Jundishapur J Health Sci. 2018 January; 10(1):e14059. doi: 10.5812/jjhs.14059.

Published online 2018 January 1. **Research Article**

Analysis of Contamination Levels of Cu, Pb, and Zn and Population Health Risk via Consumption of Processed Meat Products

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Received 2017 May 28; **Revised** 2017 June 11; **Accepted** 2017 July 11.

Abstract

Background: Due to the world research for non-carcinogenic risk assessment of heavy metals in the processed meat products, the aim of the present study was to determine the contents of heavy metals (Cu, Pb, and Zn) and associated health risks through consumption of sausage and ham marketed in Hamadan city in 2016.

Methods: In this descriptive study, 30 samples from 10 brands of sausage and 30 samples from 10 brands of ham (totally 60 samples) were collected from the market basket of Hamadan city. After preparation and processing of the samples in the laboratory, the concentration of metals was determined using inductively coupled plasma-optical emission spectrometry. The health risk index (HRI) was assessed based on the ratio of average daily intake of metal (DIM) to the reference dose of the metal. All statistical analyses were performed using SPSS (version 20).

Results: The results showed that the mean concentrations (mg/kg) of Cu, Pb, and Zn were 1.88 ± 0.69, 0.35 ± 0.18, and 4.61 ± 1.71 in sausage samples and 1.48 ± 0.25, 0.32 ± 0.11, and 3.18 ± 1.28 in ham samples. Pb was higher than the maximum permissible level (0.20 mg/kg) in 80% of the samples. In addition, the computed health risk index showed no potential risk for adults and children via consumption of studied foodstuffs.

Conclusions: According to the results, the HRI values of analyzed processed meat products were within the safe limits and there was no potential health risk for human through the consumption of them under the current consumption rate. However, considering that the mean content of Pb in 80% of the samples exceeded the MPL, serious attention should be paid to the discharge of pollutants to the environment, chemicals residue monitoring especially for toxic heavy metals in foodstuff, and control of heavy metals content during the whole production process of sausage and ham.

Keywords: Food Safety, Heavy Metals, Health Risk, Processed Meat Products, Average Daily Intake

1. Background

Heavy metals are the most dangerous pollutants that are generated by natural and anthropogenic activities (industries, urbanization, mining, etc.). They can cause serious adverse health effects to human because of some characteristics such as very long half-life, no biodegradability, and bioaccumulation. Therefore, due to the presence of heavy metals in the environment, the human is exposed to them especially via food consumption (1, 2).

Some toxic heavy metals are deposited as residues in food, during processing. They may be very harmful even at low levels when ingested over a long time (3, 4).

Copper known as an essential nutrient for good health is necessary for body pigmentation. In addition to Fe, it has roles in the prevention of anemia and the maintenance of a healthy central nervous system. Its role is interrelated with the function of Fe and Zn in the body. However, it is toxic and can cause adverse health effects such as liver and kidney damage or even death of animals, by acute or chronic intoxications if its level exceeds the maximum permitted values (5-9).

Lead is well known for its toxic and adverse health effects on public health especially development of abnormalities, deficits in intelligence quotient, and neurotoxic effects in infants. It can cause constipation, colic, and anemia in human (6-8, 10).

Zinc similar to Cu plays an important role in biological systems and therefore, known as an essential element (9, 11). The main roles of this element can be described as functional and structural. Functionally, it is involved as a catalyst in enzymatic systems by binding to substrates, thereby favoring various reactions, especially in the meditation of redox reactions. Structurally, Zn functions as a critical component of important biological molecules (12-15). It should be noted that despite this element is vital for growth, Zn may play an important role in cancer incidence and harm some physiological activities like breathing (16, 17).

In general, Pb accumulates in the plants and animals and therefore its content is magnified in the food chain. In addition, in some cases, high levels of Zn and Cu in feeds for livestock and poultry can cause contamination of produced manure. Therefore, if this manure is applied to agricultural land as organic fertilizer, it will lead to the pollution of land with heavy metals resulting in a pollution risk for human or other animals that are fed with the plants issued from that field (2, 18, 19).

Throughout the past few decades, human population has faced changes in lifestyle and food habits. Therefore, the demand has increased for processed foods especially cow's meat products including sausage and ham. In this regard, the rise of food production and subsequent development of processing technologies has increased the chance of food contamination with various pollutants, especially toxic heavy metals (2).

Risk assessment is a part of risk analysis, the results of which are qualitative or quantitative explanations of the likelihood of harm associated with exposure to a chemical. In this regard, the human health risk assessment requires identification, collection, and integration of information on the chemicals health hazards, exposure of human to the chemicals, and relationships between exposure, dose, and adverse effects (16, 20).

2. Objectives

In view of the concern for food safety, this study for the first time in Iran was conducted to determine the levels and non-carcinogenic risk assessment of Cu, Pb and Zn in 10 different brands of beef sausage and ham marketed in Hamedan city in 2016.

3. Methods

3.1. Sample Collection

In this study, according to the Cochran's sample size formula, 30 samples from 10 major brands of three types of beef sausage (German, frankfurter, and cocktail) and 30 samples from 10 major brands of three types of beef ham (martadella, dry, and jambon) consumed in Iran were purchased from different markets in Hamadan city and used for analysis of concentration of Cu, Pb, and Zn.

3.2. Chemicals and Reagents

Standard stock solutions of different metal ions at the concentration of 1000 μg/mL were used to prepare working solutions after appropriate dilution (4). Standard solutions were of analytical grade (Sigma-Aldrich, Spain). Distilled deionized water was used in all dilution procedures.

3.3. Chemical Analyses

10 g of each sample was accurately weighed and transferred to 150 mL flasks. A mixture of high-purity HNO_3-H_2SO_4 (12:2 v/v) (Merck, Germany) was added. The samples were left at room temperature overnight. Then the glass funnels were inserted into the flasks for refluxing and gradually heated on the hot plate. The presence of sulfuric acid prevented the solution from drying out at increased temperature. However, sulfuric acid could cause charring and if this occurred, as in the case of foods with a high carbohydrate or fat content, nitric acid was added dropwise and refluxing continued. The digestion was completed with the appearance of white fumes of SO_3 or $HClO_4$. The entire procedure was also carried out for two blanks, containing the same amount of acids as the samples. Then, digested solutions were filtrated through a filter paper with blue ribbon and were transferred into graduated test tubes and made up to 20 mL with double-distilled water (ddH_2O) (4, 21). Finally, for Cu, Pb and Zn analyses with three replications, a Varian710-ES inductively coupled plasma-optical emission spectrometry was used in this study.

3.4. Statistical Analysis

The statistical analysis of the obtained results was conducted first with Shapiro-Wilk test for normality. The mean levels of heavy metals were compared with maximum permissible limits using a one-sample test. Finally, to compare the mean levels of heavy metals between the sausage and ham samples, Independent T Test was performed.

3.5. Analysis of Food-Related Health Risks

In the present study, human health risks posed by chronic exposure to the heavy metals were computed as follows:

First, the average daily intake of metal (DIM) was calculated using Equation 1 (22, 23):

$$DIM = \frac{C_{metal} \times C_{factor} \times D_{\text{food intake}}}{B_{\text{average weight}}} \tag{1}$$

here C_{metal}, C_{factor}, and D_{food} intake represent the heavy metal levels in analyzed foodstuffs (mg/kg), conversion factor (0.085), and daily intake of sausage and ham (8.20E0-3 kg per person per day) for the exposure duration (assumed 70 years), respectively. In addition, $B_{\text{average weight}}$ indicated average body weight equal to 70.0 kg for adults and 15.0 kg for children (22, 24, 25).

In the second step, the health risk index (HRI) was assessed for the local population via the consumption of sausage and ham using Equation 2 (22, 23):

$$HRI = \frac{DIM}{RfD} \quad (2)$$

In this equation, DIM and RfD indicate daily intake of metal (mg) and reference dose of metal (mg/kg/day), respectively. The oral reference doses were 0.04, 0.0035, and 0.30 for Cu, Pb, and Zn, respectively. An HRI < 1 means that the exposed population is assumed to be safe (26, 27).

The total HRI (THRI) of heavy metals for sausage and ham was calculated according to Equation 3 (22, 23):

$$THRI = \text{HRI (toxicant 1)} + \text{HRI (toxicant 3)} + \cdots + \text{HRI (toxicant n)} \quad (3)$$

4. Results

The contents of Cu, Pb, and Zn in the analyzed samples are presented in Table 1. Data in Table 1 show that the percentage of metals contamination of sausage and ham samples reached 100%. Among the analyzed samples, Cu was detected in amounts ranging from 1.13 to 3.00 mg/kg for sausage and 1.20 to 2.00 mg/kg for ham. In addition, Pb was detected in amounts ranging from 0.15 to 0.70 mg/kg for sausage and 0.20 to 0.50 mg/kg for ham. Zn was detected in amounts ranging from 2.23 to 6.71 mg/kg for sausage and 1.13 to 5.77 mg/kg for ham.

Based on the independent one-sample t-test comparing the heavy metal contents in foodstuff samples with the maximum permissible levels (10.0, 0.20, and 50.0 mg/kg for Cu, Pb, and Zn, respectively) established by FAO/WHO for processed meat products including sausage and ham (28-31), it was revealed that the mean contents of Pb observed in all samples were higher than the MPL.

The results of independent samples t-test showed that there was a significant difference between sausage and ham samples in the mean contents of Zn; t (58) = 2.107, P = 0.049.

The Pearson's correlations analyses were performed on metal concentrations in sausage and ham samples to understand the relationships between them. Based on the results, we did not detect any significant correlation between Cu and Pb (r = -0.197, P = 0.586), Cu and Zn (r = 0.267, P = 0.456), and Pb and Zn (r = 0.148, P = 0.684) in sausage samples. In addition, there was no significant correlation between Cu and Pb (r = 0.416, P = 0.231), Cu and Zn (r = 0.501, P = 0.140), and Pb and Zn (r = 0.494, P = 0.147) in ham samples.

All the calculated HRI values of heavy metals were within the safe limits (HRI < 1) in the current study (Table 2). Furthermore, the THRI values in sausage samples, which varied from 1.05E-03 to 2.96E-03 for adults and from 3.64E-03 to 1.38E-02 for children, and in ham samples, which varied from 9.06E-04 to 2.11E-03 for adults and from 4.22E-03 to 9.85E-03 for children, were within the safe limits (THRI < 1). Therefore, we can conclude that people might have no potential significant health risk through only consuming the analyzed foodstuffs.

5. Discussion

5.1. Copper

In the present study, the mean contents of Cu (mg/kg) in Sausage and ham samples were 1.88 ± 0.69 and 1.48 ± 0.25, respectively, which were much lower than the MPL (10.0 mg/kg). In this regard, the mean levels of Cu were 0.22 ± 0.06 mg/kg in sausage (sosis) marketed in Turkey (4), 0.84 ± 0.12 mg/kg in sausage, and 0.73 ± 0.08 mg/kg in ham marketed in Romania (2). The results of evaluation of some heavy metals in sausage marketed in Saudi Arabia showed that the mean value of Cu in samples was 18.51 ± 0.54 mg/kg that was higher than the MPL (32). In addition, our results were in accordance with the results obtained by Santhi et al. (2008) who reported that Cu contents ranged 0.53 - 2.85 mg/kg in ham from Chennai, India (33).

5.2. Lead

The results showed that the mean contents of Pb were 0.35 ± 0.18 mg/kg in sausage samples and 0.32 ± 0.11 mg/kg in ham samples that were higher than the MPL (0.20 mg/kg) in 80% of both food product samples. Therefore, one needs to be cautious in the consumption of some brands of sausage and ham containing elevated levels of Pb. In this regard, control of the sources of this element in foodstuffs including industrial Pb aerosols, contaminated raw materials, shipping and/or processing of food, and the manufacture of processed meat products is recommended. Also, despite the mean levels of Pb in the analyzed samples were higher than the MPL, the computed health risk index of Pb showed no potential risk for adults and children via consumption of sausage and ham under the current consumption rate. In a recent study, Dasbasi et al. (2016) found an average content of 0.10 ± 0.03 mg/kg for Pb in sausage marketed in Turkey (4). Also, the mean levels of Pb were 0.82 ± 0.006 mg/kg in sausage and 0.65 ± 0.005 mg/kg in ham marketed in Romania (2), 15.43 ± 1.22 mg/kg in sausage marketed in Saudi Arabia (32), 0.088 ± 0.042 mg/kg for German, 0.39 ± 0.010 mg/kg for cocktail, 0.056 ± 0.020 mg/kg for hot dog, 0.046 ± 0.024 mg/kg for lyoner, 0.039 ± 0.006 mg/kg for dry, and 0.050 ± 0.019 mg/kg for jambon beef sausages consumed in Iran (34), and 1.35 ± 0.26 mg/kg and 1.97 ± 0.46 mg/kg respectively in sausage and ham marketed in Chennai, India (33).

Table 1. Residual Levels of Examined Heavy Metals in Processed Meat Product Samples (mg/kg, Wet Weight)

Metal	Min.	Max.	Mean	S.D
		Sausage		
Cu	1.13	3.00	1.88	0.69
Pb	0.15	0.70	0.35	0.18
Zn	2.23	6.71	4.61	1.71
		Ham		
Cu	1.20	2.00	1.48	0.25
Pb	0.20	0.50	0.32	0.11
Zn	1.13	5.77	3.18	1.28

5.3. Zinc

In the current study, the mean concentrations of Zn (mg/kg) in sausage and ham samples were 4.61 ± 1.71 and 3.18 ± 1.28, respectively, which were much lower than the MPL (50.0 mg/kg). The mean contents of Zn (mg/kg) in the literature have been reported to be 10.10 ± 0.50 in sausage consumed in Turkey (4), 38.40 ± 1.03 and 33.50 ± 2.68 in sausage and ham, respectively, marketed in Romania (2), 65.43 ± 2.06 in sausage marketed in Saudi Arabia (32) and 35.72 ± 8.71 in sausage and 34.81 ± 7.16 in ham marketed in Chennai, India (33).

5.4. Health Risk Index Values Analysis

As shown in Table 2, HRI values of Cu, Pb, and Zn for children and adults are less than 1. Here, the average HRI value in sausage samples was 5.39E-04 for adults and 2.51E-03 for children and in ham samples, it was 4.61E-04 for adults and 2.16E-03 for children. Therefore, it can be concluded that target population might have no potential significant health risk through only consuming analyzed processed meat products under the current consumption rate from the study area. However, the non-carcinogenic risks were greater for children than for adults.

5.5. Conclusion

According to the results, although the mean levels of Cu and Zn were lower than the MPL (10.0 and 50.0 mg/kg for Cu and Zn, respectively), considering that the mean contents of Pb observed in 80% of all samples exceeded the MPL (0.20 mg/kg), serious attention should be paid to the discharge of pollutants to the environment, chemicals residue monitoring especially for toxic heavy metals in the foodstuffs, and control of heavy metals content during the whole production process of sausage and ham.

5.6. Research Limitations

Although the research has reached its aims, there were some unavoidable limitations as described below:

1. Due to the insufficient funds, there was no possibility for conducting the study on other processed meat products such as chicken sausage and ham.

2. The size, convenience, and homogeneity of the sample limit the generalizability of the results of this research to all processed meat products.

Acknowledgments

The author is grateful to the Hamadan branch, Islamic Azad university, for providing facilities to conduct and complete this study.

Footnotes

Authors' Contribution: Concepts, design, literature review, experimental studies, statistical analysis and manuscript preparation: Soheil Sobhanardakani.

Funding/Support: The author received financial support for this research (contract number: 50508942004) from Hamadan branch, Islamic Azad university.

Table 2. Daily Intakes of Metals (DIM, mg) and Health Risk Index (HRI) for Individual Heavy Metal Caused by the Analyzed Foodstuffs

	Cu	Pb	Zn
		Sausage	
Adults			
DIM	1.87E-05	3.48E-06	4.59E-05
STD	6.87E-06	1.79E-06	1.70E-05
Min	1.12E-05	1.49E-06	1.04E-04
Max	2.99E-05	6.97E-06	6.68E-05
HRI	4.68E-04	9.96E-04	1.53E-04
STD	1.72E-04	5.12E-04	5.67E-05
Min	2.81E-04	4.27E-04	3.45E-04
Max	7.47E-04	1.99E-03	2.23E-04
Children			
DIM	8.73E-05	1.63E-05	2.14E-04
STD	3.21E-05	8.36E-06	7.94E-05
Min	5.25E-05	6.97E-06	1.04E-04
Max	1.39E-04	3.25E-05	3.12E-04
HRI	2.18E-03	4.65E-03	7.14E-04
STD	8.02E-04	2.39E-03	2.65E-04
Min	1.31E-03	1.99E-03	3.45E-04
Max	3.48E-03	9.29E-03	1.04E-03
		Ham	
Adults			
DIM	1.47E-05	3.19E-06	3.17E-05
STD	2.49E-06	1.09E-06	1.27E-05
Min	1.19E-05	1.99E-06	1.12E-05
Max	1.99E-05	4.98E-06	5.74E-05
HRI	3.68E-04	9.10E-04	1.06E-04
STD	6.22E-05	3.13E-04	4.25E-05
Min	2.99E-04	5.69E-04	3.75E-05
Max	4.98E-04	1.42E-03	1.91E-04
Children			
DIM	6.88E-05	1.49E-05	1.48E-04
STD	1.16E-05	5.11E-06	5.95E-05
Min	5.58E-05	9.29E-06	5.25E-05
Max	9.29E-05	2.32E-05	2.68E-04
HRI	1.72E-03	4.26E-03	4.92E-04
STD	2.90E-04	1.46E-03	1.98E-04
Min	1.39E-03	2.66E-03	1.75E-04
Max	2.32E-03	6.64E-03	8.94E-04

References

1. Harmanescu M, Alda LM, Bordean DM, Gogoasa I, Gergen I. Heavy metals health risk assessment for population via consumption of vegetables grown in old mining area; a case study: Banat County, Romania. *Chem Cent J*. 2011;**5**:64. doi: 10.1186/1752-153X-5-64. [PubMed: 22017878].
2. Vasile Hoha G, Costachescu, E , Leahu, A , Pasarin, B . Heavy metals contamination levels in processed meat marketed in Romania. *Environ Eng Manage J*. 2014;**13**(9):2411–5.
3. Lo Coco F, Monotti P, Cozzi F, Adami G. Determination of cadmium and lead in fruit juices by stripping chronopotentiometry and comparison of two sample pretreatment procedures. *Food Control*. 2006;**17**(12):966–70. doi: 10.1016/j.foodcont.2005.06.015.
4. Dasbasi T, Sacmaci S, Ulgen A, Kartal S. Determination of some metal ions in various meat and baby food samples by atomic spectrometry. *Food Chem*. 2016;**197**(Pt A):107–13. doi: 10.1016/j.foodchem.2015.10.093. [PubMed: 26616930].
5. Uluozlu OD, Tuzen M, Mendil D, Soylak M. Trace metal content in nine species of fish from the black and Aegean seas, Turkey. *Food Chem*. 2007;**104**(2):835–40. doi: 10.1016/j.foodchem.2007.01.003.
6. Duran A, Tuzen M, Soylak M. Trace metal contents in chewing gums and candies marketed in Turkey. *Environ Monit Assess*. 2009;**149**(1-4):283–9. doi: 10.1007/s10661-008-0202-0. [PubMed: 18253850].
7. Iwegbue CM. Concentrations of selected metals in candies and chocolates consumed in southern Nigeria. *Food Addit Contam Part B Surveill*. 2011;**4**(1):22–7. doi: 10.1080/19393210.2011.551943. [PubMed: 24779658].
8. Hariri E, Abboud MI, Demirdjian S, Korfali S, Mroueh M, Taleb RI. Carcinogenic and neurotoxic risks of acrylamide and heavy metals from potato and corn chips consumed by the Lebanese population. *J Food Compos Anal*. 2015;**42**:91–7. doi: 10.1016/j.jfca.2015.03.009.
9. Sobhanardakani S, Hosseini SV, Miandare HK, Faizbakhsh R, Harsij M, Regenstein JM. Determination of Cd, Cu, Mn and Zn concentrations in Iranian Caspian sea caviar of acipenser persicus using anodic stripping voltammetry. *Iran J Sci Technol*. 2017;**41**(1):139–44. doi: 10.1007/s40995-017-0217-x.
10. Uluozlu OD, Kinalioglu K, Tuzen M, Soylak M. Trace metal levels in lichen samples from roadsides in East Black Sea region, Turkey. *Biomed Environ Sci*. 2007;**20**(3):203–7. [PubMed: 17672210].
11. Ibrahim HS, Ibrahim MA, Samhan FA. Distribution and bacterial bioavailability of selected metals in sediments of Ismailia Canal, Egypt. *J Hazard Mater*. 2009;**168**(2-3):1012–6. doi: 10.1016/j.jhazmat.2009.02.132. [PubMed: 19342171].
12. Tuzen M, Sari, H , Soylak M. Microwave and wet digestion procedures for atomic absorption spectrometric determination of trace metals contents of sediment samples. *Anal Lett*. 2004;**37**:1925–36. doi: 10.1081/AL-120039436.
13. Mendil D, Demirci Z, Tuzen M, Soylak M. Seasonal investigation of trace element contents in commercially valuable fish species from the Black sea, Turkey. *Food Chem Toxicol*. 2010;**48**(3):865–70. doi: 10.1016/j.fct.2009.12.023. [PubMed: 20036302].
14. Sobhanardakani S, Jafari SM. Assessment of heavy metals (Cu, Pb and Zn) in different tissues of common carp (Cyprinus carpio) caught from Shirinsu wetland, western Iran. *J Chem Health Risk*. 2014;**4**(2):47–54.
15. Hosseini SV, Sobhanardakani S, Miandare HK, Harsij M, Regenstein JM. Determination of toxic (Pb, Cd) and essential (Zn, Mn) metals in canned tuna fish produced in Iran. *J Environ Health Sci Eng*. 2015;**13**:59. doi: 10.1186/s40201-015-0215-x. [PubMed: 26266037].
16. Sobhanardakani S. Health risk assessment of As and Zn in canola and soybean oils consumed in Kermanshah, Iran. *J Adv Environ Health Res*. 2016;**4**(2):62–7.
17. Sobhanardakani S, Taghavi L. Analysis and health risk assessment of arsenic and zinc in ghee consumed in Kermanshah city, western Iran using atomic absorption spectrometry. *J Chem Health Risk*. 2017;**7**(1):71–6.
18. Poulsen HD. Zinc and copper as feed additives, growth factors or unwanted environmental factors. *J Anim Feed Sci*. 1998;**7**(Suppl. 1):135–42. doi: 10.22358/jafs/69961/1998.
19. Halliwell D, Turoczy N, Stagnitti F. Lead concentrations in Eucalyptus sp. in a small coastal town. *Bull Environ Contam Toxicol*. 2000;**65**(5):583–90. [PubMed: 11014841].
20. Sobhanardakani S. Tuna fish and common kilka, health risk assessment of metal pollution through consumption of canned fish in Iran. *J Consum Prot Food Safety*. 2017;**12**(2):157–63. doi: 10.1007/s00003-017-1107-z.
21. Tinggi U, Reilly C, Patterson C. Determination of manganese and chromium in foods by atomic absorption spectrometry after wet digestion. *Food Chem*. 1997;**60**(1):123–8. doi: 10.1016/s0308-8146(96)00328-7.
22. Omar WA, Zaghloul KH, Abdel-Khalek AA, Abo-Hegab S. Risk assessment and toxic effects of metal pollution in two cultured and wild fish species from highly degraded aquatic habitats. *Arch Environ Contam Toxicol*. 2013;**65**(4):753–64. doi: 10.1007/s00244-013-9935-z. [PubMed: 23843042].
23. Lei B, Zhang K, An J, Zhang X, Yu Y. Human health risk assessment of multiple contaminants due to consumption of animal-based foods available in the markets of Shanghai, China. *Environ Sci Pollut Res Int*. 2015;**22**(6):4434–46. doi: 10.1007/s11356-014-3683-0. [PubMed: 25315930].
24. Falco G, Llobet JM, Bocio A, Domingo JL. Daily intake of arsenic, cadmium, mercury, and lead by consumption of edible marine species. *J Agric Food Chem*. 2006;**54**(16):6106–12. doi: 10.1021/jf0610110. [PubMed: 16881724].
25. Tang W, Cheng J, Zhao W, Wang W. Mercury levels and estimated total daily intakes for children and adults from an electronic waste recycling area in Taizhou, China: Key role of rice and fish consumption. *J Environ Sci (China)*. 2015;**34**:107–15. doi: 10.1016/j.jes.2015.01.029. [PubMed: 26257353].
26. Karimi M, Tayebi L, Sobhanardakani S. Pb and Cd in medicinal plants, (case study, Shirazi thyme, sweet violet, pennyroyal and jujube). *J Kermanshah Univ Med Sci*. 2016;**20**(3):111–6.
27. Sobhanardakani S. Potential health risk assessment of Cr, Cu, Fe and Zn for human population via consumption of commercial spices, a case study of Hamedan city, Iran. *Int Arch Health Sci*. 2016;**3**(3):119–24. doi: 10.18869/iahs.3.3.119.
28. Mariam I, Iqbal S, Nagra SA. Distribution of some trace and macro minerals in beef, mutton and poultry. *Int J Agric Biol*. 2004;**6**:16–820.
29. Salama A, Radwan M. Heavy metals (Cd, Pb) and trace elements (Cu, Zn) contents in some foodstuffs from the Egyptian market. *Emir J Food Agric*. 2005;**17**(1):34. doi: 10.9755/ejfa.v12i1.5046.
30. Demirezen D, Uruc K. Comparative study of trace elements in certain fish, meat and meat products. *Meat Sci*. 2006;**74**(2):255–60. doi: 10.1016/j.meatsci.2006.03.012. [PubMed: 22062833].
31. Nasser LA. Molecular identification of isolated fungi, microbial and heavy metal contamination of canned meat products sold in Riyadh, Saudi Arabia. *Saudi J Biol Sci*. 2015;**22**(5):513–20. doi: 10.1016/j.sjbs.2014.08.003. [PubMed: 26288552].
32. Alturiqi AS, Albedair LA. Evaluation of some heavy metals in certain fish, meat and meat products in Saudi Arabian markets. *Egypt J Aquat Res*. 2012;**38**(1):45–9. doi: 10.1016/j.ejar.2012.08.003.
33. Santhi D, Balakrishnan VB, Kalaikannan A, Radhakrishnan KT. Presence of heavy metals in pork products in Chennai, (India). *Am J Food Technol*. 2008;**3**(3):192–9. doi: 10.3923/ajft.2008.192.199.
34. Abedi A, Ferdousi R, Eskandari S, Seyyedahmadian F, Khaksar R. Determination of lead and cadmium content in sausages from Iran. *Food Addit Contam Part B Surveill*. 2011;**4**(4):254–8. doi: 10.1080/19393210.2011.637236. [PubMed: 24786248].