Determination of heavy metals and selenium content in chicken liver at Erbil city, Iraq

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Abstract

Heavy metal contamination of poultry meat is a critical issue for human health due to associated risks of cytotoxicity and systemic pathologies after ingestion of such metals. A total of twenty chicken liver samples were collected from markets of Erbil city and analyzed for ten heavy metals contents by Inductively Coupled Plasma Optical Emission Spectrometry. The targeted metals were cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), manganese (Mn), nickel (Ni), lead (Pb), mercury (Hg), zinc (Zn) and selenium (Se). The average concentrations (mg/kg) of targeted trace elements were 0.06±0.027, 0.06±0.05, 2.05±0.34, 1.85±0.47, 0.15±0.17, and 33.53±5.24 for Co, Cr, Cu, Mn, Ni, and Zn respectively. Copper (Cu) levels significantly exceeded the maximum permissible limit of WHO. Moreover, the average concentrations of toxic heavy metals and selenium were 0.07±0.037, 0.278±0.10, 0.11±0.083, and 2.01±0.454 mg/kg for Cd, Pb, Hg, and Se respectively. Hg and Pb levels exceeded the permissible limits of WHO. Higher levels of Cu and Hg in poultry may pose a serious threat to consumers which demand countermeasures and precautions to be taken. Iraqi Standards Authority and relevant official institutions are strongly recommended to regulate safe disposal of heavy metal waste in the environment to reduce animal exposure to such metals.

Introduction

Poultry meat and edible offal are important components of human meat meals especially in eastern countries. Chicken meat and edible offal, specially livers, are two of the most commonly consumed poultry products in the Kurdistan Region (Iraq) in various preparations, including fast-food recipes. Liver is the vital organ responsible for metabolism and detoxification of numerous compounds such as therapeutic drugs, chemical toxic compounds, microbial toxins, and heavy metals (Almazroo et al., 2017; Bischoff et al., 2018). Heavy metals are metallic elements mainly found in earth’s crust and characterized by high density (greater than 5 g.cm⁻³) in comparison to water (Wang and Shi, 2001).

Certain heavy metals such as copper (Cu), manganese (Mn), nickel (Ni), selenium (Se), chromium (Cr), and zinc (Zn), called micronutrients, are of paramount importance to all organisms in the three domains of life. They play important roles in enzymatic reactions, gene expression regulation (in folding of RNA, ribozymes catalysis, and ribosome functions), and energy metabolism (Draper et al., 2005; Denesyuk and Thirumalai, 2015; Kennelly, 2018). Despite the fact that the aforementioned heavy metals are required at low concentrations, higher concentrations may be toxic to cellular physiology (Kennelly, 2018). Still other heavy metals such as cadmium (Cd), arsenic (As), and lead (Pb) are highly toxic when ingested. They pose a serious threat to cardiovascular system, immune system, fetal cognition development, brain, lungs, kidney, liver, hemapoiesis, and normal cell cycle (Itoh et al., 2014; Jaishankar et al., 2014; Wu et al., 2016).

Industrial revolution and continuous development of agricultural fertilizers have contributed greatly to environmental pollution with high levels of heavy metals. Food chains are not excepted and received a fair share of heavy metal pollutants that accumulate in food chain living components, soil, vegetables, and water (Rai et al., 2019). Human is exposed to heavy metals via consumption of contaminated foodstuff, inhalation of polluted air, and dermal deposition from various sources. The continuous increase in heavy metals levels in food had led to wide investigations on heavy metals sources, bioaccumulation, and potential risks to human health (Mohmand et al., 2015; Rai et al., 2019). Published literature indicate a good correlation between heavy metals contents in animal feed and bioaccumulation level in various meats (Al Bratty et al., 2018; Kim and Koo, 2007; Wu et al., 2016). Frequent consumption of meat harboring high levels of heavy metals can result in accumulation of ingested metals in human tissues leading to toxicity and health hazards. Such implications of heavy metals in health hazards demanded World Health Organization (WHO), The European Food Safety Authority (EFSA), and many other regulatory authorities to set permissible limits for heavy metals in food.

Heavy metals contamination of different chicken tissues has been addressed in various published reports globally (Al Bratty et al., 2018; Bortey-Sam et al., 2015; Caldas et al., 2016; Hadyait et al., 2018; Khandia et al., 2015; Nazmul Haque et al., 2019). To the best of our knowledge, there is no previous study addressing the occurrence levels of heavy metals in chicken meat marketed in Erbil city. Therefore, the main objective of this study was to assess the level of some toxic heavy metals and selenium in different collected samples of chicken’s liver available in markets of Erbil city.

Materials and Methods

Samples and reagents

All chemicals used in this study were purchased from Scharlau, Spain. The reagents were of analytical reagent grade quality including 50% (v/v) hydrogen peroxide (H₂O₂) and 65% (v/v) nitric acid (HNO₃). Twenty frozen and fresh chicken liver samples were collected from popular local markets and chicken suppliers in Erbil city (Iraq) during Jun-July 2019. Samples characteristics are summarized in Table 1. Liver samples were cleaned with distilled
water, labeled, and stored in polypropylene and preserved in the refrigerator until chemical analysis.

**Preparation and digestion of the samples**

Metal analysis was performed according to previously published method (Sadeghi et al., 2015). Briefly, liver sample was individually chopped, homogenized thoroughly using stainless steel knife and dried in an oven at 100°C for 12 h till constant weights were obtained. Dried samples were pulverized and homogenized by mortar. A weight of 0.70 g was placed into a digestion conical flask containing 5 mL of HNO₃ (65%). The samples were left for acid digestion process using a classic digestion-heater at 150°C for 20 minutes. After cooling, 3 mL of H₂O₂ (50%) were added to complete digestion process to each digestion flask. After completing digestion, each solution was cooled at room temperature and filtered into a flask and the volume was brought to 25 mL with deionized water. Finally, solutions were stored in appropriate plastic bottles for the investigation. The digestion procedures were individually repeated three times for each sample.

**Metal analysis**

Inductively Coupled Plasma Optical Emission Spectrometry (Spectro, Germany) was employed for the elemental analysis of digestion solutions. The contents of cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), manganese (Mn), nickel (Ni), lead (Pb), mercury (Hg), zinc (Zn) heavy metals and selenium (Se) were determined in all of the digested samples according to standardized procedures (Sadeghi et al., 2015; Deng et al., 2007). Finally, the estimated concentrations were measured in µg mL⁻¹ (parts per million) and then converted to µg g⁻¹ after using dilution factor (Sadeghi et al., 2015; Deng et al., 2007). Average concentrations were compared to permissible limits set by Codex Alimentarius Commission (FAO/WHO, 2011; CAC, 2019). Limits of detection was calculated according to the following equation:

\[ \text{LOD} = 3 \times \text{RSD}_b \times \frac{c}{SBR} \]

where RSD_b is the relative standard deviation of 10 replicates of the blank, c is the concentration of the standard, and SBR is the signal to background ratio. Limits of detection and wavelength for each element are in Table 2. All relevant ICP operating parameters were software controlled, allowing easy selection of the optimum operating conditions according to manufacture instructions (https://extranet.spectro.com/~/media/31793ADA-B987-4D37-B597-04AF66C7C22.pdf). The accuracy and precision of the method was investigated by analyzing the standard reference material SRM 1640 (Trace Elements in Natural Water). The measured value and the certified values were in excellent agreement for all elements.

**Statistical analysis**

All data were analyzed in version 21 of IBM SPSS package. One-sample t test was employed to test for heavy metal load difference between samples items and comparison of concentration means to the maximum permissible limits. One-way ANOVA analysis was performed to meta-analyze the difference of reported heavy metal levels in studies from Iraqi and other countries. Significance level was set to 0.05.

**Results**

A total of twenty chicken liver samples were selected randomly and collected from supermarkets in Erbil city and local chicken supplies. Five liver samples were drawn from frozen chicken (CL 1-5) and the remaining samples were obtained from chicken slaughterhouses (CL 6-20). The details of collected samples and their origin are presented in Table 1. The average weight of liver samples was 68.7 ± 36 g.

**Total load of heavy metals**

The mean concentrations of detected heavy metals are depicted graphically in Figure 1. The average content of heavy

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Table 1. Characteristics of collected chicken liver samples.

| Sample | Brand/type          | Sample status | Sample origin (City) | Weight (g) |
|--------|---------------------|---------------|----------------------|------------|
| 1      | Al Shenal           | Frozen        | Local (Erbil)        | 60.1       |
| 2      | Al Etimad           | Frozen        | Local (Erbil)        | 62         |
| 3      | Dorsa Morgh         | Frozen        | Imported (Iran)      | 52.2       |
| 4      | Dondurulmu Pilic Ger| Frozen        | Imported (Turkey)    | 52.7       |
| 5      | Time Food           | Frozen        | Imported (UAE)       | 55         |
| 6      | Broiler             | Alive         | Local (Erbil)        | 57         |
| 7      | Broiler             | Alive         | Local (Erbil)        | 60         |
| 8      | Broiler             | Alive         | Local (Erbil)        | 67         |
| 9      | Broiler             | Alive         | Local (Duhok)        | 62         |
| 10     | Broiler             | Alive         | Local (Duhok)        | 70         |
| 11     | Broiler             | Alive         | Local (Duhok)        | 102        |
| 12     | Golden Comet        | Alive         | Local (Erbil)        | 34         |
| 13     | Golden Comet        | Alive         | Local (Erbil)        | 38         |
| 14     | Golden Comet        | Alive         | Local (Erbil)        | 40         |
| 15     | Country Chicken     | Alive         | Local (Erbil)        | 35         |
| 16     | Country Chicken     | Alive         | Local (Erbil)        | 39         |
| 17     | Country Chicken     | Alive         | Local (Erbil)        | 42         |
| 18     | Parent Broiler      | Alive         | Local (Erbil)        | 110        |
| 19     | Parent Broiler      | Alive         | Local (Erbil)        | 126        |
| 20     | Parent Broiler      | Alive         | Local (Erbil)        | 155        |

UAE, United Arab Emirates.
metals in chicken livers ranged from 1.98 to 8.98 mg/kg of dry weight. There is a significant difference between samples in terms of average heavy metal load (p<0.001). Poor association has been found between liver weight and total heavy metal load (r²=0.1795).

**Trace elements metals**

The details of trace elements metals detected in chicken liver samples are summarized in Table 3. Nickel was detected in only 40% (8/20) of samples, while chromium was found in 55% (11/20) of samples. Other trace element metals (Co, Cu, Mn, and Zn) were detected in all samples. Of note, the means of Co, Cr, Ni, and Zn did not exceed the permissible limit specified by WHO/FAO (Table 3). Indeed, the mean concentrations of these elements were significantly lower than maximum permissible limits of WHO. About 15% of samples exceeded the permissible limit of Zn, while all samples significantly exceeded the permissible limit of Cu (p<0.001).

**Toxic heavy metals, metalloids and Selenium**

The mean concentrations of toxic heavy metals are summarized in Table 4. Mean concentration of cadmium (Cd) in liver samples was significantly lower than permissible limit specified by WHO (t=-27.745, p<0.0001). Additionally, average of

Table 3. Mean concentrations of trace elements metals in chicken liver samples expressed as in mg/kg (mean ±SD).

| Sample | Co      | Cr      | Cu      | Mn      | Ni      | Zn      |
|--------|---------|---------|---------|---------|---------|---------|
| 1      | 0.074 ± 0.011 | 0.121   | 2.61 ± 0.51 | 2.14 ± 0.23 | ND      | 45.07 ± 18.55 |
| 2      | 0.044 ± 0.034 | 0.042   | 3.37 ± 0.65 | 2.03 ± 0.45 | 0.004   | 50.22 ± 8.88  |
| 3      | 0.084 ± 0.033 | 0.101 ± 0.035 | 2.18 ± 0.12 | 1.94 ± 0.16 | ND      | 30.69 ± 7.58  |
| 4      | 0.035 ± 0.014 | 0.054   | 1.56 ± 0.24 | 1.47 ± 0.82 | 0.019   | 52.26 ± 7.00  |
| 5      | 0.072 ± 0.017 | 0.051   | 2.51 ± 0.40 | 2.49 ± 0.23 | ND      | 31.18 ± 3.19  |
| 6      | 0.066 ± 0.011 | 0.035 ± 0.033 | 2.32 ± 0.59 | 2.30 ± 0.47 | ND      | 28.29 ± 6.44  |
| 7      | 0.061 ± 0.024 | 0.047   | 2.48 ± 0.51 | 2.16 ± 0.86 | 0.222   | 40.60 ± 8.34  |
| 8      | 0.061 ± 0.037 | ND      | 2.21 ± 0.20 | 2.95 ± 0.56 | ND      | 26.35 ± 3.86  |
| 9      | 0.069 ± 0.022 | 0.024 ± 0.028 | 1.97 ± 0.15 | 2.08 ± 0.14 | 0.328   | 22.38 ± 3.07  |
| 10     | 0.047 ± 0.015 | ND      | 1.50 ± 0.37 | 1.79 ± 0.92 | ND      | 19.28 ± 11.00 |
| 11     | 0.061 ± 0.055 | ND      | 2.21 ± 0.19 | 2.16 ± 0.27 | 0.211   | 42.16 ± 6.57  |
| 12     | 0.069 ± 0.044 | 0.032 ± 0.053 | 2.60 ± 0.64 | 2.24 ± 0.45 | 0.267   | 49.89 ± 6.77  |
| 13     | 0.060 ± 0.013 | 0.128   | 2.40 ± 0.59 | 2.37 ± 0.22 | ND      | 54.86 ± 1.48  |
| 14     | 0.068 ± 0.013 | ND      | 2.06 ± 0.98 | 2.29 ± 0.82 | ND      | 24.10 ± 11.06 |
| 15     | 0.083 ± 0.011 | ND      | 1.16 ± 0.13 | 1.23 ± 0.90 | ND      | 25.96 ± 2.03  |
| 16     | 0.073 ± 0.046 | ND      | 1.04 ± 0.10 | 1.18 ± 0.60 | ND      | 26.10 ± 2.90  |
| 17     | 0.039 ± 0.019 | ND      | 1.86 ± 0.23 | 1.64 ± 0.37 | ND      | 46.38 ± 8.14  |
| 18     | 0.039 ± 0.011 | 0.073 ± 0.015 | 1.53 ± 0.02 | 0.968 ± 0.075 | 0.092 | 12.15 ± 0.65 |
| 19     | 0.076 ± 0.077 | ND      | 1.53 ± 0.31 | 0.807 ± 0.172 | ND      | 8.60 ± 2.68  |
| 20     | 0.034 ± 0.028 | ND      | 1.95 ± 0.19 | 0.849 ± 0.071 | 0.039 | 34.03 ± 3.84  |
| Mean   | 0.06 ± 0.027* | 0.06 ± 0.05* | 2.05 ± 0.34** | 1.85 ± 0.47 | 0.15 ± 0.17* | 33.53 ± 5.24* |
| WHO PL | 1.0      | 1.0      | 0.4      | ND      | 0.5      | 50       |

*Significantly lower than maximum permissible limit (p<0.001), **significantly higher than maximum permissible limit (p<0.001). PL: Permissible limit, ND: Not detected, NS: not specified yet.
lead (Pb) concentration significantly exceeded the permissible limit ($t_{c}=7.954$, $p<0.001$). On the contrary, about 45% of samples exceeded the permissible limit set by WHO for mercury. The average of Hg in samples exceeded the limit was 0.11 mg.Kg$^{-1}$ which was significantly higher than the limit ($p=0.0281$).

**Meta-analysis**

Locational variations between studies in terms of heavy metals in chicken liver samples were analyzed. Findings of previous studies from Iraq and other countries were analyzed with our findings. Meta-analysis showed no significant difference between locations of analyzed previous reports (Table 5) in terms of trace elements contents (p=0.489, $F_{c}=0.84$). The variations between locations in terms of toxic heavy metals and metalloids are summarized in Table 5. No ANOVA test was done for these metals due to lack of data, especially pertaining to Hg levels.

**Discussion**

Presence of heavy metals in meats is a public hazard due to the cytotoxicity of such metals and disruption of normal cellular processes. Poultry meat and edible offal are not excepted and are known to associate with risks to consumers including humans. This study evaluated the concentrations of heavy metals (trace elements and toxic metals and metalloids) in chicken liver samples collected from Erbil city, Kurdistan Region, Iraq.

The detected concentration of Co and Cu were 0.06±0.027 mg/kg and 2.05±0.0344 mg/kg respectively. These concentrations are more than ten-fold higher than reported in previous study in Sulaimani city, Kurdistan (0.006 & 0.158 mg/kg) (Aljaff et al., 2014). The mean of Co in this study (Table 3) was below the maximum permissible limit in poultry (1.0 mg/kg) set by Codex Alimentarius Commission (CAC, 2019; FAO/WHO, 2011). However, higher levels of Cu were reported from Pakistan (1.49 mg/kg) and (1.60 mg/kg) (Hadyait et al., 2018; Khan et al., 2015), Saudi Arabia (1.28 mg/kg) (Al Bratty et al., 2018), Bangladesh (3.37 mg/kg) (Mottalib et al., 2018), and Turkey (10.82 mg/kg) (Duman et al., 2019).

These metals are essential micronutrients but are toxic at high level and can reach the foodstuff during food processing, agricultural activities, metals-contaminated

### Table 4. Concentrations of toxic heavy metals in chicken liver samples expressed as mean ± SD (mg.Kg$^{-1}$).

| Sample | Cd  | Pb   | Hg   | Se  |
|--------|-----|------|------|-----|
| 1      | ND  | ND   | 0.152±0.118 | 2.35±0.24 |
| 2      | ND  | ND   | 0.236 | 2.21±0.58 |
| 3      | ND  | ND   | 0.099±0.091 | 2.02±0.79 |
| 4      | 0.006±0.01 | ND | 0.134±0.116 | 1.97±0.45 |
| 5      | ND  | 0.176 | ND   | 2.23±0.50 |
| 6      | ND  | ND   | 0.083±0.082 | 1.78±0.45 |
| 7      | ND  | 0.329 | 0.138 | 1.70±0.90 |
| 8      | ND  | ND   | 0.103±0.042 | 2.85±0.10 |
| 9      | ND  | ND   | ND   | 2.14±0.41 |
| 10     | 0.034±0.059 | ND | 0.007 | 2.03±1.01 |
| 11     | ND  | 0.216 | 0.123±0.149 | 2.10±0.57 |
| 12     | 0.115±0.078 | 0.394 | ND   | 2.41±0.70 |
| 13     | 0.150±0.088 | ND | 0.075 | 2.95±0.15 |
| 14     | 0.079±0.015 | ND | 0.043±0.02 | 2.61±0.62 |
| 15     | 0.064±0.010 | ND | 0.113±0.058 | 1.56±0.12 |
| 16     | 0.054±0.027 | ND | 0.170 | 1.56±0.22 |
| 17     | ND  | ND   | 0.048±0.013 | 3.27±0.80 |
| 18     | 0.029±0.006 | ND | 0.130±0.106 | 0.708±0.082 |
| 19     | ND  | ND   | 0.080 | 0.763±0.282 |
| 20     | ND  | ND   | 0.100 | 0.975±0.357 |

**Mean ± SD0.07 ± 0.037* | 0.278 ± 0.100** | 0.11 ± 0.083*** | 2.01 ± 0.454**

WHO PL | 0.3 | 0.10 | 0.1 | NS

*significantly lower than maximum permissible limit (p<0.001). **significantly higher than maximum permissible limit (p<0.001). PL permissible limit: ND: not detected

### Table 5. Location variations between studies in terms of trace elements contents in chicken liver samples (g g$^{-1}$).

| Location (Reference) | Trace element | Co | Cr | Cu | Mn | Ni | Zn |
|-----------------------|---------------|----|----|----|----|----|----|
| Erbil, Iraq (This study) | Co             | 0.06±0.03 | 0.06±0.05 | 2.05±0.34 | 1.85±0.47 | 0.15±0.17 | 33.53±524 |
| Sulaimani, Iraq (Aljaff et al., 2014) | Co | 0.006±0.0 | 0.087±0.0 | 0.16±0.0 | 0.09±0.0 | 0.09±0.0 | 1.34±0.0 |
| Selangor, Malaysia (Abduljaleel et al., 2012) | Co | 0.27±0.12 | 5.13±0.69 | 9.67±1.60 | 7.11±1.77 | 1.91±0.96 | 78.66±21.45 |
| Benin, Nigeria (Ogbomida et al., 2018) | Co | 0.05±0.003 | 0.08±0.05 | 4.36±1.02 | 3.61±1.20 | 0.02±0.01 | 43.36±13.08 |
| Toxic metals | Cd | 0.07±0.04 | 0.11±0.08 | 0.28±0.10 | 2.01±0.45 |
| | Hg | 0.095±0.0 | NT | 0.095±0.0 | NT |
| | Pb | 0.04±0.03 | NT | 1.29±0.09 | NT |
| | Se | 0.01±0.003 | NT | 0.14±0.04 | NT |
| Mashhad, Iran (Sadeghi et al., 2015) | Co | 0.37±0.09 | NT | 3.79±3.64 | NT |
| Selangor, Malaysia (Abduljaleel et al., 2012) | Co | 0.16±0.11 | NT | 0.35±0.18 | 2.01±0.60 |
| Benin, Nigeria (Ogbomida et al., 2018) | Co | 0.29±0.34 | 0.034±0.036 | 0.17±0.19 | NT |

NT: not tested.

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chicken feed (Agade et al., 2019; Gall et al., 2015).

No permissible limit for Mn has been published by FAO/WHO or European Food Safety Agency. The average concentrations of Zn and Mn found in the present work are higher than previously published in Iraqi studies analyzed chicken meat samples including liver samples in Sulaimani and Diyala cities (Table 5) (Aljaff et al., 2014; Al-Zuhairi et al., 2015). However, the detected level of Ni in this study (0.15 mg/kg) was lower than the levels reported by the aforementioned Iraqi study in Diyala (0.414 mg/kg). No detectable level of Ni was also reported from Saudi Arabia (Al Bratty et al., 2018). Nonetheless, high concentrations of Mn in chicken liver samples were reported from Pakistan (6.26 mg/kg) (Khan et al., 2015), Turkey (9.45 mg/kg) (Duman et al., 2019) and as high as 119 mg/kg (Yayayürük & Yayayürük, 2017). Lower levels of zinc were also reported from chicken liver samples analyzed in Saudi Arabia (20.72 mg/kg) (Al Bratty et al., 2018), Sulaimani city (Aljaff et al., 2014). On the contrary, higher concentrations were documented in Turkey (100.87 mg/kg) (Duman et al., 2019). The detected level of Cr found in this study (0.06 mg/kg) was lower than WHO maximum limit but significantly higher concentration was recently reported from Bangladesh (6.368 mg/kg) (Mottalib et al., 2018).

The average level of Cd observed in this study is lower than reported in previous studies conducted in Iraq (0.095 mg/kg) (Al-Zuhairi et al., 2015), Malaysia (0.159 mg/kg) (Abduljaleel et al., 2012), Nigeria (0.29 mg/kg) (Ogbonima et al., 2018), and Iran (0.37 mg/kg) (Sadeghi et al., 2015). One the other hand, higher contents that exceeded the permissible limit of FAO/WHO (0.3 mg/kg) have recently been reported from Bangladesh (0.627 mg/kg) (Mottalib et al., 2018). It’s well-known that cadmium not only has no function in human body but also has a toxicity even at low levels due to its low excretion rate (Wu et al., 2016). Poultry can be exposed to Cd simply by contact with paints, electronic wastes, plastics, and cadmium-plated items and batteries (Rashid et al., 2013). Cadmium exposure is implicated in hepatotoxicity, respiratory diseases, and cancers of lung, kidney, and prostate (Rahimzadeh et al., 2017).

Exposure to organic mercury is linked to sever neurotoxicity in humans (Spiller, 2018). Detected concentrations of mercury exceeded the permissible limit set by FAO/WHO was in 40% of samples. The mean concentration of Hg in the present work was 0.11 ± 0.08 mg/kg. This level is three-fold higher than reported in a recent study in Nigeria (Ogbonima et al., 2018). On the contrary, a higher level (0.252 mg/kg) was reported in chicken liver samples collected from markets in Izmir city in Turkey (Yayayürük & Yayayürük, 2017). It should be noted that literature regarding Hg levels in poultry is scarce.

Lead in chicken liver samples was (0.28 mg/kg) two-fold higher than permissible limit of Codex Alimentarius Commission (0.1 mg/kg). This finding is even higher than reported by many reports from Saudi Arabia (0.14 mg/kg) (Al Bratty et al., 2018), and Nigeria (0.171 mg/kg) (Ogbonima et al., 2018). A worth mentioning point is that lead toxicity is mainly affecting hematopoiesis, kidney function, reproductive and central nervous systems (Assi et al., 2016).

Average selenium level found in this study is 2.01 mg/kg which is significantly greater than documented (0.0174 mg/kg) in previous study in Sulaimani city (Aljaff et al., 2014). However, a similar level of selenium was found in a Malaysian study (Abduljaleel et al., 2012). Till date, there is no permissible limit for selenium set by Codex Alimentarius Commission (WHO/FAO) or European commission. It was recently found that selenium assist mercury in its cellular toxicity by giving up its binding pockets in thioredoxin reductases and glutathione peroxidases enzymes to mercury. Mercury binding instead of selenium results in permanent inactivation of such enzymes (Spiller, 2018).

Conclusions

Trace elements metals of Co, Mn, Ni, Zn, and Cr in chicken liver samples collected from markets in Erbil city, Kurdistan (Iraq) did not exceed the permissible limits of FAO/WHO. Likewise, average concentration of toxic heavy metals and metalloids did not exceed the maximum limits specified by WHO. However, Cu, Pb, and the heavy metalloid Hg exceeded the permissible limits in poultry set by WHO. These findings reflect the quality and safety of chicken meat sold in the markets. Iraqi Standards Authority is strongly advised to take precautions to lower the risks of poultry exposure to Hg and Pb. Further investigations with larger sample size accompanied by risk assessment of heavy metal exposure in chicken is guaranteed to reveal a clearer picture of heavy metals in chicken meat in Erbil city.

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