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Carcinogenic and non-carcinogenic health risk assessment of heavy metals in the offal of animals from Felele Abattoir, Lokoja, Nigeria

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ABSTRACT

The consumption of metal-contaminated offal of animals will affect the health of humans. Thus, the research determined the concentrations of heavy metals in the offal and muscle tissues of cows, goats, and ram slaughtered at the main abattoir in Lokoja, northcentral Nigeria. Furthermore, an evaluation was carried out to assess the potential health hazards faced by the indigenous population due to the consumption of heavy metals from these animals. The mean concentrations of metals (Al, Cd, Cr, Ni, and Pb) in the kidney, liver, and muscle of cows, goats, and rams were determined using Inductively Coupled Plasma Optical Emission Spectrometry. Estimated daily intake of the metals, hazard quotient, hazard index, and cancer risk were calculated. All internal organs had Ni levels above the regulatory threshold limit. The average concentration of Pb in the muscle tissue and liver of the tested animals exceeded the permissible limits by the WHO. Similarly, the concentration of Cd in the muscle tissues was above the Maximum Permissible Limit (MPL) of 0.05 mg kg^{-1}. Except for cow kidneys, all internal organs contain Cr levels below the MPL (1.0) limit. The THQ value for the metals was < 1 except Cd. It indicates potential health risks due to Cd. The calculated HI values were > 1. The percentage contribution of Cd to the HI value was the highest. The observed sequence is Cd > Ni > Cr > Pb > Al. The results show that eating the offal and muscle under investigation has a carcinogenic effect.

1. Introduction

A major problem that the environment faces is the presence of heavy metals. These metals impact the environment because of their stability and are not degradable [1]. According to Ogwok et al., rapid and disorganised urban and industrial developments are to blame for the environmental buildup of heavy metals [2]. Since metals are not degradable, they are taken up by crops, vegetables, and plants and go into the food chain. When these crops are consumed, the metals will bioaccumulate in various tissues and organs of animals and humans. Food is the focal source of man's exposure to metals through food crops cultivated in soils contaminated with heavy metals or when contaminated water serves as a source of irrigation [3]. Animals can also become exposed to heavy metals by breathing in dust particles that contain metals or by drinking water tainted with metals [4]. Their entrance into the food chain is either a natural or anthropogenic activity [1,5]. A report has it that over 70 % of dietary ingestion of cadmium is through foodstuffs. This is enhanced by the prolonged intake of crops cultivated on contaminated soil eventually leading to the accretion of metals in animals and humans [6]. Cattle, goats, and sheep are domestic animals that feed on plants during grazing and hoard heavy metals in their offal, tissues, and muscles.

Meat is important for dietary intake because it provides minerals, essential amino acids, vitamins, and energy. One of the primary sources of the vitamins B1 (thiamin) and B2 (riboflavin) that humans need to survive and function properly is meat. Vitamins are splendidly present in the liver, while, the essential amino acids are in the muscle tissues [3]. Meat is an excellent source of proteins and minerals like phosphorus, calcium, zinc, selenium, and iron. The level of iron present in sheep meat is twice that of a chicken and six times more than in other animals. The offal of sheep is an excellent protein source [4]. As the toxic metals enter the animals through the food chain, so do the essential elements,

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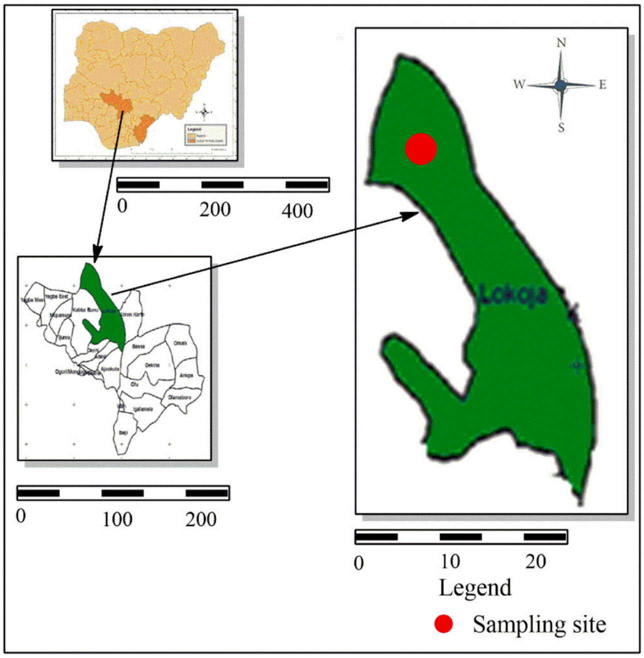

Fig. 1. Map of the study area.

minerals, and vitamins. The essential ones help the human body maintain cellular processes, while the toxic ones do a lot of damage even at low concentrations [2]. Metals like Cd, Cr, Pb, As, and Hg are toxic (have similar chemical properties) even in minor quantities. They cause interruption of several biochemical processes in humans, pose health risks, and give rise to chronic diseases like cancer, deformity, damage to the central nervous system, and neurological disorders [6,7]. Several metals accumulate in the kidneys and livers of animals, as these organs serve as filters, storage organs, and detoxifiers, respectively [2,8]. Cd and Pb are non-essential metals and their toxicity is responsible for anaemia, skeletal damage, the cause of renal tubular dysfunction, cardiovascular disease, bone disorders, mutagenic, nervous diseases, hypertension, prostatic proliferative lesions, and immunosuppressive effects in humans that are exposed to them [4,6,7]. Also, Pb is known for its teratogenic role in fetus growth when ingested by a pregnant woman. In the same way, excessive intake of Pb in infants is responsible for decreased biosynthesis of the hormonal metabolite vitamin D, the causative agent for calcium metabolism. Pb accumulation strongly affects haeme biosynthesis and erythropoiesis [2]. The chronic effects of As include peripheral neuropathy, peripheral vascular disease, dermal lesions, and skin cancer [7]. Children and pregnant women are susceptible to the toxicity of toxic metals [6]. Previous researchers examined the various harmful consequences that heavy metal consumption can have on humans. The resultant effects often depend on the concentrations present in an individual. This makes the computation of heavy metal risk factors for consumers expedient. When these metal levels in humans exceed the upper limit established by regulatory standard organisations, there is a risk to human health [4]. Owing to the potential harm that eating foods containing heavy metals can cause, it is essential to frequently monitor the amount of these metals in commonly consumed foods to assess the risk to human health and suggest preventative measures [6]. The offal of cows, goats, and rams is of enormous economic importance and epicurean value [1]. They serve as a good source of minerals (Ca, P, Zn, and Se), protein, and B-complex vitamins like thiamin, riboflavin, and niacin. While still considered red meat, ram, and goat because of the benefit of a higher iron content than chicken or fish. Thus, it is advised to be a component of a healthy diet for young people and the elderly [4]. Trace elements are essential to maintain human development, however, excessive exposure to them and toxic metals cause health risks to humans. Therefore, monitoring the essential and toxic metals in animals' offal is important. In Nigeria the government has failed to enact laws for ranching, open grazing is majorly the practice. This practice has resulted in the loss of lives due to farmer-herder clashes. In the open grazing, the animals feed on crops and plants growing in polluted lands, mining sites, along major roads, and dump sites and ingest contaminants such as heavy metals. Also, the animals are exposed to all kinds of water to drink. All these will increase the bioaccumulation of metals daily in the animals. Their evaluation is necessary because Lokoja is a hub for travel to other regions of the country, where visitors pause to consume meat and meat products before continuing, as does the aboriginal population. Thus, the objectives were to: (i) determine the concentrations of heavy metals in the offal and muscles of cows, goats, and ram for the Lokoja city market (ii) evaluate the potential risk to the general public concerning the ingestion of heavy metals bioaccumulated in these animals.

2. Materials and method

2.1. Study area

The study area is Lokoja, the Kogi State Capital, located at the confluence of the Niger and Benue rivers. Lokoja is situated between latitudes 7° 45' 27.56'' and 7° 51' 04.34'' N and longitudes 6°41' 55.64'' and 6°45' 36.58'' E of the equator (Fig. 1). It has total land coverage of about 63.82 sq. km. The built-up area of Lokoja is situated in the eastern part of the River Niger, whereas in the western part of the city is Mount Patti. Over the years, the population growth in the city has resulted in an acute shortage of decent accommodation for inhabitants and a high cost of living in the city. The increase has also led to a rise in demand for meat products. Hence, more animals, such as cattle, sheep, and goats, are slaughtered daily for consumers. Some are brought in from different places within and outside of Kogi State.

2.2. Sample collection

The samples were collected for six weeks. At each sampling, 100 g of kidney, liver, and meat samples of cattle, goats, and sheep were procured at Felele abattoir. The meat samples were obtained from one animal stock. The samples were packed in zip-lock bags and labelled appropriately. The zip-lock bags containing the samples were placed in a cooler (GeostyleTM) containing ice packs and then transported to the laboratory for analysis.

2.3. Sample preparation and analytical methods

At the laboratory, each sample was washed with distilled deionised water. Each portion was sliced with a stainless-steel knife and spread out in the laboratory to dry at ambient temperature. Dry samples were ground in a porcelain mortar, sieved using a < 2 mm mesh, and kept in labelled polyethene before analysis. Samples digestion was done by accurately weighing 1.00 g of each sample into a 100 mL PTFE beaker. A mixture of 10 mL (ratio 3:2) of 65 % HNO_3 and 70 % $HClO_4$ mixture (Sigma Aldrich, Germany) of Analar grade was added to each sample and allowed to stand overnight. The matrix was heated in a water bath at 70 °C for 3 h with intermittent gentle shaking at an interval of 30 min until the fumes were totally released. The digest was allowed to cool and built again with 20 mL of double-distilled deionised water and filtered with Whatman filter paper no. 42 (Sigma Aldrich, Germany) into a standard flask and made up to mark [3]. Heavy metal concentrations in digests were determined using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) [9,10]

2.4. Quality assurance procedures

The standard addition procedure was followed to validate the

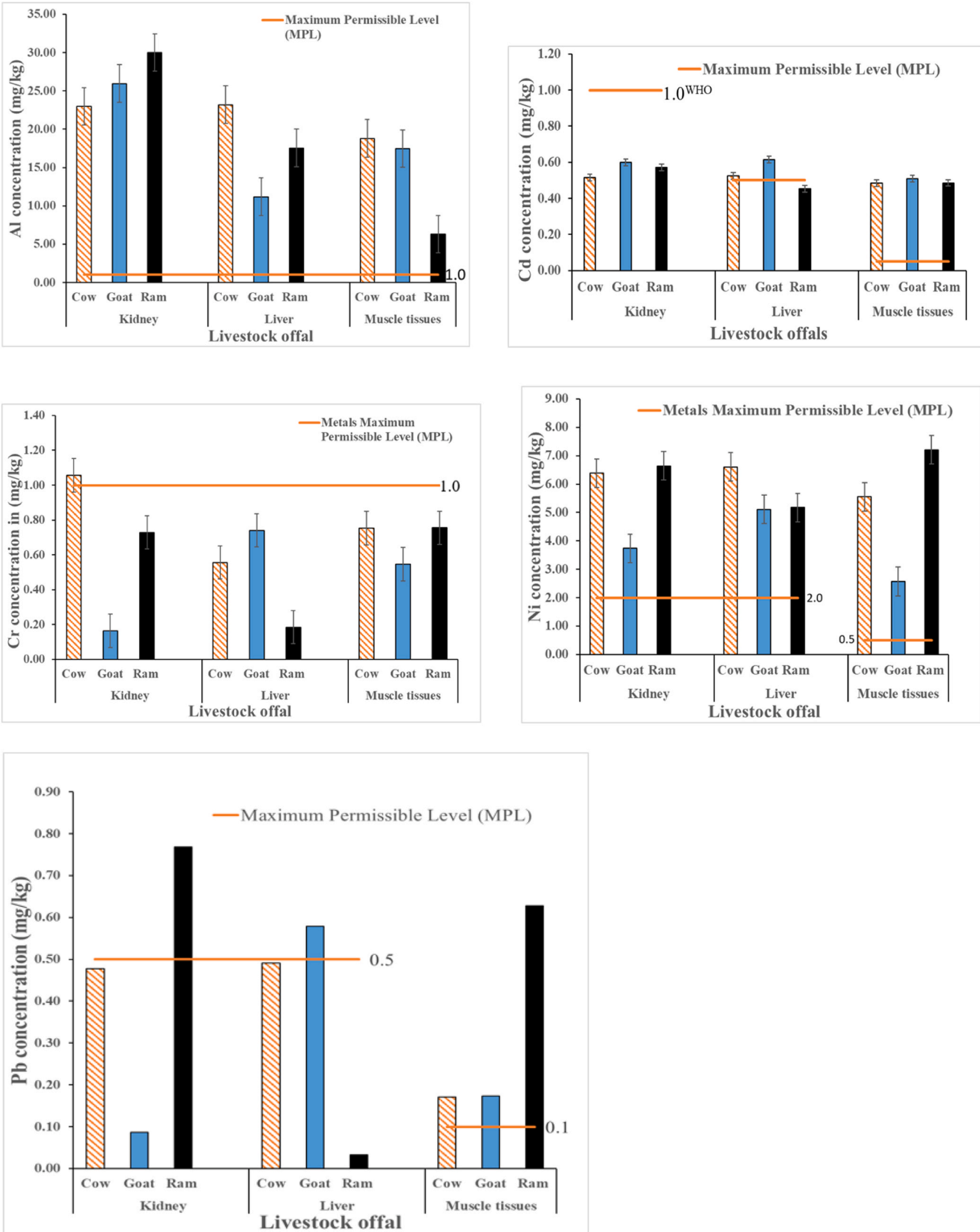

Fig. 2. Mean concentration of metals in the offal of livestock.

method's precision and accuracy. It involved spiking a sample with a known amount of metal (Duncan et al., 2002) and we adhered to the same process as in our earlier study to make sure that the instruments were accurate [11]. The percentage recovery was obtained from Eq. (1).

$$\%Recovery = \frac{S_{SP} - U_{unspk}}{Q} \quad (1)$$

The concentrations of spiked and unspiked samples are denoted as S_{sp} and U_{unspk}, respectively, with Q representing the spiking concentration.

The metals recovered average between 96.0 % and 97.7 % of their original value (see Table S1). Limit of detection (LOD) calculations followed Shrivastava and Gupta's instructions [12] and for Al, Cd, Co, Cr, Ni, and Pb, the respective detection limits are 0.00197, 0.00011, 0.00074, 0.00125, 0.00072, and 0.00240 mg kg^{-1}, respectively.

2.5. Health risk assessment

The valuation was carried out on the metal concentrations obtained from the meat samples to determine the carcinogenic and non-carcinogenic effects of the health risk assessment using the target hazard quotients (THQ) as defined by the US EPA [13–15]. When the value obtained for THQ is lower than 1, it indicates a smaller exposure than the reference dose, which means that the daily exposure may not cause any harm at that level.

2.6. Estimated Daily Intake (EDI)

The following equation was used to calculate the EDI of toxic metals:

$$EDI = \frac{M_C \times C_{RT}}{BW} \quad (3)$$

Where: MC is the mean metal content (mg kg^{-1}) of a specific metal in the meat on a dry basis, C_{RT} is the appraised daily offal and muscle consumption rate (g/person/day), and BW represents the body weight average. The meat consumption rate in Nigeria is estimated as 19.09 g/person/day [16] and is divided by BW the body weight (kg).

The assumption employed for the aboriginal inhabitants:

i) hypothetical body weight of 20 kg for children (1 – 15 years) and 70 kg for adults.

ii) absorption rate and bioavailability rate of 100 %.

The calculated EDI of the examined metals was compared with their acceptable Tolerable Daily Intakes (TDI) of metals by the USEPA Integrated Risk Information System [17].

2.7. Target hazard quotient (THQ)

THQ was the method adopted to evaluate the health risk assessment based on the non-carcinogenic effects using Equation 2.

$$THQ = \frac{EF_r \times ED_d \times C_{rt} \times M_c}{RfDo \times B_{wt} \times AT} \times 10^{-3} \quad (4)$$

Where EF_r is the exposure frequency (365 days in a year), ED_d is the exposure duration (70 years), C_{rt} is the meat intake rate (g/person/day), and M_c is the mean concentration of metal in meat (μg/g), RfDo is the oral reference dose (mg/kg/day), B_{wt} is the mean body weight of an adult (70 kg), and AT is the mean of the time of exposure (365 days/year) multiplied with the number of years of exposure, taken as 70 years in this research work.

The RfDo values of the metals are Cd 1E-04, Cr 0.003, Ni 2.0E-02, Pb 0.004, and Al1.0E+00. [18–20].

2.8. Hazard index (HI)

The hazard index is the sum of the respective THQ values of the examined metals (Eq. (5)).

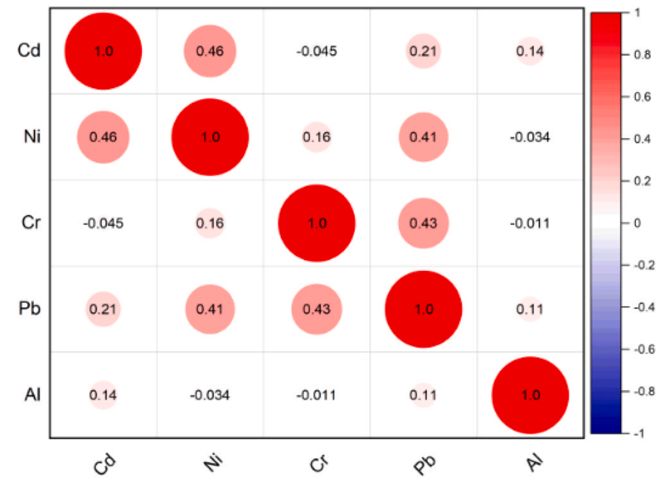

Fig. 3. Correlation between the heavy metals in animal muscle and offal.

$$HI = \sum THQ_{Cd} + THQ_{Cr} + THQ_{Ni} + THQ_{Pb} + THQ_{Al} \quad (5)$$

A THQ or HI > 1 indicates potential carcinogenic effects on human health, while a THQ or HI ≤ 1 means no possible health risk in humans [18,21].

2.9. Carcinogenic risk (CR)

The intake dose has a rectilinear connection with the ingested dose of a carcinogenic metal and the effects are often described by the CR. The CR and total cancer risk (TCR) owing to joint exposure of multiple metals through EDI of offal was appraised according to Eqs. (6) and (7) [20].

$$CR = CSF_O \times EDI \quad (6)$$

Where CSFo represents the carcinogenic slope factor or lifetime possibilities of having cancer. CSFo of 0.38, 0.5, 1.7, and 0.0085 are for Cd, Cr, Ni, and Pb mg/kg/day [22]. Carcinogenic risk values of 1.0×10^{-4} and multiple-element CR (MCR) < 1.0×10^{-4} are tolerated and do not enhance the risk of having cancer for a lifetime [19].

2.10. Multi-metal cancer risk

$$MCR = \sum_{i=1}^{n} CR \quad (7)$$

However, the value of CR and MCR that exceed 1.0×10^{-4}, indicates a possibility of carcinogenic risk to humans in a lifetime [23–25].

2.11. Statistical analysis

Data obtained were subjected to statistical analysis to obtain the mean and standard deviation. They were tested for normality and homogeneity of variance before analysis. One-way analysis of variance (ANOVA) at a significance level of 5 % was accomplished to evaluate whether heavy metals varied significantly between offal. Pearson correlation, Principal Component Analysis (PCA), and Cluster Analysis (CA) were performed to get thorough information about the distribution of heavy metals and their similarities and dissimilarities in the samples. All statistical calculations, graphs, and doughnut charts were performed with OriginPro 2022.

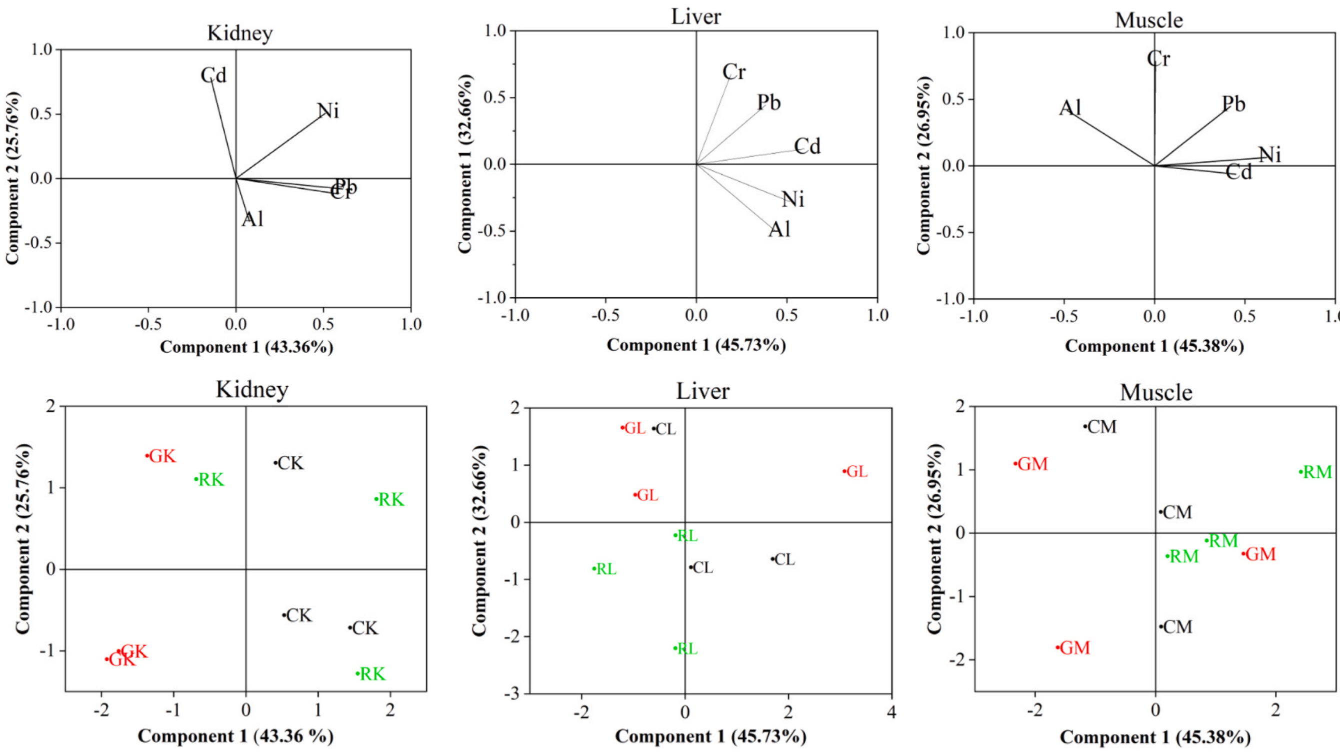

Fig. 4. Patterns of metal distribution in the offal of animals characterized by PCA (C: cow, G: goat, and R: ram).

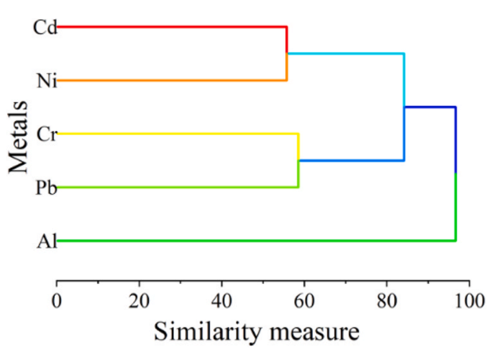

Fig. 5. : Dendrogram showing clustering of the analysed parameters.

3. Results and discussion

3.1. Heavy metal concentrations

The mean concentrations of metals (Al, Cd, Cr, Ni, and Pb) in the kidney, liver, and muscle of cows, goats, and rams were determined (Figs. 1–5). The concentration (mg kg^{-1}) of Al ranged from nd to 42.4, Cd 0.34–0.95, Cr nd to 1.68, Ni 0.42–9.22, and Pb nd to 1.49 (see Table S2). Al is a toxic element that is not required by any living organisms. It has no physiological role in metabolic processes and poses many threats that can cause adverse health effects in human beings [26]. Among other pathological conditions, aluminium toxicity has been implicated as a primary etiological factor in Alzheimer's disease [27]. Al was detected above the maximum permissible level (MPL) of 1.0 mg kg^{-1} in all the internal organs, as set by various regulatory bodies. The kidneys of rams were found to have the highest mean concentration of Al among the internal organs under study, while the kidneys of a goat had the lowest concentration (Fig. 2). The highest concentration of Al observed in the kidneys of rams is traceable to either pesticides, agrochemicals, or mining effluents [28]. The mean concentrations of Al reported in this study were similar to the range of 3.75 mg kg^{-1} in the muscle to 55.3 mg kg^{-1} in the cow's liver in the Canary Islands, Spain [29].

Cadmium (Cd) is a toxic metal that is not required by any living organisms. It poses many environmental threats that can ultimately cause disorders and diseases in human beings [30]. It has been reported that chronic Cd exposure is associated with kidney disease, osteoporosis, cardiovascular diseases, and cancer [31]. Cadmium has the highest mean concentrations in goat liver and the lowest in the liver of rams (Fig. 2). The high concentrations of Cd measured in the kidneys of goats may have come from the contaminated feeds or plants they consume and their drinking water sources. Cadmium concentrations (mg kg^{-1}) in the kidneys of animals were within 1.0 MPL but above 0.5 MPL in the liver of goats [32]. Concentration in the muscle tissues was also above the MPL 0.05 mg kg^{-1} in all the internal organs as set by regulatory bodies (Fig. 2), except in ram liver (0.45 mg kg^{-1}), cow and ram muscle tissue (0.49 mg kg^{-1}). The concentrations of Cd reported by this study were higher than the values found in the liver, kidney, and flesh of cattle, sheep, and goats from Anka and Bukkuyum Local Government areas of Zamfara State, Nigeria, which ranged from 0.00 to 0.25 μg·g^{-1} [33], 0.0037–0.0021 μg·g^{-1} found in Gombe, northeast Nigeria [34], and 0.05–0.31 μg/g in Kaduna, northwest Nigeria [35], Tarkwa, Ghana [36]. This study's mean concentrations were similar to 0.301±0.344 (muscle), 0.433±0.032 (liver), and 0.586±0.064 (kidney) in sheep meat offal in Kuwait [4].

The International Agency for Research on Cancer has designated Cr as a carcinogenic agent due to its capacity to produce reactive oxygen species (ROS), which lead to oxidative stress in biological systems [37]. Studies indicate that chromium enhances the effects of insulin by improving its efficiency and lipid profile in malnourished children and individuals with diabetes who require insulin. [37]. Chromium has the highest mean concentrations in cow kidneys and the lowest in goat kidneys (Fig. 2). The highest concentration of Cr observed in the kidneys of cows may have originated from the intake of contaminated food or water. The concentrations of Cr in this study were higher than the values found in the liver, kidney, and flesh of cattle, sheep, and goats in Delta

Table 1
Statistics of estimated daily intake (EDI) (mg/kg/day) in the offal of cow, goat and sheep from abattoirs in Lokoja.

Group	Offal	Livestock	Cd	Ni	Cr	Pb	Al
Adult	Kidney	Cow	1.41E−01	1.74E+00	2.88E−01	1.30E−01	6.27E+00
		Goat	1.64E−01	1.02E+00	4.49E−02	2.35E−02	7.09E+00
		Ram	1.56E−01	1.81E+00	1.99E−01	2.10E−01	8.19E+00
	Liver	Cow	1.43E−01	1.80E+00	1.52E−01	1.34E−01	4.22E+00
		Goat	1.68E−01	1.39E+00	2.02E−01	1.58E−01	3.06E+00
		Ram	1.23E−01	1.41E+00	5.05E−02	9.01E−03	4.80E+00
	Muscle tissues	Cow	1.32E−01	1.52E+00	2.06E−01	4.68E−02	5.14E+00
		Goat	1.39E−01	7.01E−01	1.49E−01	4.74E−02	4.77E+00
		Ram	1.33E−01	1.97E+00	2.06E−01	1.71E−01	1.72E+00
Children	Kidney	Cow	4.93E−01	6.09E+00	1.01E+00	4.56E−01	2.19E+01
		Goat	5.72E−01	3.57E+00	1.57E−01	8.21E−02	2.48E+01
		Ram	5.46E−01	6.34E+00	6.96E−01	7.34E−01	2.86E+01
	Liver	Cow	5.01E−01	6.30E+00	5.31E−01	4.69E−01	1.48E+01
		Goat	5.87E−01	4.87E+00	7.07E−01	5.53E−01	1.07E+01
		Ram	4.31E−01	4.93E+00	1.77E−01	3.15E−02	1.68E+01
	Muscle tissues	Cow	4.63E−01	5.30E+00	7.19E−01	1.64E−01	1.80E+01
		Goat	4.85E−01	2.45E+00	5.22E−01	1.66E−01	1.67E+01
		Ram	4.64E−01	6.88E+00	7.21E−01	5.99E−01	6.01E+00
TDI by FAO/WHO/FSA			1.0[a]	5.0[b]	50–200[b]	3.57[a]	

FAO: Food and Agricultural Organization.
WHO: World Health Organization.
FSA: Food Safety Agency.
a: Bortey-Sam 2015
b: Ihedioha et al., 2014

State, south-south Nigeria, which ranged from 0.010 mg kg^{-1} to 0.030 mg/kg [38] but similar to the range of 0.42–0.48 mg/kg found in Sokoto and Gusau abattoirs, Nigeria [39]. In contrast, this study's concentrations were lower than reported values in muscle (1.24±0.52), kidney (2.58±0.46), and liver (4.28±1.39b) in the southeast, Nigeria [3]. Except for cow kidneys (1.06±0.56 mg kg^{-1}), all internal organs were found to contain chromium at levels below the MPL (1.0) limit by the international regulatory body (Table 3). This result shows that consumption of the internal organs of the studied animals except cow kidneys may benefit diabetic patients since Cr increases the metabolism of carbohydrates and fat [40].

The human body requires Ni as an important cofactor for various enzymes, increasing hormonal activity and the metabolism of lipids [41]. However, its accumulation in the body from chronic exposure may lead to a lot of adverse effects on humans, like cancer of the respiratory tract, lung fibrosis, and cardiovascular diseases. High exposure to Ni and Ni compounds is also responsible for nasal and lung cancer among humans [42] The highest mean concentration of nickel, 7.2 mg kg^{-1}, was observed in ram muscle tissue and the lowest, 2.6 mg kg^{-1}, in the muscle tissue of goats (Fig. 2), Next to the muscle tissue was the liver, with a Ni concentration of 6.64 mg kg^{-1} followed by 6.38 mg kg^{-1} in the kidneys of cows. The mean value of metals of offal of cow, goat, and ram in this study is higher than reported cow values of 0.79 μg g^{-1} and 0.65 μg g^{-1} in muscle and liver, respectively, from an abattoir in Kaduna, northern Nigeria [35], 0.21±0.36 (kidney), 0.15±0.31 (liver), and 0.19±0.37 (muscle) of cattle in Nasarawa, Nigeria [43], 0.14±0.07 (kidney), 0.20±0.05 (liver), 0.14±0.07 (muscle) of goats, 0.09±0.04 (kidney), 0.33±0.13 (liver), 0.46±0.16 (muscle) of sheep in Tarkwa, Ghana [36]. The findings show that Ni, an environmental contaminant, was present in the studied animal's offal, as all internal organs had nickel levels above the regulatory bodies established MPLs (mg kg^{-1}) of 2.0 (liver and kidney) and 0.5 mg kg^{-1} (muscle) (Fig. 4).

Lead (Pb) is a proven toxic metal that does not play any role in humans or other biological systems. Lead poisoning has been associated with neurotoxicity and different types of cancer in humans [44]. In this study, Pb concentrations ranged from nd to 1.49 mg kg^{-1} (Table S2). The highest mean concentration of 0.77±0.63 mg kg^{-1} was in the kidney of ram, while the lowest concentration of 0.03±0.03 mg kg^{-1} was in the liver of ram (Fig. 2). The average concentration of Pb in the muscle tissue and liver of the tested animals exceeded the permissible limits of 0.1 mg kg^{-1} and 0.2 mg kg^{-1} respectively, as set by the WHO. However, the concentrations in the kidneys of goats (0.09±0.07 mg kg^{-1}) and the liver of rams (0.03±0.03 mg kg^{-1}) were found within the permissible limits. This study's Pb concentrations were higher than those found in cattle, sheep, and goats' liver, kidney, and flesh from Anka and Bukkuyum in Zamfara, Nigeria [33]. The results were similar to the mean concentrations reported in the muscle and liver of cows in Kaduna, northern Nigeria [35]. Abd-Elghany et al. reported Pb concentrations of 0.7066±0.098, 0.4826±0.098, and 0.5676±0.042 μg-g-1 in the kidney, muscle, and liver, respectively, of sheep in Kuwait [4]. Bortey-Sam et al., in a similar work in Tarkwa, Ghana, reported lower concentrations of Pb in the kidney, liver, and muscle of goats and sheep [36]. A high concentration of Pb (6.16 μg g-1) in the liver has been reported among sheep grazing in mining areas assumed to be polluted land in Spain [45]. Similarly, a high Pb concentration in cow liver (1.11±0.18 μg/g), kidney (0.96 ±0.08 μg/g), goat liver (0.76±0.10 μg/g), and kidney (0.38 ±0.30 μg/g) has been reported in Kampala, Uganda [2].

3.2. Distribution of metals in offal and muscle tissue

A one-way analysis of variance was employed to compare the buildup and distribution of metals in the offal of cows, goats, and rams. The distribution of metals in the kidneys, liver, and muscles of cows, goats, and rams was not statistically significant ($p > 0.05$). The Pearson correlation coefficient of metals in animal muscle and offal is displayed in Fig. 3. A weak positive relationship was observed between Cd and Ni (0.46), Pb and Cr (0.43), Pb and Ni (0.41), Pb and Cd (0.21), and Cr and Ni (0.16), signifying a possible common source. These animals get the majority of their feed from open grazing. The animals may have grazed on potentially metal-contaminated feed, water, and soil through skin contact. In monitoring metal contamination in animals for dietary intake, the kidneys and liver are the most targeted tissues, as both organs function to eliminate toxic metals from the human body [36]. Principal component analysis (PCA) was employed to evaluate the distribution of metals in the kidney, liver, and muscle tissue. The result (Fig. 4) showed that there is no separation between the offal of the animals. In the liver and kidney, all the metals (Cd, Cr, Ni, Pb, and Al) are in one cluster, while there is slight variation in the muscle tissue. It could be due to the feeding habits of the animals and the level of metallothionein (MT) in the food they eat. Animals are known to develop mechanisms that

Table 2
THQ for adults and children through the consumption of offal and muscle tissues of animals from the study areas.

Species	Offal	Livestock	Cd	Ni	Cr	Pb	Al	HI
Adult	Kidney	Cow	1.41E+00	8.71E−02	9.61E−02	3.26E−02	6.27E−03	1.63E+00
		Goat	1.64E+00	5.10E−02	1.50E−02	5.87E−03	7.09E−03	1.72E+00
		Ram	1.56E+00	9.06E−02	6.63E−02	5.25E−02	8.19E−03	1.78E+00
	Liver	Cow	1.43E+00	9.01E−02	5.06E−02	3.35E−02	4.22E−03	1.61E+00
		Goat	1.68E+00	6.97E−02	6.74E−02	3.95E−02	3.06E−03	1.86E+00
		Ram	1.23E+00	7.06E−02	1.68E−02	2.25E−03	4.80E−03	1.32E+00
	Muscle tissues	Cow	1.32E+00	7.58E−02	6.86E−02	1.17E−02	5.14E−03	1.48E+00
		Goat	1.39E+00	3.50E−02	4.98E−02	1.19E−02	4.77E−03	1.49E+00
		Ram	1.33E+00	9.83E−02	6.88E−02	4.28E−02	1.72E−03	1.54E+00
Children	Kidney	Cow	4.39E−00	3.04E−01	3.36E−01	1.14E−01	2.19E−02	5.17E+00
		Goat	5.72E+00	1.78E−01	5.23E−02	2.05E−02	2.48E−02	6.00E+00
		Ram	5.46E+00	3.17E−01	2.32E−01	1.84E−01	2.86E−02	6.22E+00
	Liver	Cow	5.01E+00	3.15E−01	1.77E−01	1.17E−01	1.48E−02	5.63E+00
		Goat	5.87E+00	2.44E−01	2.36E−01	1.38E−01	1.07E−02	6.50E+00
		Ram	4.31E+00	2.47E−01	5.89E−02	7.87E−03	1.68E−02	4.64E+00
	Muscle tissues	Cow	4.63E+00	2.65E−01	2.40E−01	4.09E−02	1.80E−02	5.19E+00
		Goat	4.85E+00	1.23E−01	1.74E−01	4.14E−02	1.67E−02	5.21E+00
		Ram	4.64E+00	3.44E−01	2.40E−01	1.50E−01	6.01E−03	5.38E+00

control the uptake and accumulation of metals in their bodies. Such mechanisms include the chelation and confiscation of heavy metals by particular ligands. Such a heavy metal-binding ligand is MT, a protein intricately involved in detoxifying metals [36].

3.3. Hierarchical cluster analysis of metals in offal

Correlational cluster analysis was employed to study the similarity and uniformity of metal concentrations within the offals and muscles of animals. The dendrogram (Fig. 5) shows the result of the cluster analysis, where three clusters are displayed. Cd and Ni in cluster 1 showed a clustering relationship in the offals. The clustering relationship between Cr and Pb was apparent in cluster 2 and formed a sub-cluster with Cd and Ni. Al occupied cluster 3 but formed a sub-cluster with the other two clusters. The clustering result indicates public sources of these metals, and it corroborates the result of the PCA.

3.4. Dietary intake of metals and target hazard quotient

The estimated daily intakes (EDI) of heavy metals that children and adults may contract from eating the muscle and offal of goats, rams, and cows are reported in Table 1. For adults, the highest EDIs (mg/kg/day) of Ni (1.81), Pb (0.210), Al (8.19), and Cr (0.288) were obtained through the consumption of the kidneys of rams and cows, respectively. For Cr, the highest EDI (mg/kg/day) was 0.288 through the ingestion of the liver of cows and Cd 0.168 through the intake of the liver of goats. Similarly, for children, the EDI (mg/kg/day) of Cd (0.587) is found in the liver of cows, Ni (6.88) in the muscle of rams, Cr (1.01) in cow kidneys, Pb (0.734) in the kidney of rams, and Al (6.01) in the muscle of rams. The order of the DIM values of the metals is Al > Ni > Cr > Pb > Cd in both adults and children.

3.5. Health risk assessment of metals in offal and muscle of animals

The target hazard quotient (THQ) and hazard index (HI) were used to calculate the non-carcinogenic health risks associated with oral consumption of the offal and muscle of cows, goats, and rams. The non-carcinogenic health risks due to the consumption of the studied offal and muscle are presented in Table 2. A THQ value < 1 means the exposed population is not likely to experience apparent adverse effects (USEPA IRIS 2011). All THQ values for Cd in this investigation were higher than 1. It indicates a concern about potential health risks due to Cd. For the other metals, the maximum THQ value for Ni (9.83E-02) was present in the muscle of ram, Pb (5.25E-02) and Al (8.19E-03) were present in the kidney of ram, whereas Cr (9.61E-02) was in the kidney of cow, all < 1. Since the THQ value of these metals (Cr, Ni, and Pb) was less than 1, there may not be any undesirable health issues arising from their intake from the offal and muscle of goats, cows, and rams in the study region. All THQs were combined to calculate the hazard index (HI) to assess the total health risk. The calculated HI values were all greater than 1. The results show that eating the offal and muscle of cows, goats, and rams under investigation has a carcinogenic effect. Table 2 reveals that goat liver had the highest value (1.86), whereas ram liver had the lowest value (1.32). The corresponding values in children were 6.50 and 4.64 in the livers of goats and rams, respectively. The general HI sequence in animals is kidney > liver > muscle. The cause of the HI values greater than one is due to the contribution of Cd. The percentage contribution of Cd to the HI value was the highest and ranged from

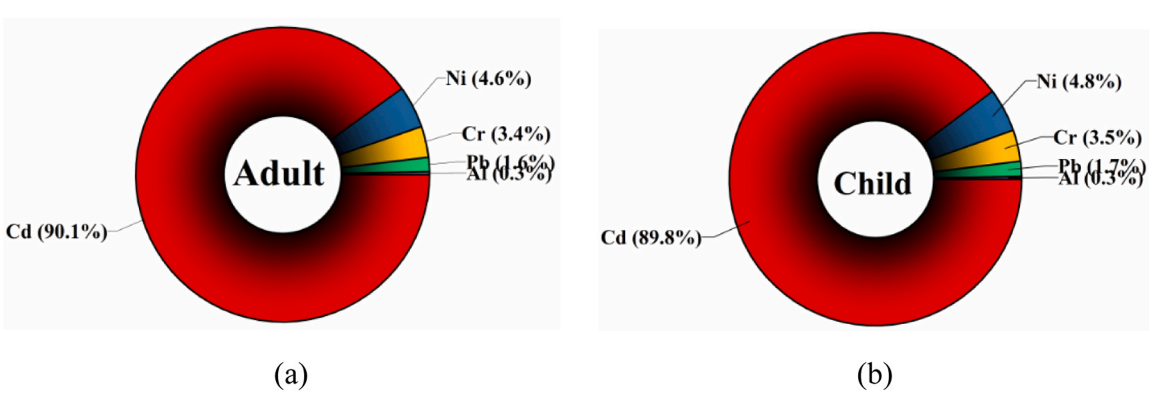

Fig. 6. Contribution of health risks caused by the different metals according to HI.

Table 3
Carcinogenic risk (CR) of heavy metals in the offal of cow, goat, and sheep from Lokoja abattoirs Lokoja, Kogi State.

	Offal	Livestock	Cd	Ni	Cr	Pb	∑MCR
Adult	Kidney	Cow	5.35E−02	2.96	1.44E−01	1.11E−03	3.16E+00
		Goat	6.22E−02	1.73	2.24E−02	2.00E−04	1.81E+00
		Ram	5.93E−02	3.08	9.95E−02	1.78E−03	3.24E+00
	Liver	Cow	5.45E−02	3.06	7.59E−02	1.14E−03	3.19E+00
		Goat	6.38E−02	2.37	1.01E−01	1.34E−03	2.54E+00
		Ram	4.69E−02	2.4	2.53E−02	7.66E−05	2.47E+00
	Muscle tissues	Cow	5.03E−02	2.58	1.03E−01	3.98E−04	2.73E+00
		Goat	5.27E−02	1.19	7.47E−02	4.03E−04	1.32E+00
		Ram	5.04E−02	3.34	1.03E−01	1.46E−03	3.49E+00
Children	Kidney	Cow	1.87E−01	10.4	5.04E−01	3.88E−03	1.11E+01
		Goat	2.17E−01	6.06	7.84E−02	6.98E−04	6.36E+00
		Ram	2.07E−01	10.8	3.48E−01	6.24E−03	1.14E+01
	Liver	Cow	1.90E−01	10.7	2.66E−01	3.98E−03	1.12E+01
		Goat	2.23E−01	8.28	3.53E−01	4.70E−03	8.86E+00
		Ram	1.64E−01	8.38	8.83E−02	2.68E−04	8.63E+00
	Muscle tissues	Cow	1.76E−01	9.01	3.60E−01	1.39E−03	9.55E+00
		Goat	1.84E−01	4.17	2.61E−01	1.41E−03	4.62E+00
		Ram	1.76E−01	11.7	3.61E−01	5.09E−03	1.22E+01

86.4 % (ram muscle) to 95.3 % (goat kidney). Other ranges in adult intake are Ni from 2.3 % (goat muscle) to 6.4 % (ram muscle), Cr from 0.9 % (goat kidney) to 5.8 % (cow kidney), Pb from 0.2 % (ram liver) to 2.9 (ram kidney), and Al from 0.1 % (total ram kidney) to 0.5 % (total ram kidney). Corresponding values for children revealed a similar pattern, and the sequence as in adults is Cd > Ni > Cr > Pb > Al. In adults, Cd (90.06 %) had the highest average percentage contribution to the HI value, followed by Ni (4.64 %), Cr (3.42 %), Pb (1.56 %), and Al (0.32 %) (Fig. 6). Similarly, in children (Fig. 6), Cd had the highest contribution of 89.83 %, followed by Ni (4.73 %), Cr (3.51 %), Pb (1.60 %), and Al (0.32 %). There is a lack of data on the health risks linked with the consumption of offal and muscle from animals in Kogi State to compare with the values of this study. However, the result indicates that the health of people who consume offal and muscle animals in Lokoja city is at risk.

3.6. The carcinogenic risk (CR)

The concentrations of potential carcinogens (Cd, Cr, Ni, and Pb) in the muscle and offal were used to estimate the risk of developing cancer. The target CR was employed. The carcinogenic health risks linked with the studied offal and muscle are shown in Table 3. The CR values (Cd, Cr, Ni, and Pb) for adults ranged from 4.69E-02 (ram liver) to 6.38E-02 (goat liver), 1.19 (goat muscle) to 3.34 (ram muscle), 2.24E-02 (goat kidney) to 1.44E-01 (cow kidney), and 7.66E-05 (ram liver) to 1.78E-03 (ram liver), respectively. Corresponding values in the children are 1.64E-01 (ram liver) to 2.23E-01 (goat liver), 7.84E-02 (goat kidney) to 5.04E-01 (cow kidney), 4.17 (goat muscle) to 11.7 (ram muscle), and 2.68E-04 (ram liver) to 6.98E-04 (goat kidney), respectively. The tolerable threshold for carcinogenic risk ranges from 1.00×10^{-4} to 1.00×10^{-6}. Cancer risk is considered negligible below 1.00×10^{-6} and above 1.00×10^{-4} is unacceptable [46]. The result revealed that for adults and children, the metals (Cd, Cr, Ni, and Pb) posed a significant carcinogenic risk in 99.9 % of the offal and muscle of animals determined (CR > 1.00×10^{-4}). All the metals pose a major concern in the consumption of the offal and muscle of the animals.

4. Conclusion

The level of Al was above the maximum permissible level (MPL) of 1.0 mg kg^{-1} in all the internal organs. Similarly, the concentration of Cd in the muscle tissues was above the MPL of 0.05 mg kg^{-1} in all the internal organs set by regulatory bodies and in the liver of goats. Also, all internal organs had Ni levels above the regulatory threshold limit. Except for cow kidneys, all internal organs contain Cr levels below the MPL (1.0) limit. While the average concentration of Pb in the muscle tissue and liver of the tested animals exceeded the permissible limits of 0.1 mg kg^{-1} and 0.2 mg kg^{-1}, respectively, as set by the WHO, the concentrations in the kidneys of goats and the liver of rams were found within the permissible limits. All THQ values for Cd were > 1, but for Cr, Ni, and Pb, they were < 1. The calculated HI values were all greater than 1. The results show that eating the offal and muscle of cows, goats, and rams under investigation has a carcinogenic effect on consumers. There is concern about the continuous consumption of these organs. Therefore, we recommend constant monitoring of the consumption of the offal and muscles of animals for health reasons and proper awareness for herders to adopt the ranching method. This approach promotes proper cleanliness and guarantees that the feed for forage comes from a site free of contamination. This will aid in decreasing the quantity of metals consumed by the animals.

Ethical approval and consent to participate

The research did not involve life animals, humans, in vitro, and other related issues where consent is needed.

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CRediT authorship contribution statement

Jude Emurotu: Conceptualization, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing, Software. **Olatayo Olawale:** Data curation, Formal analysis, Investigation. **Ephriam Musa Dallatu:** Supervision. **Tenimu Adogah Abubakar:** Software, Writing – review & editing. **Queen Ese Umudi:** Validation. **Godfrey Okechukwu Eneogwe:** Writing – review & editing. **Anthony Atumeyi:** Validation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.toxrep.2024.101701.

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