

Nutrient and antinutrient distribution of edible mushroom, *Pleurotus tuber-regium* (fries) singer

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Abstract

Edible mushroom *Pleurotus tuber-regium*, separated into cap, stalk, and tuber, was analysed. The macronutrient profile (g/100 g) showed crude protein ranging from 4.1 to 13.8, with the highest concentration in the cap (13.8) than any of the other parts and total carbohydrates from 34.0 to 56.2, while the crude fat and ash contents were generally low. Potassium, the most abundant nutritive element was found to be the highest concentration (mg/g) in the stalk (3.3) while copper was found in trace amounts in all the parts. The total cyanide (mg/100 g), phytate (mg/100 g) and tannin (%TA) concentrations were all below levels considered harmful. Amino acids analysis show that the protein contained all essential amino acids while the calculated amino acids scores showed the sulphur containing amino acids to be most limiting. The foregoing highlights the high nutritive values of the major parts of the edible mushroom, *Pleurotus tuber-regium*.

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Keywords: *Pleurotus tuber-regium*; Macronutrient; Micronutrient; Total cyanide; Phytate; Tannin

1. Introduction

Mushrooms are important for both nutritive and medicinal values (Bonatti, Karnopp, Soares, & Furlan, 2004; Agrahar-Murugkar & Subbulakshmi, 2005; Cheung & Cheung, 2005). *Pleurotus* spp., commonly known as oyster fungus, grows wildly in tropical and subtropical rainforests, and can be artificially cultivated. It has high levels of proteins, carbohydrates, minerals (calcium, phosphorus, iron) and vitamins (thiamin, riboflavin and niacin) as well as low fat (Justo et al., 1998; Manzi, Gambelli, Marconi, Vivanti, & Pizzoferrato, 1999).

Pleurotus tuber-regium (Fries) Singer is a tropical sclerotial mushroom, which has a unique ability to produce sclerotium: an underground tuber and fruit-

body/mushrooms. The tuber, ovoid, irregularly shaped and cream coloured (Alofe, Odu, & Illoh, 1998) is produced and initially embedded within the remains of the much decayed prostrate log of trees. Both the fruitbody and tuber are edible. The tuber is highly nutritive and very rich in proteins and considered a delicacy (Okhuoya & Okogbo, 1990). Though wildly obtained and consumed, the cultivation of *Pleurotus tuber-regium* has been considered most primitive in Nigeria (Oso, 1977). The tubers are obtained from their natural habitats, planted and watered to induce mushroom fruitbody growth, which occurs within a relatively short period of 14–21 days (Patrabansh & Madan, 1997). This ensures a ready and regular supply of fresh mushrooms since rapid deforestation is destroying their natural habitat.

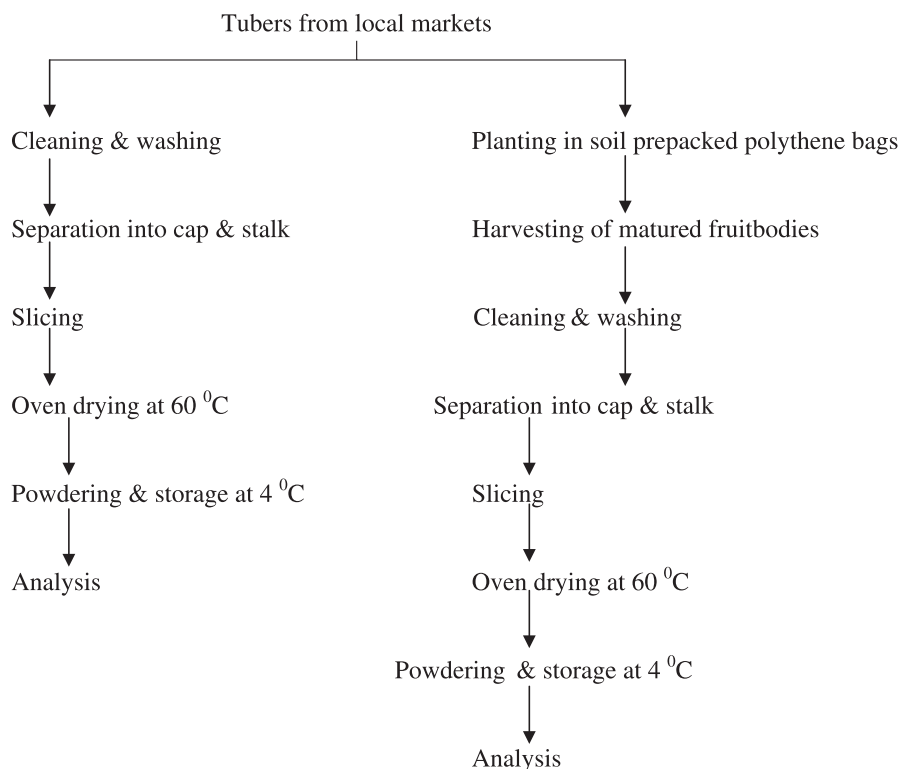
Thus, *Pleurotus tuber-regium* constitutes an important addition to diets in a world threatened by food crisis and ever increasing population. The fruitbodies and tuber have also been reported to possess medicinal

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properties. In combination with various herbs, they have been used to cure asthma, small pox, and high blood pressure (Fasidi & Olorunmaye, 1994). Since both parts are widely accepted and locally available, an understanding of the chemical composition and nutritional significance of the three separate parts, the cap, stalk, and tuber, is of importance. Earlier work of Ogundana and Fagade (1982) was done on the cap only. Hence, the foregoing seeks to evaluate the relative

moist. After 14–21 days, fruitbodies emerging from the tubers, harvested at full maturity, were washed, and cleaned to remove extraneous materials, and separated into cap and stalk. The samples oven-dried at 60 °C were powdered in a moulinex blender and kept in airtight containers at 4 °C prior to analysis. All the samples were analysed in triplicates and results were recorded as mean \pm SD. The above process is depicted in a flow diagram below:



nutrient and antinutrient qualities of these mushroom parts and to encourage efforts towards the husbandry if worthwhile.

2. Materials and methods

2.1. Sample collection and preparation

Fresh tubers of *Pleurotus tuber-regium* weighing 350–500 g were obtained from local farm markets around Ado-Ekiti, Nigeria, pooled and divided into two parts. One part was separated into cap and stalk, cleaned and washed many times, blotted dry, sliced, oven dried at 60 °C, powdered in a moulinex blender and kept in airtight containers at 4 °C prior to analysis. The second part was planted in polythene bags prepacked with soil buried very close to the soil surface, which were watered every day to keep the environment

All the glasswares used were washed in glass-distilled water and the chemicals used were of analytical grade.

2.2. Macronutrient estimation

Moisture content was determined by the direct oven drying method: the loss in weight after oven-drying 1 g each of the sample at 105 °C to constant weight was expressed as % moisture content (AOAC, 1990). Nitrogen was determined by the micro-Kjeldhal method. Because of the significant content of non-protein nitrogen in mushrooms, the protein was determined by using the adjusted conversion factor (4.38) for mushroom protein (Oei, 1991; Shashirekha, Rajathnam & Bano, 2002). Crude fat was determined by using the soxhlet extraction method using petroleum ether as the solvent (AOAC, 1984). Ash was determined as the residue of incineration of 1 g powdered sample in a crucible of known weight at 550 °C in a muffle furnace (AOAC, 1984). Total carbohydrate was determined by

the anthrone method according to Plummer (1971). Serial dilutions of glucose stock (10 mg/100 g) solution were used and the absorbance was read at 620 nm against a reagent blank.

2.3. Micronutrient estimation

The solution of ash dissolved in a drop of trioxonitrate (V) acid made up to 50 ml with deionized water was analysed for Ca, Mg, Cu, and Zn using the atomic absorption spectrophotometer, Na and K using a flame photometer, and P using UV-Visible spectrophotometer after making ammonium vanadate molybdate complex at 436 nm using established procedures of Perkin-Elmer (1982).

2.4. Amino acids determination

Triplicate samples for the amino acid analysis were hydrolysed at 105 °C for 22 h.

The amino acids in the protein hydrolysates were hydrolysed using Technicon sequential multisample (TSM) amino acid analyser according to method of Spackman, Stein, and Moore (1958). Data generated were analysed using one way Analysis of Variance (ANOVA), SPSS 10.0. The level of significance was set at $P < 0.05$. Means were compared using Duncan multiple range *t*-test.

2.5. Antinutrients determination

Tannin content was estimated as follows: 200 mg of three replicates of each sample were extracted with 70% acetone. Standard tannic acid solution (50 mg/100 ml) was also prepared and serial dilutions made. The solutions were read at 725 nm after the addition of 0.5 ml folin and 2.5 ml 20% NaCO₃ (Makkar, Blummuel, Bowwy, & Becken, 1993). Cyanide was estimated by the standard method of AOAC (1990). Four grams of three replicates per sample were soaked in a mixture of 2 ml orthophosphoric acid and 40 ml distilled water overnight to free bound cyanide. The resulting solution was distilled and distillate titrated against 0.01 mol/l AgNO₃. Cyanide concentration was obtained in mg/kg. Data were reported as means of three replicates ($X \pm SD$).

3. Results and discussion

The macronutrient profile (g/100 g) of the cap, stalk, and tuber of edible mushroom *Pleurotus tuber-regium* is shown in Table 1. Crude protein ranged from 4.1 ± 0.0 in the tuber to 13.8 ± 0.5 g/100 g in the cap. The cap contained the highest concentration of protein (13.8 ± 0.5) followed by the stalk (7.8 ± 0.6) and the

Table 1
Macronutrient profile (g/100 g dry matter, mean \pm SD^a) of edible mushrooms *Pleurotus tuber-regium*

	Cap	Stalk	Tuber
Moisture	7.4 \pm 0.0	6.3 \pm 0.0	10.8 \pm 0.3
Crude protein	13.8 \pm 0.5	7.8 \pm 0.6	4.1 \pm 0.0
Crude fat	1.1 \pm 0.1	0.7 \pm 0.3	0.2 \pm 0.0
Ash	4.9 \pm 0.1	2.6 \pm 0.1	1.0 \pm 0.0
Total Carbohydrate	53.2 \pm 0.0	34.0 \pm 0.0	56.2 \pm 0.0

^aMean \pm SD ($n = 4$).

tuber (4.1 ± 0.0). These results agree with earlier works of Ogundana and Fagade (1982) and Kadiri and Fasidi (1990) who obtained 14.6% for the cap of *P. tuber-regium*. The cap protein concentration was almost the same as that obtained (13%) for *Hydnum imbratum* (Mlodecki, Latosa, & Maty, 1974), which was on its own considered sufficiently nutritious. The cap protein concentration was higher than 8.9% DM reported for whole protein of *Auricularia auricula* (Hook) by Aletor (1995), although, the crude protein for the tuber (4.1 ± 0.0) was much lower than those obtained by Fasidi and Ekuere (1993), which was between 13.0% and 16.8%. Hence, all parts of *Pleurotus tuber-regium* can serve as a protein supplement. Generally, the nutritional value of mushrooms lies in their higher protein value than those of green vegetables (Chan, 1981).

The lipid contents of the mushroom parts were generally as low as 0.2 ± 0.0 in the tuber to 1.1 ± 0.1 in the cap. This result is in agreement with those of Aletor (1995), Ola and Oboh (2001) for various species of edible mushrooms and that of Ogundana and Fagade (1982) for *P. tuber-regium*. The tuber lipid concentration agrees with 0.0% and 0.2% observed by Fasidi and Ekuere (1993). The tuber is popularly used in soup making (Oso, 1977). In view of its low lipid content, it is suitable as a component of weight restriction diets.

Table 2 presents the micronutrient profile (mg/g) of *P. tuber-regium*. The most abundant nutritive element, potassium, was 3.3 ± 0.1 in the stalk. This agrees with initial reports of Kadiri and Fasidi (1990) and Ola and Oboh (2001) who found the highest mineral to be potassium in various species of edible mushrooms analysed. Copper was found to be the least abundant, which was found to be equally low in some wild edible mushrooms from Turkey by Mendil, Uluozlu, Hasdemir and Caglar (2004). It was apparently absent in the tuber. Sodium concentration (mg/g) was low. Values ranging between 0.07 ± 0.01 (stalk) and 1.52 ± 0.00 (tuber) were obtained. This agrees with earlier reports of Bahl (1998) that mushrooms are generally low in sodium and hence recommended for heart patients or those on salt restricted diets. The highest calcium concentration was found in the cap (2.9 ± 0.1) and the least in the stalk (1.2 ± 0.2).

Table 2
Micronutrient profile (mg/g) of *Pleurotus tuber-regium* (mean \pm SD)

Elements	Cap	Stalk	Tuber
Potassium	3.1 \pm 0.1	3.3 \pm 0.1	1.52 \pm 0.0
Calcium	2.9 \pm 0.0	1.2 \pm 0.2	1.67 \pm 0.2
Phosphorus	0.10 \pm 0.01	0.15 \pm 0.01	0.12 \pm 0.01
Sodium	0.08 \pm 0.1	0.07 \pm 0.01	1.52 \pm 0.0
Magnesium	0.02 \pm 0.0	0.04 \pm 0.01	^a ND
Copper	0.003 \pm 0.0	0.002 \pm 0.0	ND
Zinc	0.02 \pm 0.0	0.05 \pm 0.0	ND

Mean \pm SD ($n = 4$).

^aND, Not detected.

Table 3
Antinutrient profile (mg/100 g) of *Pleurotus tuber-regium* (mean \pm SD)

	Cap	Stalk	Tuber
Total cyanide	0.10 \pm 0.01	0.08 \pm 0.01	0.07 \pm 0.03
Phytate	338 \pm 0.1	1815 \pm 0.2	385 \pm 0.2
Tannin (%TA)	0.31 \pm 0.01	0.21 \pm 0.02	0.30 \pm 0.00

Mean \pm SD ($n = 4$).

The results of the antinutrients analysed are shown in Table 3. The total cyanide content (mg/100 g) ranged between 0.07 \pm 0.03 in the tuber and 0.10 \pm 0.01 in the cap. All the values were below 1.99 mg% obtained for the cap of *P. tuber-regium* by Ogundana and Fagade (1982) and much lower than those obtained for *Cajanus cajan* var. and *Vigna unguiculata* var. (393 \pm 13 and 381 \pm 5 mg/kg) (Okolie & Ugochukwu, 1989). Cyanide is a normal constituent of the blood but it is usually at low concentration of less than 12 μ mol (Osagie, 1998); at high concentration, it is a potent inhibitor of the respiratory chain (Lehninger, 1987). Aremu (1989) estimated the per capital daily intake of hydrogen cyanide in Nigeria to be 8 mg.

Phytate concentration (mg/100 g) ranged between 338 \pm 0.1 (cap) and 1815 \pm 0.2 (stalk). This compares with the reports of Ola and Obboh (2001) for higher phytate concentration in the stalk than the cap of *Pasthyrella atrombonatu* species of edible mushroom. Generally, the phytate content of the parts analysed were low compared with green leafy vegetables whose phytate content were found to be exceptionally high (Akindahunsi & Obboh, 1999). Phytic acid forms very stable complexes with mineral ions rendering them unavailable for intestinal uptake because the first step in mineral absorption requires that the mineral remain in the ionic state (Lopez, Leehardt, Coudray, & Resmesy, 2002) thus inducing mineral deficiencies.

Tannin concentrations (%TA) were generally low with the cap and tuber containing higher concentration than the stalk. These levels might not affect the nutritional potentials of the mushroom parts since they

Table 4
Amino acid profile (mg/g) of *Pleurotus tuber-regium* (mean \pm SD)

Amino Acids	Cap	Stalk	Tuber
Lysine	27.4 \pm 1.8	26.1 \pm 0.0	23.8 \pm 1.0
Histidine	14.7 \pm 1.0	13.1 \pm 1.0	12.3 \pm 0.2
Arginine	31.4 \pm 1.2	31.4 \pm 1.3	30.5 \pm 0.9
Aspartic acid	43.5 \pm 0.5	45.6 \pm 1.2	44.1 \pm 4.2
Threonine	31.4 \pm 0.8	29.2 \pm 2.0	32.0 \pm 2.9
Serine	14.5 \pm 1.8	11.6 \pm 0.3	13.3 \pm 2.2
Glutamic acid	65.7 \pm 3.2	54.2 \pm 2.3	56.6 \pm 0.2
Proline	6.6 \pm 0.4	5.9 \pm 0.1	5.7 \pm 1.1
Glycine	8.6 \pm 0.5	9.5 \pm 2.0	7.4 \pm 0.5
Alanine	28.8 \pm 3.1	23.1 \pm 2.0	28.1 \pm 1.0
Cystine	5.3 \pm 0.1	4.3 \pm 0.6	4.7 \pm 0.0
Valine	33.4 \pm 1.9	31.9 \pm 1.5	37.5 \pm 8.9
Methionine	4.8 \pm 0.6	5.4 \pm 0.3	5.7 \pm 1.2
Isoleucine	21.1 \pm 1.4	20.2 \pm 0.5	20.5 \pm 3.0
Leucine	28.4 \pm 1.1	40.6 \pm 5.0	41.5 \pm 3.5
Tyrosine	4.2 \pm 0.2	5.1 \pm 0.2	5.7 \pm 0.4
Phenylalanine	21.9 \pm 1.3	20.4 \pm 1.0	20.6 \pm 1.8

Mean \pm SD ($n = 4$).

were all less than 10% of the total dry weight of the samples (Osagie, 1996).

Table 4 shows the amino acid profile (mg/g) of the mushroom parts. Glutamic acid (54.2 \pm 2.3–65.7 \pm 3.2) and aspartic acid (43.5 \pm 0.5–45.6 \pm 1.2) dominate the amino acid profile for all the parts. This could be because these two amino acids are the precursors from which the backbones of amino acids are formed and they are storage forms of nitrogen (Onwuliri & Anekwe, 1993). The essential amino acids, leucine and valine, were the next abundant following the same trend in all the three parts. Lysine is an essential amino acid limiting in most vegetable proteins (Oei, 1991) such as the staple cereals (Buswell & Chang, 1993). It was found to have a good distribution (mg/g) (23.8 \pm 1.0–27.4 \pm 1.8) in the mushroom parts. Earlier reports of Chan (1981) and Mdachi, Nkunya, Vitus, Nyigo and Urasa (2004) showed that mushrooms are generally rich in leucine and lysine. Both histidine and arginine are particularly essential for children (FAO/WHO/UNU, 1985). The results show all the mushroom parts to be rich in these amino acids. All essential amino acids except methionine and cysteine were present in all the parts in appreciable concentrations. The practise of consuming mushrooms in conjunction with cereals and vegetable-containing diets, which are moderately high in the concentration of sulphur containing amino acids (Onwuliri & Obu, 2002) but low in concentration of lysine, which ranges between 23.8 \pm 1.0 and 27.4 \pm 1.8 mg/g in mushrooms should be further encouraged. There was no significant difference ($P > 0.05$) in the amino acid distribution of arginine, aspartic acid, threonine, serine, proline, glycine, alanine, valine, methionine, isoleucine, and phenylalanine while there was a significant difference ($P < 0.05$) in the distribution of all the other amino acids amongst the three parts analysed.

Table 5
Calculated Amino Acid Scores of Parts of *Pleurotus tuber-regium*

Amino acids	Provisional pattern (mg/g) ^a		Cap	Stalk	Tuber
	Protein	Nitrogen			
Isoleucine	250	40	0.08	0.08	0.08
Leucine	440	70	0.09	0.09	0.09
Lysine	340	55	0.08	0.08	0.07
Methionine + Cysteine	220	35	0.05	0.04	0.05
Phenylalanine + Tyrosine	380	60	0.07	0.07	
Threonine	250	40	0.13	0.12	0.17
Valine	310	50	0.11	0.10	0.12

^aFAO/WHO/UNU (1985).

Although total protein content is an important factor in the biological utilization of proteins, the level and balance of the essential amino acids primarily determine nutritional value (Okwuraiwe, Ogunmodede, & Oyenuga, 1975). Hence, the quality of dietary proteins can be measured by expressing the available amino acids in a test diet compared with needs expressed as a ratio (Bender, 1992). The provisional amino acid scoring pattern and calculated amino acid scores (obtained as the ratio of mg of amino acid per g of test protein to the mg of amino acid per g protein in reference pattern) of the three parts of *Pleurotus tuber-regium* are presented in Table 5. The calculated scores show that the sulphur containing amino acids, cysteine and methionine, are the limiting amino acids in all the mushroom samples analysed. In conclusion, all the three parts of *P. tuber-regium* contain a fair distribution of nutrients; it is a source of high quality plant proteins, which has an excellent amino acid profile, a rich addition to human diets. The antinutrients they contain are low in concentration and are unlikely to produce any undesirable effect on the consumer. Findings from further toxicological studies will confirm the nutritional qualities.

References

Agrahar-Murugkar, D., & Subbulakshmi, G. (2005). Nutritional value of edible wild mushrooms collected from the Khasi hills of Meghalaya. *Food Chemistry*, *89*, 599–603.

Akindahunsi, A. A., Oboh, G. (1999). The Abdus-Salam Int. Centre for Theoretical Physics Preprint IC/99/25.

Aletor, V. A. (1995). Compositional studies on edible tropical species of mushrooms. *Food Chemistry*, *54*, 265–268.

Alofe, F. V., Odu, E. A., & Illoh, H. C. (1998). Mushroom, man and nature. Edible wild mushrooms on decaying wood in Obafemi Awolowo University campus. *Nigerian Field*, *68*, 14.

AOAC. (1984). *Official methods of analysis* (14th ed.). Washington, DC: Association of Official Analytical Chemists.

AOAC. (1990). *Official methods of analysis* (15th ed.). Washington, DC: Association of Official Analytical Chemists.

Aremu, C. Y. (1989). Quantitative estimation of dietary constituents of Phytate, Oxalate and Hydrocyanate of six popular Nigerian foodstuffs. *Nigerian Journal of Nutrition Science*, *10*, 79–84.

Bahl, N. (1998). *Handbook on mushroom*. Oxford: An IBH Publication Co. Ltd pp. 21–23.

Bender, A. (1992). Meat and meat products in Human nutrition. Nutrition in developing countries. *FAO Food and Nutrition paper 53 FAO Rome New Delhi*, 2–8, 21–23.

Bonatti, M., Karnopp, P., Soares, H. M., & Furlan, S. A. (2004). Evaluation of *Pleurotus ostreatus* and *Pleurotus sajor-caju* nutritional characteristics when cultivated in different lignocellulosic wastes. *Food Chemistry*, *88*, 425–428.

Buswell, J. A., & Chang, S. T. (1993). Edible mushrooms: Attributes and applications. In S. T. Chang, J. A. Buswell, & P. G. Miles (Eds.), *Genetics and breeding of edible mushrooms* (pp. 297–324). Philadelphia, PA: Gordon and Breach Sci. Publisher.

Chan, H. K. M. (1981). Consumption of edible mushroom in Hong Kong. *Mushroom Newsletter for the Tropics*, *1*(2), 18–22.

Cheung, L. M., & Cheung, P. C. K. (2005). Mushroom extracts with antioxidant activity against lipid peroxidation. *Food Chemistry*, *89*, 403–409.

FAO/WHO/UNU. (1985). Energy and protein requirement. *WHO Technical report Series No 774*. Geneva.

Fasidi, I. O., & Ekuere, U. V. (1993). Studies on *Pleurotus tuber-regium* (fries) singer: cultivation, proximate composition and mineral content of sclerotia. *Food Chemistry*, *48*, 255–258.

Fasidi, I. O., & Olorunmaye, K. S. (1994). Studies on *Pleurotus tuber-regium* (Fries) Singer, a Nigerian edible mushroom. *Food Chemistry*, *50*, 379–401.

Justo, M. B., Guzmán, G. A., Mejía, E. G., Díaz, C. L. G., Martínez, G., & Corona, E. B. (1998). Composición química de tres cepas mexicanas de setas (*Pleurotus ostreatus*). *Archivos Latinoamericanos de Nutricion*, *48*(4), 359–363.

Kadiri, M., & Fasidi, O. I. (1990). Variations in chemical composition of *Chlorophyllum molybdites* (Mayerex. Fr.) masses and *Pleurotus tuber-regium* (Fries) during fruitbody development. *Nigerian Journal of Science*, *24*, 86–89.

Lehninger, A. L. (1987). *Principles of Biochemistry*. CBS Publishers India edition 1011p.

Lopez, H. W., Leehardt, F., Coudray, C., & Resmesy, C. (2002). Minerals and phytic acid interactions: is it a real problem for human nutrition? *International Journal of food Science and Technology*, *37*, 727–739.

Makkar, H. P., Blummunuel, S. M., Bowwy, N. K., & Becken, K. (1993). Determination of tannin and their correlation with chemical and protein precipitation method. *Journal of Science of Food & Agriculture*, *61*, 161–185.

Manzi, P., Gambelli, L., Marconi, S., Vivanti, V., & Pizzoferrato, L. (1999). Nutrients in edible mushrooms: an inter-species comparative study. *Food Chemistry*, *65*(4), 477–482.

Mdachi, S. J. M., Nkunya, M. H. H., Vitas A. Nyigo, V. A., & Urusa, I. T. (2004). Amino acid composition of some Tanzanian wild mushrooms. *Food Chemistry*, *86*, 179–182.

Mendil, D., Uluzlu, O. D., Hasdemir, E., & Caglar, A. (2004). Determination of trace elements on some wild edible mushroom samples from Kastamonu, Turkey. *Food Chemistry*, *88*, 281–285.

Mlodecki, H., Latosa, W., & Maty, S. J. (1974). Hygienic evaluation of *Hybndum imbricatum* I-Values for amino acids, mineral and fats. *Nutrition Abstract Review*, *44* Abs 2184.

Oei, P. (1991). Manual on mushroom cultivation. *Techniques and opportunity for commercial applications in developing countries*, CTA, pp. 21–26.

- Ogundana, S. K., & Fagade, O. E. (1982). Nutritive value of some Nigerian edible mushrooms. *Food Chemistry*, 8(4), 263–268.
- Okhuoya, J. A., & Okogbo, F. O. (1990). Induction of edible sclerotia of *Pleurotus tuber-regium* (Fr.) Singer in the Laboratory. *Annals of Applied Biology*, 117, 295–298.
- Okolie, N. P., & Ugochukwu, E. N. (1989). Cyanide content of some Nigerian legumes and the effect of simple processing. *Food Chemistry*, 32, 209–216.
- Okwuraiwe, P. E., Ogunmodede, B. R., & Oyenuga, V. A. (1975). Changes in protein fractions during mechanical processing of recommended rice varieties. *Proceedings of the first African Nutrition congress, Ibadan, Nigeria*, 123–128.
- Ola, F. L., & Oboh, G. (2001). Nutrient distribution and zinc bioavailability. Estimation in some tropical edible mushrooms. *Nahrung*, 45, 67–68.
- Onwuliri, V. A., & Anekwe, G. E. (1993). Amino acid composition of *B. pinnatum* (Linn.). *Medical Science Research*, 21, 507–508.
- Onwuliri, V. A., & Obu, J. A. (2002). Lipids and other constituents of *Vigna unguiculata* and *Phaseolus vulgaris* grown in Northern Nigeria. *Food Chemistry*, 78, 1–7.
- Osagie, A. U. (1996). *Nutritive quality of plant foods, Post-Harvest Research unit of the University of Benin* (1st ed.). Nigeria: Benin city pp. 221–244.
- Osagie, A. U. (1998). Antinutritional constituents of ten staple foods grown in Nigeria. *Tropical Science*, 36, 109–115.
- Oso, B. A. (1977). *P. tuber-regium* from Nigeria. *Mycologia*, 69, 271–279.
- Patrabansh, S., & Madan, M. (1997). Studies on cultivation, biological efficiency and chemical analysis of *Pleurotus sajor-caju* (Fr.) Singer on different bio-wastes. *Acta Biotechnology*, 17(2), 107–122.
- Perkin-Elmer (1982). *Analytical methods for atomic absorption spectrophotometry*. USA: Perkin-Elmer Corp.
- Plummer, D. T. (1971). *An introduction to practical biochemistry*. New York: McGraw Hill pp. 112–113.
- Shashirekha, M. N., Rajathnam, S., & Bano, Z. (2002). Enhancement of bioconversion efficiency and chemistry of mushroom *P.sajor caju* (Berk & Br.) Sacc. produced on spent rice straw substrate supplemented with oil seed cakes. *Food Chemistry*, 76, 27–31.
- Spackman, D. H., Stein, W. H., & Moore, S. (1958). Automatic recording apparatus for use in chromatography of amino acids. *Analytical Chemistry*, 30, 1190–1206.