Natural Resources for Human Health
eISSN: 2583-1194

Original Research

Received 22 April 2026
Revised 20 May 2026
Accepted 14 June 2026

Natural Resources for Human Health 2026, Vol. 6 (3s): 1134–1142

KEYWORDS: Wild edible macrofungi, Nutritional composition, Phytochemical analysis, Protein content, Mineral content, Bioactive compounds, Dietary supplements, Pasangkayu Regency

Proximate, Nutritional, and Phytochemical Content of Several Macrofungi Samples Utilized by the Bunggu Tribe, West Sulawesi, Indonesia

Yusran Yusran[1]*, Erniwati Erniwati[1], Rukmi Rukmi[1], Fauzia Fauzia[2]

[1]Study Program of Forestry, Department of Forestry, Faculty of Forestry, Tadulako ¬University. Jl. Soekarno-Hatta Km.9 Palu 94118, Central Sulawesi, Indonesia. Email: yyusranyusran610@gmail.com
[2]Laboratory of Forestry. Faculty of Forestry, Tadulako ¬University. Jl. Soekarno-Hatta Km.9 Palu 94118, Central Sulawesi, Indonesia

ABSTRACT: Wild edible macrofungi contain higher protein than vegetables, high fiber, vitamins and minerals, and low fat content. These mushrooms are also rich in various nutrients and bioactive compounds that can be developed into dietary supplements for health. In this study, fourteen species of wild macrofungi collected from various locations in Pasangkayu Regency were analyzed for their proximate composition, nutrients, and phytochemical compounds. The results showed that the highest water content was found in Schizophyllum commune, while the highest protein content was found in the species Volvariella volvaceae, Pleurotus ostreatus, and Picnoporus sanguineus. Furthermore, the highest fat and ash content was also found in the species Volvariella volvaceae, while the highest carbohydrate content was found in the species Termitomyces striatus. The highest P content was found in the species Volvariella volvaceae and Pleurotus ostreatus, while the highest Fe content was found in the species Ganoderma sp, Picnoporus sanguineus, Auricularia auricula-judae, Volvariella volvaceae, and Auricularia polytrica. All macrofungi samples tested contained alkaloids, flavonoids, and phenols, while tannins were found in Cookeina speciosa, Lentinus squarrosulus, Picnoporus sanguineus, and Trametes versicolor. Saponins were only detected in Lentinus squarrosulus, Lentinus sp. and Mycena sp., while carbohydrates were only detected in Schizophyllum commune, Picnoporus sanguineus and Ganoderma sp. However, none of the macrofungi samples tested contained steroids, coumarins or carotenoids.

INTRODUCTION

Macrofungi are functional foods that have high nutritional, culinary, and pharmacological value [Chang et al., 2019]. Currently, there are nearly 14,000 recorded species of fungi, and only 2,200 species are considered edible. Of these, only 650 species have been cultivated and consumed. Cultivated in waste, fungi are a rich source of protein, polysaccharides, metabolites, minerals, and vitamins (Gopal et al., 2022). Mushrooms have been recognized by several communities around the world that have used mushrooms for medicinal and health purposes [Atila et al., 2017]. Mushrooms are divided into three groups, namely Zygomycetes, Ascomycetes, and Basidiomycetes (Dimopoulou et al., 2022).

Grimm and Wosten (2018) reported that the value of macrofungi in the global market reached USD 63 billion, with 54% of the market value coming from cultivated edible macrofungi, 38% from medicinal macrofungi, and the remaining 8% from wild macrofungi. Furthermore, it was reported that global macrofungi production in 2016 reached 10,378,163 metric tons, with a significant increase in average per capita consumption, specifically increasing from 1 to 4.7 kg of cultivated edible macrofungi per capita between 1997 and 2013 [Grimm and Waston., 2018; Ramos et al., 2019].

Edible mushrooms are a type of fungus commonly used as food, either as a cultivated product or harvested from nature, and have a delicious taste. Mushrooms are highly nutritious, making them suitable for use as functional foods, both as nutraceuticals (fresh mushrooms) and nutriceuticals (processed or extracted mushroom ingredients). They are an excellent choice for infants due to their varied nutritional value.

Macrofungi have high nutritional value because they contain various nutrients that are beneficial to human health, such as protein, amino acids and essential fatty acids, carbohydrates, fiber, vitamins, and minerals [Stilinovic et al., 2020; López et al., 2024; Mayirnao et al., 2025; Mishra and Shankar., 2025]. In addition, mushrooms contain various bioactive compounds, such as polysaccharides, polyphenols, terpenoids, lectins, alkaloids, sterols, glycoproteins, ergosterol, sesquiterpenes, and lactones [Chun et al., 2021; Qutaibi and Kagne., 2024; Michalska et al., 2025; Yusran et al., 2023]. However, the content of these bioactive compounds can vary significantly depending on various factors, such as strain, substrate, cultivation method, storage conditions, and processing [Chun et al., 2021]. A study on the ethnomycology of macrofungi and their potential use as food and medicine by the Bunggu ethnic community has been conducted in several villages in Pasangkayu Regency, West Sulawesi, Indonesia. Based on the results of this research, several species of macrofungi were found to be used as a source of food and traditional medicine by the local community [Yusran et al., 2024]. However, as far as is known, the proximate content, nutrients, and phytochemical compounds of these macrofungi are not yet known. Therefore, this study aims to determine the proximate composition, nutrients, and phytochemical compounds of several species of wild macrofungi collected from Pasangkayu Regency, West Sulawesi, Indonesia.

MATERIALS AND METHODS

Collection of macrofungi samples in the field

Samples of wild macrofungi, both edible and those used by the Bunggu ethnic group as medicine, were collected in several villages in Pasangkayu Regency, West Sulawesi, Indonesia. These macrofungi were collected from several different locations, namely primary forests, secondary forests, shrublands, agroforestry lands, and residents' yards. These macrofungi grow on decaying leaves, logs, and branches. The fruiting bodies of the macrofungi were harvested up to the base of the stem, then the entire surface of the fruiting body was cleaned with dry tissue to remove all dirt. After cleaning, the wild macrofungi samples were placed in plastic containers and taken to the laboratory for identification. The wild macrofungi samples collected were the results of previous years' research.

Processing macrofungi samples

Fresh macrofungi fruit body samples were dried according to type using a drying oven at 50–55°C [Okoro and Achuba., 2012]. After drying, edible macrofungi samples were ground into a fine powder. The dry powder samples from the macrofungi were then sieved using a 100-mesh sieve. The macrofungi sample powders were stored in airtight plastic bottles, labeled according to treatment, and sealed in plastic bags to prevent water ingress, then stored in a refrigerator at 4°C prior to analysis (Yusran et al., 2022). Proximate and mineral analyses of each mushroom sample were repeated three times.

Proximate Analysis of Several Macrofungi Samples

Moisture Content Analysis

The gravimetric method is used to measure the water content in all macrofungi samples [AOAC., 2010]. Aluminum cups are dried in an oven at 130°C for 15 minutes, then cooled in a desiccator for 10 minutes. The dried cups are weighed before use. Each macrofungi flour sample is weighed at 2 g, then placed in an aluminum cup, dried at 130°C for 1 hour using an oven, cooled in a desiccator, and then weighed again until the weight is constant. The water content is calculated using the following formula:

Moisture contents (%) = (Weight loss / fresh sample weight) x 100

Ash Content Analysis

The ash content of each macrofungi sample was measured using the gravimetric method [AOAC., 2010; Humphries., 1956]. The procedure for analyzing the ash content of macrofungi was based on the procedure used by Yusran et al., 2022). The ash content was calculated using the following formula:

Ash contents (%) = (Ash weight / fresh sample weight) x 100

Carbohydrate Content Analysis

The carbohydrate content in the sample can be calculated based on the following formula

(in %) :

% Carbohydrate = 100% - % (Protein + Fat + Ash + Water)

Analysis of Total Fat Content

The fat content of edible macrofungus powder samples was analyzed using the Soxhlet method [AOAC., 2010]. Fat extraction tubes were dried in an oven at 105°C for 15 minutes, cooled in a desiccator, and weighed before use. Next, the total fat content analysis was carried out based on the procedure by Yusran et al. (2022).

Analysis of Total Protein Content

The protein content of edible macrofungi flour samples was analyzed using the Kjeldahl method [AOAC., 2010]. Total protein content analysis was performed based on the procedure by Yusran et al., (2022).

Mineral analysis of several macrofungi samples

The phosphorus and iron mineral content in macrofungi flour samples was determined using atomic absorption spectrophotometry (GBC 932, Hampshire, IL, USA) [AOAC., 2010; Humphries EC., 1956].

Analysis of phytochemical compounds in several macrofungi samples

The procedure for analyzing the phytochemical compounds of macrofungi samples was as follows: Flavonoids and Steroid/Triterpenoid (Pooja and Vidyasagar., 2016), Phenolics (Sahira and Cathrine,2015; Pandey and Tripathi, 2014), saponins (Nurhasnawati et al., 2019), Alkaloids (Pandey and Tripathi, 2014) and tannin(Pandey and Tripathi, 2014; Zohra et al., 2012).

Research methods and statistical analysis

The study used a completely randomized design with macrofungi species as treatments, namely:

A = *Schizopyllum commune*

B = *Volvariella volvaceae*

C = *Pleurotus ostreatus*

D = *Pleurotus cystidiosus*

E = *Termitomyces striatus*

F = *Auricularia polytrica*

G = *Auricularia auricula-judae*

H = *Cookeina speciosa*

I = *Lentinus squarrosulus*

J = *Lentinus* sp.

K = *Picnoporus sanguineus*

L = *Ganoderma* sp.

N = *Trametes versicolor*

Natural Resources for
Human Health
eISSN: 2583-1194

All analyses of the proximate and nutritional content parameters of each macrofungi sample were performed in triplicate. The data were analyzed using a one-way ANOVA test to compare whether the means of the samples differed significantly. The results are expressed as the mean of the three replicates. Statistical analysis was performed using SPSS software version 21.0 (IBM Corporation, New York, USA). Statistical significance was set at $p < 0.05$.

RESULTS AND DISCUSSIONS

Proximate Content of Several Species of Macrofungi

The results of the proximate analysis of each macrofungi sample used by the Bunggu ethnic community in Pasangkayu Regency, West Sulawesi, Indonesia, as food and medicine are presented in Table 1.

Table 1. Proximate content of several macrofungi samples used by the Bunggu ethnic group as food and medicine.

Treatments	Water Content (%)	Protein (%)	Ash (%)	Fat (%)	Carbohydrate (%)
Schizophyllum commune	17.476 j	13.049 a	4.660 b	1.244 d	63.571 g
Volvariella volvaceae	13.260 h	30.057 g	17.585 i	3.211 i	35.887 a
Pleurotus ostreatus	12.402 fg	15.347 c	9.001 d	1.604 f	61.646 f
Pleurotus cystidiosus	9.732 d	35.259 i	10.327 e	1.333 d	43.348 c
Termitomyces striatus	7.426 a	14.044 b	6.970 c	3.820 j	67.739 j
Auricularia polytrica	11.966 f	29.092 f	18.313 i	3.032 h	37.596 b
Auricularia auricula-judae	12.625 g	26.331 e	16.233 h	2.341 g	42.469 c
Cookeina speciosa	10.850 e	17.677 d	10.124 e	1.273 d	60.076 e
Lentinus squarrosulus	7.891 ab	15.486 c	9.778 de	0.941 b	65.904 i
Lentinus sp.	7.577 a	15.085 c	11.493 f	1.134 c	64.710 h
Mycena sp.	13.622 h	13.058 a	11.571 f	1.240 d	60.509 e
Picnoporus sanguineus	8.989 c	30.551 h	6.568 c	0.835 a	53.057 d
Ganoderma sp.	8.428 bc	15.119 c	12.767 g	0.746 a	62.939 g
Trametes versicolor	14.381 i	14.176 b	2.430 a	1.438 e	67.575 j

Note: Numbers followed by the same letter in the same column are not significantly different at the 5% test level.

The results of the research in Table 1 show that the proximate content of each macrofungus varies depending on the species. The moisture content of several macrofungus species differs depending on the macrofungus species. The highest moisture content of macrofungi is in *Schizophyllum commune* at 17.476% and the lowest is in *Termitomyces striatus* at 7.426%. The results of research by Khotimah and Popang (2016) show that the ash content in *Ganoderma* sp. (2.21%) and *Pleurotus ostreatus* (5.27%) macrofungi is lower than the results of this study, which is 12.76%. Similarly, the fat content in *Ganoderma* sp. (1.61%) and *Pleurotus ostreatus* (0.20%) was lower than the results of this study, which was 0.746%. The protein content in *Ganoderma* sp. (1.72%) and *Pleurotus ostreatus* (2.83%) was lower than the results of this study, which was 15.119%. Similarly, carbohydrates in *Ganoderma* sp. (13.01%) and *Pleurotus ostreatus* (12.68%) are lower than the results of this study, which is 62.939%.

According to Chatterjee and Samajpati (2021), macrofungi contain approximately 19-35% protein based on dry weight, and the quality of easily digestible protein in mushrooms is superior to that of all plant proteins. Based on dry weight, mushrooms generally contain 19-35% protein, compared to 7.3% in rice, 13.25% in wheat, 39.1% in soybeans, and 25.25% in milk. Furthermore, according to Fekadu (2015), the composition of mushrooms consists of water (90%), protein (2-40%), fat (2-8%), carbohydrates (1-55%), fiber (3-32%), and ash (8-10%).

P and Fe content of several species of macrofungi

The nutritional content of each macrofungi sample used by the Bunggu tribe in West Sulawesi, Indonesia, as food and medicine is presented in Table 2 below:

Table 2. P and Fe content in several macrofungi samples

Treatments	Phosporus Content (mg/100 dyr weight)	Fe Content (mg/100 dry weight)
Schizophyllum commune	1298,51 b	53,04 c
Volvariella volvaceae	1299,05 n	106,20 i
Pleurotus ostreatus	1297,99 d	21,66 a
Pleurotus cystidiosus	260,50 j	64,53 d
Termitomyces striatus	261,58 f	66,44 e
Auricularia polytrica	261,32 l	101,07 g
Auricularia auricula-judae	479,57 m	115,18 j
Cookeina speciosa	479,43 c	71,65 f
Lentinus squarrosulus	480,94 e	65,22 d
Lentinus sp.	297,90 g	64,66 d
Mycena sp.	297,60 h	101,99 h
Picnoporus sanguineus	297,86 k	253,99 k
Ganoderma sp.	958,24 i	290,77 l
Trametes versicolor	958,69 a	47,40 b

Note: Numbers followed by the same letter in the same column are not significantly different at the 5% test level.

The macrofungi above are known to contain high levels of phosphorus and low levels of available iron (Table 2). Table 2 above shows that the highest P content is found in the macrofungi *Volvariella volvaceae*, *Schizophyllum commune*, and *Pleurotus ostreatus* with values of 1299. 05 mg/100, 1298.51 mg/100, and 1297.99 mg/100, respectively, followed by and significantly different from the P content in *Trametes versicolor* (958.69 mg/100) and *Ganoderma* sp (958.24 mg/100). Furthermore, the phosphorus content in *Auricularia auricula-judae*, *Cookeina speciosa*, and *Lentinus squarrosulus* mushrooms was 480.94 mg/100, 479.57 mg/100, and 479.43 mg/100, respectively.

Similarly, the highest Fe content was found in the macrofungi *Ganoderma* sp., *Picnoporus sanguineus*, *Auricularia auricula-judae*, *Volvariella volvaceae*, *Mycena* sp. and *Auricularia polytrica*, with values of 290.77 mg/100, 253.99 mg/100, and 115.18 mg/100, 106.20 mg/100, 101.99 mg/100, and 101.07 mg/100, respectively. These five treatments were significantly different from one another. The macrofungi species with the lowest Fe content and significant differences between each other were *Pleurotus ostreatus*, *Trametes versicolor*, and *Schizophyllum commune* with values of 21.66 mg/100, 47.40 mg/100, and 53.04 mg/100, respectively. Meanwhile, *Lentinus squarrosulus*, *Lentinus* sp., and *Pleurotus cystidiosus* contained Fe at 65.22 mg/100, 64.66 mg/100, and 64.53 mg/100, respectively, with no significant differences between the three treatments. Other authors have documented Fe levels in several macrofungi species, such as *Agaricus* spp., *Macrolepiota* spp., and *Pleurotus* spp., with values ranging from 26.0 to 644 mg Kg^{-1} (Haro et al., 2020; Brzezicha-Cirocka., 2019; Mleczek et al., 2019).

Minerals are essential nutrients that regulate very important physiological functions in the body. Analysis of macro and micro nutrients in several species of macrofungi shows significant variation in concentration. This indicates the nutritional potential in their fruit bodies. Fe, Zn, and Cu are the most prominent elements detected. Compared to previous research by Dimopoulou et al. (2022), the Fe concentration in *C. comatus* and *B. plumbea* is very significant and found to be much higher and highly significant. Fe nutrition is very important in relation to efforts to overcome Fe deficiency problems that commonly occur, especially in high mountainous areas where anemia is common. Fe is an essential element for oxygen transport, DNA synthesis, and energy metabolism, and its availability in edible macrofungi is a valuable source of nutrition, especially for Fe minerals (Puig et al., 2017).

Qualitative Phytochemical Analysis of Several Macrofungi Species

The results of qualitative screening tests for phytochemical compound content in each macrofungi are presented in Table 3 below:

Table 3. Qualitative phytochemical analysis of each macrofungi sample

No	Species of macrofungi	Alkaloids	Triterpenoid	Steroids	Carbohydrates	Flavonoids	Tannins	Coumarins	Saponins	Carotenoids	Phenols
A	*Schizophyllum commune*	++	-	-	+	++	-	-	-	-	+
B	*Volvariella volvaceae*	+	-	-	-	+	-	-	-	-	+
C	*Pleurotus ostreatus*	++	-	-	-	+	-	-	-	-	+
D	*Pleurotus cystidiosus*	++	-	-	-	+	-	-	-	-	+
E	*Termitomyces striatus*	++	-	-	-	+	-	-	-	-	+
F	*Auricularia polytrica*	++	-	-	-	+	-	-	-	-	+
G	*Auricularia auricula-judae*	++	-	-	-	++	-	-	-	-	+
H	*Cookeina speciosa*	+	-	-	-	+	+	-	-	-	+
I	*Lentinus squarrosulus*	++	-	-	-	++	+	-	+	-	+
J	*Lentinus* sp.	++	-	-	-	++	-	-	+	-	+
K	*Mycena* sp.	+	-	-	-	++	-	-	+	-	+
L	*Picnoporus sanguineus*	+	-	-	++	+	++	-	-	-	+++
M	*Ganoderma* sp.	+	-	-	+	++	-	-	-	-	+
N	*Trametes versicolor*	++	-	-	-	+	+	-	-	-	+

- = undetected, + = weak, ++ = moderate, +++ = strong

Research results show that all macrofungi samples tested contain alkaloids, flavonoids, and phenols, while tannins are found in *Cookeina speciosa*, *Lentinus squarrosulus*, *Picnoporus sanguineus*, and *Trametes versicolor*. Saponins were only detected in *Lentinus squarrosulus*, *Lentinus* sp. and *Mycena* sp., and carbohydrates were only detected in *Schizophyllum commune*, *Picnoporus sanguineus* and *Ganoderma* sp. However, none of the macrofungi samples tested contained steroids, coumarins, or carotenoids.

Many researchers have reported that the fruit bodies of macrofungi have long been recognized for their culinary value and medicinal potential. Rich in bioactive compounds such as polysaccharides, terpenoids, phenolics, and proteins, mushrooms exhibit various therapeutic properties, including antioxidant, antimicrobial, anti-inflammatory, immunomodulatory, and antithrombotic, antitumor, hepatoprotective, and cardiovascular protective effects (Iqbal et al., 2025; Petrova., 2012; Wasser., 2014). Alispahić et al., (2015) determined the phenolic compounds in several macrofungi species from Bosnia, such as *Boletus edulis*, *Agaricus bisporus*, *Agaricus bisporus var Avellaneus*, *Pleurotus ostreatus*, and *Lentinula edodes* from Bosnia, and reported that the highest total phenolic content was found in *B. edulis* (35.56 mg GAE/g) and the lowest in *L. edodes* (4.94 mg GAE/g).

These research results are supported by Zekovic et al. [2005], who reported that several species of macrofungi contain β-glucans that have antitumor effects and boost the immune system. β-glucan T has specific names, such as ganoderan (*Ganoderma lucidum*), grifolan (*Grifola fondosa*), lentinan (*Lentinus edodes*), pleuran (*Pleurotus ostreatus*), and schizophyllan (*Schizophyllum commune*) [Khan et al., 2013], and these compounds are known for their antioxidant, anticancer, anticholesterol, immunomodulatory, neuroprotective, and antibacterial activities [Rasmi et al., 2010].

Macrofungi have been used as a source of nutrition and medicine due to their antioxidant activity, which makes them a potential natural source of antioxidants for reducing oxidative stress. Flavonoids are essential phytochemical compounds in cosmetic, pharmaceutical, medicinal, and nutraceutical applications. Flavonoids are highly effective free radical scavengers in preventing the formation of free radicals in the body (Rijal et al., 2021). Sitati et al. (2021) and Ghate et al. (2017) reported that *Termitomyces striatus* mushroom extract contains important phytochemical compounds, such as alkaloids, flavonoids, steroids, saponins, and phenols, which are responsible for various important biological activities in health research. These phytochemical compounds have been reported to have antibacterial activity [Wintola et al., 2015; Shegute et al., 2020; Amabye et al., 2016] and antifungal effects [de Andrade et al., 2019; Yusoff et al., 2020].

CONCLUSIONS

Macrofungi contain varying amounts of proximate, nutritional, and phytochemical compounds. Overall, the macrofungi studied show great potential for the Bunggu ethnic community in the formulation of functional foods and dietary supplements that offer a sustainable approach to addressing micronutrient deficiencies in this region. Future research should prioritize exploring the therapeutic potential of these fungi in the prevention and management of diseases related to oxidative stress. It should be noted that this study did not analyze all minerals, both macro and micro elements, including the quantification of phytochemical compounds found in the fruit bodies of the macrofungi samples mentioned above. Future studies could benefit from comprehensive analysis to further validate these findings.

ACKNOWLEDGMENTS

This research grant is funded by the National Research and Innovation Agency (BRIN) and the Education Fund Management Agency/Indonesia Endowment Fund for Education Agency (LPDP) based on Decree No. Deputy for Research and Innovation Facilities, National Research and Innovation Agency, Number 37/II.7/HK/2023 concerning Recipients of the Research and Innovation Program for Advanced Indonesia Batch 4 and the Cooperation Agreement between the Directorate of Research and Innovation Funding, the Indonesian National Research Agency, and the Research and Community Service Institute, Tadulako University, regarding the Implementation of the Research and Innovation Program for Advanced Indonesia (RIIM) Batch 4, Number 186/IV/KS/11/2023 and Number 3310/UN28.16/AL.04/2023. The author would like to express his deepest gratitude to several village heads and the Bunggu ethnic community in Pasangkayu Regency, West Sulawesi, Indonesia, for their research permission and assistance, especially in collecting mushroom samples and logistics in the field. The author also thanks the students of the Faculty of Forestry, Tadulako University (Arif Imam Wahid., S.Hut, Moh Syarif., S.Hut, Alif Bakhtiar., S.Hut, Febryan Sannu., S.Hut., Maikel Bonafit Kareba, Julriang Carlos Topanga dan Kriye Putra Anugrah Suroi) for their assistance in collecting macrofungi samples in the field.

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