Published by
NIGERIAN SOCIETY OF PHYSICAL SCIENCES
Available online @ https://journal.nsps.org.ng/index.php/jnsps

J. Nig. Soc. Phys. Sci. 7 (2025) 2978

Journal of the Nigerian Society of Physical Sciences

Assessment of the nutritional and phytochemical composition of selected mushroom species grown in Southern Nigeria

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Abstract

Mushrooms are increasingly gaining attention for their nutritional and therapeutic benefits due to their rich composition of essential nutrients and bioactive compounds. However, all-encompassing integrative data on *Calocybe indica*, *Ganoderma lucidum*, and *Pleurotus djamor* grown in southern Nigeria is lacking. This study aims to provide a detailed, parallel evaluation of the nutritional and phytochemical composition of these mushroom species through a multidimensional analysis. The proximate, mineral, and phytochemical contents of the mushrooms were determined following standard analytical methods, while the metabolites were identified using gas chromatography-mass spectrometry (GC-MS). The phytochemical, terpenoid, was of the highest level (2.25 ± 0.05 % to 15.91 ± 0.41 %), with *Ganoderma lucidum* having the highest value. In the GC-MS chromatograms of the methanol extracts of the mushrooms, the most prominent bioactive metabolites were cis-vaccenic acid (31.32 %) and *n*-hexadecanoic acid (27.75 %), ergosterol (28.02 %), and linoelaidic acid (37.83 %) for *Calocybe indica*, *Ganoderma lucidum*, and *Pleurotus djamor*, respectively. High amounts of carbohydrates, protein, fiber, and ash were recorded for all the species, with *Ganoderma lucidum* having the highest fiber content of 34.85 ± 0.74 %. Mg, Ca, and Fe were significantly higher in *Ganoderma lucidum*, while K is at the highest level in *Calocybe indica* (30119.05 mg/kg). These findings suggest that these mushrooms are potent sources of vital nutrients, with *Ganoderma lucidum* having superior antioxidant relevance. This research provides an indispensable basis for mushroom choice, formulation of functional foods and nutraceuticals, and optimization of health-promoting characteristics of the studied mushrooms.

DOI:10.46481/jnsps.2025.2978

Keywords: Proximate analysis, GC-MS analysis, Macro-minerals, Terpenoids

Article History :
Received: 30 May 2025
Received in revised form: 07 August 2025
Accepted for publication: 29 August 2025
Available online: 23 September 2025

Communicated by: E. Etim

1. Introduction

Edible mushrooms have proven to be an indispensable powerhouse of nutrition. They are endowed with nutrients such as carbohydrates, proteins, fiber, and micro and macro minerals, which are essential for energy production, bodybuilding, important cell metabolic reactions, and tissue formation and repair [1–3]. A proximate analysis of edible mushrooms revealed that carbohydrate content is of the highest values, followed by protein, fiber, moisture, ash, and fat, though there are exceptions depending on species, cultivation conditions, and processing methods [4]. Concerning mineral composition, edible mushrooms are excellent sources of potassium, magnesium, calcium, sodium, iron, copper, zinc, phosphorus, and manganese [5, 6]. Additionally, they also contain varying amounts of essential vitamins such as thiamin, riboflavin, niacin, cobalamin, and calciferol [7–9]. These nutrients have a

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critical role in immune system function, hormone production, bone health, and nervous system function [10]. Research has also proven that edible mushrooms are good sources of bioactive compounds [11, 12]. These are compounds produced by plants for their defense against different diseases [13], and are found in fruits, vegetables, whole grains, nuts, and herbs. Phytochemicals such as phenolics, flavonoids, phytates, terpenoids, alkaloids, steroids, and saponins were reported to be present in wild and domestically grown edible mushrooms [14–16]. A gas chromatography-mass spectrometry (GC-MS) screening of edible mushroom extracts supports the fact that edible mushrooms are reservoirs of bioactive compounds such as ergosterol, oleic acid, octadecadienoic acid, (*Z*, *Z*)-, palmitic acid, and so on. These compounds also contribute to the nutraceutical potential of edible mushrooms [17–23].

Ganoderma lucidum, *Calocybe indica*, and *Pleurotus djamor* are edible mushrooms belonging to the Basidiomycota division of the Kingdom Fungi. *Ganoderma lucidum* is a wood-deteriorating visible fungus [24], and a medicinal mushroom used by the Chinese as a remedy for certain ailments, and by some locals in the Southern part of Nigeria in the formulation of herbal concoctions [25]. *Calocybe indica*, otherwise known as the milky mushroom, has been found to have diverse nutraceutical properties due to its rich content of vitamins, protein, and bioactive compounds [26]. *Pleurotus djamor* is one of the oyster mushrooms, classified as one of the tastiest foods because of its excellent flavour, high nutritional content, and potential medical benefits [27, 28]. While *Calocybe indica* and *Pleurotus djamor* are consumed as a substitute for meat by a few Nigerians, *G. lucidum* is often neglected due to its non-sweet taste and woody texture. There is a dearth of data that has comprehensively assessed and compared the nutritional, mineral, and phytochemical contents of the three edible mushrooms covered in this study, grown in southern Nigeria. Thus, this research is meant to comparatively assess the amount of nutrients in terms of proximate and mineral composition of the featured mushrooms, and quantitatively evaluate the phytochemicals available in them, unlike other qualitative studies on mushrooms. The result will be used to enlighten the public on the importance of including edible mushrooms in their diet, thereby reducing the likelihood of contracting certain chronic diseases like diabetes, hepatitis, cancer, and immunological disorders, and ameliorating nutritional deficiencies. The data garnered from this study will also guide us in ascertaining possible recommendations for using any, some, or all of the species in food and drug formulations.

2. Materials and methods

2.1. Chemicals and reagents

The Anthrone reagent, standard gallic acid, and tannic acid were products of Sigma Aldrich, Saint Louis, USA. All other reagents used were analytical grade.

2.2. Mushroom collection and preparation

Fresh fruiting bodies of *Calocybe indica, Ganoderma lucidum*, and *Pleurotus djamor* were purchased from mushroom farmers at Osogbo and Ibadan in southern Nigeria. The mushrooms were subsequently recognized and verified by a Botanist of the Botany Department of the State University, Oshogbo in Osun State. They were identified by Dr. John Ayinde and given Herbarium Nos. 0273, 0274, 0275, and samples were kept for reference in the University Herbarium. The mushrooms were chopped into smaller pieces and air-dried in the shade. The air-dried mushroom samples were milled into powder using a Power Deluxe® Electric Blender (Model: PDB-8231-F) and stored in airtight polyethylene zip-lock bags before analysis and labeled according to species name with codes CCI for *Calocybe indica*, PRD for *Pleurotus djamor*, and GDL for *Ganoderma lucidum*.

2.3. Preparation of aqueous and ethanolic extracts

The extraction procedure described by Khan *et al*. [29] was followed with minor changes. 10 g of pulverized mushrooms were mixed thoroughly with 100 mL (x 3) of distilled water, left to macerate for 24 hours (x 3) with intermittent stirring, subsequently filtered, centrifuged, and the solvent evaporated using a rotary evaporator. The same procedure was followed in the preparation of ethanol extracts of the examined mushrooms. The crude extracts were kept in desiccators before analysis.

2.4. Screening and quantification of phytochemicals

Aqueous and ethanol extracts of each of the examined mushrooms were tested for the presence of phytochemicals following standard procedures [30–35]. Identified phytochemicals were then quantified according to standard methods of analysis. The amounts of alkaloids, saponins, terpenoids, flavonoids, and cardiac glycosides were gravimetrically determined [30, 36–38], oxalates and phytates by titrimetry [39, 40], while phenol content and tannin were determined by spectrophotometry [36, 41].

2.5. Preparation of methanol extracts of mushroom samples for GC-MS analysis

The mushroom powder was refluxed thrice with methanol (1 g:10 mL) at intervals of thirty (30) minutes and a temperature of 60 °C to obtain the extracts, which were subsequently pooled together, and reduced to 4 % of its original volume using RE52-2 Rotary Evaporator at 40°C, and then purified in a well-packed column [22]. For each refluxing cycle, fresh methanol was used in order to reduce the chances of degradation.

2.6. GC-MS examination of methanol extracts

The extracts obtained were analysed employing an Agilent 7890A Gas Chromatograph equipped with a 5977B Mass Selective Detector (MSD). The phytocompounds were separated using a 30 m (5 %-phenyl)-methylpolysiloxane (Hp-5ms) non-polar phase capillary column, which had a film thickness of 0.25 micrometer, and an interior diameter of 0.25 millimeter. The carrier gas, Helium gas, flowed at a rate of 1.0 mL/min. The GC oven temperature was set at 40 °C to 250 °C at an increment rate of 5 °C per minute. The sample injection volume was one microlitre. The samples were scanned fully at a range of

40 to 650 m/z, and the relative concentration of compounds in the extracts was expressed as the % peak area of the generated chromatogram. The compounds were then identified on the basis of their spectral match with the NIST Mass Spectral Library Search Program and their retention indices in correspondence with standards in the NIST RI database [42]. The retention indices of the compounds were calculated using the temperature programmed chromatography Kovat's index equation [43]:

$$RI_i = 100\left[n + \frac{t_i - t_n}{t_{n+1} - t_n}\right]. \quad (1)$$

2.7. Proximate analysis

The total carbohydrate content of the mushrooms was determined using the Anthrone method, which involved the preparation of 1 mg/mL glucose stock solution, 0.1 mg/mL glucose working standard, and subsequent formation of green to dark green solution as a result of the addition of ice-cold anthrone reagent [44]. The absorbance readings of the colored solutions were taken with an Ocean Med$^+$ England 752G UV Spectrophotometer at a wavelength of 630 nm. Crude fat, crude fiber, crude protein, moisture, and ash contents on a dry weight basis were determined following AOAC Reference methods: AOAC 2003.05, AOAC 978.10, AOAC 2001.11 Kjeldahl's method, AOAC 930.15, and AOAC 942.05 (with slight modification of washing, rinsing, drying, and igniting the porcelain crucibles at 550 °C before use for the determination of ash content) respectively [45–50].

2.8. Mineral analysis

Before the quantification of selected minerals in the edible mushroom samples using AAS, wet digestion of the samples using aqua regia was carried out. Aqua regia comprises hydrochloric acid and nitric acid in a ratio of 3:1. 1 g of sample was mixed with 10 mL of aqua regia in a 250 mL conical flask and heated on a hot plate in a fume hood until a clear solution was obtained and no more noticeable fumes. The solution was allowed to cool, filtered through a Whatman No. 1 filter paper into a 100 mL volumetric flask, and made up to mark with deionized water. The procedure described by Rashid *et al*. [51] was followed in the digestion of the samples with minor modifications.

To ensure the quality of results, recovery studies were carried out per element analysed by spiking a known concentration of the element into the already analysed samples. The percentage recovery was then calculated. Recoveries of 99.95 %, 89.9 %, 99.63 %, 99.98 %, 98.33 %, 99.98 %, 99.06 %, 99.60 %, and 98.02 % were recorded for Ca, Cu, Fe, Mg, Mn, Zn, Co, Na, and K, respectively.

2.9. Statistical evaluation

All determinations were performed in triplicate per sample. IBM SPSS Statistics 23 software was used for statistical analysis, while OriginPro 2025 Graphing and Analysis software was used for data plotting. Analysis of variance (ANOVA) was performed on the data sets obtained. Values are presented as mean ± standard deviation where applicable.

3. Results and discussion

3.1. Screening and quantification of phytochemicals

Table 1 shows the phytochemical profile of the examined mushrooms. The three mushroom samples gave a positive test for the phytochemicals: alkaloids, terpenoids, cardiac glycosides, flavonoids, oxalates, phytates, tannins, phenols, and saponins. This therefore indicates the presence of these phytochemicals in the mushrooms. Table 2 shows the mean percentage composition of identified phytochemicals in *Calocybe indica, Ganoderma lucidum*, and *Pleurotus djamor*. The results revealed that terpenoids had the highest mean values in all the mushrooms, in the order of 15.91 %, 6.20 %, and 2.25 % for *Ganoderma lucidum, Calocybe indica*, and *Pleurotus djamor*, respectively. Phenol, alkaloids, and saponin values were also higher in the three mushrooms, with values ranging from 0.72 % to 1.64 %, 0.57 % to 1.30 %, and 0.61 % to 0.75 % respectively. At $p \leq 0.05$, a significant difference was observed in the phytochemical composition of the mushrooms. Overall, the phytochemical content of the mushrooms is in the following order: terpenoid > phenol > alkaloids > saponins > cardiac glycoside > tannins > flavonoids > phytates > oxalates. Some research on bioactive compounds in *Ganoderma lucidum* agrees with the findings of this research that terpenoids were the most abundant phytochemical, followed by phenols and flavonoids. Gharib *et al*. [52] reported lower terpenoid (2,541±16.72 mg linalool /100g) and phenol (572.67 ± 16.34 mg gallic acid/100g) content for *Ganoderma lucidum*. Taofiq *et al*. [53] also recorded 27.20 mg linalool/g terpenoids and 279.34 ± 6.87 mg catechin/100g. The least mean values were recorded for oxalates in *Calocybe indica* (0.04 %), *Ganoderma lucidum* (0.06 %), and *Pleurotus djamor* (0.03 %). Terpenoids are derivatives of terpenes that contain oxygen molecules and have proven to have therapeutic potential against protozoa and parasitic diseases such as malaria, trypanosomiasis, and leishmaniasis [54]. Terpenoids exhibit antibacterial, antiviral, antioxidant, and analgesic activity, and aid digestion and other biological activities [55].

Considering the health benefits of terpenoids and their presence in higher amounts in the examined mushrooms, particularly *Ganoderma lucidum*, this accounts for its use in traditional medicine. Phenolic compounds have been linked to the anti-inflammatory activities of various mushrooms [26, 56]. The mushrooms studied had appreciable amounts of phenols, with *Ganoderma lucidum* having the highest concentration (1.64 %), followed by *Calocybe indica* (1.02 %) and *Pleurotus djamor* (0.72 %). The phenol content of *Pleurotus djamor* recorded in this study is lower than the values (10.29 ± 0.77 mg gallic acid/g; 32.55 ± 0.21 mg/g) recorded by some authors [28, 57], and higher than some others (1.14 mg GAE/g; 2.79 mg GAE/g) [58, 59]. The phenol content of *Ganoderma lucidum* from this study is also lower than the values (5.90 %, 5.90 %, 2.73 %) for methanolic, aqueous, and ethanolic extracts of *Ganoderma lucidum* and higher than 1.007 % for dichloromethane extract of the same mushroom [60]. The variations in values reported by various researchers may be due to the different sources of mushrooms, choice of drying methods, extraction conditions, and the

developmental stages of the mushroom [61]. The alkaloid and saponin content of the examined mushrooms was higher than the values (34.3 mg/g; 1.1mg/g, respectively) reported for *Ganoderma lucidum* and other mushrooms analysed by some authors [62]. *Calocybe indica* had slightly higher saponins than the others [63]. The tannin contents of the examined mushrooms were in the range of 0.11 % - 0.29 % with *Ganoderma lucidum* having the highest mean value. Tannin is a bioactive substance that quickens the healing of wounds, aids in the prevention of cancer, and is viable for the treatment of inflamed mucous membranes and ulcerated tissues [64]. Phytates have been shown in studies to possess vital health impacts, namely antioxidant, anticancer potential, decreasing pathological calcifications in blood vessels and organs, anti-diabetic potential, and prevention of osteoporosis [65]. Though phytates could also pose health risks like reduction in the availability of important elements like zinc, magnesium, and iron in the human body, the low quantity of phytates in the examined mushrooms (0.13 %, 0.14 % and 0.18 %) places them among the foods (millet, rye, oats and so on) low in phytates with values ranging from 0.18 – 1.67 %.

Thus, consumption of these mushrooms poses no threat to humans. Oxalate content in all the examined mushrooms was the lowest, with values of 0.04 %, 0.06 %, and 0.03 % for *Calocybe indica*, *Ganoderma lucidum*, and *Pleurotus djamor*, respectively. Though oxalates are associated with kidney stone problems, these low levels will have no negative impact on human health as the mushroom, as shown by some researchers and this work on the nutritional content and the amount of minerals present in these mushrooms, shows they contain significant amounts of magnesium and potassium which could reduce the risk of kidney stones [66]. According to the Kendall Reagon Nutrition Centre, including many oxalate-containing plant foods in the diet is recommended, proving that these foods play a crucial role in disease prevention, except for individuals with altered gut function [67]. The cardiac glycoside content of the studied mushrooms ranged from 0.06 % to 0.38 % with *Ganoderma lucidum* having the highest. As compared to the cardiac glycoside content of a *Pleurotus spp.* examined by Bello *et al.* [68], the levels recorded in this study were slightly higher. Cardiac glycosides are widely used in the treatment of diseases. They are steroids that could have a unique, strong impact on the cardiac muscle. A minute quantity can have a significant effect on a malfunctioning heart; hence, its use as a remedy for heart failure [69]. Therefore, these mushrooms are a vital source of cardiac glycosides for promoting better health. These facts on the therapeutic capacity of mushrooms based on their bioactive components are backed up by *in vivo* and *in vitro* studies conducted by some researchers [70–73].

3.2. GC-MS analysis

GC-MS chromatograms of methanolic extracts of *Calocybe indica, Ganoderma lucidum*, and *Pleurotus djamor* are given in Figures 1 – 3, while Tables 3 - 5 show the phytochemical content of the examined mushrooms as analysed by gas chromatography-mass spectrometry. The analysis revealed that *Calocybe indica* contained thirty (30) compounds, *Ganoderma lucidum*, twenty (20), and *Pleurotus djamor*, seven (7) compounds. The % spectral match factors and retention indices of the identified compounds, particularly those with prominent peaks, correspond in most cases closely (> 80 %) with NIST Reference standards. Oleic acid and n-hexadecanoic acid were common to all the mushrooms. Linoelaidic acid was present in *Calocybe indica* and *Pleurotus djamor*. In *Pleurotus djamor*, linoelaidic acid had the highest percentage peak area of 37.83 %, followed by 9, 12-octadecadienoic acid (*Z, Z*)- (13.33 %) and *n*-hexadecanoic acid (12.03 %), while in *Calocybe indica*, cis-vaccenic acid (31.32 %) was the highest, followed by *n*-hexadecanoic acid (27.75 %), and 9,17-octadecadienal (*Z*-) with a peak area of 16.50 %. Ergosterol had the highest peak area (28.02 %), followed by farnesol isomer (13.07 %) in *Ganoderma lucidum*. They contain bioactive chemicals, as the chromatograms showed, and the results of this study are consistent with previous research on edible mushrooms [22, 74]. Oleic acid, a monounsaturated fatty acid, has been shown to mitigate inflammation, inhibit cancer progression, avert hair loss associated with immune disorders, and enhance the synthesis of red blood cells [75].

Several studies have reported that n-hexadecanoic acid has hypocholesterolemic and nematicidal properties and also inhibits the growth of microbes [76]. It is also a potent mosquito larvicide [77]. 9,12-octadecadienoic acid-(*Z, Z*), known as

Table 1: Phytochemical composition of *Calocybe indica*, *Ganoderma lucidum*, and *Pleurotus djamor*.

Parameter	*Calocybe indica*	*Ganoderma lucidum*	*Pleurotus djamor*
Alkaloid	+	+	+
Terpenoid	+	+	+
Total glycoside	+	+	+
Flavonoid	+	+	+
Oxalates	+	+	+
Phytates	+	+	+
Tannins	+	+	+
Phenol	+	+	+
Saponin	+	+	+

Table 2: Phytochemical composition of *Calocybe indica*, *Ganoderma lucidum*, and *Pleurotus djamor*.

Parameter	*Calocybe indica*	*Ganoderma lucidum*	*Pleurotus djamor*
Alkaloid	0.85±0.04	1.27±0.03	0.57±0.03
Terpenoid	6.20±0.05	15.91±0.41	2.25±0.05
Cardiac glycoside	0.23±0.05	0.38±0.04	0.08±0.01
Flavonoid	0.27±0.03	0.16±0.01	0.06±0.003
Oxalates	0.04±0.001	0.06±0.001	0.03±0.001
Phytates	0.15±0.003	0.13±0.001	0.1841±0.003
Tannins	0.20±0.001	0.29±0.002	0.11±0.002
Phenol	1.02±0.01	1.64±0.004	0.72±0.01
Saponin	0.75±0.03	0.61±0.03	0.67±0.01

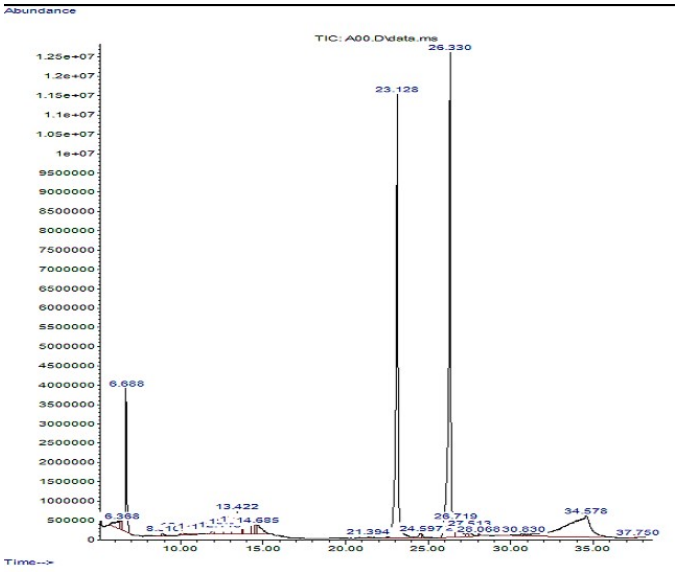

Figure 1: GC-MS chromatogram of methanolic extract of *Calocybe indica*.

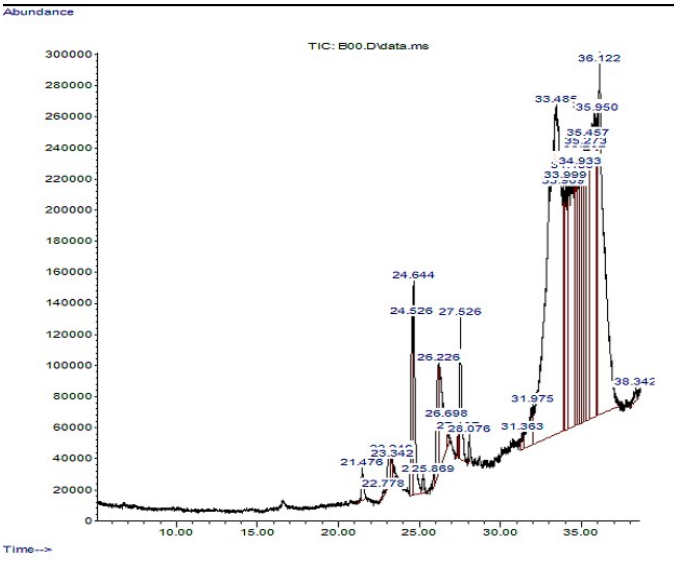

Figure 2: GC-MS chromatogram of methanolic extract of *Ganoderma lucidum*.

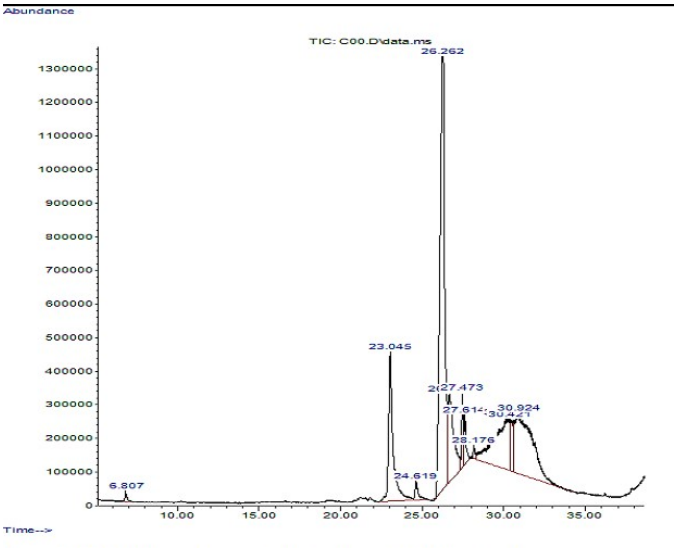

Figure 3: GC-MS chromatogram of methanolic extract of *Pleurotus djamor*.

linoleic acid, is also known to act as an inflammation-reducing, hepatoprotective, antihistaminic, and antieczemic agent. Similarly, linoelaidic acid is known to significantly reduce cancer cell lines and oxidative stress in the cells [78]. Thus, the presence of linoelaidic acid in the studied mushrooms implies that the mushrooms could be harnessed in the formulation of cancer drugs. *Calocybe indica* was found to have a high percentage of cis-vaccenic acid. This omega-7-monounsaturated fatty acid can limit gluconeogenesis and fat accretion in the liver [79]. It's also known to have antibacterial and hypolipidemic effects [80]. 9,17- octadecadienal, (Z), also present in *Calocybe indica*, has antimicrobial activity too [81]. *Ganoderma lucidum* had a high percentage of Ergosterol (provitamin D), which is a bioactive compound. The valuable health impact of ergosterol and its prevalence in many foods, nutritional supplements, and edible mushrooms have made it indispensable in pharmacological studies. Ergosterol has healing potential for immune function, diabetes, cancer, and several ailments [82]. Farnesol isomer, also present in *Ganoderma lucidum*, a sesquiterpene alcohol, could have the anti-inflammatory ability to ameliorate allergic asthmatic inflammation [83]. Cyclopropanes are commonly used components in drug design. This is because incorporating them in pharmaceuticals leads to an elevated target affinity, enhanced metabolic stability, and accelerated rigidity to acquire bioactive conformation [84]. Thus, cyclopropane octanal, 2-octyl, though not a bioactive compound, could be used as a component in the synthesis of pharmaceuticals and also as an intermediate in organic synthesis processes [85].

3.3. Quantification of Proximate Parameters

Figure 4 shows the proximate composition of the studied mushrooms. Of the proximate parameters analysed, total carbohydrates had the highest percentage mean values, ranging from 39.13±0.79 % to 50.94±1.11 % while the lowest values of 2.61±0.35 % to 6.43±0.49 % were recorded for crude fat. These values were significantly different between the studied mushrooms. It was observed that *C. indica* had the highest amount of carbohydrate and fat as compared to the other two mushroom species. Carbohydrates, which are part of the major nutrients in man's diet, play an indispensable role in providing energy to the body and enhancing certain vital metabolic reactions in human cells. It is recommended that an adult's daily diet contain 200 to 300g of carbohydrates [86]. Thus, the inclusion of these mushrooms in food, particularly *C. indica*, can be a good source of healthy carbohydrates. Fats are essential nutrients, but are required in small amounts of not more than 30 g per day for men and 20 g per day for women

Table 3: Phytochemicals identified in the methanolic extracts of *Calocybe indica* by GC-MS.

PK	RT (Mins)	Compound	IUPAC Name	Molecular formula	Molecular weight (g/mol)	Peak Area (%)	% SMF[1]	RI[2]
1	6.2053	Carbonic acid, octadecyl prop-1-en-2-yl ester	octadecyl prop-1-en-2-yl carbonate	$C_{22}H_{42}O_3$	354.6	1.16	27	717.11
2	6.3676	Carbonic acid, prop-1-en-2-yl tetradecyl ester	Carbonic acid, prop-1-en-2-yl tetradecyl carbonate	$C_{18}H_{34}O_3$	298.5	0.4274	38	731.64
3	6.6877	Tripropyl orthoformate	1-(dipropoxymethoxy)propane	$C_{10}H_{22}O_3$	190.29	6.1078	50	760.29
4	8.8869	Heptadecyl acetate	Heptadecyl acetate	$C_{19}H_{38}O_2$	298.5	0.238	46	894.38
5	10.0508	(S)-3,3,6-Trimethylhepta-1,5-dien-4-yl acetate	3,3,6-trimethylhepta-1,5-dien-4-yl acetate	$C_{12}H_{20}O_2$	196.29	0.3103	47	979.65
6	10.3306	Carbonic acid, eicosyl prop-1-en-2-yl ester	Icosyl prop-1-en-2-yl carbonate	$C_{24}H_{46}O_3$	382.62	0.0779	46	1001.05
7	11.1568	Heptanal dipropyl acetal	1,1-dipropoxyheptane	$C_{13}H_{28}O_2$	216.4	0.1768	53	1094.91
8	11.5275	2-Hexen-1-ol, 2-ethyl-	2-ethylhex-2-en-1-ol	$C_8H_{16}O$	128.21	0.1424	35	1135.50
9	11.6936	8-Hexadecenal, 14-methyl-, (Z)-	(Z)-14-methylhexadec-8-enal	$C_{17}H_{32}O$	252.44	0.1541	46	1153.60
10	11.936	Propanoic acid, 3-mercapto-, methyl ester	methyl 3-sulfanylpropanoate	$C_4H_8O_2S$	120.17	0.3238	27	1180.01
11	12.4149	1-Decanol, 2-hexyl-	2-hexyldecan-1-ol	$C_{16}H_{34}O$	242.44	0.8227	41	1233.50
12	13.0189	n-Propyl DECYL ETHER	1-propoxydecane	$C_{13}H_{28}O$	200.36	1.3875	30	1301.77
13	13.4222	Linolool oxide, TMS derivative	2-(5-ethenyl-5-methyloxolan-2-yl)propan-2-yloxy-trimethylsilane	$C_{13}H_{26}O_2Si$	242.43	2.8939	27	1342.28
14	13.7322	Hexanoic acid, ethyl ester	ethyl hexanoate	$C_8H_{16}O_2$	144.21	0.5755	35	1373.41
15	14.1416	Tris(aziridinomethyl)hydrazine	1,1,2-tris(aziridin-1-ylmethyl)hydrazine	$C_9H_{19}N_5$	197.28	2.1184	18	1447.57
16	14.309	E-8-Methyl-7-dodecen-1-ol acetate	[(E)-8-methyldodec-7-enyl] acetate	$C_{15}H_{28}O_2$	240.38	0.9551	53	1500.71
17	14.4725	E-11(13,13-Dimethyl)tetradecen-1-ol acetate	[(E)-13,13-dimethyltetradec-11-enyl] acetate	$C_{18}H_{34}O_2$	200.3	0.8223	74	1515.36
18	14.6855	Cyclotetradecane	Cyclotetradecane	$C_{14}H_{28}$	196.37	1.3697	62	1534.44
19	21.3938	Hexadecanoic acid, methyl ester	methyl hexadecanoate	$C_{17}H_{34}O_2$	270.5	0.0623	93	1900.47
20	23.1285	*n*-Hexadecanoic acid	hexadecanoic acid	$C_{16}H_{32}O_2$	256.4	27.7467	99	1966.68
21	24.5069	Hexadecanoic acid, propyl ester	2,3-diacetyloxypropyl hexadecanoate	$C_{19}H_{38}O_2$	298.51	0.4597	91	2030.08
22	24.5969	9-Octadecenoic acid (Z)-, methyl ester	methyl octadec-9-enoate	$C_{19}H_{36}O_2$	296.49	0.3075	93	2035.43
23	26.3303	cis-Vaccenic acid	(Z)-octadec-11-enoic acid	$C_{18}H_{34}O_2$	282.46	31.3226	97	2113.46
24	26.7186	Octadecanoic acid	octadecanoic acid	$C_{18}H_{36}O_2$	284.48	2.0151	99	2121.51
25	27.3636	Linoelaidic acid	(9*E*,12*E*)-octadeca-9,12-dienoic acid	$C_{18}H_{32}O_2$	280.45	0.2331	96	2373.20
26	27.5127	cis-9-Octadecenoic acid, propyl ester	propyl (*E*)-octadec-9-enoate	$C_{21}H_{40}O_2$	324.54	0.5779	89	2364.97
27	28.0676	Cyclopropaneoctanal, 2-octyl-	8-(2-octylcyclopropyl)octanal	$C_{19}H_{36}O$	280.5	0.1152	60	2334.35
28	30.7174	Linoelaidic acid	(9*E*,12*E*)-octadeca-9,12-dienoic acid	$C_{18}H_{32}O_2$	280.45	0.4908	95	2436.74
29	30.83	Oleic Acid	(Z)-octadec-9-enoic acid	$C_{18}H_{34}O_2$	282.46	0.114	92	2444.30
30	34.5781	9,17-Octadecadienal, (Z)-	(9Z)-octadeca-9,17-dienal	$C_{18}H_{32}O$	264.5	16.4985	91	2687.12
31	37.7501	Z,Z-10,12-Hexadecadienal	(10Z,12Z)-hexadeca-10,12-dienal	$C_{16}H_{28}O$	236.39	-0.0071	38	2891.78

[1]: percentage similarity match factor, [2]: retention index.

[87]. The levels of fat present in the mushrooms indicate that they could augment other sources of fat and also offer a better choice for patients with cholesterol issues, resulting in heart disease and stroke. A research work reported similar fat content for *C. indica* and *P. djamor* but lower carbohydrate values of 11.70±0.25 % and 39.19±0.30 % respectively [1]. The crude fiber content recorded in this research ranged from 11.80±0.75 % to 34.85±0.74 % with *G. lucidum* having the highest amount (34.85±0.74 %). Some authors reported similar values, though with slight variations [1, 2]. Comparing the three mushrooms examined, *G. lucidum* is more promising in preventing digestive issues like constipation due to its higher crude fiber content, while *C. indica* would be a better option for individuals interested in weight gain and energy needs, as it has higher carbohydrate and crude fat content, followed by *P. djamor*. *P. djamor*, however, recorded a higher amount of crude protein (19.38±1.36 %) against 16.69±0.33 % and 14.93±0.23 % reported for *G. lucidum* and *C. indica*, respectively. Based on the Recommended Daily Allowance of protein for an adult female (46 g per day or 0.8 g per Kg body weight) [88], *P. djamor* provides 42.13 %, *G. lucidum* 36.28 % while *C. indica* offers 32.46 % of the daily requirement for an adult female.

The ash content of a food material gives insight into the amount of minerals it contains [4]. Looking at Figure 4, the mean percentage content of ash recorded ranged from 7.34±0.58 % to 10.34±0.47 % on a dry weight basis, with *C. indica* having the highest. These values indicate that these mushrooms could be good sources of essential minerals. The amount of moisture contained in an edible mushroom has a great bearing on its stability and storage. Our findings showed that *P. djamor* had the highest moisture content (10.04±0.89 %), followed by *C. indica* (6.47±0.50 %) and *G. lucidum* (1.91±0.10 %). This implies that *G. lucidum* will have a better shelf life than the other two mushrooms examined. The mushrooms, though having varying amounts of the nutrients analysed, adding them to the daily diet depending on body needs, could contribute to the man's overall well-being.

3.4. Mineral content

As revealed by the ash content of the examined mushrooms, they contain many essential macro and trace minerals. Figures 5 and 6 show the mineral composition of the edible mushrooms investigated. It was observed that potassium and magnesium (Figure 5) were significantly higher as compared to other minerals across all the mushrooms, with values ranging from 17536.95 mg/kg to 30119.05 mg/kg, and 6027.67 mg/kg to 45562 mg/kg, respectively. There was a significant difference in the mineral levels recorded for the studied mushrooms at $p \leq$

Table 4: Phytochemicals identified in the methanolic extracts of *Ganoderma lucidum* by GC-MS.

PK	RT (Mins)	Compound	IUPAC Name	Molecular formula	Molecular weight (g/mol)	Peak Area (%)	% SMF[1]	RI[2]
1	21.4762	Hexadecanoic acid, methyl ester	methyl hexadecanoate	$C_{17}H_{34}O_2$	270.5	0.4183	96	1903.62
2	22.7783	Undec-10-ynoic acid, dodecyl ester	dodecyl undec-10-ynoate	$C_{23}H_{42}O_2$	350.6	0.049	64	1953.31
3	23.1696	*n*-Hexadecanoic acid	hexadecanoic acid	$C_{16}H_{32}O_2$	256.4	0.5986	98	1968.24
4	23.2463	*n*-Hexadecanoic acid	hexadecanoic acid	$C_{16}H_{32}O_2$	256.4	0.1762	98	1971.17
5	23.3421	*n*-Hexadecanoic acid	hexadecanoic acid	$C_{16}H_{32}O_2$	256.4	0.1726	95	1974.83
6	24.5265	Hexadecanoic acid, propyl ester	2,3-diacetyloxypropyl hexadecanoate	$C_{19}H_{38}O_2$	298.51	1.612	96	2031.24
7	24.6435	11-Octadecenoic acid, methyl ester	methyl octadec-11-enoate	$C_{19}H_{36}O_2$	296.49	2.7933	99	2038.21
8	25.2403	Methyl stearate	methyl octadecanoate	$C_{19}H_{38}O_2$	298.51	0.1915	55	2073.73
9	25.8687	Oleic Acid	(*Z*)-octadec-9-enoic acid	$C_{18}H_{34}O_2$	282.46	0.0704	58	2102.24
10	26.1851	9,17-Octadecadienal, (*Z*)-	(9*Z*)-octadeca-9,17-dienal	$C_{18}H_{32}O$	264.4	1.523	95	2110.45
11	26.2257	2-Methyl-*Z*,*Z*-3,13-octadecadienol	(3*Z*,13*Z*)-2-methyloctadeca-3,13-dien-1-ol	$C_{19}H_{36}O$	280.5	2.4932	92	2111.29
12	26.6982	Oxiraneundecanoic acid, 3-pentyl-, methyl ester, cis-	methyl 11-[(2*R*,3*S*)-3-pentyloxiran-2-yl]undecanoate	$C_{19}H_{36}O_3$	312.5	0.2052	49	2121.09
13	27.3776	trans,trans-9,12-Octadecadienoic acid, propyl ester	propyl (9*E*)-octadeca-9,12-dienoate	$C_{21}H_{38}O_2$	322.53	0.1435	95	2135.19
14	27.4071	9,17-Octadecadienal, (*Z*)-	(9*Z*)-octadeca-9,17-dienal	$C_{18}H_{32}O$	264.4	0.0806	96	2135.80
15	27.5262	*n*-Propyl 11-octadecenoate	propyl (*Z*)-octadec-11-enoate	$C_{21}H_{40}O_2$	324.54	1.6211	99	2138.27
16	28.0759	Oleic Acid	(*Z*)-octadec-9-enoic acid	$C_{18}H_{34}O_2$	282.46	0.1787	18	2149.67
17	31.3627	Oleic Acid	(*Z*)-octadec-9-enoic acid	$C_{18}H_{34}O_2$	282.46	0.1654	78	2220.21
18	31.9748	Oleic Acid	(*Z*)-octadec-9-enoic acid	$C_{18}H_{34}O_2$	282.46	1.1599	45	2234.58
19	33.4848	Ergosterol	(3*S*,9*S*,10*R*,13*R*,14*R*,17*R*)-17-[(*E*,2*R*,5*R*)-5,6-dimethylhept-3-en-2-yl]-10,13-dimethyl-2,3,4,9,11,12,14,15,16,17-decahydro-1*H*-cyclopenta[a]phenanthren-3-ol	$C_{28}H_{44}O$	396.65	28.0206	95	2270.03
20	33.9089	Oleic Acid	(*Z*)-octadec-9-enoic acid	$C_{18}H_{34}O_2$	282.46	0.9996	94	2279.98
21	33.9988	Oleyl alcohol, trifluoroacetate	[(*Z*)-octadec-9-enyl]2,2,2-trifluoroacetate	$C_{20}H_{35}F_3O_2$	364.48	4.7967	90	2282.09
22	34.4387	Cyclopropaneoctanal, 2-octyl-	8-(2-octylcyclopropyl)octanal	$C_{19}H_{36}O$	280.5	8.3611	76	2292.42
23	34.6835	Oleic Acid	(*Z*)-octadec-9-enoic acid	$C_{18}H_{34}O_2$	282.46	2.4188	95	2298.17
24	34.7783	Oleic Acid	(*Z*)-octadec-9-enoic acid	$C_{18}H_{34}O_2$	282.46	2.8266	96	2300.40
25	34.9329	Oleic Acid	(*Z*)-octadec-9-enoic acid	$C_{18}H_{34}O_2$	282.46	2.5296	81	2304.11
26	35.1302	Oleic Acid	(*Z*)-octadec-9-enoic acid	$C_{18}H_{34}O_2$	282.46	3.872	93	2308.84
27	35.2019	Cyclohexane, 1-(1,5-dimethylhexyl)-4-(4-methylpentyl)-	1-(1,5-dimethylhexyl)-4-(4-methylpentyl)cyclohexane	$C_{20}H_{40}$	280.53	1.9664	86	2310.56
28	35.2729	9-Octadecenal, (*Z*)-	(*E*)-octadec-9-enal	$C_{18}H_{34}O$	266.46	1.0884	89	2312.26
29	35.4571	Oleic Acid	(*Z*)-octadec-9-enoic acid	$C_{18}H_{34}O_2$	282.46	4.2692	91	2316.68
30	35.7839	Palmitoleic acid	(*Z*)-hexadec-9-enoic acid	$C_{16}H_{30}O_2$	254.41	9.649	90	2324.52
31	35.9504	Oleic Acid	(*Z*)-octadec-9-enoic acid	$C_{18}H_{34}O_2$	282.46	2.2831	92	2328.51
32	36.1221	Farnesol isomer a	(2*E*,6*E*)-3,7,11-trimethyldodeca-2,6,10-trien-1-ol	$C_{15}H_{26}O$	222.37	13.0656	70	2332.63
33	38.342	Heptadecanolide	heptadecane-7,9-dione	$C_{17}H_{32}O_2$	268.43	0.2006	94	2385.87

Table 5: Phytochemicals identified in the methanolic extracts of *Pleurotus djamor* by GC-MS.

PK	RT (Mins)	Compound	IUPAC Name	Molecular formula	Molecular weight (g/mol)	Peak Area (%)	% SMF[1]	RI[2]
1	6.8073	2,3-Bis(ethylthio)hexane	2,3-bis(ethylsulfanyl)hexane	$C_{10}H_{22}S_2$	206.41	0.34	38	770.99
2	23.0451	*n*-Hexadecanoic acid	hexadecanoic acid	$C_{16}H_{32}O_2$	256.4	12.03	99	1963.49
3	24.6191	Hexadecanoic acid, propyl ester	2,3-diacetyloxypropyl hexadecanoate	$C_{19}H_{38}O_2$	298.51	1.04	96	2036.75
4	26.2621	Linoelaidic acid	(9*E*,12*E*)-octadeca-9,12-dienoic acid	$C_{18}H_{32}O_2$	280.45	37.83	99	2112.04
5	26.6819	9,12-Octadecadienoic acid (*Z*,*Z*)-	octadeca-9,12-dienoic acid	$C_{18}H_{32}O_2$	280.45	8.49	97	2120.75
6	27.4733	9,12-Octadecadienoic acid (*Z*,*Z*)-	octadeca-9,12-dienoic acid	$C_{18}H_{32}O_2$	280.45	2.23	98	2137.17
7	27.6141	9,12-Octadecadien-1-ol, (*Z*,*Z*)-	(9*Z*,12*Z*)-octadeca-9,12-dien-1-ol	$C_{18}H_{34}O$	266.46	1.77	92	2140.09
8	28.1759	Oleic Acid	(*Z*)-octadec-9-enoic acid	$C_{18}H_{34}O_2$	282.46	0.43	92	2151.75
9	30.1401	9,12-Octadecadienoic acid (*Z*,*Z*)-	octadeca-9,12-dienoic acid	$C_{18}H_{32}O_2$	280.45	13.33	98	2192.49
10	30.4215	9,12-Octadecadienoic acid (*Z*,*Z*)-	octadeca-9,12-dienoic acid	$C_{18}H_{32}O_2$	280.45	3.25	97	2198.33
11	30.9242	9,12-Octadecadienoic acid (*Z*,*Z*)-	octadeca-9,12-dienoic acid	$C_{18}H_{32}O_2$	280.45	9.26	96	2209.91

0.05. *G. lucidum* recorded the highest amount of magnesium, and its magnesium content in comparison with all other minerals analysed was also the highest, thus making it a better option for patients with magnesium deficiencies. These values are higher than those reported in one research work [89]. *C. indica*, however, had the highest amount of potassium. Given that magnesium is an element with multiple cellular functions, its deficiency could lead to the pathogenesis of migraine headaches. This thus implies that Mg could be used in the treatment and prevention of migraine headaches [90]. As identified by Musso [91], too much Mg and K from food does not pose a health risk in healthy individuals because the kidney eliminates excess amounts in urine. Thus, these amounts in the mushrooms are in no way a threat to human health.

Calcium, like Mg and K, plays a significant role in bone health and facilitates the formation of strong teeth. The calcium content of the samples ranged between 124.76 mg/kg and 493.06 mg/kg (Figure 5). *G. lucidum* also recorded a higher amount of Ca. Sodium is another essential macronutrient that aids the normal function of cells, nerve impulse transmission,

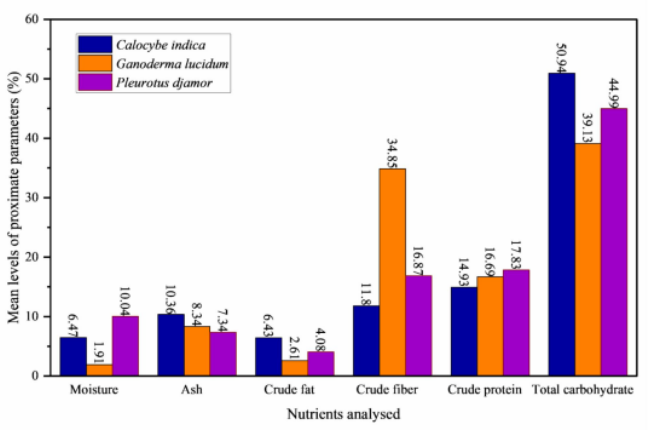

Figure 4: Proximate composition of *Calocybe indica*, *Ganoderma lucidum*, and *Pleurotus djamor*.

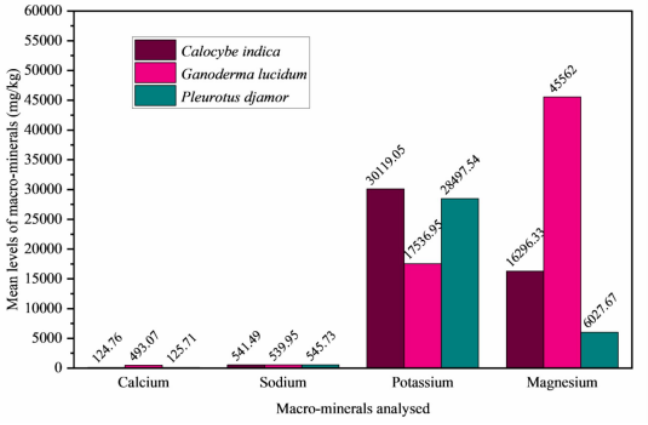

Figure 5: Macro-mineral composition of *Calocybe indica*, *Ganoderma lucidum*, and *Pleurotus djamor*.

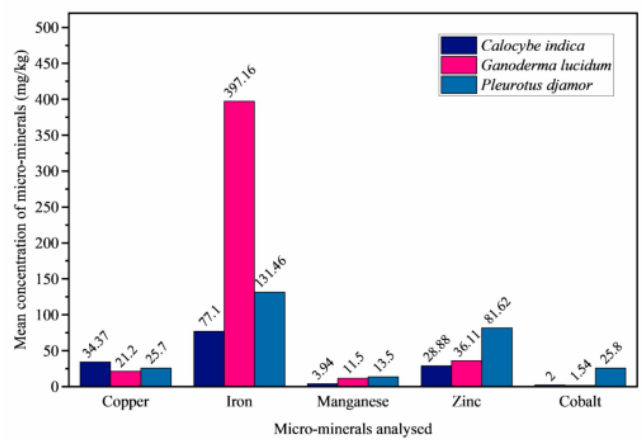

Figure 6: Micro-mineral composition of *Calocybe indica*, *Ganoderma lucidum*, and *Pleurotus djamor*.

and maintenance of plasma volume. Similar but slightly different sodium content (539.95 mg/kg for *G. lucidum*, 541.49 mg/kg for *C. Indica*, and 545.73 mg/kg for *P. djamor*) was recorded in this study. WHO recommends a daily sodium intake of less than 2000mg/day as higher doses result in debilitating health issues such as high blood pressure, kidney disease, and even death. Based on this premise, consuming these mushrooms daily leads to better health [92]. Anemia is a medical condition associated with iron deficiency. Our investigation revealed high levels of iron with mean values of 397.16 mg/kg for *G. lucidum*, 131.46 mg/kg for *P. djamor*, and 77.10 mg/kg for *C. indica*. The high amount of Fe contained in *G. lucidum* gives it an edge over the others in the management of diets for patients suffering anemia of chronic diseases like rheumatoid arthritis, inflammatory bowel disease, and some forms of cancer [93]. *P. djamor* had more than double the mean levels of Zinc in *G. lucidum* (36.11 mg/kg) and *C. indica* (28.88 mg/kg). It recorded a Zn mean level of 81.62 mg/kg. The zinc content recorded for *G. lucidum* in this study is higher than that reported by some authors for the same species [91]. Zn is very advantageous to all, but more importantly, for those with digestive disorders, sickle cell disease, and pregnant and breastfeeding mothers. Copper is necessary for brain development and proper functioning of the immune system, amongst other physiological processes [94]. Cu content of the studied mushrooms, as shown in Figure 6, ranged from 21.20 mg/kg to 34.37 mg/kg, with *C. indica* having the highest value. These values corresponded to those documented by Obodai et al. [89]. Manganese is another trace mineral that contributes to a better immune system and energy production in the human body. *P. djamor* and *G. lucidum* recorded values (13.50 mg/kg; 11.50 mg/kg) much higher than those for *C. indica*. Lead was not detected in the samples. Cobalt concentration in the studied mushrooms ranged from 1.54 mg/kg to 25.80mg/kg. *P. djamor* had a very high amount of cobalt, about 13 times higher when compared with the other two species. Cobalt, though not classified as an essential nutrient, is involved in the Krebs-cycle for the breakdown of sugars into energy in the body, the metabolism of fats and carbohydrates, as well as the synthesis of proteins and the conversion of folate in its active form [95].

4. Conclusion

From our diversified comparative examination of *Calocybe indica* (P&C), *Ganoderma lucidum* (Fr.) P. Karst and *Pleurotus djamor* (Rumph. Ex Fr.), we found that all the mushrooms were rich in bioactive compounds, essential minerals (macro and trace), and essential body-building nutrients like protein, carbohydrates, and fiber in significantly different amounts. Comparing the amount of vital nutrients in the studied mushrooms, *G. lucidum* has a better prospect of improving and maintaining the good well-being of humans based on our results. This species is often neglected because of its woody texture and non-sweet taste, thus undermining its rich nutritional content and wealth of bioactive compounds with disease-preventive and curative properties. We therefore recommended that this mushroom be ground into powder and added to foods like soups, pastries, and so on by the locals, and also be incorporated into food formulations by food processors. The presence of these bioactive compounds, essential minerals, and nutrients in the

edible mushrooms studied highlights the importance of incorporating them into the daily human diet. It will help to promote better health and reduce health risks such as those related to cancer and diabetes. As applicable to other foods, it is pertinent to look out for symptoms of allergies or intolerances while consuming mushrooms, as there may be chances of high levels of toxins in the mushroom fruiting body, depending on the composition of its growth substrate. We would also suggest that, concerning the phytochemicals present in the mushrooms studied, further research be carried out to isolate each of these vital bioactive compounds and perform in vitro and in vivo studies using each of the prominent identified compounds to ascertain their efficacy, dosage, and dietary limit for use in drug and food formulations.

Data availability

Data used in this study will be made available on request from the corresponding author.

Acknowledgment

The authors are grateful to the Department of Chemistry, Federal University Lokoja, for providing the laboratory facilities for this research. We also thank the National Open University of Nigeria in collaboration with TETFUND for their financial support.

References

[1] N. Sifat, F. Lovely, S. M. N. K. Zihad, Md. G. Hossain, J. A. Shilpi, I. D. Grice, M. S. Mubarak & S. J. Uddin, "Investigation of the nutritional value and antioxidant activities of common Bangladeshi edible mushrooms", Clinical Phytoscience **6** (2020) 88. https://doi.org/10.1186/s40816-020-00235-3.

[2] J. Raman, H. Laskshmanan, K.-Y. Jang, M. Oh, Y.-L. Oh & J.-H. Im, "Nutritional composition and antioxidant activity of pink oyster mushrooms (Pleurotus djamor var. roseus) grown on a paddy straw substrate", Journal of Mushrooms **18** (2020) 189. https://doi.org/10.14480/JM.2020.18.3.189.

[3] R. Singh, N. Kaur, R. Shri, A. P. Singh & G. S. Dhingra, "Proximate composition and element contents of selected species of Ganoderma with reference to dietary intakes", Environmental Monitoring and Assessment **192** (2020) 270. https://doi.org/10.1007/s10661-020-08249-7.

[4] Q. Yu, M. Guo, B. Zhang, H. Wu, Y. Zhang & L. Zhang, "Analysis of nutritional composition in 23 kinds of edible fungi", Journal of Food Quality **2020** (2020) 8821315. https://doi.org/10.1155/2020/8821315.

[5] A. N. Teke, M. E. Bi, L. M. Ndam & T. R. Kinge, "Nutrient and mineral components of wild edible mushrooms from the Kilum-Ijim forest, Cameroon", African Journal of Food Science **15** (2021) 152. https://doi.org/10.5897/AJFS2021.2089.

[6] I. C. Nnorom, S. O. Eze & P. O. Ukaogo, "Mineral contents of three wild-grown edible mushrooms collected from forests of South eastern Nigeria: an evaluation of bioaccumulation potentials and dietary intake risks", Scientific Africana **8** (2020) e00163. https://doi.org/10.1016/j.sciaf.2019.e00163.

[7] G. Jaworska, K. Pogon, A. Skrzypczak & E. Bernas, "Composition and antioxidant properties of wild mushrooms Boletus edulis and Xerocomus badius prepared for consumption", Journal of Food Science and Technology **52** (2015) 7944. https://doi.org/10.1007/s13197-015-1933-x.

[8] F. Watanabe, Y. Yabuta, T. Bito & F. Teng, "Vitamin B_{12}-containing plant food sources for vegetarians", Nutrients **6** (2014) 1861. https://doi.org/10.3390/nu6051861.

[9] C. Radulescu, L. C. Buruleanu, A. A. Georgescu & I. D. Dulama, "Correlation between enzymatic and non-enzymatic antioxidants in several edible mushrooms species", in *Food Engineering*, IntechOpen: London, UK, 2019, pp. 1–38. https://doi.org/10.5772/intechopen.82578.

[10] USFDA, 2021. https://www.accessdata.fda.gov/scripts/InteractiveNutritionFactsLabel/assets/InteractiveNFL_Vitamins&MineralsChart_October2021.pdf. Retrieved 16th November, 2024.

[11] A. Kumar, P. Birmal, M. Kumar, A. Jose, V. Tomer, E. Oz, C. Proestos, M. Zeng, T. Elobeid, K. Sneha & F. Oz, "Major phytochemicals: recent advances in health benefits and extraction method", Molecules **28** (2023) 1. https://doi.org/10.3390/molecules28020887.

[12] Y. Yusran, E. Erniwati, A. Khumaidi, R. Pitopang & I. R. A. P. Jati, "Diversity of substrate type, ethnomycology, mineral composition, proximate, and phytochemical compounds of the Schizophyllum commune Fr. in the area along Palu-Koro Fault, Central Sulawesi, Indonesia", Saudi Journal of Biological Sciences **30** (2023) 103593. https://doi.org/10.1016/j.sjbs.2023.103593.

[13] S. Wu, S. Zhang, B. Peng, D. Tan, M. Wu, J. Wei, Y. Wang & H. Luo, "Ganoderma lucidum: a comprehensive review of phytochemistry, efficacy, safety and clinical study", Food Science and Human Wellness **13** (2024) 568. https://doi.org/10.26599/FSHW.2022.9250051.

[14] M. Kozarski, A. Klaus, D. Jakovljevic, N. Todorovic, K. J. Vundu, P. Petrovic, M. Niksic, M. M. Vrvic & L. van Griensven, "Antioxidants of edible mushrooms", Molecules **20** (2015) 19489. https://doi.org/10.3390/molecules201019489.

[15] B. O. Ekute, "Screening and quantitative determination of phytochemical constituents of Pleurotus ostreatus and Pleurotus pulmonarius commonly grown in South-western Nigeria", Sokoto Journal of Medical Laboratory Science **4** (2019) 132. https://sokjmls.com.ng/index.php/SJMLS/article/view/205.

[16] Z. M. Thu, K. K. Myo, H. T. Aung, M. Clericuzio, C. Armijos & G. Vidari, "Bioactive phytochemical constituents of wild edible mushrooms from Southeast Asia", Molecules **25** (2020) 1972. https://doi.org/10.3390/molecules25081972.

[17] R. Zhao, Q. Chen & Y. M. He, "The effect of Ganoderma lucidum extract on immunological function and identify its anti-tumor immunostimulatory activity based on the biological network", Scientific Reports **8** (2018) 12680. https://doi.org/10.1038/s41598-018-30881-0.

[18] Y. Fu, L. Shi & K. Ding, "Structure elucidation and anti-tumor activity in vivo of a polysaccharide from spores of Ganoderma lucidum (Fr.) Karst", International Journal of Biological Macromolecules **141** (2019) 693. https://doi.org/10.1016/j.ijbiomac.2019.09.046.

[19] D. O. Adekunle, E. O. Faboro & L. Lajide, "Identification and quantification of bioactive compounds in different extracts of Morinda lucida Benth (Rubiaceae) root using GC-MS analysis", Journal of Nigerian Society of Physical Sciences **5** (2023) 1. https://doi.org/10.46481/jnsps.2023.5.1534.

[20] Y. A. Qaisi, I. Alfarrayeh, A. Al sarayreh, K. Khleifat & N. Abu-Nwas, "Assessment of antioxidant potential, cytotoxicity, and anticancer activity of methanolic extracts from selected wild medicinal plants", Phytomedicine Plus **4** (2024) 100534. https://doi.org/10.1016/j.phyplu.2024.100534.

[21] M. A. Qutaibi & S. R. Kagne, "Exploring the phytochemical compositions, antioxidant activity, and nutritional potentials of edible and medicinal mushrooms", International Journal of Microbiology **2024** (2024) 6660423. https://doi.org/10.1155/2024/6660423.

[22] J. O. Oni, F. A. Akomaye, A. A. Markson & A. C. Egwu, "GC-MS analysis of bioactive compounds in some wild-edible mushrooms from Calabar, Southern Nigeria", European Journal of Biology and Biotechnology **1** (2020) 1. https://doi.org/10.24018/ejbio.2020.1.6.129.

[23] M. Dimopoulou, A. Kolonas, S. Mourtakos, O. Androutsos & O. Gortzi, "Nutritional composition and biological properties of sixteen edible mushroom species", Applied Sciences **12** (2022) 8074. https://doi.org/10.3390/app12168074.

[24] A. Bhardwaj & M. Kshipra, "Ganoderma spp: the royal mushroom for high-altitude ailments", in *Management of high-altitude pathophysiology*, M. Kshipra, P. Sharma, A. Bhardwaj (Eds.), Academic Press, 2018, pp. 115–152. https://doi.org/10.1016/B978-0-12-813999-8.00007-0.

[25] R. N. Okigbo & S. I. Obanubi, "A study on the Ganoderma lucidum of Warri South Local Government Area", Journal of Food Technology and Nutrition Science **2** (2020) 1. https://doi.org/10.47363/jftns/2020(2)103.

[26] M. Shashikant, A. Bains, P. Chawla, M. Fogarasi & S. Fogarasi, "The current status, bioactivity, food, and pharmaceutical approaches of Calocybe indica: a review", Antioxidants **11** (2022) 1. https://doi.org/10.3390/antiox11061145.

[27] G. Chowdhury, R. Sharma & U. Sarkar, "Cultural studies and yield attributes of pink oyster mushroom (Pleurotus djamor) in West Bengal", BioResources **19** (2024) 1696. https://doi.org/10.15376/biores.19.1.1696-1706.

[28] R. Sasidhara & T. Thirunalasundari, "Phytochemicals and antioxidant potentials of Pleurotus djamor", Journal of Chemical and Pharmaceutical Research **6** (2014) 950. https://www.jocpr.com/abstract/phytochemicals-and-antioxidant-potentials-of-pleurotus-djamor-3295.html.

[29] M. E. Khan, C. E. Elum, A. O. Ijeomah, P. J. Ameji, I. G. Osigbemhe, E. E. Etim, J. V. Anyam, A. Abel & C. T. Agber, "Isolation, characterization, antimicrobial and theoretical investigation of some bioactive compounds obtained from the bulbs of Calotropis procera", Journal of Nigerian Society of Physical Sciences **5** (2023) 1. https://doi.org/10.46481/jnsps.2023.1576.

[30] B. C. Anyanwu, O. U. Akoh & I. E. Otuokere, "Phytochemical screening and proximate analysis of the leaves of Launaea (Lactuca) taraxacifolia", Journal of Chemical Society of Nigeria **47** (2022) 421. https://doi.org/10.46602/jcsn.v47i2.737.

[31] D. R. Pant, N. D. Pant, D. B. Saru, U. N. Yadav & D. P. Khanal, "Phytochemical screening and study of antioxidant, antimicrobial, antidiabetic, anti-inflammatory and analgesic activities of extracts from stem wood of Pterocarpus marsupium Roxburgh", Journal of Intercultural Ethnopharmacology **6** (2017) 170. https://doi.org/10.5455/jice.20170403094055.

[32] J. B. Harborne, *Phytochemical methods*, Chapman & Hall Ltd., London, England, 1973, pp. 49–188.

[33] O. O. Orole, "GC-MS evaluation, phytochemical and antinutritional screening of Ganoderma lucidum", Journal of Advances in Biology and Biotechnology **5** (2016) 1. https://doi.org/10.9734/JABB/2016/24261.

[34] C. V. Ratnavathi & V. V. Komala, "Sorghum grain quality", in *Sorghum biochemistry: an industrial perspective*, C. V. Ratnavathi, J. V. Patil, U. D. Chavan (Eds.), Academic Press, 2016, pp. 1–61. https://doi.org/10.1016/B978-0-12-803157-5.00001-0.

[35] J. Mendham, R. C. Denney, J. D. Barnes & M. J. K. Thomas, *Vogel's textbook of quantitative chemical analysis*, 6th ed., Pearson Education Ltd., 2008. https://chem.hbcse.tifr.res.in/wp-content/uploads/2019/10/vogels-textbook-of-quantitative-chemical-analysis-5th-edition.pdf.

[36] O. I. Cyriacus, C. M. Ezeji, M. C. Nwoko & C. G. Ezeh, "Productivity, proximate, and phytochemicals contents of Pleurotus ostreatus (Jacq. Ex. Fr) p. Kumm. fruit bodies produced on carbonized sawdust substrate", Australian Journal of Science and Technology **5** (2021) 562. https://www.aujst.com/vol-5-2/AJST-5-2_HTML/AJST-5-562.html.

[37] C. S. Ezeonu & C. M. Ejikeme, "Qualitative and quantitative determination of phytochemical contents of indigenous Nigerian softwoods", New Journal of Science **2016** (2016) 5601327. https://doi.org/10.1155/2016/5601327.

[38] A. S. Patil, *Plant secondary metabolites: isolation, characterization & biological properties*, Studera Press, 2020, pp. 75–87. https://books.google.com.ng/books?id=VpTmDwAAQBAJ&pg=PA75&source=gbs_toc_r&cad=1#v=onepage&q&f=false.

[39] D.-C. B. Filho, J. Odimar, M. B. Filho, J. Pedro, D. S. Rafaela & P. R. Karina, "Extraction and quantification of oxalic acid in leaves of plant species used in the treatment of chronic non-communicable diseases", Revista Colombiana de Ciencias Quimico-Farmaceuticas **51** (2022) 7. https://doi.org/10.15446/rcciquifa.v51n1.10260.

[40] J. C. Ifemeje, C. Egbuna, J. O. Eziokwudiaso & F. C. Ezebuo, "Determination of the anti-nutrient composition of Ocimum gratissimum, Corchorus olitorius, Murraya koenigii Spreng and Cucurbita maxima", International Journal of Innovation and Scientific Research **3** (2014) 127. https://ijisr.issr-journals.org/abstract.php?article=IJISR-14-101-01.

[41] O. E. Udu-Ibiam, O. Ogbu, U. A. Ibiam, A. U. Nnachi, M. V. Agah, C. O. Ukaegbu, O. S. Chukwu, N. B. Agumah & K. I. Ogbu, "Phytochemical and antioxidant analyses of selected edible mushrooms, ginger, and garlic from Ebonyi State, Nigeria", IOSR Journal of Pharmacy and Biological Sciences **9** (2014) 91. https://doi.org/10.9790/3008-09348691.

[42] NIST Chemistry WebBook, NIST Standard Reference Database Number 69, National Institute of Standards and Technology, Gaithersburg MD, USA. [Online]. https://webbook.nist.gov/chemistry/.

[43] IUPAC, Retention index, I, in column chromatography, IUPAC Compendium of Chemical Terminology (the "Gold Book"), 2nd ed., 1997. https://doi.org/10.1351/goldbook.R05360.

[44] E. Yemm & A. J. Willis, "The estimation of carbohydrates in plants by anthrone", Biochemical Journal **57** (1954) 508. https://doi.org/10.1042/bj0570508.

[45] AOAC Official Method 2003.05, Crude fat in feeds, cereal grains, and forages, in *Official methods of analysis of AOAC international*, 18th ed., AOAC Int. Arlington, VA, 2005, pp. 40–42.

[46] AOAC Official Method 978.10, Fiber (crude) in animal feed and pet food, in *Official methods of analysis of AOAC international*, 18th ed., AOAC Int. Gaithersburg, MD, 2005, pp. 46–47.

[47] AOAC Official Method 2001.11, Determination of protein (crude) in animal feed, forage (plant tissue), grain, and oilseeds. Block digestion with a copper catalyst and steam distillation into boric acid: collaborative study. https://img.21food.cn/img/biaozhun/20100108/177/11285182.pdf.

[48] N. Thiex, "Evaluation of analytical methods for the determination of moisture, crude protein, crude fat, and crude fiber in distillers dried grains with solubles", Journal of Association of Official Analytical Chemists International **92** (2009) 61. https://doi.org/10.1093/jaoac/92.1.61.

[49] AOAC Official Method 942.05, Ash of animal feed, in *Official methods of analysis of AOAC international*, 18th ed., AOAC Int. Gaithersburg, MD, 2005, p. 8. https://www.researchgate.net/publication/292783651_AOAC_2005.

[50] N. Thiex, L. Novotny & A. Crawford, "Determination of ash in animal feed: AOAC official method 942.05 revisited", Journal of Association of Official Analytical Chemists International **95** (2012) 1392. https://doi.org/10.5740/jaoacint.12-129.

[51] Md. H. Rashid, Z. Fardous, M. A. Z. Chowdhury, Md. K. Alam, Md. L. Bari, M. Moniruzzaman & S. H. Gan, "Determination of heavy metals in the soils of tea plantations and in fresh and processed tea leaves: an evaluation of six digestion methods", Chemistry Central Journal **10** (2016) 7. https://doi.org/10.1186/s13065-016-0154-3.

[52] M. A. Gharib, H. A. Radwan & Y. A. Elhassaneen, "Nutrients and nutraceuticals content and in vitro biological activities of Reishi mushroom (Ganoderma lucidum) fruiting bodies", Alexandria Science Exchange Journal **43** (2022) 301. https://doi.org/10.21608/ASEJAIQJSAE.2022.24571.

[53] O. Taofiq, S. A. Heleno, R. C. Calhelha, M. J. Alves, L. Barros, A. M. Gonzalez-Paramas, M. F. Barreiro & I. C. F. R. Ferreira, "The potential of Ganoderma lucidum extracts as bioactive ingredients in topical formulations, beyond its nutritional benefits", Food Chemistry and Toxicology **108** (2017) 139. https://doi.org/10.1016/j.fct.2017.07.051.

[54] M. B. Isah, N. Tajudeen, M. I. Umar, Z. A. Alhafiz, A. Mohammed & M. A. Ibrahim, "Terpenoids as emerging therapeutic agents: cellular targets and mechanisms of action against protozoan parasites", in *Studies in natural products chemistry*, Vol. 59, 2018, pp. 227–. https://doi.org/10.1016/B978-0-444-64179-3.00007-4.

[55] M. Fan, S. Yuan, L. Li, J. Zheng, D. Zhao, C. Wang, H. Wang, X. Liu & J. Liu, "Application of terpenoid compounds in food and pharmaceutical products", Fermentation **9** (2023) 119. https://doi.org/10.3390/fermentation9020119.

[56] Y. Matsumura, M. Kitabatake, S. Kayano & T. Ito, "Dietary phenolic compounds: their health benefits and association with the gut microbiota", Antioxidants **12** (2023) 1. https://doi.org/10.3390/antiox12040880.

[57] P. Naknaen, T. Itthisoponkul & P. Charoenthaikij, "Proximate compositions, nonvolatile taste components and antioxidant capacities of some dried edible mushrooms collected from Thailand", Food Measure **9** (2014) 259. https://doi.org/10.1007/s1.1694-015-9231-x.

[58] H. Nayak, A. Kushwaha, P. C. Behera, N. C. Shahi, K. P. S. Kushwaha, A. Kumar & K. K. Mishra, "The pink oyster mushroom, Pleurotus djamor (Agaricomycetes): a potent antioxidant and hypoglycemic agent", International Journal of Medicinal Mushrooms **23** (2021) 29. https://doi.org/10.1615/IntJMedMushrooms.2021041411.

[59] G. Sudha, A. Janardhanan, A. Moorthy, M. Chinnasamy, S. Gunasekaran, A. Thimmaraju & J. Gopalan, "Comparative study on the antioxidant activity of methanolic and aqueous extracts from the fruiting bodies of an edible mushroom Pleurotus djamor", Food Science and Biotechnology **25** (2016) 371. https://doi.org/10.1007/S10068-016-0052-4.

[60] C. A. Ihayere & J. A. Okhuoya, "Phytochemical analysis of cultivated medicinal mushroom- Ganoderma Sp.", Nigerian Journal of Biotechnology **35** (2022) 11. https://doi.org/10.4314/njbot.v35i1.2.

[61] B. O. Ekute & L. M. Nwokocha, "Nutritive value of the sclerotia of Pleurotus tuberregium: a mushroom", Science World Journal **16** (2021) 256. https://www.ajol.info/index.php/swj/article/view/221739.

[62] O. C. Ogidi & V. O. Oyetayo, "Phytochemical property and assessment of antidermatophytic activity of some selected wild macrofungi against pathogenic dermatophytes", Mycology **7** (2016) 9. https://doi.org/10.1080/21501203.2016.1145608.

[63] O. I. Ogidi, L. M. O. Oguoma, P. C. Adigwe & B. B. Anthony, "Phytochemical properties and in-vitro antimicrobial potency of wild edible mushrooms (Pleurotus ostreatus) obtained from Yenegoa, Nigeria", Journal of Phytopharmacology **10** (2021) 180. https://doi.org/10.31254/phyto.2021.10306.

[64] G. Albahri, A. Badran, A. Hijazi, A. Daou, E. Baydoun, M. Nasser & O. Merah, "The therapeutic wound healing bioactivities of various medicinal plants", Life (Basel) **13** (2023) 1. https://doi.org/10.3390/life13020317.

[65] S. M. G. Pires, R. S. Reis, S. M. Cardoso, R. Pezzani, E. Paredes-Osses, A. Seilkhan, A. Ydyrys, M. Martorell, E. S. Gurer, W. N. Setzer, A. F. A. Razis, B. Modu, D. Calira & J. Sharifi-Rad, "Phytates as a natural source for health promotion: a critical evaluation of clinical trials", Frontiers in Chemistry **11** (2023) 1174109. https://doi.org/10.3389/fchem.2023.1174109.

[66] M. Lopez-Moreno, M. Garces-Pimon & M. Miguel, "Antinutrients: lectins, goitrogens, phytates and oxalates, friends or foe?", Journal of Functional Foods **89** (2022) 104938. https://doi.org/10.1016/j.ff.2022.104938.

[67] KRCN, "Should I be avoiding oxalates?", Retrieved from https://www.chhs.colostate.edu/krcn. Accessed February 8, 2024.

[68] M. Bello, M. O. Oluwamukomi & V. N. Enujiugha, "Influence of drying on the antinutritional contents and antioxidant capacities of oyster mushrooms (Pleurotus sajur-caju)", Journal of Applied Tropical Agriculture **24** (2019) 49. https://journals.futa.edu.ng/home/paperd/1002/62111.

[69] N. Morsy, "Cardiac glycosides in medicinal plants", InTech, 2017. https://doi.org/10.5772/65963.

[70] P. Dash, B. Kar, M. Ghocchi, G. Ghosh, V. K. Rai, C. Das, D. Pradhan, T. K. Rajwar, J. Halder, D. Dubey, S. Manoharadas & G. Rath, "Antimicrobial properties of the edible pink oyster mushroom, Pleurotus eaus : in-vivo and in-vitro studies", Microbial pathogenesis **196** (2024) 106915. https://doi.org/10.1016/micpath.2024.106915.

[71] C. Liu, S. Zhao, C. Zhu, Q. Gao, J. Bai, J. Si & Y. Chen, "Ergosterol ameliorates renal inflammatory responses in mice model of diabetic nephropathy", Biomedicine & Pharmacotherapy **128** (2020) 110252. https://doi.org/10.1016/j.biopha.2020.110252.

[72] M. Shashikant, A. Bains, P. Chaula, M. Sharma, R. Kaushik, S. Kandi & R. C. Kuhad, "In-vitro antimicrobial and anti-inflammatory activity of modified solvent evaporated ethanolic extract of Calocybe indica: GCMS and HPLC characterization", International Journal of Food Microbiology **376** (2022) 109741. https://doi.org/10.1016/j.ijfoofmicro.2022.109741.

[73] M. Zangeneh, M. M. Derakhshankhan, B. Haghshenas, Z. Foroozanfar & Z. Izadi, "In-vitro evaluation of antioxidant, probiotic, and antiproliferative activity of Ganoderma lucidum-extracted polysaccharides for the prevention of complication associated with gastrointestinal inflammatory diseases", Heliyon **11** (2025) e42936. https://doi.org/10.1016/j.heliyon.2025.e42936.

[74] J. O. Odiase-Omoighe & B. O. Agoreyo, "Identification of bioactive compounds in sclerotia extracts from Pleurotus tuber-regium (Fr.) Sing. using gas chromatograph-mass spectrometer (GC-MS)", Nigerian Journal of Biotechnology **1** (2022) 39. https://doi.org/10.4314/njb.v38i.4s.

[75] A. Pauldasan, I. T. Arockiyaehil & V. G. Anand, "Phytochemical screening and GC-MS studies of Cyperus compressus Rottb", Journal of Medicinal Plants Studies **8** (2020) 90. https://www.plantsjournal.com/archives/?year=2020&vol=8&issue=6&part=B&ArticleId=1231.

[76] H. I. Hameed, J. A. Huda & J. M. Ghaidaa, "Evaluation of antifungal and antibacterial activity and analysis of bioactive phytochemical compounds of Cinnamomum Zeylanicum (Cinnamon bark) using gas chromatography-mass spectrometry", Oriental Journal of Chemistry **32** (2016) 1769. http://dx.doi.org/10.13005/ojc/320406.

[77] A. Vanitha, V. Chinnadurai & K. Kalimuthu, "A comparative study of phytochemical constituents of Benkara malabarica (Lam.) leaf and leaf callus extracts", International Journal of Pharma Research and Health Sciences **6** (2018) 2401. https://doi.org/10.21276/ijprhs.2018.2018.02.11.

[78] A. Dutta, T. Panchali, A. Khatun, S. R. Jarapala, K. Das, K. Ghosh, S. Chakrabarti & S. Pradhan, "Anti-cancer potentiality of linoelaidic acid isolated from marine Tapra fish oil (Ophisthopterus tardoore) via ROS generation and caspase activation on MCF-7 cell line", Scientific Reports **13** (2023) 14125. https://doi.org/10.1038/s41598-023-34885-3.

[79] N. L. Weir, L. Johnson, W. Guan, B. Steffen, L. DJousse, K. J. Mukamal & M. Y. Tsai, "Cis-vaccenic acid is associated with lower HOMA-IR and incident T2D in participants from the MESA cohort", Diabetes **67** (2018) 1552-P Supplement_1. https://doi.org/10.2337/DB18-1552-P.

[80] P. Semwal, S. Painuli, H. Badoni & R. K. Bacheti, "Screening of phytoconstituents and antibacterial activity of leaves and bark of Quercus leucotrichopjora A. Camus from Uttarakhand Himalaya", Clinical Phytoscience **4** (2018) 1. https://doi.org/10.1186/s40816-018-0090-y.

[81] K. Krishnamoorthy & P. Subramaniam, "Phytochemical profiling of leaf, stem, and tuber parts of Solena amplexicaulis (Lam.) Gandhi using GC-MS", International Scholarly Research Notices **567409** (2014) 1. https://doi.org/10.1155/2014/567409.

[82] P. Rangsinth, R. Sharika, N. Pttarachotanant, C. Duangjan, C. Wongwan, C. Sillapachaiyaporn, S. Nilket, N. Wongsirojkul, A. Prasansuklab, T. Tencomnao, G. P.-H. Leung & S. Chuchawankul, "Potential beneficial effects and pharmacological properties of ergosterol, a common bioactive compound in edible mushrooms", Foods **12** (2023) 1. https://doi.org/10.3390/foods12132529.

[83] C.-M. Ku & J.-Y. Lin, "Farnesol, a sesquiterpene alcohol in herbal plants, exerts anti-inflammatory and antiallergic effects on ovalbumin-sensitized and -challenged asthmatic mice", Evidence Based Complementary Alternative Medicine (2015) 1. https://doi.org/10.1155/2015/387357.

[84] M. Sardana, K. S. Muhlfenzi, S. T. M. Wenker, C. Akesson, M. A. Hayes, C. S. Elmore & S. Pithani, "Exploring the enzyme-catalyzed synthesis of isotope labeled cyclopropanes", Journal of Labelled Compounds and Radiopharmacy **65** (2022) 86. https://doi.org/10.1002/jlcr.3962.

[85] S. J. Chawner, M. J. Cases-Thomas & J. A. Bull, "Divergent synthesis of cyclopropane-containing lead-like compounds, fragments and building blocks through a cobalt catalyzed cyclopropanation of phenyl vinyl sulfide", European Journal of Organic Chemistry **34** (2017) 5015. https://doi.org/10.1002/ejoc.201701030.

[86] J. E. Holesh, S. Aslam & A. Martin, "Physiology, carbohydrates", in StatPearls. StatPearls Publishing, 2023. PMID: 29083823.

[87] BNF, "Fat". (2024). https://www.nutrition.org.uk/nutritional-information/fat/. Accessed 27th October, 2024.

[88] BHF, "Protein: what you need to know". (2020). https://bhf.org.uk/informationsupport/heart-matters-magazine/nutrition/protein. Accessed 1st November, 2024.

[89] M. Obodai, D. L. N. Mensah, A. Fernandes, N. K. Kortei, M. Dzomeku, M. Teegarden, S. J. Schwartz, L. Barros, J. Prempeh, R. K. Takli & I. C. F. R. Ferreira, "Chemical characterization and antioxidant potential of wild *Ganoderma* species from Ghana", Molecules **22** (2017) 196. https://doi.org/10.3390/molecules22020196.

[90] C. Sun-Edelstein & A. Mauskop, "Role of magnesium in the pathogenesis and treatment of migraine", Expert Review of Neurotherapeutics **9** (2009) 369. https://doi.org/10.1586/14737175.9.3.369.

[91] C. G. Musso, "Magnesium metabolism in health and disease", International Urology and Nephrology **41** (2009) 357. https://doi.org/10.1007/s11255-009-9548-7.

[92] WHO, "Sodium reduction", 2024. Accessed 29th October, 2024. [Online]. https://www.who.int/news-room/fact-sheets/detail/saltreduction.

[93] NIH, "Iron fact sheet for consumers". Accessed 2nd November, 2024. [Online]. https://ods.od.nih.gov/factsheets/Iron-Consumer/.

[94] J. F. Collins, "Copper", in *Modern Nutrition in Health and Disease*, A. C. Ross, B. Caballero, R. J. Cousins, K. L. Tucker & T. R. Ziegler, Eds., 11th ed. Baltimore, MD: Lippincott Williams Wilkins, 2014, pp. 206–216.

[95] "Cobalt". Accessed 13th November, 2024. [Online]. https://www.humanitas.net/wiki/mineral-salts/cobalt/.