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Cadmium and Lead Levels in Muscle and Edible Offal of Cow Reared in Nigeria

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Abstract The study assessed the concentration of cadmium and lead in the muscle, liver, kidney, intestine and tripe of cow in Nigeria. Results show that the ranges of detectable values of cadmium in mg/kg were 0.01–0.80 in muscle, <0.004–0.90 in liver, 0.10–1.12 in kidney, 0.01–0.90 in intestine and 0.01–1.10 in tripe while for lead, the ranges were <0.005–0.72 in muscle, 0.08–501.79 in liver, 0.04–44.89 in kidney, 0.01–108.02 in intestine and 0.01–127.90 in tripe. Cadmium was accumulated mostly in kidney while Pb accumulated more in liver and both were above international maximum permissible levels in most samples.

Keywords Cadmium · Lead · Cow · Nigeria

Continuous and rapid growth in population, urbanization, industrialization and transportation in recent years has resulted in indiscriminate exploitation of the natural resources and environment in Nigeria. Environmental management practices in the country are inefficient due to poor infrastructure and lack of environmental protection awareness. Toxic wastes generated by industries are discharged indiscriminately, polluting the air, soil and water. This leads to abnormal levels of chemicals contaminant in the local environment. Free ranging animals can pick toxicants such as cadmium and lead by grazing, scavenging for fodder in open waste dumps, drinking polluted water from drains and streams, and exposure to atmospheric depositions especially from automobile fumes and open burning of solid wastes. Close correlations have been reported between concentrations of trace metals in cattle tissues and concentrations in soil, feed, and drinking water (Qiu et al. 2008). Cadmium and lead are environmental contaminants of great importance due to their high degree of toxicity. Human adults may suffer headache, abdominal pain, memory loss, kidney failure, male reproductive problems, and weakness, pain, or tingling in the extremities due to exposure lead. In children, loss of appetite, abdominal pain, vomiting, weight loss, constipation, anemia, kidney failure, irritability, lethargy, learning disabilities, and behavior problems may occur (Pearce 2007). Children may also experience hearing loss, delayed growth, drowsiness, clumsiness, or loss of new abilities, especially speech skills. Long term chronic exposure to cadmium has been associated with anaemia, anosmia, osteomalacia and cardiovascular disease (Ayodele et al. 1999). Recently, five villages in Anka L.G.A of Zamfara State, in Northwest Nigeria recorded the death of over 160 children and hundreds more hospitalized due to dumping of galena polluted ore obtained from a gold mining site, in their compounds where the children barebodied streaked with the dust sit to play, running their hands through the silt and sucking their fingers. The soils in the affected compounds were reported to have lead levels up to 23 times the maximum acceptable concentration (MAC) in soil set by USEPA (Associated press 2010).

Livestock rearing has been on the increase in Nigeria. According to the Federal Ministry of Agriculture and Water Resources reports (Federal Ministry of Agriculture and Water Resources 2008), 85% of cattle are produced in the Northern region. The report also shows that 99.50% of the cattle are traditionally managed, which involves free ranging animals taken from place to place seeking pasture and market. Free ranging animals can be good indicators of

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the general environmental pollution status. Toxic trace metals can be transferred to free-ranging animals from polluted air, feed or pasture contaminated with agricultural chemicals and vehicle emissions; and polluted water. Many trace metals bioaccumulate and bioconcentrate in organs and tissues of animals (Tahvonen 1996), until toxicity manifests depending on dosage and length of exposure.

Thus, the objective of this study was to investigate the impact of environmental contamination on the levels of cadmium and lead in the tissues and edible offal of cow bred and consumed in Nigeria.

Materials and Methods

Samples of muscle, liver, kidney, intestine and tripe from the same cow were purchased from butchers at the abattoirs in Nsukka and Enugu. Between August 2007 and November 2008, 30 cows were sampled in the manner described, giving a total of 150 meat samples, consisting of 30 each of muscle, liver, kidney, intestine and tripe. These were oven-dried at 105°C, pulverised in porcelain mortar, and kept in acid-leached polythene bags in a dessicator. 2.00 g of the sample weighed in tight fitting poly-ethylene bottle were spiked with a solution containing lead and cadmium and 10 mL 3:2 HNO_3 (65%v/v): $HClO_4$ (70% v/v) were added. The mixture was allowed to digest overnight in the cold and later heated for 3 h in a water bath at 70°C with swirling at 30 min intervals to ensure complete digestion (Clark 1989). All reagents used were analytical grade from Rie del-de Haen, Germany. After cooling, the digest was transferred into 20 mL standard flasks, rinsing with de-ionized water and made up to the mark. Prepared sample solutions were kept in acid-leached polyethylene bottles at room temperature until metal analyses were done with AAS model GBC Avanta ver 2.02, equipped with air-acetylene flame. Unspiked samples were digested by the same procedure, while 10 mL of the digestion mixture were taken through the same procedure and used as blank. On obtaining good recoveries, all samples analysed were prepared by the same procedure. Statistical analysis was carried out with SPSS ver 15 for windows.

Results and Discussion

Results of recovery experiments (Table 1) gave 101–106% for Cd and 99–103% for Pb with precisions of 2.8 and 2.06% respectively.

Table 2 shows that the mean Cd concentrations were in the range of 0.24–0.44 mg/kg while Table 3 shows that the mean concentrations of Pb were in the range of 0.09–0.26 mg/kg. Cd was detectable in 43% of muscle, 95% of liver, all of kidney, 70% of intestine and 50% of the tripe samples, while Pb was detectable in all samples of liver, kidney, intestine, tripe and 70% of muscle. Thus, the two metals are widespread in the environment. Of all detectable levels, cadmium was higher than the EU set limit of 0.05 mg/kg for Cd in meat (Anonymous 2005), in 82% of samples, in spite of the moderately low frequencies of its occurrence in some tissues (muscle 43% and tripe 50%). This could suggest that Cd contamination is largely from unidentified point sources. The higher frequencies in intestine (70%), liver (95%), and kidney (all samples) are likely due to their special functions; intestine as major route due to feeding, liver as storage organ and kidney as excretory organ (Stoyke et al. 1995), although Pompe-Gotal and Crnic (2002) had attributed this to bioaccumulation. There have also been suggestions that animals exposed to cadmium accumulate it in their kidneys because of the presence of free protein-thiol groups which leads to a strong fixation of heavy metals. Pompe-Gotal and Crnic (2002) inferred that the excretory mechanism for such metals, which is based on low molecular compounds with –SH groups, was poorly developed in vertebrates and could not cope with the present level of today's anthropogenic contamination level.

Likely unidentified sources of Cd which the animals could come in contact with include municipal waste, electroplating, plastic and paint waste. Other sources include leachates from nickel–cadmium based batteries which are so carelessly discarded by battery chargers and users in Nigeria, and cadmium plated items and recently, electronic wastes are disposed and often burnt at refuse dumps. Cd is a constituent of some pigments. Cadmium is a common impurity in phosphate fertilizer (Steoppler 1991) and with increasing use of fertilizers in agriculture in the country, Cd contamination and dispersion from this source would increase. Igwilo et al. (2006) reported high concentrations of cadmium (0.07–3.45 ppm) in soil samples near Anam River, at Otuocha, in Southeast Nigeria.

Atmospheric deposition is likely the most important diffuse source of cadmium. The cadmium content fermented cassava samples sun-dried along a busy highway was found to increase 53% above that of samples sundried far from the road (Ugwu et al. 2011). Sources of atmospheric cadmium include smelting of raw sulphide ores, mines and refineries, coal combustion and refuse incineration. High cadmium levels (0.07–3.08 μg/g) have been reported by Okoye and Ugwu (2010) in goat meat in Nigeria, and were ascribed largely to atmospheric deposition and grazing. High concentrations Cd have been determined in satchet water in Eastern Nigeria (Orish et al. 2006).The cadmium content of 78 Nigerian food types

Table 1 % Recoveries of cadmium and lead from meat samples after digestion

Elements	Spiked (added) concentration (μg/mL)	Concentration of unspiked sample (μg/mL)	Concentration of spiked sample (μg/mL)	Recovered concentration (μg/mL)	% Recovery	Precision (%)
Cd	0.100	0.077	0.178	0.101	101	2.8
	0.100	0.076	0.182	0.106	106	
	0.100	0.076	0.177	0.101	101	
Mean ± SD					103 ± 2.89	
Pb	0.100	0.051	0.150	0.099	99	2.06
	0.100	0.058	0.158	0.100	100	
	0.100	0.077	0.180	0.103	103	
Mean ± SD					101 ± 2.08	

Table 2 Concentrations of cadmium in cow meat parts (mg/kg, dry weight) in Nigeria

Samples (cow)	Muscle	Liver	Kidney	Intestine	Tripe
1	0.05	0.31	1.12	0.52	0.16
2	0.08	0.29	0.79	0.06	0.47
3	0.13	0.29	0.68	0.37	0.27
4	0.16	0.07	0.29	0.40	0.50
5	0.61	0.15	0.67	0.84	0.66
6	0.50	0.34	0.87	0.90	0.69
7	0.71	0.24	0.73	0.89	0.55
8	0.61	0.32	0.79	0.64	1.10
9	0.26	0.24	0.58	0.56	0.78
10	0.32	0.22	0.56	0.63	0.62
11	0.29	0.80	0.89	0.09	0.24
12	0.80	0.62	0.30	0.03	<0.004
13	<0.004	0.48	0.29	<0.004	<0.004
14	<0.004	0.90	0.30	0.02	<0.004
15	<0.004	<0.004	0.30	<0.004	0.03
16	0.01	<0.004	0.10	<0.004	<0.004
17	<0.004	0.02	0.20	0.05	<0.004
18	<0.004	0.10	0.20	0.04	<0.004
19	<0.004	0.00	0.45	<0.004	<0.004
20	<0.004	0.08	0.27	0.02	<0.004
21	<0.004	0.02	0.15	0.08	<0.004
22	<0.004	0.06	0.33	0.01	0.01
23	<0.004	0.02	0.19	0.02	<0.004
24	<0.004	0.05	0.33	0.01	<0.004
25	<0.004	0.03	0.26	<0.004	<0.004
26	<0.004	0.05	0.56	<0.004	<0.004
27	<0.004	0.03	0.14	<0.004	<0.004
28	<0.004	0.08	0.27	0.08	<0.004
29	<0.004	0.03	0.16	<0.004	0.01
30	<0.004	0.77	0.37	0.03	0.03
Mean ± SD	0.35 ± 0.27	0.24 ± 0.26	0.44 ± 0.27	0.29 ± 0.33	0.41 ± 0.33

Detectable limit for Cd = 0.004 mg/kg

were found to be higher than the levels obtained in such foods in some developed countries (Oniawa et al. 2000). Also, levels of Cd above critical toxic levels have been reported in plant leaves in both dry and rainy seasons; and in the soil and vegetation along roadsides (Oluyemi et al. 2008).

The mean concentrations of Cd in muscle, liver and kidney in this study is similar to 0.33 mg/kg reported in

Table 3 Concentrations of lead in cow meat parts (mg/kg, dry weight) in Nigeria

Samples (cow)	Muscle	Liver	Kidney	Intestine	Tripe
1	0.72	0.15	0.31	108.02*	127.90*
2	0.02	501.79*	44.89*	2.48*	60.04*
3	0.36	0.86	0.13	0.20	0.31
4	0.01	0.13	0.23	0.18	0.22
5	0.11	0.35	0.09	0.24	0.33
6	0.04	0.33	0.14	0.24	0.23
7	0.16	0.19	2.66*	0.25	0.21
8	0.08	2.42*	0.18	0.71	0.48
9	0.03	0.15	0.13	0.21	0.25
10	0.05	0.08	0.16	0.24	0.78
11	0.03	0.88	0.08	0.06	0.16
12	0.02	0.81	0.11	0.15	0.11
13	<0.005	0.69	0.13	0.09	0.11
14	<0.005	0.14	0.08	0.10	0.08
15	<0.005	0.24	0.13	0.12	0.10
16	<0.005	0.13	0.08	0.07	0.07
17	<0.005	0.12	0.08	0.12	0.08
18	<0.005	0.12	0.12	0.01	0.11
19	0.02	0.14	0.15	0.12	0.07
20	0.01	0.12	0.10	0.15	0.04
21	<0.005	0.11	0.10	0.16	0.07
22	0.05	0.15	0.04	0.18	0.10
23	0.05	0.11	0.05	0.16	0.20
24	<0.005	0.15	0.35	0.14	0.07
25	0.03	0.10	0.16	0.15	0.12
26	<0.005	0.08	0.11	0.13	0.01
27	0.04	0.10	0.06	0.15	0.10
28	0.06	0.13	0.06	0.15	0.11
29	0.02	0.14	0.07	0.12	0.15
30	0.05	0.51	0.12	0.10	0.13
Mean ± SD	0.09 ± 0.16*	0.26 ± 0.25*	0.13 ± 0.07*	0.17 ± 0.12*	0.17 ± 0.16*

Detectable limit for Pb = 0.005 mg/kg

Mean values for lead exclude those with asterisk considered outliers due to likely point source contamination

Lahore (Mariam et al. 2004) but higher than values (0.023–0.126 mg/kg) reported in muscle in Slovak (Koréneková et al. 2002), (0.011–0.092, 0.003–0.009 and 0.006 mg/kg) in muscle, liver and kidney respectively in Kenya (Oyaro et al. 2007) and (0.07 mg/kg) in muscle in Korea (Ji-Hun et al. 2006). The mean value in kidney is similar to 45 mg/kg reported in Austria (Falandysz 1994). Higher levels are reported in kidney (0.909 mg/kg) and liver (0.42 mg/kg) of cattle in Lahore (Mariam et al. 2004) and in muscle (0.69 mg/kg), liver (0.35 mg/kg) and kidney (0.83 mg/kg) in goat in Nigeria (Okoye and Ugwu 2010).

Lead tends to accumulate most in the liver (Miranda et al. 2005; Koréneková et al. 2002). Lead levels except in 4 samples of muscle, 7 of liver, 2 of kidney, 3 of intestine and 3 of tripe were within the Codex Alimentarius guideline for Pb in muscles (0.1 mg/kg) and edible offal (0.5 mg/kg) of cattle. However, there were some very high concentrations determined in two cows as follows: 108.02 mg/kg in intestine and 127.90 mg/kg in tripe of cow 1, and 501.79 mg/kg in liver, 44.89 mg/kg in kidney, 2.48 mg/kg in intestine and 60.04 mg/kg in tripe of cow 2. Such extreme concentrations have been attributed to recent and acute point source contamination; whereby the animals may have fed on highly contaminated fodder or waste not long before slaughter as they have been observed to be capable of feeding not only on grass, but also on many other items including those from industrial sources. Such could occur where lead-acid battery or other leaded materials have been dumped. Dumping of lead-acid batteries and similar lead products is common in Nigeria (Okoye 1994).

Diffuse lead dispersion and exposure to free ranging animals through drinking water even in rural areas include runoff from waste dumps and agricultural lands. Agricultural and industrial effluents can contaminate water body from which these animals drink and thus increase their metal burden. Asonye et al. (2007) has reported high lead levels in some streams, rivers and waterways in the Western and Midwestern regions while Okoye et al. (2010) reported high levels of Pb (0.13–2.24 mg/L,) in rural water resources in parts of South-east, Nigeria. Transportation remains a significant source of air-borne lead in Nigeria. Recent data show that petrol and diesel marketed in Nigeria contain lead in the ranges of 0.002–0.008 mg/L in petrol and 0.261–0.410 mg/L in diesel. Ano et al. (2007) reported high lead in soil and cassava along Enugu-Port Harcourt expressway. In the north central, Aremu et al. 2006 reported high levels of Cd and Pb in food crops along roadsides, while Ugwu et al. (2011) showed an enrichment of 185% in Pb in cassava meal samples sundried along roadside above what was obtained in samples sun-dried under ambient atmosphere. The domestic annual consumption of petrol and diesel are above 9.57 and 2,361.48 billion litres respectively (Rowland 2008). Thus, annual lead emission from petroleum fuel sources could be at least in the range of 616, 241.14–968,086.56 kg. This could have significant impact on atmospheric levels and deposition of lead on pasture.

The mean lead concentration in this study 0.09mgkg^{-1} in muscle, 0.26 mg/kg in liver and 0.13 mg/kg in kidney are higher than 0.008, 0.04 and 0.04 mg/kg for muscle, liver and kidney respectively reported in Northern Spain (Miranda et al. 2005). The mean lead values in muscle was also higher than mean values in muscles of ruminants found in literature e.g. 0.05 mg/kg in Slovenia (Doganoc and Gacnick 1995) and 0.01 mg/kg in Finland (Tahvonen and Kumpulainen 1995). The mean concentration in liver was higher than 0.10 mg/kg reported by Doganoc and Gacnick (1995). However the mean lead value (mg/kg) in muscle (0.09) is lower than 0.14 reported in Korea (Ji-Hun et al. 1999), 0.227–0.386 reported in Kenya (Oyaro et al. 2007), 0.146–0.237 in Slovak (Koréneková et al. 2002), and 0.45 and 2.19 in Lahore (Mariam et al. 2004) but the mean liver concentration is higher than values (0.162–0.171) reported in Kenya (Oyaro et al. 2007).

The non-accumulation in a particular organ for the two metals could be attributed to low levels of diffuse contamination of the environment so far. However, the occurrence of cadmium up to 95% in liver shows that animals largely bioaccumulates cadmium in the liver.

One way analysis of variance showed no significant difference for Cd and Pb in the various meat parts ($p > 0.05$) indicating that Cd and Pb are mainly from anthropogenic source since they have no function in the tissues but are rather toxic.

Levels of Cd in the muscle and edible offal of cow bred in Nigeria are high, while Pb levels were moderate except in cases of likely recent point source contamination. Most occurrence were in the liver and kidney, these are the main storage organs and can be good indicators in monitoring Cd and Pb levels in livestock and in the environment.

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