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Determination of some Heavy Metals in Chilled Meat Sold in Tripoli City, Libya

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ABSTRACT

Heavy metal detection in foods, particularly meat, is important for both nutritional reasons and consumer safety. The present study investigated the content of lead, cadmium, copper, and zinc in chilled meat. The red meat included cows, sheep, and camels' muscle, liver, and kidneys. The white meat included the muscle and liver of chickens. Sixty-six samples were collected from meat markets in Tripoli, Libya. An atomic absorption spectrophotometer was used to determine heavy metal concentrations. Data were analyzed by the SAS program. The results showed that the concentrations of lead range from 0.0020 to 0.1033 mg/kg, and the concentrations of cadmium range from 0.0074 to 0.0947 mg/kg. Also, the results showed that copper concentrations were below the detection limit (BDL) in all types of meat except the liver of cows, sheep, and camels, where copper concentrations ranged from 42 to 100 mg/kg. For zinc, the concentration ranges from BDL to 34 mg/kg in muscles, BDL to 34 mg/kg in the livers, and 28 to 34 mg/kg in the kidneys. In general, the concentrations of all polluted and essential elements in the selected meat organs of the selected animals did not exceed the permissible maximum level set by health authorities.

تقدير بعض المعادن الثقيلة في اللحوم المبردة المباعة في مدينة طرابلس، ليبيا

ثريا أحمد أبوحليقة ، عفاف أبوزيد أبوحليقة

يُعد الكشف عن المعادن الثقيلة في الأغذية، وخاصة اللحوم، أمرًا مهمًا لأسباب غذائية وسلامة المستهلك. بحثت الدراسة الحالية في محتوى الرصاص، والكادميوم، والنحاس، والزنك في اللحوم المبردة. شملت اللحوم الحمراء عضلات، وكبد، وكلى الأبقار، والأغنام، والإبل. وشملت اللحوم البيضاء عضلات، وكبد الدجاج. تم جمع ستة وستين عينة من أسواق اللحوم في طرابلس، ليبيا. تم استخدام جهاز الامتصاص الدري؛ لتحديد تركيزات المعادن الثقيلة. تم تحليل البيانات بواسطة برنامج SAS. أظهرت النتائج أن تركيزات الرصاص تراوحت من 0.0020 إلى 0.1033 ملغم/كغم، وتركيزات الكادميوم تراوحت من 0.0074 إلى 0.0947 ملغم/كغم. كما أظهرت النتائج أن تركيزات النحاس كانت أقل من الحد الأقصى للكشف (BDL) في جميع أنواع اللحوم باستثناء كبد الأبقار، والأغنام، والإبل، حيث تراوحت تركيزات النحاس من 42 إلى 100 ملغم/كغم. بالنسبة للزنك، يتراوح تركيزه بين BDL و34 ملغ/كغ في العضلات، وبين BDL و34 ملغ/كغ في الكبد، وبين 28 و34 ملغ/كغ في الكلى. وبشكل عام، لم تتجاوز تركيزات جميع العناصر الملوثة والأساسية في أعضاء اللحوم المختبرة من حيوانات مختارة الحد الأقصى المسموح به من قبل السلطات الصحية.

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INTRODUCTION

Meat is a high-nutritional food source that meets different needs of the human body as meat and meat products are excellent sources of zinc (Zn), iron, phosphorous, B vitamins, and essential amino acids (Albashr et al., 2021; Bohrer, 2017; Nkansah & Ansah, 2014; Akan et al, 2010). However, food, including meat and meat products, is the main route of exposure to heavy metals. Heavy metals are minerals with a density of five times that of water (Baykov et al., 1996). They may be essential or harmful to the human body.

Essential heavy metals, such as copper (Cu) and Zn, play an important role in biological systems. The food chain is the major source of such elements (Bilandžić et al., 2014). Cu plays a vital role in bone and cardiovascular health, immune function, and cholesterol metabolism (Araya et al., 2007). Meat is an important food source of zinc as it has a much higher bioavailability than zinc from vegetables and is often called the metal of life (Bilandžić et al., 2014; Djinovic-Stojanovic et al., 2017). The biological role of Zn includes catalytic, structural, and regulatory functions (Hill Shannon, 2019). However, essential metals can also produce toxic effects at high concentrations (Alturiqi & Albedair, 2012; Brito et al., 2005). Importantly, harmful heavy metals, including lead (Pb) and cadmium (Cd) are toxic heavy metals, even in trace amounts (EC, 2001).

Environmental pollution is a significant source of lead and cadmium contamination in meat (Manea et al., 2017). With the increase in industrial and urban activity, concerns about environmental pollution are rising as heavy metals continue to be released into aquatic and terrestrial ecosystems (Yabe et al., 2011). Their detrimental effects stem from their toxicity, accumulation, and bio-magnification in the food chain (Nkansah & Ansah, 2014; Eisler, 1988). Heavy metals such as Pb and Cd can have numerous adverse effects on health. The impacts of Pb include decreased intelligence, weakened joints, accelerated skeletal maturation, higher incidence of cavities, elevated blood pressure, anemia, spontaneous abortion, impaired kidney function, altered hormone levels, and increased immunoglobulin E, leading to allergic diseases (de Vasconcelos Neto et al., 2019). Negative effects of Cd exposure on human health include anemia, as Cd interacts with iron, reducing hemoglobin and hematocrit levels; further, Cd diminishes Cu concentrations in the liver and plasma and lowers plasma ceruloplasmin levels; Cd also disrupts Zn metabolism, inhibits Zn-containing enzymes, competes for gastrointestinal absorption, and displaces Zn in metallothioneins; in addition, osteoporosis, Cd accumulation in bones, and hypercalciuria occur due to Cd interacting with calcium (Jaishankar et al., 2014). Furthermore, cadmium accumulation in the body can lead to cancer in the liver, kidneys, and stomach (Okoye et al., 2011).

The concentration of heavy metals in the meat tissues of livestock, including camels, cows, sheep, and poultry, can rise due to soil, grass, air, and water pollution in their pastures. The most common sources of exposure are contaminated feed and water (Ihedioha and Okoye, 2012; Kia et al., 2014).

The heavy metals concentrations rise in the liver and kidneys more than in other body organs because these organs are responsible for detoxifying toxic substances such as heavy metals (Khalafalla et al., 2015). Over time, continuously eating contaminated meat with heavy metals can cause them to accumulate in the human body, causing poisoning and the emergence of cancerous diseases (Demirezen and Uruç, 2006).

There is a tendency and preference in Libyan society to purchase chilled raw meat (muscle), as well as to use the internal organs of livestock (liver and kidney), such as sheep, cows, camels, and poultry, as a source of protein in preparing main meals for family members of different ages (lunch and dinner). As a result of hazards that the consumers may be exposed to because of eating contaminated meat, especially with heavy metals, the study aimed to determine the content of toxic heavy metals (Pb and Cd) in chilled muscle, liver, and kidney. As well as to evaluate the content of essential heavy metals (Cu and Zn) in chilled muscle, liver, and kidney, consumed by citizens in Tripoli city. In addition, bringing recommendations that may help to achieve the consumers' safety and health.

MATERIALS AND METHODS

Study Plan

The study was conducted in 2023. Meat samples (66) were collected from the main selling meat markets in various municipalities in Tripoli city. Eleven samples from each municipality, with three replicates for each sample. The markets were selected randomly and grouped according to the geographic border of 6 municipalities, which are Ain Zara, Abusleem, Hai Al-Andalus (Al hai al aslami), Suk Alguma, Tajura, and Tripoli Center. The red meat samples consisted of muscle, liver, and kidney of cows, sheep, and camels, and the white meat consisted of muscle and liver of chicken. The weight of one sample was 200 g. All collected samples were stored in polyethylene bags according to type and transferred to the laboratory at the Libyan Advanced Center for Chemical Analysis for testing. Once they arrived at the laboratory, each sample was stored at -18°C until being analyzed and homogenized.

Sample preparation

The samples were wet digested to determine the intended metals based on the method of Damin et al. (2007). All materials used were of high purity (analytical grade). All dilutions and dissolutions were carried out using double-distilled water. The samples were defrosted using the microwave. Approximately five grams of each sample were introduced into a 250 ml digestion flask.

Three replicates of the sample were made. Twenty-four mL of 65% concentrated nitric acid was added to the sample flask. The digestion flask was heated at 60°C until the sample dissolved and the acid evaporated to 5 mL. The digestion flasks were gently agitated manually to avoid foam formation. After that, 10 mL of 32% hydrogen peroxide was added to oxidize the sample, and the mixture was heated at the same temperature. When the effervescence disappeared, 3 ml of nitric acid was added, after that, 2 mL of nitric acid was added. The digestion was complete when all the fat of the meat had dissolved. After cooling, the mixture was filtered into a standard 100 mL flask, and the volume was completed to the mark using distilled water. After that, the sample was transferred to the atomic absorption laboratory to conduct the required subsequent analyses. The freshly standard solutions were prepared from the standard solution stock and they were used for the initial calibration of each metal.

Heavy metal determination

Measurement of Pb, Cd, Cu, and Zn in the prepared solutions of targeted meat samples was done using atomic absorption spectroscopy, Nova 800, Technology Quality Innovation, Germany.

Statistical analysis

The results of laboratory data were recorded in Microsoft Excel 2010. Descriptive statistics (Means and standard deviations) were used for summarizing heavy metal concentrations. The experiment was conducted using a Complete Randomized Design (CRD). Analysis of variance and statistical tests were performed to study the effects of regions, animal parts, and their interactions, utilizing the Statistical Analysis System (SAS-2002) program. Duncan's multiple range test was used to determine the significance of differences between the means of different parameters at a probability level of $p \leq 0.05$. The mathematical model for the experimental design was as follows:

$$\mathbf{Y_{ijkl} = \mu + A_i + B_j + AB_{ij} + E_{ijkl}}$$

Where:

Y_{ijkl} = response
μ = overall mean
A_i = effect of regions (i = 1, 2, 3, 4, 5, 6)
B_j = animal parts (j = 1, 2, 3)
AB_{ij} = effect of interactions between regions and animal parts
E_{ijkl} = experimental error

RESULTS AND DISCUSSION

This study targets the concentrations (mg/kg) of Pb, Cd, Cu, and Zn in samples of chilled meat of different organs sold at meat markets in Tripoli City. The red meat samples consisted of muscle, liver, and kidney of cows, sheep, and camels, and the white meat consisted of muscle and liver of chicken.

Regarding the Pb concentration in different organs of chilled meat from types of animals in various municipalities (Ain Zara, Abusleem, Hai Al-Andalus, Suk Alguma, Tajura, and Tripoli center), Table 1 shows the distribution of Pb in targeted organs. The concentrations of Pb range from 0.0020 to 0.1033 mg/kg. The highest concentrations in muscle, liver, and kidney were 0.0834±0.0228, 0.0845±0.0202, and 0.0878±0.0147 mg/kg in cow muscle, sheep liver, and camel kidney, respectively. The results of the statistical analysis showed a significant difference in Pb concentrations between the liver and kidney, while there was no significant difference between the liver and kidney with muscles ($p \leq 0.05$). Thus, no sample exceeded the permissible maximum level (PML) according to the Libyan standard (LNS, 594/2009), which stipulates that it should not exceed 0.1 mg/kg and 0.5 mg/kg in all kinds of meat muscles and internal organs (offal), respectively. This is probably because these animals were raised in an unpolluted environment. In contrast to these results, in Beijing, China, Liang et al. (2019) recorded higher concentrations in the liver and kidney, at 0.15±0.02 and 0.17±0.02 mg/kg, respectively. Also, in a similar study in North Lebanon, the results showed higher levels of Pb in the various tissues of goats, cows, and sheep, ranging from 0.0005 to 0.09595 mg/Kg (Obeid et al., 2016). Unlike the studies above, González-Weller et al. (2006) found that the concentrations of lead in muscles, were 0.00694 mg/kg in chicken, 0.00191 mg/kg in cows, and 0.00135 mg/kg in sheep, respectively.

Table (1): Concentrations of Lead (mg/kg) in samples of meat collected from meat markets

Type of organ	Type of animal	Mean ±SD*/ Municipalities						Mean ±SD*
		Ain Zara	Abusleem	Hai Al-Andalus	Suk Alguma	Tajura.	Tripoli center	
Muscles	Cows	0.0940[a] ±0.127	0.0837[a] ±0.008	0.0670[a] ±0.036	0.0890[a] ±0.006	0.1033[a] ±0.002	0.0633[a] ±0.008	0.0834±0.0228
	Sheep	0.1013[a] ±0.003	0.1[a] ±0.005	0.0510[b] ±0.006	0.0873[a] ±0.002	0.0470[b] ±0.000	0.0403[b] ±0.006	0.0712±0.0284
	Camels	0.0580[b] ±0.001	0.0463[b] ±0.004	0.0820[a] ±0.002	0.1[a] ±0.020	0.0877[a] ±0.050	0.0873[a] ±0.006	0.0623±0.0221
	Chicken	0.0697[a] ±0.001	0.0803[a] ±0.000	0.0020[a] ±0.0014	0.0520[a] ±0.001	0.0583[a] ±0.008	0.0910[a] ±0.000	0.0589±0.1018
Livers	Cows	0.0403[c] ±0.008	0.0420[c] ±0.000	0.0810[a] ±0.0542	0.0461[c] ±0.001	0.0570[b] ±0.002	0.0423[c] ±0.009	0.0515±0.0149
	Sheep	0.0877[a] ±0.009	0.1033[a] ±0.030	0.0580[b] ±0.045	0.0783[ab] ±0.004	0.1[a] ±0.006	0.0797[ab] ±0.005	0.0845±0.0202
	Camels	0.0733[ab] ±0.008	0.0747[ab] 0.009	0.073[ab] ±0.075	0.0937[a] ±0.004	0.0897[a] ±0.002	0.050b ±0.003	0.0757±0.0227
	Chicken	0.0670[ab] ±0.016	0.0407[c] ±0.052	0.0693[ab] ±0.004	0.0840[a] ±0.003	0.0577[bc] ±0.001	0.087[a] ±0.007	0.0676±0.0196
Kidneys	Cows	0.0430[b] ±0.010	0.0787[a] ±0.079	0.1[a] ±0.012	0.1033[a] ±0.009	0.1033[a] ±0.060	0.0870[a] ±0.011	0.0858±0.0249
	Sheep	0.0627[b] ±0.020	0.0453[b] ±0.045	0.0583[b] ±0.064	0.0943[a] ±0.001	0.0443[b] ±0.001	0.0867[a] ±0.023	0.0653±0.0225
	Camels	0.0873[a] ±0.002	0.1027[a] ±0.008	0.089[a] ±0.021	0.0703[a] ±0.003	0.0883[a] ±0.008	0.0890[a] ±0.004	0.0878±0.0147

SD* = Standard Deviation; a, b, c: Means that share at least one letter within a row are not significantly different

Table (2): Concentrations of Cadmium (mg/kg) in samples of meat collected from meat markets

Type of organ	**Type of animal**	**Mean ±SD*/ Municipalities**						Mean ±SD*
		Ain Zara	**Abusleem**	**Hai Al-Andalus**	**Suk Alguma**	**Tajura.**	**Tripoli Center**	
Muscles	Cows	0.0440[a] ±0.041	0.0173[a] ±0.010	0.0377[a] ±0.015	0.0180[b] ±0.000	0.0370[a] ±0.002	0.0383[a] ±0.004	0.0321±0.0118
	Sheep	0.0074[c] ±0.087	0.0460[a] ±0.029	0.0377[b] ±0.004	0.0947[ab] ±0.007	0.0407[b] ±0.074	0.0400[b] ±0.002	0.0444±0.0134
	Camels	0.0427[a] ±0.007	0.0410[a] ±0.001	0.0393[a] ±0.009	0.0187[b] ±0.005	0.0183[b] ±0.004	0.0420[a] ±0.001	0.0337±0.0120
	Chicken	0.0417[ab] ±0.041	0.0463[a] ±0.004	0.0390[b] ±0.021	0.0427[ab] ±0.056	0.0440[ab] ±0.002	0.0400[b] ±0.001	0.0423±0.0034
Livers	Cows	0.0490[a] ±0.010	0.0430[a] ± 0.014	0.0380[a] ±0.041	0.0407[a] ±0.075	0.0250[b] ±0.009	0.0427[a] ±0.005	0.0416±0.0095
	Sheep	0.0477[a] ±2.152	0.0413[ab] ±0.007	0.0427[ab] ±0.014	0.0360[b] ±0.002	0.0427[ab] ±0.001	0.0180[c] ±0.009	0.0381±0.0106
	Camels	0.0463[a] ±0.002	0.0420[ab] ±0.004	0.0403[b] ±0.005	0.0423[ab] ±0.004	0.0400[b] ±0.004	0.0427[ab] ±0.000	0.0423±0.0028
	Chicken	0.0420[a] ±0.032	0.0300[abc] ±0.045	0.0410[a] ±0.004	0.0240[bc] ±0.024	0.0357[ab] ±0.070	0.0183[c] ±0.009	0.0318±0.0116
Kidneys	Cows	0.0440[a] ±0.003	0.0164[c] ±0.077	0.0360[b] ±0.061	0.0403[ab] ±0.004	0.0413[ab] ±0.002	0.0417[ab] ±0.004	0.0366±0.0102
	Sheep	0.0407[a] ±0.005	0.0420[a] ±0.022	0.0420[a] ±0.011	0.0320[b] ±0.047	0.0427[a] ±0.007	0.0423[a] ±0.004	0.0403±0.0042
	Camels	0.0427[a] ±0.010	0.0400[a] ±0.051	0.0400[a] ±0.043	0.0400[a] ±0.080	0.0423[a] ±0.072	0.0427[a] ±0.043	0.0413±0.0002 8

SD* = Standard Deviation; a, b, c: Means that share at least one letter within a row are not significantly different

Table (3): Concentrations of copper (mg/kg) in samples of meat collected from meat markets

Type of organ	Type of animal	Mean ±SD*/ Municipalities						Mean ±SD*
		Ain Zara	Abusleem	Hai Al-Andalus	Suk Alguma	Tajura.	Tripoli Center	
Muscles	Cows	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Sheep	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Camels	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Chicken	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Livers	Cows	99^{a} ±0.111	99^{a} ±0.127	100^{a} ±0.132	95^{b} ±0.124	95^{b} ±0.177	95^{b} ±0.187	97.2 ±2.5029
	Sheep	88^{a} ±0.8164	42^{d} ±0.102	88^{a} ±0.182	85^{b} ±0.118	80^{c} ±0.116	82^{c} ±0.111	77.5 ±16.639
	Camels	99^{ab} ±0.211	100^{a} ±0.162	100^{a} ±0.107	95^{bc} ±0.124	95^{bc} ±0.177	90^{c} ±1.122	96.5 ±3.3936
	Chicken	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Kidneys	Cows	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Sheep	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Camels	BDL	BDL	BDL	BDL	BDL	BDL	BDL

SD* = Standard Deviation; BDL: Below Detected Limit; a, b, c: Means that share at least one letter within a row are not significantly different

Cd is one of the toxic contaminants (Tomović et al., 2013). Table 2 reveals the results of Cd concentrations in different organs of chilled meat from types of animals in the various municipalities (Ain Zara, Abusleem, Hai Al-Andalus, Suk Alguma, Tajura, and Tripoli Center). The concentrations of Cd range from 0.0074 to 0.0947 mg/kg. The differences in heavy metal levels in meat among various animals result from factors including environmental conditions, type of pasture, and industrial development (Demirbaş, 1999; El-Faer et al., 1991). The highest concentrations were observed in sheep muscles (0.0947±0.007), cow livers (0.0490±0.010), and cow kidneys (0.0440±0.003). Thus, except sheep muscles from Suk Alguma, no sample exceeded PML according to the Libyan standard (LNS, 681/2009), which stipulates that it should not exceed 0.05, 0.50 and 1.0 mg/kg in in all kinds of meat muscles, livers of all animals and kidneys of all animals, respectively. This is probably because these animals were raised in an unpolluted environment. Additionally, the statistical analysis revealed no significant differences in cadmium (Cd) concentrations among the muscle, liver, and kidney ($p \leq 0.05$). In a similar study, the results showed higher levels of Cd in the various tissues of goats, cows, and sheep, ranging from 0.00055 to 0.68895 mg/Kg (Obeid et al., 2016). On the contrary, the study carried out by González-Weller et al. (2006) showed lower concentrations of cadmium, which were 0.00168 mg/kg in chicken muscles, 0.0019 mg/kg in cows' muscles, and 0.00122 mg/kg in sheep muscle samples, respectively. In the same line, Mohamed et al. (2023) found that Cd levels in chilled beef meat were within the PML in all samples.

Cu is an essential element that plays a significant role in human health (González Weller et al., 2014). Table 4 presents the results of Cu concentrations in various parts of chilled meat from different animal types across several municipalities (Ain Zara, Abusleem, Hai Al-Andalus, Suk Alguma, Tajura, and Tripoli Center). The results indicated that copper concentrations were below the detection limit (BDL) in all types of meat except for the livers of cows, sheep, and camels. Cu concentrations ranged from BDL to 100 mg/kg. The highest levels, reaching 100 mg/kg, were found in the livers of cows from Hai Al-Andalus and in the livers of camels from both Abusleem and Hai Al-Andalus. This may be attributed to the blood filtration process taking place in the liver, which accumulates Cu. This explains why variations are more likely to be revealed in the liver than in other animal tissues (Yakubu et al., 2017; McDowell, 2003). The Cu concentrations in the livers of cows, sheep, and camels were below the PML of 200 mg/kg (ANZFA, 2001). Further, the results of the statistical analysis showed no significant difference in Cu concentrations between the muscles and kidneys, while there was a significant difference between the muscles and kidneys with livers ($p \leq 0.05$). On the same line, the calf and cow liver contained the highest concentration of cu compared to the kidney and muscle, which were 64.6, 4.91, 0.677 mg/kg, and 60.3, 3.67, 1.26 mg/kg, respectively (López Alonso et al., 2000). In a similar study by Yakubu et al. (2017), Cu concentrations were lower than those observed in the present study, with the highest level reported at 0.52 ± 0.30 mg/kg in a cow liver. Also, in a study conducted by Milam et al. (2015), the levels of Cu in the cattle heart, intestine, stomach, kidney, and liver were lower, ranging from 0.20±0.00 to 1.98±0.00 mg/kg.

Zn is an essential trace element for human health; however, excessive exposure can lead to adverse health effects (ATSDR, 2004). Table 5 reports the results of Zn concentrations in various parts of chilled meat from different animal types across several municipalities (Ain Zara, Abusleem, Hai Al-Andalus, Suk Alguma, Tajura, and Tripoli Center). Meat is an important food source of Zn, and its deficiency is observed in populations that consume more cereals than meat (Roohani et al., 2013). High concentrations of zinc were found in the muscles, livers, and kidneys of cows, sheep, and camels compared with the muscles and livers of chickens. The Zn concentration ranges from BDL to 34 mg/kg in muscles, BDL to 34 mg/kg in the livers, and 28 to 34 mg/kg in the kidneys. Liver and kidney, as types of offal, are valuable sources of zinc in the human diet (WHO, 1996). The high level of Zn in the liver may be due to the blood filtration process that takes place in the liver (Yakubu et al., 2017). The Zn concentrations in this study in all tested samples were below the PML of 150 mg/kg (ANZFA, 2001). Further, the results of the statistical analysis showed no significant difference in Zn concentrations between the muscles and livers, while there was a significant difference between the muscles and livers with kidneys ($p \leq 0.05$). In a similar study, the zinc concentrations were lower than in this study, wherein the cow liver and kidney were 1.32±0.06 mg/kg and 1.02±0.08 mg/kg, respectively (Yakubu et al., 2017). Also, Milam et al. (2015) found that the levels of Zn in the cattle heart, intestine, stomach, kidney, and liver were lower, ranging from 1.91±0.00 to 3.96±0.00 mg/kg. In this study, the lowest Zn concentrations (BDL) were found in the meat and liver of chickens. Zn levels in meat can be influenced by factors such as pasture type and genetic characteristics (Demirezen & Uruç, 2006). The lowest concentrations in this study were in the muscle and liver of chicken (BDL). The Zn concentration in meat is affected by pasture type and genetic characteristics (Demirezen & Uruç, 2006). Heavy metals such as Zn occur naturally and are widely distributed in the environment, particularly in the Earth's crust. As a result, their presence in food can vary depending on their environmental abundance (Arshad et al., 2024).

Table (4): Concentrations of zinc (mg/kg) in samples of meat collected from meat markets

Organ	Type of animal	Mean ±SD*/ Municipalities						Mean ±SD*
		Ain Zara	Abusleem	Hai Al-Andalus	Suk Alguma	Tajura	Tripoli Center	
Muscles	Cows	32[b] ±0.2410	30[c] ±0.119	32[b] ±0.106	30[c] ±0.136	32[b] ±0.117	34[a] ±0.110	31.7 ±1.6449
	Sheep	30[a] ±0.132	28[b] ±0.117	28[a] ±0.110	28[b] ±0.109	30[a] ±0.124	30[b] ±0.173	29 ±1.3284
	Camels	34[a] ±0.163	32[ab] ±0.180	34[a] ±0.101	30[b] ±0.172	30[b] ±0.199	30[b] ±1.201	31.7 ±2.0864
	Chicken	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Livers	Cows	34[a] ±0.1660	30[b] ±0.126	34[a] ± 0.117	32[ab] ±0.184	32[b] ±0.111	30[b] ±0.100	32 ±1.9967
	Sheep	32 ±1.4142	30 ±0.153	30 ±0.119	30 ±0.120	32 ±0.107	30 ±0.197	30.7 ±1.4552
	Camels	30[b] ±0.125	32[ab] ±0.118	34[a] ± 0.012	32[ab] ±0.117	30[b] ±0.116	32[ab] ±0.187	31.7 ±1.9704
	Chicken	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Kidneys	Cows	32[a] ±0.1220	30[a] ±0.114	30[a] ±0.107	32[a] ±0.184	28[a] ±0.182	30[a] ±0.102	30.3 ±2.0291
	Sheep	30[a] ±0.1240	30[a] ±0.126	28[a] ±0.194	30[a] ±0.144	28[a] ±0.171	28[a] ±0.115	29 ±1.8302
	Camels	34[a] ±0.1280	32[a] ±0.105	32[a] ±0.137	32[a] ±0.176	30[a] ±0.188	32[a] ±0.111	32 ±1.8787

SD* = Standard Deviation; BDL: Below Detected Limit; a, b, c: Means that share at least one letter within a row are not significantly different

CONCLUSION

Based on the concentrations of lead, cadmium, copper, and zinc, the chilled meat parts, including muscles, livers, and kidneys of commonly consumed animals sold in various markets in Tripoli, Libya, appear to be safe for consumption. This may reflect low levels of environmental contamination in the regions where the animals were raised.

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