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Evaluation of Some Heavy Metals' Concentration Levels in Fresh and Smoke-Dried Porcupine (*Atherur africanus*) Meat

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Abstract

In this study, fresh and smoke-dried porcupine meat were assessed for levels of some metal elements contamination. Muscle, liver and kidney samples of wild porcupine were purchased from the three agro ecological zones of Edo State, Nigeria and chemically analyzed using Atomic Absorption Spectrophotometer (AAS) at the appropriate wavelengths (nm) for Lead (Pb), Chromium (Cr), Cadmium (Cd), Arsenic (As) and Nickel (Ni). Generated data were statistically analyzed using GENSTAT in a 3×3×2 randomized complete block design. The concentration of heavy metals in raw and smoke-dried porcupine meat was observed to be between 0.015 mg/kg to 0.392 mg/kg. Cadmium and Arsenic were not detected in all samples analyzed. Concentrations (mg/kg) of Pb, Cr and Ni of assessed organs range from 0.123 - 0.392; 0.074 - 0.347; and 0.087 - 0.231 respectively in the raw porcupine and 0.047 – 0.170; 0.027 – 0.145 and 0.015 – 0.111 respectively in the smoke-dried porcupine. The concentration of the studied heavy metals was significantly higher ($P < 0.05$) in raw porcupine samples. The domestication of porcupine by public and private sectors as a viable and environmentally-friendly alternative is thus recommended in order to prevent them from contamination by heavy metals, especially nickel whose amounts exceeds permissible limits.

Keywords: *Contamination; Domestication; Fresh; Heavy metals; Porcupine meat; Smoke-drying*

Introduction

The major sources of protein intake in Africa are from animal and animal by-products. Among animal products, bush meat is an important delicacy in local soup preparations to many Africans. In Nigeria, bush meat could constitute up to 84% of total animal protein intake in areas near large forest reserves. In most cases, these are majorly harvested from the wild and as such, their habitats are often times contaminated with heavy metals discharge as a result of industrial activities. These heavy metals find their way into the organs of these animals through their diet and consequently build up in these animal products. The consumption of such heavy metal contaminated meats over a period of time and in large quantity poses a great risk to human health [1]. For this reason, the presence of heavy metals in animal food products has continued to receive a lot of attention from food scientists and researchers. The main threats to human health from heavy metals are associated with exposure to lead, cadmium, nickel, and arsenic [2]. Studies have shown that acute, large dose of some heavy metals, particularly arsenic causes gastric intestinal damage with profuse watery diarrhea, bleeding and death [3].

Bush meat is a general term applied to meat obtained from any wild terrestrial mammal, bird, reptile or amphibian harvested for subsistence or trade, mostly illegally [4,5]. Several studies have demonstrated that game meat contain low levels of fat and a higher proportion of polyunsaturated (omega-3) fatty acids compared with meat from conventional species like beef, lamb and pigs [6]. Bush meat is one of the most valuable tropical forest products after timber. It is an important source of protein, widely consumed in both rural and urban areas [7]. Bush meat has been part of the local diet for centuries [7]. It often provides cheap and rich source of protein in regions where meat from domestic animals such as cattle, goats and chickens are scarce or more expensive. Bush meat is one of those forest products which have been demonstrated to have major significance for rural communities, particularly in the humid and sub humid tropics. National estimates of the value of the domestic trade in bush meat range from US$42 to US$205 million across countries in West and Central Africa [8]. Game meat provides protein for many poor rural families without land or access to agricultural markets. Often, there is no replacement for bush meat, which represents 80% of all animal-based household protein consumed in much of Central Africa [9].

The bushed-tailed porcupine (*Atherur africanus*) is one of the most commonly consumed bush meat in parts of Africa. It is a hystricomorphic rodent which is found in the forest of West and Central Africa with average weight of 3 kg. It is widely hunted and constitute a favorite protein source for both rural and urban populations in Cameroon, Gabon and Nigeria [10]. These animals usually live on the ground and can inhabit deserts, grasslands, and forests. *A. africanus* (African brush tailed porcupine) has been known to feed on cultivated crops. They also feed on the bark and the fleshy tissues of trees, a practice that is commonly referred to as "ringing". This habit can be devastating for trees and often causes death. *A. africanus* is also a carrier of *Plasmodium atheruri*, a malaria parasite [11]. *Atherur africanus* is hunted in large quantities and prices often higher than that of other game meat or domestic animal. As a result of its popularity and market price, the meat of porcupine is more frequently sold as a source of income than it is consumed by the family of the hunters [10].

Toxic substances in meat tissues can be caused by a variety of sources including animal drugs, pesticides, feed and other agricultural or industrial chemical substances [12]. With the increase in industrialization heavy metals have been introduced into the environment. These metals remain in the environment because they are not biodegradable and may contaminate food materials and from there migrate into tissues of animals [12]. Heavy metals like lead and cadmium are transmitted from mobile and stationary sources into the air which could be deposited in food [13]. Consequently, contamination with these metals may occur most in areas with heavy traffic [14].

Although the level of these toxic substances in muscle is generally low, offal such as liver and kidney showed higher concentration of toxic substances than most other foods [15]. The metalloid, Arsenic (As) has been classified as the most hazardous substance in the environment [16], thus raising concerns as to how hygienic the bush meat processing environment and personnel are. The toxicity of As is largely related to the intake of *As* III and *As* V which, in acute doses, can lead to multiple organ failure. A chronic, long-term ingestion of these with As-contaminated water has been associated with a range of health effects from skin lesions, cancer in the lung, bladder, kidney and skin, cardiovascular diseases, neurotoxicity, developmental toxicity, abnormal glucose metabolism and diabetes [17,18].

Studies have shown that most game meats especially in Nigeria are harvested with guns. The bullets used contain lead and often times result in the contamination of harvested meat. Nickel is carcinogenic to humans and has been shown to be potential inducers of kidney and lung tumors in experimental animals [19-21]. It is important to always determine the bioaccumulation for heavy metals by organs especially the edible ones in order to assess potential risk to human health. Although game meat is source of animal protein in the diet in Africa, little work has been done on the level of heavy metal concentration on porcupine whose meats are special delicacy for many people Africa and they are therefore ignorant of the danger of consuming them. For safety reasons, there is need to investigate the levels of heavy metals in these meats and thus ascertain the safety in the consumption of this meat in the based area of study. The main objective of the current study therefore was to evaluate and compare the levels of heavy metal contamination in the organs (muscle, liver and kidney) of both fresh and smoke-dried porcupine meats sold in Edo State, Nigeria.

Methodology

Sample Collection

Fresh porcupine meat was purchased from the three agro ecological zones of Edo State and at three different locations. The organs of liver, kidney and muscle were collected and used. In Edo North, samples were collected from Auchi, Egono and Agbede communities. In Edo Central, samples were collected from Iruekpen, Uromi and Ekpoma markets and in Edo South and samples were collected from Ehor, Ugboyaya and Udo. All meat samples used for the current analysis were obtained from the wild. Samples were collected with aluminum foil paper and transported with a picnic box filled with ice to keep the sample fresh and stored in a deep freezer prior to use. Both raw and smoke-dried porcupine were tested for heavy and metal toxicity levels.

Experimental Treatments

A total of 54 samples were collected and analyzed in this study. A 3x3x2 (3 location x 3 organs x 2 meat status) factorial arrangement in three replications in randomized complete block design was used.

Smoke Drying of Samples

The fresh porcupine meat was subjected to smoke drying using the smoking kiln in the Faculty of Agriculture, University of Benin, Nigeria before laboratory analysis for heavy metals was carried out.

Sample Preparation

The collected samples were subjected to wet digestion method for determination of various heavy metals following the procedure of [22]. In the laboratory, 1 g of each samples (liver, kidney and muscle) was weighed into the digestion flask, 5 mL and 15 mL of PerChloric acid and concentrated HNO3 respectively were added and then heated in an electric plate until samples became clear. After digestion, 5 mL of 20% HCl was added and contents of the flask filtered using filter paper into 100 mL volumetric flask and was made up to mark with distilled water and then stored in a plastic reagent bottle in preparation for analysis using AAS.

Heavy Metal Determination

Lead (Pb), Chromium (Cr), Cadmium (Cd), Arsenic (As) and Nickel (Ni) in fresh and smoked-dried liver, kidney and muscle samples of standard solutions were analyzed using AAS (SOLAAR 969 UNICAM Series) at wavelength (nm) of 217.0 (Pb), 357.8 (Cr), 228.8 (Cd), 193.7 (As) and 232.0 (Ni).

Statistical Analysis

Data obtained were analyzed statistically using GENSTAT [23] software. Duncan Multiple Range Test was used to test the differences between means where differences existed at 5% level of significance.

Results

The mean concentration (mg/kg) of heavy metals in raw and smoke-dried muscle, liver and kidney of porcupine with respect to location and organs are shown in the (Tables 1- 4) below. The concentration of heavy metals in raw and smoke-dried porcupine meat was observed to be between 0.015 mg/kg to 0.392 mg/kg.

(Table 1) shows that the highest concentration of chromium (mg/kg) in raw porcupine muscle was recorded in Edo North with a mean concentration of 0.181. Next to it was Edo Central with mean concentration of 0.122 and 0.074 for Edo South. There was a significant difference ($P < 0.05$) in the mean values of Cr in the three locations analyzed for. The same order was observed in chromium concentration of liver from raw porcupine 0.260 > 0.152 > 0.124 in Edo North, Central and South respectively with a significance difference ($P < 0.05$) in Edo North and no significant difference in Central and South. The chromium concentration for kidney has the highest recorded mean value in the North (0.347 mg/kg) with a significant difference ($P < 0.05$) from both Central and South. The chromium concentration in the organs from Edo North agro-ecological zone was highest in the kidney (0.035 mg/kg) followed by liver (0.260 mg/kg) and lowest in the muscle (0.181 mg/kg). A similar decreasing trend was also observed in the South 0.188 mg/kg > 0.124 mg/kg > 0.074 mg/kg (kidney > liver > muscle) with all the organs having significant difference ($P < 0.05$) in both North and South. The chromium concentration in the organs in Edo Central was lowest in the muscle with a concentration of 0.122 mg/kg followed by 0.01517 mg/kg in the liver and highest in the kidney with a concentration of 0.190 mg/kg with a significant difference ($P < 0.05$) from the kidney but not significantly different ($P > 0.05$) in the muscle and liver.

Heavy Metals	Location	Muscle	Liver	Kidney	SEM ±
Chromium	Edo North	0.1813_{A}^{c}	0.2597_{A}^{b}	0.3467_{A}^{a}	0.0185
	Edo Central	0.1220_{B}^{b}	0.1517_{B}^{b}	0.1893_{B}^{a}	0.00942
	Edo South	0.0743_{C}^{c}	0.1237_{B}^{b}	0.1880_{B}^{a}	0.00983
	SEM ±	0.01124	0.01306	0.01516	
Lead	Edo North	0.2750_{A}^{b}	0.3413_{A}^{ab}	0.3923_{A}^{a}	0.0308
	Edo Central	0.1513_{B}^{b}	0.1773_{B}^{ab}	0.2180_{B}^{a}	0.01488
	Edo South	0.1227_{B}^{c}	0.1883_{B}^{b}	0.2220_{B}^{a}	0.00844
	SEM ±	0.0177	0.0214	0.0217	
Nickel	Edo North	0.1203_{A}^{b}	0.1660_{A}^{b}	0.23117_{A}^{a}	0.0177
	Edo Central	0.0873_{AB}^{c}	0.1150_{B}^{b}	0.1397_{B}^{a}	0.00477
	Edo South	0.0527_{B}^{c}	0.09067_{B}^{b}	0.1267_{B}^{a}	0.00761
	SEM ±	0.01050	0.01018	0.01336	

Table 1: *Mean Concentration of Heavy Metals in Various Tissues and Locations of Raw Porcupine (mg/kg).*

SEM: Standard Error of Mean.

a, b, c; superscripts within rows that indicates organs are statistically significant.

A, B, C, D subscript within columns indicates locations are statistically significant

Mean with different scripts are significantly different at P < 0.05

Mean with the same scripts are not significantly different at P > 0.05

The highest Lead concentration in the muscle of raw porcupine was recorded in Edo North with mean concentration of 0.028 mg/kg followed by 0.151 mg/kg and 0.123 mg/kg in Central and South respectively with a significant difference (P < 0.05) in the North, but no significant difference (P > 0.05) in South and Central. The recorded concentration of Pb in the liver was in the order of 0.341 mg/kg > 0.189 mg/kg > 0.177 mg/kg in Edo North, South and Central respectively and the recorded concentration of Lead in the kidney was 0.392 mg/kg > 0.222 mg/kg > 0.218 mg/kg in the North, South and Central respectively with a significant difference (P < 0.05) from the North and no significant difference (P > 0.05) from the South and Central. The accumulation of lead in the muscle, liver and kidney of Edo North was 0.028 mg/kg < 0.314 mg/kg < 0.392 mg/kg with a significant difference (P < 0.05) in the muscle and kidney but no significant difference (P > 0.05) between muscle and liver and then liver and kidney. In Edo Central however, the muscle, liver and kidney concentration was in the order 0.151 mg/kg < 0.177 mg/kg < 0.218 mg/kg with a significant difference (P < 0.05) between the muscle and kidney but no significant difference (P > 0.05) in the muscle and liver and that of the liver and kidney. The same order goes for Edo South 0.123 mg/kg < 0.188 mg/kg < 0.222 mg/kg in the muscle, liver and kidney respectively with significant differences (P < 0.05) in the three organs.

Nickel concentration in the muscle was highest in Edo North with a concentration of 0.120 mg/kg followed by 0.087 mg/kg and 0.053 mg/kg in Central and South respectively with no significant difference (P > 0.05) between the muscles of Edo North and Central and that of Central and South but with a significant difference (P < 0.05) between the muscles of Edo North and South. The highest Ni concentration in the liver was recorded in Edo North (0.166 mg/kg) > 0.115 mg/kg > 0.091 mg/kg in Central and South respectively. The same order was observed in the Ni concentration of the kidney with 0.232 mg/kg, 0.140 mg/kg and 0.122 mg/kg in North, Central and South respectively with a significant difference (P < 0.05) in the North and no significant difference (P > 0.05) in the South and Central. The Ni concentration in the muscle, liver and kidney in Edo North was 0.120 mg/kg < 0.166 mg/kg < 0.232 mg/kg with no significant difference (P > 0.05) between the muscle and liver in Edo North both were significantly different (P < 0.05) from the kidney. The same order was recorded in Edo Central (0.083 mg/kg < 0.115 mg/kg < 0.1397 mg/kg) and South with significant difference (P < 0.05) in the three organs of Central (0.083 mg/kg < 0.115 mg/kg < 0.140 mg/kg and South (0.053 mg/kg < 0.091 mg/kg < 0.122 mg/kg).

Chromium concentration in the muscle of smoke-dried porcupine was highest in the North with mean concentration of 0.0613 mg/kg > 0.06 mg/kg > 0.027 mg/kg in Central and South respectively with no significant difference (P > 0.05) in the muscle of the three locations.

Heavy Metals	Location	Muscle	Liver	Kidney	SEM ±
Chromium	Edo North	0.0613_A^c	0.0950_A^b	0.1447_A^a	0.00567
	Edo Central	0.0600_A^a	0.0747_B^a	0.1027_B^a	0.01749
	Edo South	0.0270_A^c	0.0507_C^b	0.0847_B^a	0.00469
	SEM ±	0.00580	0.00580	0.00891	
Lead	Edo North	0.0927_A^b	0.1243_A^b	0.1703_A^a	0.01149
	Edo Central	0.06967_{AB}^b	0.0917_{AB}^{ab}	0.11867_B^a	0.01323
	Edo South	0.0467_B^c	0.0757_B^b	0.10133_B^a	0.00399
	SEM ±	0.00761	0.01170	0.01132	
Nickel	Edo North	0.04467_A^c	0.07533_A^b	0.11067_A^a	0.00637
	Edo Central	0.03100_B^c	0.05033_B^b	0.07900_B^a	0.00520
	Edo South	0.01500_C^c	0.03767_B^b	0.06267_B^a	0.00563
	SEM ±	0.00243	0.00633	0.00730	

Table 2: *Mean Concentration of Heavy Metals in Various Tissues and Locations of Smoke-dried Porcupine(mg/kg).*

SEM: Standard Error of Mean.

a, b, c; superscripts within rows that indicates organs are statistically significant.

A, B, C, D subscript within columns indicates locations are statistically significant

Mean with different scripts are significantly different P < 0.05

Mean with the same scripts are not significantly different at P > 0.05

Chromium concentration in the liver was highest in Edo North (0.095 mg/kg) > Central (0.075 mg/kg) > South (0.051 mg/kg) with significant differences (P < 0.05) in three locations. The chromium concentration in the kidney is in the order (0.145 mg/kg) > 0.103 mg/kg > 0.085 mg/kg in Edo North, Central and South respectively with a significant difference (P < 0.05) in Edo North and no significant difference (P > 0.05) in the South and Central. The concentration of chromium in muscle, liver and kidney of Edo North was 0.061 mg/kg, 0.095 mg/kg and 0.015 mg/kg respectively with significant difference (P > 0.05) among the organs. In Edo Central the concentration of chromium in muscle, liver and kidney were 0.060 mg/kg, 0.075 mg/kg and 0.121 mg/kg with no significant difference (P > 0.05) The concentration of chromium in muscle liver and kidney of Edo South was recorded as 0.027 mg/kg, 0.051 mg/kg and 0.086 mg/kg respectively they were all significantly different (P < 0.05).

The highest concentration of lead in the muscle was recorded in Edo north (0.093 mg/kg) followed by 0.070 mg/kg and 0.047 mg/kg in Central and South the same order goes for the liver with mean concentration of 0.124 mg/kg, 0.092 mg/kg and 0.076 mg/kg in Edo North, Central and South respectively with significant differences (P < 0.05) in Edo North and no significant difference (P > 0.05) in the South and Central of various organs. In Edo North, the concentrations of lead in muscle, liver and kidney were 0.093 mg/kg, 0.124 mg/kg and 0.170 mg/kg respectively with no significant difference (P > 0.05) between the muscle and liver, both significantly different (P < 0.05) from the kidney. Lead has a concentration of 0.070 mg/kg < 0.092 mg/kg < 0.119 mg/kg in muscle, liver and kidney in Edo Central with a significant difference (P < 0.05) between the muscle and kidney but no significant difference (P < 0.05) between muscle and liver and liver and kidney. The concentration of lead in Edo South were 0.047 mg/kg, 0.076 mg/kg and 0.101 mg/kg in muscle, liver and kidney respectively with a significant difference (P < 0.05) in all the organs.

The Nickel concentration in muscle was recorded with mean value of 0.045mg/kg, 0.031mg/kg and 0.015 mg/kg in Edo North, Central and South respectively with a significant difference (P < 0.05) in the three locations. Nickel concentration in the liver has the highest concentration in Edo North with mean value 0.075 mg/kg, 0.050 mg/kg and 0.038 mg/kg for Central and South respectively. The order goes for the kidney. The values for the liver and kidney in Edo North has a significant difference (P < 0.05) there was no significant difference (P > 0.05) between South and Central. Nickel has a concentration of 0.045 mg/kg < 0.075 mg/kg < 0.011 mg/kg in Edo North 0.031 mg/kg < 0.050 mg/kg < 0.079 mg/kg in Edo Central 0.015 mg/kg < 0.038 mg/kg < 0.063 mg/kg in Edo South with all the organs having a significant difference (P < 0.05) within their locations. Results from this study also showed that arsenic and cadmium concentration (mg/kg) were not detected in the muscle, liver and kidney of raw and smoke-dried porcupine from all locations assessed. This result may be due to the fact that animals were unaffected or very minute concentrations of these elements were found at the location of study.

Heavy Metal	Location	Muscle	Liver	Kidney
Cadmium	Edo North	ND	ND	ND
	Edo Central	ND	ND	ND
	Edo South	ND	ND	ND
Arsenic	Edo North	ND	ND	ND
	Edo Central	ND	ND	ND
	Edo South	ND	ND	ND

Table 3: *Mean Concentration of Cadmium and Arsenic in Various Tissues and Locations of raw porcupine.*

ND: Not Detected

Heavy Metal	Location	Muscle	Liver	Kidney
Cadmium	Edo North	ND	ND	ND
	Edo Central	ND	ND	ND
	Edo South	ND	ND	ND
Arsenic	Edo North	ND	ND	ND
	Edo Central	ND	ND	ND
	Edo South	ND	ND	ND

Table 4: *Mean Concentration of Cadmium and Arsenic in Various Tissues and Locations of smoke-dried porcupine.*

ND: Not Detected

Discussion

Chromium (Cr)

The result indicates that the concentration of chromium in the raw and smoke-dried samples of porcupine from the three agro ecological zones of Edo State were lower than the permissible limit (1.0 mg/kg) set by European Commission [24] and USDA [25]. The value observed is similar to levels reported by [26] in which chromium content of pork was observed to be between 0.05 mg/kg to 0.14 mg/kg on a wet weight basis. In contrast the value observed is lower than that reported by Igene [5] from the fresh muscle samples of grass cutter sold at New Benin market. Studies carried out by Iwegbue., *et al.* reported that Cr concentration in turkey meat and Chicken meat ranged between 0.01 - 3.43 mg/kg and 0.01 - 4.8 mg/kg respectively and this was higher than the permissible limit.

Chromium is an essential element at low concentration and at the same time carcinogenic at a higher concentration, the daily requirement for adult is estimated to be 0.02 and 0.5 mg/day [27]. The result revealed that the concentrations of chromium in the fresh and smoke-dried muscle, liver and kidney of porcupine were at safe levels and poses no danger to human health. It was observed in this study that the concentration of chromium was significantly higher in fresh tissue than in the smoke-dried tissues. This is in line with the findings of Ajani., *et al.* [28] Eboh., *et al.* [29] and Igene., *et al.* [5]. Also, the concentration of chromium was higher in kidney than in the liver and muscle of all the animals in the three locations, this could be as a result of the function of the kidney in animal body system. It was also observed that the concentration of chromium was higher in Edo North and lowest in Edo south in most cases.

Lead (Pb)

The amount of heavy metals allowed in food from country to country differs and are based on the recommendation of World Health Organization (WHO) and local requirement [30]. The results indicate that the concentration of lead in the raw and smoke-dried tissue and organs of porcupine were lower than the permissible limit of (1mg/kg or ppm) set by Australia-New Zealand Food Authority [31]. This was also approved by the Federal Environmental Protection Agency of Nigeria [32]. Similarly, Okoro., *et al.* [5] reported lead to be lower than the permissible limit of (1 ppm) in raw and smoke-dried grass cutter sold in Edo State. A similar permissible limit was also reported in a study by Jarzynska and Falandysz [33]. In the study, lead contents in the liver and kidney of deer was 0.17 mg/kg and 0.30 mg/kg (dry weight) respectively. Similar to this study, Falandysz, reported lead content in the liver and kidney ranging from 0.90 mg/kg to 0.240 mg/kg and 0.080 mg/kg to 0.366 mg/kg respectively, for wild boar roe and deer in Poland. In agreement, Doganoc and Gacnik, [34] found lower level of lead in the liver of Roe, Fallow deer, pheasant wild duck and hare in Slovenia.

In contrast the value observed was lower than that reported by Maldonado., *et al.* [35], whose findings reported that Pb with reference to its intestinal mobilization during lactation in rats showed higher levels in the liver and kidney. This was also in agreement with a study by Mariam., *et al*. [36] with mean levels of 2.18 mg/kg, 4.25 mg/kg and 3.15 mg/kg in beef, mutton and poultry respectively. In an early study carried out by Kreager., *et al*. [37], it was reported that lead content in liver of birds (turkey, pheasant duck and partridges) were 6 - 25 mg/kg. This is in concordance with the study by Aranha., *et al*. [37]. Lead is present in ammunition, high lead concentration in meat sometimes maybe related to the number of pellets and fragment found in the meat. The higher the numbers, the higher the lead concentrations in samples in which they are found. This was demonstrated by Falandysz, in pieces of large game captured in the North Poland between 1987 and 1991. The findings were later confirmed in other countries and in another game species [38]. In Spain, Mateo., *et al*. [39] have studied Pb content and fragment in red-legged partridges and they found that those sample containing pellets and small fragment of metal had higher Pb content that those that were free from pellets or fragments. The result showed that the concentration of lead in the fresh and smoke-dried muscle, liver and kidney of porcupine are safe for consumption.

Nickel (Ni)

The concentration of nickel in raw and smoke-dried porcupine (0.015 mg/kg - 0.02317 mg/kg) were higher than the tolerance limit (0.05 ppm) as set by the WHO. It was observed that the concentration of nickel was higher in the kidneys of raw and smoke-dried porcupine samples than in the other raw and smoked dried organs. This findings is similar to that of Igene., *et al*. [5] that the concentration of Nickel in raw and smoke-dried muscle from New Benin market was higher than the permissible level (0.05 ppm) set by WHO. In earlier study carried out by Flanjjank and Lee [40] nickel in the liver and kidney of cattle were 0.33-0.54ppm and 0.46-0.87 respectively which were higher than the permissible level. In contrast Korenekova., *et al*. [41] reported mean concentrations of 0.176 - 0.231 mg/kg in the liver of cattle rear in the vicinity of the metallurgic industry in Slovakia. From the present result, it can be concluded that porcupine under study are unsafe for consumption with respect to nickel toxicity.

Conclusion

The current study showed that there is a significant difference ($P < 0.05$) in the concentration of heavy metals in raw and smoked dried porcupine and concentrations higher ($P < 0.05$) in raw porcupine meats than the smoked dried samples. Cadmium and Arsenic were not detected in the various tissues of porcupine samples investigated. From the study, it can therefore be recommended that due to the fact that smoke-dried porcupine is usually consumed more and are displayed along with the kidneys by sellers, the consumer should consume more muscle from porcupine than kidney. Also, the domestication of porcupine by public and private sectors should be encouraged as this may lower incidences of food contamination and by extension public health concerns by heavy metals. More so, further studies should be conducted in order to determine the effect of processing methods on the levels of heavy metals in raw porcupine.

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Volume 4 Issue 4 August 2016