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SHORT COMMUNICATION

IMPACT OF ENVIRONMENTAL CADMIUM, LEAD, COPPER AND ZINC ON QUALITY OF GOAT MEAT IN NIGERIA

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ABSTRACT. This study evaluated the levels of cadmium, lead, copper and zinc in the muscles and edible offal's of goat bred from Nigeria. The samples were digested with a 3:1 mixture of HCl and HNO_3 and analysed with a Unicam Solar 32 AAS. The results obtained expressed in mgkg^{-1} showed that kidney had the highest mean concentration of 0.83 ranging from 0.07-3.08 for cadmium, 0.53 from nd-0.63 for lead; while liver had 134.02 ranging from 26.36-398.16 for copper and muscle 131.55 from nd-417.00 for zinc. Most of the samples studied were found to have these metals above the permissible limits set by some regulatory bodies. Pearson's correlation analysis showed significant correlation ($p < 0.01$) between the metal levels in the heart and kidney, an indication of common source of contamination. The meat quality was found to be impaired by high levels of Zn, Cu and Cd and indicates widespread contamination of the environment by these trace metals.

KEY WORDS: Heavy metals, Goat muscles, Edible offal's, Environmental impact

INTRODUCTION

Environmental pollution associated with heavy metals has been of global concern over many decades [1]. These metals are natural components of the environment but high rate of industrialisation has been responsible for their wider diffusion and dispersal in the environment [2]. Metal salts have been used therapeutically in human and veterinary medicine for centuries, but man and animals are now exposed to more metals than they were previously. Metals for which there are no nutritional requirements may react with biological systems to cause adverse effects. Excessive doses of nutritionally essential metals can also cause adverse effect [3].

Long term chronic exposure of cadmium has been associated with anaemia, anosmia, osteomalacia and cardiovascular disease especially hypertension [4]. Zinc, unlike cadmium is essential for normal functioning of cells including protein synthesis, carbohydrate metabolism, cell growth and cell division [5]. However, at high levels, metal fume fever may result which causes fever, depression, malaise, cough, vomiting, salivation and headache. Lead is a toxic heavy metal with widespread industrial use, but no known nutritional benefits. Chronic exposure at relatively low levels can result to damage to kidneys and liver and to the immune, reproductive, cardiovascular, nervous and gastrointestinal systems [6].

A lot of studies have reported the prevalence of heavy metals in the Nigerian environment. For example, in the southern states, Okoye and Ibeto [7] reported high levels of lead and cadmium in soils from Enugu state; Oluyemi *et al.* [8] reported levels of Cd, Ni, Pb and Cr above critical toxic levels in plant leaves in both dry and rainy seasons; Amusan *et al.* [9] and Ano *et al.* [10] reported high levels of lead and cadmium in the soil and vegetation along roadsides in Osun state and Enugu-Port Harcourt expressway, Nigeria, respectively. In the north central, Aremu *et al.* [11] reported high levels of Cd and Pb in food crops along roadsides in Nassarawa state, Nigeria. Several other reports have shown the occurrence of high levels of these metals in water [12-15], and industrial effluents, such as a range of 21.70-446.40 mg/L of

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lead in effluents from Sharada Industrial Estate in Kano, in northwest Nigeria [16]. These metals come from various sources like atmospheric depositions, vehicle emissions, tyre and engine wears, and agricultural chemicals, urban and industrial wastes.

Livestock rearing has been on the increase in Nigeria. Goat production has risen from 45.3 million to 52.5 million goats from 2001 to 2007 [17]. According to the Federal Ministry of Agriculture and Water Resources reports [17], 80% of goats, 70% of sheep and 85% of cattle in the country are produced in the northern regions, while 80% of pigs and 85% of poultry are produced in the south. The traditional system of management of livestock has remained the most practised in the country. The Federal Ministry of Agriculture and Water Resources reports [17] show that 99.97% of goats, 99.50% of cattle, 99.84% of sheep, 96.76% of pigs and 86.17% of poultry are traditionally managed.

The most common breed of goat reared in Nigeria is the *Red Sokoto/Kano brown.* These are produced in the north-west, north-east, and north-central states, where all their grazing are done in the derived/savannah region and at maturity transported to the south where most of them are usually confined and fed with fresh forage (fodder) until they are sold for slaughter. Thus, the north supplies 80% of goat slaughtered and sold in most Nigerian markets including Nsukka market.

Free ranging animals as is the case in the traditional management of livestock in Nigeria can be good indicators of the general environmental pollution status. Toxic trace metals can be transferred to these animals by respiration of polluted air, intake of feed or pasture contaminated with agricultural chemicals and vehicle emissions; and drinking of polluted water. These heavy metals bio-accumulate increasingly in organs and tissues of these animals [18], and toxicity depends on dosage and length of time of exposure.

The objective of the study was to investigate the impact of the environmental contamination on the levels of cadmium, lead, copper and zinc in the tissues and internal organs of goat bred and consumed in Nigeria.

EXPERIMENTAL

Sampling and sample pre-treatment. Thirteen sets of samples (*Red Sokoto/Kano brown* breed) each comprising of muscle, liver, kidney and heart, were procured from the abattoir in Nsukka between the months of June and July 2007. The samples were oven-dried at 105 ^{o}C to constant weight. The dried samples were pulverised in a porcelain mortar and stored in a dessicator prior to digestion.

Metal recovery and sample preparation. A recovery experiment involving the digestion of 2 g of spiked powdered liver samples with 20 mL of 3:1 mixture of Analar grade HCl and HNO_3 (Riedel-de Haen, Germany) was carried out to validate the method of analysis. The samples were allowed to stand overnight, then heated at a low temperature of 60-70 ^{o}C for about 45 min, cooled and transferred into a 25 mL standard flask and made up to mark with deionised water, after which they were stored in polyethylene bottles for analysis with a UNICAM SOLAR 32 Atomic Absorption Spectrophotometer (UNICAM, UK) using air-acetylene flame. Following good recovery (Table 1), samples were digested in the same procedure.

Statistical analysis. Bivariate analysis (Pearson's correlation) using SPSS, 12.0 for windows was carried out to analyse the data in order to determine the relationship between the metals in the different parts of meat studied.

Table 1. Percent mean (n = 3) recovery for Pb, Cd, Zn and Cu in liver samples.

Element	Added concentration (μg/mL)	Concentration of unspiked sample (μg/mL)	Concentration of spiked sample (μg/mL)	Recovered concentration (μg/mL)	Recovery (%) ± SD
Pb	0.100	0.051	0.150	0.099	99 ± 1.15
Cd	0.100	0.077	0.178	0.101	101± 0.57
Zn	0.100	0.872	0.966	0.094	94 ± 2.00
Cu	0.250	0.298	0.528	0.230	92 ± 0.72

RESULTS AND DISCUSSION

The levels of Cd, Pb, Cu and Zn determined in the muscle, liver, kidney and heart samples of goat are summarised in Table 2. Cadmium was detectable in all kidney and muscle samples; 12 liver samples, and 8 heart samples. Cadmium concentration was highest in the kidney with a mean concentration of 0.83 $mgkg^{-1}$, ranging from 0.07-3.08 $mgkg^{-1}$. This is in line with the suggestion that the kidney is the main storage organ in animals subjected to chronic low-level cadmium exposure [19]. Seventy seven percent (77%) of the muscles and 69% of the kidney samples exceeded the Slovak Republic standard for cadmium in muscle, 0.1 $mgkg^{-1}$ and in edible offal's, 0.5 $mgkg^{-1}$. The detectable levels of cadmium in the heart samples were within the limits, but two liver samples exceeded the limit of 0.5 $mgkg^{-1}$.

Table 2. Mean concentrations of cadmium, lead, copper and zinc ($mgkg^{-1}$) in the muscle, kidney, liver and heart of goat.

Metal	Liver	Kidney	Heart	Muscle
Cadmium				
Range	Nd-1.15	0.07-3.08	Nd-2.04	0.09-1.26
Mean ±SD	0.35 ± 0.36	*0.83 ± 0.73	*0.34 ± 0.57	0.69 ± 0.42
Lead				
Range	Nd-0.65	Nd-0.63	Nd-1.11	Nd-1.18
Mean ± SD	0.65	*0.53 ± 0.14	*0.20 ± 0.37	0.47 ± 0.50
Copper				
Range	26.36-398.16	12.23-178.53	3.30-157.30	5.09-20.95
Mean ± SD	134.02 ± 115.48	*49.62 ± 49.23	*38.84 ± 43.09	10.44 ± 5.97
Zinc				
Range	Nd-285.80	29.25-201.38	Nd-211.63	Nd-417.00
Mean± SD	120.44 ± 84.50	*72.95 ± 41.61	71.61 ± 57.43	131.55 ± 115.88

Nd = not detectable; SD = standard deviation; *correlation significant at $p < 0.01$.

The mean of detectable concentrations of cadmium in all the meat parts were higher than 0.161 $mgkg^{-1}$ reported by Miranda *et al.* [2] on calves from polluted industrialised area of Northern Spain and 0.096 $mgkg^{-1}$ for those in rural areas. All the mean values were also higher than 0.038 $mgkg^{-1}$ reported by Falanysz *et al.* [20] on liver of poultry from polluted area in Poland; 0.021 $mgkg^{-1}$ reported by Tahvonen [18] in Finland; 0.053 $mgkg^{-1}$ reported by Bokori and Fekete [21] in Hungary and 0.0985 $mgkg^{-1}$ reported by Skalická *et al.* [22] in Eastern Slovakia. However, the values were lower than 1.6 $mgkg^{-1}$ (fresh weight), reported by Garcia-Rico, *et al.* [23] in swine kidney from Sonora. Cadmium has a long biological half-life of about 30 years in humans [24]. It damages the proximal tubules of nephron, leading first to leakage of low molecular weight proteins and essential ions like calcium into the urine, with progression over time to kidney failure [25]. Even the loss of calcium caused by the adverse effect of cadmium on the kidney can lead to the weakening of the bones resulting to itai-itai disease [26].

Lead was detected in 10 of heart, 8 of muscle, 3 of kidney and 1 of liver out of 13 samples each. The single value detected in the liver (0.65 $mgkg^{-1}$) was higher than all other values indicating localized pollution. However it was contrary to most reports which tend to show that liver accumulates Pb [2, 27] more than other tissues. The lead concentration in this study was higher than 0.038 $mgkg^{-1}$ for both kidney and liver, and 0.008 $mgkg^{-1}$ for muscles reported by Miranda *et al.* [2], but lower than 0.671 $mgkg^{-1}$ for muscle and 1.072 $mgkg^{-1}$ for liver reported by Koréneková *et al.* [27]. Four samples of muscle and one sample each of heart, kidney, and liver exceeded the Codex standard of 0.1 $mgkg^{-1}$ for muscle and 0.5 $mgkg^{-1}$ for edible offal's in cattle [28], respectively.

Copper was detectable in all the samples but was highest in the liver with a mean concentration of 134.02 $mgkg^{-1}$. All the liver samples, 10 samples each of kidney and heart exceeded the 20 mg/kg recommended by Food Stuff, Cosmetics and Disinfectant Act Regulation [29]. The results from this study were higher than 26.6, 3.94 and 1.46 $mgkg^{-1}$ reported by Miranda *et al.* [2], in muscle, liver and kidney, respectively. They were also higher than those reported in the muscle (4.14 $mgkg^{-1}$), liver (36.88 $mgkg^{-1}$) and kidney (8.66 $mgkg^{-1}$) by Sharif *et al.* [30]; as well as those reported by Koréneková *et al.* [27] in muscle (4.57 $mgkg^{-1}$) and liver (31.07 $mgkg^{-1}$). However, 70 mg/kg reported by Sabir *et al.* [31] for muscle was higher than the results of this study.

The concentrations of Zn in the muscles were relatively higher compared with those of the liver, kidney and heart. According to Lopez-Alonso *et al.* [32], muscle is one of the important tissues for Zn accumulation and possesses Zn concentrations that were similar to those in the liver. This is demonstrated in this study with mean values in muscle (131.55 $mgkg^{-1}$) and liver (120.44 $mgkg^{-1}$). This is in agreement with studies by Johrem *et al.* [33], who reported similar concentrations (49.00; 40.00 $mgkg^{-1}$) in muscles and liver for cattle in Sweden; Falandysz [34], who reported (34.00; 42.00 $mgkg^{-1}$) in Poland; Miranda *et al.* [2] who reported (46.60; 36.80 $mgkg^{-1}$) and (47.00; 40.20 $mgkg^{-1}$) for both industrialised and rural areas in Spain. However, all the cited concentrations were lower than the concentrations from this study. In addition, about 80% of the muscle samples and 62% of the liver samples showed values above the Slovak Republic acceptable limits of 50 $mgkg^{-1}$ in muscle and 80 $mgkg^{-1}$ in edible offal's.

The Cd/Zn ratio in the kidney was 0.01, while it was 0.003 in liver and 0.005 in heart and muscle. Thus, the low zinc concentration in the kidney is attributed to higher cadmium accumulation in that organ. Cadmium causes reductions in both intestinal zinc absorption and hepatic zinc reserves in cattle [35], as a result of competition for the cation-binding sites of metallothionein (MT) [36].

Pearson's correlation showed strong significant correlations at $p < 0.01$ for Pb, Cd, Cu in heart and Pb, Cd, Zn, Cu in kidney, thus indicating a common source of contamination and an indication of serious environmental impact on the meat quality. The high standard deviations obtained in some of the metals could be attributed to different breeding environments, variations in the daily source of food, and the individual inherent capacity of the animals to excrete these metals through their urine and dung.

CONCLUSIONS

The results obtained in this study show high levels of Cd, Cu and Zn in the liver, kidney and muscles of goat bred in Nigeria. This could be indicative of wide and substantial contamination of the Nigerian environment by these heavy metals. Thus, the high levels of these metals determined in these animals impair the quality of meat obtained from them; however, lead levels determined were relatively within safe limits.

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