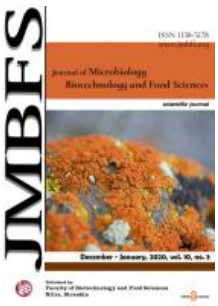

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PROXIMATE AND CHEMICAL PROPERTIES OF SOME UNDERUTILIZED NIGERIAN WILD MUSHROOMS

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ABSTRACT

This investigation aims at determining the nutritional value of twenty-three underutilized wild macrofungi from a biodiversity forest in Southwest Nigeria. The mushroom species collected across the ligneous (woody) and terrestrial (soil) habitats were analysed for proximate (moisture, protein, fibre, lipid, ash and carbohydrate), minerals (potassium, sodium, phosphorus, magnesium, calcium, iron and zinc) and vitamins A and C content following standard analytical procedures. Interestingly, all the mushrooms had high moisture (>80.91%) and those harvested from soil debris in the terrestrial habitat contained significantly high protein content (26.80 - 48.68%). Dietary fibre was in the range of 0.20 and 42.37%; low lipid (0.12 - 9.89%) and ash (1.25 - 14.08%) were also recorded. Furthermore, all the samples contained high carbohydrate except *Macrolepiota procera* (2.01%). Minerals varied across the habitats and ranged as follows: potassium (268.13 - 8972.00 mg. 100 g^{-1}), sodium (89.36 - 425.92 mg. 100 g^{-1}), phosphorus (0.32 - 375.51 mg. 100 g^{-1}), magnesium (9.39 - 19.32 mg. 100 g^{-1}) and calcium (7.98 - 37.82 mg. 100 g^{-1}). Low iron (0.55 - 1.32 mg. 100 g^{-1}) and zinc (2.21 - 4.98 mg. 100 g^{-1}) were obtained. While vitamin A ranged between 0.41 and 1.41 mg. 100 g^{-1}, vitamin C was from 4.68 to 6.93 mg. 100 g^{-1}. Conclusively, the mushrooms investigated are a good source of nutrients and thus, can be exploited as foods or food supplements.

Keywords: wild mushrooms, habitats, nutrient composition, minerals, vitamins, Nigeria

INTRODUCTION

Mushrooms are important constituents of forest produce and very significant in the human diet **(Gbolagade *et al.*, 2006; Jonathan *et al.*, 2013)**. They are spore-bearing fruitbodies of fungi growing on soil or its food substrates, with some existing in natural habitats in a mycorrhizal relationship with trees **(Onuoha and Obi-Adumanya, 2010)**, and are abundant during the rainy season in the tropics **(Adeniyi *et al.*, 2018a)**. Mushrooms were formerly grouped under the Kingdom *Plantae* that does not photosynthesize, now, classified under divisions *Basidiomycota* and *Agaricomycota* of the Fungi Kingdom **(Thatoi and Sindevsachan, 2014)**.

During the growing season of mushrooms in the wild, women, especially in rural communities, practice traditional hunting of edible varieties **(Jonathan, 2002; Ayodele *et al.*, 2011)** for diverse purposes including nutritional and medicinal **(Odebode, 2005; Okhuoya *et al.*, 2010)**, augmenting family income **(Osemwegie and Okhuoya, 2009; Okhuoya *et al.*, 2010; Ayodele *et al.*, 2011)**, amongst others. Generally, mushrooms are rich in proteins, vitamins and minerals, but low in cholesterol levels **(Belewu and Belewu, 2005; Afiukwa *et al.*, 2015)**. Factors including the growing site, substrate, and mushroom types, are crucial to their nutrient composition **(Nasiri *et al.*, 2012; Okwulehie *et al.*, 2014)**. They are considered an alternative rich source of meat, fish, vegetables, and fruits and ideal supplements for many low vitamin food materials in human diets **(Afiukwa *et al.*, 2013)**.

Globally, the nourishment potential of the over 14,000 wild mushroom taxon's has long been outshined by the well-known cultivated edible species such as *Lentinus edodes*, *Pleurotus* species, and *Agaricus bisporus* **(Wasser, 2002; Shelley and Geoffrey, 2004; Nakalembe *et al.*, 2015)**. However, in some developing countries of the world including India, Uganda and Kenya, the dietary contents of some wild species are reported with much emphasis on the varieties known to be safe for consumption **(Johnsy *et al.*, 2011; Musieba *et al.*, 2013; Kumari and Atri, 2014; Nakalembe *et al.*, 2009; 2015)**.

In spite of the proliferation of wild mushrooms in the nooks and crannies of Nigeria, there is still a paucity of information on their nutritional values. Few edible varieties in the genera *Auricularia*, *Lentinus*, *Pleurotus*, *Schizophyllum*, *Volvoriella*, *Psathyrella*, *Russula* and the highly-priced *Termitomyces* are commonly reported **(Egwim *et al.*, 2011; Afiukwa *et al.*, 2013; Ayodele and Okhuoya, 2009; Ijioma *et al.*, 2015)**. This represents only about 5 % of the previously reported wild Nigerian mushroom **(Adeniyi *et al.*, 2018a)**. In the current study, the proximate, minerals and vitamins A and C content of twenty-three underutilized wild macrofungi from a biodiversity forest in Southwest Nigeria were determined.

MATERIALS AND METHODS

Sample collection and presumptive identification

Exactly 10 specimens of 23 wild mushroom species were collected from the biodiversity forest of Environmental Pollution Science and Technology (ENPOST) farm, Ido-Ijesa, Ilesa, Southwest Nigeria located at latitude 4°42'30''E to 4°42'45''E and longitude 7°36'55''N to 7°37'10''N. After harvest, mushrooms were presumptively identified using standard keys and comparison of the surface morphologies with existing literature **(Nwordu *et al.*, 2013; Odeyemi and Adeniyi, 2015)**. Following probable identification, 3 to 9 different carpophores of each species were cleaned, dried and ground for further analysis.

Edibility test

Mushrooms with characteristic woody or tough texture and small-sized were classified as inedible. The soft fleshy ones were screened for the presence of toxin following the methods previously described **(Feeney *et al.*, 2014; Ohnuki *et al.*, 2016)**. A droplet of fresh mushroom juice was placed on a piece of old paper print, allowed to dry and HCl was dropped on it. A blue spot indicated a positive reaction for the presence of a toxin.

Proximate analysis of mushroom samples

Proximate analysis including moisture, protein, dietary fibre, lipid, ash and carbohydrate of the mushrooms were performed accordingly **(AOAC, 2016)**.

Mineral determination of mushroom samples

Atomic absorption spectrophotometric (AAS) (Buck Scientific, 210VGP, UK) was employed in the determination of Mg, Ca, Fe and Zn using oxidizing air-acetylene flame at 285.2 nm, 422.6 nm, 248.3 nm, and 213.3 nm respectively,

following the manufacturer's instruction. Determination of sodium (Na) and potassium (K) were done using flame photometry (Jenway, PFP7, UK) following the manufacturer's guide. The spectrophotometry method using Yellow Vanado molybdate was used in the determination of phosphorus in the mushroom samples **(AOAC, 2016)**.

Determination of vitamins A and C

The chemicals and reagents used included HPLC-grade. Analytical reagent-grade acetonitrile and methanol (Tedia, USA) and vitamins A and C standards (Sigma, Dorset) were used for the analysis.

Vitamin A

One gram (1 g) of pyrogallic acid, 70 ml ethanol and 30 ml (50 %) KOH were added to 10 g mushroom powder, stirred, and refluxed for 40 min using a water bath (50 ± 2 °C). Extracts were obtained three times using 50, 30 and 20 ml ether. Double-distilled water was used to neutralize the extract, anhydrous sodium sulphate added to dehydrate it and further concentrated to 5 ml using a water bath (50 ± 2 °C). Methanol was added to the concentrate to 10 ml mark, filtered using a 0.45 μm membrane, and finally subjected to HPLC analysis.
Reversed-phase (RP) HPLC analysis was performed with the Agilent 1100 series HPLC system (Agilent; USA), including a diode array detector. The column was made of stainless steel Agilent Eclipse XDB-C18 column (5 μm, 4.6 × 150 mm) and methanol and UV detection was recorded at 325 nm for vitamin A. Separation was based on isocratic elution and the solvent flow rate was maintained at 1 ml. min^{-1}. Twenty microlitre of mushroom extract was directly injected into the HPLC column. Identification was done by comparing their retention times with those of known standards. All procedures were carried out under subdued light conditions. Standard solutions of vitamin A were prepared from stock stored in the dark at –20 °C by serial dilution to concentrations of 0.1, 1, 2, 5, and 10 mg per litre of vitamin A. Twenty microlitre of the standard solution was injected, and peak areas were determined to generate standard curves.

Vitamin C

Ten grams (10 g) of mushroom powder was mixed with extracting solution prepared by dissolving 15 g of metaphosphoric acid with 40 ml acetic acid and made up to 500 ml with distilled water. The mixture was filtered through Whatman No. 1 filter paper and samples were extracted in triplicate. Ascorbic acid standard solution was prepared by weighing 100 mg ascorbic acid, dissolved and made up to 100 ml with metaphosphoric acid – acetic solution. The calibration line was converted to a line arrange based on four measured concentration levels. Quantification of ascorbic acid content was performed on an Agilent HPLC system. Chromatographic separation was achieved on an RP-HPLC column through the isocratic delivery of a mobile phase (A/B 33/67; A: 0.1M potassium acetate, pH = 4.9, B: acetonitrile: water [50:50]) at a flow rate of 1 ml. min^{-1}. UV absorbance was recorded at 254 nm at room temperature.

Data analysis

All experiments were carried out in triplicates. Data analyses were performed using SPSS IBM version 23 software. All data were expressed as mean ± standard deviation. The difference in means was evaluated using ANOVA and Duncan multiple tests employed in case of variance heterogeneity. Values with a probability level of less than 0.05 were considered significant. Nutritional distance and similarity among mushrooms were determined and dendrogram obtained using a complete linkage approach.

RESULTS AND DISCUSSION

Presumptive identification of mushroom samples

Mushrooms play significant roles in biogeochemical recycling of elements in the environment, human nutrition and dietetics, and medicines **(Odeyemi *et al.*, 2014)**. In this study, a total of 23 different mushroom samples were collected between April and October, 2018 at ENPOST farm, Ido-Ijesa, Ilesa, Southwest Nigeria, and classified into 17 genera, namely: *Amanita*, *Auricularia*, *Cantharellus*, *Ganoderma*, *Hydnellum*, *Hydnum*, *Inonotus*, *Lentinus*, *Macrolepiota*, *Marasmiellus*, *Oxyporus*, *Pleurotus*, *Polyporus*, *Stereum*, *Termitomyces*, *Trametes* and *Tricholoma*. Representative pictures of the mushrooms are shown in figure 1. All the genera had one species each except *Auricularia* (2), *Termitomyces* (4), *Trametes* (2) and *Tricholoma* (2). These mushrooms had been previously reported **(Zoberi, 1973; Alofe, 1985; Gbolagade *et al.*, 2006; Oyetayo, 2009; Okhuoya *et al.*, 2010; Adedayo, 2011; Djelloul and Samraoul, 2011; Johnsy *et al.*, 2011; Nwordu *et al.*, 2013; Adeniyi *et al.*, 2018a;b)**.
In nature, mushrooms grow on lignocellulose containing substrates **(Jonathan *et al.*, 2013; Adeniyi *et al.*, 2018a)**. While some grow on soil or wood substrates, others exist in mycorrhizal relationship with trees **(Onuoha and Obi-Adumanya, 2010)**. In the current study, eight (8) of the mushrooms were from terrestrial habitats whereas the remaining fifteen (15) were of the ligneous origin. This corroborates **Adeniyi *et al.* (2018a)** who detected higher mushroom species from the ligneous habitat than the terrestrial. This could probably be attributable to the abundance of lignocellulose substrates, which support the growth of mushrooms on the farm. All the terrestrial mushrooms grew directly on soil debris except *Pleurotus tuber-regium*, whereas the ligneous mushrooms grew on woody substrates including decaying *Cola nitida*, *Mangifera indica*, *Bambusa vulgaris* leaves, *Cordyline australis*, and *Mangifera indica*, decaying *Elaeis guineensis* and unidentified burnt tree associated with termite nest (Tab 1).

Edibility of the mushroom samples

All the mushrooms from the terrestrial habitat were fleshy, as against those from the ligneous habitat that were either fleshy, woody or tough. Presumptively, nine of the mushrooms (*Ganoderma applanatum*, *Hydnellum peckii*, *Hydnum* sp., *Inonotus radiatus*, *Marasmiellus candidus*, *Oxyporus populinus*, *Stereum hirsutum*, *Trametes ochracea*, and *Trametes pubescens*) were inedible, twelve (*Auricularia auricular-judae*, *Auricularia polytricha*, *Cantharellus cibarius*, *Lentinus subnudus*, *Macrolepiota procera*, *Pleurotus tuber-regium*, *Termitomyces striatus*, *Termitomyces bulborhizus*, *Termitomyces robustus*, *Termitomyces letestui*, *Tricholoma inocybeoides* and *Tricholoma ustale*) edible, one (*Amanita cokeri*) poisonous suspect and one (*Polyporus* sp.) with unknown edibility status (Tab 1).


a **b** **c** **d** **e** **f**


g


h


i


j

Figure 1 Representative pictures of the mushroom samples
Legend: a - *Auricularia polytricha*, b - *Amanita cokeri*, c - *Ganoderma applanatum*, d - *Inonotus radiatus*, e - *Macrolepiota procera*, f - *Marasmiellus candidus*, g - *Oxyporus populinus*, h - *Polyporus* sp., i - *Termitomyces bulborhizus*, j - *Trametes ochracea*

Table 1 Characteristics of mushrooms used in the study

S/N	Mushroom	Habitat	Substrate	Texture	Edibility	Date of collection
1	*Amanita cokeri*	Terrestrial	Soil debris	Fleshy	Poisonous / suspect	05/04/2019
2	*Auricularia auricular-judae*	Ligneous	Dead *Cola nitida* stem log	Fleshy	Edible	29/05/2019
3	*Auricularia polytricha*	Ligneous	Dead *Mangifera indica* stem log	Fleshy	Edible	21/06/2019
4	*Cantharellus* cibarius	Ligneous	Decaying *Elaeis guineensis*	Fleshy	Edible	17/04/2019
5	*Ganoderma applanatum*	Ligneous	Dead *Cola nitida* stem log	Woody	Inedible	19/05/2019
6	*Hydnellum peckii*	Ligneous	*Bambusa vulgaris* leaves	Tough	Inedible	14/05/2019
7	*Hydnum* sp.	Ligneous	*Cordyline australis* tree	Tough	Inedible	25/04/2019
8	*Inonotus radiatus*	Ligneous	Dead *Mangifera indica* stem log	Woody	Inedible	16/06/2019
9	*Lentinus subnudus*	Ligneous	Dead *Mangifera indica* stem log	Fleshy	Edible	23/04/2019
10	*Macrolepiota procera*	Terrestrial	Soil debris	Fleshy	Edible	10/05/2019
11	*Marasmiellus candidus*	Ligneous	Decaying *Elaeis guineensis*	Fleshy	Inedible	13/05/2019
12	*Oxyporus populinus*	Ligneous	Dead *Cola nitida* stem log	Woody	Inedible	19/05/2019
13	*Pleurotus tuber-regium*	Terrestrial	Sclerotium on soil debris	Fleshy	Edible	02/05/2019
14	*Polyporus* sp.	Ligneous	Dead *Cola nitida* stem log	Fleshy	Unknown	08/06/2019
15	*Stereum hirsutum*	Ligneous	Dead *Mangifera indica* stem log	Tough	Inedible	20/05/2019
16	*Termitomyces striatus*	Ligneous	Unidentified burnt tree associated with termite nest	Fleshy	Edible	12/06/2019
17	*Termitomyces bulborhizus*	Terrestrial	Termite mound	Fleshy	Edible	09/10/2019
18	*Termitomyces robustus*	Terrestrial	Termite mound	Fleshy	Edible	14/10/2019
19	*Termitomyces letestui*	Terrestrial	Termite mound	Fleshy	Edible	12/10/2019
20	*Trametes ochracea*	Ligneous	Dead *Cola nitida* stump	Woody	Inedible	25/08/2019
21	*Trametes pubescens*	Ligneous	Dead *Mangifera indica* stem log	Woody	Inedible	25/08/2019
22	*Tricholoma inocybeoides*	Terrestrial	Soil debris	Fleshy	Edible	07/05/2019
23	*Tricholoma ustale*	Terrestrial	Termite nest	Fleshy	Edible	25/08/2019

Proximate analysis of the mushroom samples

Moisture contents

Water exists virtually in all foods, and its importance in many physiological processes cannot be over-emphasized. Generally, all the mushrooms analysed in our study contained high moisture ranging from 80.91 to 98.44% (Tab 2) and agrees with **Gbolagade *et al*. (2006)** and **Johnsy *et al.* (2011)** whose report ranged from 85.4 to 98.5 % and 87.3 to 95.17% respectively. High moisture contents in mushrooms contribute to low shelf life owing to high water activity that enhances microbial growth and enzyme activity **(Gbolagade *et al*., 2006; Johnsy *et al*., 2011)**. Moisture variation may be linked to prevailing environmental growth conditions **(Mattila *et al*., 2001)**.

Proteins

Protein contents of mushrooms vary according to the genetic make-up of species and disparity in physicochemical properties of growth substrate **(Ragunathan and Swaminathan, 2003; Sanmee *et al*., 2003; Agrahar-Murugkar and Subbulakshmi, 2005)**. Overall, mushrooms harvested from soil debris (terrestrial habitat) were higher in protein than those from the ligneous habitat (Tab 2). This may be due to high organic matter in substrates constituting the habitat. Of all the higher fungi investigated, *M. procera* was the richest in protein (48.68 ± 0.13%). This disagrees with **Kumari and Atri (2014)** who reported 19.95 ± 1.06% for the same mushroom. The protein value (45.50 ± 0.06%) obtained for *A. cokeri*, a poisonous suspect mushroom was higher than the presumed edible *Termitomyces* and *Tricholoma* species suggesting it as an attractive and useful species for biotechnological manipulation as a food source. The lowest protein content was detected in *Hydnum* sp. (11.48 ± 0.06 %). Protein obtained for other edible species including *A. auricular-judae* (19.60 ± 0.06%), *A. polytricha* (12.29 ± 0.06%), *L. subnudus* (18.74 ± 0.12%) and *P. tuber-regium* (19.84 ± 0.67%) were higher than the report of **Johnsy *et al.* (2011)** but lower than the findings of **Gbolagade *et al*. (2006)**. The difference in geographical location and substrates may be responsible for this.

Dietary fibres

Current trends recommend a drive towards diets that contain a greater amount of plant foods as implicated in preserving and/or improving personal wellbeing **(Rodrı´guez *et al*., 2006; Usha and Suguna, 2014)**. Dietary fibres of the mushrooms studied varied across habitats (Tab 2). With the exception of *T. ochracea* (0.20 ± 0.01 %) and *G. applanatum* (42.37 ± 0.02%), the values recorded fell within the ranges reported elsewhere **(Breene, 1990; Chye *et al*., 2008; Egwim *et al*., 2011; Johnsy *et al*., 2011; Musieba *et al*., 2013; Kumari and Atri, 2014)**. The significantly high dietary fibre in *G. applanatum* indicates the presence of high leftovers of plant cells resistant to hydrolysis by the alimentary enzymes of man (**Capuano, 2017)**. However, the value obtained in *T. ochracea* is comparable with broccoli (0.15%), red radish (0.19%), white radish (0.16%), sweet yellow pepper (0.11%), spring onions (0.21%) and tomato (0.18%) **(Januškevičius *et al*., 2012)**. Dietary fibre benefits in preventing of heart diseases, colon cancer and diabetes **(Kassegn, 2018)**.

Lipids

Lipids provide the major caloric value in foods and excess intake can consequentially lead to coronary heart disease and other health issues **(dos**

Passos *et al.*, 2013). Mushrooms are low in lipids dominated by unsaturated fatty acids, contributing less to the energy required in human diet and serving as a means of combating obesity **(Wani *et al.*, 2010)**. Generally, the current investigation ranged between 0.12 and 9.89% (Tab 2). This tally with the observation of **Maftoun *et al*. (2015)**. Difference in mushroom species may account for the varied lipid contents observed in the study.

Ash

Ash contents indicate the presence of mineral contents in any given food sample **(Kassegn, 2018)**. Other than *T. pubescens* (0.64 ± 0.01%), *T. inocybeoides* (1.25 ± 0.01%) and *T. ustale* (1.37 ± 0.01%), ash contents obtained for others correspond with the outcomes of **Gbolagade *et al*. (2006)** and **Colak *et al*. (2009)** who had 4.7 to15.5% and 2.00 to 11.38% respectively (Tab 2). Previous study reported relatively high ash contents in *Termitomyces microcarpus* (15.13%) and *Termitomyces clypeatus* (16.87%) **(Nakalembe *et al*., 2015)**.

Carbohydrates

Carbohydrates are good sources of energy desirable for breakfast and weaning food formulae **(Kassegn, 2018)**. In mushrooms, carbohydrate content constitutes the bulk of fruiting bodies accounting for 50 to 65% on a dry weight basis **(Wani *et al.*, 2010; Di Aniba *et al.*, 2015)**. In the present investigation, carbohydrate ranged from 2.01 to 67.73% with *M. procera* and *T. pubescens* having the lowest and highest values of 2.01 ± 0.04% and 67.44 ± 0.06% respectively (Tab 2). Our findings on *M. procera* concur with **Egwim *et al*. (2011)** who indicated 8% but opposes **Kumari and Atri (2014)** who reported 60.82%. Similarly, **Usha and Suguna (2014)** reported lower carbohydrate content (28.5 %) for *A. polytricha* in their study. In the case of **Johnsy *et al*. (2011)**, 50.20, 43.4, 47.83 and 33.23% were documented for *P. tuber-regium*, *P. ostreatus*, *Lentinus squarrosulus* and *A. auricular-judae* respectively.

Table 2 Proximate composition of the twenty-three mushrooms (dry weight basis)

Mushroom	MC [%]	P [%]	DF [%]	LD [%]	A [%]	CHO [%]
Amanita cokeri	95.84±0.08^{efg}	45.50±0.06^{b}	12.44±0.01^{h}	3.81±0.01^{l}	12.32±0.01^{c}	21.50±0.62^{q}
Auricularia auricular-judae	95.55±0.30^{fgh}	19.60±0.06^{jk}	2.41±0.02^{r}	0.53±0.03^{r}	4.98±0.02^{k}	67.40±0.04^{a}
Auricularia polytricha	94.92±0.68^{ij}	12.29±0.06^{q}	4.32±0.01^{t}	0.55±0.01^{r}	2.27±0.01^{r}	67.44±0.06^{a}
Cantharellus cibarius	95.94±0.09^{ef}	31.05±0.06^{f}	4.56±0.01^{s}	9.30±0.01^{b}	11.53±0.03^{e}	29.94±0.04^{o}
Ganoderma applanatum	95.12±0.28^{hi}	21.20±0.12^{i}	42.37±0.02^{a}	6.60±0.01^{e}	2.09±0.01^{s}	17.64±0.12^{r}
Hydnellum peckii	94.31±0.01^{k}	21.40±0.00^{i}	18.55±0.03^{c}	1.14±0.01^{o}	4.57±0.01^{m}	43.94±0.01^{i}
Hydnum sp.	91.25±0.07^{n}	11.48±0.06^{r}	7.34±0.01^{o}	6.09±0.01^{g}	14.02±0.03^{b}	48.18±0.08^{g}
Inonotus radiatus	80.91±0.13^{q}	16.20±0.06^{m}	12.41±0.02^{i}	0.93±0.01^{q}	11.88±0.01^{d}	44.96±0.03^{h}
Lentinus subnudus	95.31 ±0.44^{ghi}	18.74±0.12^{l}	29.91±0.01^{b}	1.00±0.01^{p}	14.08±0.02^{a}	27.73±0.12^{p}
Macrolepiota procera	95.59±0.16^{efgh}	48.68±0.13^{a}	14.35±0.01^{e}	8.59±0.02^{c}	10.83±0.02^{f}	2.01±0.04^{s}
Marasmiellus candidus	94.54±0.28^{jk}	31.57±0.06^{e}	8.38±0.01^{m}	6.48±0.02^{f}	7.69±0.01^{h}	38.14±0.05^{l}
Oxyporus populinus	88.87±0.19^{o}	19.44±0.06^{k}	11.77±0.01^{k}	0.12±0.01^{u}	4.77±0.01^{l}	51.90±0.08^{e}
Pleurotus tuber-regium	95.41±0.28^{fghi}	19.84±0.67^{j}	6.45±0.01^{p}	0.26±0.01^{t}	2.62±0.01^{o}	55.91±0.64^{d}
Polyporus sp.	92.45±0.06^{m}	15.30±0.00^{n}	13.03±0.00^{g}	0.44±0.01^{s}	2.34±0.01^{q}	56.27±0.03^{cd}
Stereum hirsutum	83.09 ±0.13^{p}	14.67±0.00^{o}	13.25±0.01^{f}	1.97±0.01^{m}	2.43±0.02^{p}	56.48±0.03^{c}
Termitomyces striatus	94.91 ± 0.14^{ij}	26.53±0.12^{h}	12.36±0.01^{j}	7.44±0.01^{d}	4.76±0.01^{l}	42.69±0.43^{j}
Termitomyces bulborhizus	98.44±0.20^{a}	27.53±0.06^{g}	6.25±0.01^{q}	4.74±0.03^{k}	5.97±0.01^{j}	49.00±0.01^{f}
Termitomyces robustus	97.80±0.15^{b}	31.00±0.06^{f}	7.36±0.01^{o}	6.50±0.02^{f}	4.36±0.01^{n}	39.51±0.08^{k}
Termitomyces letestui	96.95±0.08^{c}	26.80±0.06^{h}	5.46±0.14^{r}	5.21±0.14^{i}	7.45±0.01^{i}	48.80±0.06^{f}
Trametes ochracea	93.53 ±0.20^{l}	16.04±0.06^{m}	0.20±0.01^{u}	5.43±0.01^{h}	9.26±0.01^{g}	57.27±0.06^{b}
Trametes pubescens	94.10 ± 0.13^{k}	12.77±0.06^{p}	16.61±0.01^{d}	1.82±0.01^{n}	0.64±0.01^{v}	67.73±0.08^{a}
Tricholoma inocybeoides	96.10±0.13^{de}	41.30±0.06^{c}	9.21±0.01^{l}	4.92±0.01^{j}	1.25±0.01^{u}	31.45±0.06^{n}
Tricholoma ustale	96.46±0.20^{cd}	34.43±0.12^{d}	7.53±0.01^{n}	9.89±0.01^{a}	1.37±0.01^{t}	33.48±0.04^{m}

Mean with a different letter in each column are significantly different from each other at $p < 0.05$.
Mean values are averages of 3 values.
Legend: MC - Moisture content, P - Protein, DF - Dietary fibre, LD - Lipid, A - Ash, CHO - Carbohydrate.

Mineral and vitamin compositions of mushroom samples

Potassium

Potassium controls the water and minerals in the blood and tissues, and significant in the transmission of electrical impulses in the heart **(Kowey, 2002)**. Among all the nutrients analysed, potassium predominates other minerals (Tab 3). This is in line with some studies conducted elsewhere **(Akyüz and Kirbağ, 2010; Ayodele and Okhuoya, 2009; Okwulehie and Ogoke, 2013; Nakalembe *et al.*, 2015)**. However, the range of potassium indicated in this study (268.13 - 8972.00 mg. 100 g^{-1}) was higher than those of **Gbolagade *et al*. (2006)** (7.8 - 60.1 mg. 100 g^{-1}) and **Okwulehie and Ogoke (2013)** (112.14 - 164.54 mg. 100 g^{-1}).

Sodium

Sodium is the main electrolyte and major cation outside the cell (**Knochel, 1999; Wardlaw and Kessel, 2002)**. In contrast to some previous studies **(Gbolagade *et al.*, 2006; Akyüz and Kirbağ, 2010)**, the sodium content of mushrooms studied was significantly high (89.36 - 425.92 mg. 100 g^{-1}) (Tab 3). While **Gbolagade *et al*. (2006)** documented a range of 0.2 to 6.3 mg. 100 g^{-1}, **Akyüz and Kirbağ (2010)** had 0.2 to 1.2 mg. 100 g^{-1}. Furthermore, the values obtained exceeded the recommendations of the World Health Organisation (WHO) daily sodium intake (≤2000 mg) and the UK government (2400 mg per day) **(WHO, 2006; Mohan *et al.*, 2009)**. High dietary sodium has been found implicated in some health consequences including an increase in blood pressure, hypertension, direct vascular and cardiac damage, obesity, stomach cancer, osteoporosis, kidney stones and severity of asthma symptoms (**de Wardener and MacGregor, 2002; Mohan *et al.*, 2009)**.

Phosphorus

Phosphorus is needed to build strong and healthy bones, sustains normal acid/base balance, supports growth and is involved with the storage and use of energy **(dos Passos *et al.*, 2013)**. In this study, phosphorus was found to vary across habitats and differ significantly ($p < 0.05$). Its content (0.32 - 375.51 mg. 100 g^{-1}) (Tab 3) was lower than the report of **Nakalembe *et al*. (2015)** (10.2 - 16.8 mg. 100 g^{-1}) but higher in **Okwulehie and Ogoke (2013)** except for *Hydnum* sp. (23.62 mg. 100 g^{-1}) and *Trametes* pubescens (0.32 mg. 100 g^{-1}) (Tab. 3). The tolerable upper intake level for phosphorus is 3 µg per day for children and 3 to 4 µg per day for adults **(Food and Nutrition Board, 2016)** suggesting that little dose of the mushrooms is needed in daily diet.

Magnesium

Magnesium ranged from 9.39 to 19.32 mg. 100 g^{-1}) (Tab 3) and its lower compared to many common legumes (178 - 197 mg. 100 g^{-1}), whole-grain cereal (121 - 434 mg. 100 g^{-1}) **(FAO, 2012)**, and edible mushrooms **(Nakalembe *et al.*, 2015)**. However, it is higher than **Sanmee *et al*. (2003)** and **Gbolagade *et al*. (2006)** who observed a range of 0.5 - 1.6 mg. 100 g^{-1} and 0.4 - 6.7 mg. 100 g^{-1} respectively. Magnesium is crucial in control of muscle contraction, blood pressure, insulin metabolism, and synthesis of DNA, RNA and proteins **(Grober *et al.*, 2015)**. It plays an important role in nerve transmission and neuromuscular conduction and protection against excessive excitation that can lead to excitotoxicity **(Kirkland *et al.*, 2018)**.

Calcium

Calcium is one of the foremost microminerals in the bone and teeth of human beings and animals and reduces the chance of having cardiac disorder or any heart-related challenge **(Titilawo *et al.*, 2018)**. The obtained values (7.98 - 37.82 mg. 100 g^{-1}) (Tab 3) were comparable to many common kinds of cereals (12 - 51 mg. 100 g^{-1}), starchy food (11 - 43 mg. 100 g^{-1}), meat and poultry products (4 - 69 mg. 100 g^{-1}) **(FAO, 2012)**. However, **Chye *et al*. (2008)** obtained a range (77 - 144.7 mg. 100 g^{-1}) higher than ours. Consumption of a very high concentration of calcium may adversely affect the absorption of the essential elements **(Nova Scotia Environment, 2005)**, nonetheless, its paucity could result in osteoporosis and osteomalacia. Hypertension has also been linked to low calcium in the body **(Kožíšek, 2003; Titilawo *et al.*, 2018)**.

Iron

Iron is required for the synthesis of haemoglobin in red blood corpuscles and also aids growth and metabolic processes in humans and animals **(Kumar and Puri, 2012, Edward *et al.*, 2013; Vetrimurugan *et al.*, 2017; Titilawo *et al.*, 2018)**. In this work, the iron content (0.55 - 1.30 mg. 100 g^{-1}) (Tab 3) was within the published data for cabbage (0.6 mg. 100 g^{-1}) and meat (1.6 mg. 100 g^{-1}) **(Eyabi, 2001)**. It was however higher than those observed in previous studies **(Gbolagade et al., 2006; Ayodele and Okhuoya, 2009)**, and lower when compared with the findings of **Colak *et al*. (2009)**, **Patil *et al*. (2010)** and **Kumari and Atri (2014)**. Largely, a low quantity of iron was observed in the mushrooms and fell below the recommended nutritional limit (18 mg) for iron, **(Food and Nutrition Board, 2016)**. Thus, the mushrooms are not good sources of dietary iron.

Zinc

Zinc is a major micronutrient for living organisms. It is present almost in all foods and water as a salt of organic complexes **(Swaminathan *et al.*, 2011; Salano, 2013)**. Generally, the mushrooms in the current study are low in zinc and fell below the 15 mg recommended dietary intake **(Food and Nutrition Board, 2016)**. The range obtained was between 2.21 and 4.98 mg. 100 g^{-1} (Tab 3). This is lower than the results of previous studies **(Gbolagade *et al*., 2006; Nakalembe *et al.*, 2015)** but higher than the report of **Okwulehie and Ogoke (2013)**. When zinc is lacking in the diet, it may lead to a reduction in fertility, forfeiture of taste, stunted growth and hypogonadism. Low levels of zinc can as well weaken the body's immunity **(Edward *et al.*, 2013; Titilawo *et al.*, 2018)**.

Vitamin A

Mushrooms are non-animal sources of vitamin, contributing a very small percentage in human diet and crucial in disease prevention and lengthening of life span (**Olaniyi, 2000**). The outcome of our work revealed that all the wild mushrooms analysed contained vitamin A (Tab 3). This is contrary to **Afiukwa *et al*. (2013)** who detected vitamin A only in *Agaricus bisporus* among other varieties and with a value higher (38.36 mg. 100 g^{-1}) than what was observed in our case (0.14 - 1.41 mg. 100 g^{-1}). Likewise, **Musieba *et al*. (2013)** investigated vitamin A in *P. citrinopileatus* and reported a low value <10 µg/100 g. Our findings agree with vitamin A level reported for some animal and plant materials including butter (0.59 mg. 100 g^{-1}), cheese (0.39 mg. 100 g^{-1}), egg (0.28 mg. 100 g^{-1}), milk (0.04 mg. 100 g^{-1}) and salmon (0.041 mg. 100 g^{-1}) **(Souci *et al.*, 2000)**. Vitamin A role has been established to include apt sight, reproduction, growth and development, cellular differentiation and immune function **(Bowman, 2001)**.

Vitamin C

The range of vitamin C obtained in this work was from 5.22 to 6.93 mg. 100 g^{-1}. While the highest vitamin C content was found in *Pleurotus tuber-regium*, the lowest was detected in *T. pubescens* (Tab. 3). The values indicated that the mushrooms are considered good sources of ascorbic acid. Earlier studies by **Sapers *et al*. (1999)**, **Mattila *et al.* (2001)** and **Mattila *et al.* (2000)** reported vitamin C content of up to 7 mg. 100 g^{-1}. Also, **Muthangya *et al*. (2014)** observed 5.07 to 5.29 mg. 100 g^{-1} in edible sections of mushrooms whereas **Musieba *et al*. (2013)** recorded a low value of <1 µg. 100 g^{-1} in *Pleurotus citrinopileatus*. Ascorbic acids are major antioxidants with known health benefits **(Rao and Agarwal, 2000)**. It empowers the body against viral and bacterial attack and also vital in wound healing **(Hemilä, 2017)**. It is vital for the production of collagen, a key structural constituent of tendons, bones, teeth, blood vessels and muscles. Vitamin C enhances iron absorption and regenerates other antioxidants including vitamin E **(Brody, 1994)**. On the contrary, deficiency in vitamin C causes bruising, haemorrhage, dry skin and depression **(Olson, 1999)**. The vitamin is reported to directly interact with radicals in plasma, averting impairment to red cell membranes **(Jayakumar *et al*., 2009)**.

Table 3 Mineral and vitamin composition of the selected mushroom samples (dry weight basis) (mg. 100g^{-1})

Mushroom	Sodium	Potassium	Magnesium	Calcium	Iron	Zinc	Phosphorus	Vitamin A	Vitamin C
Amanita cokeri	280.37±0.01^{f}	8972.00±0.05^{a}	12.68±0.01^{n}	28.04±0.01^{e}	1.05±0.01^{f}	2.78±0.01^{l}	127.56±0.01^{l}	1.14±0.01^{ef}	5.48±0.02^{cd}
Auricularia auricular-judae	131.57±0.02^{s}	2473.68±0.01^{k}	15.36±0.01^{l}	8.76±0.01^{t}	1.22±0.01^{bc}	2.33±0.01^{n}	159.55±0.02^{i}	1.34±0.01^{b}	6.25±0.01^{b}
Auricularia polytricha	231.56±0.01^{h}	1260.72±0.01^{o}	18.56±0.01^{d}	17.14±0.01^{j}	1.01±0.01^{g}	2.32±0.01^{n}	93.25±0.01^{m}	1.23±0.01^{c}	5.34±0.01^{cd}
Cantharellus cibarius	425.15±0.25^{b}	5954.62±0.01^{c}	15.36±0.01^{l}	37.82±0.01^{a}	1.24±0.01^{b}	3.87±0.02^{b}	208.35±0.01^{g}	1.12±0.01^{fg}	6.43±0.02^{b}
Ganoderma applanatum	152.43±0.02^{q}	670.73±0.00^{u}	17.69±0.01^{e}	10.17±0.01^{l}	1.30±0.01^{a}	3.25±0.01^{j}	75.74±0.02^{r}	1.22±0.01^{cd}	5.44±0.01^{cd}
Hydnellum peckii	196.25±0.02^{k}	1570.10±0.01^{m}	10.36±0.01^{p}	18.67±0.02^{h}	1.30±0.01^{a}	3.49±0.01^{f}	90.60±0.01^{n}	1.23±0.01^{c}	6.32±0.01^{b}
Hydnum sp.	174.43±0.01^{m}	406.97±0.01^{v}	19.32±0.01^{a}	29.08±0.01^{d}	1.10±0.02^{e}	2.21±0.01^{o}	23.62±0.01^{v}	1.41±0.01^{a}	5.38±0.01^{cd}
Inonotus radiatus	247.26±0.01^{g}	1236.28±0.02^{p}	17.67±0.01^{e}	36.65±0.02^{b}	1.32±0.01^{a}	2.54±0.01^{m}	80.99±0.01^{p}	1.11±0.01^{fg}	6.22±0.01^{b}
Lentinus subnudus	113.11±0.01^{u}	1724.78±0.01^{l}	16.32±0.02^{h}	9.32±0.11^{q}	0.64±0.01^{k}	3.13±0.01^{k}	154.83±0.01^{j}	1.36±0.01^{b}	5.56±0.04^{c}
Macrolepiota procera	166.35±0.01^{o}	3632.14±0.04^{h}	15.84±0.01^{j}	9.24±0.02^{r}	0.74±0.02^{i}	3.25±0.13^{j}	70.07±0.01^{u}	1.04±0.01^{i}	6.32±0.01^{b}
Marasmiellus candidus	329.97±0.05^{c}	4241.96±0.01^{f}	18.92±0.01^{b}	31.43±0.01^{c}	1.24±0.01^{b}	3.44±0.01^{g}	375.51±0.37^{a}	1.32±0.01^{b}	6.39±0.02^{b}
Oxyporus populinus	199.44±0.01^{i}	1453.00±0.01^{n}	17.67±0.01^{e}	9.51±0.01^{o}	0.82±0.01^{h}	3.63±0.01^{d}	193.94±0.00^{h}	1.05±0.07^{hi}	5.39±0.02^{cd}
Pleurotus tuber-regium	115.95±0.01^{t}	927.55±0.01^{t}	16.29±0.01^{h}	19.31±0.01^{g}	0.68±0.01^{j}	3.44±0.01^{g}	80.29±0.01^{q}	1.09±0.01^{gh}	6.93±0.54^{a}
Polyporus sp.	158.03±0.01^{p}	1106.22±0.02^{r}	10.32±0.01^{q}	17.56±0.01^{i}	1.30±0.01^{a}	3.55±0.01^{e}	74.12±0.01^{s}	1.02±0.01^{i}	5.29±0.02^{cd}
Stereum hirsutum	93.01±0.01^{v}	953.49±0.00^{s}	9.39±0.02^{r}	15.52±0.02^{k}	1.13±0.02^{d}	3.34±0.01^{i}	73.63±0.01^{t}	1.18±0.04^{de}	6.22±0.01^{b}
Termitomyces striatus	195.34±0.01^{l}	5860.46±0.01^{d}	16.49±0.02^{g}	9.32±0.02^{q}	0.69±0.01^{j}	3.78±0.01^{c}	371.89±0.01^{b}	1.12±0.01^{fg}	6.29±0.02^{b}
Termitomyces bulborhizus	167.07±0.01^{n}	5250.60±0.01^{e}	15.70±0.01^{k}	7.98±0.02^{v}	0.55±0.01^{l}	4.98±0.01^{a}	222.55±0.01^{e}	1.23±0.01^{c}	6.36±0.04^{b}
Termitomyces robustus	198.01±0.01^{j}	7673.26±0.01^{b}	15.29±0.02^{m}	8.24±0.02^{u}	1.09±0.01^{e}	3.37±0.01^{i}	217.15±0.01^{f}	1.23±0.01^{c}	5.49±0.01^{c}
Termitomyces letestui	310.43±0.01^{d}	3668.87±0.01^{g}	18.78±0.01^{c}	9.42±0.01^{f}	1.19±0.01^{c}	3.40±0.01^{h}	271.50±0.01^{c}	1.14±0.01^{ef}	6.43±0.01^{b}
Trametes ochracea	138.13±0.01^{r}	1160.24±0.02^{q}	11.66±0.01^{o}	27.63±0.01^{f}	1.02±0.01^{g}	3.53±0.01^{e}	86.64±0.01^{o}	0.14±0.01^{j}	5.22±0.01^{cd}
Trametes pubescens	89.36±0.01^{w}	268.13±0.01^{w}	16.26±0.02^{i}	9.94±0.01^{m}	1.01±0.01^{g}	2.55±0.01^{m}	0.32±0.01^{w}	1.33±0.01^{b}	4.68±0.01^{e}
Tricholoma inocybeoides	425.92±0.01^{a}	2608.70±0.00^{j}	15.32±0.01^{m}	8.84±0.05^{s}	1.21±0.01^{bc}	3.36±0.01^{i}	146.71±0.01^{k}	1.19±0.01^{cd}	6.29±0.01^{b}
Tricholoma ustale	292.96±0.01^{e}	3281.11±0.21^{i}	16.67±0.02^{f}	9.77±0.01^{n}	1.14±0.00^{d}	3.39±0.01^{h}	223.34±0.01^{d}	1.12±0.01^{fg}	5.48±0.01^{cd}

Mean with a different letter in each column are significantly different from each other at $p < 0.05$.
Mean values are averages of 3 values.

Nutritive hierarchical cluster analysis of the mushrooms

Mushrooms fruitbodies are characterized by assimilated mineral constituents whose level depends on, amongst other species, age of mushroom, the diameter of pileus and substratum **(Dermirdaş, 2001; Falandysy *et al.*, 2001; Mattila *et al*., 2001)**. The nutrition hierarchy cluster shows that there is dietary relatedness among the mushroom species irrespective of their habitat, texture or edibility (figure 2). For instance, the fleshy, edible *P. tuber-regium* and *T. inocybeoides* in the terrestrial habitat closely associated with woody/tough, inedible *G. applanatum* and *S. hirsutum* in the ligneous habitat respectively. Likewise, the fleshy and edible *T. striatus* and *C. cibarius* in the ligneous habitat closely related to fleshy, edible *T. bulborhizus* (terrestrial habitat); and the fleshy, inedible *M. candidus* in the ligneous habitat found clustered with fleshy, edible *M. procera*, *T. ustale* and *T. letestui* in the terrestrial habitat (figure 2). Also, the nature of the

nutrient-rich organic substrate on which *M. candidus*, *C. cibarius*, and *T. striatus* grew may be responsible for dietary relatedness with mushrooms from terrestrial habitat. Likewise, the presence of sclerotium in *P. tuber-regium* and decaying debris where *Tricholoma inocybeoides* were harvested may be the reason their nutrient content is comparable with mushrooms from the ligneous habitat.

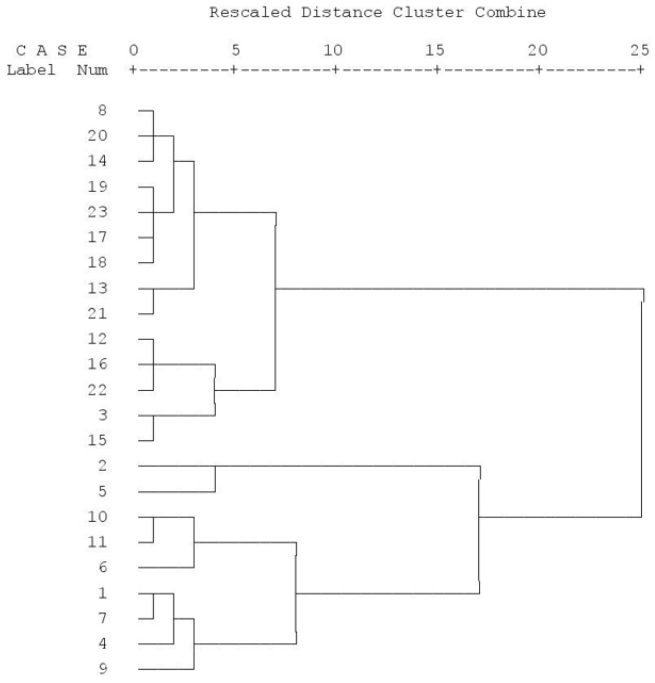

Figure 2 Dendrogram of the nutritive value of the selected mushroom samples
Legend: 1 - *Macrolepiota procera*, 2 - *Amanita cokeri*, 3 - *Tricholoma inocybeoides*, 4 - *Tricholoma ustale*, 5 - *Termitomyces robustus*, 6 - *Termitomyces bulborhizus*, 7 - *Termitomyces letestui*, 8 - *Pleurotus tuber-regium*, 9 - *Marasmiellus candidus*, 10 - *Cantharellus cibarius*, 11 - *Termitomyces striatus*, 12 - *Hydnellum peckii*, 13 - *Hydnum* sp., 14 - *Ganoderma applanatum*, 15 - *Auricularia auricular-judae*, 16 - *Oxyporus populinus*, 17 - *Trametes ochracea*, 18 - *Polyporus* sp., 19 - *Inonotus radiatus*; 20 - *Stereum hirsutum*, 21 - *Trametes pubescens*, 22 - *Lentinus subnudus*, 23 - *Auricularia polytricha*

CONCLUSION

The nutritional composition of twenty-three underutilized Nigerian wild mushrooms was studied. While eight of the mushrooms were from the terrestrial habitat, fifteen were of the ligneous source. Interestingly, all the mushroom species are rich in moisture, protein, dietary fibre, ash, carbohydrate and minerals including sodium, potassium, calcium, magnesium, zinc, and phosphorus, and vitamins A and C, but low in lipid and iron, an indication that they are highly nutritious; although other sources of sodium must be checked when consuming these mushrooms. Similarly, the nutritive hierarchical cluster analysis shows that the dietary composition of all the mushrooms is related irrespective of their habitat, texture or edibility. Thus, they are potential foods and food supplements and stand to meet the diverse human dietary needs if objectively exploited. Further study is however encouraged to ascertain the safety of these mushrooms for consumption.

Conflicts of interest: The authors declare no conflict of interest.

Author contributions: M.A.T and O.O. designed the experiment, M.A.T. performed the experiment and drafted the manuscript, M.A.T. and A.O.O. analysed the data, A.O.O. and M.A.T. supervised the study. All authors read and approved the final manuscript.

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