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Proximate Composition and Functional Properties of Mushroom Flours from *Ganoderma spp.*, *Omphalotus olearius* (DC.) Sing. and *Hebeloma mesophaeum* (Pers.) Quél. Used in Nasarawa State, Nigeria

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ABSTRACT

The proximate composition and functional properties of three edible mushroom (*Ganoderma spp., Omphalotus olearius* (DC.) Sing. and *Hebeloma mesophaeum* (Pers.) Quél.) flours used in Nasarawa state, Nigaria were investigated using standard analytical techniques. The samples contained crude protein in the range of 18.5% in *Omphalotus olearius* to 21.5% in *Ganoderma spp.* Crude fat varied with values ranging from 6.9% in *Ganoderma spp.* to 8.7% in *Omphalotus olearius*. Other proximate composition values were in the following ranges: moisture content 10.0 – 11.1%, ash 7.3 – 8.3%, crude fibre 2.8 – 3.5% and carbohydrate (by difference) 50.3 – 50.9%. The range values of functional properties were: foaming capacity 101.8 – 131.5%, foaming stability 51.0 – 54.0%, water absorption capacity 260.0 – 390.0%, oil absorption capacity 450 – 480%, oil emulsion capacity 57.3 – 61.0mLg^{-1}, least gelation concentration 12.0 – 14.0% and bulk density 230.0 – 410.0gmL^{-1}. The results showed that these nutrient rich mushroom flours under investigation may prove useful in the formulation of different food products where foaming, emulsification, retention of flavour and palatability as well as gel formation are required.

Keywords: Proximate, functional properties, mushrooms, gelation

INTRODUCTION

Food proteins are usually composed of several discrete proteins, each with different properties (e.g. solubility, isoelectric point and susceptibility to denaturation). Thus functionality associated with certain protein preparations may not reflect the properties of the total proteins, but rather one of the components (Chel-Guerrero *et al.*, 2002). In

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view of this, systematic determination of functional properties should be made when developing new sources of proteins, protein concentrates and isolates. This is required to evaluate and possibly help predict how new proteins may behave in specific systems, as well as demonstrate whether such proteins can be used to simulate or replace conventional protein sources.

Mushrooms consist of two main parts, the mycelium and the fruity body (sporocarp). The mycelium consists of a tree-like structure called hypae hidden in the soil. The mycelium absorbs food nutrients while the hypae form into mycelia which forms the fruit (sporocarp) structure on the surface when atmospheric conditions particularly humidity is favourable. The spore producing tissue is called the hymenium (Etang, Essian & Odejimi,2006). Mushrooms vary in sizes, colour, texture and structure that favour their spore formation. The cap is called the cuticle and varies among different mushroom species, being sticky or slimy in texture. The stalk is the stem-like structure on which the cap is mounted and this varies in length depending on the species (Gyar & Ogbonna, 2006).

Many species of mushrooms are edible, for example, *Plevritis sp., Agricus bisporus* (J. Lange) Imbach and *Volvariella volvaceae* (Bulliard ex Fries) Singer. Some are medicinal like *Auricularia sp.* and *Tremella fuciformis* Berk. for treating haemorrhoids and maintaining healthy lung tissue, respectively; while others are poisonous like *Pholiota semarrasa* and *Amanta vaginata* (Bull.: Fr.) Lam. (Chang & Buswell, 1996). *Ganoderma sp., Omphalotus olearius* (DC.) Sing. and *Hebeloma mesophaeum* (Pers.) Quél. are species reported here to be among the most edible mushrooms commonly found in Nigeria. Mushrooms have assumed greater importance in the diets of both rural and urban drivellers, unlike previously when consumption was confined to rural dwellers. Mushrooms are now marketed along highways and urban centres (Aremu *et al.*, 2008). Most of the mushrooms consumed in Nigeria are picked by rural drivellers from farmlands, forests and around waste dump sites when environmental conditions particularly humidity favour their sporocarp formation.

The ultimate success of utilising plant proteins as ingredients depends largely upon the beneficial qualities they impart to foods which by extension depend largely on their functional properties. The functionality of plant protein has been reported to be dependent upon the chemical characteristics inherent in the seed (Mattil, 1973). Therefore, the present study aims at investigating the proximate composition and functional properties of *Ganoderma spp.*, *Omphalotus olearius* and *Hebeloma mesophaeum* mushroom flours found in Nasarawa State, Nigeria and doing a comparative study on them with a view to providing vital information towards effective utilisation of these mushroom flours in various food applications.

MATERIALS AND METHODS

Collection and treatment of samples

Mushrooms grow abundantly in the wild during the rainy season in every part of Nasarawa State (Middle Belt), Nigeria. Fruiting of three mushroom species were harvested in September, 2007 from decaying logs and oil palm stalks dump site inside a bush located at Yelwa Bassa in Kokona Local Government Area of Nasarawa State, Nigeria. The mushroom species were identified by a mycologist in the Department of Biological Sciences, Nasarawa State University, Keffi, Nigeria as *Ganoderma spp.*, *Omphalotus olearius* (DC.) Sing. (Family: Paxillaceae) and *Hebeloma mesophaeum* (Pers.) Quél. (Family: Cortinariaceae). Mushroom samples were then treated according to the method described by Aremu *et al.* (2008).

Proximate analyses

The moisture, ash, ether extract, crude fiber, crude protein (N x 6.25) and carbohydrate (by difference) were determined in accordance with AOAC methods (AOAC, 1995). All proximate analyses of the mushroom flours were carried out in triplicate and reported in percent. All chemicals were of analytical (Analar) grade from EMerck.

Functional properties determination

The foaming capacity and stability and least gelation concentration were determined using the procedure of Coffman and Garcia (1977). The water and oil absorption capacities; oil emulsion capacity and stability were determined as reported by Beuchat(1977) using Executive Chef Oil with density of $0.98gmL^{-1}$. Bulk density of the seed flour was determined using the procedure of Narayana & Narasinga (1984). All chemicals used were of analytical (Analar) grade from EMerck. SPSS statistical package (version 11.0) was used for statistical analyses.

RESULTS AND DISCUSSION

Table 1 presents the proximate composition (%) of three edible mushroom flours. The percentage moisture content ranged between 10.2% in *Ganoderma spp.* to 11.1% in *Omphalotus olearius*. These values are higher than the value of *Lentinus trigrinus* (Bull.) Fr., (9.2%) previously reported by Adejumo & Awosanya (2005). This is an indication that mushrooms are highly perishable because high moisture content promotes susceptibility to microbial growth and enzyme activity which accelerates spoilage. The ash content ranged from 7.3% in *Hebeloma mesophaeum* to 8.3% in *Omphalotus olearius*. Ether extract (crude fat) ranged from 6.9% in *Ganoderma spp.* to 8.7% in *Omphalotus olearius*. None of the studied mushroom samples qualified as oil rich plant food compared with crude fat content of soybean (22.8 and 23.5%) as reported by Salunke, Kadam & Chawan (1985) respectively; *Citrullus vulgaris* Schrader ex Ecklon & Zeyher, 47.9 – 51.1% (Ige, Ogunsua & Oke, 1984); pumpkin seed, 49.2 and 47.0% (Aisegbu, 1989). Crude protein ranged between 18.5% in *Omphalotus olearius* to 21.5% in *Ganoderma spp.* Overall, crude protein values in all the three samples were found to be higher compared to crude proteins present in protein-rich foods such as soybeans, cowpeas and pigeon pea (Olaofe, Umar &Adediran, 1993) and Kersting's groundnut (Aremu, Olafe & Akintayo, 2006).

An adult man of 70kg body weight requires $0.57gkg^{-1}$ (FAO / WHO, 1973), that is, 39.9g of protein daily. This means that varieties of mushrooms under study would supply the required protein assuming complete protein absorption. The crude fibres (2.8 – 3.5%) are comparable with most legumes such as pigeon pea and cowpea, *Phaseolus coccineous* L. (Aremu *et al*., 2006), oil seeds (Olaofe, Adeyemi & Adediran, 1994). There is evidence that dietary fibre has a number of beneficial effects related to its indigestibility in the small intestine . The value of carbohydrate (by difference) obtained in this study compares favourably with the value of *Volvariella volvacea* mushroom as reported by Anthony & Joyce (2007). The calculated metabolisable energy values which ranged between 1476.7KJ / 100g in *Ganoderma spp.* to 1513.5KJ / 100g in *Hebeloma mesophaeum* indicate that the studied samples were concentrated sources of energy and compared favorably to cereals (Brain & Allan, 1977) in terms of their energy values.

The foaming capacity and stability of the three edible mushroom flours are presented in Table 2. Foaming capacity ranged between 101.8 ± 4.0% in *Omphalotus olearius* to 131.48 ± 5.0% in *Hebeloma mesophaeum*. These values are greater than some legume seeds flours as reported by some workers: benniseed, 18.0% (Oshodi, Ogunbenle & Oladimeji, 1999), scarlet runner bean, 28.1%

Table 1. Proximate composition of mushroom flours from *Ganoderma spp.* *Omphalotus olearius* and *Hebeloma mesophaeum*

Parameters	Concentration[a]		
	Ganoderma spp.	*Omphalotus olearius*	*Hebeloma mesophaeum*
Moisture	10.2 ± 0.2	11.1 ± 0.2	10.0 ± 0.2
Ash	7.8 ± 0.6	8.3 ± 0.0	7.3 ± 0.3
Crude fat	6.9 ± 0.5	8.7 ± 0.1	8.1 ± 0.2
Crude protein	21.5 ± 0.5	18.5 ± 2.0	20.5 ± 0.2
Crude fibre	3.5 ± 0.2	2.8 ± 0.5	3.2 ± 1.0
Carbohydrate by difference	50.3 ± 2.0	50.6 ± 1.0	50.9 ± 1.0
Energy value (KJ/100g)	1476.7	1496.0	1513.5

[a] Values are mean ± standard deviation of triplicate determinations

Table 2. Some functional properties of mushroom flours from *Ganoderma spp.*, *Omphalotus olearius and Hebeloma mesophaeum* [a]

Properties	*Ganoderma spp*	*Omphalotus olearius*	*Hebeloma mesophaeum*	*Mean*	*SD*	*CV%*
Foaming capacity (%)	103.7 ± 3.0	101.8 ± 4.0	131.5 ± 5.0	112.3	16.6	14.7
Foaming stability (%)	54.0 ± 1.0	51.0 ± 0.5	51.1 ± 2.0	52.0	1.7	3.2
Water absorption capacity (%)	390.0 ± 5.0	380.0 ± 2.0	260.0 ± 15	343.3	72.3	21.0
Oil absorption capacity (%)	470.0 ± 5.0	450.0 ± 12	480.0 ± 11	466.6	15.2	3.2
Oil emulsion capacity (mLg^{-1})	61.0 ± 0.5	58.1 ± 2.0	57.3 ± 5.0	58.8	1.9	3.2
Oil emulsion stability (mLg^{-1})	28.0 ± 1.0	32.0 ± 2.0	38.0 ± 3.0	32.6	5.6	15.3
Least gelation concentration (%)	14.0 ± 0.0	12.0 ± 0.0	12.0 ± 0.0	12.7	1.16	9.1
Bulk density (gL^{-1})	230.0 ± 5.0	390.0 ± 2.0	410.0 ± 8.0	343.3	98.7	28.8

[a]Values are mean ± standard deviation of triplicate determinations
SD = standard deviation; CV% = coefficient of variation percent

(Aremu *et al.*, 2007b), great northern bean 32% (Sathe & Salunkhe, 1981) and rare cowpea, 15.5% (Aremu, Olaofe & Akintayo, 2007). The foaming stability after 24 hours ranged between 51.0% in *Omphalotus olearius* to 54.0% in *Ganoderma spp.* This suggests that the mushroom samples studied may be attractive for products like cakes or whipping topping where foaming is important (Kinsella, 1979).

The water and oil absorption capacities are presented in Table 2. The water absorption capacity varied from 260% in *Hebeloma mesophaeum* to 390% in *Ganoderma spp.* with a mean value of 343.3% and CV% of 21.0. The values are comparatively higher than African yam bean colour varieties of flours which were 118 – 179% as reported for soybean flour by Oshodi, Ipinmoroti & Adeyeye (1997); 130% in the case of Kersting's groundnut (Lin, Humbert & Sosulski, 1974); 240.5% in various lima bean flours (Aremu *et al.*, 2007); 130 – 140% in wheat flour (Oshodi & Adeladun, 1993); 140.6% in the case of oil seeds flours (Adeyeye & Aye, 2005), 70 – 120% (Olaofe *et* *al*., 1994); and 90.2% in *Telfairia occidentales* Hook. f. flour, (Akintayo, 1997). The high water absorptivity reported in the present study suggests that a variety of mushroom flours may be used in the formulation of some foods such as sausage, dough, processed cheese, baked products and soups (Aremu *et al*., 2008). The highest oil absorption capacity was found in *Hebeloma mesophaeum* (480.0%) and the lowest in *Omphalotus olearius* (450.0%)

The values are higher than previously reported for different varieties of legume seeds flours, 127.8 – 172.0% (Aremu *et al*., 2007), cowpea flours, 281 – 310% (Olaofe *et al*., 1993), jack bean flour, 170.0% (Adebowale & Lawal, 2004), African yam bean flours, 93.3 – 145.0% (Oshodi *et al*., 1997), *Bilphia sapida* K. Konig pulp and seed flours, 125.0 – 131.6% (Akintayo, Adebayo & Arogundale, 2002), melon seed flour, 122% (Olaofe *et al*., 1994) and *Phaseolus angularis* flour 147.0% (Chau & Cheung, 1998). Oil absorption capacity is important since oil acts as a flavour retainer and increases the mouth feel of foods. It has been reported that variations in the presence of non-polar side chains, which might bind the hydrocarbon side chains of oil among the flours, explain differences in the oil binding capacity of the flours (Adebowale & Lawal, 2004). However, the results showed that the mushroom flours are potentially useful in structural interaction in food especially in flavour retention, improvement of palatability and extension of shelf life particularly in bakery or meat products where fat absorption is desired.

The oil emulsion capacity and stability are presented in Table 2. The emulsion capacity values range between 57.3mlg^{-1} in *Hebeloma mesophaeum* to 61.0mlg^{-1} in *Ganoderma spp*. These values are lower than the values reported for varieties of mushroom sample flours of 76.0 – 87.0mlg^{-1} by Adeyeye *et al*. (2005). However, the values are much higher than for soybean flour (18.0%) and wheat flour (11.0%) (Lin *et al*., 1974). This suggests that the varieties of mushroom flours in the present study may be most useful as an additive for the stabilisation of fat emulsions in the production of sausage, soup and cake (Altschul & Wilcke, 1985). Table 2 further shows that after 24 hours, the emulsion stability which is the volume of water separated, ranges from 28.0mlg^{-1} in *Ganoderma spp*. to 38.0mlg^{-1} in *Hebeloma mesophaeum*. All the flours showed comparatively high values over a period of 24 hours and they produced good and stable emulsion stability. The decrease in emulsion capacity with time might be due to increased contact leading to coalescence reducing the stability.

The least gelation concentration which is defined as the lowest protein concentration at which gel remains in the inverted tube was used as an index of gelation capacity. The lower the level of the least gelation concentration, the higher the gelating ability of the protein ingredient (Akintayo *et al*., 2002). Least gelation concentration in the present study ranged from 12.0% in *Omphalotus olearius* and *Hebeloma mesophaeum* to 14.0% in *Ganoderma spp*. Variation in the values obtained might be linked to the relative ratio of different constituents such as protein, carbohydrates and lipids as suggested by Sathe, Deshpande & Salunkhe (1982) that the interaction between such components may affect functional properties. The values recorded for *Ganoderma spp*. is comparable to pumpkin seed, 14.0%, as reported by Olaofe *et al*. (1994) and lupin seed flour, 14.0% as reported by Sathe *et al*. (1982). The ability of protein to form gels and provide a structural matrix for holding water, flavours, sugars and food ingredients is useful in food applications and in new product development, thereby providing an added dimension to protein functionality (Oshodi *et al*., 1997; Sathe *et al*.,1982; Aremu, 2008). The low gelation concentration observed may be an asset in the use of these flours for the formulation of curd or as an additive to other gel-forming materials in food products.

Table 3. Rate change in foaming stability of mushroom flours from *Ganoderma spp.*, *Omphalotus olearius* and *Hebeloma mesophaeum*

Time (min)	*Ganoderma spp.*	*Omphalotus olearius*	*Hebeloma mesophaeum*	*Mean*	*SD*	*CV%*
0.0	53.0	53.0	54.0	53.3	0.57	1.06
30	55.0	51.0	51.0	52.3	2.30	4.39
60	49.2	48.0	46.7	47.9	1.25	2.60
90	46.0	45.4	45.1	45.5	0.45	0.98
120	–	–	–	–	–	–
Rate[a]	0.08	0.08	0.09	0.08	0.01	12.5

[a]Rate = change min^{-1}
SD = standard deviation; CV% = coefficient of variation percent

Table 4. Rate change in oil emulsion stability of mushroom flours from *Ganoderma spp.*, *Omphalotus olearius* and *Hebeloma mesophaeum*

Time (min)	*Ganoderma spp.*	*Omphalotus olearius*	*Hebeloma mesophaeum*	*Mean*	*SD*	*CV%*
0.0	47.5	57.2	58.0	54.2	5.84	10.8
30	46.0	49.6	55.0	50.2	4.52	9.00
60	44.0	47.5	50.0	47.2	3.01	6.38
90	43.0	46.0	47.2	45.4	2.16	4.76
120	38.0	38.0	41.0	39.0	1.73	4.44
Rate[a]	2.38	4.80	4.25	3.81	1.27	33.33

[a]Rate = change min^{-1}
SD = standard deviation; CV% = coefficient of variation percent

Bulk density values for the mushroom sample flours are also presented in Table 2. The values ranged between 230.0gL^{-1} in the case of *Ganoderma spp.* compared to 410gL^{-1} in *Hebeloma mesophaeum*. The values are comparable to the values reported for various samples of extrusion texturised soya products with varied protein and soluble sugar contents, 238.2 – 446.0gL – 1 and various processed defatted fluted pumpkin seed flours, 180 – 380gL^{-1} (Fagbemi, Oshodi & Ipinmoroti, 2006). However, the values are lower than those reported for rare cowpea flour, 531.2gL^{-1} and bambara groundnut flour, 586.8gL^{-1} (Aremu *et al.*, 2006).

The rate of change in foaming stability of the three mushroom sample flours is presented in Table 3. The flour samples were stable up to 90 minutes with a rate change of 0.08, 0.08 and 0.09% min^{-1} for *Ganoderma spp.*, *Omophalolus olearius* and *Hebeloma mesophaeum*, respectively. The coefficient of variation (CV%) for the mushroom samples was 12.5%. Although the rates are noticeably different when compared to the study by Oshodi *et al.* (1997) for African yam bean [*Sphenostylis stenocarpa* (Hochst. ex A. Rich.) Harms] flours (hulled and dehulled seeds), they are comparable to the one reported for *Luffa cylindrica* (L.) seed flour by Aremu (2008).

Table 4 presents the rate of change in the oil emulsion stability of three different mushroom flour samples. The changes for *Ganoderma ssp.*, *Omphalotus olearius* and *Hebeloma mesophaeum* are 2.38, 4.80 and

4.25% minutes, respectively with mean values of 3.81 and CV%, 33.33. These values are higher than that of foaming stability. This suggests that the oil emulsion stability will be more stable than foaming stability.

CONCLUSIONS

This article provides an overview of nutritional aspects of three mushroom species from Nigeria. Our study showed that these mushroom species are good sources of proteins and carbohydrates. Several functional properties have also been detected as favourable, making it potentially useful in many food formulations. These are foaming capacity and stability, water and oil absorption capacities, oil emulsion capacity and stability, least gelation concentration and bulk density. Our results indicate that these mushroom flours under investigation may prove useful in the formulation of different food products where foaming, emulsification, retention of flavour and palatability as well as gel formation are required.

This study encourages further investigation of different available and less-reported food sources such as other related species of mushrooms from developing parts of the globe with rich forest resources, high biodiversity and agrarian economy. This research indicates that sustainable use of different species of nutrient rich mushrooms from this agro-climatic zone could possibly serve as an important dietary source for the local and regional population and also has the potential to be transformed into an "export item" that can bring in economic benefits for the betterment of rural communities.

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