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Research Article/Araştırma Makalesi

Determination of Heavy Metal Content in Imported and Local Red Meat in Northern Iraq (Erbil) Region

Kuzey Irak (Erbil) Bölgesinde İthal ve Yerli Kırmızı Etlerde Ağır Metal Miktarının Belirlenmesi

Ali RAMADHAN ALI[1], İbrahim HAYOĞLU[2*], Ahmet Sabri ÜNSAL[3]

[1,2,3]Harran University, Engineering Faculty, Food Engineering Department, Sanliurfa, Türkiye

[1]https://orcid.org/0000-0002-2425-3702; [2]https://orcid.org/0000-0002-6358-8302; [2]https://orcid.org/0000-0002-8012-3208

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***Address for Correspondence:**
İbrahim HAYOĞLU
e-mail:
ihayoglu@harran.edu.tr

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ABSTRACT

Red meat is one of the most important and highly demanded foods worldwide. This research investigates the levels of ten elements (Cr, Mn, Fe, Ni, Cu, Zn, As, Cd, Hg, and Pb) in red meat samples from local sources and four countries. The elements evaluated are categorized into three major groups based on their concentration: macro elements (Fe, Zn, Pb), microelements (Hg, As, Cu, Ni), and trace elements (Mn, Cr, Cd). The results, reported in mg Kg^{-1}, showed the following ranges: Fe: 0.113-0.118, Pb: 0.396-1.46, Zn: 1.573-4.689, Hg: 0.238-0.456, As: 1.687-1.886, Cu: 1.177-4.653, Ni: 0.012-3.078, Mn: 0.000-0.001, Cr: 0.000-0.003, Cd: 0.000-0.051. The findings indicate that heavy metal concentrations generally remained below established limits, with variability depending on the meat sample's origin.

Key Words: Meat, heavy metals, Iraq

ÖZ

Kırmızı et, dünyadaki en önemli ve en çok talep gören gıdalardan biridir. Bu araştırmada yerel ve dört farklı ülkeden alınan kırmızı et örneklerinde on elementin (Cr, Mn, Fe, Ni, Cu, Zn, As, Cd, Hg ve Pb) düzeyi incelendi. Araştırmada değerlendirilen elementler konsantrasyonlarına göre makro, mikro elementler ve iz elementler olmak üzere üç ana gruba ayrılmıştır. Birinci grup, Fe, Zn ve Pb gibi Makro veya temel elementlerdir. İkinci grup Hg, As, Cu ve Ni'den oluşan mikro elementlerdir. Üçüncü grup eser elementler ise Mn, Cr ve Cd'dir. Elde edilen sonuçlara göre değerler mg Kg^{-1} olarak sırasıyla, Fe: 0.113-0.118, Pb:0.396-1.460, Zn:1.573-4.689, Hg:0.238-0.456, As:1.687-1.886, Cu:1.177-4.653, Ni:0.012-3.078, Mn:0.000-0.001, Cr:0.000-0.003, Cd:0.000-0.051 arasında bulunmuştur. Elde edilen değerler, genel olarak ağır metal konsantrasyonunun limit değerlerin altında olduğunu ve et örneklerindeki ağır metal miktarının kaynağına göre değişim gösterdiğini ortaya koymuştur.

Anahtar Kelimeler: Et, ağır metaller, Irak

Introduction

Meat is a fundamental component of human diets, providing essential proteins and amino acids for health (Ibrahim, 2002). However, global concerns have escalated regarding the safety of meat products, particularly due to contamination with heavy metals. In regions like Iraq, challenges such as limited natural pastures and escalating feed prices have amplified dependence on imported meats, raising critical issues of consumer trust in the origin and safety of these products (Dean and Bowen, 1994). Almost 30 of the 92 naturally produced components and metalloids are highly harmful to humans, including Be, Li, Al, Ti, Cr, Mn, Cu, Ni, Cu, As, Se, Sr, Mo, Pd, Ag, Cd, Sn, Sb, Te, Cs, Ba, Pt, Au, Hg, Pb, and Bi. The general name for metallic elements with an atomic weight greater than 40.04 is heavy metal. (Ming-Ho, 2005). Owing to their tendency to persist in human and animal bodies, toxic elements can be quite dangerous even at low concentrations when consumed over a long period. (Ray, 1994; Santhi et al., 2008). Global attention on food safety has intensified due to the potential risks associated with consuming foods contaminated by pollutants such as heavy metals (D'Mello, 2003). Meat, being a primary source of nutrition for many, is not exempt from these concerns. Studies indicate that heavy metals like cadmium, lead, and mercury can accumulate in meat through environmental pollution and agricultural practices, posing significant health risks upon consumption (Badis et al., 2014; Abdallah, 2005). The industrial and agricultural sectors contribute significantly to heavy metal pollution, which enters the food chain through water, soil, and ultimately affects animal products intended for human consumption (Ahmad, 2002). Contaminants can also originate from animal medications, fertilizers, and other chemicals used in agriculture, exacerbating the issue of meat safety (Nkansah and Ansah, 2014). Despite its nutritional richness in proteins, essential amino acids, vitamins (D, B12), and minerals (zinc, iron), meat faces persistent scrutiny due to the potential health implications of heavy metal exposure (Khalafalla et al., 2011). Addressing these concerns necessitates stringent regulatory measures and effective enforcement to ensure food safety standards are upheld throughout production and processing (Pandey and Madhuri, 2014). Advancements in meat processing technologies have undoubtedly improved efficiency but also present challenges in mitigating heavy metal contamination (Lukacova et al., 2014). The environmental impact of heavy metals from meat production extends beyond immediate health concerns, posing risks through bioaccumulation and food chain contamination, thereby affecting ecosystems and human health (Mansour et al., 2009). Studies on the danger of food intake polluted by heavy metals have boosted the growing need for food protection. (Cnossen et al., 2009). Ensuring the quality and safety of meat products demands continuous research efforts and comprehensive monitoring strategies to mitigate the risks associated with heavy metal contamination (Liu et al., 2004; Lasztity, 2009). This study aims to contribute to this field by investigating the levels of heavy metals in locally sourced and imported beef in Erbil, emphasizing the critical need for reliable data to inform regulatory practices and consumer choices.

Materials and Methods

Study area and samples collection

The study used red meat (frozen) imported from four different sources and one local fresh red meat. The samples were obtained by arbitrarily collecting twenty-five samples from different parts of the carcasses in the commercial local markets in the city of Erbil. Each sample is coded as A, B, C, D and E according to its country.

Preparation and treatment of samples

Every group was collected from March to May 2020. The samples were taken in five different positions in the Carcass, afterwards they mixed and minced. Then samples taken from the mixed minced beef, the collected samples were put into clean polythene bags. As demonstrated in the below figure 1, samples were taken from the loin, chuk, rip, plate and hip.

Meat samples were transported to the laboratory, gently washed with distilled water to remove contaminated particles and chopped into small pieces using a clean ceramic knife.

In order to determine the general characteristics of the meat used in the research, pH, water activity

(Majeed et al. 2023), water content, fat, protein and ash analyses were performed on the prepared meat samples (Gökalp et al., 1995). The samples were then prepared for heavy metal analysis.

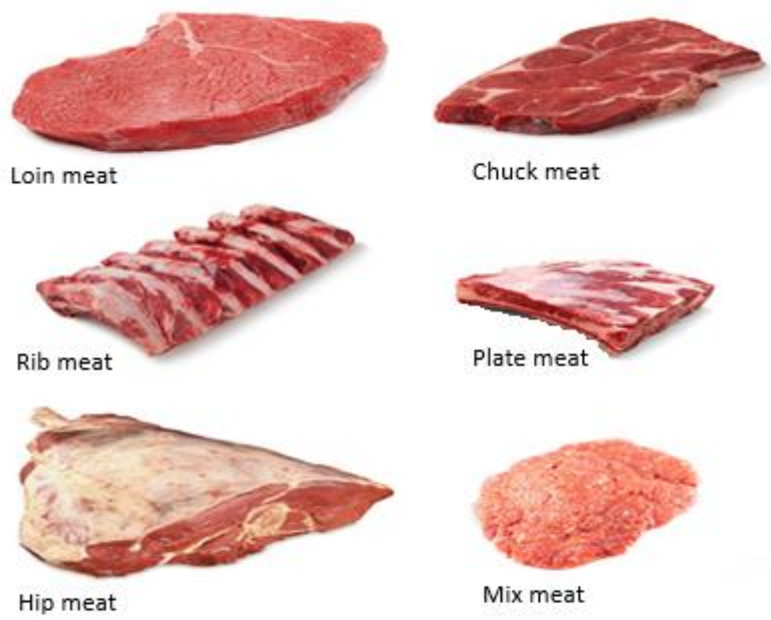

Figure 1. Meat samples used in analysis

Heavy metals determination in meat using ICP-MS
Preparation and treatment of samples

To eradicate any polluted particles, the extracted samples were cleaned with purified water. Then, using a sterile ceramic knife, specimens were cut into small pieces (1 mm thick) and then dried in the oven at 90 ° C until a known mass was collected. The dried samples were ground into fine powder in a ceramic mortar, sieved and then placed in polyethylene bags in the dark in desiccators until they were applied for acid digestion.

For the processing of specimens, the Milestone microwave method was used. The specimens (0.2 g) were weighed and excreted in a microwave digestion method with 10 ml of HNO_3 conc (65 %) and 5 ml of H_2O_2 (digestion requirements are: the first stage with power: 650 W for 10 min, second step with power: 350 W for 10 min) and then distilled with a dual filtered 18 mega Ω cm deionized method. Prodigy Axial high dispersion ICP-OES (Thermo) (RF frequency: 40, RF power: 1.3 K watt, Coolant gas flow rate: 18 L min^{-1}, Auxiliary flow rate: 0.3 L min^{-1}, Carrier gas

pressure: 34 psi, Integration time: 4 sec, Sample intake rate: 1.0 ml sec^{-1}) was used to determine the elements in all specimens at the Central Lab for Elementary and Isotopic Analysis in the Nuclear Research Center, Van Yüzüncü Yıl University.

Statistical analysis

The study applied SPSS software (version 25) to analyze the differences between meat samples. Furthermore, the ANOVA test was conducted to determine the level of significance both between and within groups. Significant differences between the means have been determined by Tukey test and $P \leq 0.05$ values accepted as significant.

Results and Discussion

General composition of meat samples provided for heavy metal analysis are given in table 1.

Table 1. Average values of the general characteristics of the meat samples

Meat Sample	Components %					
	pH	Water Content	Water Activity	Fat	Protein	Ash
A	5.70±0.13[b]	68.40±0.36[a]	0.92±0.01[ab]	6.40±0.30[a]	21.44±0.41[a]	2.02±0.08[ab]
B	5.45±0.10[b]	69.03±0.31[a]	0.95±0.01[a]	6.90±0.20[a]	21.95±0.15[a]	1.66±0.05[b]
C	6.16±0.15[a]	68.00±0.26[a]	0.92±0.02[ab]	6.13±0.15[a]	21.15±0.30[a]	1.19±0.09[c]
D	5.74±0.07[b]	67.20±0.70[a]	0.88±0.02[b]	6.27±0.27[a]	21.10±0.10[a]	2.17±0.06[a]
E	5.73±0.06[b]	68.00±0.36[a]	0.96±0.01[a]	6.38±0.34[a]	21.33±0.33[a]	2.27±0.07[a]

The differences between the values shown with the different letters in the same column are significant (P≤ 0.05).

As can be seen from Table 1, the mean pH values of the meat samples varied between 5.45 and 6.16. While the moisture contents of the samples varied between 67.20-69.03%, their water activities were found within the range of 0.88-0.96. Fat ratios of the samples used were determined between 6.13-6.90% and protein ratios were determined between 21.10-21.95%. Ash ratios of meat samples varied between 1.19-2.27%. In general, the values obtained are compatible with the values given in the literature AL-Hussainy and AL-Fadhly (2019), Al-Husseiny (2017), Khoshnaw (2015), Fennema and Carpenter (1984).

This research studied the level of ten elements (Cr, Mn, Fe, Ni, Cu, Zn, As, Cd, Hg, and Pb) in red meat samples from local and four different countries. The evaluated elements in the research are divided three major groups according to their concentration: macro, micro and trace elements.

The first group, the macro or essential elements, such as Fe, Zn and Pb are usually present in high concentrations in red meat in comparison to other elements. The second group is microelements, which consist of Hg, As, Cu and Ni. One of the most important sources of microelements such as Hg, As, Cu and Ni is red meat. The final group of elements in this study includes Mn, Cr and Cd. The mean, standard deviation, minimum and maximum (mg Kg^{-1}) values of red meat samples from five different countries are shown in Table 2.

Table 2. The mean, standard deviation, minimum and maximum values of red meat samples from five different countries (mg Kg^{-1}).

		N	Mean	Std. Deviation	Minimum	Maximum
Fe	A	3.000	0.114	0.003	0.110	0.120
	B	3.000	0.113	0.009	0.100	0.120
	C	3.000	0.117	0.009	0.110	0.120
	D	3.000	0.118	0.007	0.110	0.130
	E	3.000	0.116	0.011	0.110	0.130
Pb	A	3.000	1.460	1.670	0.456	3.400
	B	3.000	0.420	0.126	0.303	0.554
	C	3.000	0.407	0.059	0.356	0.472
	D	3.000	0.436	0.082	0.348	0.510
	E	3.000	0.396	0.180	0.250	0.597
Zn	A	3.000	1.573	0.224	1.360	1.807
	B	3.000	4.656	0.324	4.330	4.978
	C	3.000	3.258	1.982	1.447	5.375
	D	3.000	3.628	1.008	2.660	4.672
	E	3.000	4.689	0.146	4.551	4.842
Hg	A	3.000	0.268	0.108	0.150	0.360
	B	3.000	0.456	0.132	0.330	0.590
	C	3.000	0.297	0.135	0.150	0.420
	D	3.000	0.283	0.155	0.150	0.460
	E	3.000	0.238	0.111	0.160	0.370
As	A	3.000	1.687	0.189	1.520	1.890
	B	3.000	1.753	0.258	1.500	2.020
	C	3.000	1.886	0.216	1.700	2.120
	D	3.000	1.842	0.309	1.590	2.190
	E	3.000	1.857	0.189	1.670	2.050
Cu	A	3.000	1.247	1.101	0.000	2.080
	B	3.000	1.177	1.103	0.000	2.190
	C	3.000	3.713	3.290	0.000	6.270
	D	3.000	1.806	1.743	0.000	3.480
	E	3.000	4.653	1.814	3.160	6.670
Ni	A	3.000	3.078	3.043	0.000	6.090
	B	3.000	0.012	0.012	0.000	0.020
	C	3.000	1.953	1.965	0.000	3.930
	D	3.000	0.717	0.625	0.000	1.150
	E	3.000	2.268	0.592	1.900	2.950
Mn	A	3.000	0.001	0.001	0.000	0.000
	B	3.000	0.000	0.000	0.000	0.000
	C	3.000	0.000	0.000	0.000	0.000
	D	3.000	0.000	0.000	0.000	0.000
	E	3.000	0.001	0.001	0.000	0.000
Cr	A	3.000	0.000	0.000	0.000	0.000
	B	3.000	0.000	0.000	0.000	0.000
	C	3.000	0.001	0.001	0.000	0.000
	D	3.000	0.003	0.006	0.000	0.010
	E	3.000	0.000	0.000	0.000	0.000
Cd	A	3.000	0.051	0.08	0.000	0.130
	B	3.000	0.000	0.000	0.000	0.000
	C	3.000	0.001	0.001	0.000	0.000
	D	3.000	0.000	0.000	0.000	0.000
	E	3.000	0.000	0.000	0.000	0.000

It can be seen in Table 2, there are slight variation in the level of Fe in the red meat samples. While the highest Fe concentration (0.118 mg Kg^{-1}) was in the red meat sample from C, the lowest level (0.113mg Kg^{-1}) of Fe was in the B local meat sample. It is shown that the A sample contain the highest Pb (1.468 mg Kg^{-1}). However, all the other meat samples contained low level of Pb. The concentrations of Pb were (0.420, 0.407, 0.436 and 0.396 mg Kg^{-1}) in red meat samples of B, C, D and E, respectively. The main source of Pb contamination for livestock is food, water and air according to Halliwell et al. (2000). It is clear that the E sample had the highest Zn concentration (4.689mg Kg^{-1}) compared to the other meat samples. The concentration of Zn in A, B, C and D samples were (1.573, 4.656, 3.258 and 3.628 mg Kg^{-1}), respectively. In general, meat, milk products such as cheese are the main sources of Zn. The result of Zn content of the samples is consistent with the results of Amfo-Otua et al. (2014). While the sample B had the biggest Hg content (0.456) mg Kg^{-1} the smallest amount of Hg (0.238) mg Kg^{-1} was in E meat sample. In addition, the Hg concentrations were (0.268, 0.297, 0.283 and 0.238 mg Kg^{-1}) in A, B, C and E meat samples, respectively. The main sources of Hg exposure are food and air. Life threatening damages to the lungs can occur by the exposure to high concentration of Hg. The data obtained shows that the mercury content of meat samples is within the limits of IEC standards (EC, 2006). The amount of As in red meat from A, B, C and E and B local meat varied. It is shown that the C meat sample had the highest As content (1.886 mg Kg-1) whereas the A meat had the lowest As concentration (1.687 mg Kg^{-1}). Furthermore, the concentrations of As in B, C and E meat samples were (1.753, 1.886 and 1.857 mg Kg^{-1}) respectively. The As usually dispersed in natural water as a result of geological sources. The exposure to as chronically causes high risk of developing skin, liver, bladder, kidney and lung cancer. While the amount of as in meat is given as a maximum of 0.5 mg Kg^{-1} according to FAO standards (FAO, 2008), it is stated as 1 mg Kg^{-1} according to Australian and New Zealand standards (2015). The concentrations of Cu in red meat from A, B, C, D and E were (1.247, 1.177, 3.713, 1.806 and 4.653 mg Kg^{-1}) correspondingly. It is shown that the E meat sample had the biggest Cu content (4.653mg Kg^{-1}) while the B sample had the smallest Cu concentration (1.177mg Kg^{-1}). Health issues like liver and kidney damages might be caused by high level of Cu. The result of Cu content of the samples is consistent with the results of Amfo-Otua et al. (2014). There were variations in the content of Ni red meat from A, C, D and E and B local meat. It is revealed that the A meat sample had the biggest Ni content (3.078mg Kg^{-1}) but the B local meat had the lowest Ni concentration (0.012 mg Kg^{-1}). Moreover, the amount of Ni in C, D and E meat samples were (1.953, 0.717and 2.268 mg Kg^{-1}) separately. General Ni is found in tiny amount in soil, air, food and air. The most extremely poisonous Ni compound is nickel carbonyl. While Mn, Cr and Cd could not be detected in most of the samples, it was determined that the values were below the limit values in some samples.

Comparison the content of elements in red meat samples with other reported values

Table 3 indicates the comparison between the amount of (Mn, Cr and Fe) found in this study and other findings. It is revealed that Cabrera et al. (2010), Schönfeldt et al. (2010), Williams (2007), Williamson et al. (2005) have found slightly higher Mn content compared to the present study. In addition, while the present study found 0.00 amount of Cr in the studied red meat samples, Tinggi et al., (1997) and Jorhem et al. (1989) found 0.049 to 0.3 mg Kg^{-1}. Furthermore, Sivertsen et al. (1995), Jorhem et al. (1989), López-Alonso et al. (2012) and Vikøren et al. (2005) stated that the concentration of Fe was between 0.18- 0.20 mg Kg^{-1}; however, the concentration of Fe in the present study ranged from 0.1134 to 0.1184 mg Kg^{-1}. Briefly, it can be stated that the concentration of Manganese, Iron and Chromium in red meat samples were lower in this research compared to some other literatures.

Table 3. The comparison of the concentration of microelements (Mn, Cr and Fe) in red meat samples in this study with other literatures about red meat samples

Elements	Concentrations (mg Kg^{-1})	References
Mn	Not detected	This study
	<0.01	Cabrera et al., 2010; Schönfeldt et al., 2010; Williams, 2007: Williamson et al., 2005
Cr	Not detected	This study
	0.049- 0.03	Tinggi et al., 1997; Jorhem, L. et al., 1989
Fe	0.1134- 0.1184	This study
	0.18 – 0.20	López-Alonso et al., 2012; Vikøren et al., 2005; Sivertsen et al., 1995; Jorhem et al.,1989;

Table 4 displays the results of the level of zinc (Zn), nickel (Ni), copper (Cu), arsenic (As) in red meat in this study and other research. There is variation between the results of the present study and the other reported values. It can be seen that this research found significantly lower amount of Zn in red meat samples compared to Williams (2007), Sadler et al. (1993), Sinclair et al. (1999). However, AMAP (2002), Mertz, (1980), Mertz (1986), Biehl (1987), McDowell (2003) found significantly higher level of Ni in comparison to the present study. In addition, the difference in Cu concentration the present study and Williams (2007), Sadler (1993), Sinclair et al. (1999) was small. Moreover, AMAP (2002), Mertz (1980), Biehl et al. (1987), McDowell (2003) found considerably bigger amount of as in red meat samples than the present study.

Table 4. Concentration of elements (Zn, Ni and Cu) in red meat samples in this study and some other research

Elements	Concentrations (mg Kg^{-1})	References
Zn	1.573-4.689	This study
	45.55- 46.00	Williams, 2007; Sinclair et al.,1999; Sadler et al.,1993
Ni	0.12- 3.07	This study
	19.7 -101.7	McDowell, 2003; AMAP, 2002; Biehl, 1987; Mertz, 1980
Cu	1.17- 4.65	This study
	1.2- 2.2	Williams, 2007; Sinclair et al.,1999; Sadler et al.,1993
As	1.68- 1.88	This study
	1,3-82.6	McDowell, 2003; AMAP, 2002; Biehl,1987; Mertz, 1980

The concentration of elements such as (Cd, Hg and Pb) in red meat samples from various countries is explained in table 5. There are differences between the findings of this research and the other reported values. The results of this study do not comply with AMAP (2002), Mertz (1980), Biehl, (1987), McDowell (2003) who found considerably higher amount of Cd in red meat samples. In addition, the present study found noticeably lower concentration of Hg in comparison to Williams (2007), Sadler et al. (1993), Sinclair et al. (1999). Nonetheless, AMAP (2002) Mertz (1980), Biehl (1987), McDowell (2003) found close level of Pb in comparison to the present study.

Table 5. Concentration of elements (Cd, Hg and Pb) in red meat samples in this study and some other research

Elements	Concentrations (mg Kg^{-1})	References
Cd	0.00-0.051	This study
	45.55- 46.00	McDowell, 2003; AMAP, 2002; Biehl, 1987; Mertz,1980;
Hg	0.238-0.456	This study
	19.7 -101.7	Fujise and Geiken-Tsushin, 2020; Iwasaki et al., 2002
Pb	0.396-1.468	This study
	1.2- 2.2	McDowell, 2003; AMAP, 2002; Biehl, 1987; Mertz, 1980

Conclusion and Recommendations

Conclusion

There is no significant difference between the nutritional contents of imported and locally produced meat.

There are differences in terms of heavy metal contents and these differences arise from the region where the meat comes from,

It has been determined that heavy metal contents are below international limits.

Recommendations

Implementation of regulatory frameworks and controls on heavy metal levels in meat products will contribute to the protection of consumer health. In order to increase transparency in the meat supply chain, especially in imported products, the implementation of labeling indicating the origin of the product will help consumers make informed choices about their purchases.

It would be beneficial to launch educational campaigns to inform the public about the risks associated with heavy metal exposure resulting from meat consumption. Empowering consumers with information will promote safer dietary practices and facilitate demand for safer products.

Priority should be given to continued research into alternative methods for reducing heavy metal concentrations in livestock farming and improving meat processing technologies.

Facilitating collaboration between government agencies, research institutions and international organizations will promote the sharing of best practices and standards in food safety. This collaborative approach will be beneficial in addressing global concerns about heavy metal contamination in food products.

Implementation of these recommendations will contribute to ensuring the safety and quality of meat products in Erbil, Northern Iraq and other regions, thereby protecting public health and increasing consumer confidence in the food supply chain.

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