Environmental Science and Pollution Research (2019) 26:23002–23009
https://doi.org/10.1007/s11356-019-05639-4

RESEARCH ARTICLE

Public health risk of heavy metal residues in meat and edible organs of broiler in an intensive production system of a region in Pakistan

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Received: 28 April 2019 / Accepted: 29 May 2019 / Published online: 10 June 2019

Abstract
The aim of this study was to find the concentration of lead (Pb), cadmium (Cd), nickel (Ni), manganese (Mn), and zinc (Zn) in feed, drinking water, and their residues in meat and internal organs in broilers at three different locations in Charsadda. For this purpose, a total of 48 representative water and feed samples and 240 meat and internal organs of broilers were collected. Significantly ($P < 0.05$) higher concentrations of Zn and Mn were found in feed samples. In water samples assessed for heavy metals, a significantly ($P < 0.05$) higher concentration of Pb was observed at Umerabad and Kula Dher as compared with Nisatta whereas a significantly ($P < 0.05$) higher concentration of Ni was recorded at Umerabad as compared with Nisatta and Kula Dher. Similarly, a significantly ($P < 0.05$) higher concentration of Mn in water was recorded at Kula Dher as compared with Nisatta and Umerabad. The concentration of Pb in water at all locations and the concentration of Ni at Umerabad were above the maximum permissible limits. A significantly ($P < 0.05$) higher concentration of Pb in the liver, breast, and thigh muscles and a significantly ($P < 0.05$) higher concentration of Mn in the liver, gizzard, breast, and thigh muscles of broilers were recorded at Kula Dher. A significantly ($P < 0.05$) higher mean concentration of Pb, Cd, Ni, Mn, and Zn was recorded in the liver as compared with the gizzard, breast, and thigh muscles. It was concluded from the present study that broiler farms near the roadside/canal and waste disposal site/wastewater drains cause accomulaiton of high concentrations of some heavy metals in meat and internal organs of broiler birds.

Keywords Heavy metals · Broiler feed · Drinking water · Broiler farms · Meat · Internal organs

Introduction

Macrominerals are important dietary nutrients for poultry and livestock (Henry and Miles 2001; Khan et al. 2014. Both macro- and microelements can adversely affect human and animal health if the concentration of these elements is excessively high in the diet (Okoye et al. 2011; Rahman et al. 2014). The class of microelements that have adverse effects on human as well as animal health even at minute concentrations are called heavy metals. Because of bioaccumulation in living tissue and arrest of the intracellular biochemical processes, heavy metals are considered as the most toxic elements (Ghimpeteanu et al. 2012; Darwish et al. 2018). Heavy metals are potentially toxic, and the most important heavy metals are vanadium (V), cadmium (Cd), mercury (Hg), lead (Pb), copper (Cu), iron (Fe), cobalt (Co), manganese (Mn), and zinc (Zn) (Hu et al. 2018; Duman et al. 2019).

Heavy metals can enter the animal body through direct contact, contaminated water, vehicle emission, industrial discharges, crops irrigated on contaminated manure, and polluted slaughter houses (Oforka et al. 2012). Poultry meat can be contaminated by heavy metals through different sources like poultry feed, drinking water, and processing (Iwegbue et al. 2008). Some minerals are added in poultry feed as mineral supplements but, when their level exceeds above the

Responsible editor: Philippe Garrigues

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recommended limit, can accumulate in the body tissues of chicken and can be released in litter which ultimately pollutes the environment (McBride and Spiers 2001).

These pollutants often have direct pathological effects on nervous, cardiovascular, kidney, and bone disorders (Steenland and Boffetta 2000). To the best of our knowledge, the level of heavy metals (Cd, Pb, Mn, Ni, and Zn) in poultry feed and drinking water and their residues in poultry meat and internal organs have not been assessed in Charsadda, Khyber Pakhtunkhwa. Therefore, the present research work was planned to assess the level of heavy metals in poultry feed and drinking water and their residues in poultry meat and internal organs in Charsadda, Khyber Pakhtunkhwa.

Materials and methods

This study was approved by the Departmental Committee on Issues and Welfare of Animal, Faculty of Animal Husbandry and Veterinary Sciences, The University of Agriculture, Peshawar, Pakistan.

Collection of feed and water samples

A total of 48 representative feed and water samples, including 24 water and 24 feed samples, were collected from 12 broiler farms located at three different locations, i.e., Nisatta, Umerabad, and Kula Dher in Tehsil Charsadda, Khyber Pakhtunkhwa, Pakistan. Poultry farms at Nisatta were at least one km away from the main road with no canal/waste disposal site/wastewater drain nearby. Poultry farms at Umerabad were 300–800 m away from the main road with a solid waste disposal site and drain of wastewater nearby while poultry farms at Kula Dher were along the roadside with a Kula Dher canal nearby. At each location, four poultry farms were selected, and at each farm, four samples (two each of feed and water) were collected. The feed samples collected were of two different feed mills which were given the names as feed mill A and feed mill B. Farms at Nisatta and Umerabad were using feed of feed mill A, while farms at Kula Dher were using feed of feed mill B. Out of the total of 24 feed samples, 16 samples were of feed mill A and the remaining eight were of feed mill B. The feed and water samples were collected in clean polyethylene according to the method of the American Public Health Association (APHA 1995). All samples were labeled accordingly and stored in a refrigerator at 4 °C until analyzed. All collected feed samples were subjected to wet digestion for heavy metal analysis. All possible precautionary measures were taken to avoid contamination of the samples during collection and transportation.

Sample preparation and determination of heavy metals in feed

The method described by Abdulkhaliq et al. (2012) was used to determine heavy metals in feed samples through atomic absorption spectroscopy (Model Perkin Elmer 2380).

Determination of heavy metals in water

For determination of heavy metals including Pb, Ni, Mn, Cd, and Zn in water, 100 ml of each water sample was acidified with concentrated HNO_3 and analyzed using Perkin-Elmer 2380 atomic absorption spectroscopy (AAS) (Reddy et al. 2012) in the Department of Soil and Environmental Sciences, the University of Agriculture, Peshawar.

Collection of samples of meat and internal organs

The broiler farms having positive heavy metal(s) samples of feed and/or water were selected in order to find out the residues of heavy metals in meat (thigh, breast muscles) and internal organs (liver and gizzard) of broiler birds. For this purpose, five broiler birds were selected randomly at each positive farm and the samples of meat (thigh, breast muscles) and internal organs (liver and gizzard) were obtained. As all samples of feed and water were positive for heavy metals, so a total of 240 samples (60 samples each of breast muscles, thigh muscles, liver, and gizzard) were collected including 80 samples (20 each of breast muscles, thigh muscles, liver, and gizzard) at each location.

The samples of meat and internal organs were collected in clean polyethylene bags. All possible precautionary measures were taken to avoid contamination of samples during collection and transportation.

Sample preparation and determination of heavy metals in meat and internal organs

For determination of residues of heavy metals in meat and internal organs, the collected samples were first decomposed by the wet digestion method. The same procedure was employed for heavy metal determination in meat and internal organs as described for analysis of heavy metals in feed according to the method of Abdulkhaliq et al. (2012).

Statistical analysis

Collected data was subjected to one-way analysis of variance (ANOVA) to assess whether heavy metals varied significantly ($P < 0.05$) and was presented as mean and standard error (mean ± S.E.). Statistical analysis was performed on a computer using software "Statistix 8.1."

Results

Table 1 shows concentrations of heavy metals in feed samples of two different feed mills collected from different broiler farms in Tehsil Charsadda. Significant ($P < 0.05$) differences were recorded in the concentrations of Mn and Zn ($P < 0.05$) between feed samples of feed mill A and feed mill B. Significantly ($P < 0.05$) higher concentrations of Mn and Zn were found in feed samples of feed mill B and feed mill A, respectively. The order of heavy metals found in the samples of two feed mills was Zn > Mn > Pb > Ni > Cd.

Significant differences were observed only in concentrations of Pb, Ni, and Mn ($P < 0.05$) across different locations (Table 2). A significantly higher concentration of Ni was recorded at Umerabad as compared with Nisatta and Kula Dher. Similarly, a significantly higher concentration of Mn was recorded at Kula Dher as compared with Nisatta and Umerabad. The concentration of Mn recorded at Kula Dher was 15.53 and 7.25% higher than that at Nisatta and Kula Dher, respectively.

The concentrations of Pb in meat and internal organs of broilers across different locations in Tehsil Charsadda are presented in Table 3. Liver, thigh, and breast muscles collected from broiler birds at Kula Dher contained significantly higher concentrations of Pb as compared with Nisatta and Umerabad ($P < 0.05$). The concentration of Pb in gizzard across different locations was not statistically significant.

Concentrations of Cd in meat and internal organs of broiler birds across different locations in Tehsil Charsadda are presented in Table 4. Statistically, no significant difference was observed in meat and internal organs across different locations. However, numerically, the concentration of Cd at Nisatta was slightly higher in meat and internal organs than in other locations.

Concentrations of Ni recorded in the liver, gizzard, breast, and thigh muscles across different locations are presented in Table 5. Statistically, no significant difference was observed in the liver, gizzard, breast, and thigh muscles across different locations. But numerically, a higher Ni concentration was recorded in all body parts at Umerabad than in other locations. The liver had 13.46% and 18% higher concentrations of Ni at Umerabad than at Nisatta and Kula Dher, respectively. Similarly, gizzard had 14.70% and 18.18% and breast had 8.11% and 11.11% whereas thigh had 7.89% and 7.89% higher Ni concentrations at Umerabad than at Nisatta and Kula Dher, respectively.

Concentrations of Mn in meat and internal organs of broiler birds across 3 different locations in Tehsil Charsadda are presented in Table 6. All body parts, i.e., liver, gizzard, breast, and thigh muscles, collected from broiler birds at Kula Dher, had significantly higher concentrations of Mn as compared with Nisatta and Umerabad ($P < 0.05$). The concentration of Mn at Kula Dher was 41.02 and 34.15% higher in liver, 55 and 47.62% higher in gizzard, 52.17 and 40% higher in breast muscles, and 50 and 44% higher in thigh muscles when compared with meat and internal organs of Nisatta and Umerabad, respectively.

Concentrations of Zn recorded in meat and internal organs of broiler birds across different locations in Tehsil Charsadda are presented in Table 7. The liver, gizzard, breast, and thigh muscles, collected from broiler birds at Umerabad, had significantly higher concentrations of Zn in contrast to other locations ($P < 0.05$). The concentration of Zn at Umerabad was 35.74% and 43.22% higher in the liver; 21.43% and 29.44% higher in gizzard, 29.75% and 41.96% higher in breast muscles, and 34.02% and 43.38% higher in thigh muscles when compared with Nisatta and Kula Dher, respectively.

Mean concentrations of Pb, Cd, Ni, Mn, and Zn in meat (breast and thigh muscles) and internal organs (liver and gizzard) of broiler birds in Tehsil Charsadda are presented in Table 8. Significantly higher concentrations of all selected heavy metals were recorded in the liver than gizzard, breast, and thigh muscles ($P < 0.05$). The least concentration of Pb was recorded in thigh muscles and Cd and Zn in breast muscles whereas least concentrations of Ni and Mn were recorded in gizzard.

Table 1 Concentration (ppm) of heavy metals in feed samples at broiler farms in Tehsil Charsadda

Sample source at broiler farms		Pb	Cd	Ni	Mn	Zn
Feed mill A		3.50 ± 0.19	0.23 ± 0.02	3.07 ± 0.30	22.80b ± 0.36	40.95a ± 0.39
Feed mill B		3.74 ± 0.13	0.25 ± 0.03	2.75 ± 0.21	24.16a ± 0.50	38.12b ± 0.55
P value		0.32	0.44	0.39	0.04	0.00
Permissible limits	NRC (2005)	10	10	250	2000	500
	EC (2003)	5	0.5	NG	NG	250

Means within the same column having different lowercase letters differ significantly ($P < 0.05$)

NG not given

Table 2 Concentrations (ppm) of heavy metals in water samples at broiler farms in Tehsil Charsadda

Location of water samples	Pb	Cd	Ni	Mn	Zn
Nisatta	81.88b ± 10.4	3.87 ± 0.57	12.37b ± 3.20	128.00b ± 3.38	123.75 ± 38.55
Umerabad	111.25a ± 10.4	2.62 ± 0.57	27.00a ± 3.20	137.88b ± 3.38	154.50 ± 38.55
Kula Dher	120.63a ± 10.4	3.12 ± 0.57	15.00b ± 3.20	147.88a ± 3.38	141.12 ± 38.55
P value	0.03	0.32	0.00	0.00	0.85
Max. permissible limit according to Pak-EPA (2008)	50	10	20	500	5000

Means within the same column having different lowercase letters differ significantly ($P < 0.05$)

Discussion

Heavy metals are potential environmental contaminants and are gaining immense importance throughout the world because of the toxicity they cause, even at very low concentrations. Findings of the present study revealed significantly ($P < 0.05$) higher concentrations of Mn and Zn in feed samples of feed mill B and feed mill A, respectively. In order to meet the nutritional requirements of broiler, Mn is added to the broiler ration. According to the National Research Council (NRC 1994), broilers need a minimum of 60 ppm of Mn in the ration. However, concentrations of Mn in samples of both feed mills were lower than the minimum nutritional requirements. According to the Agriculture Research Council (ARC 1975), Zn is a necessary element for poultry. The minimum dietary requirement of Zn for broilers is 40 ppm (NRC 1994) so only feed of feed mill A can fulfill minimum Zn requirements of broilers whereas feed of feed mill B was deficient in Zn. Usually, Pb is not added to poultry and livestock feed because it has no nutritional significance for animals (Li et al. 2005). The presence of Pb in feed may be due to its presence in the water used for irrigation of crops and possible absorption by the plants (used in animal feed) that are capable of absorbing far more Pb than others (Ona et al. 2006). Like Pb, Cd has no nutritional value in animal feed, but it might be present in mineral mixtures used as feed ingredients, especially P-containing minerals (Sager 2007). Similarly, Ni is discharged from a number of sources such as electroplating units, steel, petroleum-processing plants, fertilizers, motor cars and batteries, and mining. Concentrations of all heavy metals recorded in the present study were below the permissible limits in samples of both feed mills.

Suleiman et al. (2015) recorded the Mn concentration within a range of 0.94 to 3.12 ppm in different types of poultry feeds in Sokoto, Nigeria. The concentrations of Zn recorded in the present study are in agreement with the findings of Imran et al. (2015) who reported a 40.54-ppm mean concentration of Zn in feeds of different companies and farms in Kasur city, Pakistan. Similarly, Okoye et al. (2011) also reported mean Zn concentration in the range of 34.038 to 49.950 ppm in different brands of chicken feeds sold in southeastern, Nigeria, which support findings of the present study. In contrast, Mahesar et al. (2010) reported higher Zn concentrations in poultry feed than the present findings. The concentration of Pb recorded in the present study was comparable to the findings of Imran et al. (2015) who found 3.78 ppm of Pb in poultry feeds of different farms and companies. Similarly, Wang et al. (2013) reported 4.51 ppm of Pb in the ration of broiler chicks. The concentration of Cd recorded in the present study was comparable to the findings of Alkhalaf et al. (2010) who obtained mean concentrations of 0.20 ppm in the starter ration. Imran et al. (2015) reported a higher mean Cd concentration of 0.44 ppm in feeds of different companies and farms in Kasur city, Pakistan, while Wang et al. (2013) obtained a

Table 3 Concentrations (ppm) of Pb in meat and internal organs of broiler birds at three different locations in Tehsil Charsadda

Meat/internal organs	Nisatta	Umerabad	Kula Dher	P value	Max. permissible limit according to Pak-EPA (2008)
Liver	0.23b ± 0.03	0.26ab ± 0.03	0.35a ± 0.03	0.04	0.2
Gizzard	0.18 ± 0.03	0.19 ± 0.03	0.24 ± 0.03	0.24	
Breast	0.15b ± 0.02	0.14b ± 0.02	0.20a ± 0.02	0.05	
Thigh	0.15b ± 0.02	0.15b ± 0.02	0.22a ± 0.02	0.04	

Means within the same row having different lowercase letters differ significantly ($P < 0.05$)

Table 4 Concentration (ppm) of Cd in meat and internal organs of broiler birds across different locations in Tehsil Charsadda

Meat/internal organs	Nisatta	Umerabad	Kula Dher	*P* value	Max. permissible limit according to Pak-EPA (2008)
Liver	0.030 ± 0.002	0.028 ± 0.002	0.029 ± 0.002	0.81	0.5
Gizzard	0.022 ± 0.002	0.021 ± 0.002	0.021 ± 0.002	0.96	
Breast	0.017 ± 0.001	0.016 ± 0.001	0.016 ± 0.001	0.88	
Thigh	0.018 ± 0.001	0.017 ± 0.001	0.017 ± 0.001	0.96	

mean Cd concentration of 0.851 ppm in the broiler ration in China. The concentration of Ni recorded in the present study was almost similar to the findings of Okoye et al. (2011) and Alkhalaf et al. (2010) for starter feeds.

Present research findings revealed a significantly ($P < 0.05$) higher concentration of Pb in water at Umerabad and Kula Dher as compared with Nisatta. However, at all locations, the Pb concentration exceeded the maximum permissible limits set by the Pakistan Environmental Protection Agency (Pak-EPA 2008). Results of the present study also showed a significantly ($P < 0.05$) higher concentration of Ni in water at Umerabad as compared with other locations. Similarly, the Ni concentration at Umerabad was above the maximum permissible limits of 20 μg/l as set by Pak-EPA (2008). Similarly, a significantly ($P < 0.05$) higher concentration of Mn was recorded at Kula Dher as compared with Nisatta and Umerabad. Concentrations of Cd, Mn, and Zn were below the permissible limits.

Lead is commonly used as plumbing material (Bakraji and Karajo 1999) so its presence in water may be a consequence of leaching from old pipes as well as transportation (Khan et al. 2012, 2015). The uncontrolled disposal of lead batteries can also result in the relatively high level of Pb in groundwater (Oyeku and Eludoyin 2010). Similarly, high concentrations of Pb may also be attributed to high traffic density. Since farms at Umerabad and Kula Dher were located near the road with solid waste disposal site and drain of wastewater nearby which may be responsible for the high Pb concentration recorded in the present study. Zara et al. (2015) found that the level of Ni in water samples of most of the study areas was more than national and international standards. Sewage water contains a significant amount of heavy metals including nickel (Latif et al. 2008). The higher concentration of Ni in water recorded at Umerabad in the present study might be due to the wastewater drains in the area which might contain high Ni concentration. Traffic and unsanitary deposits are important causes of Mn pollution (Baride et al. 2012). The higher concentration of Mn in water recorded at Kula Dher may be due to vehicle emission as these farms were located along the roadside. However, domestic wastewater and disposal of sewage sludge in the nearby canal might have also contributed to the high content of Mn in water (Nartey et al. 2012).

Khan et al. (2012) found the Pb concentration in the range of 1.59–372.2 μg/l in different water sources of District Charsadda and mentioned that transportation could be one of factors responsible for the higher concentration of Pb in urban areas of District Charsadda which is in agreement with the present study. Baride et al. (2012) reported that the high concentration of Ni in surface water and groundwater indicates disposal of solid waste and industrial and municipal wastewater which support findings of the current study. Similarly, Latif et al. (2008) found that tube wells installed on the banks of sewage drains may lead to elevated concentrations of some heavy metals including Ni in tube well water due to seepage. These drains were found to contain 10–2080 μg/l of Ni concentration. Baba et al. (2009) reported that motor vehicles, engine oil, battery wastes, and car tires could result in higher concentrations of heavy metals including Mn in soil. This statement supports the findings of the present study. Ilyas and Sarwar (2003) recorded an average of 130 μg/l of Mn in water. However, they reported a greater concentration of Mn in deep wells than shallow wells in the vicinity of Palosai drain Peshawar.

Table 5 Concentrations (ppm) of Ni in meat and internal organs of broiler birds across different locations in Tehsil Charsadda

Meat/internal organs	Nisatta	Umerabad	Kula Dher	*P* value	Max. permissible l imit according to Pak-EPA (2008)
Liver	0.52 ± 0.04	0.59 ± 0.04	0.50 ± 0.04	0.44	0.5
Gizzard	0.34 ± 0.04	0.39 ± 0.04	0.33 ± 0.04	0.52	
Breast	0.37 ± 0.04	0.40 ± 0.04	0.36 ± 0.04	0.83	
Thigh	0.38 ± 0.04	0.41 ± 0.04	0.38 ± 0.04	0.86	

Table 6 Concentrations (ppm) of Mn in meat and internal organs of broiler birds across different locations in Tehsil Charsadda

Meat/internal organs	Nisatta	Umerabad	Kula Dher	*P* value	Max. permissible limit according to Pak-EPA (2008)
Liver	0.39b ± 0.05	0.41b ± 0.05	0.55a ± 0.05	0.04	0.5
Gizzard	0.20b ± 0.03	0.21b ± 0.03	0.31a ± 0.03	0.04	
Breast	0.23b ± 0.03	0.25b ± 0.03	0.35a ± 0.03	0.05	
Thigh	0.24b ± 0.03	0.25b ± 0.03	0.36a ± 0.03	0.02	

Means within the same row having different lowercase letters differ significantly ($P < 0.05$)

Findings of the present study revealed significantly ($P < 0.05$) higher concentrations of Pb and Mn in meat and internal organs at Kula Dher as compared with Nisatta and Umerabad. Similarly, s significantly higher concentration of Zn in meat and internal organs of broilers was found at Umerabad than other locations. No significant differences were recorded in concentrations of Cd and Ni in meat and internal organs across locations. All samples at Kula Dher and only liver at all locations had Pb concentrations above the maximum permissible limit. Similarly, the concentration of Mn in the liver at Kula Dher and concentration of Ni in the liver at all locations were also above the maximum permissible limit. Significantly ($P < 0.05$) higher mean concentrations of all heavy metals were recorded in the liver than in other organs of the body. However, only the mean concentration of Pb and Ni in liver was above the maximum permissible limit. According to Khan et al. (2015), Pb can enter the body via ingestion of contaminated food and water, inhalation, and dermal contact. So a significantly higher concentration of Pb in the liver, breast, and thigh muscles at Kula Dher may be due to use of contaminated feed and water in the present study. Firdevs (2005) reported that the high Pb content in cattle manure is due to high traffic and industrial pollution. A small quantity of Mn is needed for normal development and function of the central nerves system (Aljaff et al. 2014). It is suggests that high concentration of Mn in feed used at Kula Dher might have resulted in high concentration of Mn in meat and internal organs. The high concentration of Zn in diet may interfere with Cu and Fe metabolism. Interference with Cu and Fe metabolism may ultimately lead to copper deficiency and anemia, respectively. However, in small amount, zinc is an important element in human growth (Renfro et al. 1975). The accumulation of Cd in the liver is associated with Cd-binding protein, metallothionein (Hamasalim and Mohammed 2013). According to Kan and Meijer (2007), Cd content of liver and kidney is mainly affected by the predominant chemical form of Cd in the feed. Similarly, according to McLaughlin et al. (1999), Cd interacts with some essential elements like Zn, Fe, Cu, and Se due to the chemical resemblance with these elements and competes for the binding site. Nickel-and Ni-containing compounds may enter the human and animal body through ingestion, inhalation, and dermal contact (Khan et al. 2015). Although a significantly higher concentration of Ni in water was observed at Umerabad, no significant difference was observed in meat and internal organs across locations. This may be because a maximum quantity of Ni excretes through litter. However, absorbed Ni can mostly be accumulated in the liver, kidney, and lungs (Demirezen and Uruc 2006).

Results of the present study are in agreement with the findings of Oforka et al. (2012) who reported higher levels of Pb in the liver (0.3042 ppm) than gizzard (0.2867 ppm) and muscles (0.2151 ppm). Oforka et al. (2012) also reported the highest mean concentration of Mn in the liver (0.415 ppm) followed by muscles (0.2657 ppm) and gizzard (0.1265 ppm), respectively. Similarly, Akan et al. (2010) reported a greater mean concentration of Mn in the liver of chicken than other samples. Khan et al. (2015) determined the highest Zn concentration in the liver of chicken (8.393 ppm) collected from Karachi and the lowest in the blood of chicken (3.028 ppm) collected from Thatta. All the values recorded for Zn in the present study were lower than those reported by Iwegbue et al. (2008) and Mariam et al. (2004). Mohammed et al. (2013) reported higher concentrations of Cd in kidneys followed by gizzard, liver,

Table 7 Concentrations (ppm) of Zn in meat and internal organs of broiler birds across different locations in Tehsil Charsadda

Meat/internal organs	Nisatta	Umerabad	Kula Dher	*P* value	Max. permissible limit according to Pak-EPA (2008)
Liver	4.98b ± 0.21	6.76a ± 0.21	4.72b ± 0.21	0.00	150
Gizzard	4.20b ± 0.21	5.10a ± 0.21	3.94b ± 0.21	0.00	
Breast	2.79b ± 0.16	3.62a ± 0.16	2.55b ± 0.16	0.00	
Thigh	2.91b ± 0.16	3.90a ± 0.16	2.72b ± 0.16	0.00	

Means within the same row having different lowercase letters differs significantly ($P < 0.05$)

Table 8 Mean concentrations (ppm) of heavy metals in meat and internal organs of broiler birds in Tehsil Charsadda

Meat/internal organs	Heavy metals				
	Pb	Cd	Ni	Mn	Zn
Liver	0.28a ± 0.01	0.029a ± 0.001	0.54a ± 0.02	0.45a ± 0.02	5.48a ± 0.13
Gizzard	0.20b ± 0.01	0.021b ± 0.001	0.36b ± 0.02	0.24b ± 0.02	4.41b ± 0.13
Breast	0.17b ± 0.01	0.016c ± 0.001	0.38b ± 0.02	0.28b ± 0.02	2.99c ± 0.13
Thigh	0.16b ± 0.01	0.017c ± 0.001	0.39b ± 0.02	0.28b ± 0.02	3.18c ± 0.13
P value	0.00	0.00	0.00	0.00	0.00
Reported/permissible levels in liver/muscles	0.2*	0.5**	0.5*	0.5*	150**

Means within columns having different superscripts differs significantly ($P < 0.05$)

* Oforka et al. (2012))

** Akan et al. (2010)

and breast meat, respectively, which is contrary to the findings of the present research study. Akan et al. (2010) also reported the highest Cd concentration in kidneys. Ei-Salam et al. (2013) reported higher levels of Ni in liver than meat and other organs of chicken in Kohat, Pakistan, which support our findings. Some other researchers (Oforka et al. 2012; Akan et al. 2010) also found greater concentrations of Ni in the liver than in other body parts. In contrast, found a maximum concentration of Ni in muscles followed by liver and skin. Iwegbue et al. (2008) reported a greater concentration (20.78 ppm) of Ni in turkey meat from the Warri zone in Southern Nigeria while determining residues of heavy metals in poultry meat, gizzard, and turkey meat.

Conclusion

Concentrations of Mn and Zn were significantly higher in feed samples of feed mill B and feed mill A, respectively, and concentrations of all metals were within the safe levels. The concentration of Pb was significantly higher at Umerabad and Kula Dher. Similarly, the concentration of Ni and Mn in water samples was higher at Umerabad and Kula Dher, respectively. The concentration of Pb was above the maximum permissible limits at all locations whereas the concentration of Ni at Umerabad exceeded the maximum permissible limits. A significantly higher mean concentration of all selected heavy metals was recorded in the liver than gizzard, breast, and thigh muscles, and the mean concentration of Pb and Ni in the liver was slightly above the maximum tolerable levels. The concentration of Pb in the liver, breast, and thigh muscles and the concentration of Mn in the liver, gizzard, breast, and thigh muscles of broiler were higher at Kula Dher, while the concentration of Zn in the liver, gizzard, breast, and thigh muscles of broilers was higher at Umerabad.

Compliance with ethical standards

This study was approved by the Departmental Committee on Issues and Welfare of Animal, Faculty of Animal Husbandry and Veterinary Sciences, The University of Agriculture, Peshawar, Pakistan.

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