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Heavy Metal Levels in Fruiting Bodies of Edible and Non-edible Mushrooms from the Niger Delta Region of Nigeria

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ABSTRACT

Fruiting bodies of ten mushroom species (edible & non-edible) were analysed for their heavy metals content. Results indicated that the concentration of heavy metals accumulated by the mushrooms were species-dependent. *Formes applanatus* had the highest concentration of Zn and Cu, while the levels of Pb and Cd were highest in the non-edible species of *Paragyrodon sphaerosporus*. Iron was highly accumulated by *Polyporus frondosis* with a maximum value of 731.6 ± 13.2 mg kg^{-1} DM. The heavy metal accumulating potential of the mushrooms generally decreased in the trend: Fe > Zn > Cu > Mn > Pb > Cd. However, the levels in all the edible species (*Polyporus frondosis, Armillariella mellea, Pleurotus sapidus, Polyporus sulphureus, Pleurotus ostreatus*) did not exceed the stipulated FAO/WHO (1976) dietary standards.

Key Words: Heavy metals; Mushroom; Dietary standards; Accumulating potential; Niger delta

INTRODUCTION

Today, with the development of better technologies and greater realization of their nutrient values, mushrooms have occupied an important place in food in several parts of the world (Hafiz *et al*., 2003). Researches on the nutritive value of edible mushrooms indicate that they may be regarded as healthy foods, even though they are deficient in calories and fat and consist of about 90% water (Nylen, 1985; Manzi, *et al*., 1999; Sanmee *et al*., 2003). Mushrooms have been reported to be of therapeutic value, useful in preventing diseases such as hypertension, hypercholesterolemia, cancer and also having antibacterial and antiviral properties. These functional characteristics are mainly due to their chemical composition (Cochran, 1978; Chovot *et al*., 1997; Gunde-Cinerman, 1999; Manzi *et al*., 2001).

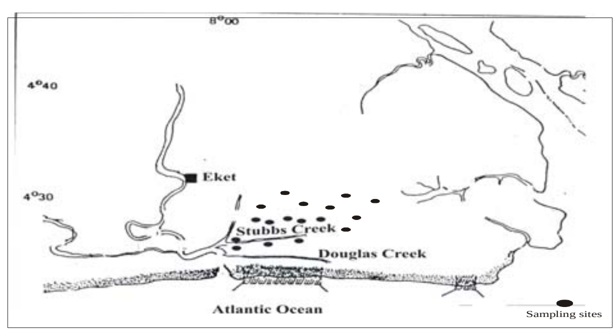
Compared to green plants, mushrooms can build up large concentrations of some heavy metals, particularly cadmium (Cd^{2+}), mercury (Hg^{2+}) and lead (Pb^{2+}) (Kuusi *et al*., 1981; Kalac & Svoboda, 2000). This suggests that mushrooms possess a very effective mechanism that enables them readily to take up heavy metals from the substrates (Turkekul *et al*., 2004). Concentrations of heavy metals have been observed in the fruiting bodies of mushrooms collected adjacent to heavy metal smelters (Kalac *et al*., 1991; Kalac *et al*., 1996; Isiloglu *et al*., 2001), landfills of sewage sludge (Zabowski *et al*., 1990), emission areas (Cibulka *et al*., 1996; Lepsova & Mejstrik, 1998).

In the South-Eastern part of the Niger Delta region of Nigeria, the climate is mild and rainy. During the rainy season, average rainfall lies between 3500 – 4000 mm with temperatures in the range of 24–26°C. These conditions favor fungal growth of edible mushrooms and toadstools. The inhabitants of these areas consume edible mushrooms because of the nutritive value, flavor and abundance and as an alternative to the costly seafoods. However, studies have not been carried out on mushrooms in this oil impacted area of Nigeria. In this work, Fe, Zn, Cu, Mn, Cd and Pb in the fruiting bodies of ten mushroom samples collected from Stubbs Creek forest reserve area within Nigeria were determined using atomic absorption spectrometry.

MATERIALS AND METHODS

The sporocarps of ten mushroom species including *Polyporus frondosis; Formes applanatus; Paragyrodon sphaerosporus; Poria sp; Armillariella mellea; Pleurotus sapidus; Gonoderma lucidum; Pleurotus ostreatus; Polyporus sulphureus; Nectria cinnabarina* were collected from Stubb Creek forest reserve area located within the Niger Delta region of Nigeria during the rainy season (Fig. 1). The sporocarp of the species was carefully cleaned, cut and sun-dried for five days. They were then oven-dried (Gallenkamp, DV 333) at 45°C for 40 h. Dried samples were homogenized using an agate homogenizer, and stored in pre-cleaned polyethylene bottles, prior to analyses. All reagents were of analytical grade, except otherwise stated. Double deionized water was used for all dilutions. Each

Fig. 1. Map of the Niger Delta region showing sampling area



sample (1 g) was placed in a porcelain crucible and ashed at 450°C for 18 – 24 h; then the ash was dissolved in 2 mL concentrated HNO_3 (BDH), heated again at 450°C for 4 h and dissolved in 1 mL concentrated H_2SO_4 (BDH), 1 mL HNO_3 and 1 mL H_2O_2 (BDH), and then diluted with double deionised water up to a volume of 25 mL. A blank digest was carried out in the same way.

For elemental analysis, an atomic absorption spectrometer (Pye Unicam, Model 919) was used. Pb and Cd levels in the samples were determined using HGA graphite furnace, using argon as inert gas. Other measurements were carried out in an air/acetylene flame. All the experimental values were reported in mg kg^{-1} DM. Results were expressed as means ± S.D of triplicate analysis. Data were evaluated using one way analysis of variance.

RESULTS AND DISCUSSION

The families, habitat and edibility of the mushrooms under study are given in Table I. Heavy metal concentrations in the fruiting bodies of the macrofungi varied generally between species (Table II). This may be ascribed to differences in substrate composition, as determined by the ecosystem and great differences in uptake of individual metals by the mushroom species (Tyler, 1982; Michelot *et al*., 1998; Kalac & Svoboda, 2000). Kalac and Svoboda (2000) reported that the age of the fungal fruiting body or its size is of less importance in the accumulation of heavy metals by mushrooms. However, variations in heavy metal accumulation could be ascribed to individual species potential and their ecosystem (Seeger, 1982).

Zinc was accumulated in high concentrations (137.4 mg kg^{-1} DM) by *Fomes applanatus*, while the least concentration of 30.1 mg kg^{-1} DM was found in *Nectria cinnabarina* (Fig. 2). Zinc is widespread in living organisms due to its biological significance. The levels reported here are in agreement with values reported by Turkekul *et al.* (2004), Tuzen *et al.* (1998) and Kalac and Svoboda (2000).

Minimum and maximum concentration of Cu accumulated by the mushrooms was 29.3 and 60.8 mg kg^{-1} DM respectively, with *F. applanatus* accumulating the highest Cu concentration of 60.8 mg kg^{-1} DM (Fig. 3). Isildak *et al.* (2004) reported a Cu concentration of 107 ± 8.5 µg g^{-1} in wild growing *Agaricus biosporus* from the middle black sea region of Turkey. However, the Cu range obtained in this study is in agreement with reported range of 10 – 70 µg g^{-1} (Anderson *et al*., 1982; Vetter, 1994; Isildak *et al*., 2004; Agrahar-Murugkar & Subbulakshmi, 2005).

Fig. 2. Distribution of Zn in mushroom species: A, *Polyporus frondosis*; B, *Formes applanatus*; C, *Paragyrodon sphaerosporus*; D, *Poria* spp; E, *Armillariella mettea*; F, *Pleurotus sapidus*; G, *Gonoder lucidum*; H, *Pleurotus ostreatus*; I, *Polyporus sulphureus*; J, *Nectria cinnabarina*

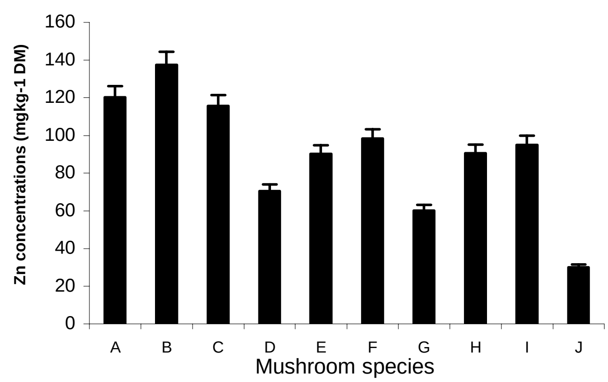


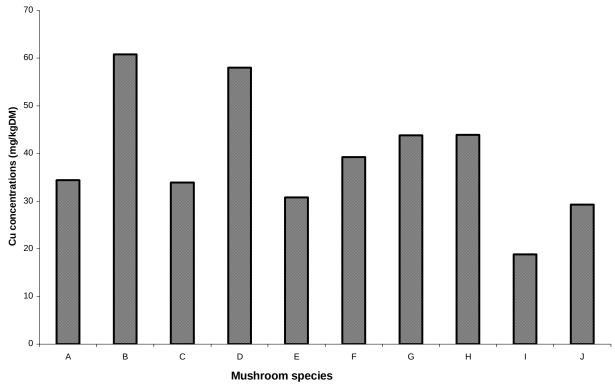
Table I. Families, habitat and edibility of mushroom species under study

No	Mushroom species	Sub-Class	Family	Habitat	Edibility
A	*Polyporus frondosis*	Homobasidiomycetidae	Polyporaceae	Tree trunks and logs	Edible
B	*Fomes applanatus*	Homobasidiomycetidae	Polyporaceae	Tree trunks and logs	Non-edible
C	*Paragyrodon sphaerosporus*	Homobasidiomycetidae	Boletaceae	Tree trunks and logs	Non- edible
D	*Poria sp.*	Homobasidiomycetidae	Polyporaceae	Tree trunks and logs	Non- edible
E	*Armillariella mellea*	Homobasidiomycetidae	Agaricaceae	Tree stumps, trunks and logs	Edible
F	*Pleurotus sapidus*	Homobasidiomycetidae	Agaricaceae	Logs and tree stumps	Edible
G	*Gonoderma lucidum*	Homobasidiomycetidae	Agaricaceae	Logs and tree stumps	Non-edible
H	*Pleurotus ostreatus*	Homobasidiomycetidae	Polyporaceae	Tree trunks and logs	Edible
I	*Polyporus sulphureus*	Homobasidiomycetidae	Polyporaceae	Tree trunks and logs	Edible
J	*Nectria cinnabarina*	Pyrenomycetes	Nectriaceae	Parasite of fruit trees	Non- edible

Table II. Heavy metal concentrations in fruiting bodies of mushrooms (mg/kg DM) (mean ± SD) n = 5

Mushroom samples	Zn	Cu	Pb	Mn	Cd	Fe
Polyporus frondosis	120.1 ± 6.7	34.4 ± 2.3	0.4 ± 0.01	37.3 ± 1.8	0.2 ± 0.01	731.6 ± 19.5
Fomes applanatus	137.4 ± 5.2	60.8 ± 3.1	0.7 ± 0.02	25.8 ± 1.5	0.3 ± 0.02	560.7 ± 20.8
Paragyrodon sphaerosporus	115.6 ± 5.1	33.9 ± 3.1	1.2 ± 0.20	21.5 ± 2.4	0.4 ± 0.01	545.6 ± 9.7
Poria sp.	70.4 ± 4.3	58.3 ± 3.6	0.4 ± 0.02	24.4 ± 3.9	0.2 ± 0.01	631.2 ± 11.8
Armillariella mellea	90.3 ± 6.6	30.8 ± 3.1	1.0 ± 0.10	31.3 ± 2.7	0.3 ± 0.02	480.9 ± 8.1
Pleurotus sapidus	98.4 ± 5.5	39.2 ± 3.1	0.8 ± 0.05	28.4 ± 4.3	0.1 ± 0.02	473.5 ± 6.2
Gonoderma lucidum	60.1 ± 3.4	43.8 ± 4.4	0.7 ± 0.06	30.4 ± 2.6	0.3 ± 0.04	604 .8 ± 11.2
Pleurotus ostreatus	90.6 ± 6.2	45.9 ± 2.7	0.4 ± 0.05	39.8 ± 2.9	0.3 ± 0.02	407.7 ± 9.3
Polyporus sulphureus	95.1 ± 4.8	18.8 ± 1.7	1.1 ± 0.03	19.5 ± 2.3	0.2 ± 0.01	337.5 ± 6.2
Nectria cinnabarina	30.1 ± 1.8	29.3 ± 1.7	1.9 ± 0.14	19.3 ± 2.1	0.2 ± 0.02	277.2 ± 5.9

Fig. 3. Distribution of Cu in mushroom species: A, *Polyporus frondosis*; B, *Formes applanatus*; C, *Paragyrodon sphaerosporus*; D, *Poria* spp; E, *Armillariella mettea*; F, *Pleurotus sapidus*; G, *Gonoder lucidum*; H, *Pleurotus ostreatus*; I, *Polyporus sulphureus*; J, *Nectria cinnabarina*



Cadmium concentrations in the mushroom samples ranged from 0.1 to 0.4 mg kg^{-1} DM (Fig. 4), with *Paragyrodon sphaerosporus* and *Pleurotus sapidus* recording the highest and least concentrations, respectively. Cadmium is accumulated mainly in the kidneys and liver and its level in blood serum increases considerably following mushroom consumption, however the reported Cd levels in this study are in agreement with values reported by Sova *et al*. (1991), Cibulka *et al*. (1996).

Lead was remarkably accumulated by *Paragyrodon sphaerosporus* (1.2 mg kg^{-1} DM) (Fig. 5). Very low level of Pb was found in Poria sp. and *Pleurotus ostreatus* (0.4 mg kg^{-1} DM). Similar observation had earlier been reported by Kalac *et al*. (1989b), Falandysz *et al*. (1994) and Yilmaz *et al*. (2003). Mn concentrations had a minimum and maximum value of 19.3 and 39.8 mg kg^{-1} DM in the species *Nectria cinnabarina* and *Pleurotus ostreatus* respectively (Fig. 6). Manganese is an important trace element in many enzyme systems and values obtained in this study are remarkably lower than values reported for mushrooms collected from the Khasi Hills of Meghalaya (Agrahar-Murugkar & Subbulakshmi, 2005). However, there is relative agreement with other reports by Falandysz and Bona, (1992), Vetter (1994).

The highest Fe concentration was found in *Polyprus frondosis* (731.6 mg kg^{-1} DM) and the least concentration (277.2 mg kg^{-1} DM) in *Nectria cinnabarina* (Fig. 7). Latiff *et al*. (1996) reported an Fe concentration range of 100 – 1216 µg g^{-1} in mushroom. Similarly, Turkekul *et al*. (2004) reported Fe content of 568 – 3562 mg kg^{-1} DM in mushroom samples from Tokat, Turkey. Variations in Fe content may be attributed to the different mushroom species, uptake levels and the levels accumulated by the substrate from, which the mushrooms were harvested.

CONCLUSION

Among the non-edible species: *F. applanatus* and

Fig. 4. Distribution of Cd in mushroom species: A, *Polyporus frondosis*; B, *Formes applanatus*; C, *Paragyrodon sphaerosporus*; D, *Poria* spp; E, *Armillariella mettea*; F, *Pleurotus sapidus*; G, *Gonoder lucidum*; H, *Pleurotus ostreatus*; I, *Polyporus sulphureus*; J, *Nectria cinnabarina*

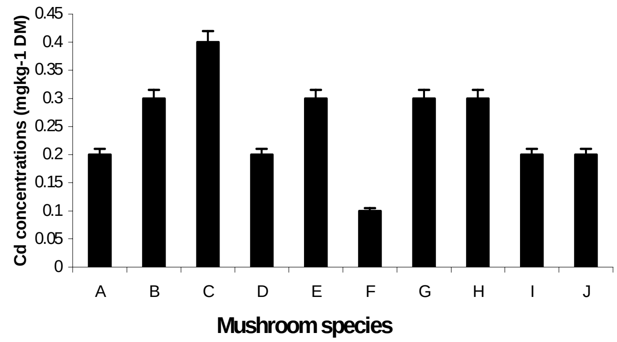


Fig. 5. Distribution of Pb in mushroom species: A, *Polyporus frondosis*; B, *Formes applanatus*; C, *Paragyrodon sphaerosporus*; D, *Poria* spp; E, *Armillariella mettea*; F, *Pleurotus sapidus*; G, *Gonoder lucidum*; H, *Pleurotus ostreatus*; I, *Polyporus sulphureus*; J, *Nectria cinnabarina*

Fig. 6. Distribution of Mn in mushroom species: A, *Polyporus frondosis*; B, *Formes applanatus*; C, *Paragyrodon sphaerosporus*; D, *Poria* spp; E, *Armillariella mettea*; F, *Pleurotus sapidus*; G, *Gonoder lucidum*; H, *Pleurotus ostreatus*; I, *Polyporus sulphureus*; J, *Nectria cinnabarina*

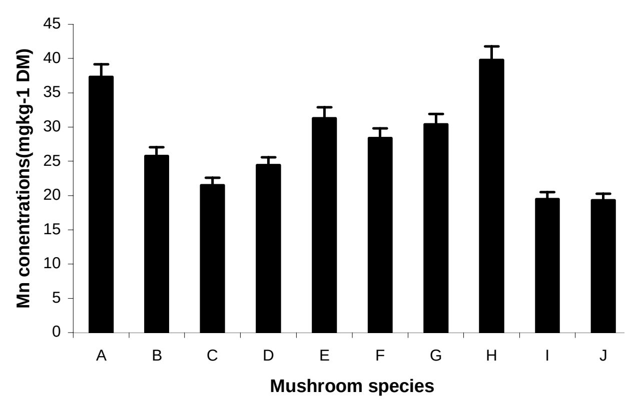
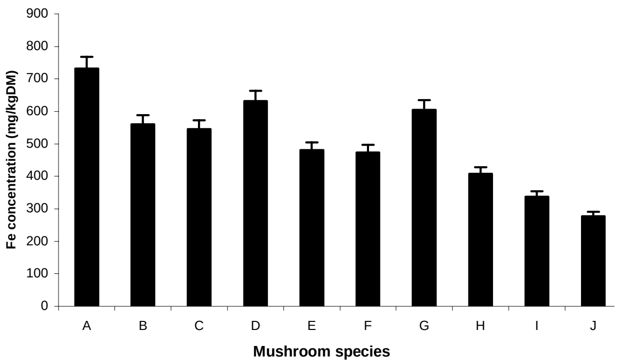


Fig. 7. Distribution of Fe in mushroom species: A, *Polyporus frondosis*; B, *Formes applanatus*; C, *Paragyrodon sphaerosporus*; D, *Poria* spp; E, *Armillariella mettea*; F, *Pleurotus sapidus*; G, *Gonoder lucidum*; H, *Pleurotus ostreatus*; I, *Polyporus sulphureus*; J, *Nectria cinnabarina*



Paragyrodon sphaerosporus accumulated very high concentrations of Zn, Cu, Pb, and Cd, while low metal content were found in the edible ones. However, the ability of the edible mushrooms to accumulate detectable concentrations of Pb, and Cd is a pointer to health risk associated with excessive consumption of mushrooms harvested from the oil impacted Niger Delta region of Nigeria.

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