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Review Article

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A Review: Accumulation of Toxic Metals among Meat from Different Species

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Abstract

Meat contamination is a problem that must be addressed since it can affect consumers' health. Standard acceptable limits for heavy metals in meat and organs have been established by many international organizations. Livestock including sheep, cattle, camels, and goats' side by side with other poultry species are the most significant sources of meat for protein. Heavy metal contamination in animal products may be harmful to people's health. The earth's crust naturally contains heavy metals, but uncontrolled human activity has significantly changed their geochemical cycles and biological equilibrium. This causes a buildup of metals in animal tissue that contain secondary metabolites, which gives rise to a specific pharmacological action. Humans can have negative health effects from prolonged exposure to heavy metals as lead, cadmium, arsenic, and mercury. This review showed that most of the studies conducted in different countries on heavy metals were mostly in red meat, and the research was few in the cases of domesticated birds and very rare in game birds, although it is considered a good example for investigating heavy metals in the environment.

KEYWORDS
Heavy metal, Red meat, Poultry, Lead, Cadmium, Mercury, Arsenic.

INTRODUCTION

Meat from animal and poultry species considered as an essential part of human diet. In addition to vitamins and minerals including zinc (Zn), calcium (Ca), selenium (Se), and iron (Fe), meat is a most important source of essential amino acid (Haytowitz and Pehrsson, 2018; Algahtani *et al*., 2020; Saleh *et al*., 2021). Despite these benefits, meat may include hazardous compounds due to the bioaccumulation of heavy metals and trace elements at dangerous levels, which might raise the risk of developing certain diseases (Demirezen and Uruç, 2006; Rudy, 2009; Morshdy *et al*., 2019; Morshdy *et al*., 2021). According to Mikulewicz *et al*. (2013), elements are divided into three groups: macroelements (such as sodium (Na), calcium (Ca), and magnesium (Mg), hazardous elements or or toxic metals (such as arsenic (As), cadmium (Cd), lead (Pb), nickel (Ni), and mercury (Hg) and essential trace elements include Fe, Zn, and Se. The body needs trace elements, which are present in very small amounts, to support a variety of biological and metabolic processes that are essential to maintaining body homeostasis. However, excessive exposure to these elements has been linked to a number of health problems (Divrikli *et al*., 2006). Toxic metals have an atomic weight between 63.5 and 200.6 and a specific gravity of at least 5.0 for heavy metals, and they have slowly accumulated in the food chain with detrimental effects on human health. Numerous of these elements do not contribute to biological life, but also have major harmful effects and participate in several signaling pathways that lead to the development of cancer (Chen and Costa, 2018; Dasgupta *et al*., 2020). As human civilization becomes more sophisticated and geological resources are used, the amount of heavy metals in the environment is rising (Grodzińska *et al*., 2003; Valko *et al*., 2005). Meat from different species that have been contaminated with heavy metals are a significant source of toxic metal exposure in the food chain and can have major negative health effects (Badis *et al*., 2014; Obeid *et al*., 2016). Since heavy metals cannot be broken down or eliminated, they may build up in tissues including muscle, the kidneys, and the liver. On the other hand, because these tissues rid the body of harmful substances, they are referred to as target tissues for heavy metal analysis (Abou-Arab, 2001). Animals can be exposed to harmful substances and have those substances enter their bodies in a number of ways, such as through breathing in contaminated air or eating contaminated food and plants. Industrial processes like metal smelting or burning coal can have an impact on the livestock and the goods they produce (Beyer *et al*., 2007). Due to the negative effects on the neurological system, metabolism, and the cardiovascular system, eating this toxic meat might have an impact on human health and raise the possibility of major risks to the health of people (Bhardwaj *et al*., 2021). International agencies such the Food and Agricultural Organization (FAO), World Health Organization (WHO), and US Environmental Protection Agency (US EPA) have established the permitted quantities of heavy metals in meat and offal. In recent

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times, many nations have reported the presence of heavy metals in meat that obtained from different species (Collado-López *et al.*, 2022). Due to heavy metals bioaccumulation across food chains, consuming food items contaminated with it is a significant public health problem. Numerous investigations on heavy metals concentrations in various animals' species have been carried out in several countries, but no literature analysis has been done for meat from different species. Consequently, the current study provides an overview of the heavy metal status in various red meat and poultry meat items that were consumed worldwide.

Toxic metals in red meat and offals

In Palestine, Swaileh *et al*. (2009) analyzed Cd and Pb in cattle, sheep and goat carcasses, the author found that, the highest levels of metals were in the liver and heavy metal concentrations in the other organs followed the pattern (kidneys > heart > lungs > muscles). In addition, the level of heavy metals in examined organs descending order as (Cu > Pb > Cr > Cd). Cattle kidneys contained significantly higher concentrations of Cd compared to kidneys of other studied groups, and Cd contents of sheep and goat lungs were much higher than those of the cattle. Badis *et al*. (2014) measured the levels of Pb, Cd, and Hg in fresh beef, sheep, and camel meat in the north and south of Algeria. They found that Pb and Cd levels in various meat samples exceeded the FAO's maximum allowable levels for fresh meat while Hg level was below the accepted limits. The kind of pasture, the surrounding environment, and the degree of industrialization were identified in this study as the main determinants of the various amounts of heavy metal found in animal flesh. In Egypt, Hasballah (2019) examined beef meat from five regions he recorded a high variation of Pb, an intermediate variation of Cd in meat samples between different areas and all samples were higher than the regulatory limit (FAO/WHO, 2000). In an Iranian study, Bazargani-Gilani *et al*. (2016) found that the Pb levels in all samples were greater than the legal limit (>1 ppm), and there was no discernible difference between male and female samples. Young sheep (those under 3 years old) had greater liver Pb levels than older sheep, which may be connected to age. In addition, all species' kidneys, with the exception of those from cattle and sheep, had Cd concentrations below the permissible limit, and animals' kidney Cd concentrations were much greater than those of their livers, which may be related to the kidneys' excretory function. The existence of Pb and Cd in grazing areas may be the cause of the elevated Pb and Cd contents in those samples. It is possible for heavy metals to go from the soil to the animal food chain. In this study, female goats' kidneys had considerably greater Cd levels than did those of male goats. In addition, animals older than 3 years had greater levels of Cd in their liver and kidneys than younger animals, with the exception of cattle. Finally, the scientists ranked the organs according to their metal content as follows: liver > kidney > heart > lungs > muscles. According to their theory, the liver and kidneys are in charge of removing harmful metals from the body; hence, the animals under study had the highest metal contamination in these two organs (Bazargani-Gilani *et al.*, 2016). In Lebanon, Obeid *et al*. (2016) reported that compared to sheep and goat, beef has a lower level of Pb and Cd. The size of the animal, the characteristics of how the components are distributed throughout the organism, and the feeding practices used to rear the animals might all be contributing factors. For instance, the researcher stated that one of the feeding practices of animals in Lebanon is that goats and lambs are often fed outside meadows whereas cows are typically kept indoors. The Cd levels in the liver and kidney samples, however, above the maximum residue limit for Cd 0.05 ppm, even though none of the samples evaluated had exceeded the maximum residue limit for Pb 0.1 ppm. The high concentration of Cd in the kidney and liver may be due to their distinct roles as excretory and storing organs, respectively. In Syria, Soliman (2016) measured As using Graphite Furnace Atomic Absorption Spectrophotometry (FAAS) in muscle, liver, and kidney of calves. The author found that elevated levels of As were found (kidneys and liver) followed with meat. The kidneys had the greatest levels of As concentration, which is more likely a result of their critical function in blood filtration and toxin clearance, as well as the fact that these tissues contain fat, leading to increase As buildup. Furthermore, due to the liver's physiological activity in the storage of minerals, potassium, iron, zinc, and fats, metabolization of toxins and biologically active substances, as well as detoxification into safe substances in the body, As concentrations were high in liver samples. (Soliman, 2016). In Turkey, Yayayürük and Yayayürük (2017) conduct a study for detection of Hg, Cd, and Pb in the liver of cows and sheep. Pb and Cd concentrations in the samples used in this investigation were all below the graphite furnace atomic absorption spectroscopy (FAAS) detection limit for all samples. A research was carried out in Iraq to examine the levels of Pb, Hg, and Cd in goat and camel Carcasses. Goat meat exhibited a significantly different Pb concentration (0.9975 ppm) than camel meat (Sabeeh, 2018). Hg and Pb levels in goat meat were significantly different, although Cd concentration was not. Another study (Alperkhdri *et al.*, 2018) evaluated the content of heavy metals (Pb, Cu, and Cd) in goat meat in the winter and summer in several locations of Iraq (Kirkuk, Daqouq, and Debis). The findings indicated that throughout the winter, Kirkuk's center had the considerably higher levels of lead. Goat liver had the greatest Pb concentration in the winter (7.925 ppm), whereas muscles had the lowest Pb concentration in the summer (0.983 ppm). Almayahi *et al*. (2019) detected Pb, Cd concentrations in the meat of animals including cow and lamb from five different parts of Najaf, Iraq. The mean value of Pb (0.343±0.043) was higher than the mean concentration of Cd (0.129±0.023), although both were within the permissible limits. In a different research, Mahmoudi *et al*. (2018) examined the levels of Pb in buffalo muscle in three regions of Iran's north-west. In 80.33% of the buffalo muscle samples, Pb was found, and the level of Pb discovered was greater than the EC's authorized limits. The major sources of pollution, according to the authors, may be industrial and chemical industries (through the air that animals breathe). The maximum permitted weekly consumption of Pb, according to FAO/WHO (2000), is 25 ppb bw per week . The amount of red meat consumed on a daily basis in Iran has been estimated to be between 50 and 90 g, and this study's buffalo muscle samples had a mean Pb value of 0.043 ppm. The average Pb content was found to be lower than the WHO and EU MRLs in all samples, including offal and meat from beef and sheep, according to different research conducted in the east of Iran (Zeinali *et al.*, 2019). Additionally, Cd levels in muscle, liver, and kidney samples from the study animals were on the lower end of the MRLs recommended by the WHO and EU (0.05, 0.5, and 1 ppm, respectively). With the exception of sheep liver, where the average Cd concentration in the cold season was much greater than that in the hot season, the mean metal concentrations throughout the hot (summer) and cold (winter) seasons were the same in all samples. They contended that even if typical Cd and Pb levels were below MRLs, bioaccumulation of these metals in the organism might prolong the toxicity to domestic and foreign consumers (Zeinali *et al.*, 2019. In kingdom Saudi Arabia El-Ghareeb *et al*. (2019) which analyzed the levels of Pb, Cd and As and using atomic absorption spectroscopy in muscle, livers, and kidneys of

Table 1.1. Studies evaluated the level of toxic metal (mg/Kg) accumulation in red meat and offal.

Country	Species	Sample	Toxic metals	Result	Author
Spain	Cattle	Muscle	Pb	1.91 DW	González-Weller *et al.* (2006)
			Cd	1.9 DW	
	Sheep	Muscle	Pb	1.35 DW	
			Cd	1.22 DW	
Ghana	Sheep	Liver	Pb	0.14±0.07 DW	Akoto *et al.* (2014)
			As	0.02±0.01 DW	
			Cd	0.07±0.03 DW	
			Hg	0.03±0.03 DW	
		Kidney	Pb	0.18±0.07 DW	
			As	0.03±0.03 DW	
			Cd	0.18±0.07 DW	
			Hg	0.03±0.03 DW	
		Lung	Pb	0.20±0.20 DW	
			As	0.03±0.02 DW	
			Cd	0.03±0.01 DW	
			Hg	0.03±0.03 DW	
		Brain	Pb	0.13±0.17 DW	
			As	0.02±0.02 DW	
			Cd	UDL	
			Hg	UDL	
		Intestine	Pb	0.16±0.11 DW	
			As	0.06±0.02 DW	
			Cd	0.03±0.01 DW	
			Hg	UDL	
		Heart	Pb	0.17±0.04 DW	
			As	0.02±0.01 DW	
			Cd	UDL	
			Hg	UDL	
	Goat	Liver	Pb	0.04±0.02 DW	
			As	0.02±0.01 DW	
			Cd	0.06±0.03 DW	
			Hg	UDL	
		Kidney	Pb	0.13±0.04 DW	
			As	0.03±0.02 DW	
			Cd	0.15±0.03 DW	
			Hg	0.01±0.01 DW	
		Lung	Pb	0.09±0.05 DW	
			As	0.02±0.01 DW	
			Cd	0.02±0.01 DW	
			Hg	0.07±0.02 DW	
		Brain	Pb	UDL	
			As	UDL	
			Cd	UDL	
			Hg	UDL	
		Intestine	Pb	UDL	
			As	0.004±0.01 DW	
			Cd	0.004±0.01 DW	
			Hg	UDL	
		Heart	Pb	UDL	
			As	0.02±0.01 DW	
			Cd	UDL	
			Hg	UDL	

DW: Dry weight; WW: Wet weight

Table 1.2. Studies evaluated the level of toxic metal (mg/Kg) accumulation in red meat and offal.

Country	Species	Sample	Toxic metals	Result	Author
Iran	Cattle	liver	Pb	21.1±3.30 DW	Bazargani-Gilani *et al.* (2016)
			Cd	0.14±0.02 DW	
		Kidney	Pb	28.10±3.39 DW	
			Cd	0.93±0.13 DW	
	Sheep	liver	Pb	17.05±5.17 DW	
			Cd	0.21±0.40 DW	
		Kidney	Pb	14.34±4.62 DW	
			Cd	1.93±0.41 DW	
	Goat	liver	Pb	1.69±0.13 DW	
			Cd	0.01±0.005 DW	
		Kidney	Pb	2.48±0.17 DW	
			Cd	0.33±0.06 DW	
Taiwan	Cattle	Muscle	Pb	0.009±0.0.08 WW	Chen *et al.* (2013)
			Cd	<0.002 WW	
			As	0.008±0.009 WW	
	Sheep	Muscle	Pb	0.009±0.007 WW	
			Cd	0.002±0.004 WW	
			As	0.005±0.003 WW	
Egypt	Cattle	Liver	Cd	0.298±0.067 WW	Darwish *et al.* (2015)
			Pb	0.603±0.096 WW	
		Kidney	Cd	0.627±0.176 WW	
			Pb	0.609±0.863 WW	
		Muscle	Cd	0.009±0.001 WW	
			Pb	0.485±0.153 WW	
	Sheep	Liver	Cd	0.203±0.014 WW	
			Pb	0.298±0.067 WW	
		Kidney	Cd	0.337±0.106 WW	
			Pb	0.502±0.076 WW	
		Muscle	Cd	0.006±0.002 WW	
			Pb	0.258±0.081 WW	
Kingdom Saudi Arabia	Camel	liver	Cd	2.18±0.71WW	El-Ghareeb *et al.* (2019)
			Pb	9.26±3.32 WW	
			As	38.41±25.15 WW	
		kidney	Cd	1.83±0.63 WW	
			Pb	7.91±2.39 WW	
			As	24.14±12.85 WW	
		muscles	Cd	0.29±0.27 WW	
			Pb	2.26±0.67 WW	
			As	12.89±4.29 WW	
	Sheep	liver	Cd	1.79±0.66 WW	
			Pb	10.81±4.54 WW	
			As	30.29±22.57 WW	
		kidney	Cd	1.18±0.37 WW	
			Pb	8.32±2.97 WW	
			As	30.34±20.86 WW	
		muscles	Cd	0.29±0.27 WW	
			Pb	2.71±0.68 WW	
			As	10.05±3.77 WW	
Bangladesh	Cattle	Muscle	Pb	4.83±1.01WW	Chowdhury and Alam, (2023)
			Cd	0.48±0.005 WW	
		Liver	Pb	10.54±2.23 WW	
			Cd	2.40±0.008 WW	
	Goat	Muscle	Pb	2.05±1.33 WW	
			Cd	0.31±0.025 WW	
		Liver	Pb	81.87±29.95 WW	
			Cd	1.81±0.024 WW	

both camel and sheep. The author concluded that camel liver and kidney tissues had the highest mean Cd concentrations than the sheep samples, however, the camel muscle contained the lowest Cd residues. Concentrations of Cd reported in this study were within the MPLs of Cd in the muscle and offal and none of the samples analyzed in this study exceeded the MPLs of Pb established by the EC. The author noticed a strong positive correlation between the age of examined species and the load of toxic metals Cd, Pb, and As (El-Ghareeb *et al.*, 2019). In research conducted in Kuwait in Abd-Elghany *et al.* (2020) recorded that heavy metals in 600 sheep samples' liver, muscle, and kidney were examined. The findings showed that Hg, As, Pb, and Cd levels were higher than those allowed by major international food authorities. The THQ and hazard index (HI) values for Hg (>1.0) in the examined sheep samples also point to a danger to Kuwait's public health. Pb and Cd levels in fresh cattle, sheep, and goat tissues (muscle, lung, kidney, heart, fat, liver, bone marrow, and spleen). The levels of Cd and Pb in the liver and kidney of bovine (older than 4 years) and ovine (older than 1 year) were examined in different research conducted in Algeria (Zenad *et al.*, 2020). The liver and kidney Cd levels were greater among the female animals older than four years due to a significant difference in Cd concentrations across age and sex groups. Sex and age have a considerable impact on the accumulation of hazardous metals, according to Zenad *et al.* (2020). In Pakistan, Arif *et al.* (2021) determined Pb and Cd in organ samples of heart, liver, and muscles, from red meat (mutton and beef) the highest level of Pb was detected in heart mutton, the Cd, and Pb were not detected in the majority of meat samples. The authors concluded that the metal accumulation correlated with the metals in the living environment of the examined species (Arif *et al.*, 2021).

Toxic metals in poultry meat and offals

In Nigeria after nitric acid/perchloric acid digestion, the levels of cadmium (Cd) and lead (Pb) in the chicken meat, chicken gizzard, and turkey meat consumed in southern Nigeria were assessed using graphite furnace atomic absorption spectrophotometry. The elements' concentration ranges are 0.01-4.60 $mg.kg^{-1}$ Pb, 0.01-3.43 $mg.kg^{-1}$. While the concentrations of cadmium, nickel, chromium, and lead in some samples were at levels above the permitted limits, those of iron, manganese, copper, and zinc were below the permissible limits (Iwegbue *et al.*, 2008). In Taiwan heavy metals were determined in poultry meat from 30 chicken, 10 duck and 10 goose meat. The Pb concentration was higher in duck than chicken and goose. Additionally, arsenic concentrations in chicken were higher than duck and goose (Chen *et al.*, 2013). In Pakistan, 240 broiler carcasses and internal organs were gathered and tested for Pb and Cd levels. Liver samples showed significantly (P < 0.05) higher Pb and Cd than gizzard, breast, and thigh muscle (Abbas *et al.*, 2019). In Kingdom Saudi Arabia, Korish and Attia (2020), they assessed the level of Pb and Cd, and in chicken meat products, to determine the risk factors from the consumption of poultry meat. The results declared that Cd and Pb were under detection limit in poultry meat products and eggs, suggesting that there is no threat from toxic heavy metals. In Egypt, Morshdy *et al.* (2022) evaluated the residual levels of various hazardous metals, such as Pb, Cd, and Hg, in five different bird meat items, including chicken burgers, fillets, luncheons, nuggets, and pane. Additionally, for Egyptian adults and children, estimated daily intakes (EDI) and potential health risks from heavy metals due to consumption of such meat products were calculated. The obtained data showed that there was no evidence of Hg in any sample. The other measured

Table 2.1. Studies evaluated the level of toxic metal (mg/Kg) accumulation in poultry meat and offal.

Country	Species	Sample	Toxic metals	Result	Author
Taiwan	Duck	Muscle	Pb	0.046±0.098 WW	Chen *et al.* (2013)
			Cd	0.036±0.042 WW	
			As	0.012±0.004 WW	
	Goose	Muscle	Pb	0.021±0.014 WW	
			Cd	<0.002 WW	
			As	0.011±0.005 WW	
Egypt	Quail	Liver	Cd	0.17±0.05 WW	Darwish *et al.* *(*2018)
			pb	0.91±0.14 WW	
			As	0.09±0.02 WW	
			Ni	3.33±0.31 WW	
		Kidney	Cd	0.21±0.05 WW	
			pb	1.31±0.37 WW	
			As	0.17±0.05 WW	
			Ni	3.04±0.31 WW	
		Muscles	Cd	0.07±0.02 WW	
			pb	0.18±0.16 WW	
			As	0.006±0.002 WW	
			Ni	1.55±0.23 WW	
Egypt	layers	liver	Cd	0.06±0.01 WW	El Bayomi *et al.* (2018)
			Pb	0.21±0.05 WW	
			Hg	0.41±0.07 WW	
			Cu	0.18±0.03 WW	
			Zn	5.53±0.45 WW	
		Muscles	Cd	0.06±0.01 WW	
			Pb	0.10±0.05 WW	
			Hg	0.45±0.14 WW	
			Cu	0.08±0.02 WW	
			Zn	2.59±0.10 WW	
	briolers	Liver	Cd	0.10±0.01 WW	
			Pb	0.34±0.06 WW	
			Hg	0.65±0.12 WW	
			Cu	0.21±0.03 WW	
			Zn	4.76±0.44 WW	
	briolers	Muscles	Cd	0.09±0.01 WW	
			Pb	0.31±0.04 WW	
			Hg	0.62±0.11 WW	
			Cu	0.04±0.02 WW	
			Zn	2.46±0.30 WW	
	Turkey	Liver	Cd	0.10±0.01 WW	
			Pb	0.45±0.19 WW	
			Hg	0.47±0.13 WW	
			Cu	0.26±0.08 WW	
			Zn	5.56±1.21 WW	
		Muscle	Cd	0.07±0.01 WW	
			Pb	0.18±0.10 WW	
			Hg	0.44±0.11 WW	
			Cu	0.13±0.12 WW	
			Zn	3.70±0.33 WW	
	quail	Liver	Cd	0.08±0.02 WW	
			Pb	0.34±0.05 WW	
			Hg	0.70±0.15 WW	
			Cu	0.15±0.05 WW	
			Zn	2.40±0.38 WW	
		Muscle	Cd	0.04±0.01 WW	
			Pb	0.18±0.08 WW	
			Hg	0.52±0.05 WW	
			Cu	0.10±0.05 WW	
			Zn	1.13±0.35 WW	

Table 2.2. Studies evaluated the level of toxic metal (mg/Kg) accumulation in poultry meat and offal.

Country	Species	Sample	Toxic metals	Result	Author
Saudi Arabia	Broilers	Fresh meat	Cd	UDL	Korish and Attia (2020)
			Pb	UDL	
			As	UDL	
			Ni	UDL	
		Frozen meat	Cd	UDL	
			Pb	UDL	
			As	UDL	
			Ni	UDL	
		Liver	Cd	1.12 WW	
			Pb	16.51 WW	
			As	UDL WW	
			Ni	6.68 WW	
Bangladesh	Poultry	Muscle	Pb	3.13±1.01 WW	Chowdhury, and Alam, (2023)
			Cd	0.16±0.005 WW	
		Liver	Pb	7.05±.73 WW	
			Cd	0.65±0.017 WW	
	Pigeon	Muscle	Pb	5.91±.94 WW	
			Cd	0.13±0.022 WW	
		Liver	Pb	2.79±1.42 WW	
			Cd	0.69±0.075 WW	
	Quail	Muscle	Pb	1.64±1.32 WW	
			Cd	UDL	
		Liver	Pb	4.88±1.16 WW	
			Cd	0.78±0.023 WW	
	Duck	Muscle	Pb	1.92±.88 WW	
			Cd	0.11±0.022 WW	
		Liver	Pb	7.48±1.64 WW	
			Cd	15.98±0.87 WW	

DW: Dry weight; WW: Wet weight; UDL: Under detection limit

components, however, were found in varying amounts in each sample of chicken meat product that was analyzed. The most metal was found in the chicken burger. The maximum allowable values for Pb and Cd were exceeded in a number of samples. However, no potential risks were identified by the calculated EDI, hazard ratio, and hazard index for consumer. In Noakhali, Bangladesh, researchers assessed the levels of heavy metals (Cd, Cr, Pb, Ni, Fe, and Cu) in commercially available meat, poultry, and game products as well as their effects on cancer and other health issues. Heavy metals were analyzed using atomic absorption spectroscopy, and the health risks were calculated using the estimated daily intake (EDI), targeted hazard quotient (THQ), total hazard quotient (THQ), and total carcinogenic risk (TCR). Maximum Allowable Concentrations (MAC) for heavy metals were exceeded in the majority of samples. For duck liver, goat liver, and pigeon brain, the EDI value for Cd, Pb, and Cr was greater than the Maximum Tolerable Dietary Intake (MTDI).

CONCLUSION

Scientists all-over the world explained that variations in environmental contamination situations and variations in cattle feeding and watering systems were the reasons for the variations in metal accumulation models in their studies. Furthermore, they attributed the elevated level of toxic metals in the liver and kidneys of examined species relative to muscle due to their important role in the metabolism of toxic metals and detoxification. Additionally, interspecies variations in metal detoxification and xenobiotic metabolizing enzymes may be responsible for variations in metal accumulation in different sources of meat.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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