

Distribution and concentration of heavy metals in tissues of cattle slaughtered in Western Agricultural Zone of Nasarawa State, Nigeria

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ABSTRACT: Heavy metals may occur as inherent components of meat in which their accumulations may influence tissue quality. The present study was conducted to determine the presence and concentrations of heavy metals from liver (n=50), kidney (n=50), muscle (n=50), intestine (n=50) and skin (n=50) of cattle slaughtered in western agricultural zone of Nasarawa State, Nigeria. Cross-sectional study and laboratory analysis were adopted. The tissues were collected from the abattoir and analysed for the presence of Cadmium (Cd), Chromium (Cr), Lead (Pb), Copper (Cu) and Nickel (Ni) using an Atomic Absorption Spectrophotometer (AAS). A total of fifty samples of the selected tissues were collected and analysed. Values obtained were compared with that of Food and Agricultural Organization recommendations. Statistical analysis was done using descriptive statistics such as frequency and percentages while ANOVA was used to analyse the effect of age and sex on the occurrence of heavy metals. The mean concentrations (mg/kg) of Ni, Cd, Pb and Cu in all the sampled tissues are generally low and below the codex standards (Cd 0.5 mg/kg, Pb 0.5 mg/kg, Cu 0.5 mg/kg, Ni 0.5 mg/kg and Cr 1.0 mg/kg). The mean concentration of Cr in the liver was 1.3795 ± 5.1737 mg/kg and above the codex permissible limit of 1.0 mg/kg. There was a significant ($p < 0.05$) difference in the concentration of Cd between male and female cattle. A significant difference ($p < 0.05$) in the concentration of Ni, Pb and Cd between animals of age < 3 years and > 3 years was established. The establishment of cattle colonies and ranches across Nigeria by regulatory bodies is highly recommended. This could reduce access to contaminated pasture and water. Public insight on the danger of grazing cattle around heavy metals prone areas such as automobile workshops, construction sites and paint factory premises should be advocated through policy-making, stakeholder engagement and awareness campaigns. Measures should be put in place for continuous monitoring of heavy metals in cattle by surveillance and routine evaluation of tissues of slaughtered cattle from the western agricultural zone of Nasarawa state, Nigeria.

Keywords: AAS, abattoir, cattle, heavy metals, Nasarawa State, tissues.

INTRODUCTION

The consumption of food contaminated with heavy metals results in toxicity and diseases in humans and animals, which is an issue of global concern and priority (Michael *et al.*, 2018). These metals are natural components of the environment but a high rate of industrialization has been

responsible for their wider diffusion and dispersal in the environment (Rajaganapathy *et al.*, 2011). Nigeria is considered the most populous country in Africa (WHO, 2015) and one of the consequences of increased human population is the rise in anthropogenic activities and

impacts on the environment, it is possible to establish relationships between overpopulation, poverty and urban air pollution. Contaminated food is one of the main sources of exposure to heavy metals and an increased dietary heavy metal intake may contribute to the development of various disorders such as gastrointestinal and kidney dysfunction, cancer, low blood pressure and immune system disorder (Michael *et al.*, 2018). Heavy metal toxicosis in animals occurs when livestock ingest contaminated forage and water or inhale contaminated air from their surroundings. This ultimately bio-accumulates in the tissues and organs such as the liver, and kidney, which are consumed by humans as a source of animal protein (Okareh and Oladipo, 2015). Anthropogenic activities such as mining, use of inorganic agricultural products, and unselective dumping of waste on land and water contribute to the existence of toxic metals in the ecosystem (Jayasekara *et al.*, 1992). Other anthropogenic sources of heavy metal contamination include agricultural activities, such as pesticide and herbicide application for the control of pests and shrubs on farmlands, contaminated irrigation water, and municipal waste used for fertilization of crops (Alloway and Jackson, 1991). Heavy metal contamination can be transferred to cattle through direct exposure, drinking polluted water, eating crops grown on sewerage, contact with industrial effluents, and inhalation of vehicles and other emissions as they migrate from one place to another. These animals in the process could be liable to exposure to high levels of contaminants in the environment (Krajnc *et al.*, 2013). On the other hand, Cr (III) is an essential nutrient that plays a role in glucose, fat and protein metabolism by potentiating the action of insulin (Goyer, 2001). However, studies reported by Gumbleton and Nicholls (1988) and Sidney *et al.* (2001) found that high levels of Cr (VI) induced renal damage and hepatic mitochondrial and microsomal lipid peroxidation, as well as enhanced excretion of urinary lipid metabolites including malondialdehyde in rats when administered by single subcutaneous injection and orally respectively. Although Nasarawa State is not an industrial state, the state has abundant solid mineral resources thereby attracting significant mining activities which in most instances are in close proximity to communities where humans and animals are residing and agricultural activities are practised. The mining activities alongside anthropogenic activities may result in the spread of heavy metals and contamination of pasture and grazing fields in the study area. The significance of this study to the study area is informed by the lack of available records on the levels of heavy metals in animal tissues as well as the rising mining and agricultural activities in the state. The aim of this study therefore is to detect the presence and concentration of some heavy metals including toxic heavy metals from the skin and some selected internal organs of cattle slaughtered from the western agricultural zone of Nasarawa State, Nigeria.

MATERIALS AND METHODS

Study design

A cross-sectional study was conducted to determine the presence and concentration of heavy metals in the tissues of cattle. A laboratory analysis was also performed using an Atomic Absorption Spectrophotometer (AAS) to determine the concentration of Cd, Cr, Cu, Ni and Pb.

Study location and sampling procedures

The study was conducted in the Western Agricultural Zone of Nasarawa State. The zone falls within the Guinea Savannah agro-ecological zone. Nasarawa State is found between latitudes 7°52'N and 8°56'N and longitudes 7°25'E and 9°37'E. Annual rainfall figures range from 1100 to 2000 mm with mean monthly temperatures ranging between 20 and 34°C (Lyam, 2000). The state has a total human population of about 2,523,400 (NPC, 2016) and the vegetation is Guinea Savannah which is conducive for farming and rearing livestock.

Nasarawa's western agricultural zone comprises of five local government areas named; Karu, Keffi, Kokona, Nasarawa and Toto. Two local government areas (Keffi and Nasarawa) were randomly selected for the sampling. Each of these local government areas has one central abattoir with different slaughter houses located across the communities. The central abattoirs from the two randomly selected areas were considered because they are the only registered and recognized abattoirs by the government of the local authority. Most of the slaughterhouses were not registered and were operating illegally, therefore, they were excluded from the study. The sample population consisted of slaughtered cattle from the abattoirs recruited. Sheep and goat were excluded from the study because singeing is the dressing method adopted in the abattoir for these species. Used automobile tyres along with other plastic materials were used in generating the heat, while diesel oil was used in fuelling the fire. This procedure could affect the outcome of our findings, thus sheep and goats were excluded from the study.

Sample size

A total of 50 cattle were sampled, from which 250 tissues were collected for analysis. The characteristics of the sampled cattle considered before slaughtered include age and sex. Breed and management practices were not considered. Cattle that were presented for slaughtering from areas outside the study location were excluded from the study.

Sample collection

Six different visits were made to the abattoir within the

study period. The samples collected include muscle, kidney, liver, intestine and hide from the slaughtered cattle. The characteristics of the sampled cattle (age and sex) were considered and recorded against each of the corresponding samples collected. The ageing of the cattle was done according to the dentition methods described by the Food Safety Inspection Service (2013) of the United States Department of Agriculture. The samples were labelled and put in polyethylene bags, preserved in an ice pack and transported to the Chemical Laboratory of the National Research Institute for Chemical Technology, Zaria, Nigeria.

Sample preparation

The frozen samples collected were placed in a watch glass and allowed to thaw for one hour at room temperature before the digestion process.

Samples digestion

The samples of intestine, muscle, liver, hide and kidney from cattle were weighed and decomposed by dry digestion method for the determination of lead, chromium, nickel, copper and cadmium residues as described by Oyugi *et al.* (2024) but with minor modifications. Briefly, the frozen samples were allowed to thaw as described earlier. About 5.0 g each of the collected cattle tissues are oven dried at 80° for 2 hours, made into powder (Using mortar) by approximately weighing 2.0 g each of the samples and ashed in a furnace at 550° for 90 minutes. The ash was transferred into a beaker containing 2 mL of concentrated nitric acid (conc. HNO₃) and hydrochloric acid in the ratio 3:1 and heated on a hot plate at 50°C for a couple of minutes to ensure entire dissolution. The resultant solution was allowed to cool and thereafter distilled water (15 mL) was added, and the mineralized solution was subsequently filtered with Whatman no. 42 filter paper into a 25 mL volumetric flask; finally, it was made up to the mark with distilled water. The digested samples were kept in the refrigerator at 4°C until analysis.

Analysis of samples

The heavy metal contents (Cu, Cd, Ni, Cr, and Pb) in the sediment samples after pre-treatment (Digestion) were detected by an atomic absorption spectrometer (AA-6300, Shimadzu, Japan) with an air/acetylene flame and acetylene (0.09 MPa) as the auxiliary gas at a pressure of 0.4 Mpa. The calibration was done with standard solutions containing the five elements (Cu, Cd, Ni, Cr and Pb) after which they were aspirated into the AAS apparatus for analysis.

Data analysis

The concentration of Pb, Cd, Ni, Cu and Fe was evaluated using descriptive statistics such as frequency and percentages while ANOVA was used to analyse the effect of age and sex on the concentration of the metals using IBM SPSS Statistics, version 20.

RESULTS

The distribution of sampled cattle as affected by sex and age

Out of the total cattle sampled, 10% (5) were male while 90% (45) of the sampled cattle were female as described in Table 1. This shows that most of the cattle slaughtered in the study area are female, the male cattle are usually reserved for festivals and breeding purposes as shown by Sabuwa *et al.* (2019). From the 50 cattle sampled, 76% (38) were young cattle of age < 3 years. While 24% (12) were older cattle of age > 3.5 years. This also indicates that the majority of the cattle slaughtered during the period of study are animals of relatively younger age.

The distribution of heavy metals as related to organs

Table 2 describes the distribution of heavy metals as related to organs. The liver is the organ that is most affected by heavy metals in the study area. Muscle is the least affected organ when compared with other organs. No significant difference ($p > 0.05$) exists in the concentration of heavy metals between organs.

The result for mean concentrations (mg/kg) of Ni, Cu, Cr, Pb and Cd as affected by sex is presented in Table 3. Cr is the most and least detected metal in female and male cattle, respectively. The mean concentration (mg/kg) of Ni is the highest detected heavy metals in animals of age >3 years. Cr and Pb are the least detected metals with a negative value in animals of age >3 years.

Mean concentration (mg/kg) of heavy metals as affected by age

The mean concentration (mg/kg) of heavy metals as affected by age is indicated in Table 4. The highest concentration (mg/kg) of heavy metal is Cr detected in female cattle. There exists a significant difference ($p < 0.05$) in the concentration (mg/kg) of Cd between male and female cattle.

DISCUSSION

The current study analysed the mean concentration of heavy metals in the tissues of cattle in the western

Table 1. Distribution of cattle according to sex and age

Parameters	Number examined	Percentage
Sex		
Female	29	58.0
Male	21	42.0
Age (years)		
<3	31	62.0
>3	19	38.0

Table 2. Mean concentration (mg/kg) of heavy metals as related to organs from the western agricultural zone of Nasarawa State (n = 50).

Parameters	Intestine	Kidney	Liver	Muscle	Skin	S.D	LOS
Ni (Nickel)	0.2981	0.4565	0.3293	0.3272	0.1619	0.3942	NS
Cu (Copper)	0.0021	0.0024	0.0030	0.0033	0.0049	0.0064	NS
Cr (Chromium)	0.5645	-0.3078	1.3795	-0.4980	0.8643	5.1737	NS
Pb (Lead)	0.0281	0.0035	0.0499	-0.0752	0.0524	0.1547	NS
Cd (Cadmium)	0.0025	0.0020	0.0025	0.0034	0.0016	0.0039	NS

S.D = Standard deviation, LOS= level of significance, NS= Not significant.

Table 3. The mean concentration of heavy metals in the tissues of cattle as related to sex.

Parameters	Female	Male	S. D	LOS
Ni (Nickel)	0.3351	0.2862	0.3942	NS
Cu (Copper)	0.0038	0.0023	0.0064	NS
Cr (Chromium)	1.2790	-0.8127	5.1737	NS
Pb (Lead)	0.0342	-0.0192	0.1547	NS
Cd (Cadmium)	0.0034 ^a	0.0009 ^b	0.0039	*

^{ab} means on the same row having different superscript differ significantly (P<0.05); S.D = Standard deviation; LOS= level of significance.

Table 4. Mean concentration (mg/kg) of heavy metals in the tissues of cattle as related to age.

Parameters	1-3 years	>3 years	S. D	LOS
Ni (Nickel)	0.1949 ^b	0.5099 ^a	0.3942	*
Cu (Copper)	0.0040	0.0017	0.0064	NS
Cr (Chromium)	0.8834	-0.3874	5.1737	NS
Pb (Lead)	0.0451 ^a	-0.0427 ^b	0.1547	*
Cd (Cadmium)	0.0033 ^a	0.0008 ^b	0.0039	*

^{ab} means on the same row having different superscript differ significantly (P<0.05); S.D = Standard deviation; LOS= level of significance.

agricultural zone of Nasarawa State, Nigeria. The heavy metals detected from various organs investigated in this study area are Ni, Cu, Cr, Pb and Cd. The majority of the cattle sold and slaughtered during the current study were

female. This is not in line with the findings of Riehn *et al.* (2010) that sound economic management demands that animals meant for slaughter should be mainly males and reproductively inactive females. Sixty-two per cent (31) of

the cattle were <3 years of age while 38% (19) of the cattle sampled were >3 years. The ageing of the cattle was done according to the dentition methods described by the Food Safety Inspection Service (2013) of the U. S. Department of Agriculture. This indicates that the majority of the cattle slaughtered in the abattoir were relatively younger animals. This finding concurs with that of Sabuwa and Nafarnda (2020) conducted in the southern agricultural zone of Nasarawa State. The mean concentration of heavy metals across all organs was insignificant and agrees with the result obtained by Sabuwa *et al.* (2021) who also showed no significant difference in the concentration of heavy metals in tissues of cattle. Cr is the most detected heavy metal when compared with other metals. The liver recorded the highest concentration of Cr followed by the intestine. This pattern of distribution of heavy metals in the tissues of cattle does not agree with the findings of Okara and Oladipo (2015) who showed that the kidney bio-accumulate Cr than the liver. The least concentration of Cr is detected in the kidney followed by muscle. This is contrary to the results obtained by Fathy *et al.* (2011). They reported mean concentrations of 0.011 and 0.025 mg/kg in muscle and kidney, respectively, values that are far higher than those obtained in this study. The concentration of Cr in the liver is higher than the maximum permissible limit of 1.0 mg/kg recommended by FAO (2011). This is similar to the study of Simon *et al.* (2017) conducted in Makurdi North Central Nigeria who also reported higher Cr concentration in cattle tissue above the maximum permissible limit. Cr is toxic in animals and the human body and the liver is largely responsible for the detoxification of toxic substances in the body, including metals. The higher concentration of Cr detected in the liver could be due to the failure of the organ to filter and completely eliminate Cr compounds from the animal system, which eventually bio-accumulated in the liver as opined by Abou-Arab (2001). The high concentration of Cr discovered in the current study is comparable to the findings of Zahurul *et al.* (2011) who reported a high concentration of Cr in fresh cattle organs above the recommended limit. Cr is commonly incorporated in stainless steel and used as an anti-corrosive agent in pipes, tanks and wood-treated compounds as demonstrated by Oliveira (2012). This shows that the high concentration of Cr detected from the western agricultural zone of Nasarawa State could be due to anthropogenic pollution as a result of widespread usage of chromium-bond utensils. Furthermore, Zayad and Terry (2003) opined that Cr exists in different oxidation states and is more stable in the environment when compared with Ni, Cd, Cu and Pb. This could also explain why Cr was found in higher concentrations than the rest of the metals. Napoleon *et al.* (2019) conducted a study in Ghana to evaluate the presence of heavy metals in the skin of cattle; they reported high mean concentrations (mg/kg) of 2.01, 0.34 and 0.08 respectively for Cu, Pb and Cd from the skin

of slaughtered cattle. Their findings far exceed the result obtained in this study conducted in Nasarawa State, North Central Nigeria. The high concentration of these metals recorded in their study could be due to the high level of anthropogenic and industrial activities in Wa Municipality of the Republic of Ghana.

The concentration of Cd in the liver is higher than in the kidney. Least Cd concentration is detected in the skin followed by the kidney. This pattern of Cd predilection in organs of cattle is not in agreement with the studies of Simon (2017) and Pompe-Gotal and Crnic (2002) conducted in Nigeria and Croatia respectively which revealed Cd bio-accumulate more in the kidneys than any organ of the body. The mean concentration (mg/kg) of Cd from cattle tissues recorded from the study area was generally low. This shows that the environment where these cattle are raised is free from excessive Cd contamination. This is an addendum to the study of Miranda *et al.* (2009) that reported cattle and other ruminants are indicators of environmental contamination with heavy metals. Cd compounds are classified as human carcinogens by the International Agency for Research on Cancer (IARC, 1993). The skin recorded the lowest mean concentration of Ni, kidney recorded the highest concentration of Ni compared with other tissues, with a mean concentration that is about 3 times higher than the concentration detected in the skin (0.0044 mg/kg). Iwegbue (2008) in his study conducted in southern Nigeria recorded higher levels of Ni in kidneys (0.20 mg/kg) and liver (0.12 mg/kg) than the concentration recorded in this study. Although Ni plays a vital role in the body by regulating prolactin and stabilization of RNA and DNA structures, an excess amount of Ni can produce severe allergic reactions, bronchial asthma, dermatitis and myocardial infection as shown by Murtic and Viswanathan (1989). The concentration of Pb is highest in the liver (0.0499 mg/kg), followed by the skin (0.0524 mg/kg), and the lowest concentration is detected in muscle (-0.0752 mg/kg). The pattern of distribution of Pb in the tissues of cattle in this study is in addendum to the findings of Flora (2006) which disclosed that the maximum percentage of lead in the body concentrates more in the kidneys and liver. All the sampled tissues recorded concentrations that were lower than the recommended daily intake of 0.1 mg/kg (FAO, 2011). The level of Pb in tissues and blood has a significant correlation with the levels and metabolism of essential trace metals (Singh *et al.*, 1994). Ahamed *et al.* (2007) in India studied the *in vivo* interaction of Pb with some essential trace elements in the blood of underage children, and their results showed a significant association between elevated blood Pb levels and the risk of anaemia. This establishes that elevated tissue Pb levels will result in a corresponding decrease in the concentration of some essential metals in the animal and human body. Bala *et al.* (2014) in their study conducted in Sokoto, northwestern Nigeria reported an elevated mean concentration of Pb in

the liver (1.523 mg/kg) and kidney (0.8442 mg/kg) of cattle, values that are exceedingly higher than the values obtained from this study conducted in north-central Nigeria. Zahurul *et al.* (2011) in their study conducted in Bangladesh to determine the levels of Pb in slaughtered cows reported a high mean Pb concentration (0.7 mg/kg) in the liver that is over 10 times the concentration detected in this study. Monitoring the residual concentration of Pb in different tissues parts and organs is important for human health. Lead has been shown to increase blood pressure and cardiovascular diseases in adults (Badis *et al.*, 2014). The levels of Pb detected from this study reveal that the public in the study area are not exposed to significant health risks associated with the consumption of cattle meat. This outcome is similar to the study of Ihedioha and Okoye (2013) carried out in Enugu state, Nigeria where they reported low health risks due to Pb associated with the consumption of cattle meat. The current study demonstrates the intestine and kidneys have nearly equal mean Cu concentrations of 0.0021 mg/kg and 0.0024 mg/kg, respectively. The highest mean Cu concentration was detected in the skin. This is in contrast to the findings of Oymak *et al.* (2017) who revealed Cu bio-accumulates primarily in the liver, compared to other tissues. The Cu concentrations obtained from this study were lower than those recorded by Abou-Arab (2002), he obtained a mean concentration of 2.20 mg/kg in fresh meat far lower than the average concentration detected by Oymak *et al.* (2017) in muscle (3.85 mg/kg), liver (280.86 mg/kg) and kidneys (15.82 mg/kg). Cu is an essential metal that is required for the formation of red blood cells, as well as many oxidation and reduction reactions in humans and animals. However, high Cu concentration is toxic to tissues, which can result in liver and kidney damage. The concentrations of Cu across all tissues observed from the study are below the FAO permissible limit of 20 mg/kg.

The concentration of Cu in animals of age <3 years is higher than observed in the >3 years category. There exists a significant difference ($p < 0.05$) in the concentration of Ni, Pb and Cd between animals of age <3 years and >3 years. No significant difference ($p > 0.05$) exists in the concentration of Cr and Cu between the two age categories. The concentration of Ni in the older age category is over 2.5 times higher than detected in the younger age group. The possible reason for the higher concentration in the older age group could be the effects of prolonged bioaccumulation over time. As the animal ages, more residual levels of Ni accumulate in the blood and tissues of the cattle. This is in line with the findings of Mukesh *et al.* (2010) that Cd and other heavy metals are almost absent in the body at birth, but they accumulate with age. The mean concentration of Cr and Cd in the younger age group is higher than detected in the older age group. This outcome contradicts a similar study conducted by Sabuwa *et al.*, (2020) which showed older cattle bio-accumulate Cr and Cd in their tissues than cattle

of young age. All the metals (Ni, Cu, Cr, Pb and Cd) detected showed a mean concentration (mg/kg) that is higher in female cattle than in male cattle. This could probably be due to the high feeding pattern of female cattle owing to physiological (when pregnant or lactating) demand. Female cattle show a significantly ($p < 0.05$) higher concentration (mg/kg) of Cd than the mean concentration in male cattle. This is at par with the study of Sabuwa *et al.* (2017) who showed no significant difference ($p > 0.05$) in the concentration of Cd between male and female cattle.

Conclusion/Recommendation

The study discovered the presence of residues of heavy metals in some organs of cattle slaughtered in the western agricultural zone of Nasarawa State, Nigeria. The concentrations of Ni, Cd, Cu and Pb are low and within the permissible limits. The concentration of Cr was found in higher concentration and above the permissible limit of FAO indicating that the environment and or feed where the cattle grazed is heavily contaminated. Sex and age have significant effects on the concentrations of heavy metals in the tissues of cattle slaughtered from the western agricultural zone of Nasarawa State.

This calls for the continuous monitoring of heavy metals in both animals and the environment of the study area, by continuous chemical assessment of animal tissues, pasture and other sources of animal feed. Public awareness by both government and cattle breeders' associations on the potential risk of pasturing cattle near manufacturing and mechanic factories through town hall meetings, media talks and advocacy campaigns is hereby recommended. The extensive application of agricultural chemicals on crops, pasture and other agricultural produce should be discouraged and be substituted with organic and environmentally friendly alternative compounds. The establishment of ranches and colonies by government and private investors is extremely recommended especially in Nigeria where open grazing is the predominate practice of cattle rearing. This could lessen the likelihood of cattle grazing and drinking from heavy metals contaminated pastures and water sources.

CONFLICT OF INTEREST

The authors declare that they have no conflict interest.

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