Slov Vet Res 2018; 55 (Suppl 20): 211–19 **Original Research Article**
DOI 10.26873/SVR-647-2018

# HUMAN HEALTH RISK ASSESSMENT OF HEAVY METALS AND TRACE ELEMENTS RESIDUES IN POULTRY MEAT RETAILED IN SHARKIA GOVERNORATE, EGYPT

Rasha M. El Bayomi, Wageh S. Darwish*, Shimaa S.M. Elshahat, Abdelsalm E. Hafez

Department of Food Control, Faculty of Veterinary Medicine, Zagazig University, El-Zeraa str. 114, 44519-Zagazig, Egypt

*Corresponding author, E-mail: wagehdarwish@gmail.com; wagehdarwish@yahoo.ca

**Abstract:** The objective of this study was to estimate the residual concentrations of copper (Cu), zinc (Zn), cadmium (Cd), lead (Pb) and mercury (Hg) in muscles and livers of chicken (broilers and layers), turkeys and quails marketed in Egypt. Metal-metal correlations were further analyzed. Moreover, metal's dietary intake and health risk assessment among Egyptian consumers were calculated. Livers had higher metal residues compared with the muscles in all species examined. The ranges (μg/g ww) of the elemental concentrations in the livers of the examined bird species were 0.03-0.46 (Cu), 1.77-10.33 (Zn), 0.05-1.09 (Pb), 0.02-0.15 (Cd) and 0.13-0.99 (Hg). Such ranges (μg/g ww) in the muscle samples were 0.007-0.60 (Cu), 0.69-4.64 (Zn), 0.01-0.55 (Pb), 0.02-0.13 (Cd) and 0.11-0.94 (Hg). Correlation analysis among metals revealed both tissue-dependent and inter-species differences for the accumulation patterns of metals. The potential risk assessment of all investigated metals in poultry meats revealed no significance risk on Egyptians. However, intake of repetitive small concentrations of metals may lead to severe toxicological implications.

**Key words:** poultry; heavy metals; risk assessment

## Introduction

Poultry meat is an excellent source of high quality animal protein that is required for feeding convalescents, adults, young children and infants (1). Increasing the popularity of poultry meat is mainly due to its ideal chemical composition including essential polyunsaturated fatty acids, essential amino acids, as well as easy digestibility, availability, acceptance and low price compared with other meat (2).

Contamination of meat with heavy metals is a serious hazard because of their toxicity, bioaccumulation and biomagnification in the food (3). The main sources of poultry exposure to heavy metals are feed, drinking water and litter contamination (4,5). These metals find their way to the human food mainly via the consumption of contaminated meat (6).

Toxic metals with severe health hazards include lead (Pb), cadmium (Cd) and mercury (Hg) (7). Human exposure to heavy metals may lead to several acute or chronic adverse effects (8). The main toxic effects of lead include hypertension, reproductive dysfunction, gastrointestinal track damage, nephropathy, and damage of central and peripheral nervous systems (9). The toxicity of cadmium is linked to its interactions with zinc and other essential elements leading to sever renal dysfunction and

Received: August 2018
Accepted for publication: September 2018

respiratory symptoms (10). Mercury is a neurotoxin that causes neuro-behavioral alterations, renal damage and gastrointestinal toxicity (11). Zinc (Zn) and copper (Cu) are essential trace elements that play several physiological and biological roles in maintenance of animal performance and health, however, high intake of these elements can cause health problems (12).

As humans are on the top of the ecosystem, it is essential to evaluate their dietary exposure to such toxicants (13). Moreover, the human health risk assessment due to consumption of poultry meat contaminated with heavy metals is a major task of food hygiene. Therefore, this study aimed to estimate the concentrations of metals (Cu, Zn, Cd, Pb and Hg) in fresh poultry meat samples (muscle and liver) collected from Sharkia Governorate, Egypt and to evaluate the risks associated with consumption of such meat. Furthermore, metal-metal correlations were analyzed to investigate their inter-species differences in metal accumulation pattern.

## Material and methods

*Chemicals and reagents*

The standards of the tested metals and other reagents including nitric and perchloric acids were of analytical grade and purchased from Merck, Darmstadt, Germany.

*Collection and preparation of samples*

Eighty samples from breast muscles and liver of layers, broilers, turkeys and quails (10 samples, each) retailed for human consumption were randomly collected from Zagazig city, Sharkia Governorate, Egypt. After being sacrificed in poultry meat shops, 10 grams from each sample were identified and wrapped separately in polyethylene bags, then stored at –20°C until metal extraction and measurements. The analysis of heavy metals (Cu, Zn, Cd, Pb and Hg) was estimated by Atomic Absorption Spectrometry (AAS) (Per Kin Elmer model (spectra-AA10, USA) in the Central Laboratory, Faculty of Veterinary Medicine, Zagazig University, Egypt.

*Analytical procedures*

One gram of each tissue sample was digested overnight in 5 mL volume of a mixture 3 volumes of 65% nitric acid and 2 volume of 70% perchloric acid (14, 15). The tubes were moist heated for 3 h at 70°C followed by cooling and filtration. The filtrates were kept at 4°C until measurement of the metals. Levels of Hg were measured using hydride generation/cold vapor atomic absorption spectroscopy, while in case of Cu, Zn, Pb and Cd, a graphite furnace was used (Perkin Elmer® PinAAcle™ 900T atomic absorption spectrophotometer (Shelton, CT, USA).

*Quality assurance and quality control*

The standard reference (DORM–3, fish protein) (National Research Council, Canada) was used for validation of the analytical method. The recovery rates (%) for Cu, Cd, Pb, Zn and Hg were 98%, 98%, 97%, 96% and 95, respectively. The instrumental limits of detection (LOD) were 0.02, 0.005, 0.01, 0.02 and 0.02 μg/g for Cu, Cd, Pb, Zn and Hg, respectively. The concentrations of Cu, Cd, Pb, Zn and Hg were expressed as μg/g wet weight (ww). Residual metal concentrations in the examined samples were compared with the maximum permissible limits of metals set by FAO/WHO (16).

*Metal's dietary intakes and health risk assessment*

The potential health risks of Egyptian adults due to consumption of metal-contaminated poultry meat were assessed based on calculation of the estimated daily intake (EDI), hazard quotient (HQ), and hazard index (HI) of the metals examined. EDI was calculated using the equation described by the United States Environment Protection Agency (USEPA) (17) as follows

$$EDI = (C \times FIR)/BW$$

Where, BW is the body weight of the Egyptians adults, which was set as 70 kg. C is the concentration of the metal in the tested samples (μg/g ww). FIR is the rate of the ingestion of poultry meat (muscle) in Egypt, which was estimated to be 39.53 g/day (18) and the ingestion rate of liver tissue was set as 0.1 g/day (19). EDI values were expressed as (μg/kg BW/day) for the heavy metals. EDI values were then compared with metal's tolerable daily intakes (TDIs) (FAO/WHO) (20).

The assessment of heavy metal-related non-cancer risks followed the guide lines recommended by USEPA (21) using the following equation:

$$THQ = \frac{ED \times C \times FIR \times EF}{RFD \times BW \times AT} \times 10^{-3}$$

Where THQ is the target hazard quotient; C is the heavy metal concentration in poultry meat (μg/g); FIR is the food ingestion rate (g/day); ED is the exposure duration (70 years, average lifetime); EF is exposure frequency (365 days/year); RFD is the oral reference doses for Cu, Cd, Pb, Zn and Hg (0.04, 0.001, 0.004, 0.3 and 0.0016 mg/kg BW/day) (22). AT is the average exposure time (365 days/ year × exposure years, assumed as 70 years); BW is the average adult body weight (70 kg).

Hazard index (HI) was generated to evaluate the risk of the combined metals using the following equation: $HI = \Sigma HQi$, Where i represent each metal. When the value of HQ and/or HI exceeds 1.0, there is a concern for potential health effect (23).

*Statistical analysis*

Heavy metals concentrations were recorded as means ± standard errors (SE). Results were analyzed using one-way analysis of variance (ANOVA) (SPSS for Windows 21.0). Duncan's test was used for statistical analysis. Comparing metals in muscles and liver of the same bird was done by T-test. The value of $P<0.05$ was used to indicate statistical significant differences. Correlation analyses among the measured metals were calculated based on Spearman's coefficient using JMP program (SAS Institute, Cary, NC, USA).

## Results and discussion

*Levels of the tested heavy metals*

Residual concentrations of copper (μg/g ww) were recorded in Table (1). Samples collected from turkeys had the highest Cu residues (0.13 ± 0.12) compared with other bird species, particularly in the muscle. The recorded concentrations in the present study were far below the values recorded in muscles of broilers and quails in Egypt (6, 24). However, copper residues were below the detection limit on livers of broilers in Philippines (25). All examined samples in the present study had copper residues within the permissible limits set by FAO/WHO and Egyptian authorities (16,26)

**Table 1:** Heavy metal residual concentrations in the examined meat samples from different poultry species (n = 10 each)

| Item | | Cu | | Zn | | Pb | | Cd | | Hg | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Mean ± SE (Range)** | **%** | **Mean ± SE (Range)** | **%** | **Mean ± SE (Range)** | **%** | **Mean ± SE (Range)** | **%** | **Mean ± SE (Range)** | **%** |
| **Layers** | **Muscle** | $0.08 \pm 0.02^{ab}$ (0.06-0.14) | 0 | $2.59 \pm 0.10^{b}$ (2.26-2.86) | 0 | $0.10 \pm 0.05^{a}$ (0.01-0.24) | 40 | $0.06 \pm 0.01^{ab}$ (0.02-0.10) | 80 | $0.45 \pm 0.14^{a}$ (0.11-0.83) | 80 |
| | **Liver** | $0.18 \pm 0.03^{a*}$ (0.11-0.25) | 0 | $5.53 \pm 0.45^{a*}$ (4.81-7.32) | 0 | $0.21 \pm 0.05^{a}$ (0.05-0.34) | 0 | $0.06 \pm 0.01^{a}$ (0.02-0.09) | 0 | $0.41 \pm 0.07^{b}$ (0.20-0.60) | 20 |
| **Broilers** | **Muscle** | $0.04 \pm 0.02^{b}$ (0.007-0.11) | 0 | $2.46 \pm 0.30^{bc}$ (1.26-2.88) | 0 | $0.31 \pm 0.04^{a}$ (0.17-0.4) | 100 | $0.09 \pm 0.01^{a}$ (0.05-0.13) | 80 | $0.62 \pm 0.11^{a}$ (0.23-0.94) | 100 |
| | **Liver** | $0.21 \pm 0.03^{a*}$ (0.10-0.29) | 0 | $4.76 \pm 0.44^{a*}$ (3.69-5.86) | 0 | $0.34 \pm 0.06^{a}$ (0.19-0.48) | 0 | $0.10 \pm 0.01^{a}$ (0.04-0.15) | 0 | $0.65 \pm 0.12^{a}$ (0.23-0.99) | 80 |
| **Turkeys** | **Muscle** | $0.13 \pm 0.12^{a}$ (0.04-0.60) | 0 | $3.70 \pm 0.33^{a}$ (2.94-4.64) | 0 | $0.18 \pm 0.10^{a}$ (0.01-0.55) | 80 | $0.07 \pm 0.01^{ab}$ (0.03-0.1) | 60 | $0.44 \pm 0.11^{a}$ (0.17-0.79) | 80 |
| | **Liver** | $0.26 \pm 0.08^{a}$ (0.19-0.46) | 0 | $5.56 \pm 1.21^{a}$ (3.51-10.33) | 0 | $0.45 \pm 0.19^{a*}$ (0.16-1.09) | 20 | $0.10 \pm 0.01^{a}$ (0.06-0.14) | 0 | $0.47 \pm 0.13^{ab}$ (0.13-0.88) | 40 |
| **Quails** | **Muscle** | $0.10 \pm 0.05^{ab}$ (0.02-0.28) | 0 | $1.13 \pm 0.35^{c}$ (0.69-2.54) | 0 | $0.18 \pm 0.08^{a}$ (0.01-0.46) | 40 | $0.04 \pm 0.01^{b}$ (0.03-0.08) | 60 | $0.52 \pm 0.05^{a}$ (0.43-0.71) | 80 |
| | **Liver** | $0.15 \pm 0.05^{a}$ (0.03-0.27) | 0 | $2.40 \pm 0.38^{b}$ (1.77-3.82) | 0 | $0.34 \pm 0.05^{a}$ (0.19-0.45) | 0 | $0.08 \pm 0.02^{a}$ (0.04-0.12) | 0 | $0.70 \pm 0.15^{a}$ (0.14-0.97) | 40 |

Means within the same sample (muscle or liver) carrying different subscripted letter are significantly different ($p < 0.05$) based on Duncan's multiple comparisons. *indicates significant difference among muscle and liver of the same bird species. % indicates percentage of samples exceeding maximum permissible limits (MPL) for the tested heavy metals set by Egypt organization for Standardization (EOS 2010)(26) and FAO/WHO (2000) (16). MPL for Cu, Cd, Pb, Zn and Hg (µg/kg ww) in muscles were set to be 15.00; 0.05, 0.1, 50, 0.2, respectively; in liver, they were set to be 15.00, 1.00, 0.5, 50, 0.5, respectively.

In the present study, residual concentrations of zinc were the highest among the examined elements as shown in Table (1). This may be attributed to the addition of zinc to the poultry feed formula for improvement of the physiological body functions (27). Similar to copper, turkeys had the highest residual concentrations of zinc in the muscles among the examined avian species (3.70±0.33 µg/g ww). The detected levels of zinc in the current investigation were comparable to 1.29 and 1.28 (µg/g ww) in the muscles of quails reared in either battery or deep litter systems, respectively in Egypt (4) and lower than those recorded in broilers examined in; Egypt (24), India (28, 29) and Zambia (30) and in free-range chicken from Ghana (31) and Nigeria (32). Zinc levels were within the accepted permissible limits of zinc in meat (16).

Residual concentrations of cadmium were recorded in Table (1). The ranges (µg/g ww) of Cd residual concentrations in the livers and muscles of the examined bird species were 0.02-0.15 and 0.02-0.13, respectively. Levels of Cd in livers and muscles of the examined species were comparable to that recorded in broilers (33) and quails (6) examined in Egypt and and in broilers from India (29). However, higher Cd concentrations were recorded in the livers of free-range chicken collected from Poland (34), Zambia (30), Ghana (31), Egypt (35) and Nigeria (32) and in turkeys collected from Spain (36). Levels of cadmium recorded in muscles were 80%, 80%, 60% and 60% in broilers, layers, turkeys and quails, respectively (Table 1) that exceeded maximum permissible limits of cadmium (16,26) This is may be attributed to the high levels of cadmium in poultry ration, drinking water and/or environment (6,37).

Lead is an environmental toxin that is linked to several health adverse effects (15). The obtained concentrations of lead in the present study were shown in Table (1). The results indicated that turkeys had the highest lead residues among the examined avian species. The average Pb residual concentrations (µg/g ww) in the muscles and livers of turkeys were

0.18±0.10 and 0.45±0.19, respectively. The recorded concentrations in the present study were in agreement with the recorded concentrations in poultry meat samples collected from Poland (34), India (29), Egypt (38). However, lower concentrations of Pb were reported in turkeys from Spain (36), quails from Egypt (6) and broilers from Philippines and Zambia (25,30). Lead had exceeded the established MPL (16,26) in all examined bird species with different percentages as indicated in Table (1). This might be due to the contamination of birds' feed and water with lead that is commonly used in the manufacturing of water pipes (39) and might be contained in bone and fish meals (40).

Mercury occurs naturally in the environment at low levels and characterized by its high bioaccumulation and biomagnification nature (41), it can find its way to food chain via industrial wastes (42), water, feed, dust and soil (31,43). The mean concentrations of Hg in the current study were declared in Table (1). The recorded mercury concentrations in the livers of broilers (0.65±0.12 µg/g ww) were lower than that recorded in broilers in India (28) and in free-range chicken from Ghana (31) and higher than those recorded in poultry meat in Philippines, Zambia and Nigeria (25, 30, 32). In the present study, 80%, 100%, 80% and 80% of the examined samples of layers, broilers, turkeys and quails, respectively were higher than the recommended maximum permissible limits of Hg (16,26).

In general, liver had higher accumulation pattern for metals compared with muscle in the examined avian species, this is may be attributed to the fact that liver is the organ of metabolism and detoxification of xenobiotics in humans and animals (6,15)

*Correlation analysis among metals in poultry meat*

In order to investigate the inter-metal`s tendency of accumulation, Spearman`s coefficient factors were calculated in both liver and muscle tissues of the different birds as indicated in Tables (2 and 3). Interestingly, the achieved results revealed both interspecies and tissue-dependent variations in the tendency of accumulation of the tested metals. For instances, significant negative correlations were observed between the essential trace elements as copper and zinc from one side and the toxic ones from the other side as clear in case of Cd-Cu (r = -0.21, p = 0.74 in layers and r = -0.67, p = 0.22 in layers); Cd-Zn (r = -0.87, p = 0.05) and Hg-Zn (r = -0.60, p = 0.28). This may be attributed to the physiological trials of the body for detoxification of such toxicants. Essential elements such as copper and zinc were reported to induce metal binding proteins and antioxidant enzymes (6). These findings agreed with the inter-metal correlations detected in the livers of cattle and sheep (15), chicken (31) and quails (6).

**Table 2:** Correlation analysis among the examined metals in the muscle tissues of different poultry species

| | | Layers | | Broilers | | Turkey | | Quails | |
|---|---|---|---|---|---|---|---|---|---|
| | | *R* | *p* | *r* | *p* | *r* | *p* | *r* | *p* |
| **Cd** | **Cu** | -0.15 | 0.81 | **0.81** | **0.01** | -0.80 | 0.11 | 0.11 | 0.87 |
| **Pb** | **Cu** | **0.9** | **0.04** | 0.45 | 0.45 | 0.45 | 0.45 | -0.11 | 0.87 |
| **Pb** | **Cd** | 0.15 | 0.81 | 0.05 | 0.93 | -0.05 | 0.93 | **-1.00** | **<.0001** |
| **Zn** | **Cu** | -0.51 | 0.39 | -0.45 | 0.45 | 0.11 | 0.86 | **0.71** | **0.01** |
| **Zn** | **Cd** | -0.56 | 0.32 | -0.62 | 0.27 | 0.11 | 0.87 | -0.11 | 0.87 |
| **Zn** | **Pb** | **-0.77** | **0.05** | -0.11 | 0.87 | -0.31 | 0.62 | 0.11 | 0.87 |
| **Hg** | **Cu** | 0.31 | 0.62 | **-0.89** | **0.04** | **-0.67** | **0.02** | -0.20 | 0.75 |
| **Hg** | **Cd** | 0.41 | 0.49 | -0.62 | 0.27 | 0.15 | 0.81 | -0.40 | 0.51 |
| **Hg** | **Pb** | 0.44 | 0.51 | **-0.7** | **0.05** | **-0.71** | **0.05** | 0.41 | 0.51 |
| **Hg** | **Zn** | -0.90 | 0.04 | **0.61** | **0.04** | 0 | 1.00 | 0.50 | 0.39 |

*r*: spearman`s correlation factor; *p*: probability and Values in bold show significant correlation between each two metals.

**Table 3:** Correlation analysis among the examined metals in the livers of different poultry species

| | | Layers | | Broilers | | Turkeys | | Quails | |
|---|---|---|---|---|---|---|---|---|---|
| | | *r* | *P* | *r* | *p* | *r* | *p* | *r* | *p* |
| **Cd** | **Cu** | -0.21 | 0.74 | -0.67 | 0.22 | 0.58 | 0.31 | -0.21 | 0.74 |
| **Pb** | **Cu** | -0.20 | 0.75 | -0.56 | 0.32 | **0.65** | **0.02** | 0.31 | 0.62 |
| **Pb** | **Cd** | -0.41 | 0.49 | **0.68** | **0.02** | -0.14 | 0.82 | -0.15 | 0.81 |
| **Zn** | **Cu** | -0.31 | 0.62 | -0.60 | 0.28 | **-0.86** | **0.05** | 0.31 | 0.62 |
| **Zn** | **Cd** | **-0.87** | **0.05** | **0.87** | **0.05** | -0.29 | 0.63 | **0.67** | **0.02** |
| **Zn** | **Pb** | 0.51 | 0.39 | 0.56 | 0.32 | -0.55 | 0.34 | 0.31 | 0.62 |
| **Hg** | **Cu** | -0.11 | 0.87 | 0.15 | 0.80 | -0.59 | 0.29 | 0.1 | 0.87 |
| **Hg** | **Cd** | 0.67 | 0.22 | -0.13 | 0.83 | -0.34 | 0.57 | 0 | 1.0 |
| **Hg** | **Pb** | -0.40 | 0.50 | -0.29 | 0.64 | -0.08 | 0.89 | 0.31 | 0.61 |
| **Hg** | **Zn** | -0.60 | 0.28 | 0.36 | 0.55 | **0.87** | **0.05** | -0.36 | 0.55 |

*r*: spearman`s correlation factor; *p*: probability and Values in bold show significant correlation between each two metals.

*Health risk assessment*

*Daily intake of heavy metals*

Estimation of dietary intake of metals is considered as a good tool for identification of the human exposure frequencies to heavy metals. The estimated daily intakes of Cu, Zn, Cd, Pb and Hg were assessed based on the average concentrations of the accumulated metals as indicated in Table (4). The estimated metal intake from consumption of muscles and livers of poultry were lower than the tolerable daily intake of Cu (500), Cd (1.00), Pb (3.57), Zn (300-1000), and Hg (0.71) (20). This may indicate that such metals had minimum potential health risks from consumption of poultry meat in the study area. Similarly, Darwish *et al.* (6) reported that the EDIs of Pb and Cd from consumption of the edible tissues of the quails were below TDI.

**Table 4:** Estimated daily intake (EDI) (µg/ kg BW) of different tested metals tested

| **Examined samples** | | **Cu** | **Zn** | **Pb** | **Cd** | **Hg** |
|---|---|---|---|---|---|---|
| **Layers** | **Muscle** | 0.045 | 1.463 | 0.057 | 0.034 | 0.254 |
| | **Liver** | 0.0003 | 0.008 | 0.0003 | 0.0001 | 0.001 |
| **Broilers** | **muscle** | 0.023 | 1.389 | 0.175 | 0.051 | 0.350 |
| | **liver** | 0.0003 | 0.007 | 0.001 | 0.0001 | 0.001 |
| **Turkeys** | **muscle** | 0.073 | 2.089 | 0.102 | 0.040 | 0.249 |
| | **liver** | 0.0004 | 0.008 | 0.001 | 0.0001 | 0.001 |
| **Quails** | **muscle** | 0.057 | 0.638 | 0.102 | 0.023 | 0.294 |
| | **liver** | 0.0002 | 0.003 | 0.001 | 0.0001 | 0.001 |
| **TDIs** | | **500** | **300 - 1000** | **3.57** | **1** | **0.71** |

EDI: estimated daily intake and TDI: tolerable daily intake.

*Target hazard quotient and hazard index*

Heavy metals were highly accumulated in the livers compared with the muscle. However, the potential risks from consumption of the livers were minor when compared with the muscle owing to their extremely low ingestion rates (5). The non-carcinogenic risks from consumption of poultry meat were assessed based on the THQs and HI as indicated in Table (5). Amongst all the examined metals, Hg in muscle of layers posed the highest potential health risk (0.219), while Cd was the lowest (Table 5). In general, THQ and HI values were far below one, which indicate minimum potential hazards for Egyptian consumers from poultry meat. However, this finding should be handled carefully due to the extensive consumption of poultry meat to compensate the shortage in the red meat in Egypt, which may lead to higher accumulation for metals. Therefore, continuous screening for metal accumulation in the poultry meat should be conducted. The recorded THQ and HI values corresponded with that reported in Ghana, Nigeria and Egypt (6,31,32).

**Table 5:** Hazard analysis due to consumption of poultry meat in Egypt

| Examined samples | | THQ Cu | THQ Zn | THQ Pb | THQ Cd | THQ Hg | HI |
|---|---|---|---|---|---|---|---|
| **Layers** | **muscle** | 0.001 | 0.005 | 0.014 | 0.034 | 0.159 | 0.213 |
| | **liver** | >0.000 | >0.000 | 0.001 | >0.000 | >0.000 | 0.001 |
| **Broilers** | **muscle** | 0.001 | 0.005 | 0.043 | 0.051 | 0.219 | 0.319 |
| | **liver** | >0.000 | >0.000 | 0.0001 | >0.000 | 0.001 | 0.001 |
| **Turkeys** | **muscle** | 0.002 | 0.007 | 0.02 | 0.040 | 0.155 | 0.229 |
| | **liver** | >0.000 | >0.000 | 0.0002 | 0.000 | >0.000 | 0.001 |
| **Quails** | **muscle** | 0.001 | 0.002 | 0.025 | 0.023 | 0.184 | 0.235 |
| | **liver** | >0.000 | >0.000 | >0.000 | >0.000 | >0.001 | 0.001 |
| **RFD** | | 0.04 | 0.3 | 0.004 | 0.001 | 0.002 | |

**THQ**: target hazard quotient; **RfD**: oral reference dose for each metal; **HI**: hazard index.

## Conclusion

The present study revealed accumulation of Cu, Zn, Cd, Pb and Hg in the livers and muscles of layers, broilers, turkeys and quails marketed in Egypt. Metals varied in their accumulation tendency based on tissue and species. The recorded concentrations had exceeded maximum permissible limits for Cd, Pb and Hg. Non-carcinogenic risk assessment of the examined metals revealed minimum risk among Egyptian populations due to consumption of poultry meat.

## Conflict of interest

The authors declare no conflict of interest.

## References

(1) Hassanin F, Mahmoud A, Mohamed E. Heavy metals residue in some chicken meat products. Benha Vet Med J 2014; 27: 256–63.

(2) Institute of Medicine. Dietary reference intakes for Vitamin A, Vitamin K, arsenic, boron, chromium, copper, iodine, iron, managanese, molybdenum, nickel, silicon, vanadium and zinc. Washington DC, pp 733–6. 2003.

(3) Khan ZI, Ahmad K, Ashraf M, Parveen R, Bibi Z, Mustafa I, Noorka IR, Tahir HM, Akram NA, Ullah MF, Yaqoob R, Tufarelli V,Fracchiolla M, Cazzato E. Risk assessment of heavy metal and metalloid toxicity through a contaminated vegetable (Cucurbita maxima) from wastewater irrigated area: A case study for a site-specific risk assessment in Jhang, Pakistan. Hum Ecol Risk Assess 2016; 22: 86–98.

(4) Ahmed AM, Hamed DM, Elsharawy NT. Evaluation of some heavy metals residues in batteries and deep litter rearing systems in Japanese quail meat and offal in Egypt. Vet World 2017; 10: 262–9.

(5) Hu Y, Zhang W, Chen G, Cheng H, Tao S. Public health risk of trace metals in fresh chicken meat products on the food markets of a major production region in southern China. Environ Pollu 2018; 234: 667–76.

(6) Darwish W, Samir Atia A, Khedr M, Fathy Saad Eldin W. Metal contamination in quail meat: residues, sources, molecular biomarkers, and human health risk assessment. Environ Sci Pollut Res Int 2018; 25: 20106–15.

(7) Järup L. Hazards of heavy metal contamination. British Medical Bulletin. 2003; 68: 167–82.

(8) Saei-Dehkordi SS, Fallah AA. Determination of copper, lead, cadmium and zinc content in commercially valuable fish species from the Persian Gulf using derivative potentiometric stripping analysis. Microchem J 2011; 98: 156–62.

(9) Rubio C, Gonzalez-Iglesias T, Revert C, Reguera JI, Gutierrez AJ, Hardisson A. Lead dietary intake in a Spanish population (Canary Islands). J Agric Food Chem 2005; 53: 6543–9.

(10) Lafuente A, González-Carracedo A, Esquifino AI. Differential effects of cadmium on blood lymphocyte subsets. Biometals 2004; 17: 451–6.

(11) The Standardization Administration China/Ministry of Health, China) (SAC/MOHC). Maximum levels of contaminants in foods (GB2762-2005). Beijing. 2005.

(12) Richards JD, Zhao J, Harrell RJ, Atwell CA, Dibner JJ. Trace Mineral Nutrition in Poultry and Swine. Asian-Australas J Anim Sci 2010; 23: 1527–34.

(13) Islam MS, Ahmed MK, Habibullah-Al-Mamun M, Raknuzzaman M. The concentration, source and potential human health risk of heavy metals in the commonly consumed foods in Bangladesh. Ecotoxicol Environ Saf 2015; 122: 462–9.

(14) Tekin-Özan S. Determination of heavy metal levels in water, sediment and tissues of tench (Tinca tinca L., 1758) from Beyşehir Lake (Turkey). Environm Monit Assess 2008; 145: 295–302.

(15) Darwish WS, Hussein MA, El-Desoky KI, Ikenaka Y, Nakayama S, Mizukawa H, Ishizuka, M. Incidence and public health risk assessment of toxic metal residues (cadmium and lead) in Egyptian cattle and sheep meats. Int Food Res J 2015; 22: 1719–26.

(16) FAO/WHO. Report of Codex Committee on foodAdditives and Contaminants. Available on www FAO/ drocrep/ meeting/005. 2000.

(17) United States Environmental Protection Agency (USEPA)., Integrated Risk Information System (IRIS). Cadmium (CASRN- 7440-43-9) http://wwwepagov/iris/subst/0141html. 2010.

(18) FAOSTAT. Food Balance Sheets. Available online from:
http://www.fao.org/faostat/en/#data/FBS
(accessed on April 17, 2018). 2013.

(19) World Health Organization (WHO) Food Safety Issues GEMS/Food Regional Diets. Regional per capita consumption of raw and semi-processed agricultural commodities prepared by the Global Environment Monitoring System/Food Contamination Monitoring and Assessment Programme (GEMS/Food). Food Safety Department WHO, Geneva, Switzerland. 2003.

(20) Food Agricultural Organization/ World Health Organization (FAO/WHO) Joint FAO/WHO Food Standards Program Codex Committee on Contaminants in Foods, Fifth Session, The Hague, The Netherlands, 21-25 March. 2011.

(21) United States Environmental Protection Agency (USEPA). Risk assessment guidance for superfund, vol 1. EPA/540/1-89/002. Office of Emergency and Remedial Response. US EPA, Washington, DC. 1989.

(22) United States Environmental Protection Agency (USEPA). Risk-based concentration table. United States Environmental Protection Agency. Philadelphia. 2000.

(23) Huang CF, Hsu CJ, Liu SH, Lin-Shiau SY. Neurotoxicological mechanism of methylmercury induced by low-dose and long-term exposure in mice: oxidative stress and down-regulated Na+/K(+)-ATPase involved. Toxicol Lett 2008; 176: 188–97.

(24) Morshdy AMA, El-Desoky KI. Some heavy metal residues in poultry. Zag Vet J 2007; 35: 121–5.

(25) Villar TDC, Elaine J, Kaligayahan P, Flavier ME. Lead and cadmium levels in edible internal organs and blood of poultry chicken. J Appl Sci 2005; 5: 1250–3.

(26) Egyptian Organization for Standardization (EOS.7136). Maximum level for certain contaminants in food stuffs. ESNO.7136/2010. Cairo, Egypt. 2010.

(27) Larison JR, Likens GE, Fitzpatrick JW, Crock JG. Cadmium toxicity among wildlife in the Colorado Rocky Mountains. Nature 2000; 406: 181–3.

(28) Mariam I, Iqbal S, Nagra SA. Distribution of Some Trace and Macrominerals in Beef, Mutton and Poultry. Int J Agri Bio 2004; 6: 816–20.

(29) Giri S, Singh AK. Heavy metals in eggs and chicken and the associated human health risk assessment in the mining areas of Singhbhum copper belt, India. Arch Environ Occup Health 2017; 1–10.

(30) Yabe J, Nakayama SM, Ikenaka Y, Muzandu K, Choongo K, Mainda G, Kabeta M, Ishizuka M, Umemura T. Metal distribution in tissues of free-range chickens near a lead-zinc mine in Kabwe, Zambia. Environ Toxicol Chem. 2013; 32: 189–92.

(31) Bortey-Sam N, Nakayama SM, Ikenaka Y, Akoto O, Baidoo E, Yohannes YB, Mizukawa H, Ishizuka M. Human health risks from metals and metalloid via consumption of food animals near gold mines in Tarkwa, Ghana: estimation of the daily intakes and target hazard quotients (THQs). Ecotoxicol Environ Saf 2015; 111: 160–7.

(32) Ogbomida ET, Nakayama SMM, Bortey-Sam N, Oroszlany B, Tongo I, Enuneku AA, Ozekeke O, Ainerua MO, Fasipe IP, Ezemonye LI, Mizukawa H, Ikenaka Y, Ishizuka M. Accumulation patterns and risk assessment of metals and metalloid in muscle and offal of free-

range chickens, cattle and goat in Benin City, Nigeria. Ecotoxicol Environ Saf 2018; 151: 98–108.

(33) Abd El-Dayem RH. Detection of lead and cadmium in muscle, gizzard and liver of broilers chickens. J Egypt Vet Med Assoc 2004; 64: 127–34.

(34) Dobrzański Z, Kołacz R, Opaliński S, Górecka H, Chojnacka K, Trziszka T. The content of cadmium and lead in muscle and liver of laying hens housed in a copper industry region. XIth European Symposium on the Quality of Eggs and Egg Products. Doorwerth, The Netherlands 23–6. 2005.

(35) Mahmoud M, Abdel-mohsein H. Health Risk Assessment of Heavy Metals for Egyptian Population via Consumption of Poultry Edibles. Adv Animal Vet Sci 2015; 3: 58–70.

(36) Gonzalez-Weller D, Karlsson L, Caballero A, Hernandez F, Gutierrez A, Gonzalez-Iglesias T, Marino M, Hardisson A. Lead and cadmium in meat and meat products consumed by the population in Tenerife Island, Spain. Food Addit Contam. 2006; 23: 757–63.

(37) Heshmati A, Salaramoli J. Distribution Pattern of Cadmium in Liver and Kidney of Broiler Chicken: An Experimental Study. J Food Quality Hazards Conrol 2015; 2: 15–9.

(38) Zalat MA. Some heavy metal residues in poultry carcasses, M.V.Cs Thesis (Meat Hygiene). Fac Vet Med Zag, University, Egypt. 2010.

(39) (Renner R. Out of plumb: when water treatment causes lead contamination. Environ Health Perspect 2009; 117: A542-A7.

(40) Ishii C, Nakayama SMM, Ikenaka Y, Nakata H, Saito K, Watanabe Y, Mizukawa H, Tanabe S, Nomiyama K, Hayashi T, Ishizuka M. Lead exposure in raptors from Japan and source identification using Pb stable isotope ratios. Chemosphere 2017; 186: 367–73.

(41) Carrasco L, Barata C, Garcia-Berthou E, Tobias A, Bayona JM, Diez S. Patterns of mercury and methylmercury bioaccumulation in fish species downstream of a long-term mercury-contaminated site in the lower Ebro River (NE Spain). Chemosphere 2011; 84: 1642–9.

(42) Clarkson TW. The three modern faces of mercury. Environ Health Perspect 2002; 1: 11–23.

(43) McKelvey W, Gwynn RC, Jeffery N, Kass D, Thorpe LE, Garg RK, Palmer CD, Parsons PJ . A biomonitoring study of lead, cadmium, and mercury in the blood of New York city adults. Environ Health Perspect 2007; 115: 1435–41.