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Nutritional, Phytochemical and Therapeutic Attributes of Edible Wild Mushrooms as Influenced by Substrates in Humid Tropical Environment

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ABSTRACT

Edible wild mushrooms (EWM) help low-income families maintain their food security and nutrition. Information on the nutritional and phytochemical compositions of EWM is needed due to their contribution to food security, nutrition and therapeutic values to millions of people in Africa and Asia. The objective of this study was to assess the proximate, mineral, vitamin, and phytochemical compositions of therapeutic importance in edible wild mushrooms. Seven EWM species were gathered, identified, and analyzed for physical, nutritional, and phytochemical composition. The data were statistically analysed. The EWMs' proximate, mineral, vitamin and phytochemical contents varied significantly. Protein concentrations ranged from 3% to 19.48%. The ranges for fibre, ash, and carbohydrate were 0.83-5.25%, 1.77–12.25%, and 1.42–9.08%, respectively. K, Na, and P were the most abundant minerals in this study, followed by Mg and Ca. Vitamin A was the most abundant vitamin in the wild mushrooms studied, followed by vitamin C and vitamin E. Phenols, alkaloids, flavonoids, tannins, and saponin were also found in the EWM. The mean performance and stability analysis indicated that *Termitomyces le-testui* ranked higher than the population mean in mineral, vitamins and phytochemical compositions. *Ganoderma lucidum* was the least ranked mushroom for mineral, vitamins and phytochemical compositions. The results of this study can aid dieticians, nutritionists and pharmacists in identifying mushrooms with high nutritional and therapeutic values while foraging in the wild. Exploring these differences in mushroom content will be helpful in the pharmaceutical industry, in clinical settings for human therapeutic applications, and in reducing hidden hunger.

Keywords: Edible mushrooms, Nutrients, Pharmaceutical value, Substrates.

Introduction

Forest products provide food security and nutrition to an estimated 2.4 billion people worldwide.[1] They are divided into two categories: wood and non-wood forest products. The majority of edible non-wood forest products are important in the traditional health care system because they store essential micronutrients. Mushrooms are non-wood forest products that are used for a variety of purposes around the world. Mushrooms can be edible or poisonous depending on their nutrient composition.[2] Through careful selection, man has been gathering and eating edible mushrooms from the wild for millennia.[3] Mushrooms are consumed not only for their flavour, aroma, and texture, but also for their medicinal and health benefits.[4] Wild edible mushrooms play a crucial role in enhancing food security and income generation for low-income households. In regions where resources and economic opportunities are limited, these mushrooms serve as a valuable source of nutrition and livelihood. They offer a diverse range of benefits, contributing to the well-being of communities facing food insecurity and financial challenges.

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Mushrooms are a rich source of carbohydrates, phenolic compounds, vitamins, and minerals.[5,6] Mushrooms' polyunsaturated fatty acids are beneficial to the cardiovascular system, while its dietary fiber has immune-stimulatory and anticancer properties.[7,8] Mushrooms have higher protein content than most vegetables, and their protein content has been compared to dairy and animal protein.[4,9].Mushrooms are described as vegetable meat,[10] and has been recommended as an alternative to animal protein for vegetarians and low-resource households.[9,11] For low-income households, these mushrooms provide an accessible and vital source of nourishment, especially in areas where other nutritious foods are scarce or unaffordable.[12]
Furthermore, wild mushrooms offer seasonal availability, augmenting the diet during specific times of the year. This is particularly valuable in regions where agricultural productivity is limited or vulnerable to seasonal fluctuations. Their growth patterns can help diversify food sources and enhance food security, complementing other food supplies. Edible non-wood forest products, provide important nutrient-rich supplements and add variety to the bland diets that are common in rural food-insecure households.[1] In addition to meeting nutritional needs, wild edible mushrooms offer economic opportunities. In regions with market demand, these mushrooms can be sold locally or transported to urban areas, creating income streams for mushroom collectors. This economic activity plays a crucial role in improving the financial stability of low-income households and alleviating poverty.
Beyond the economic and nutritional aspects, wild mushroom collection preserves traditional knowledge and cultural heritage[3]. This practice is often steeped in ancestral wisdom, passed down through generations. By continuing to gather wild mushrooms, low-income households uphold their cultural traditions and strengthen social cohesion within their communities. Mushroom foraging promotes the sustainable use of forest resources while providing ecological benefits

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such as carbon sequestration and soil health. Bakiga people of Uganda protect termitaria in order to continue harvesting mushrooms from them.[3] Other researchers have discovered a mutualistic or symbiotic relationship between termites and mushrooms.[13,14] The identified benefits obtained from a plant increase the plant's usefulness.[15] Information on the nutritional and phytochemical compositions of wild mushrooms are needed due to their contribution to food security and nutrition of millions of people in Africa and Asia. Food composition data is vital for estimating essential nutrient intake as well as exposure risks from toxic non-essential nutrient intake.[16] Edible mushrooms are biological and genetic resources with nutritional value and biotechnological potential.[11] However, mushroom resources in Nigeria are understudied and their attractive potential is underutilized.[4] This underutilization is not peculiar to Nigeria but extends to other African countries like Burundi and Rwanda.[17] This study aims to contribute to the body of literature on the prevalent wild mushroom species in Nigeria. It also aims to provide new insights into the nutritional and phytochemical compositions of wild mushroom species in Nigeria, an area where these resources are understudied and underutilized. By examining their proximate, mineral, vitamin, and phytochemical profiles, this research addresses a significant gap in the literature. The findings from this study will contribute to food security and nutrition planning, offering valuable data for future research and biotechnological applications, thereby enhancing the recognition and use of wild mushrooms in Africa. The objective of this study was to assess the proximate, mineral, vitamin, and phytochemical compositions of edible wild mushrooms.

Materials and Methods

Site description

Enugu State experiences a tropical climate with distinct wet and dry seasons. The region generally falls within the Aw climate classification, characterized by high humidity, abundant rainfall, and moderate temperatures throughout the year. The State receives the majority of its rainfall during the wet season, which typically spans from April to October. The highest rainfall amounts are usually observed between June and September. The average annual rainfall in Enugu State ranges between 1,500 and 2,000 millimeters (59 to 79 inches), contributing to lush vegetation and fertile agricultural land. Enugu State experiences relatively mild temperatures, with variations influenced by elevation and seasonality. The average annual temperature ranges between 22°C (72°F) and 28°C (82°F). The hottest months are typically between February and March, with average maximum temperatures reaching around 32°C (90°F). The coolest months are usually between December and January, with average minimum temperatures dropping to around 14°C (57°F).

Wild mushroom samples were collected from different substrates, namely; logs of wood, humus soil, and termitaria in seven local government areas in Enugu State, Nigeria (Figure 1) from May 2016 to November 2017. The sampling zone is within the derived savannah agro-ecology.

Mushroom collection and preservation

About 3-5 fruiting bodies were selected from matured, non-infected wild mushrooms with similar body size. Soil debris and other plant matters were carefully removed from the samples before being packaged, labelled and transported to the Department of Crop Science laboratory, University of Nigeria, for identification and nutrient analysis. Preliminary identification of the mushrooms was based on the conventional method.[18] The plants voucher number is UNN/12995-FUN. Molecular identification of the wild mushroom samples confirmed the conventional method. *Volvariella volvacea*, *Lactarius deliciosus*, and *Lactarius species* were harvested from humus soil; *Ganoderma lucidum*, and *Pleuotus ostreatus* came from a log of wood, while *Termitomyces species* and *Termitomyces le-testui* came from termitaria. The sampling locations are presented in Table S1 and Figure 1.

Morphological features and chemical analyses

The length of the stipe (LS) and pileus diameter (PD) of three fruiting bodies from each mushroom sample were measured using a meter rule. The LS and PD were used to compute the stipe-pileus ratio (SPR), while the PD was used to calculate the pileus circumference (PC) and area (PA).

The protein (Method No. 978.04), fat (Method No. 930.09), fiber (Method No. 930.10), ash (Method No. 930.05), and moisture percentages of the proximate composition of the mushrooms were analyzed using standard methods of Association of Official Analytical Chemists[19]. The carbohydrate content was obtained by subtracting the sum values of protein, fat, fiber, ash, and moisture from 100.

The following formula was used to calculate energy:

$$Energy(kcal) = 4\,X\,(g\ protein) + 3.75\,X\,(g\ carbohydrate) + 9\,X\,(g\ fat) \ldots\ldots\ldots\ldots\ldots . Equation\ 1$$

Vitamins A, B1, B2, C, and E were determined using the standard methods.[20] The ash was boiled in a beaker with 10 ml of 2.4 N hydrochloric acid before being filtered into a 100-ml standard flask. Deionized water was used to bring it up to par. From the resulting solution, sodium, potassium, phosphorus, magnesium, and calcium content was determined using atomic absorption spectrophotometry (Shimadzu Model AA-7000), while the concentrations of alkaloid, flavonoids, tannins, saponin, and total phenol were determined using quantitative the methods.[21] All chemical analyses were carried out in three replicates per mushroom species.

Statistical analysis

A minimum of three replicates per mushroom species were used for one-way analysis of variance in the SPSS v. 16.0 program. The Tukey's HSD Test was used as a post hoc test at a 5% probability level. The findings are presented as mean values with standard deviations (SD). To show the performance of each substrate, the mean values of the mushroom species were ranked using GGEbiplot software version 4.1. The fifteen mushroom samples were subjected to a principal component analysis in order to identify the characteristics that explained the most variation in the mushrooms. The similarity between the fifteen mushroom species sampled was determined using hierarchical cluster analysis. The GenStat Discovery Ed. 4 (VSN Int. Ltd., Hempstead, UK) was used to perform principal component analysis and hierarchical cluster analysis.

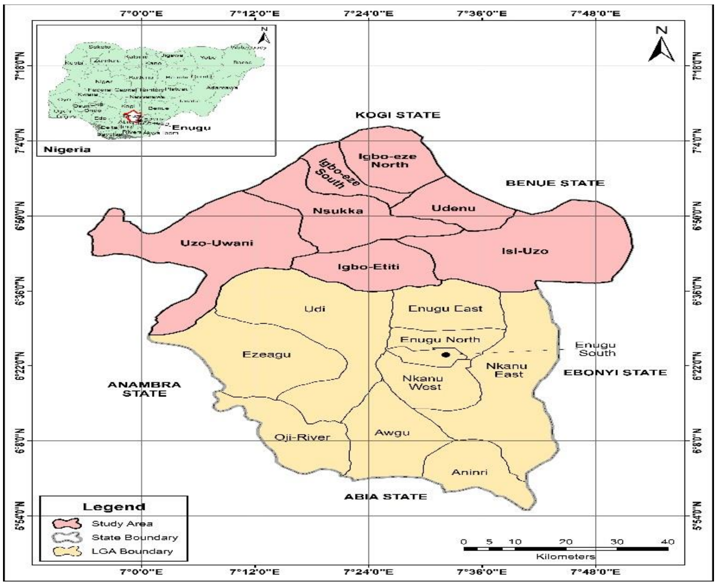

Figure 1: Map of the sampling location

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Table S1: Identification of mushroom species with corresponding natural substrate and sampling locations

Order	Family	Genus	Species	Substrate	Sampling locations	Edibility*
Agaricales	Pleurotaceae	*Pleurotus*	*ostreatus*	log of wood	IU, NS, UE, UU, IE	Good
Agaricales	Lyophyllaceae	*Termitomyces*	*Sp*	Termitaria	UE	Good
Agaricales	Lyophyllaceae	*Termitomyces*	*le-testui*	Termitaria	NS, IN	Good
Agaricales	Pluteaceae	*Volvariella*	*volvacea*	Humus	UE	not good
Polporales	Ganodermataceae	*Ganoderma*	*lucidum*	log of wood	IN, IS	not good
Russulales	Russulaceae	*Lactarius*	*deliciosus*	Humus	IS, IN	not good
Russulales	Russulaceae	*Lactarius*	*Sp*	Humus	IU, NS	not good

LGA = Local Government Area, IU = Isi-Uzo LGA, NS = Nsukka LGA, UE =Udenu LGA, UU = Uzo-Uwani LGA, IE = Igbo-Etiti LGA, IN = Igboeze-North LGA, IS = Igboeze-South, and * = edibility rating was based on local perceptions

Results and Discussions

Physical characteristics and proximate composition

Ganoderma lucidum had the largest pileus diameter, circumference, and area, which were all significantly larger than the other mushrooms (Table 1). *Pleurotus ostreatus* trailed *G. lucidum* in pileus diameter, circumference and area. The pileus area ranged from 11.76 cm^2 in *L. deliciosus* to 101.6 cm^2 in *G. lucidum*. The ranges for pileus diameter and pileus circumference were 3.87–11.35 cm and 12.15–35.67 cm, respectively. The longest stipe length was produced by *T. le-testui*, which was statistically similar to *Termitomyces sp* but significantly longer than the other mushrooms. *Ganoderma lucidum* did not have a stipe. The stipe-pileus ratio ranged from 0.0 in *G. lucidum* to 1.13 in *V. volvacea*.

This study finds significant morphological diversity among the seven mushroom species examined, with *G. lucidum* standing out due to its exceptionally large pileus size. This aligns with previous research highlighting *G. lucidum*'s robust growth characteristics and substantial fruiting body dimensions.[22] The significant variation in pileus area, diameter, and circumference across species, ranging from *L. deliciosus* to *G. lucidum*, reflects the intrinsic differences in their growth forms and ecological adaptations. This variation is in line with the work of Vilas et al.[23] who documented extensive morphological variability among wild mushroom species. The unique absence of a stipe in *G. lucidum*, compared to the notably long stipe of *T. le-testui*, underscores the diverse structural adaptations among these fungi, which is supported by findings from Atri et al.[24] regarding the varied stipe development across different mushroom species.

The principal component analysis of the which-won-where analysis showed that the measured physical traits explained 99% of the variation among the seven mushroom species (Figure 2). There are four sectors and three vertices in the graph, with *G. lucidum, T. le-teshui*, and L. deliciosus occupying the different vertices. *P. ostreatus* is in the *G. lucidum* sector, which contains the following traits: pileus diameter, circumference, and area. The length of the stipe is in the *T. le-teshui*sector, while the stipe-pileus ratio falls within the *L. deliciosus*. *Termitomyces sp.* and *Lactarius sp.* fell into the first concentric circle. The principal component analysis demonstrated that physical traits could explain nearly all the observed variation among the mushrooms, highlighting the key differentiating factors.

Termitomyces sp. had a significantly higher moisture content than *Lactarius sp., V. volvacea*, and *G. lucidum* (Table 2). Protein concentrations ranged from 3% in *Termitomyces sp*. to 19.48% in *V. volvacea*. The fat content of the mushrooms did not differ significantly. However, *G. lucidum* contained significantly more fibre and ash than the other mushrooms. *Termitomyces species* had the highest ash and fiber content. For fibre, ash, and carbohydrate, the ranges were 0.83-5.25%, 1.77-12.25%, and 1.42-9.08%, respectively. The most energy was produced by *V. volvacea*, which was significantly greater than *G. lucidum*, *Termitomyces sp*., and *P. ostreatus*.

The first (PC1) and second (PC2) principle component axes explained 89.7% of the variation in the mushrooms due to their proximate compositions (Figure 3). No trait or mushroom species appeared in the first concentric circle. Each mushroom species occupied a polygon vertex, except for *Lactarius species.* Moisture fell in the *Termitomyces sp.* sector, while fat and carbohydrates were found in the *P. ostreatus* sector. The *L. deliciosus* sector contained energy, while protein, ash, and fiber fell in the *G. lucidum* sector.

This study's range of wild mushroom protein was higher than the range of 0.88-1.58 reported in wild mushrooms from Greece.[25] Mushrooms have higher protein content than most vegetables, and their protein content have been compared to dairy and animal protein.[4,9] In fact, the edible mushrooms have been described as vegetable meat, because of their safe nature. It has also been suggested as a vegetarian and low-resource household protein alternative.[9,11] The mushrooms with low moisture content (*G. lucidum, V. volvacea, L. deliciosus*, and *Lactarius sp*.) had higher protein content. This observation is consistent with the data presented by Kalogeropoulos et al.[25] where mushrooms with low moisture content gave high protein content. The protein content of *V. volvacea* was reported to be 19.95%, [26] which is similar to the findings of this study. The protein contents observed in these wild mushrooms compared favourably with the protein contents reported by other researchers.[11] The mushrooms moisture content of 64.5 g/100 g in *G. lucidum* and 85.0 g/100 g in *Termitomyces species* can be compared to 79.78–91.64%[27] and 88.95–94.89%.[25] The moisture percentage in mushrooms varies by species and is affected by growth stage, harvesting, and storage conditions.[28]

The ash content and moisture content of *G. lucidum* were the highest and lowest, respectively. *Termitomyces sp*., on the other hand, had the highest moisture content and the second highest ash content. The presence of high moisture and ash content were reported for *Lactarius sanguifluu*[[25] and *Agaricus bisporus*[27]. The highest fibre content found in *G. lucidum* and *Termitomyces sp*, may have contributed to their high ash and low carbohydrate content. The carbohydrate content of wild mushrooms (1.4–9.1%) in this study is comparable to Kalogeropoulos et al.[25] that ranged from 3.5 to 8.55%. Mushrooms are low-calorie foods because they contain little fat. Mushrooms' high moisture content, in addition to their low fat content, contributed to their low calorie content[25]. This may explain this study's low fat content, which compares favourably to the findings of earlier studies.[25, 27] Children and some adults, especially sedentary women, need fewer than 2,000 calories (2.0 kcal) a day and may want to select foods with a calorie count of 1,600 (1.6 kcal) a day.[29] Hence, these wild mushrooms could be a preferred choice compared to other high-calorie foods. These findings also add to the nutritional benefits of low calorie content of the mushrooms used in this study.

Mineral

Lactarius sp. contained significantly more calcium than *Termitomyces sp*. and *V. volvacea* (Table 3). The highest Mg content was found in *P. ostreatus*, which was statistically similar to that of *Termitomyces sp*. and *V. Volvacea* while *T. le-testui* contained significantly more K and P than the other mushrooms. It was followed by *Termitomyces sp.* in both minerals. *Termitomyces sp.* had significantly higher sodium concentrations than *P. ostreatus* and *G. lucidum*. Calcium levels ranged from 0.01 to 0.08 mg/g, magnesium levels from 0.03 to 0.15 mg/g, potassium levels from 6.92 to 171.5 mg/g, sodium levels from 1.34 to 7.41 mg/g, and phosphorus levels from 1.01 to 18.06 mg/g.

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The PCA in the mean performance and stability analysis revealed that PC1 and PC2 explained 76.2% of the variation in mineral content among the mushrooms (Figure 4). The mushroom species were ranked in the following order based on their mean performance and stability: *T. le-teshui*>*Termitomyces sp.*> population mean >*Lactarius sp.*>*V. volvacea*>*L. deliciosus*>*P. ostreatus*>*G. lucidum*aalong the average tester axis (ATA, the red line with a single arrow, while the little circle in the red line is the average tester). The ATA coordinate (the double arrow blue line) represents the mean mineral content of the seven mushroom species investigated. The black line connecting the mushroom species to the red was the stability indicator. The short black line reflects the stability of the mineral composition of the mushrooms. The shorter the black line, the more stable a species is in its ability to have high or low concentrations of all minerals.

A variety of wild and cultivated edible mushroom species hold great promise for reducing mineral deficiencies in human diets in several developing countries[26]. Earlier research found that mushroom ash is primarily composed of potassium, phosphorus, and magnesium[27, 30]. The most abundant minerals in this study were K, Na, and P, followed by Mg and Ca. Foods rich in magnesium and calcium are good for both infants and the aged.[31] The high K content of *Termitomyces* mushrooms was consistent with the findings of earlier studies that reported high K content in *Termitomyces species*.[30,32] K is a mineral that helps regulate fluid balance, muscle contractions, and nerve signals in the body. A high-potassium diet may help lower blood pressure and water retention as well as protect against stroke, osteoporosis, and kidney stones. Ca was the lowest mineral found in the wild mushrooms studied, with the exception of *L. deliciosus* and *Lactarus sp*. Other researchers have reported low calcium content in mushrooms.[30, 33] The lower level of Na in the mushrooms also emphasized the mushrooms' beneficial effect on the heart. Low-Na foods have been recommended to reduce high blood pressure and the risk of cardiovascular disease, stroke, and coronary heart attack.[34]

Table 1: Physical characteristics (mean ± standard deviation) of the different wild mushrooms

Wild mushroom	SPR	PA cm^2	PD Cm	LS Cm	PC
G. lucidum	0.00 ± 0.00 ^{c}	101.60 ± 13.8 ^{a}	11.35 ± 0.76 ^{a}	0.00 ± 0.00 ^{c}	35.67 ± 2.38 ^{a}
L. deliciosus	1.07 ± 0.02 ^{a}	11.76 ± 0.70 ^{c}	3.87 ± 0.12 ^{d}	4.13 ± 0.06 ^{b}	12.15 ± 0.36 ^{d}
Lactarius sp.	0.74 ± 0.25 ^{a}	31.69 ± 26.42 ^{c}	5.89 ± 252 ^{cd}	3.92 ± 0.66 ^{b}	18.51 ± 7.93 ^{cd}
P. ostreatus	0.40 ± 0.18 ^{b}	58.93 ± 21.11 ^{b}	8.53 ± 1.53 ^{b}	3.55 ± 2.11 ^{b}	26.82 ± 4.81 ^{b}
T. le-teshui	0.92 ± 0.02 ^{a}	49.88 ± 1.01 ^{bc}	7.97 ± 0.08 ^{bc}	7.30 ± 0.17 ^{a}	25.04 ± 0.25 ^{bc}
Termitomyces sp.	0.74 ± 0.00 ^{a}	33.20 ± 0.00 ^{bc}	6.50 ± 0.00 ^{bcd}	4.80 ± 0.00 ^{ab}	20.43 ± 0.0 ^{bcd}
V. volvacea	1.13 ± 0.66 ^{a}	15.18 ± 14.79 ^{c}	4.07 ± 2.04 ^{d}	3.73 ± 0.93 ^{b}	12.78 ± 6.42 ^{d}

Each value is a mean of three replicates; means with the same superscripts (letter) within the same column are not significantly different at 5% probability level. SPR = stipe-pileus ratio, PA = pileus area, PD = pileus diameter, LS = length of stipe, and PC = pileus circumference

Table 2: Proximate composition (mean ± standard deviation) of the different wild mushrooms

Wild mushroom	Moisture %	Protein %	Fat %	Fibre %	Ash %	Carbohydrate %	Energy Kcal
G. lucidum	64.5 ± 1.1^{c}	14.9 ± 0.0^{a}	0.20 ± 0.1^{a}	5.25 ± 0.7^{a}	12.3 ± 0.3^{a}	2.9 ± 1.9^{b}	1.45 ± 0.1^{bc}
L. deliciosus	73.0 ± 1.0^{b}	13.8 ± 0.0^{ab}	0.30 ± 0.1^{a}	1.95 ± 0.0^{c}	3.0 ± 1.0^{cd}	8.0 ± 0.1^{a}	1.75 ± 0.0^{ab}
Lactarius sp	75.7 ± 4.4^{b}	11.4 ± 5.4^{ab}	0.30 ± 0.1^{a}	1.71 ± 0.1^{c}	3.6 ± 0.5^{c}	7.4 ± 3.3^{a}	1.52 ± 0.2^{abc}
P. ostreatus	81.9 ± 3.4^{a}	7.1 ± 5.5^{b}	0.32 ± 0.1^{a}	0.83 ± 0.3^{d}	1.8 ± 0.6^{d}	8.1 ± 2.2^{a}	1.23 ± 0.2^{c}
T. le-teshui	77.6 ± 5.1^{ab}	9.7 ± 4.4^{ab}	0.30 ± 0.0^{a}	1.23 ± 0.8^{cd}	2.1 ± 1.0^{d}	9.1 ± 1.2^{a}	1.51 ± 0.1^{abc}
Termitomyces sp	85.0 ± 0.0^{a}	3.0 ± 0.0^{b}	0.20 ± 0.0^{a}	3.43 ± 0.0^{b}	7.0 ± 0.0^{b}	1.4 ± 0.0^{b}	0.38 ± 0.0^{d}
V. volvacea	72.5 ± 1.0^{b}	19.5 ± 0.1^{a}	0.20 ± 0.0^{a}	1.70 ± 0.1^{c}	3.5 ± 0.5^{c}	2.6 ± 0.5^{b}	1.79 ± 0.0^{a}

Each value is a mean of three replicates; means with the same superscripts (letter) within the same column are not significantly different at 5% probability level.

Table 3: Mineral concentrations (mean ± standard deviation) of the different wild mushrooms

Wild mushroom	Calcium mg/100 g	Magnesium mg/100 g	Potassium mg/100 g	Sodium mg/100 g	Phosphorus mg/100 g
G. lucidum	0.06 ± 0.02 ^{ab}	0.07 ± 0.06 ^{bc}	6.92 ± 1.1 ^{c}	1.34 ± 0.86 ^{b}	1.01 ± 0.07 ^{b}
L. deliciosus	0.07 ± 0.01 ^{ab}	0.03 ± 0.01 ^{c}	8.12 ± 0.0 ^{c}	4.16 ± 0.00 ^{ab}	1.34 ± 0.02 ^{b}
Lactarius sp	0.08 ± 0.01 ^{a}	0.03 ± 0.02 ^{c}	11.59 ± 5.6 ^{c}	5.66 ± 2.95 ^{a}	1.38 ± 0.19 ^{b}
P. ostreatus	0.06 ± 0.03 ^{ab}	0.15 ± 0.02 ^{a}	7.32 ± 2.0 ^{c}	2.85 ± 0.90 ^{b}	1.73 ± 0.24 ^{b}
T. le-teshui	0.05 ± 0.01 ^{abc}	0.07 ± 0.05 ^{bc}	171.50 ± 47.0 ^{a}	5.60 ± 0.70 ^{a}	18.06 ± 3.20 ^{a}
Termitomyces sp	0.02 ± 0.00 ^{bc}	0.13 ± 0.00 ^{ab}	130.33 ± 0.0 ^{b}	7.41 ± 0.00 ^{a}	1.82 ± 0.00 ^{b}
V. volvacea	0.01 ± 0.00 ^{c}	0.09 ± 0.00 ^{abc}	7.74 ± 0.0 ^{c}	3.73 ± 0.00 ^{ab}	1.82 ± 0.00 ^{b}

Each value is a mean of three replicates; means with the same superscripts (letter) within the same column are not significantly different at 5% probability level.

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Table 4: Vitamin concentrations (mean ± standard deviation) of the different wild mushrooms

Wild mushroom	Vitamin A mcg/100 g	Vitamin B_1 mg/100 g	Vitamin B_2 mg/100 g	Vitamin C mg/100 g	Vitamin E mg/100 g
G. lucidum	375.0 ± 0.0 ^{b}	0.61 ± 0.06 ^{b}	1.69 ± 0.13 ^{b}	4.87 ± 0.89 ^{b}	2.50 ± 0.09 ^{b}
L. deliciosus	482.1 ± 0.3 ^{b}	2.13 ± 0.00 ^{a}	2.14 ± 0.00 ^{ab}	17.37 ± 0.00 ^{a}	3.21 ± 0.00 ^{ab}
Lactarius sp	455.0 ± 64.6 ^{b}	2.12 ± 0.50 ^{a}	2.28 ± 0.50 ^{ab}	17.10 ± 0.87 ^{a}	3.56 ± 1.24 ^{ab}
P. ostreatus	606.4 ± 64.9 ^{a}	2.10 ± 0.55 ^{a}	2.65 ± 0.62 ^{a}	16.89 ± 1.12 ^{a}	4.00 ± 0.83 ^{a}
T. le-teshui	373.9 ± 19.0 ^{b}	2.50 ± 0.24 ^{a}	2.65 ± 0.67 ^{a}	17.04 ± 0.65 ^{a}	4.71 ± 0.65 ^{a}
Termitomyces sp	248.6 ± 0.0 ^{c}	2.36 ± 1.00 ^{a}	2.52 ± 1.00 ^{ab}	17.89 ± 1.00 ^{a}	5.23 ± 1.00 ^{a}
V. volvacea	482.1 ± 0.3 ^{b}	2.07 ± 1.00 ^{a}	2.14 ± 0.00 ^{ab}	16.58 ± 1.00 ^{a}	3.21 ± 1.00 ^{ab}

Vitamins

The concentration of vitamins in the mushrooms varied significantly. *P. ostreatus* contained significantly more vitamin A than the other mushrooms (Table 4). *T. le-testui* had the highest vitamin B_1 concentration, while *Termitomyces sp*. had the highest vitamin C and E concentrations. The ranges for vitamins A, B_1, B_2, C, and E were 248.57–606.43 mcg/100g, 0.61-2.50 mg/100g, 1.69–2.65 mg/100g, 4.87–17.89 mg/100g, and 2.5–5.23 mg/100g, respectively. *G. lucidum* had the lowest vitamin concentrations among the mushrooms, except for vitamin A. PC1 and PC2 explained 93.3% of the variation among the mushrooms based on their vitamin contents (Figure 5). The ranking of the mushroom species showed the following order: *P. ostreatus*> *T. le-teshui*>*Termitomyces sp.*>*Lactarius sp.*> *L. deliciosus*> *V. volvacea*> population mean >*G. lucidum*.

The most abundant vitamin in the studied wild mushrooms was vitamin A, which was followed by vitamin C and vitamin E. The high amount of vitamin A in *P. ostreatus* found in this study was in contrast to the finding of Afiukwa et al [35] who found no vitamin A in *P. ostreatus.* In this study, *P. ostreatus* produced the highest amount of vitamin A. Vitamin A is a fat-soluble vitamin that is necessary for cell development, metabolism, immunity, vision, and reproduction[36]. Vitamin A deficiency is a widespread health problem linked to significant morbidity and mortality, affecting primarily young children in impoverished areas around the world. Ocular symptoms associated with vitamin A deficiency have been shown to develop at concentrations less than 10 micrograms/dL.[37] Although the vitamin contents of all the edible mushrooms studied were significantly lower than that of vitamin A, they were still within the normal range of the recommended daily dietary intake for foods. For example, the recommended daily dietary intake for vitamin C in children is 15 to 25 mg, while that for vitamin E, thiamin, and riboflavin is 1.5 to 3.0, 0.2 to 1.4, and 0.3 to 1.6 mg, respectively for all ages and genders.[29] As a result, the edible mushrooms studied can be used in the formulation of complementary foods and even as raw materials to combat hidden hunger in both urban and rural populations.

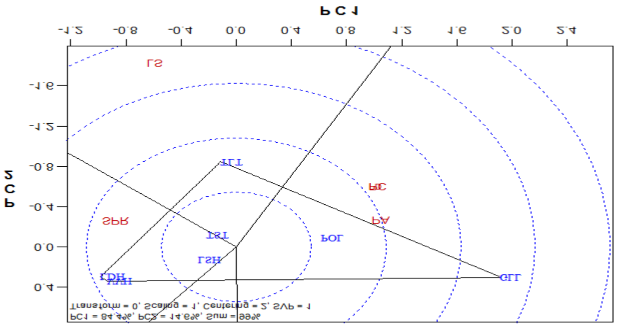

Figure 2: The which-won-where graph of wild mushrooms based on physical characteristics

VVH = *V. volvacea*, LDH = *L. deliciosus*, LSH = *Lactarius sp*, GLL = *G. lucidum*, POL = *P. ostreatus*, TLT = *T. le-teshui*, TST = *Termitomyces sp*, SPR = stipe-pileus ratio, PA = pileus area, PD = pileus diameter, LS = length of stipe, and PC = pileus circumference

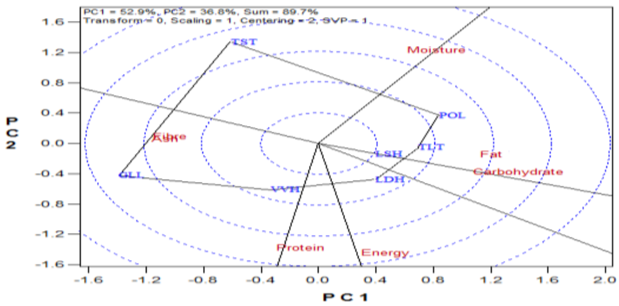

Figure 3: Which-won-where view of wild mushrooms based on proximate compositions

VVH = *V. volvacea*, LDH = *L. deliciosus*, LSH = *Lactarius sp*, GLL = *G. lucidum*, POL = *P. ostreatus*, TLT = *T. le-teshui*, and TST = *Termitomyces sp*

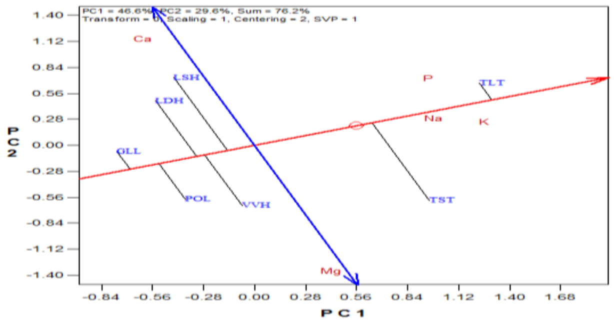

Figure 4; Mean performance and stability ranking of wild mushrooms based on mineral concentrations

VVH = *V. volvacea*, LDH = *L. deliciosus*, LSH = *Lactarius sp*, GLL = *G. lucidum*, POL = *P. ostreatus*, TLT = *T. le-teshui*, and TST = *Termitomyces sp*

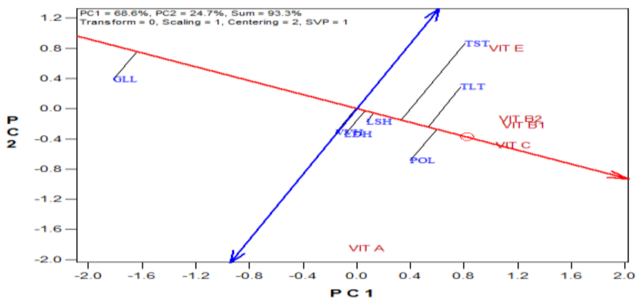

Figure 5: Mean performance and stability ranking of wild mushrooms based on vitamins contents

VVH = *V. volvacea*, LDH = *L. deliciosus*, LSH = *Lactarius sp*, GLL = *G. lucidum*, POL = *P. ostreatus*, TLT = *T. le-teshui*, and TST = *Termitomyces sp*

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Phytochemicals

The concentrations of phytochemicals in the mushrooms varied significantly. *T. le-testui* had significantly higher saponin levels than the other mushrooms, with the exception of *Termitomyces sp* (Table 5). *Lactarius sp*. produced significantly more alkaloid than *Termitomyces sp*. and *T. le-testui*. The most tannin was produced by *Lactarius sp*., followed by *T. le-testui*. *Lactarius sp*. had significantly higher flavonoid levels than *Termitomyces sp*. and *G. lucidum*, while *T. le-testui* had significantly higher total phenol levels than the other mushrooms except *Lactarius sp*. and *P. ostreatus*. The first and second principal component axes accounted for 89.3% of the variation in the phytochemical contents of the mushrooms based on their phytochemical contents (Figure 6). The ranking of the mushroom species showed the following order: *T. le-teshui*>*Lactarius sp*.>*P. ostreatus*> population mean > *L. deliciosus*> *V. volvacea*>*Termitomyces sp*.>*G. lucidum.*

The fungal species, environmental factors, the abundance of elements in the substrate, and the mushroom's ability to absorb the elements have all been linked to the accumulation of elements in mushrooms[16,26,38]. The presence of alkaloids, flavonoids, phenol saponins, and tannins in all of the mushrooms tested demonstrated that these five phytochemicals are present in mature mushrooms in the studied environment.

Some other mushrooms have been screened for phytochemicals and found alkaloids, saponins, and tannins in the mature fruit body but could not find flavonoids.[26] However, only saponins and tannins were found in the young fruit body.[26] The phytochemical analysis of *Termitomyces robustus* revealed the presence of only saponins and flavonoids[39]. On the other hand, phytochemical analysis of *Pleurotus tuberregium* revealed the presence of polyphenols, alkaloids, flavonoids, tannin, and saponin.[40] The phenols, alkaloids, flavonoids, tannins, and saponin levels in the wild mushrooms used in this study varied, indicating their varying health benefits.

The absence of phytochemicals in a mushroom reduces its therapeutic value.[39] As a result, the presence of these phytochemicals in the mushrooms studied is a sign of their therapeutic potential. Mushroom polyphenols may enhance drug bioavailability and pharmacokinetics in the body system[41] while plant alkaloids from mushrooms can be useful in the production of pain relieving drugs.[42,43] However, some alkaloids may have toxicological manifestations such as gastrointestinal upsets and neurological disorders in excess dose.[44] The presence of saponins, alkaloids and flavonoids in mushrooms has been linked to their metalloprotective properties.[40] Similarly, flavonoids are important in the antioxidant activities.[45] Antioxidants are substances that can neutralize oxidative activities in the body by donating an electron or hydrogen atom to the free radicals.[46] The combination of *G. lucidum* and *P. ostreatus* extracts has significantly higher antioxidant and alfa-amylase inhibitory activities compared to the single individual extract.[47]

This study reveals that the wild mushrooms analyzed possess significant nutritional and health benefits. The protein content in these mushrooms is notably higher than in other reported wild mushrooms, making them a valuable protein source comparable to dairy and meat, especially for low-resource households. Mushrooms with lower moisture content exhibited higher protein levels, aligning with previous findings. The mineral analysis showed high levels of potassium, sodium, and phosphorus, beneficial for fluid balance and muscle function, while low sodium content supports cardiovascular health. Notably, these mushrooms are rich in vitamins A, C, and E, with *P. ostreatus* having the highest vitamin A content, highlighting their potential in addressing vitamin deficiencies. The presence of key phytochemicals like alkaloids, flavonoids, phenols, saponins, and tannins further underscores their therapeutic potential, offering antioxidant and metalloprotective benefits. These findings emphasize the nutritional and medicinal value of wild mushrooms, advocating for their increased utilization in diet and health interventions.

Conclusion

The proximate, mineral, vitamin and phytochemical contents of edible wild mushrooms varied significantly. *Termitomyces le-testui* ranked higher than the population mean in mineral, vitamins and phytochemical compositions. *Ganoderma lucidum* was the least ranked mushroom for mineral, vitamins and phytochemical compositions. The results of this study can aid nutritionists, dieticians and low-income households in locating nutritious mushrooms when foraging in the outdoors, thereby minimizing hidden hunger. Exploring these variations in mushroom content will be useful for pharmaceutical and therapeutic purposes.

Table 5: Phytochemical concentrations (mean ± standard deviation) of the different wild mushrooms

Wild mushroom	Saponin %	Alkaloids %	Tannin %	Flavonoid %	Total phenol %
G. lucidum	0.43 ± 0.2 d	3.35 ± 0.63 ab	1.07 ± 0.00 bc	1.30 ± 0.09 c	4.52 ± 0.89 d
L. deliciosus	0.50 ± 0.1 cd	2.75 ± 1.00 ab	0.81 ± 0.10 bc	3.70 ± 0.20 abc	6.13 ± 1.00 bcd
Lactarius sp	2.84 ± 1.4 b	4.02 ± 0.80 a	1.46 ± 0.51 ab	6.63 ± 2.33 a	11.01 ± 3.84 ab
P. ostreatus	1.64 ± 0.7 c	3.18 ± 0.99 ab	1.43 ± 0.62 b	5.00 ± 2.04 ab	9.31 ± 3.24 abc
T. le-teshui	4.43 ± 0.1 a	2.72 ± 0.31 b	2.13 ± 0.14 a	6.43 ± 0.48 a	12.81 ± 0.88 a
Termitomyces sp	3.25 ± 0.1 ab	2.35 ± 0.05 b	0.87 ± 0.10 bc	2.40 ± 0.10 bc	5.00 ± 1.00 cd
V. volvacea	1.35 ± 0.0 cd	3.15 ± 0.00 ab	0.49 ± 0.00 c	3.70 ± 0.00 abc	5.16 ± 0.00 cd

Each value is a mean of three replicates; means with the same superscripts (letter) within the same column are not significantly different at 5% probability level.

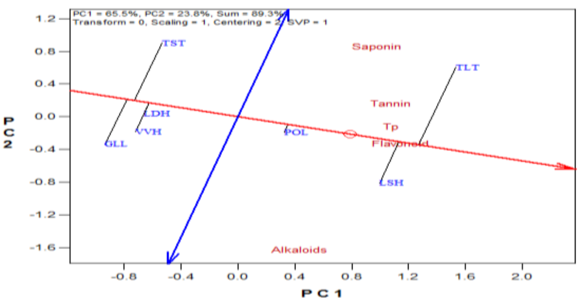

Figure 6: Mean performance and stability ranking of wild mushrooms based on phytochemical contents
VVH = *V. volvacea*, LDH = *L. deliciosus*, LSH = *Lactarius sp*, GLL = *G. lucidum*, POL = *P. ostreatus*, TLT = *T. le-teshui*, and TST = *Termitomyces sp*

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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