FOUNTAIN JOURNAL OF NATURAL & APPLIED SCIENCES

A Publication of the College of Natural & Applied Sciences

Fountain University, Osogbo, Nigeria

Assessment of heavy metal toxicity potential in the meat of randomly selected cows and goats slaughtered in Ado Ekiti abattoirs, Nigeria

Adeoye, A. O.,[1*] Imam, N.,[1] Quadri, R. O.,[1] Lawal, O. S.[1]

[1]*Department of Chemistry, Federal University Oye-Ekiti, Ekiti State, Nigeria.*

**Correspondence:* bioken2017@gmail.com

ABSTRACT

Meat is a premier protein source that enhances human health and well-being by facilitating tissue repair, growth, and antibody synthesis. However, heavy metal contamination in animal tissues and organs is a growing concern due to its potential health risks through bioaccumulation in the food chain. This study investigated the concentration of cadmium (Cd), chromium (Cr), lead (Pb), and zinc (Zn) in blood and selected organs (liver, kidney, heart, and intestine) of bovine and caprine species from the Ado Ekiti, Nigeria, abattoir. Samples were collected, prepared, and digested using standard protocols, while an atomic absorption spectrophotometer (AAS) was employed to determine the metal concentrations as an index of potential toxicity. The findings revealed varying levels of heavy metals across all samples, with the kidney and intestine showing higher concentrations of heavy metal contaminants, followed by the liver and heart. Consistently, Zn was found in higher concentrations, while Cd, Pb, and Cr exceeded World Health Organisation (WHO) permissible limits in most samples. Comparatively, results indicated higher metal concentrations in goats than cows, possibly due to differences in feeding habits and environmental exposure. Blood samples also reflected recent exposure, with metal levels slightly above acceptable limits. The research highlighted the potential health risks associated with consuming contaminated animal products and called for continuous monitoring of heavy metals in livestock to safeguard public health.

ARTICLE INFO

Article history:
Received August 2025
Revised November 2025
Accepted December 2025

Keywords:
Bioaccumulation; Cows; Goats; Heavy metals; Public health

Introduction

In recent years, environmental protection agencies have faced challenges in attaining sustainable development through environmental balance strategies, such as enhancing quality of life by ensuring access to potable water and safe food, as well as fostering conditions that may ameliorate the declining health of both humans and animals, given the inextricable connection between food safety, nutrition, and security [1-2].

Anthropogenic factors have increased heavy metal pollution in our water, soil, air, and food. Heavy metals are ubiquitous [3], persistent [4], and have spread across all forms of environmental media and ecosystems [5]. They are also known to bioaccumulate, meaning they can build up in living organisms through deposition or consumption [4]. Heavy metal pollution is a global threat to the environment, as heavy metals are widely present in the earth's crust, air, water, and food, and have become a major concern due to their adverse effects on the health of living organisms via bioaccumulation [6]. Modern farming methods, such as the use of nanotechnology for soil remediation, could lead to heavy metal accumulation in soil [7].

The major vitamins and minerals required for normal human bodily function are derived from food, and when food comes into contact with heavy metals through air, water, or soil, it becomes contaminated. WHO [2] reported an estimated population of 600 million people who fall sick early from eating contaminated food, and 420,000 die due to this per year.

DOI: https://doi.org/10.53704/fujnas.v14i2.920

Ingestion of contaminated food items by animals is highly likely in Ekiti State due to the nomadic farming system for raising cattle, which could lead to the deposition of varying concentrations of heavy metals in their bloodstream, kidneys, liver, and intestines. The open grazing system is considered cheap for raising cattle, but the toxicity of the biomass waste they feed on cannot be consistently determined; hence, it could affect humans who consume their meat. We could then say with certainty that food safety and human health have been threatened by the negative effects of heavy metal contamination, as these metals are toxic even at low concentrations and can accumulate in human and animal bodies [8-9].

Cows and goats are important sources of meat and dairy products for human consumption, especially in southwestern Nigeria, where they are used for weddings, funerals, and naming ceremonies due to large crowds and a long-standing preference for their meat. As a premier source of protein, meat enhances general health and well-being by facilitating tissue repair and growth, as well as antibody synthesis [3]. However, heavy metal contamination in animal tissues and organs has been a growing concern lately due to its potentially hazardous impact on human health through bioaccumulation in the food chain. Castro-González et al. [10] demonstrated in their study that heavy metals bioaccumulate in living organisms as a whole and in different animal organs. Specifically, their research further observed that the liver and kidney are often the primary sites of deposition of these heavy metals [10]. Possibly, as confirmed, these organs are more susceptible to higher concentrations of heavy metals than other body parts. This assertion corroborates the fact that these organs play a vital role in detoxification and excretion systems. Similarly, these obnoxious metals travel through the bloodstream as a transport medium in the body [11], and their concentrations are the most likely measure of recent or long-term exposure to heavy metals. Prior research has reported heavy metal concentrations in the organs of cows and goats across various geographical locations worldwide. In Nigeria, for instance, a study [12] investigated the levels of Cd, Pd, and Cr in the muscle, kidney, liver, and blood of goat samples collected from the Sokoto and Gusau new abattoirs. Egigba et al. [13] investigated the concentrations of copper, chromium, cadmium, and lead in bovine kidney, liver, and muscle tissues in an oil-producing community, the Niger Delta, Nigeria. Their findings were significant despite reporting that the investigated heavy metals were within acceptable limits. Furthermore, assessing metal content in bodily fluids (urine or blood) is typically employed as a biomarker for exposure [14]. Hence, the decision was made to sample the blood of the selected animals. According to a study [15], regulating animal inputs may serve as an effective means of mitigating human health hazards associated with animal products and significantly reducing environmental pollution from manure. However, this goal could not be achieved without continuous monitoring of heavy metals, which is paramount for public health. Ogu and Akinnibosu [16] showed that public health risk linked to heavy metals is of great concern. The study examined a total of 240 randomly selected chickens, with Ado Ekiti selected as one of the four study locations for heavy metals, including Cu, Pd, Cr, Cd, Mn, Ni, and Zn. The study reports a low non-carcinogenic risk in all the locations except Cd. The study also suggests at least 1 cancer case in 1000 people exposed to heavy metals in both children and adults.

Aspergillus species, which are notorious for producing aflatoxins, a causative agent for cancer, have also been reported to be found in dried beef sold in markets in Ekiti [17], and there were also suspected cases of anthrax, which has prompted the local health authority in Ekiti to warn against indiscriminate meat consumption [18]. The available information suggests the possibility of other toxic contaminants (organic or inorganic) in the widely consumed cow and goat meat sold in Ado Ekiti, Ekiti State.

Food safety is a global concern due to the recent increase in heavy metal concentrations and other industrial contaminants found in analysed food materials [19]. The primary industrial activity in Ekiti State is quarrying, which disseminates hazardous heavy metals into the ecosystem through the dispersion of tiny particles. The rise in automotive dismantling activities contributes to soil pollution with heavy metals, including those released during battery disassembly, further exacerbating the dispersion of these contaminants. Hence, this current study aimed to assess the potential toxicity level via assessment of the concentration of heavy metals in the animal parts (heart, kidney, liver, and intestine) and blood of cows and goats obtained in Ado Ekiti, Ekiti State, southwest Nigeria, since heavy metal bioaccumulation, even at low concentrations, is a potential toxic material. The study is also justified, as there is an ongoing need to determine the presence and concentration of heavy metals in various organs and blood of livestock

DOI: https://doi.org/10.53704/fujnas.v14i2.920

animals, which serve as a major source of protein for the Ekiti people. In addition to building the literature on heavy metals in livestock, the research findings will also provide useful information on the potential health risks of consuming animal products in the study area (Ado-Ekiti, Nigeria) and other countries.

Material and methods

Sampling area, collection of blood and organ samples of the cow and the goat

Blood and organ samples were collected on 20th November 2023 from an abattoir location in Ado Ekiti, Ekiti State (Ekiti State Cows Slaughter). Five samples of four (4) different organs and blood of each cow and goat were sampled randomly from a population of 48 cows and 15 goats for the research. Approximately 1 kg of each organ was purchased; this weight was achieved by randomly cutting from different parts of each organ. Blood was collected from a large bowl. The animal population was assumed to be homogeneous with respect to diet, environmental exposure, and maturity (age). Heavy metal contamination assessment is easily detectable in a number of selected animals. The selected organs were the heart, liver, kidney, and intestine, making a total of 25 samples (including blood). The samples were separated into different clean polythene bags, kept in a cooler packed with ice, and immediately transported to the Three in One Chemistry laboratory at the Federal University, Oye, Ekiti, for further treatment, digestion, and elemental analysis. Quality control protocols were observed from sample collection through analysis to minimise contamination from external metallic sources.

Organs preparation and digestion

About 100 g each of the collected cow and goat parts (heart, liver, intestine, and kidney) obtained from the major abattoirs in Ado Ekiti was cut into smaller pieces and dried at a constant temperature of 65 °C in a muffle furnace for a timeframe until constant weight was achieved at a period of 72 hrs. After drying, the tissue was pulverised and further ground using a porcelain mortar and pestle. About 2 g of the well-ground portion was dissolved in 20 ml of distilled H_2O, and 20 ml of concentrated HNO_3 was added after that to perform the first digestion. The mixture was then boiled at 100 °C on a laboratory hotplate for 60 minutes to form a colloidal solution, which was then allowed to cool. After cooling, 10 ml of 98% purity conc. H_2SO_4 was added to the solution, and the mixture was heated and maintained at 140 °C until a dense white fume was largely observed. A Whatman No. 2 filter paper was used to filter the solution after it had been cooled, transferred quantitatively to a 50 ml volumetric flask, and topped up to the meniscus level with distilled H_2O. The solution was transferred into a clean, labelled plastic sample bottle for the determination of heavy metal concentration using an atomic absorption spectrophotometer (AAS).

Blood sample preparation and digestion

To each 1.5 ml cow and goat blood sample collected from the Ado Ekiti animal slaughterhouse, 0.5 ml of a mixed solution of HNO_3 and H_2SO_4 (20:1, v/v) and 10 ml of distilled H_2O were added and stirred rigorously. The mixture was then gently heated to 70 °C in a water bath until the sample had reduced to half its original volume, after which 1 ml of HNO_3 was added. The solution was continually heated until a clear solution was obtained, then allowed to cool, filtered using Whatman filter paper, and quantitatively transferred into a 50 ml volumetric flask. The solution was transferred into clean, labelled plastic sample bottles for the determination of heavy metal concentrations using AAS.

Instrumental analysis for heavy metal determination

The instrumental analysis was carried out at the Afe Babalola University Research Laboratory using an atomic absorption spectrophotometer (AAS; Buck Scientific Model 211 VGP) in accordance with ALPHA 20^{th} Edition 3111B and 311D, ASTM D 3561, and ASTM D 5198 methods. The method required direct aspiration of the digestive liquid sample in an acidic medium into an air/acetylene flame at specified wavelengths of 228.0 (nm), 357.9 (nm), 283.3 (nm), and 214.0 (nm) for cadmium (Cd), chromium (Cr), lead (Pb), and zinc (Zn), respectively [20].

For each metal under investigation, the equipment was calibrated prior to use using working standards of known concentrations. The sample's metal concentrations were obtained by aspirating the digested samples directly into the flame.

Quality control and quality assurance

All chemicals and standard stock solutions used in this study were of analytical grade with a purity of 99.0% obtained from Sigma-Aldrich. For quality control, blanks were examined following every five samples, and a calibration curve for each element was established with an R^2 close to 0.999. The detection

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limits for the examined heavy metals were as follows: Cd (0.014 µg/mL), Cr (0.015 µg/mL), Pb (0.030 µg/mL), and Zn (0.005 µg/mL).

Data analysis

Concentration of heavy metal expressed in mg/kg in organs and mg/L in blood was expressed as mean ± standard deviation.

Results and discussion

Level of heavy metals in different organs of the cow

The levels of heavy metal (mg/kg) in various organs of the cow from the slaughter location are presented in Table 1. The results revealed varying levels of the metals across different organs, with the highest concentrations observed in the kidney and liver. Heavy metals were detected in all samples, except Cd in the heart and liver. Cadmium has a high concentration in the intestine, followed by the kidney, and it is slightly above the permissible limit. By contrast, Cr was highest in the kidney, followed by the intestine, whereas Pb showed the opposite pattern, similar to Cd. A similar pattern was also observed across the different organs, with either the kidney or intestine having the highest concentrations of the metals investigated. It is worth noting that the heart has the fewest metals among all the samples observed.

Numerically, as presented in Table 1, the kidney showed high levels of lead (0.0275 to 0.0425 mg/kg), cadmium (0.0075 to 0.0175 mg/kg), and chromium (0.0175 to 0.0275 mg/kg). Additionally, the high concentrations of lead, 0.0225 to 0.0375 mg/kg, and chromium, 0.0125 to 0.0225 mg/kg, were recorded. When compared with the WHO standard limits for the reported metals in meat, all reported metals were above the permissible levels (Table 1), except in the kidneys of samples A and B (A_k and B_k). These results conform with the findings of the study [11], which reported higher accumulations of heavy metals in cattle kidney and liver tissues. The kidney's role in filtration and the liver's function in detoxification make these organs the primary sites for heavy metal deposition.

The WHO permissible limit for cadmium is 0.001 mg/kg; data presented in Table 1 for cows showed Cd concentration was generally below or at the permissible limit except for some intestine samples coded (A_I, C_I, D_I, E_I) where concentration values slightly exceeded the WHO limit, which demonstrates toxicity implications of kidney damage and skeletal deformation when consumed over a long period. In all samples, chromium concentration significantly exceeds the WHO permissible limit of 0.004 mg/kg, especially in samples of intestines and kidneys, which can cause liver and kidney damage and also present a carcinogenic risk. Abakpa et al. [21] reported chromium concentrations higher than permissible limits in the milk of cattle grazing around coal mining zones. The lead concentration violates the WHO limits of 0.008 mg/kg in all cases, specifically in the intestines, similar to the analysed violation records of Cd and Pb in kidney, liver, and muscle tissues in studies [22] & [23], which could result in lead poisoning linked to neurological disorders, growth retardation, and gastrointestinal disorders [19]. The zinc concentrations across all samples also violate a permissible limit of 0.005 mg/kg. Even though zinc is an essential element, its high concentration can cause nausea, weaken the immune system, and alter the absorption of other metals, as reported in [19], which documented Zn toxicity in cattle due to contaminated feed and water sources.

Levels of heavy metals in different organs of the goat

A similar trend was observed across the goat's different organs analysed, with the kidneys and liver showing the highest concentrations of heavy metals. It is noteworthy that all the metals were detected except in B_H and C_H for Cd. Additionally, the heart sample shows the least amount of these metals. As presented in Table 2, lead levels in goat kidneys ranged from 0.0225 to 0.0375 mg/kg, while cadmium concentrations were between 0.0075 and 0.0175 mg/kg. The liver samples contained notable levels of lead (ranging from 0.0175 to 0.0325 mg/kg) and chromium (ranging from 0.0125 to 0.0225 mg/kg). All the results were above the WHO permissible limit, which is a cause for alarm and a threat to human health.

These observed findings are comparable to those reported in [24], who found significant accumulations of lead and cadmium in goat kidneys and livers from Nigerian abattoirs. The consistent reporting of heavy metal accumulation in these organs, particularly the kidney and liver, across different studies suggested a tendency to accumulate heavy metals and thus warranted continuous monitoring or caution before eating.

Cadmium concentration in goats consistently violates

DOI: https://doi.org/10.53704/fujnas.v14i2.920

Table 1: Concentration of heavy metals in different organs of a cow's sample collected

Sample Code*	Organ(s)	Heavy Metals Concentrations (mg/kg)			
		Cd	Cr	Pb	Zn
A_H	Heart	ND ± ND	0.022 ± 0.026	0.015 ± 0.013	0.114 ± 0.119
A_K	Kidney	0.001 ± 0.001	0.152 ± 0.156	0.071 ± 0.073	0.368 ± 0.368
A_L	Liver	ND ± ND	0.060 ± 0.065	0.037 ± 0.040	0.176 ± 0.177
A_I	Intestine	0.007 ± 0.010	0.181 ± 0.186	0.094 ± 0.095	0.277 ± 0.278
B_H	Heart	ND ± ND	0.031 ± 0.030	0.026 ± 0.023	0.125 ± 0.122
B_K	Kidney	0.001 ± 0.002	0.166 ± 0.163	0.085 ± 0.087	0.375 ± 0.377
B_L	Liver	ND ± ND	0.043 ± 0.047	0.025 ± 0.022	0.134 ± 0.139
B_I	Intestine	0.006 ± 0.005	0.155 ± 0.150	0.123± 0.122	0.315 ± 0.311
C_H	Heart	ND ± ND	0.014 ± 0.013	0.014 ± 0.013	0.095 ± 0.092
Ck	Kidney	0.006 ± 0.006	0.181 ± 0.180	0.077 ± 0.074	0.314 ± 0.312
C_L	Liver	ND ± ND	0.090 ± 0.096	0.056 ± 0.055	0.205 ± 0.208
C_I	Intestine	0.013 ± 0.011	0.173 ± 0.179	0.084 ± 0.085	0.254 ± 0.259
D_H	Heart	ND ± ND	0.027 ± 0.025	0.019 ± 0.020	0.105 ± 0.108
D_K	Kidney	0.002 ± 0.001	0.096 ± 0.092	0.070 ± 0.072	0.318 ± 0.317
D_L	Liver	ND ± ND	0.118 ± 0.112	0.063 ± 0.060	0.190 ± 0.193
D_I	Intestine	0.008 ± 0.009	0.124 ± 0.120	0.068 ± 0.064	0.362± 0.370
E_H	Heart	ND ± ND	0.016 ± 0.015	0.032 ± 0.035	0.122 ± 0.126
E_K	Kidney	0.006 ± 0.005	0.154 ± 0.156	0.068 ± 0.067	0.305 ± 0.300
E_L	Liver	ND ± ND	0.055 ± 0.060	0.048 ± 0.042	0.156 ± 0.152
E_I	Intestine	0.018 ± 0.015	0.216 ± 0.212	0.115 ± 0.110	0.293 ± 0.298
WHO Permissible Limit		**0.001**	**0.004**	**0.008**	**0.005**

*The samples were coded A_x to E_x, where x represents the organ (first letter of each organ), and ND- Not Detected

Table 2: Concentration of heavy metals in different organs of the goat's sample collected

Sample Code*	Organ(s)	Heavy Metals Concentrations (mg/kg)			
		Cd	Cr	Pb	Zn
A_H	Heart	0.001 ± 0.001	0.091 ± 0.090	0.046 ± 0.048	0.326 ± 0.330
A_K	Kidney	0.005 ± 0.004	0.257 ± 0.258	0.104 ± 0.109	0.927 ± 0.930
A_L	Liver	0.002 ± 0.001	0.194 ± 0.197	0.066 ± 0.065	0.522 ± 0.527
A_I	Intestine	0.018 ± 0.020	0.367 ± 0.368	0.162 ± 0.161	1.308 ± 1.312
B_H	Heart	ND ± ND	0.278 ± 0.077	0.052 ± 0.051	0.398 ± 0.392
B_K	Kidney	0.005 ± 0.005	0.278 ± 0.283	0.116 ± 0.115	1.063 ± 1.072
B_L	Liver	0.001 ± 0.001	0.162 ± 0.160	0.050 ± 0.050	0.398 ± 0.397
B_I	Intestine	0.012 ± 0.015	0.297 ± 0.292	0.188 ± 0.185	1.615 ± 1.610
C_H	Heart	ND ± ND	0.086 ± 0.088	0.039 ± 0.036	0.217 ± 0.212
Ck	Kidney	0.003 ± 0.002	0.195 ± 0.197	0.120 ± 0.122	0.956 ± 0.959
C_L	Liver	0.001 ± 0.001	0.188 ± 0.185	0.076 ± 0.077	0.583 ± 0.587
C_I	Intestine	0.026 ± 0.025	0.385 ± 0.389	0.147 ± 0.149	1.133 ± 1.130
D_H	Heart	0.001 ± 0.001	0.072 ± 0.070	0.043 ± 0.040	0.342 ± 0.349
D_K	Kidney	0.010 ± 0.008	0.220 ± 0.226	0.135 ± 0.738	1.178 ± 1.183
D_L	Liver	0.002 ± 0.008	0.205 ± 0.207	0.090 ± 0.093	0.728 ± 0.724
D_I	Intestine	0.017 ± 0.018	0.354 ± 0.360	0.172 ± 0.175	0.984 ± 0.982
E_H	Heart	0.002 ± 0.003	0.104 ± 0.100	0.060 ± 0.062	0.376 ± 0.375
E_K	Kidney	0.006 ± 0.005	0.285 ± 0.284	0.216 ± 0.125	0.958 ± 0.962
E_L	Liver	0.006 ± 0.005	0.195 ± 0.196	0.084 ± 0.085	0.606 ± 0.606
E_I	Intestine	0.028 ± 0.030	0.379 ± 0.372	0.138 ± 0.139	1.317 ± 1.320
WHO Permissible Limit		**0.001**	**0.004**	**0.008**	**0.005**

DOI: https://doi.org/10.53704/fujnas.v14i2.920

the permissible limit of WHO in all the organ samples, with exceptionally high values in the intestines in case of samples (AI, CI, DI, EI), similar to high concentration reported in the study [25]. Similarly, chromium concentrations exceed WHO limits in all organs analysed significantly in (AK, AI, EI), as reported in [26], which also violates limits for Cd and Cr. Liver and kidney damage are linked to Cr toxicity, and also, its hexavalent chromium compounds are carcinogenic. Pd concentration assessment exceeds permissible limits of WHO, with the highest concentration recorded in the intestinal samples (B_I, D_I, E_K). Bataa et al. [27] reported a high concentration of Cd and Pd in goats linked to the mining effluent contamination of plants and water they consumed during open grazing. Pd Altered neurological development in children, while in adult cases of anaemia. Hypertension and kidney damage are very likely with prolonged exposure. Zn conc. also violates the standard, especially in their kidneys and intestines (A_I, B_I, E_I), similar to [25], which identified Zn contamination in goat organs near mining zones, with the intestines and kidneys showing the highest concentrations due to bioaccumulation from contaminated feed and water sources.

Levels of heavy metals in the blood sample

The levels of metals in blood samples from both cows and goats are presented in Table 3. They showed detectable levels of heavy metals, albeit generally slightly higher than those found in organ tissues. It is important to note that Cd in the goat was below the analytical instrument's detection limit. Across the two blood samples, the cow shows higher concentrations of all metals than the goat, except for Zn, where the goat's blood had a higher concentration, which may be associated with the goat's eating habits and environment. The lead concentrations in cow blood samples ranged from 0.0075 to 0.0175 mg/L, while goat blood showed slightly higher levels (0.0125-0.0225 mg/L). The presence of these metals in the blood samples indicated a likely recent exposure and ongoing circulation of these contaminants within the animals' bodies. Castro-González et al. [10] also confirmed the associations between blood heavy metal concentrations and environmental exposure in cattle. All detected metal concentrations exceeded the WHO limits, except for cadmium, where most data were within acceptable ranges, though some samples showed slightly elevated values.

Table 3: Concentration of heavy metals in the goat and cow blood samples

Sample Code*	Animal	Heavy Metals Concentrations (mg/L)			
		Cd	Cr	Pb	Zn
A_G	Goat	ND ± ND	0.016 ± 0.079	0.062 ± 0.066	1.528 ± 1.522
A_C	Cow	0.003 ± 0.001	0.114 ± 0.110	0.134 ± 0.133	0.382 ± 0.390
B_G	Goat	0.001 ± 0.001	0.093 ± 0.090	0.094 ± 0.090	1.760 ± 1.780
B_C	Cow	0.001 ± 0.001	0.289 ± 0.292	0.106 ± 0.100	0.485 ± 0.436
C_G	Goat	0.001 ± 0.001	0.085 ± 0.083	0.086 ± 0.083	1.868 ± 1.873
C_C	Cow	0.004 ± 0.005	0.115 ± 0.116	0.112 ± 0.119	0.376 ± 0.372
D_G	Goat	0.001 ± 0.001	0.064 ± 0.068	0.062 ± 0.065	0.975 ± 0.970
D_C	Cow	0.008 ± 0.009	0.176 ± 0.178	0.083 ± 0.079	0.269 ± 0.264
E_G	Goat	0.002 ± 0.001	0.070 ± 0.072	0.078 ± 0.077	1.212 ± 1.216
E_C	Cow	0.016 ± 0.013	0.245 ± 0.238	0.190 ± 0.196	0.426 ± 0.434
WHO Permissible Limit		**0.001**	**0.004**	**0.008**	**0.005**

*The samples were coded A_x to E_x, where x represents the organ (first letter of each animal), and ND- Not Detected

Comparative analysis

Comparatively, goats generally showed higher concentrations of heavy metals in their organs and blood than cows, as shown in Fig. 1. The difference may be attributed to their feeding habits, metabolism, and/or environmental factors. Notably, Zn was highest across all sampled animal organs, but was higher in goats than in cows. Generally, Fig. 1 depicts a similar trend in that the metal concentrations in goat organs were in the order of Zn>Cr>Pb>Cd. Equally, lower levels of the heavy metals were observed in the heart and liver samples compared to the kidney and intestine tissues in both animals' organs (Fig. 1). Specifically, the lowest level was observed in the

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goat's heart compared to the cow's. This could be attributed to the feeding habits of different animals, as goats are more domesticated than cows, especially in Nigeria. Egigba et al. [13] reported higher heavy metal accumulation in the kidneys and livers than in muscle tissues in cattle and goats, corroborating the findings of the present investigation.

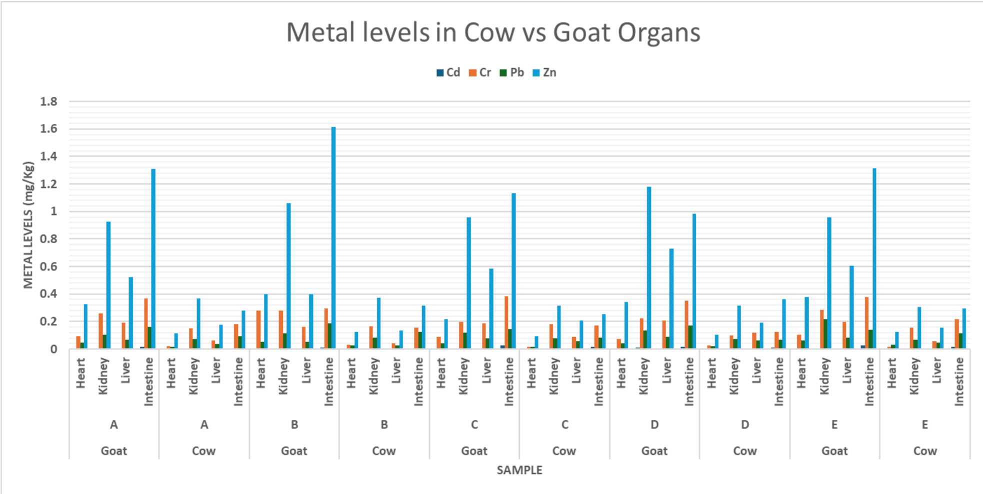

Fig. 1. Comparative view of heavy metals in different organs of cows and goats

As presented in Fig. 2, the blood samples from cows and goats showed varying concentrations of heavy metals. However, a similar trend (as observed in Fig. 1) was also observed in the animal's blood samples. Zinc metal was highest in all the blood samples, followed by chromium, lead, and cadmium. While Zn was classified as an essential metal [15], others, such as Pb, Cd, and Cr, were reported to be completely unnecessary in the body [28], and may be detrimental and induce many physiological dysfunctions in human beings [13, 29-30]. Lead concentrations in cow blood samples ranged from 0.0075 to 0.0175 mg/L, and cadmium levels ranged from 0.0025 to 0.0075 mg/L. However, chromium concentrations ranged from 0.0075 to 0.0125 mg/L. Contrarily, the goat blood samples revealed lower lead levels than those of cows, ranging from 0.0125 to 0.0225 mg/L. Meanwhile, the cadmium concentrations were the lowest in goats and similar to the level observed in cows (within the range of 0.0025 to 0.0075 mg/L). Notably, chromium levels in goat samples were also slightly lower (ranging from 0.0075 to 0.0175 mg/L) than in cows.

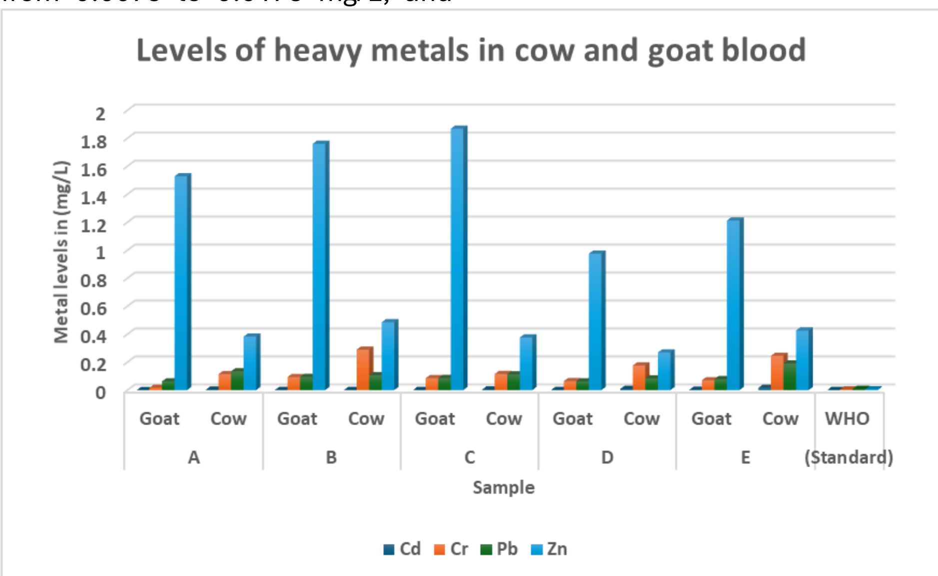

Fig. 2. Levels of heavy metals in cow and goat blood.

DOI: https://doi.org/10.53704/fujnas.v14i2.920

The presence of these heavy metals in the blood samples of both animals is worrisome and suggests ongoing environmental exposure, which is likely to lead to bioaccumulation in other tissues. Akan et al. [11] found detectable levels of heavy metals in the blood of cattle and small ruminants in Nigeria and called for urgent measures to sanitise the meat and dairy industry. The findings are in conformity with these research observations. The results obtained from the blood samples suggested that the animals were recently exposed to heavy metals, which complemented the data obtained from the analysis of the different organs. Hejna et al. [15] reported that heavy metals significantly affect human and animal health, leading to stunted growth and development, cancer, organ damage, neurological impairment, and, in severe instances, mortality. Consuming animals with higher levels of these metals is a potential source for these ailments, a serious threat to human health. Additionally, metal workers in Kano noted health issues related to their practice due to heavy metal contamination through ingestion and assimilation, including metal fume fever, ocular and dermal irritation, disorientation, and respiratory complications [14].

Analysis of mean concentrations of heavy metals against the WHO standards across different organs of cows and goats, and blood samples, showed that none violated the WHO permissible limits, as shown in Figs. 3-5.

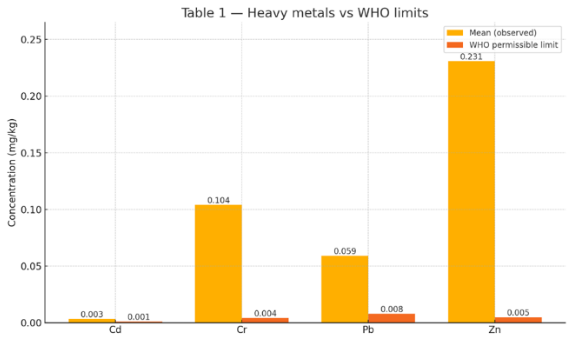

Fig. 3. Mean concentration of heavy metals vs WHO standards in different organs of the cow's sample collected

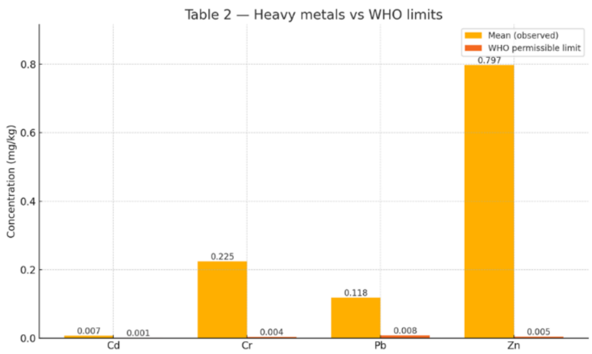

Fig. 4. Mean concentration of heavy metals vs the WHO standards in different organs of the goat's sample collected

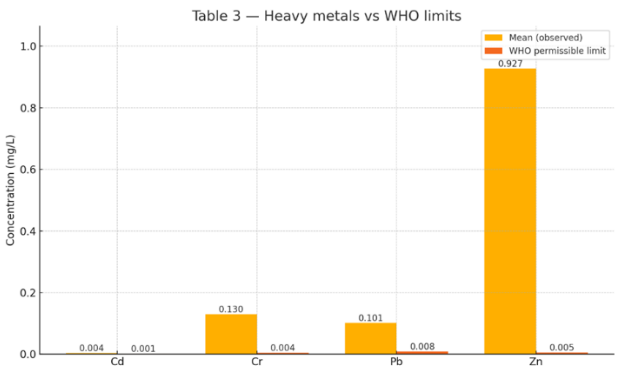

Fig. 5. Mean concentration of heavy metals vs WHO standards in different organs of cow and goat blood sample collected

DOI: https://doi.org/10.53704/fujnas.v14i2.920

Carcinogenic risk

The carcinogenic risk was determined using *Eq*.(***Error! Reference source not found.***), where the mean concentration denotes the average concentration of the heavy metal in the tissue. The Exposure Factor denotes the level of ingestion or exposure (0.0001), while the cancer slope factors are Cd = 10, Cr(VI) = 50, and Pb = 0.0085.

The carcinogenic risk assessment has shown that chromium (Cr) poses the greatest risk across cow and goat organs and blood samples, ranking well above cadmium and lead, as shown in Tables 4 and 5. The risks of cadmium (Cd) were usually less considerable but still significant, especially on the kidneys and intestines, where bioaccumulation is likely to happen. Lead (Pb) had very low carcinogenic risk values, implying it contributes less to the total cancer risk in the samples studied. Cr values of 1.54×10^{-3}, 1.78×10^{-3}, and 1.24×10^{-3} on Table 4 exceeds 1.0×10^{-4} which indicates a possibility of carcinogenic risk to humans in a lifetime [31]. The high chromium risk indicates exposure to hexavalent chromium, which is highly carcinogenic and a major health concern. This result is similar to the high carcinogenic risk observed in cow kidneys, which may have arisen from the consumption of contaminated food or water [32-33]. These findings reinforce the importance of extreme screening and prevention measures to limit human contact with Cr, particularly in the ingestion of contaminated animal tissues or blood.

$$\textbf{Carcinogenic Risk} = \textbf{mean concentration} \times \textbf{exposure factor} \times \textbf{cancer slope factor} \quad (1)$$

Sample Code*	Organ	Heavy metal	Carcinogenic Risk (mg/kg) Cow	Carcinogenic Risk (mg/kg) Goat
A_H	Heart	Cd	4.80×10^{-5}	9.00×10^{-7}
B_H	Heart	Cr	1.40×10^{-4}	5.28×10^{-4}
C_H	Heart	Pb	1.98×10^{-7}	4.05×10^{-4}
A_k	Kidney	Cd	2.00×10^{-6}	2.10×10^{-5}
B_k	Kidney	Cr	1.54×10^{-3}	1.78×10^{-3}
C_k	Kidney	Pb	1.22×10^{-7}	1.37×10^{-7}
A_L	Liver	Cd	1.25×10^{-4}	5.30×10^{-6}
B_L	Liver	Cr	3.85×10^{-4}	1.24×10^{-3}
C_L	Liver	Pb	3.00×10^{-7}	1.61×10^{-7}
A_I	Intestine	Cd	1.70×10^{-5}	2.80×10^{-6}
B_I	Intestine	Cr	1.84×10^{-3}	9.44×10^{-4}
C_I	Intestine	Pb	1.61×10^{-7}	6.25×10^{-8}

Table 4. Carcinogenic risk in organs of the cow and goat

DOI: https://doi.org/10.53704/fujnas.v14i2.920

Conclusion

This research investigated the bioaccumulation of heavy metals (Cd, Cr, Pb, and Zn) in the blood and selected organs (kidney, liver, heart, and intestine) of cows and goats slaughtered in Ado Ekiti, Nigeria. Samples from four organs and blood were collected, transported to the laboratory, and analysed by wet digestion. The results showed varying levels of heavy metals across all analysed samples, with concentrations exceeding the WHO permissible limits in most cases, particularly in the kidney and intestine.

Zinc was found to be the most abundant metal in both organs and blood, followed by Cr, Pb, and Cd. Goats had higher concentrations of heavy metals than cows, which could be attributed to their feeding behaviour and environmental exposure. Furthermore, the blood sample indicated recent exposure, which in turn confirmed the ongoing contamination of the animals' environment. The research findings highlight potential health risks associated with consuming contaminated animal products. It was established that heavy metal accumulation in humans can lead to severe health issues such as organ damage, neurological disorders, and increased toxicity over time. Therefore, strict regulatory measures, continuous monitoring of heavy metals in livestock, and proper environmental and food safety practices should be adopted to protect public health. The public should be properly oriented on the dangers of heavy metal contamination and mitigation strategies.

Table 5. Carcinogenic risk in blood of cow and goat

Heavy metal	Carcinogenic Risk (mg/L) in blood of Cow	Carcinogenic Risk (mg/L) in blood of Goat
Cd	6.10×10^{-6}	9.00×10^{-7}
Cr	9.37×10^{-4}	3.60×10^{-4}
Pb	1.06×10^{-7}	6.49×10^{-8}

Conflicts of interest

The manuscript was read and approved for submission by all authors. They therefore declare no conflict of interest.

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