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Nutritional composition of three edible ectomycorrhizal mushrooms from Center of Côte d'Ivoire

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Abstract

Wild edible mushrooms of ectomycorrhizal are consumed in the center region of Côte d'Ivoire. In this study, the proximate composition, mineral element profile and amino acid profile of three selected wild edible ectomycorrhizal mushrooms from Center of Côte d'Ivoire including *Lactarius subsericatus*, *Cantharellus platyphyllus* and *Amanita rubescens* investigated. The mushrooms were harvested fresh, dried in an oven at 45°C for 48 hours, ground and analysed according to standard procedures. Proximate analysis showed high level of proteins (32.80±0.42–40.30±1.05%), crude fibre (7.27±0.28–18.72±0.5%), carbohydrate (44.20±1.30–49.15±2.17%), ash (8.61±0.42–14.79±0.85%) and fat (2.39±0.04–4.70±0.06%) in all species. Mineral analysis of all species indicated the mushrooms were specifically rich in potassium, phosphorus and calcium. Potassium was found to be the most abundant mineral present in all specie ranging from 301.2 to 580.8 mg/100g. There were 18 amino acids, and the most predominant ones were glutamic acid and lysine in all species. In addition, the ratios of essential amino acids to total amino acids were 0.43 to 0.53. The high scores of essential amino acids present in these mushrooms implied that they have a high biological protein value. These mushrooms could be considered a potential health food and may be of use to the food industry as a source of ingredients with high nutritional value.

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Introduction

More than 2000 species of mushrooms exist in nature; however, less than 25 species are widely accepted as food and only a few have attained the level of an item of commerce (Lindequist *et al.*, 2005). Most of these mushrooms (species of *Russula*, *Agaricus*, *Cantharellus*, *Boletus* etc.) form mutual symbiotic association with forest trees in the form of ectomycorrhizal, which is most important for their growth, nutrient absorption and protection of roots from pathogens (Marx, 1997). Ectomycorrhizal create distinct features in roots of forest trees. These characters are preferentially dependent, influenced and fashioned by the fungal hyphae of these essentially important structures of the root system (Agerer, 2002). Many species of fungi are normally involved in ectomycorrhizal association with a single tree or a single species may involve in this association with more than one tree (Marx, 1997).

Wild mushrooms are becoming more and more important in our diet for their nutritional (Manzi*et al.*, 1999), organoleptic (Maga, 1981) and pharmacological (Bobek and Galbavy, 1999) characteristics. The consumption of wild edible mushrooms is increasing due to a good content of protein, sugars, glycogen, lipids, vitamins,amino acids and crude fibres. They also contain importantmineral nutrients, which are required for normalfunctioning of the body (Ogundana and Fagade, 1982; Fasidi, 1996;Kuforiji*et al.*, 2003). A large number of ectomycorrhizal are better known for their antimicrobial and antioxidant activities and thus having medicinal significance (Mercan*et al.*, 2006; Liu, 2007; Jain and Pande, 2013).

In Côte d'Ivoire, wild edible mushrooms are known and consumed in many households. In rural areas where they are abundant, most people collect them for home consumption as well as for extra income (Koné *et al.*, 2013).

Despite of the potential economic importance of these wild edible mushrooms in the collecting area (Center of Côte d'Ivoire), this is the first study has been carried out on their nutritional values. In this study, we have examined the nutritional quality of three wild edible mushrooms, i.e. *Lactarius subsericatus*, *Cantharellus platyphyllus* and *Amanita rubescens* from center region of Côte d'Ivoire.

Materials and methods

Raw materials

The sporocarps ectomycorrhizal were collected from their natural habitat at various locations across center region (Côte d'Ivoire). The type of vegetation at the sites of collection consisted of a typical clear forest. Collected samples were *L. subsericatus*, *C. platyphyllus* and *A. rubescens*. Collection was done between July 2013 and June 2014.

Sample Preparation

Mushrooms were first washed thoroughly to free from mud, ferns and other extraneous material, dried on blotting paper and cut into pieces. The mushrooms selected are normally harvested for consumption without division into pileus and stipe. Therefore, the whole mushrooms (Pileus + stipe) after washing, they were dried in an oven at 45°C for 48 hours. The dried samples were mechanically milled into powder with flat-hammer grinding mill and sifted through a 60-mesh screen and then stored in airtight containers for analysis (AOAC, 1995).

Proximate Composition Analysis

Dry matters were determined by drying in an oven at 105°C during 24 h to constant weight (AOAC, 1990). Crude protein was calculated from nitrogen (Nx6.25) obtained using the Kjeldahl method by AOAC (1990). Crude fat was determined by continuous extraction in a Soxhlet apparatus for 8 h using hexane as solvent (AOAC, 1990). Carbohydrate content was determined through the method used by Samant and Rege (1989). Total ash was determined by incinerating in a furnace at 550°C (AOAC, 1990). Method described by Dubois *et al.* (1956) was used to determine total sugars while reducing sugars were analysed according to the method of Bernfeld (1955) using 3.5 dinitrosalycilic acids (DNS). The crude fibre contents were determined according to standard method (AOAC,

1990).

The energy values of mushrooms were evaluated using formula described by Crisan and Sands (1978).
Energy value (kcal/100g) = (2.62 × % protein) + (8.37 × % fat) + (4.2 × % carbohydrate)

Minerals analysis

Minerals were determined employing AOAC (1990) method. Flour was digested with a mixture of concentrated nitric acid (14.44 mol/L), sulfuric acid (18.01 mol/L) and perchloric acid (11.80 mol/L) and analysed using an atomic absorption spectrophotometer. The total phosphorus was determined as orthophosphate by the ascorbic acid method after acid digestion and neutralization using phenolphthalein indicator and combined reagent (APHA, 1995).

Amino acid composition

Total amino acid composition of samples was determined after hydrolysis in 6 M HCl with phenol (1%) at 150°C for 60 min, in Pico-Tag system (Waters, Milford, Mass., U.S.A.). The phenylisothiocyanate (PITC) amino acid derivatives were eluted on HPLC Applied Biosystems Model 172 A (Applera Corp, Foster City, Calif., U.S.A.) equipped with a PTC RP-18 column (2.1 mm × 22 cm). Sodium acetate (45 mM, pH 5.9) and sodium acetate (105 mM, pH4.6; 30%), and acetonitrile (70%) were used as buffers.

Statistical analysis

All analyses were performed in triplicates. Results are expressed as the mean ± standard deviation of several sample with Kyplot (version 2.0 beta 15, ©1997-2001, Koichi Yoshioka) statistical software. The data were statistically analysed by one way analysis of variance (ANOVA). Means were compared by Turkey's test. Differences were considered statistically significant at $P < 0.05$.

Results and discussion

Proximate Composition

The results of the proximate composition of the mushroom samples are presented in Table 1.

Table 1. Proximate composition values of Mushroom samples.

Parameters	Mushroom samples		
	Lactarius subsericatus	*Cantharellus platyphyllus*	*Amanita rubescens*
Moisture (%)	84.78±1.67^a	86.97±1.05^b	89.04±1.17^b
Dry matter (%)	15.55±0.69^b	13.36±0.85^a	10.96±0.84^a
Fibre (%)	16.5±0.28^b	18.72±0.5^c	7.27±0.28^a
Crude protein (%)	35.36±0.36^b	40.30±1.05^c	32.80±0.42^a
Crude fat (%)	3.5±0.1^b	2.39±0.04^a	4.70±0.06^c
Carbohydrates (%)	49.15±2.17^c	44.20±1.30^a	48.44±1.59^b
Total ash (%)	08.61±0.42^a	10.04±0.18^b	14.79±0.85^c
Reducing sugars (%)	0.70±0.06^b	0.79±0.16^b	0.31±0.03^a
Total sugars (%)	19.58±0.18^a	21.61±0.45^b	22.75±0.11^c
Energy value (kcal/100g)	328.36±2.35^c	311.31±2.08^a	326.87±3.06^b

The moisture content of all studied mushroom species ranged from 84.78 % to 89.04 % with the lowest amount of dry matter ranged from 10.96 % to 15.55 %. This high moisture content is an indication that fresh mushrooms cannot keep for long time. This is because high water activity enhances microbial growth (Brock *et al.,* 1986). Similar observation was made by Çaglarlrmak*et al.* (2002) for *Lactarius piperatus* and *Cantharellus cibarius*, and by Heleno *et al.* (2009) for *Lactarius salmonicolor and Russula delica*.

Edible mushrooms are highly valued as a good source of carbohydrates and their contents usually range

from 28.38 % to 82.8 % of dry weight (dw) (Thatoi and Singdevsachan, 2014). In the present study the highest carbohydrates content usually ranged from 44.20% to 49.15% dw. The relatively high carbohydrates content recorded in the samples (Table 1) is a proof of their being highly nutritious and good for human consumption.

Ash content of different mushrooms ranged from 6.61 % to 14.79 % dw. The fruiting bodies of mushrooms are characterized by a high level of well assimilated mineral elements (Bano *et al.*, 1981). The most distinguishing feature of this analysis is the very high ash content (14.79 %) in *A. rubescens*. This ash content was higher compared to those of to that reported by Kumar *et al.* (2013) on *C. Cibarius* (7.78 %) and Agrahar-murugkar and Subbulakshmi (2005) on *Lactarius quieticolor* (6.6 %).

Fat content ranged from 2.39 % to 4.70 % dw in the present study. These results were similar with those obtainedby Yang *et al.* (2001), Kalac (2009) and Johnsy *et al.* (2011)in several edible mushrooms.These low values of fat content suggest that those with heart or weight problems can consume wild edible mushrooms (Chan, 1981).

Table 2. Mineral contents of Mushroom samples.

Mineral contents (mg/100 g of dry weight product)	*Mushroom samples*		
	Lactarius subsericatus	*Cantharellus platyphyllus*	*Amanita rubescens*
Ca	360±2.58^{a}	410±2.94^{b}	581±2.30^{c}
P	520±3.45^{b}	580.8±2.27^{c}	301.2±2.06^{a}
Fe	19.4±0.54^{a}	55.3±0.58^{c}	39±1.56^{b}
Mn	5.32±0.18^{a}	7.68±0.16^{c}	6.5±0.21^{b}
Cu	1.41±0.04^{a}	4.36±0.70^{c}	3.72±0.01^{b}
Zn	39.4±1.02^{c}	6.83±0.24^{b}	3.8±0.05^{a}
Na	21±0.45^{a}	29±0.18^{b}	39±0.58^{c}
K	170±2.14^{b}	47.9±0.22^{a}	422±0.86^{c}
Mg	25.31±0.28^{a}	46.2±0.06^{b}	93±0.54^{c}
Se	9.75±0.92^{b}	2.95±0.17^{a}	ND
Ca/P	0.69	0.70	1.92
K/Na	8.1	1.65	10.82

Each value is an average of three replicate.
Values are mean ± standard deviation.
Means not sharing a similar letter in a line are significantly different $p \leq 0.05$ as assessed by the test of Duncan.
ND: Not Detected.

Total protein content ranged from 32.80 % to 40.30 %dw, the most distinguishing feature of this analysis is the very high protein content (40.30 %) in *Cantharellus platyphyllus*. This value is higher than the values reported in previous studies on mushrooms (Agrahar-murugkar and Subbulakshmi, 2005; Okwulehie *et al.*, 2014; Vieira *et al.*,2014). It is also higher than those reported for some protein- rich foods such as green vegetables (Jonathan, 2002), cowpea seeds (22.5%) and lima beans (23.3%) (Ghogomu and Sondengam, 1989). The studied mushrooms can therefore be ranked as protein rich food for both humans and livestock thus can support the protein need of the poor peasants and solve the problem of malnutrition. Therefore the molecular studies and commercialization of these mushrooms should be encouraged.

Mineral composition

Mineral elements are essential for human health. The concentration of elements has an important physiological effect on different organs and cellular

mechanisms (Vetter, 2003); therefore, it is necessary to know the levels of essential elements in mushrooms before using them. The mineral composition of these mushrooms shown in Table 2. This study indicates that the mushrooms were specifically rich in potassium, phosphorus and calcium. Potassium was found to be the most abundant mineral present in all specie ranging from 301.2 to 580.8 mg/100g. The preponderance of potassium in these mushrooms may be due to the absorption and accumulation of this element from their habitat. Minerals generally in the diet are required for metabolic reactions, transmission of nerve impulses, rigid bone formation and regulation of water and salt balance among others (Egwim *et al.*, 2011).

Table 3. Amino acidsof Mushroom samples.

Amino acids contents (g/100g of protein)	*Mushroom samples*		
	Lactarius subsericatus	*Cantharellus platyphylus*	*Amanita rubescens*
Leucine*	5.38±0.16^{b}	7.75±0.08^{c}	4.06±0.05^{a}
Isoleucine*	4.45±0.08^{b}	6.17±0.04^{c}	3.07±0.03^{a}
Valine*	6.31±0.18^{b}	2.56±0.2^{a}	9.93±0.25^{c}
Tryptophane*	4.65±4.58^{b}	0.15±0.02^{a}	0.93±0.15^{a}
Lysine*	7.18±0.07^{c}	5.82±0.06^{b}	5.14±0.08^{a}
Thréonine*	3.99±0.1^{b}	5.88±0.15^{c}	3.19±0.04^{a}
Phenylalanine*	2.94±0.14^{a}	6.84±0.17^{c}	5.4±0.25^{b}
Methionine*	0.86±0.09^{a}	1.01±0.17^{a}	3.73±0.06^{b}
Histidine *	2.3±0.17^{a}	2.1±0.01^{a}	2.96±0.2^{b}
Arginine	4.14±0.06^{b}	3.47±0.2^{a}	3.31±0.21^{a}
Alanine	2.8±0.1^{a}	7.33±0.05^{c}	5.97±0.15^{b}
Proline	0.28±0.01^{b}	0.09±0.02^{a}	0.12±0.01^{a}
Aspartic Acid	4.63±0.05^{b}	10.8±0.21^{c}	3.51±0.07^{a}
Glycine	4,27±0,14^{b}	4.84±0.14^{c}	3.43±0.05^{a}
Tyrosine	0.24±0.02^{b}	0.16±0.02^{a}	5.21±0.01^{c}
Serine	5.54±0.06^{b}	3.5±0.4^{a}	5.7±0.1^{b}
Glutamic Acid	13.91±1.01^{a}	20.86±1.41^{b}	13.66±0.5^{a}
Cystine	0.57±0.03^{a}	0.43±0.09^{a}	0.76±0.05^{b}
Total essential amino acids	38.99±1.19^{a}	38.31±2.31^{a}	38.45±1.45^{a}

Each value is an average of three replicate. Values are mean ± standard deviation.

*Essential amino acid.

Means not sharing a similar letter in a line are significantly different $p \leq 0.05$ as assessed by the test of Duncan.

Amino acid composition

The amino acid profile of these mushrooms is shown in table 3. Among the amino acids, 18 were determined, and the most predominant ones were glutamic acid and lysine in all species. This was in agreement with those reported by Ribeiro *et al.* (2008) and Beluhan and Ranogajec (2011). The results presented suggest that these mushrooms were rich in essential amino acids. The ratios of essential amino acids to total amino acids were 0.43 to 0.53 and may well meet the minimum daily requirements (WHO, 1975). The quality of a food protein depends largely on its amino acid content. The cells, in making their own protein, need a full array of amino acids from food. Cells can synthesize non-essential amino acids when they are unavailable from food, but essential amino acids can only be obtained from foods (Sizer and Whitney, 2000). The high scores of

essential amino acids present in these mushrooms implied that they have a high biological protein value. This is particularly important as there is a need for novel protein sources owning to the increasing cost of conventional sources of protein in the third world. In addition, the cereal based diets common in developing countries could receive a boost with the inclusion of these mushrooms in their diet.

Conclusion

Results from the present study indicate that the three wild edible mushrooms species ectomycorrhizal from a various locations across center region (Côte d'Ivoire) are rich in nutrients including protein, carbohydrates, fibre, especially essential amino acids and minerals. Therefore, these mushrooms could be considered a potential health food and may be of use to the food industry as a source of ingredients with high nutritional value.

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