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Heavy metal composition of livers and kidneys of cattle from southern Nigeria

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ABSTRACT

Results are presented for the levels of cadmium, chromium, copper, lead, iron, manganese and nickel as determined by atomic absorption spectrophotometry, in the livers and kidneys of 88 cattle from seven different locations in southern Nigeria. The mean and range for each metal in mg.kg^{-1}, in livers and kidneys were as follows; cadmium 0.08 (0.01-0.23) and 0.14 (0.01-0.46); chromium 3.62 (0.98-6.33) and 3.63 (1.08-5.87); copper 1.99 (0.11-8.99) and 3.27 (0.22-7.49); 0.8 (n.d-0.23) and 0.04 (n.d-0.95); iron 37.75 (2.64-85.60) and 32.26 (0.10-78.65); Ni 0.12 (0.01-0.55) and 0.20 (0.02-0.46). Significant differences were observed in the heavy metal levels in livers and kidneys from the different locations and between the heavy metal levels in livers and kidneys from the same location. The levels of the various metals were generally low, and within international statutory safe limits.

Key words: heavy metals, liver, kidney, cattle, environmental pollution, Nigeria

Introduction

Trace metals are ubiquitous in the environment of man and animals. Iron, zinc, copper, chromium, cobalt and manganese are essential, while lead, cadmium, nickel and mercury are toxic at certain levels (FLANJAK and LEE, 1979; UNDERWOOD, 1977; ALLOWAY and AYRE, 1994). Those metals that are equivocally essential, owe their essentiality to being constituents of enzymes and other important proteins involved in key metabolic pathways. Hence, a deficient supply of micro nutrients will result in a shortage of enzymes which leads to metabolic dysfunction causing disease, whereas, so-called toxic metals cause toxicity at levels which exceed the tolerance limit of the organism, but do not cause deficiency disorders like the essential metals (ALLOWAY and AYRE, 1994). For example,

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lead can adversely affect many organs, systems and numerous conditions such as high pressure, anemia, kidney damage, impaired wearing and metal retardation (WAGNER, 1995) elevated levels in women may result in a shortened gestation period (WAGNER, 1995), while young children are considered at great risk because of their ability to effectively absorbed lead and thereby suffer mental and physical development retardation (KOCAK et al., 2005). Cadmium toxicity affects many target tissues such as appetite and pain centres (in brain), brain, heart and blood vessel, kidney and lungs. This toxicity may cause anemia, dry and scaly skin, emphysema, fatigue, hair loss, heart disease, depressed immune system response, hypertension, joint pain, kidney stones or damage, liver dysfunction or damage, loss of sense of smell, lung cancer, pain in the back and legs, and yellow teeth in humans (KOCAK et al., 2005). In Nigeria cattle are free grazing and drink water from ditches, streams, rivers and other possible contaminated water sources. They graze along runways and other sites that might have been contaminated with toxic substances. Animals in the process could be liable to exposure to high levels of contaminants in the environment. These metals accumulate in the organs and other tissues. The muscles and other organs (including intestines) are sold in the market to the populace for consumption. In view of the fact that there are very little or no available original data on metal concentrations in tissues of domestic and wild animals in Nigeria, this study was undertaken in order to determine the levels of these metals (Cd, Pb, Cr, Ni, Cu, Mn and Fe) in livers and kidneys of cattle in southern Nigeria, with attention given to hygienic and toxicological aspects.

Materials and methods

Liver and kidney samples from free grazing cattle were obtained from abattoirs situated in seven widely spread localities in southern Nigeria. The animals were not selected according to sex or age but on the acknowledged assumption that they were aged from 2 - 5 years, and taking the parts that reach the final consumers. The samples were collected in the months of August to November 2006. The samples were packed in polyethylene bags and conveyed to the laboratory. Upon reception, gross fat was removed and stored at -10 ^{o}C in sealed plastic container until required (FLANJAK and LEE, 1979).

5 g samples were wet ashed in a Pyrex beaker with 35 mL of a mixture of nitric and perchloric acids (6+1) and was placed on a hotplate at 135 ^{o}C for 2 h. Care must be exercised with fatty materials to maintain excess nitric acid until most of the organic matter is destroyed. The colorless liquor formed was evaporated slowly to dryness (avoiding prolonged baking); cooled and dissolved in 5 mL of 20% nitric acid and diluted to 25 mL mark with the deionized water. The solution was analyzed for metals using graphite furnace atomic absorption spectrophotometer (GBC Scientific equipment Sens AA) equipped with D_2 background correction device.

Appropriate quality assurance procedures and precautions were carried out to ensure reliability of the results. Samples were generally carefully handled to avoid contamination. Glassware was properly cleaned, and the reagents (nitric acid and distilled water) were of analytical grade. Reagent blank determinations were used to correct the instrument readings. Calibration standards were made by dilution of high purity commercial BDH metal standards for atomic absorption analysis. A recovery test of the total analytical procedure was carried out for metals in selected samples by spiking analyzed samples with aliquots of metal and then reanalyzing the samples. Acceptable recovery of 96%, 95.2%, 94%, 92.5%, 91.8%, 93% and 98.2% was obtained for Cr, Fe, Cd, Pb, Ni, Mn and Cu, respectively.

Results

The mean (± standard deviation) and range of the concentrations of the metals in the livers and kidneys of cattle analyzed with respect to localities are given in Tables 1 and 2 respectively. Table 3 presents the overall mean (± SD) and range for all samples. Analysis of variance (ANOVA) ($P = 0.05$) shows appreciable variation in the concentrations of the various metals within localities. This variation is due to differences in levels of exposure to metal contaminants.

Iron is the most abundant of all the metals studied. The mean levels of Cr, Pb, Fe and Mn found in the livers from the different localities are generally greater than the mean levels of these metals in the kidneys. This is an indication that these metals accumulate more in the livers than in the kidneys. However, there are a few exceptions, where the concentrations of these metals are higher in the kidneys than the livers. Contrary to these metals, cadmium, copper and nickel levels are found to be higher in the kidneys than in liver samples from the different localities

Discussion

The highest level of cadmium was found in kidney samples collected from Sapele area. Several studies have shown that cadmium concentrates more in the kidneys than in the livers (HETCHT et al., 1984; FROSILE et al., 1986; MUSANTE et al., 1993; FALANDYSZ, 1994; DOGANOC and GACNICK, 1995; KOTFEROVA and KORENEKOVA, 1998; POKORNY and RIBARIC-LASNIK, 2000; POMPE-GOTAL and CRNIC, 2002; GASPARIK et al., 2004). The higher concentration of cadmium in the kidney tissue is due to the detoxification function of the organ where these metals are accumulated (ARANHA, 1994; STOYKE et al., 1995). Animals exposed to cadmium accumulate it in their livers and kidneys as their free protein-thiol group content leads to a strong fixation of heavy metals. Despite the excretory mechanism for such metals, which is based on low molecular compounds with -SH groups, vertebrates could not develop these mechanisms during the period of evolution

Table 1. Characteristic levels of heavy metal (mean ± SD) ($mg.kg^{-1}$ in wet weight basis) in livers and kidneys of cattle from different localities in southern Nigeria

		Cr	Fe	Cd	Pb	Ni	Mn	Cu
Sapele	Liver	2.88 ± 1.20	31.49 ± 13.54	0.13 ± 0.06	0.26 ± 0.49	0.03 ± 0.02	9.44 ± 4.06	0.46 ± 0.33
	Kidney	3.76 ± 0.96	28.32 ± 11.05	0.20 ± 0.12	0.01 ± 0.01	0.21 ± 0.04	8.49 ± 3.31	3.36 ± 0.73
Onitsha	Liver	3.95 ± 0.71	22.89 ± 13.73	0.07 ± 0.03	0.07 ± 0.18	0.11 ± 0.09	6.86 ± 4.12	1.81 ± 1.48
	Kidney	3.57 ± 1.28	31.18 ± 20.39	0.15 ± 0.18	0.16 ± 0.39	0.09 ± 0.08	9.35 ± 6.11	1.42 ± 1.34
Warri	Liver	4.05 ± 1.74	28.61 ± 7.15	0.08 ± 0.04	0.01 ± 0.01	0.07 ± 0.09	8.58 ± 2.14	1.19 ± 1.53
	Kidney	4.01 ± 1.57	22.88 ± 15.44	0.24 ± 0.10	0.02 ± 0.04	0.06 ± 0.03	6.86 ± 4.63	0.93 ± 0.58
Benin	Liver	2.96 ± 0.44	39.64 ± 23.22	0.07 ± 0.04	0.03 ± 0.06	0.18 ± 0.06	11.89 ± 6.89	2.91 ± 0.90
	Kidney	2.51 ± 1.22	20.37 ± 8.39	0.07 ± 0.07	0.01 ± 0.03	0.21 ± 0.03	6.11 ± 2.52	3.48 ± 0.51
Ughelli	Liver	3.67 ± 1.59	49.76 ± 23.06	0.07 ± 0.07	0.00 ± 0.00	0.30 ± 0.13	14.93 ± 6.92	4,89 ± 2.11
	Kidney	4.92 ± 0.66	46.59 ± 23.54	0.11 ± 0.05	0.06 ± 0.15	0.30 ± 0.13	13.97 ± 7.06	4.85 ± 2.15
Asaba	Liver	4.43 ± 1.16	57.86 ± 18.14	0.03 ± 0.02	0.10 ± 0.17	0.04 ± 0.01	17.35 ± 5.44	0.71 ± 0.17
	Kidney	3.32 ± 1.49	41.92 ± 11.04	0.12 ± 0.09	0.01 ± 0.02	0.29 ± 0.11	12.57 ± 3.31	4.75 ± 1.76

Table 2. Range of heavy metals in livers and kidneys (mg.kg^{-1} fresh weight basis) of cattle from different locations in southern Nigeria

		Cr	Fe	Cd	Pb	Ni	Mn	Cu
Sapele	Liver	1.05-4.38	15.20-61.20	0.06-0.21	nd-1.23	0.10-0.06	4.56-18.35	0.14-0.99
	Kidney	2.48-4.80	13.50-40.50	0.12-0.41	nd-0.02	0.16-0.28	4.05-12.15	2.65-4.52
Onitsha	Liver	2.68-4.90	2.64-41.60	0.04-0.12	nd-0.47	0.01-0.30	0.79-12.48	0.19-4.84
	Kidney	1.76-5.04	10.55-58.60	0.03-0.46	nd-0.95	0.02-0.20	3.17-17.57	0.22-3.25
Warri	Liver	0.98-6.33	15.65-37.90	0.02-0.14	nd-0.03	0.01-0.23	4.74-11.37	0.11-3.70
	Kidney	2.09-5.87	5.62-47.15	0.15-0.40	nd-0.11	0.03-0.12	1.89-14.14	0.41-1.99
Benin	Liver	2.30-3.51	6.49-64.40	0.02-0.12	nd-0.16	0.12-0.25	1.95-19.31	1.98-3.99
	Kidney	1.11-4.21	5.84-29.25	0.01-0.20	nd-0.10	0.17-0.25	1.75-8.77	2.81-4.10
Ughelli	Liver	1.54-5.86	5.03-75.35	0.02-0.23	nd-0.01	0.14-0.55	1.51-22.60	2.21-8.99
	Kidney	3.82-5.74	0.10-78.65	0.04-0.17	nd-0.40	0.14-0.46	0.03-23.59	2.28-7.49
Asaba	Liver	2.94-5.79	30.45-85.60	0.01-0.07	nd-0.45	0.03-0.06	9.13-25.67	0.43-0.89
	Kidney	1.08-4.92	19.25-52.45	0.02-0.03	nd-0.07	0.09-0.43	5.77-15.73	1.35-7.06

Table 3. Trace metal concentrations in livers and kidneys of cattle (mg.kg^{-1} fresh weight basis)

	Liver		Kidney	
Trace metal	Range	Mean ± SD	Range	Mean ± SD
Cr	0.98-6.33	3.62 ± 1.29	1.08-5.87	3.63 ± 1.40
Fe	2.64-85.60	37.75 ± 20.18	0.10-78.65	2.26 ± 17.80
Cd	0.01-0.23	0.08 ± 0.05	0.01-0.46	0.14 ± 0.11
Pb	nd-1.23	0.08 ± 0.24	nd-0.95	0.04 ± 0.16
Ni	0.01-0.55	0.12 ± 0.12	0.02-0.46	0.20 ± 0.12
Mn	0.79-25.67	11.32 ± 6.05	0.03-23.59	9.67 ± 5.34
Cu	0.11-8.99	1.99 ± 1.96	0.22-7.49	3.27 ± 1.98

to the extent necessary for today's anthropogenic sources of pollution (POMPE-GOTAL and CRNIC, 2002). The herbivores of terrestrial fauna, birds as well as mammals, demonstrate generally higher renal cadmium than carnivores since vegetation is contaminated by aerial deposition or by absorption of cadmium from the soil (PETERSON and ALLOWAY, 1979).

According to the data obtained by ZMUDZKI and SZKODA (1995) in the course of a monitoring survey performed in 1993, cadmium levels in the livers and kidneys of young cattle from Poland were 0.146 and 0.580 $mg.kg^{-1}$ respectively and in older animals cadmium levels of 0.204 and 0.829 $mg.kg^{-1}$ were observed in the livers and kidneys respectively. Similarly, FALANDYSZ (1994) reported cadmium concentrations of 0.10 and 0.450 $mg.kg^{-1}$ in livers and kidneys respectively for cattle in northern Poland. The levels of cadmium in cattle kidney in some countries of the European Union (EU) were of the same magnitude e.g. 0.45 mg Cd kg^{-1} in Austria (1991) and 0.231 mg Cd kg^{-1} in Holland (KOFER and FUCHS, 1993; KESSELS and WENSING, 1993) while values recorded for cattle livers were 0.061 mg Cd kg^{-1} in Finland (1991), 0.070 mg Cd kg^{-1} in Sweden (1991) and 0.105 mg Cd kg^{-1} in Holland (1987) (TAHVONEN and KUMPULAINEN, 1994). The permissible limit for cadmium in kidney and liver has been reported as 1 ppm and 0.5 ppm Cd respectively (VOS et al., 1991). The levels of cadmium found in the livers and kidneys in this study were below the FAO/WHO permissible limits and comparable to levels reported for EU countries (KOFER and FUCHS, 1993; KESSELS and WENSING, 1993; TAHVONEN and KUMPULAINEN, 1994).

The highest mean level of chromium in livers and kidneys was recorded in samples from the Asaba and Ughelli areas respectively, while the lowest level of chromium in the livers and kidneys was found in samples from the Sapele and Benin areas, respectively. The overall mean levels of chromium reported in this study were higher than chromium levels reported for chromium in livers and kidneys of cattle from different localities of New South Wales, Australia (FLANJAK and LEE, 1979).

Copper occurs in food in many chemical forms and combinations, which affects its availability to the animal. It is known to be essential at low concentrations for both human and animals but it is toxic at high levels. The lethal dose of copper for humans is 100 ppm but food with concentration of 5-7 ppm becomes repulsive for human consumption. Thus, there is no danger for humans of copper poisoning (VOS et al., 1991). Copper concentration (wet tissue weight) was 56.7 ppm in livers of Flemish cattle, 8.8 ppm in Irish cattle and 22.1 ppm in the liver of Polish cattle (ZMUDZKI et al., 1991). In New South Wales(Australia), the concentrations of copper in the livers and kidneys of cattle ranged from 0.81-82.8 ppm and 1.84-9.2 ppm respectively (FLANJAK and LEE, 1979). Similarly, MARIAM et al. (2006) reported mean copper levels of 93.24 ± 15.8 ppm Cu and 5.42 ± 2.01 ppm Cu for livers and kidneys respectively of beef in Lahore. The levels of copper found in this study are lower than levels reported by these investigators (FLANJAK and

LEE, 1979; MARIAM et al., 2004). The concentration of copper in the liver and kidney tissues are below the permissible limit of 20 ppm Cu (SHARIF et al., 2005; ZASADOWSKI et al., 1999).

The levels of lead in the livers and kidneys are generally low compared to any other metals studied. The highest concentrations of lead in livers and kidneys of the cattle examined were 1.23 $mg.kg^{-1}$ and 0.95 $mg.kg^{-1}$ respectively. 75% of the liver and kidney samples have lead concentrations less than 0.001 $mg.kg^{-1}$. MARIAM et al. (2004) reported mean lead concentrations of 2.18 ± 0.38 ppm and 2.02 ± 0.44 ppm for livers and kidneys respectively of beef in Lahore whereas FLANJAK and LEE (1979) reported concentrations ranging from n.d - 0.85 ppm and n.d - 2.25 ppm for livers and kidneys of cattle in New South Wales, Australia. The levels of lead reported in this study are lower than levels reported by MARIAM et al. (2004) but are similar to levels reported by FLANJAK and LEE (1979). The result indicates that the concentrations of lead in the livers and kidneys were less than the permissible limit of 1ppm except for one sample.

Iron and manganese are essential metals and are required for normal metabolic activity in both plants and animals. The livers and kidneys have higher concentration of iron and manganese compared to any other metals studied.

The concentration of iron and manganese in the liver is significantly higher than that of kidneys. The levels of iron and manganese in sample are below permissible limits for these elements in animal tissues. The levels of manganese reported in this study are comparable to levels reported for livers and kidneys of cattle from South Wales, Australia (FLANJANK and LEE, 1979). The level of iron observed in the liver samples are comparatively lower than the mean levels of 125.2 - 146.8 $mg.kg^{-1}$ reported for liver of cattle from 3 region of Slovakia (KORENEKOVA et al., 2002).

Nickel was detected in the entire samples. The concentrations of nickel in the kidney samples are higher than those of the livers. This agrees with the observation of FLANJANK and LEE (1979) who reported 0.33 ± 0.54 ppm Ni and 0.46 ± 0.87 ppm Ni in livers and kidneys of cattle respectively. Similarly, KORENEKOVA et al. (2002) reported mean concentrations of 0.176 - 0.231 $mg.kg^{-1}$ in the livers of cattle reared in the vicinity of the metallurgic industry in Slovakia. The levels of nickel reported in this study are comparable to that of FLANJANK and LEE (1979). Contrary to the general expectation that the such free grazing animals will accumulate high and excessive concentrations of trace and toxic metals in its organs, it was found that the levels of the metals was generally low. This is possibly due to reduction in the levels of lead in gasoline and low levels of industrialization in the northern region of Nigeria, were the animals migrated from to the southern part of Nigeria.

Overall, the study shows that the levels of various metals in livers and kidneys were generally low, within international statutory safe limits and the data obtained will be valuable in complementing available food composition data, estimating dietary intakes of heavy metals and framing food standards in Nigeria.

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SAŽETAK

Predočeni su rezultati istraživanja razina kadmija, kroma, bakra, olova, željeza, mangana i nikla ustanovljenih atomskom apsorpcijskom spektrofotometrijom u jetrima i bubrezima podrijetlom od 88 goveda sa sedam različitih područja u južnoj Nigeriji. Srednje vrijednosti razine te razmak od najmanje do najveće vrijednosti u mg.kg^{-1} u jetrima i bubrezima bile su sljedeće: za kadmij 0,08 (0,01-0,23) u jetrima te 0,14 (0,01-0,46) u bubrezima; za krom 3,62 (0,98-6,33) u jetrima te 3,63 (1,08-5,87) u bubrezima; za bakar 1,99 (0,11-8,99) i 3,27 (0,22-7,49); za olovo 0,8 (0,23) te 0,04 (do 0,95); za željezo 37,75 (2,64-85,60) i 32,26 (0,10-78,65); za nikal 0,12 (0,01-0,55) i 0,20 (0,02-0,46). Značajne razlike u razini teških metala ustanovljene su ovisno o pretraženom organu te o području na kojem su obitavale pretražene životinje. Razine različitih metala bile su općenito niske i unutar međunarodno propisanih vrijednosti.

Ključne riječi: teški metali, jetra, bubreg, govedo, onečišćenje okoliša, Nigerija