INDONESIAN JOURNAL OF SOCIAL AND ENVIRONMENTAL ISSUES (IJSEI)
Journal Homepage: https://ojs.literacyinstitute.org/index.php/ijsei
ISSN: 2722-1369 (Online)
Research Article

Volume 3	Issue 2	August (2022)	DOI: 10.47540/ijsei.v3i2.488	Page: 159 – 166

Assessment of Heavy Metal Contamination in Liver, Gizzard, and Brain of Parent, Broiler, Layer, and Domestic Poultry Chickens in Dhaka, Bangladesh: A Threat to Bangladeshi Chicken Consumers

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ARTICLE INFO

Keywords: Domestic Poultry; Environmental Deposition; Heavy Metal.

Received : 30 March 2022
Revised : 29 August 2022
Accepted : 30 August 2022

ABSTRACT

The presence of heavy metals in poultry chicken which climbs up to the body through the regular food chain is a matter of prime concern for health safety issues. A total of five types of chicken were collected from Kaptan Bazar, Gulistan, Dhaka, and three samples from each namely liver, gizzard, and brain were analyzed by using AAS (Atomic Absorption Spectrophotometer) to detect the concentration of heavy metals which are Cadmium (Cd), Chromium (Cr), Lead (Pb) and Zinc(Zn). The founding concentration are (2.486,2.490 and 2.493), (0.998,1.497 and 1.689), (2.498,0.998 and 0.999), (2.497,0.998 and 0.998), (0.999,1.495 and 1.781) mg/kg for Cd, (3.381,1.544 and 1.096), (1.048,2.245 and 1.746), (2.340,4.732 and 2.498), (0.499,0.848 and 2.495), (1.999,1.395 and 0.950) mg/kg for Cr,(7.458, 7.931 and 7.977), (5.190,10.479 and 9.008), (13.443,8.982 and 8.548), (2.397,6.483 and 4.141), (1.849,1.198 and 1.306) mg/kg for Pb and (32.430,49.810 and 58.421), (348.52, 474.051 and 619.648), (BDL), (153.476, 98.528 and 149.700), (68.267,74.775 and 53.778) mg/kg for Zn in the liver, gizzard and brain of parent, broiler, layer, domestic and cockerel chicken respectively. All the concentration found in the sample exceeds the recommended value set by WHO/FAO. A precautionary measure should be taken for proper waste management and public awareness need to be raised to resist the exposure of heavy metal from an industrial zone to the open place.

INTRODUCTION

The meat of poultry chicken is a vital source of protein to meet up the nutritional demand of the body for growth and nourishment which are cheaply available throughout the country like Bangladesh produced by different poultry firms. Despite having such great nutritional value, the attribute of meat is deteriorated by the deposition of heavy toxic metals resulting from heavy industrialization and environmental pollution greatly. Heavy hazardous metals typically do not degrade due to their extended biological half-lives and propensity to concentrate in various human organs, which can result in negative side effects and other issues (Jarup et al., 2003; Banerjee et al., 2011). The liver, brain, and gizzard of chickens are readily accessible in Bangladeshi local markets at low prices, either bought from various sources or from locally bred and butchered chicken. Heavy metals like Cadmium, Lead, Chromium, and Zinc are likely to trace in those poultry chickens which mainly originated from the feed or drinking water of the chicken as well as from the feed or through rearing processes. Accumulation of such heavy toxic substances is a great concern for the present world because the gradual reach of these heavy toxic metals through the food chain imparts a risky health hazard to the human body. Those heavy metals have detrimental effects on the human body. The negligible concentration of such heavy metal is desirable but the increased value above the permissible limit inflicts environmental imbalance and causes various diseases like diabetes, high blood pressure, children's defects, etc of the human body climbing through the food chain directly or indirectly inhibiting the normal biological activity.

Cadmium is a very poisonous metal that hardens and destroys the human body including toughens the tissues and hardening the arteries. It affects the cardiovascular system and has a toxic impact on the kidney in several ways which cause sudden cardiac death, peripheral arterial disease (A. Navas-Acien et al., 2005) increased vascular intimae media thickness, and myocardial infarction. Lead causes anemia, a rise in blood pressure, kidney damage, miscarriages, and covert abortions, harm to the neurological and nervous system, brain damage, and other problems. The trivalent form of chromium requires trace amounts for human health but the hexavalent form of chromium is carcinogenic for health and accumulates in the body through the regular food chain. Consuming large amounts of zinc also causes stomach cramps, nausea, and vomiting. Previously many similar studies were conducted tracing heavy metals in poultry chicken in various regions of different countries. The purpose of this article was to highlight the toxicity levels in the consumer food chain comprising heavy metals cadmium, chromium, lead, and zinc. This study also demands the implementation of proper waste management in industrial areas. Considering the following objective five types of chicken were collected from Kaptan Bazar, Dhaka which is normally found in Bangladesh, and the concentration of heavy metals was assessed within the food chain.

MATERIALS AND METHODS

Sampling location

The study was carried out in 2020 in the major city of Bangladesh Capital Dhaka city. The sample was collected from the main poultry market in Dhaka city which was named Kaptan Bazar. It's situated in Gulistan in Dhaka and is the biggest poultry market.

Sample collection

Different tissues like the liver, gizzard, and brain are used for the analysis of heavy metals. To find environmental deposition of Cadmium (Cd), Chromium (Cr), Lead (Pb), and Zinc, four samples from each category were taken from Kaptan Bazar, the largest chicken market located in an industrial district in Dhaka and the city's primary poultry market (Zn). The quantities of the metals Cadmium (Cd), Chromium (Cr), Lead (Pb), and Zinc (Zn) in the samples were calculated and expressed in milligrams per kilogram (ppm, parts per million). Total of five types of chickens from commercial poultry farms were used in this study.

Parent (which Plymouth rock),
Broiler (Rhode Islam write)
Layer (Isa Brown),
Cock (cockerels) and
Gallus

Sample Preparation

The procedure for sample preparations in this study was been adopted from the analytical techniques presented in (Belton et al., 2006). The harvested tissues and organs were cleaned and washed with deionized water. They were cut into small size pieces with a stainless-steel knife and oven-dried at 1000 C for about 72 until a constant weight was obtained. After the samples were dried, then were pounded into a fine powder with a ceramic pestle and mortar and kept in a glass bottle until the acid digestion process.

Sample Digestion

0.5g sample was taken by measuring in a chemical balance and then digested by 10ml of HNO3 (65%) at 2000c in a microwave digestion system (CEM, model: MARS 240/50). The resultant solution was then poured into a volumetric flask measuring 25 ml that had been filled to the proper level with deionized water. The digested samples were then filtered and kept in a plastic bottle that had been cleaned with nitric acid for analysis. These samples were kept at room temperature until metal content analysis was carried out by flame AAS. Flame Atomic Absorption Spectrophotometer (FAAS), model Analyst 200 and Analyst 800. Samples were then aspirated through a nebulizer and the absorbance was measured with a blank as reference. The sample had to be diluted by many folds to keep the result in the analytical range.

Instrumentation

AAS (Atomic Absorption Spectrophotometer) was utilized in this investigation to examine the samples that were collected. The Atomic Absorption Spectrophotometer (AAS) was used to measure the amounts of Cadmium (Cd), Chromium (Cr), Lead (Pb), and Zinc (Zn) in various samples that were collected, by the manufacturer's instructions.

Lamp type : Specific hollow cathode lamp was used to analyze the sample.

Flame type : The type of flame was air acetylene.

Photometer type : Single beam.

All statistical analyses were performed with windows (Open office program).

RESULTS AND DISCUSSION

Table 1 shows the concentration of heavy metal found in the different genres of chicken.

Table 1. Presence of heavy metals in the following sample

Type of Chicken	Parts of Chicken	Cadmium (Cd) (mg/kg)	Chromium (Cr) (mg/kg)	Lead (Pb) (mg/kg)	Zinc (Zn) (mg/kg)
Parent Chicken	Liver	2.486	3.381	7.458	32.430
	Gizzard	2.490	1.544	17.931	49.810
	Brain	2.493	1.096	7.977	58.421
Broiler Chicken	Liver	0.998	1.048	5.190	348.520
	Gizzard	1.497	2.245	10.479	474.051
	Brain	1.689	1.746	9.008	619.648
Layer Chicken	Liver	2.489	2.340	13.443	BDL
	Gizzard	0.998	4.732	8.982	BDL
	Brain	0.999	2.498	8.548	BDL
Domestic Chicken	Liver	2.497	0.499	2.397	153.476
	Gizzard	0.998	0.848	6.483	98.528
	Brain	0.998	2.495	4.141	149.700
Cockerel Chicken	Liver	0.999	1.999	1.849	68.267
	Gizzard	1.495	1.395	1.198	74.775
	Brain	1.781	0.950	1.306	53.778

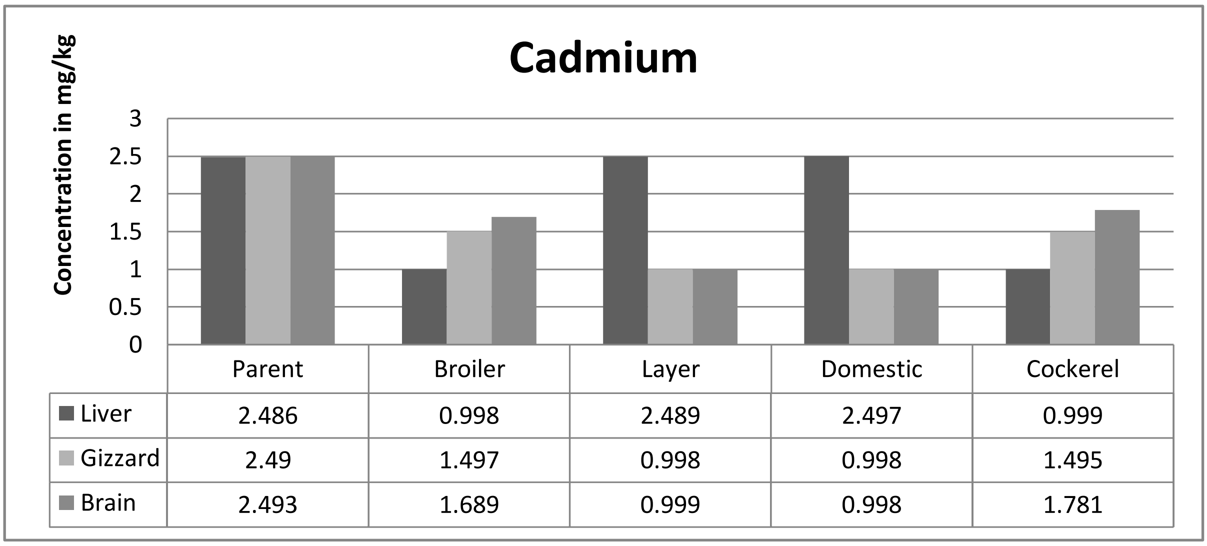
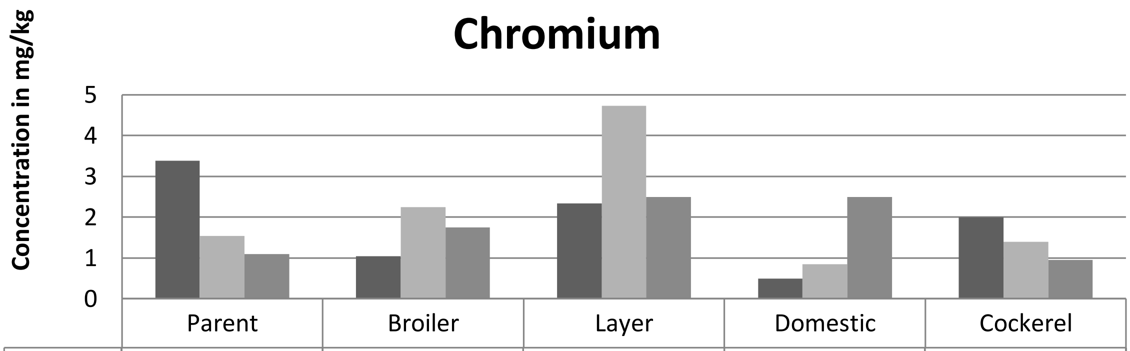


Figure 1. The concentration of Cd in all sample

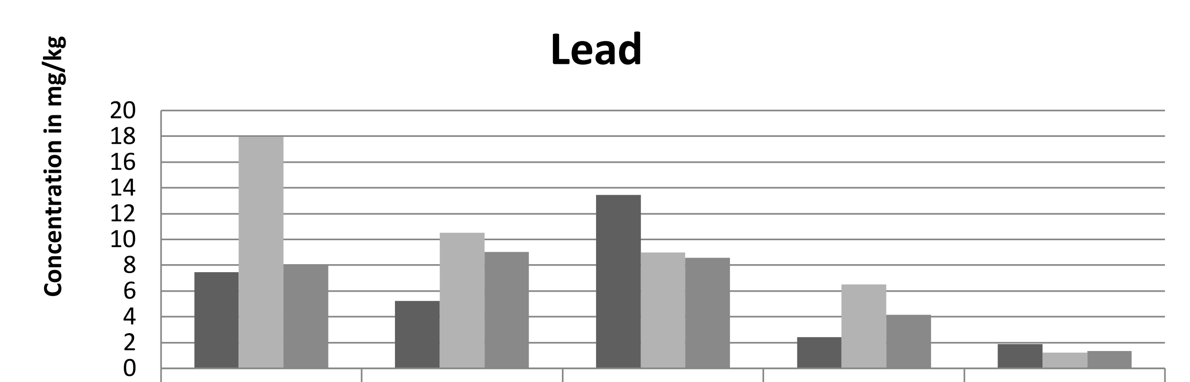
From the analysis, it was seen from figure 1 that the concentration of Cd in the liver, gizzard, and brain of parent chicken were 2.486, 2.490, 2.493 mg/kg respectively which were comparatively somewhat greater than other chicken samples. The lowest amount of concentration of Cd was found in the liver of broiler chicken following gizzard and brain of layer and domestic chicken which were 0.998 mg/kg. Cd is a highly toxic metal that was found highest in the liver of domestic chicken which was 2.497 mg/kg. Besides cockerel samples contain Cd concentrations of 0.999, 1.495, 1.781 mg/kg in the liver, gizzard, and brain. The Cd level found in this analysis was lower than the Cd level found in the study of Rahman et al., (2014) which was 3.33-16.67 mg/kg. kg However the maximum Cd presence in feed has been set by European Union at 0.5 mg/kg (European Commission et al., 2003) for all animal species but the value of Cd concentration in this study exceeds that limit. Again, the levels of cadmium found in this study were greater than those identified in previous studies, which found values of 0.012-0.008-0.227 mg/kg (Abdolgader RE et al., 2013) and 0.45-2.23 mg/kg (Mottaleb et al., 2016) in various tissues of the chicken sample, respectively. In addition, the average Cd concentration across all chicken tissues in the study (Al-Bratty et al., 2018) was found to be 0.006 mg/kg, which was lower than the results of this study and was in line with other values found in the previous analysis in Iraq (0.095 mg/kg; Al-Zuhairi et al., 2015); Malaysia (0.159 mg/kg; Abduljaleel et al., 2012); Nigeria (0.29) mg/ (Sadeghi et al., 2015).



	Parent	Broiler	Layer	Domestic	Cockerel
Liver	3.381	1.048	2.34	0.499	1.999
Gizzard	1.544	2.245	4.732	0.848	1.395
Brain	1.096	1.746	2.498	2.495	0.95

Figure 2. The concentration of Cr in all sample

Figure 2 denoted the presence of Cr in the analysis ranging from 0.499 -to 4.732 mg/kg. The liver, gizzard, and brain of layer chicken contained a notable amount of Cr concentrations which are 2.340, 4.732, 2.498 mg/kg comprising the highest in the gizzard among all other types of chicken. But the lowest amount was traced in the liver of domestic chicken which was 0.4999 mg/kg following gizzard and brain of domestic and cockerel chicken in 2nd and 3rd lowest denoting 0.848 and 0.950 mg/kg. 3.381 mg/kg concentration was found in the liver sample of parent chicken which was 2nd highest in figure 2. The highest Cr level (0.18 mg/kg) was found in the liver and brain of chicken in the study (Al-Bratty et al., 2018) which was lower than the value of this analysis. Besides the founding value of Cr was higher than the values from the study ranging from 0.1-2.440 mg/kg (Bari ML et al., 2015) and 0.01–3.43 mg/kg (Iwegbue CM et al., 2008). Again, according to (USEPA et al., 1989) the maximum acceptable limit for Cr in meat is 1 mg/kg but the detected value of Cr in this study is much higher than the above limit. The value of Cr found in the analysis of (Mottaleb et al., 2018) at 96.62 mg/kg was also much more compared to the finding value of this study. The trace value of Cr in this study (4.732 mg/kg) was higher than the permissible limit of WHO (FAO/WHO et al., 2011).



	Parent	Broiler	Layer	Domestic	Cockerel
Liver	7.458	5.19	13.443	2.397	1.849
Gizzard	17.931	10.479	8.982	6.483	1.198
Brain	7.977	9.008	8.548	4.141	1.306

Figure 3. The concentration of Pb in all sample

From figure 3 heavy metals like Pb also dominated in the analysis comprising ranging from 17.931-1.198 mg/kg. The highest and lowest were found both in the gizzard of parent and cockerel chicken samples with the above range. Pb is a highly toxic metal and undesirable in the food chain but the concentration found in the parent chicken sample was 7.458,17.931,7.977 mg/kg and 5.190,10.479,9.008 mg/kg in the liver, gizzard, and brain of broiler chicken respectively which are greater than the other 3 samples in total. Cockerel chicken contained a low amount of Pb among the rest of other samples with 1.849, 1.198, 1.306 mg/kg concentrations. Besides domestic and layer chicken samples contained 2.397, 6.483, 4.141 mg/kg, and 13.443, 8.982, 8.548 mg/kg in liver, gizzard, and brain. Even the lowest amount of Pb was found in the gizzard of cockerel chicken (1.198mg/kg) which exceeds the permissible limit of 0.1 mg/kg (FAO/ WHO et al., 2002 Codex Alimentarius Commission) and 0.1 mg/kg (European Commission et al., 2006). This result is even more than many reports found in Saudi Arabia 0.14 mg/kg (Al Bratty et al., 2018) and in Nigeria 0.171 mg/kg (Ogbomida et al., 2018). Besides range with 0.01–4.60 mg/kg (IwegbueCM et al., 2008) and 0.257-1.750 mg/kg (IwegbueCM et al., 2015) were reported in the previous study were likely to find low than the range of this study. Maximum lead levels were discovered in a brain sample. 1.10 mg/kg (Al-Bratty et al., 2018) which was also less than the lowest value of this analysis 1.198 mg/kg following Pb contents reported in the range from 0.13-0.38 mg/kg in Ghana (Bortey-Sam et al., 2015) respectively.

	Parent	Broiler	Layer	Domestic	Cockerel
Liver	32.43	348.52	0	153.476	68.267
Gizzard	49.81	474.051	0	98.528	74.775
Brain	58.421	619.648	0	149.7	53.778

Figure 4. The concentration of Zn in all sample

On the other hand, figure 4 depicts the presence of zinc being an essential element of the body that is required in sufficient amount for health was found in high concentration in brain sample of broiler chicken with a value of 619.648 mg/kg. The lowest amount was traced in the liver of the parent chicken having a value of 32.430 mg/kg. But no concentration was detected in the layer chicken sample. The maximum presence of zinc was found in a sample of broiler chicken's liver, gizzard, and brain consisting of 348.520, 474.051, and 619.648 mg/kg. Secondly domestic chicken contained 153.476, 98.528, and 149.700 mg/kg in the liver, gizzard, and brain respectively. Besides parent chicken contained 32.430, 49.810, and 58.421 mg/kg whereas cockerel chicken comprised 68.267, 74.775, and 53.778 mg/kg of Pb concentration.

According to the (European Commission et al., 2003) Zinc was listed as a nutrient in broiler starter and grower feeds at (50-110 mg/kg), finisher feed at (100-110 mg/kg), and layer feed at (50-70 mg/kg), but this analysis found the highest concentration of zinc in broiler chicken at (619.648 mg/kg), which was significantly higher than the aforementioned standard. Lean meat or poultry was found to contain 28.53 mg/kg of zinc according to Mariam et al. (2004), and samples evaluated in Saudi Arabia contained 20.72 mg/kg of zinc (Al Bratty et al., 2018), which was even lower than the lowest figure found in this study, 32.430 mg/kg. Again, zinc concentration was discovered to be lower than the average zinc concentration identified in this investigation, with values of 100.87 mg/kg recorded (Duman et al., 2019) in Turkey and ranging from 4.116- to 3.266 mg/kg reported at (Hussain et al, 2012). The value of Zn obtained in this investigation was significantly greater than the values reported for Turkey and Nigeria, which were reported to be 0.00121-0.0243 mg/kg (Uluozlu et al., 2009) and 0.00287 mg/kg (Onianwa et al., 2001), respectively.

CONCLUSION

The result of this study found the concentration of Cd, Cr, Pb, and Zn in different genres of chicken was higher than the recommended value of WHO/FAO and that heavy metals continue to transport from chicken to the human body through the food chain. Such presence of those toxic metals leads to carcinogenic effects on the human body causing kidney damage, cancer, liver heart diseases, hearing loss, urinary problem, nervous system damage, etc. That's why the proper dumping facility should be ensured for the wastes as they are very much harmful to human health and the environment. Monitoring and public awareness should be raised more on food items, especially poultry chicken which is a major route for entrance to the body. Besides maintenance of proper rules and regulations for waste management should be made obligatory and need to conduct more analyses on the safe food chain as well as contamination of heavy metals in the human body.

REFERENCES

A. Navas-Acien, E. KSlibergeld, A.R. Sharrett, E. Calderon-Aranda, E. Selvin and E. Guallar. (2005). Metals in urine and peripheral arterial disease. *Environmental Health Perspectives,* 2005,113(2), 164-169.

Abdolgader RE, Hussain RA, Hasan SM, Agoub AA. (2013). Quantitative determination of Cd and Pb in tissues and organs of chickens raised in El-Jabel Alakhder region-Libya. *Food Nutr Sci*. (4), 763-6.

Abduljaleel SA, Shuhaiml-Othman M, Babji A. (2012). Assessment of trace metals contents in chicken (Gallusgallusdomesticus) and quail (Coturnixcoturnixjaponica) tissues from Selangor (Malaysia). *J.Environ Sci Technol* 5:441–51.

Al-Bratty M, Alhazmi HA, Ogdi SJ, Otaiif JA, Al-Rajab AJ, Alam MF, Javed SA. (2018). Determination of heavy metals in various tissues of locally reared (Baladi) chicken in Jazanregion of Saudi Arabia: Assessment of potential health risks. *PakJZool*, 50:1509–17.

Aljaff P, Rasheed B, Salh DM. (2014). Assessment of heavy metals in livers of cattle and chicken by spectroscopic method. *J.Appl Phys*, (6), 23–6.

Al-Zuhairi W, Farhan M, Ahemd M. (2015). Determine heavy metals in the heart, kidney, and meat of beef, mutton, and chicken from Baquba and Howaydirmarket in Baquba, Diyala province, Iraq. *Int.J.Recent SciRes*, (6), 5965–7.

Banerjee D, Kuila P, Ganguli A, Das D, Mukherjee S and Ray L (2011). Heavy metal contamination in vegetables collected from market sites of Kolkata, India. Electronic *Journal of Environmental, Agricultural and Food Chemistry*, 10: 2160-2165.

Baykov BD, Stoyanov MP, Gugova ML. (1996). Cadmium and lead bioaccumulation in male chickens for high food concentrations. *Toxicological & Environmental Chemistry*, (54), 155–9.

Belton, P.S. (ed). (2006). *Trace Element Analysis of Food and Diet RSC Food Analysis Monographs Royal Society of Chemistry*. Tomas Graham House Science Park, Milton Road, Cambridge, CB40WF, UK 2006.

Bortey-Sam, N., Nakayama, S.M.M., Ikenaka, Y., Akoto, O., Baidoo, E., Yohannes, Y.B., Mizukawa, H. and Ishizuka, M., 2015. 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). *Ecotoxic. environ. Safe*, (111), 160-167.

Demirezen D, Uruç K. (2006). Comparative study of trace elements in certain fish, meat, and meat products. *Meat Sci*, (74), 255–60.

Duman E, Özcan EM, Hamurcu MM, Özcan MM. (2019). Mineral and Heavy MetalContents of Some Animal Livers. *Eur JSciTechnol* (15), 302–7.

EC (The Commission of the European Communities) 2006 Commission Regulation No. 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs. *Official Journal of the European Communities*, L 364/18-19.

FAO/WHO 2002 Codex Alimentarius, Schedule 1 of the proposed draft Codex general standards for contaminants and toxins in food. Joint FAO/WHO Food Standards Programme, Codex Committee, Rotterdam. Reference CX/FAC 02/16

FAO/WHO, 2011. Joint FAO/WHO food standards program Codex Committee on contaminants in foods fifth session working document for information and use in discussions related to contaminants and toxins in the GSCTFF (Prepared by Japan and the Netherlands). CF/5 INF/1.

Hunt CD, Shuler TR, Mullen LM. (1991). The concentration of boron and other elements in human foods and personal-care products. *J Am Diet Assoc*, (91), 558–68.

Hussain, R.Th., Ebraheem, M. Kh., Moker, H.M. 2012. Assessment of heavy metals (Cd, Pb, and Zn) contents in livers of chicken available in the local markets of Basrah city, Fraq. *Basrah J. Vet. Res*.11, 43-51.

Iwegbue CM, Nwajei GE, Iyoha EH. (2008). Heavy metal residues of chicken meat and gizzard and turkey meat consumed in Southern Nigeria. *Bulg J Vet Med*. 11(4):275-80.

Iwegbue CM, Simol HA, Khandokar N, Begum R, Sultana UN. (2015). Potential human health risks of tannery waste-contaminated poultry feed. *J Health Pollut* [Internet]. 5(9):68-77.

Jarup L. (2003). Hazards of heavy metal contamination. *British Medical Bulletin* (68), 167-182.

Kjellström T. (1992). Mechanism and epidemiology of bone effects of cadmium. *IARC Scientific Publications*, 1992:301–10.

López Alonso M, Benedito JL, Miranda M, Castillo C, Hernández J, Shore RF. (2002). Cattle as biomonitors of soil arsenic, copper, and zinc concentrations in Galicia (NW Spain). *Arch Environ Contam Toxicol*, (43), 103–8.

Madden EF, Fowler BA. (2000). Mechanisms of nephrotoxicity from metal combinations: a review. *Drug Chem Toxicol*, (23), 1–12.

Mariam, I., lqbal, S., Nagra, S.A. 2004. Distribution of some trace and mocro minerals in beef, mutton, and poultry. Int. J. AB 6, 816- 820.

Mottalib MA, Sultana A, Somoal SH, Abser MN. (2016). Assessment of heavy metals in tannery waste contaminated poultry feed and their accumulation in different edible parts of the chicken. *IOSR J Environ Sci Toxicol Food Technol*, 10(11), 72-8.

Mottalib MA, Zilani G, Suman TI, Ahmed T, Islam S. (2018). Assessment of trace metals in consumer chickens in Bangladesh. *J. Health and Pollut* (8), 1-10

Ogbomida ET, Nakayama SMM, Bortey-SamN, Oroszlany B, Tongo I, Enuneku AA, Ozekeke O, Oshioriamhe M, FasipeI R, Ezemonye LI, Mizukawa H, Ikenaka Y, Ishuzuka M. (2018). Accumulationpatterns and risk assessment of metals and metalloids in muscle and offal of free-range chickens, cattle, and goat in Benin City, Nigeria. *Ecotoxicol Environ Safety*, (151), 98–108

Onianwa, P.C., Adeyemo, A.O., Idowu, O.E. and Ogabiela, E.E., 2001. Copper and zinc contents of Nigerian foods and estimates of the adult dietary intakes. *Fd. Chem*., 72: 89-95.

Rahman MA, Kamal S, Salam A, Salam MA. (2014). Assessment of the quality of the poultry feed and its effect on poultry production in Bangladesh. *J. Bangladesh ChemSoc*. 27(1&2).

Sabath E, Robles-Osorio ML. (2012). Renal health and the environment: heavy metal nephrotoxicity. *Nefrologia*, (32), 279–86.

Sadeghi A, Hashemi M, Jamali-Behnam F, Zohani A, Esmaily H, Dehghan AA. (2015). Determination of Chromium, Lead, and Cadmium Levels in Edible Organs of Marketed Chickensin Mashhad, Iran. *J Food Qual Hazards Control* (2), 134-8.

Uluozlu, O.D., Tuzena, M., Mendila, D. and Soylak, M., 2009. Assessment of trace element contents of chicken products from Turkey. *J. Hazardous Materials*, 163: 982-987.

USEPA, 1989. Human health evaluation manual, EPA/540/1-89/002, Vol. I. Office of Solid Waste and Emergency Response. US Environmental Protection Agency. Washington, DC.