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Health risk assessment of some heavy metals in fresh and frozen chicken meat consumed in Kirkuk – Iraq

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Abstract:

The study aims to summarize the findings regarding the heavy metal status in different types of chicken meat samples consumed in Kirkuk city and assess the health risk associated with their consummation.

A selection of meats was taken from various sources in the markets of Kirkuk Governorate between December 1, 2024, and February 1, 2025. These included (imported frozen Turkish chicken, imported frozen Brazilian chicken and fresh Iraqi chicken). Ten samples were taken from each type of meat, with 30-50 grams of each sample being collected. The concentrations of the studied heavy elements were measured using inductively coupled plasma-optical emission spectrometry (ICP-OES).

The findings indicated that Cadmium (27.02±6.55), Nickel (7.59±0.57), and Lead (0.82±0.03) were present in elevated amounts in imported Turkish chicken, but Chromium (7.34±3.43), Cobalt (0.12±0.04), and Manganese (10.6±1.85) were notably high in fresh Iraqi chicken. Zinc levels were elevated in imported Brazilian chicken (14.00±0.46). Imported frozen chicken meat exhibited a significant rise in cadmium consumption, with an estimated daily intake (EDI) of 0.019303 mg/day, surpassing the tolerable daily intake (TDI) threshold of 0.001 mg/day. The EDI of chromium is 0.003516 mg/day. The EDI values for zinc (Zn), nickel, lead, cobalt, and manganese in imported Chicken were below safe limits and did not surpass the TDI values, indicating no direct risk to consumers. Fresh chicken samples had an EDI value of 0.013707 mg/day, exceeding the limit. Chrome's EDI (0.00525 mg/day) was likewise over the limit, suggesting persistent exposure to this hazardous element. The results for other elements (Zn, Ni, Pb, Co, and Mn) were below the allowed limits, indicating reasonable safety and no hazardous danger to consumers. Results indicate that cadmium and chromium have the highest THQ values in both frozen and fresh samples, above the permissible limit (THQ > 1) posing a health concern with sustained use. Elements zinc, nickel, lead, cobalt, and manganese had acceptable THQ values (THQ < 1), indicating no health hazards at regular consumption concentrations.

According to the study, eating Turkish and locally produced chicken poses a significant health risk due to excessive cadmium and chromium concentrations surpassing permissible limits. The cumulative hazard index (HI) is 21.29, indicating potential systemic toxicity. Brazilian chicken had the lowest contamination, with zinc and lead concentrations below international limits.

Keywords: Brazilian chicken, Cumulative hazard index, Heavy metals, ICP-OES.

Introduction

Pollution is the most important problems facing the human being at the present time. Pollution is the most serious problem because of its direct relation to human health and other organisms. Different types of pollutants enter the environment and transfer through the food chains. Meat and its derivatives are essential to the human diet. Meat is a superior source of protein and comprises minerals including zinc (Zn), calcium (Ca), selenium (Se), iron (Fe), and vitamins (1, 2). Meat is distinguished by its little muscle fat and cholesterol content, rendering it a favored option for numerous consumers.

Toxic elements, or heavy metals (HMs), are metallic elements with atomic weights ranging from 63.5 to 200.6 and specific gravities exceeding 5. They have progressively accumulated within the food chain, resulting in detrimental impacts on human health (3). Numerous elements are not only superfluous for biological existence but also exhibit significant harmful characteristics and participate in several signaling pathways linked to carcinogenesis (4). The concentration of heavy metals escalates with the advancement of human civilization and the extraction of geological resources (5). In the food chain, meat and meat products contaminated with heavy metals represent a substantial pathway for exposure to these harmful elements, potentially resulting in severe health difficulties. These metals are indestructible and can accumulate in tissues, including muscles, kidneys, and the liver (6). These tissues also contribute to the detoxification of the organism, which is why they are recognized as target tissues for heavy metal lysis (7). Living organisms rely heavily on a group of heavy metals known as micronutrients, which include copper, manganese, nickel, selenium, chromium, and zinc. Enzymatic reactions, gene expression regulation (RNA folding, ribozyme catalysis, and ribosome activities), and energy metabolism all depend on heavy metals to function properly (8). Other heavy metals, such as lead, cadmium, and arsenic, are particularly dangerous when consumed. High concentrations of heavy metal pollution are largely attributable to the Industrial Revolution and the continuous development of agricultural fertilizers. Food chains do not absorb their fair share of heavy metal pollution, which accumulates in the soil, crops, and water that comprise the food chain. Numerous studies have been conducted on the origins of heavy metals, their bioaccumulation, and their potential health risks resulting from the steady increase in their concentration in food (9).

Animals are exposed to and ingest these toxic elements in several ways, including inhaling polluted air or consuming contaminated water and plants. Industrial activities, such as coal burning or metal smelting in grazing areas, can also affect livestock and their products (10). Consequently, human consumption of this contaminated meat may negatively impact health and increase the risk of serious health threats due to its adverse effects on the nervous system, metabolism, and cardiovascular system (11,12).

International organizations such as the Food and Agriculture Organization (FAO), the World Health Organization (WHO), and the US Environmental Protection Agency (US-EPA) have established permissible limits for heavy metal concentrations in food (13). Recently, the presence of heavy metals in fresh, frozen, and processed meat has been reported in Iraq (14). Consuming food products contaminated with heavy metals poses a significant public health challenge due to the bioaccumulation of these metals through the food chain. Several studies have been conducted on heavy metal concentrations in various types of livestock and their products in a number of Iraqi governorates. Therefore, this study aims to summarize the findings regarding the heavy metal status in different types of chicken meat products consumed in Kirkuk governate and assess the health risk associated with their consumption.

Material and Methods

Sample Collection

A selection of meats was taken from various sources in the markets of Kirkuk Governorate between December 1, 2024, and February 1, 2025. These included (imported frozen Turkish chicken, imported frozen Brazilian chicken and fresh Iraqi Orchard chickens). Ten samples were taken from each type of meat, with 30-50 grams of each chest sample being collected. These samples were then placed in clean plastic bags and refrigerated boxes until they reached the laboratory for storage at -20°C(15).

Sample Preparation

The samples were thoroughly washed with distilled water to remove any remaining impurities, then cut into small pieces using a ceramic knife. The samples were then dried in an electric oven at 105°C for 6–24 hours. After drying, the samples were ground into a fine powder using a ceramic mortar. Approximately 1 gram of this powder was used for elemental analysis.

Sample Digestion

The Meat samples were digested according to the 1983 Regional Organization for the Protection of the Marine Environment (ROPME) guidelines (16), using the dry digestion method to determine the minerals under investigation. The samples were prepared using HNO3and concentrated HCl, then filter the prepared samples using filter paper, then complete the volume with distilled water and obtain a volume of incineration solution of 50 ml. We used ICP-OES at the University of Kufa/Najaf to measure the heavy element concentrations.. (17).

Calculation of Heavy Metal Concentrations in the Studied Samples

The results for heavy metal concentrations in the tissues were calculated as described in ROPME (16). By measuring the residual concentrations of the elements (mg/g), the results were calculated using the following equation:

$$\textbf{Element} = \frac{RxD}{W}$$

Where:

R is the element concentration reading (parts per million) on the instrument.

D is the final volume of the prepared sample (ml).

W is the weight of the sample (g).

Health and Carcinogenic Risk Assessment in Meat Products

The potential health risks associated with consuming meat contaminated with heavy metals were assessed in terms of the Estimated Daily Intake (EDI) and Target Hazard Quota (THQ), according to the U.S. Environmental Protection Agency (EPA) standards (17).

Estimated Daily Intake (EDI)

The Estimated Daily Intake (EDI) for the studied elements was calculated using the formula below, which is based on the U.S. EPA Human Health Assessment Manual (18).

Target Hazard Quotient (THQ):

The non-cancer target hazard quotient for both adults and children associated with the consumption of the tested sheep tissue was calculated according to the formula approved and recommended by the US Environmental Protection Agency (19).

Heavy Metals Intake (HI)

Heavy metals intake is represented by the sum of the Hazard Index (HI), which ranges from 1 to 10 according to the recommendations of the U.S. Environmental Protection Agency (19). The assessment of the effects of heavy metal intake is based on the HI value, where HI < 1 indicates mild or no adverse health effects, HI ≥ 1 indicates adverse non-cancerous health effects, and HI ≥ 10 indicates the potential for chronic toxic and carcinogenic effects.

Statistical Analysis

The results were statistically analyzed using Analysis of Variance (ANOVA) and the Least Significant Difference (LSD) test at a significance level of 0.05, using SPSS version 26. Differences between sources were determined at a probability level of 0.05 ($P \leq 0.05$).

Results

The results in table (1) showed that cadmium was at high mean concentration in imported frozen Turkish chicken (27.02±6.55), then in Fresh Iraqi chicken (19.18±5.17) with (P=0.008). While the lowest mean level of cadmium was in Imported frozen Brazilian chicken(5.54±4.54) with (p=0.0001).

Table (1): Cadmium concentrations in chicken meat samples under study

Cadmium	Imported frozen Turkish chicken	Fresh Iraqi chicken	Imported frozen Brazilian chicken
Mean ± SD	**27.02±6.55**	**19.18±5.17**	**5.54±4.54**
T-test	**2.97**		**6.27**
P value	**0.008***		**0.0001*****

***Mean there was a significant, *** mean high significant**

The results in table (2) showed that Chromium was at high mean level in Fresh Iraqi chicken (7.34±3.43), compared with Imported frozen Turkish chicken (2.42±4.92) with (P=0.08) and Imported frozen Brazilian chicken(3.95±2.76) with (p=0.02).

Table (2): Chromium concentrations in chicken meat samples under study

Chromium	Imported frozen Turkish chicken	Fresh Iraqi chicken	Imported frozen Brazilian chicken

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Mean ± SD	**2.42±4.92**	**7.34±3.43**	**3.95±2.76**
T-test	**1.82**	**2.43**	
P value	**0.08**	**0.02***	

The results in table (3) showed that zinc was at high mean concentration in Imported frozen Brazilian chicken (14.00±0.46), compared with Fresh Iraqi chicken (8.71±0.01) with (P=0.0001) and Imported frozen Turkish chicken(8.44±1.20) with (p=0.48).

Table (3): Zinc concentrations in chicken meat samples under study

Zinc	**Imported frozen Turkish chicken**	**Fresh Iraqi chicken**	**Imported frozen Brazilian chicken**
Mean ± SD	**8.44±1.20**	**8.71±0.01**	**14.00±0.46**
T-test	**0.71**	**36.4**	
P value	**0.48**	**0.0001*****	

The results investigated that Nickel was at high mean level in Imported frozen Turkish chicken (7.59 ± 0.57), compared with Fresh Iraqi chicken (0.73±0.46) and Imported frozen Brazilian chicken(2.49±0.25) with (p=0.0001) as shown in table(4).

Table (4): Nickel concentrations in chicken meat samples under study

Nickel	**Imported frozen Turkish chicken**	**Fresh Iraqi chicken**	**Imported frozen Brazilian chicken**
Mean ± SD	**7.59 ± 0.57**	**0.73±0.46**	**2.49±0.25**
T-test	**29.74**	**10.64**	
P value	**0.0001*****	**0.0001*****	

The results investigated that there was a significant differences in mean level of Lead between chicken meat samples, Imported frozen Turkish chicken (0.82±0.03), Fresh Iraqi chicken (0.67±0.18) and Imported frozen Brazilian chicken(0.03±0.02) as shown in table(5).

Table (5): Lead concentrations in chicken meat samples under study

Lead	**Imported frozen Turkish chicken**	**Fresh Iraqi chicken**	**Imported frozen Brazilian chicken**
Mean ± SD	**0.82±0.03**	**0.67±0.18**	**0.03±0.02**
T-test	**2.51**	**11.21**	
P value	**0.019***	**0.001*****	

The results investigated that there was a significant differences in mean level of Cobalt between chicken meat samples, Imported frozen Turkish chicken (0.05±0.09), Fresh Iraqi chicken (0.12±0.04) and Imported frozen Brazilian chicken(0.08±0.05) as shown in table(6).

Table (6): Cobalt concentrations in chicken meat samples under study

Cobalt	**Imported frozen Turkish chicken**	**Fresh Iraqi chicken**	**Imported frozen Brazilian chicken**

Mean ± SD	**0.05±0.09**	**0.12±0.04**		**0.08±0.05**
T-test	**1.94**		**2.79**	
P value	**0.068**		**0.012***	

The results investigated that manganese was at high mean level in Imported frozen Turkish chicken (1.9±13.61), compared with Fresh Iraqi chicken (10.6±1.85) and Imported frozen Brazilian chicken(0.70±0.05) with (p=0.0001) as shown in table(7).

Table (7): manganese concentrations in chicken meat samples under study

Manganese	**Imported frozen Turkish chicken**	**Fresh Iraqi chicken**		**Imported frozen Brazilian chicken**
Mean ± SD	**1.9±13.61**	**10.6±1.85**		**0.70±0.05**
T-test	**43.37**		**22.56**	
P value	**0.0001*****		**0.0001*****	

Potential Health Risks of Heavy Metals

Estimated Daily Intake of Heavy Metals in Chicken Meat

The results in table(8) showed value of estimated daily intake of heavy metals in studied chicken samples comparing to Tolerable daily Intake. Food exposure to hazardous substances and their health effects can be assessed by calculating the EDI.

Imported frozen chicken meat had a considerable increase in cadmium (Cd) intake, with an EDI of 0.019303 mg/day, exceeding the TDI limit (0.001 mg/day). Cadmium's toxicity and bioaccumulation in tissues, especially the kidneys, make this exposure risky. Chromium (Cr) has an EDI of 0.003516 mg/day. The EDI values for zinc (Zn), nickel (Ni), lead (Pb), cobalt (Co), and manganese (Mn) in imported beef were below safe limits and did not surpass the TDI values, indicating no direct risk to consumers.

Like imported chicken meat, fresh chicken samples had an EDI value of 0.013707 mg/day, exceeding the limit. This shows elevated cadmium concentrations in both meats. Chrome's EDI (0.00525 mg/day) was likewise over the limit, suggesting persistent exposure to this hazardous element. The results for other elements (Zn, Ni, Pb, Co, and Mn) were below the allowed limits.

Table (8): Estimated Daily Intake (EDI) of Heavy Metals in Chicken Meat

Sample	**Element**	**EDI**	**Mean**	**SD**	**TDI**
Imported frozen chicken (Turkish and Brazilian)	Cd	**0.019303**	**27.0236**	**6.5575**	**0.001**
	Cr	**0.003516**	**4.9223**	**2.4272**	**0.003**
	Zn	**0.006029**	**8.4406**	**1.2063**	**0.3**
	Ni	**0.005423**	**7.5918**	**0.5756**	**0.02**
	Pb	**0.000587**	**0.8223**	**0.0357**	**0.0035**
	Co	**5.32E-05**	**0.0744**	**0.0533**	**0.0003**
	Mn	**0.026098**	**1.2786**	**0.3833**	**0.14**
Fresh chicken	Cd	**0.013707**	**19.1898**	**5.1729**	**0.001**
	Cr	**0.00525**	**7.3495**	**3.4326**	**0.003**

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	Zn	**0.006224**	**8.7132**	**0.0184**	**0.3**
	Ni	**0.000525**	**0.7344**	**0.4612**	**0.02**
	Pb	**0.00048**	**0.6724**	**0.1853**	**0.0035**
	Co	**8.67E-05**	**0.1213**	**0.0422**	**0.0003**
	Mn	**0.009722**	**1.0921**	**1.8558**	**0.14**

Target Hazard Quotient (THQ) for heavy metals in chicken meat

Table (9) displays the Target Hazard Quotient (THQ) values for heavy metals in frozen and fresh imported chicken meat, based on RfD values and element concentrations. Results indicate that cadmium and chromium have the highest THQ values in both frozen and fresh samples, above the permissible limit (THQ > 1), posing a health concern with sustained use. Elements zinc, nickel, lead, cobalt, and manganese had acceptable THQ values (THQ < 1).

The cumulative hazard ratio (HI) for imported frozen chicken was 21.2972, while fresh chicken was 15.9994.

Table(9): Target Hazard Quotient (THQ) for heavy metals in chicken meat

Sample	HI	Risk	Mean	SD	THQ	RfD	Element
Imported frozen chicken (Turkish and Brazilian)	Hi > 1	Health risk	27.0236	6.5575	19.3026	0.0010	Cd
	Hi > 1	Health risk	4.9223	2.4272	1.1720	0.0030	Cr
	Hi < 1	No Health risk	8.4406	1.2063	0.0201	0.3000	Zn
	Hi < 1	No Health risk	7.5918	0.5756	0.2711	0.0200	Ni
	Hi < 1	no	0.8223	0.0357	0.1678	0.0035	Pb
	Hi < 1	Health risk	0.0744	0.0533	0.1772	0.0003	Co
	Hi < 1	No Health risk	**1.2786**	0.3833	0.1864	0.1400	Mn
	Hi				21.2972		
Fresh chicken	Hi > 1	Health risk	19.1898	5.1729	13.7070	0.0010	Cd
	Hi > 1	Health risk	7.3495	3.4326	1.7499	0.0030	Cr
	Hi < 1	No Health risk	8.7132	0.0184	0.0207	0.3000	Zn
	Hi < 1	No Health risk	0.7344	0.4612	0.0262	0.0200	Ni
	Hi < 1	No Health risk	0.6724	0.1853	0.1372	0.0035	Pb
	Hi < 1	No Health risk	0.1213	0.0422	0.2889	0.0003	Co
	Hi < 1	No Health risk	1.0921	1.8558	0.0694	0.1400	Mn
	Hi				15.9994		

Discussion

Despite significant local chicken production in Iraq, public interest favors imported chicken over live, locally bred birds, which are readily available for cooking. A Kirkuk Governorate public survey concluded that local chicken is tastier than imports. It may prefer local chicken because it eats richer food scraps than imported fowl. Chickens are contaminated with heavy metals worldwide, especially in industrialized nations(20). These contaminants have been found in avian feathers. Heavy metals cannot be eliminated by heat treatment, therefore they can reach people through the food chain (21).

In this study, imported chicken had a higher average cadmium level than in Iraq (20), Malaysia (21), Nigeria (22), Iran (23), and Bangladesh. Cadmium has a function in the body and is harmful at low concentrations due to its low excretion rate (24). Paints, electronic debris, plastics, and cadmium-plated components and batteries can expose poultry to cadmium (25). Cadmium exposure causes liver poisoning, respiratory illnesses, and lung, kidney, and prostate malignancies (26). This suggests that exporting countries' pollution may contribute to cattle buildup of heavy and trace elements. Despite the challenges of preparing locally produced meat in Iraqi restaurants and homes, it is encouraged to promote its consumption.

The highest heavy metal concentrations were discovered in imported Brazilian chicken, which matches a study of imported frozen chicken in Erbil Governorate. Researchers found significant zinc (Zn) and lead (Pb) contents, especially in Brazilian samples, exceeding WHO guidelines. Imported poultry may not fulfill international safety standards (27).

Nickel values in Turkish and Brazilian chickens were 7.59 and 2.49 mg/kg, respectively. Al-Zuhairi et al. (28) found 0.414 mg/kg in imported chicken in Diyala. Imported chicken had no nickel content in the research. In Saudi Arabia (29), both types of imported chicken had greater chromium concentrations than in Ali et al. (20), which was 0.06 mg/kg and within the WHO standard. Chromium concentrations in Bangladesh were higher (6.368 mg/kg) (30).

Environmental zinc, an intestinal irritant, can affect human health (31). Frozen Brazilian and Turkish chicken muscle tissue had zinc amounts over the limit. However, Brazilian chicken has far higher concentration than Turkish chicken. There is no apparent explanation for these discrepancies, yet breed or species distinctions cannot be overlooked. This result matches Hamasalim and Mohammad (32) and Abduljaleel et al. (21). Duman et al. (33) found 100.87 mg/kg zinc in Turkish chicken. According to Chelebi and Jinan (34), Brazilian and Turkish chicken have safe lead contents for ingestion. Lead reduces cognitive development and intellectual performance in youngsters and raises blood pressure and cardiovascular illness in adults (35). Air, water, feed, cooking equipment, and food packaging contaminate cattle food with lead. A study by Ali et al. (20) found a lower cobalt concentration of 0.06 ± 0.027 mg/kg in Erbil Governorate, compared to the current study for both imported chicken species. The current investigation reported lower amounts than a Sulaymaniyah, Kurdistan study (0.006 and 0.158 mg/kg) (32,36). This study's average cobalt content was below the Codex Alimentarius Commission's poultry standard of 1.0 mg/kg. Although important micronutrients, these hazardous minerals can enter food through food processing, agriculture, and contaminated poultry feed (9).

Fresh chicken flesh has 13.6 ppm manganese, similar to Alturiqi and Albedair (37), who discovered 9.98 ppm and 4.32 ppm in chicken meat and liver. The liver is where metabolism occurs, hence manganese is predicted to be abundant. Manganese concentrations in Saudi chicken meat ranged from 21.48 to 34.42 ppm (38). Manganese poisons induce fetal weight loss and delayed skeletal and organ development. Manganese poisoning can damage DNA, induce chromosomal abnormalities, and harm the fetus through brain buildup, neurotoxicity, Parkinson's-like disease, and oxidative stress (39). Abdulrahman (27) observed manganese concentrations above limits in all chicken muscle tissues. The average manganese concentration in Turkish chickens was much greater than in Brazilian chickens. Turkish chickens eat more manganese, which explains this. Although manganese intake should be 67 µg/kg body weight for adults and 101 µg/kg for juveniles even trace amounts are crucial for human growth and health, and deficiency can lead to nervous system issues (40).

In this investigation, heavy metal EDI values in frozen and fresh imported chicken samples were frequently lower than the tolerated daily intake (TDI), indicating low dietary exposure from chicken meat consumption alone. For cadmium (Cd), the EDI in frozen imported chicken was 0.0193 µg/kg body weight/day, while in fresh chicken, it was 0.0137 µg/kg body weight/day, both within the acceptable concentrations. This supports recent findings that chicken meat cadmium exposure rarely exceeds guideline concentrations and does not constitute a health risk (41). The EDI values for chromium (Cr) and zinc (Zn) were low, supporting previous findings suggesting meat eating has limited impact on daily heavy metal exposure relative to acceptable limits (42).

While lead (Pb) concentrations in this study were low (<0.001 µg/kg body weight/day), other studies suggest that Pb in poultry may exceed permissible limits and pose health risks when combined with dietary exposure from eggs, feed, and water (43). According to Morshdy et al. (44), health risk assessments of Egyptian poultry products, including EDI calculation, Target Hazard Quotient (THQ), and Hazard Index (HI), found that while heavy metal concentrations exceeded limits, daily hazard indices remained within acceptable limits (<1), indicating minimal risk under normal consumption conditions.

The results surpass the safe limit, indicating that simultaneous exposure to heavy metals may constitute a health risk to consumers. which is consistent with recent studies showing that long-term exposure to these metals can cause kidney and systemic problems in humans, even when meat is eaten regularly (45).

These findings emphasize the need of monitoring meat contamination and following heavy metal restrictions to ensure food safety and consumer health. Cadmium and chromium are the biggest risk metals in chicken meat,

Conclusion

The statistical data and biohazard indicators show that consuming the tested chicken samples (imported and locally produced) is dangerous due to significant cadmium and chromium contamination. The Electronic Daily Intake (EDI) and Hazardous Target Quota (THQ) rose to concentrations over the threshold value (>1) due to imported Turkish and fresh Iraqi chicken concentrations that exceeded internationally acceptable limits. The record-high cumulative hazard index (HI), which reached its greatest level in frozen Turkish chicken, indicates that these heavy metals bioaccumulate and cause systemic toxicity and renal impairment. Zinc, nickel, lead, cobalt, and manganese remained safe for human consumption.

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