur in the form of polysaccharides represented by starch, glycogen and fibers which is necessary for proper functioning of the

alimentary tract (Manzi et al. 2001). Studies have reported edible mushrooms to be rich source of carbohydrates which range from 28.38 to 82.8% (DW) (Thatoi and Singdevsachan 2014). In the present study, the total carbohydrate content ranged from 38.44 g/100 g (DW) in *L. edodes* to 5.31 g/100 g (DW) in *S. commune* and is found as an abundant macronutrient. The reducing sugar content ranged from 7.81 g/100 g (DW) in *T. heimii* to 2.33 g/100 g (DW) in *S. commune*. The non-reducing sugar was calculated as the difference between total carbohydrate and reducing sugar and ranged from 52.04 g/100 g (DW) in *L. edodes* to 1.73 g/100 g (DW) in *L. sajor-caju*.  $\beta$ -glucans are the main polysaccharides found in mushrooms which are responsible for antioxidant, anti-tumor, anti-cancer, anti-cholesterolemic, immunomodulating and neuroprotective activities of many mushrooms (Khan et al. 2013).

Fiber is also a part of carbohydrate and the presence of fibers is an important characteristic in mushrooms as fibers are important in maintaining healthy human diet. The amount of crude fiber was found to be 11.1% in *A. auricula-judae*, 11.01% in *S. commune*, 10.45% in *A. polytricha*, 8.11% in *T. heimii*, 7.09% in *L. tigrinus*, 7.02% in *L. sajor-caju*, 6.1% in *L. squarrosulus* var. *squarrosulus*,

6.09% in *L. sulphureus*, 5.09% in *L. piperatus*, 3.6% in *L. edodes*, and 1.71% in *L. squarrosulus*.

In the present study, the highest ash value was observed in *L. squarrosulus* (10.66%) followed by *A. polytricha* (8.44%), *L. sajor-caju* (8.41%), *S. commune* (6.02%), *T. heimii* (5.66%), *L. edodes* (5.59%), *L. piperatus* (5.38%), *L. sulphureus* (4.81%), *L. tigrinus* (3.41%), *A. auricula-judae* (3.15%) and *L. squarrosulus* var. *squarrosulus* (3.12%). The value of ash content is important because it determines the minerals present in the food. Similar ash values in the studied WEM species have been reported by some previous workers (Ayaz et al. 2011; Enas et al. 2016).

The current study shows that all the mushrooms are rich in its nutritional compositions but there are wide variations in the macronutrient profiles even for the same species by different workers. During the present investigation, *L. squarrosulus* and *L. squarrosulus* var. *squarrosulus* collected from different locations showed variations in their macronutrient compositions and the remaining mushrooms also showed variations in their nutritional profiles. The differences in the nutritional compositions of mushrooms is related with factors like different species, mycelium and fructifications, climatic conditions, soil conditions, level of pollution, metal accumulations etc. which overall affects the nutritional composition of mushrooms (Rudawska and Leski 2005; Kalac 2009).

The antioxidant capacity of the mushrooms studied was determined by DPPH scavenging assay and the methanolic extracts of the mushrooms showed significant antioxidant activity. The IC<sub>50</sub> value was calculated to study the inhibition ability of the mushrooms against DPPH radicals. IC<sub>50</sub> is the quantity of sample required to scavenge 50% of the radicals. The lower the IC<sub>50</sub> value, higher is the antioxidant activity of the samples. Among the ten WEM species studied, *L. tigrinus* (47.5 µg/ml, IC<sub>50</sub>) exhibited the highest scavenger of DPPH radicals followed by *L. squarrosulus* (82.6 µg/ml, IC<sub>50</sub>). The scavenging effect (%) of the ten WEM at different extract concentrations against Trolox on DPPH radicals is shown in Fig. 1 and the IC<sub>50</sub> values are shown in Table 2.

Generally, the presence of phenols and flavonoids indicates mushrooms as source of biologically active compounds and exhibits antioxidant, anticancer, anti-inflammatory, immunomodulatory etc. properties which play an important in pharmacology. The phenolic and flavonoid content of the studied mushrooms are shown in Table 2. The highest phenolic content was observed in *L. squarrosulus* (18.7 g/100 g DW) and lowest in *A. auricula-judae* (7.3 g/100 g DW). The flavonoid content was found to be lower as compared to phenolic content in the present study and ranged from 9.3 g/100 g in *L. sulphureus* to 1.5 g/100 g in *A. auricula-judae*. Antioxidants play an essential role in maintaining human health due to their ability to

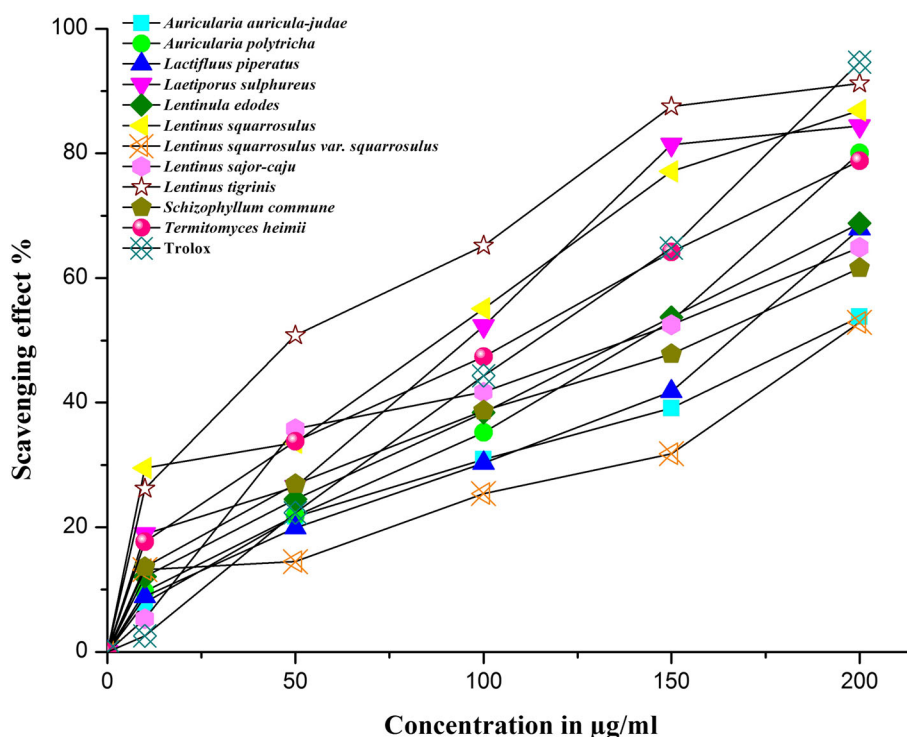
scavenge free radicals in the bodies reducing oxidative damage (Elmastas et al. 2007; Ferreira et al. 2007) and mushrooms are rich sources of antioxidants (Puttaraju et al. 2006). The antioxidant potential, phenolic and flavonoid content of various mushrooms have been reported by many workers (Boonsong et al. 2016; Sanchez 2017) and it is said that the antioxidant potential of mushrooms is higher than most vegetables and fruits (Sanchez 2017).

There has been tremendous progress in mushroom cultivation and research because of its nutritional and medicinal properties. These wild edible mushrooms are healthy food supplements required to maintain balanced diets as it contains macro as well as micro nutrients and functional minerals. It is highly popular as a low caloric diet food especially for cancer, diabetic and cardiac patients. Moreover, mushrooms are gaining importance as a protein supplementary food for the people especially living in under developed countries. The State of Food Security and Nutrition in the World (SOFI) has called upon all countries and stakeholders to act together to end hunger and prevent all forms of malnutrition by 2030 as the present scenario is that the number of undernourished people in the world is increasing alarmingly. Thus, the present study creates awareness about the nutritional and medicinal importance of mushrooms. This study also shows the potential for cultivation and production of mushrooms in Nagaland and the rest of the world as mushroom farming is eco-friendly and cost-effective. This will provide alternative means of income to the people. Moreover, a thorough screening of the wild mushrooms is of necessity to study its medicinal properties and bioactivity. The work realizes the need to conserve and manage this natural resource as the present environmental crisis like climate change and global warming adversely affects the survivability of mushrooms which require specific micro-climatic conditions for its growth.

## Conclusion

Mushrooms have the solution to some extent on many of the present day problems like food quality, unemployment, environmental pollutions and pharmaceutical applications. Mushrooms as food and medicines are solutions to many health problems. The present study highlights the potential commercial use of these wild mushrooms. However, extensive explorations and thorough screening of the wild mushrooms is the need of the hour as mushrooms are valuable natural resource to mankind with immense health benefits and should be exploited judiciously for the betterment of society.

**Fig. 1** The scavenging effect (%) of the ten wild edible mushrooms at different extract concentrations against Trolox on DPPH radicals



**Table 2** Total phenolic (TPC g GAE/100 g DW), total flavonoid (TFC g QE/100 g DW) and IC<sub>50</sub> (µg/ml) values of the ten wild edible mushrooms

Mushroom species	TPC g GAE/100 g DW	TFC g QE/100 g DW	IC <sub>50</sub> (µg/ml)
<i>Auricularia auricula-judae</i>	7.3 ± .03	1.5 ± .04	187.8 ± .05
<i>Auricularia polytricha</i>	9.9 ± .04	1.8 ± .02	130.1 ± .06
<i>Lactifluus piperatus</i>	8.1 ± .04	2.1 ± .04	157.7 ± .03
<i>Laetiporus sulphureus</i>	16.1 ± .02	9.3 ± .03	95.1 ± .04
<i>Lentinula edodes</i>	10.2 ± .03	3.2 ± .03	137.4 ± .05
<i>Lentinus sajor-caju</i>	17.2 ± .04	6.6 ± .05	137.9 ± .07
<i>Lentinus squarrosulus</i>	18.7 ± .03	4.5 ± .04	82.6 ± .03
<i>Lentinus squarrosulus</i> var. <i>squarrosulus</i>	7.7 ± .02	1.7 ± .02	212.8 ± .06
<i>Lentinus tigrinus</i>	10.1 ± .02	3.7 ± .08	47.5 ± .03
<i>Schizophyllum commune</i>	16.4 ± .04	5.6 ± .02	153.1 ± .02
<i>Termitomyces heimii</i>	17.4 ± .05	4.7 ± .03	107.2 ± .05
Trolox	–	–	111.1 ± .04

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#### Compliance with ethical standards

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

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