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Research Article

Bioaccumulation of Heavy Metals in the Fruiting Bodies of Four Edible Mushrooms Collected From Polluted Areas in Akure, Ondo State, Nigeria

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Abstract: The present study investigated the concentrations of some heavy metals (Pb, Cu, Cr, Cd, Fe and Ni) in the cap and stipe of four edible species of mushroom (*Lentinus squarrosulus*, *Volvariella volvacea*, *Psathyrella candolleana* and *Termitomyces mammiformis*). Mushroom samples were collected from two polluted areas (Ondo road and Oda road) in Akure, Ondo State, Nigeria. These areas are prone to high vehicular and other anthropogenic activities. The mushrooms were sun dried, separated into cap and stipe and analysed for the heavy metals using Atomic Absorption Spectrophotometry. All element concentrations were determined on dry weight basis. The results showed that there was a variation in the concentration of heavy metals in different edible mushroom species analysed. Results revealed variations in the distribution of the metals in the cap and stipe of the mushroom species. In the cap of the mushrooms, the highest concentration (mg/kg) of Cu (797.34), Cd (34.92) and Ni (54.88) were obtained in *P. candolleana* while Cr (94.98) and Fe (1267.36) concentrations were highest in *T. mammiformis*. Highest lead concentrations (14.98) were obtained in *L. squarrosulus* and *P. candolleana*. In the stipe of the mushrooms, the highest concentrations (mg/kg) of Cu (753.79), Cr (94.89), Cd (29.96) and Ni (49.92) were obtained in *L. squarrosulus* while the concentrations of Pb (12.50) and Fe (1308.43) were highest in *P. candolleana*. Generally, the values obtained for the heavy metals exceeded the recommended limits for human consumption. Vehicular and other anthropogenic activities in the study areas could be the most likely sources of the contamination. Hence, consumption of mushrooms from such areas poses risks to human health.

Keywords: bioaccumulation, heavy metals, mushrooms, polluted area, anthropogenic activities, Ondo State.

INTRODUCTION

In recent decades, environmental pollution is one of the most serious problems in many countries. There has being a constant increase in the emission of heavy metals from various anthropogenic activities (Ademoroti, 1996). Heavy metals are capable of bio accumulating in living organisms thus, their persistence in the environment pose a threat to living organisms (Audu and Lawal, 2005). Compared to green plants, mushrooms can build up large concentrations of some heavy metals, particularly cadmium, mercury and lead (Kuusi *et al.*, 1981; Kalac and Svoboda, 2000). This implies that mushrooms possess a very effective mechanism that enables them to readily uptake heavy metals (Turkekul *et al.*, 2004). Because of this effective mechanism of heavy metal uptake, mushrooms can act as an effective bio sorbent of toxic metals. The metal content in fruiting bodies of mushrooms can be influenced by several factors such as the density and depth of the mycelium, species of mushroom, various environmental factors and soil properties, type of substrate, geochemistry of substrate and distance from the source of pollution (Nikkarinen and Mertanen, 2004; Garcia *et al.*, 2013).

Mushrooms grow naturally in Nigeria during the early and late rainy seasons (Gbolagade *et al.*, 2006). They are usually found in forests, grasslands, damp rotten logs, on living trees and other plants. In, Nigeria, edible mushrooms are a popular and favourite delicacy. There has being an increase in their collection

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and consumption over the years from different locations due to their flavour and taste. They are also considered as a source of revenue as some people specialize in their collection and sale.

Many wild edible mushroom species are known to accumulate high levels of heavy metals such as As, Cd, Ni and Hg and these are toxic for the people when consumed (Turkekul *et al.*, 2004; Kalač, 2001; Svoboda *et al.*, 2006)). Many elements are essential for the human metabolism such as Fe, Zn, Mn, Cu, Cr, Se, but in low concentrations because they are enzyme activators. These essential elements become toxic in the situation of increasing their concentrations too much (Stihi *et al.*, 2011). The determination of heavy metal concentration in the fruiting bodies of mushrooms is essential in dietary intake studies (Stihi *et al.*, 2009). Accurate food consumption data are estimating the adequacy of essential nutrient intakes and assessing exposure risks from intake of toxic non-essential metals (Soylak *et al.*, 2005). It has been reported that trace elements above threshold concentration levels can increase mortality and mutagenic effects in human bodies (Olumuyiwa *et al.*, 2007). Hence, it is necessary to investigate the level of metals concentration in wild growing edible mushrooms. High levels of metal concentration have been reported in mushrooms collected near metal polluted areas and metal smelters (Collin-Hansen and Andersen, 2003; Svoboda *et al.*, 2000).

Mushrooms are a distinct group of living organisms with considerable nutritional and pharmaceutical value. They are documented as being rich in proteins, minerals, vitamins and low in lipids (Pathak *et al.*, 1997). They could be a source of many different nutraceuticals such as unsatured fatty acids, phenolic compounds, tocopherols, ascorbic acid and carotenoids. Thus, they might be used directly in diet and health promoting programmes, taking advantage of the additive and synergistic effects of all the bioactive compounds present (Pereira *et al.*, 2012).

The aim of this study was to investigate the level and distribution of some heavy metals in the fruiting bodies of four edible mushrooms collected from two polluted areas in Akure, Ondo State, Nigeria with a view to guiding their consumption.

MATERIAL AND METHODS

Collection and Identification of Mushrooms

Four different species of wild growing mushrooms (*Lentinus squarrosulus, Volvariella volvacea, Psathyrella candolleana* and *Termitomyces mammiformis*) were collected from two polluted areas in Akure, Ondo State, Nigeria in the year 2016. These areas include Ondo road and Oda road which are prone to high vehicular and other anthropogenic activities. The mushrooms were properly identified at the herbarium unit of the Department of Plant Science and Biotechnology, Ekiti State University, Ado-Ekiti. The mushrooms were separated into cap and stipe for the study.

Determination of Heavy Metals in the Mushrooms

The cap and stipe of each mushroom were sun dried for seven days. They were then oven-dried at 45^0C for 40 h. Dried samples were homogenized and stored in pre-cleaned polyethylene bottles prior to analyses. All reagents used were of analytical grade. In detection of elements like Cu, Pb, Cd, Fe, Ni and Cr, 0.5g each of the powdered samples were weighed into beakers and digested with concentrated nitric acid and perchloric acid in a ratio of 4:1 respectively (Ayodele *et al.*, 2013). The mixtures were placed on a hot plate set at 135^0C for two hours. The clear digested samples were filtered. The filtrates were then made up to 50 ml each with distilled water. The digested mushroom samples were analysed using an atomic absorption spectrophotometer (Buck scientific model, 210). The results of the analyses were expressed in mg/kg.

RESULTS

The profile of the mushrooms under study is shown in Table 1. The four mushrooms belong to four different families which include Polyporaceae, Plutaceae, Psathyrellaceae and Lyophyllaceae.

The results of the findings revealed the presence of heavy metals such as Pb, Cu, Cr, Cd, Fe and Ni in the cap and stipe of the studied mushrooms and their mean concentrations are presented in Tables 2 and 3 respectively. The mean heavy metal contents (mg/kg) in the cap of the mushrooms ranged from 7.48 in *V. volvacea* to 14.98 in *L. squarrosulus* for Pb, 487.42 in *L. squarrosulus* to 797.34 in *P. candolleana* for Cu, 28.67 in *L. squarrosulus* to 94.98 in *T. mammiformis* for Cr, 16.29 in V. volvacea to 34.98 in *P. candolleana* for Cd, 742.15 in *L. squarrosulus* to 1267.37 in *T. mammiformis* for Fe and 22.45 in *L. squarrosulus* to 54.88 in *P. candolleana* for Ni (Table 2).

The mean heavy metal contents (mg/kg) in the stipe of the mushrooms ranged from 4.98 in *V*. volvacea to 12.50 in *P. candolleana* for Pb, 536.57 in *V*. volvacea to 753.79 in *L. squarrosulus* for Cu, 52.17 in *V*. volvacea to 94.87 in *L. squarrosulus* for Cr, 17.39 in *V*. volvacea to 29.96 in *L. squarrosulus* for Cd, 789.94 in *V*. volvacea to 1308.43 in *P. candolleana* for Fe and 24.95 in *T. mammiformis* to 49.92 in *L. squarrosulus* for Ni (Table 3).

The concentrations of the heavy metals in the cap and stipe of each mushroom species are shown in Table 4. The concentrations obtained for the heavy metals in the cap of *T. mammiformis* and *V. volvacea* were more than those recorded for the stipe with the exception of nickel in *V. volvacea*. However, the concentrations of all the heavy metals except lead were more in the stipe of *L. squarrosulus* than those obtained in the cap. In *P. candolleama*, lead, copper, cadmium and nickel were more concentrated in the cap while chromium and iron were more concentrated in the stipe.

Table 1: Profile of the mushroom species

Mushroom species	Common/local name	Family	Location
Lentinus squarrosulus	Erirokiro	Polyporaceae	Ondo road
Volvariella volvacea	Ogiri agbe	Plutaceae	Ondo road
Psathyrella candolleana	Ekikanko	Psathyrellaceae	Ondo road
Termitomyces mammiformis	Osu rooro	Lyophyllaceae	Oda road

Table 2: Heavy metal levels (mg/kg) in the cap of the mushrooms

Mushroom species	Pb	Cu	Cr	Cd	Fe	Ni
A	14.98 ±1.17	487.42 ±8.09	28.68 ±2.74	16.21 ±1.54	742.15 ±17.31	22.45 ±2.01
B	7.48 ±0.60	601.30 ±11.81	57.37 ±5.62	24.96 ±2.20	998.00 ±20.06	27.45 ±2.07
C	14.98 ±1.15	797.34 ±18.37	64.86 ±4.45	34.92 ±2.18	1219.81 ±32.15	54.88 ±3.61
D	12.48 ±1.12	735.29 ±14.50	94.98 ±6.06	32.49 ±2.85	1267.36 ±31.34	32.49 ±2.43

Values are means of three replicates

A**:** *Lentinus squarrosulus,* B: *Volvariella volvacea,* C**:** *Psathyrella candolleana,* D: *Termitomyces mammiformis*

Table 3: Heavy metal levels (mg/kg) in the stipe of the mushrooms

Mushroom species	Pb	Cu	Cr	Cd	Fe	Ni
A	9.98 ±1.16	753.79 ±16.10	94.88 ±5.57	29.96 ±3.02	1240.51 ±29.82	49.92 ±3.11
B	4.98 ±0.43	536.57 ±12.05	52.17 ±3.03	17.39 ±2.05	789.94 ±16.13	37.26 ±2.90
C	12.50 ±1.91	721.63 ±13.60	79.90 ±5.81	27.48 ±2.63	1308.43 ±34.02	42.45 ±3.08
D	7.50 ±0.54	558.88 ±13.11	59.88 ±4.01	17.47 ±2.11	843.31 ±18.77	24.95 ±2.49

Values are means of three replicates

A**:** *Lentinus squarrosulus*, B: *Volvariella volvacea*, C**:** *Psathyrella candolleana*, D: *Termitomyces mammiformis*

Table 4: Heavy metal levels (mg/kg) in the cap and stipe of each mushroom species

Mushroom species		Pb	Cu	Cr	Cd	Fe	Ni
A	Cap	14.98	487.42	28.67	16.21	742.14	22.45
	Stipe	9.98	753.79	94.88	29.95	1240.51	49.92
B	Cap	7.48	601.29	57.37	24.95	998.00	27.45
	Stipe	4.97	536.56	52.16	17.39	789.94	37.26
C	Cap	14.98	797.34	64.85	34.92	1219.81	54.88
	Stipe	12.50	721.63	79.90	27.47	1308.43	42.45
D	Cap	12.48	735.29	94.98	32.49	1267.36	32.49
	Stipe	7.49	558.88	59.88	17.47	843.31	24.95

A**:** *Lentinus squarrosulus,* B: *Volvariella volvacea,* C**:** *Psathyrella candolleana,* D: *Termitomyces mammiformis*

DISCUSSION

The knowledge of the heavy metal contents of wild growing mushrooms is important for public health due to the fact that some mushrooms are widely consumed for food in many countries. The present study revealed the presence of heavy metals such as Pb, Cu, Cr, Cd, Zn, Fe and Ni in varying quantities in the edible mushrooms studied. This is in agreement with the reports of several authors (Udochukwu *et al.*, 2004; Stihi *et al.*, 2009; Arvay *et al.*, 2014) who have worked on different species of edible mushrooms. The range of Pb (4.98 – 14.98 mg/kg) obtained in the present study is higher than 0.82 – 1.99 mg/kg and 0.9 – 2.6 mg/kg reported for edible mushrooms by Soylak *et al*. (2005) and Sesli *et al*. (2008) respectively. However, the range in this study is lower than values (over 100 mg/kg) reported by Kalac *et al*. (1991) in edible mushrooms collected in the vicinity of metal smelters. The highest value of Pb (11.72 mg/kg) reported for some edible mushrooms by Yamac *et al*. (2007) fell within the range observed in the present study. The range of Cu content (487.42 - 797.34 mg/kg) obtained in the present study is higher than values reported for some edible mushrooms by previous authors (Ita *et al.,* 2006; Stihi *et al.,* 2011; Elekes *et al.,* 2010). Copper concentrations in the accumulating mushroom species are usually 100-300 mg/kg of dry matter which is not considered a risk for human health (Kalac and Svoboda, 2000) and a concentration higher than those in vegetable should be considered as a nutritional source of this element (Sesli *et al.,* 2008). The range obtained for Cr (28.67 – 94.98 mg/kg) in this study is higher than values reported in edible mushrooms by previous workers (Arvay *et al.,* 2014; Siric *et al.,* 2014) but lower than the maximum value (370.4 mg/kg) reported by Mugivisha *et al.* (2017) in some mushrooms harvested from polluted areas in South Africa. However, the values (73.8 mg/kg) and (72.44 mg/kg) reported for Cr by Yamac *et al.* (2007) and Seni *et al*. (2012) respectively fell within the range reported in the present study. The range of Cd (16.21-34.92 mg/kg) obtained in the present study is lower than the value (92.45 mg/kg and 300 mg/kg) reported by Ndimele *et al.* (2017) and Schmitt and Meisch (1985) respectively in some wild mushroom species. However, it is higher than ranges (1.01-19.55 mg/kg) and (2.25 - 4.88 mg/kg) reported by Seni *et al.* (2012) and Udochukwu *et al*. (2014) respectively in wild edible mushrooms. In most edible mushroom species growing in unpolluted areas, cadmium levels are below 2 mg/kg d/w (Kalac *et al.,* 2004). The high Cd concentration observed in the present study is of particular concern because Cd is known to be a toxic element as it inhibits many life processes (Vetter, 1993). However, the bioavailability of Cd in mushrooms is as low as 10% due to various detoxification mechanisms which make it biologically unavailable (Kalac *et al.,* 2004). The high level of Pb and Cd accumulated by these edible mushrooms is a pointer to the health risks associated with excessive consumption of mushrooms from these sources. The range reported for Fe (742.15 – 1308.43 mg/kg) in the present study is higher than the value (434 mg/kg) reported in a wild edible mushrooms (Arvay *et al.,* 2014), comparable to the value (731.6 mg/kg) reported by Ita *et al.* (2006) in *Polyporus frondosis*, an edible mushroom collected from the Niger Delta region of Nigeria but lower than the value (11460 mg/kg and 2075 mg/kg) reported for some edible mushrooms by Yamac *et al.* (2007) and Borovicka and Randa (2007). The range reported for Ni (22.45 – 54.88mg/kg) in the present study is comparable to the range reported by Yamac *et al.* (2007) and Mugivhisa *et al.* (2017) but higher than value reported for mushrooms by Chen *et al*. (2009).

The concentrations of the heavy metals varied generally among the species in the present study. This suggests that the heavy metal content of most mushrooms is species-dependent since some of these mushrooms were collected from the same habitat. It has been reported that the concentrations of trace elements are not only related to the particular mushroom species and collection sites but also to other factors such as mycelium and distance from the pollution source (Kalac *et al.,* 1991). Other factors as reported by Kalac and Svoboda (2000) include differences in substrate composition and uptake of individual metals by the mushroom species.

The results of this findings revealed that there were variations in the distribution of the heavy metals in the cap and stipe of the four mushroom species. This is in agreement with previous studies (Thomet *et al.,* 1999; Kalac *et al.,* 2004; Elekes *et al.,* 2010).

CONCLUSION

The present study revealed that there were variations in the distribution of heavy metals in the cap and stipe of the mushroom species. The heavy metal levels in the mushrooms in the present study were relatively high. Hence, the cultivation of mushrooms in heavy metal – polluted substrates should be discouraged. Of particular note is the ability of these edible mushrooms to accumulate high levels of Pb and Cd which is a pointer to the health risks associated with the consumption of mushrooms harvested from these areas.

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