Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2019; 7(5): 965-971

Received: 10-07-2019
Accepted: 12-08-2019

MT Akter
Department of Anatomy and Histology, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh

KA Ferdous
Department of Anatomy and Histology, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh

T Rahaman
Department of Anatomy and Histology, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh

MA Hassan
Department of Anatomy and Histology, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh

T Monjur
Department of Anatomy and Histology, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh

Corresponding Author:
MA Hassan
Department of Anatomy and Histology, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh

Exposure to environmental heavy metal (cadmium) through feed and its effect on bio-histomorphological changes in commercial quail

MT Akter, KA Ferdous, T Rahaman, MA Hassan and T Monjur

Abstract
The present study was aimed to investigate the toxic effects of Cd exposure in commercial quail. A total number of 72 quail chicks (12 days of old) were assigned in four dietary treatments with three replicates. Control group T0 received only basal diet and the other groups T1, T2 and T3 received supplemented Cd with feed at a dose level of 0.2, 1 and 5mg/kg feed respectively. The body weight of each bird was weighed at 7 days interval and found decreases in weight gain significantly (P<0.01) among the Cd treated groups. Cd caused elevation of ALT (P<0.01) and decreased serum creatinine attributed to gross and histo-pathological changes in liver and kidney respectively. Gross pathological changes showed diffuse congestion, haemorrhage, presence of necrotic foci on liver and congestion in kidney and haemorrhage in muscle and lung. Accumulation of gas on intestine, mucosal erosion and discoloration of gizzard were also found in Cd treated birds. Histopathological lesions in liver included infiltration of reactive cells in central vein, hepatic vein and sinusoidal space in group T1 and T2 whereas group T3 showed highly necrosis of hepatocyte, picnotic nucleus and disarrangement of hepatic cord. In kidney, tubules were filled with reactive cells in all Cd treated groups while necrosis and disarrangement of tubules were found in groups fed Cd at higher doses (T3).

Keywords: Quail, cadmium toxicity, body weight, alanine transaminase (ALT), serum creatinine, morphological and histopathology

1. Introduction
The poultry sector is an integral part of farming systems that shares a significant contribution to theemployment opportunity, food security and thereby economic growth and poverty reduction in the rural area of Bangladesh. Quail farming may be an alternative to chicken and ducks due to its immense potentiality for meat and egg production. Poultry production largely depends on quality feed. There are various sources of raw materials for poultry feed production and in many ways these sources of feed can be associated with anthropogenic heavy metal pollution. Cadmium, a rare but widely dispersed one of the most hazardous heavy metal and environmental pollutant. Most Cadmium is refined during zinc production. It is released into the environment through mining and smelting, usage of phosphate fertilizers, presence in sewage sludge and various industrial uses such as Ni, Cd batteries, plating, pigments and plastics. In the ground, cadmium moves easily through soil layers and is taken up into the food chain by uptake by plants such as leafy vegetables, crops, cereals and grains [22]. Accumulated Cd in various tissues of poultry remains as non-degradable heavy metal that can be transferred to human through poultry meat and impose health impact. 'International Agency for Research on Cancer' has classified cadmium and its compounds as a group I human carcinogen [36]. Although several studies have been done on the toxic effect of Cd in quail physiology, in details study of dose dependent impact of dietary Cd in body weight gain, the biochemical alteration and histo-morphological changes in visceral organs of quail has not been well addressed. Therefore, the present research work was undertaken to evaluate the effect of Cd on the growth performance, morphometric, hematological parameters and observe the histo-pathological changes in liver and kidney sample due to Cd toxicity in quail.

2. Materials and methods
In this study seventy-two 12 days old quail chicks about 87gm body weight were randomly allotted into four groups T0, T1, T2 and T3 (having 3 replications containing 6 birds in each replication). The experiment (rearing of quail, body weight measurement and blood collection)

was carried out in the laboratory of Anatomy and Histology department, Hajee Mohammad Danesh Science and Technology University (HSTU) during the period of 6 months from October 2017 to April 2018. The birds of group T0 were kept as healthy control group received only basal diet from Nourish Feeds Ltd. while birds of group T1 received Cd powder @ 0.2 mg/kg feed, group T2 @ 1 mg/kg feed and group T3 @ 5mg/kg feed. The chicks were supplied with fresh drinking water twice daily as per requirement. The chicks were kept under observation for 3 days with basal diet before starting of treatment with Cd. All birds during the treatment period were examined daily for abnormal physical and behavioral changes as well as mortality (if any) due to Cd toxicity. The effect of Cd toxicity on growth performance in quail was evaluated on the basis of average weekly feed consumption, body weight and feed conversion ratio. For average body weights, initial body weight of individual chick on first day of experiment was recorded. Subsequently body weights were recorded at seven days interval up to 29th days of experiment for each group. At the end of the experiment, 16 birds (4 birds from each replicate) from each treatment group were randomly selected and slaughtered after 12h of fasting to collect theviscera (liver, kidney, lung, gizzard, intestine) and muscle samples to find the gross changes of those organs. Blood samples were collected from the wing vein at initial day and before slaughtering for blood analysis [Alanine Transaminase (ALT) and Serum Creatinine].

For histopathological study the collected samples were preserved for fixation in the Bouin's fluid for 24 hours. The tissues were then dehydrated by using ascending graded of alcohol (70%, 80%,90%, 95%, 100% and 100%) and kept for one hour in each grade of alcohol. The tissues werethen transferred to the xylene-1 and xylene-2 each for ninety minutes. Then the tissues wereinfiltrated in the liquid paraffin at 60 degree centrigrade temperature for ninety minutes andrepeated again. Finally the tissues were embedded in paraffin and paraffin blocks were made. The paraffin blocks were cut at 6 µm thickness using microtome machine (Mu 509, Euromex, Japan). After sectioning of paraffin block, the slices were floated on warm water in a water bathat 45 0C for stretching. The sections with glass slides were stained with Hematoxylin and Eosin's (H & E) stain for general histological study. Observations of the slides were done by using a lightmicroscope and photographs were taken with an automatic photo micrographic system. Datawere expressed as mean ± standard error (SE) and analyzed using one way Analysis of Variance followed by Duncan's test as a post-hoc test using IBM SPSS Statistics 20.0 softwarepackage and the chart was created by Microsoft Excel 2010 software. Results were considered tobe statistically significant when P values are less than 0.01.

3.Results and Discussion

3.1 Clinical findings

In the present study, the salient clinical symptoms including depression, reduced feed intake, ruffled feathers, generalized weakness and gastrointestinal signs such as bloody diarrhoea were observed in birds treated with Cd. Intoxication were primarily related to the effects of Cd on the nervous, GI, hematopoietic and renal systems. The above findings were similar to Agency for Toxic Substance and Disease Registry that was observed by ATSDR., Osama SEO, Mohamed AL. *etal.*, [22, 2]. Diarrhoea in Cd poisoning that might be due to regurgitation and decreased motility ofthe upper GI tract (esophagus, proventriculus, and ventriculus) and signs related to hematopoietic impairment including weakness.

3.2 Body weight

During the experiment, supplemental dietary Cd significantly reduced body weight (P<0.01) compared to control (Table1). Decreased body weight was found throughout the experimental period in Cd treated birds and the rate of decrease was proportional to consumption of Cd. At 29th day of treatment, group T3 (Cd 5mg/kg feed) showed lowest body weight (78.7250±1.9gm) whereas group T2 (Cd 1mg/kg feed), group T1 (Cd 0.2mg/kg feed) and control T0 (no Cd) had body weight (91.7500±4gm), (99.5000±4.94gm) and (130.7500±1.49gm) respectively. Such finding is in agreement with previous findings of Anderson O at el, Omid K *et al,* Sajjad S *et al*., Osama SEO *et al*., Elmonem HA *et al*., Okeke OR *et al.*,Vodela JK *et al*., Sant'Ana MG *et al*., [34, 7, 9, 2, 26, 4, 37, 10]. The decreased body weight gain may be associated with several factors such asinterruption in absorption and imbalanced metabolism produced by impairing zinc- dependent enzymes which are necessary for many metabolic processes and decreased level of erythropoietin hormone which has anabolic effect that was observed by Padilla MA *et al*., [14]. Lowered body weights in the heavy metal treated birds could be also due to the reduction in the feed utilization or due to the metabolic disarray resulting in loss of the cellular functions and tissue damage which was showen by Erdogan Z *et al.*,[28].

3.3 Gross findings

At the end of experiment, postmortem examination grossly showed diffuse congestion (Fig.1), haemorrhage (Fig.2) and presence of necrotic foci (Fig.3) on liver and in kidney congestion (Fig.4). These findings are in accordance with previous work of Jin T *et al.,* Dehn PF *et al.,* Tohamy HG *et al.,* El- Sharak AS *et al.,* [33, 25, 43, 27]. In muscle (Fig.5) and lung (Fig.6) there was also haemorrhage. Cadmium toxic effects induced the detoxification in liver and kidney enzymes which may lead to kidney dysfunction, hepatic injury, lung damage that was similar with the Foulkes EC., Foulkes EC., Webb M., [30, 29, 38]. Accumulation of gas on intestine (Fig.7), mucosal erosion (Fig.8) and discoloration of gizzard (Fig.9) were also found in Cd treated birds Cadmium initiates the generation of free radicals that was reported by Berzina N *et al.,* [23], which may induce metal othionein (MT) production also reported by Markov *J et al.,* [44] and participate in the manifestation of intestinal injury. No gross lesion was found in the quails slaughtered from the control group.

3.4 Microscopic findings

The microscopic view of liver in current study revealed that varying degree of degenerative changes as well as vascular changes like infiltration of reactive cells in central vein, hepatic vein and sinusoidal space in Group T1 (Fig.11) and T2 (Fig.12) whereas group T3 (Fig.13) showed highly necrosis of hepatocyte, picnotic nucleus, disarrangement of hepatic cord of liver. Appearance of inflammatory cells in the hepatic tissue might be due to the interaction between proteins and enzymes of the hepatic interstitial tissue which interfered with the antioxidant defense mechanism and leading to reactive oxygen species (ROS) generation which in turn may imitate an inflammatory response that was compliance with Shah TM *et al*., Anderson O., Omid K *et al*., [11, 3, 6]. Microstructure of liver of control group T0(Fig.10) seems no

changes. Microscopic view of kidney of group T1 (Fig.15) and T2 (Fig.16) showed reactive cells infiltration in the tubular and peritubular space, kidney tubules (proximal and distal convoluted tubules & Henley's loop). Necrosis in kidney tubules and deformation of normal structure of kidney tubules found in the group T3 (Fig.17). These findings are in agreement with previous study of Hesaraki S *et al*., Bharavai K *et al*., Binkowski LJ *et al*., Uyanik F *et al*., Shukla GS *et al*., Ibraheem AS *et al*., [31, 15, 16, 19, 6, 17] had reported that cadmium may induce oxidative damage in a variety of tissues by enhancing peroxidation of membrane lipids due to inhibition of antioxidant enzymes. By intake of Cadmium stimulates the formation of beta 2-microglobulin in urine which induces renal tubular dysfunction reported by Suganya T *et al*., [18] Microstructure of kidney of T_0 (Fig.14) was normal.

3.5 Hematological parameter

Birds exposed to Cd showed a significant decrease in serum creatinine (P<0.01) at 29th days of treatment as compared with the control group (table 2). Decreased serum creatinine was found in group T3 (0.12±0.04787), T2 (0.33±0.04082) and T1 (0.40±0.0482) with doses of 5mg/kg feed, 1mg/kg feed and 0.2mg/kg feed respectively compared to control T0 (0.60±0.0482) received normal feed. On the other hand, birds exposed to Cd showed a significant increase in SGPT/ALT (P<0.01) concentrations at 29th days of treatment compared to the control group (table 3). Highest SGPT was found in group T3 (25±4.75447) followed by group T 2 (10.18±3.84152) and group T1 (9±0.23805) compared to control T0 (3.03±0.04787). Significant decrease in creatinine was reported in Cd treated animals which is similar with Ibraheem AS *et al*., [12] study. However, this is contradictory with few outcomes of Brzoska MM *et al*., Karimi O., Subhan F *et al*., Saeed AA., Tahir MW *et al*., Elmonem HA *et al*., [39, 41, 13, 8, 20, 26] as well who reported significant increase in serum creatinine in all Cd treated groups. Such variation in serum creatinine could be associated with different dose, route of administration, species and other environmental or dietary factors. In this study, birds exposed to Cd showed a significant increase in SGPT/ALT concentrations as compared with the control group (table 2). The increased serum levels of transaminases, which are located primarily in the cytosol of hepatocytes. It indicate the sign of damage which leads to liver dysfunction in treated birds that was observed by Karimi O *et al*., Saeed AA., Elmonem HA *et al*., Elmonem HA *et al*., Sajjad S *et al*., [41, 40, 8, 26, 9]. The function of ALT enzymes in blood may also be used as a stress indicator. The significant change in activities of these enzymes in blood plasma indicates tissue impairment caused by stress that was observed by Svoboda M., James R *et al*., [42, 32]. The increase in concentration of AST and ALT in blood plasma indicates impairment of liver. Such biochemical changes in kidney and liver associated with structural alteration in those organs is more supported by histological study. In the present study, birds exposed to Cd showed a significant increase in ALT concentrations as compared with the control group (Table 2). The elevated serum levels of transaminases, which are located primarily in the cytosol of hepatocytes is a sign of damage which lead to liver dysfunction in treated birds. This finding is similar to some findings Omid K *et al*., Omid K., Saeed AA *et al*., Elmonem HA *et al*. Sajjad S *et al*. [6, 5, 8, 26, 9]. The activity of ALT enzymes in blood may also be used as a stress indicator. The increase in concentration of AST and ALT in blood plasma indicates impairment of liver.

Table 1: The effects of different dosage of Cd on growth performance (gm) of quails from 0 days to 29 days of experiment

Days	Various treatment groups showing mean ± SE value				p value	Level of Significance
	T_0	T_1	T_2	T_3		
Initial day	87.6000±0.84853[a]	87.5000±0.86603[a]	87.5000±0.86603[a]	85.5000±2.62996[a]	0.720	NS
8th day	113.8750±1.66302[b]	92.3000±1.92137[a]	91.7750±1.94952[a]	88.2500±3.11916[a]	0.000	**
15th day	122.7750±1.52773[c]	101.5000±3.94757[b]	98.2500±4.44175[b]	87.2500±3.06526[a]	0.000	**
22th day	127.7500±1.03078[c]	100.2500±4.87126[b]	96.2500±4.80234[b]	84.3000±2.64386[a]	0.000	**
29th day	130.7500±1.49304[c]	99.5000 ±4.94132 [b]	91.7500±4.00780[b]	78.7250±1.90848[a]	0.000	**

Means on the same row with different superscripts are significantly different (P<0.01).SE: Standard Error, **means highly significant, NS means Non-Significant

Table 2: Serum creatinine (mg/dl) of quail at 29 days fed varying levels of Cd

Test	Various treatment groups showing mean ± SE value				p value	Level of Significance
	T_0	T_1	T_2	T_3		
Initial day of experiment	0.6000±.04082[a]	0.6000±.04082[a]	0.6000±.04082[a]	0.6000±.04082[a]	1.000	NS
29th day of experiment	0.6000±.04082[c]	0.4000±.04082[b]	0.3250±.04082[b]	0.1750±.04787[a]	0.000	**

Means on the same row with different superscripts are significantly different (P<0.01).SE: Standard Error, **means highly significant, NS means Non-Significant

Table 3: ALT (U/L) of quail at 29 days fed varying levels of Cd

Test	Various treatment groups showing mean ± SE value				p value	Level of Significance
	T_0	T_1	T_2	T_3		
Initial day of experiment	3.0000±.05774 [a]	3.0000±.05774 [a]	3.0000±.05774 [a]	3.0000 ±.05774 [a]	1.000	NS
29th day of experiment	3.0250±0.04787[a]	9.00003±0.23805[a]	10.1750±3.84152[a]	25.0000±4.75447[b]	0.005	*

Means on the same row with different superscripts are significantly different (P<0.01).SE: Standard Error, *means significant at the level of 1%, NS means Non Significant

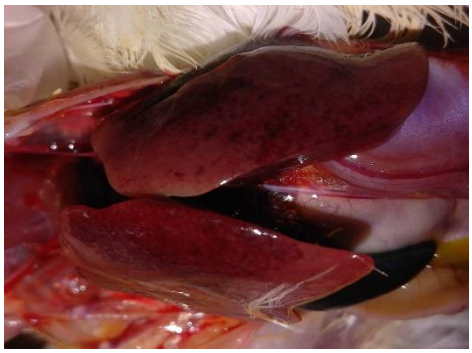

Fig 1: Congestion of liver

Fig 2: Haemorrhage on liver

Fig 3: Presence of necrotic foci on liver

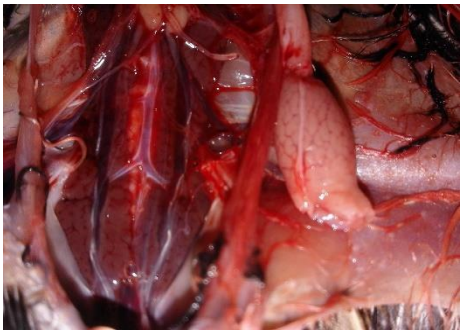

Fig 4: Congestion of kidney

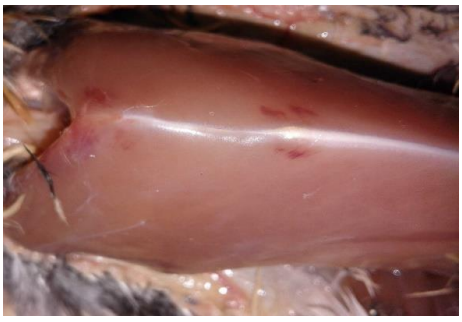

Fig 5: Haemorrhage on muscle

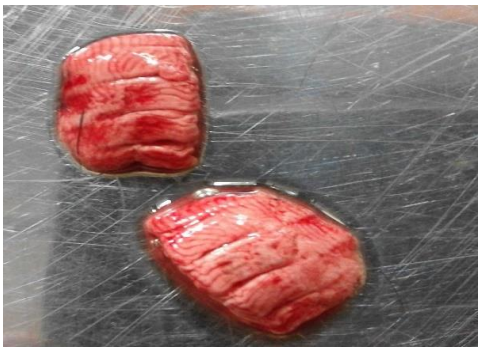

Fig 6: Haemorrhage on lung

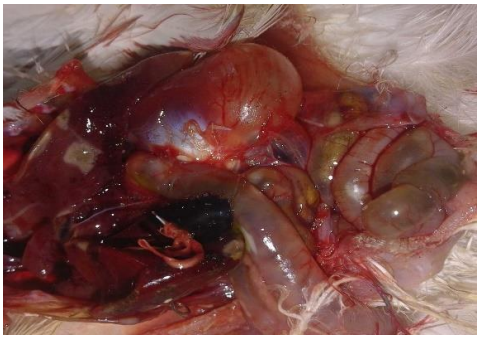

Fig 7: Accumulation of gas on intestine

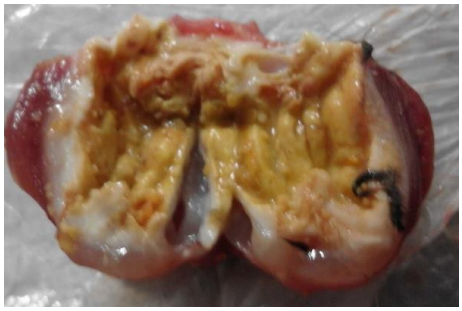

Fig 8: Mucosal erosion of gizzard

Fig 9: Discoloration of gizzard

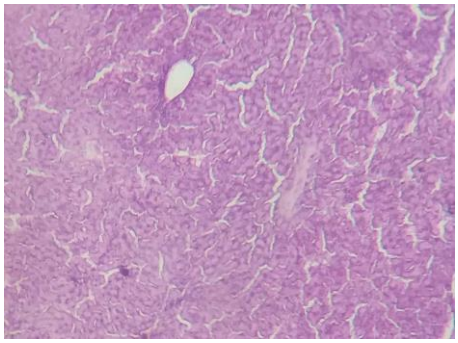

Fig 10: Microscopic view of liver in T_0 group (H and E;10x)

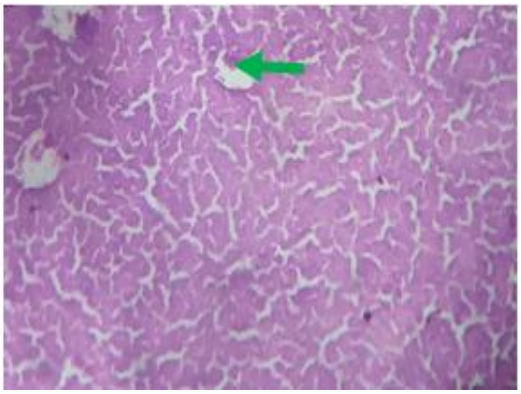

Fig 11: Microscopic view of liver: showing reactive cell infiltration (Green arrow) in T_1 group (H and E;10x)

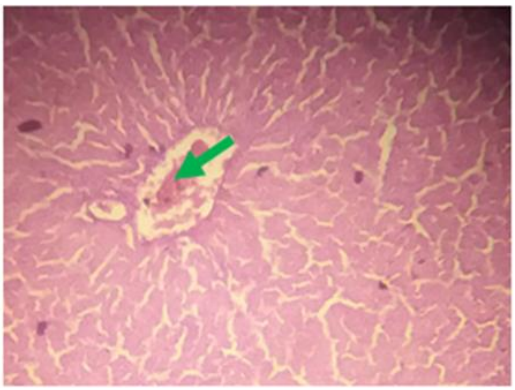

Fig 12: Microscopic view of liver: showing reactive cell infiltration (Green arrow) in T_2 group (H and E;10x)

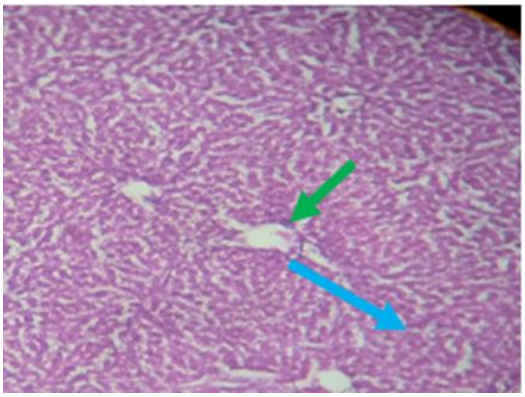

Fig 13: Microscopic view of liver: showing reactive cell infiltration (Green arrow) and Necrosis (Blue arrow) in T_3 group (H and E, 10x)

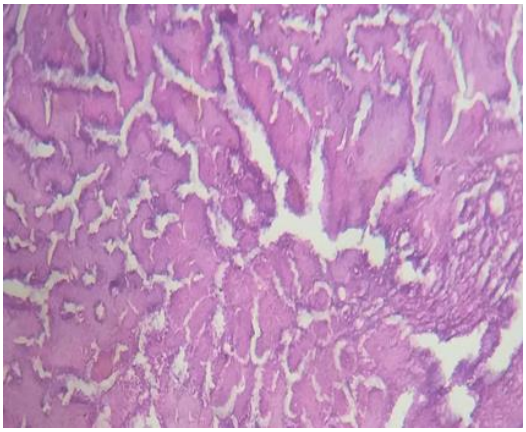

Fig 14: Microscopic view of normal kidney in T_0 group (H and E;10x)

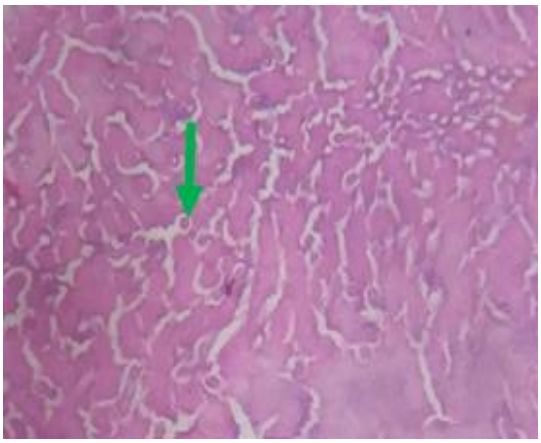

Fig 15: Microscopic view of kidney: Showing reactive cell infiltration (Green arrow) in T_1 group (H and E;10x)

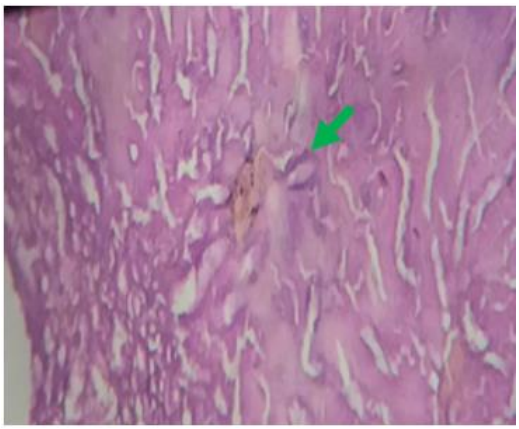

Fig 16: Microscopic view of kidney: Showing reactive cell infiltration (Green arrow) in T_2 group (H and E;10x)

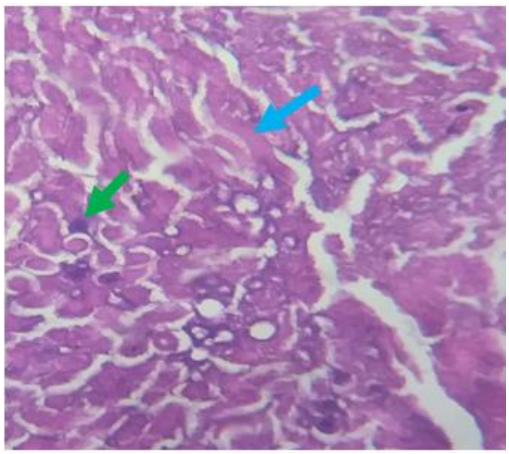

Fig 17: Microscopic view of kidney: Showing reactive cell infiltration (Green arrow) and necrosis on kidney tubule (Blue arrow) in T_3 group (H and E;10x)

4. Conclusions

A large portion of Bangladeshi people consume poultry meat and egg to fulfill their protein demand. The exposure of the heavy metals like Cd may affect the physiology of poultry which in turn may be the issue of public health through feed chain. It was observed from the current study that supplementation of Cd in quail diets at 0.2, 1 and 5 mg/kg feed produced various deleterious effects on growth performance; gross and microscopic study of different organs as well as biochemical parameters. Decreased body weight in Cd treated birds was due to malabsorption and altered

metabolism. Severe gross and histo-morphological changes were recorded in liver and kidney.

5. Acknowledgements
The authors express their keen thanks to Ministry of Science and Technology (MOST), Bangladesh due to the grant to conduct the research.

6. References

1. Bancroft JD, Gamble M. Theory and practice of histological techniques. In: Microorganisms, B. Swisher, (Editor), Churchill. Livingstone, Philadelphia. 2002, 325-344.
2. Osama SEO, Mohamed AL. Could Alpha-Lipoic Acid Protect Against Sub-chronic Toxicity of Heavy Metals Mixture in Japanese Quails? Life Science Journal. 2014; 11(12):907-917. (ISSN:1097-8135).
3. Anderson O. Oral cadmium exposure in mice: Toxicokinetics and efficiency of chelating agents. Critical Reviews in Toxicology. 1989; 20:83-112.
4. Okeke OR, Ujah II, Okoye PAC, Ajiwe1 VIE, Eze CP. Effect of Different Levels of Cadmium, Lead and Arsenic on the Growth Performance of Quail and Layer Chickens. IOSR Journal of Applied Chemistry (IOSR-JAC). 2015; 8(1):57-59.
5. Omid K, Saeed H, Seyyed PM. Morphological and Functional Changes of Japanese Quail (*Coturnix japonica*) Liver Exposed to Cadmium. International Journal of Biology, Pharmacy and Allied Science (IJBPAS). 2015; 4(9):491-497.
6. Omid K, Saeed H, Seyyed PM. Histological and Functional Alteration in the Liver and Kidney and the Response of Antioxidants in Japanese quail Exposed to Dietary Cadmium. Iranian Journal of Toxicology. 2017; 11(3):19-26.
7. Omid K, Saeed H, Tehran, Seyyed PM. Histological and Functional Changes of Japanese Quail (*Coturnix japonica*) Kidneys Exposed to Cadmium. The Caspian Sea Journal. 2016; 10(1):61-64.
8. Saeed AA, Huda A. Effect of cadmium in drinking water on growth, some haematological and biochemical parameters of chicken. European Journal of Experimental Biology. 2013; 3(5):287-291.
9. Sajjad S, Malik H, Farooq U, Rashid F, Nasim H, Tariq S *et al*. Cadmium Chloride Toxicity Revisited: Effect on Certain Andrological, Endocrinological and Biochemical Parameters of Adult Male Rabbits. Physiological Research. 2014; 63:505-512.
10. Sant'Ana MG, Moraes R, Bernardi MM. Toxicity of cadmium in Japanese quail: evaluation of body weight, hepatic and renal function, and cellular immune response. Environmental Research. 2005; 99(2):273-277.
11. Shah TM, Patel UD, Nimavat VR, Fefar DT, KalariaVA, Javia BB *et al*. Toxico-pathological studies on experimentally induced lead acetate toxicity in quail chickens with protective effect of *Opuntia elatior* and *Withania somnifera*. Asian Journal of Animal Sciences. 2016; 11(1): 33-39.
12. Ibraheem AS, Seleem AA, Mohamed, Sayed FE, Hamad BH. Single or combined cadmium and aluminum intoxication of mice liver and kidney with possible effect of zinc. The Journal of Basic & Applied Zoology. 2016; 77:91-101.
13. Subhan F, Khan A, Wahid F, Shehzad A, Ullah A. Determination of optimal toxic concentration and accumulation of cadmium in quail chicks. Toxicological Research, 2011; 27(3):143-147.
14. Padilla MA, Elobeid M, Ruden DM, Allison DB. An examination of the association of selected toxic metals with total and central obesity indices. International Journal of Environmental Research and Public Health. 2010; 7(9):3332-3347.
15. Bharavai K, Gopala A, Rao GS, Rama Rao SV. Reversal of cadmium-induced oxidative stress in chicken by hebal adaptogens *Withania somnifera* and *Ocimum sanctum*, Toxicology International. 2010; 17(2):59-63.
16. Binkowski LJ, Kapusta KS, Szarek J, Stryzewska E, Felsmann M. Histopathology of liver and kidneys of wild living mallards anasplatyrhynchos and coots *Fulica atra* with considerable concentration of lead and cadmium. Science of the Total Environment. 2013; 450-451:326-33.
17. Shukla GS, Shukla A, Potts RJ, Osier M, Hart BA, Chiu JF. Cadmium-mediated oxidative stress in alveolar epithelial cells induces the expression of gamma-glutamylcysteine synthetase catalytic subunit and glutathione S-transferase alpha and pi isoforms: potential role of activator protein-1. Cell Biology and Toxicology. 2000; 16(6):347-62.
18. Suganya T, Senthilkumar S, Deepa K, Muralidharan J, Sasikumar P, Muthusamy N. Metal Toxicosis in Poultry. International Journal of Science, Environment and Technology. 2016; 5(2):515-524. ISSN 2278-3687 (O).
19. Uyanik F, Eren M, Atasever A, Tun OG, Kolsuz AH. Changes in some biochemical parameters and organs ofquail exposed to cadmium and effects of zing on cadmium induced alteration, Israel Journal of Veterinary Medicine. 2001; 56(4):128-134.
20. Tahir MW, Saleemi MK, Icon AKO, Yousaf MSL, Butt, Siriwong W *et al*. Hematobiochemical effects of cadmium intoxication in male Japanese quail (*Coturnix japonica*) and its amelioration with silymarin and milk thistle. Toxin Reviews. 2017; 36(3):187-193.
21. Anderson O. Oral cadmium exposure in mice: Toxicokinetics and efficiency of chelating agents. Critical Reviews in Toxicology. 1989; 20:83-112.
22. ATSDR, Toxicological profile for cadmium. Agency for Toxic Substances and Disease Registry, Atlanta, GA, 1999.
23. Berzina N, Jurijs M, Sergejs I, Mirdza A, Galina S. Cadmium-Induced Enteropathy in Domestic Cocks: A Biochemical and Histological Study after Subchronic Exposure. Basic & Clinical Pharmacology & Toxicology. 2007; 101:29-34.
24. Binkowski LJ, Sawicka Kapusta K, Szarek J, Stryzewska E, Felsmann M. Histopathology of liver and kidneys of wild living Mallards *Anas platyrhynchos* and Coots *Fulica atra* with considerable concentration of lead and cadmium. Science of the Total Environment. 2013; 450-451:326-33.
25. Dehn PF, White CM, Conners DE, Shipkey G, Cumbo TA. *In vitro* characterization of the human hepatocellular carcinoma (hepg2) cell lines an *in vitro* model of cadmium toxicity studies. *In Vitro* Cellular & Developmental Biology-Animal. 2004; 40:172-182. doi: 10.1290/1543-706X(2004)40<172:COTHHC>2.0.CO;2.
26. Elmonem HA, Ali EA, Wakwak MM. Toxicological Impact of Inhaling Burned Plastic Bag Exhausts on

Japanese quail Birds and the Protective Role of Vitamins E and A. International Journal of Advanced Research. 2014; 2(10): 939-949.
27. El-Sharak AS, Newair AA, Badreldeen MM, Ewada SM, Sheweita SA. Protective role of selenium against renal toxicity induced by cadmium in rats. Toxicology. 2007; 235:185-193. doi: 10.1016/j.tox.2007.03.014.
28. Erdogan Z, Erdogan S, Aksu T, Baytok E. The effects of dietary lead exposure and ascorbic acid on performance, lipid peroxidation status and biochemical parameters of quails. Turkish Journal Veterinary Animal Science. 2005; 29:1053-1059.
29. Foulkes EC, Mc Mullen DM. Endogenous metallothionein as determinant of intestinal cadmium absorption: a reevaluation. Toxicology. 1986; 38:285.
30. Foulkes EC. Transport of toxic heavy metals across cell membranes. Proceedings of the Society for Experimental Biology and Medicine. 2000; 223:234.
31. Hesaraki S, Gharagozlou MJ, Amoli JS, Bokaee S, Javaheri V. Histopathological and ultrastructural changes of kidneys in response to cadmium chloride toxicity in quail chicken. Journal of Veterinary Research.2008; 65(4):281-288.
32. James R, Sampath K, Jancy PV, Devakiamma G. Journal of Aquaculture in the Tropics. 1992; 7:189-196.
33. Jin T, Nordber GF, Nordberg M. Uptake of cadmium in isolated kidney cells-influence of binding form and *in vivo* pretreatment. Journal of Applied Toxicology. 1986; 6:397-400. doi: 10.1002/jat.2550060603.
34. Shahidur R, Tomohiro S, Makoto M. Effects of Cadmium Administration on Reproductive Performance of Japanese Quail (*Coturnix japonica*). The Journal of Poultry Science. 2007; 44: 92-97.
35. IARC. List of evaluations according to IARC monographs, occupational sources' column edited by IPCS, Geneva, 1993.
36. Vishwanathan R, Goodrow-Kotyla EF, Wooten BR, Wilson TA, Nicolosi RJ. Consumption of 2 and 4 egg yolks/d for 5 wk increases macular pigment concentrations in older adults with low macular pigment taking cholesterol-lowering statins. The American Journal of Clinical Nutrition. 2009; 90(5):1272-9.
37. Vodela JK, Renden JA, Lenz SD, Mcelhenney WH, Kemppainen BW. Drinking Water Contaminants (Arsenic, Cadmium, Lead, Benzene, and Trichloroethylene). Interaction of Contaminants with Nutritional Status on General Performance and Immune Function in Quail Chickens. Poultry Science. 1997; 76:1474-1492.
38. Webb M. Role of metallothionein in cadmium metabolism. In: FOULKES E. C. (Ed.) Cadmium, Springer - Verlag, Berlin/New York. 1986; 281-337.
39. Brzoska MM, Moniuszko-Jakoniuk J, Piłat-Marcinkiewicz B, Sawicki B. Liver and kidney function and histology in rats exposed to cadmium and ethanol. Alcohol and Alcoholism.2003; 38(1):2-10.
40. Karimi O, Hesaraki S, Mortazavi SP. Morphological and functional changes of Japanese quail (*Coturnix japonica*) liver exposed to cadmium. International Journal of Biology, Pharmacy and Allied Science (IJBPAS). 2015; 4(9):491-497.
41. Karimi O, Hesaraki S, Mortazavi SP. Histological and functional alteration in the liver and kidney and the response of antioxidants in Japanese quail exposed to dietary cadmium. Iranian Journal of Toxicology. 2017; 11(3):19-26.
42. Svoboda M. Stress in fish – review. Buletin VURH Vodnany. 2001; 37:69-191.
43. Tohamy HG, Shourbela RM. Pathological Investigations on Galilee Tilapia (*Sarotherodon galilaeus*) Following Chronic Exposure to Cadmium Chloride. Journal of Aquaculture Research & Dev elopment. 2016; 7:446. ISSN: 2155-9546.
44. Markov J, Berzina N, Apsite M, Basova N. Cadmium and zinc: effects on free radical formation in liver. Proceeding of the Latvian Academy of Sciences, Section B. 2001; 55:30-32.