RESEARCH ARTICLE

Assessment of Heavy Metal Contents in Commercial Feedstuffs and Broiler (*Gallus domesticus*) Meat and Its Impact on Swiss Albino Mice as an Animal Model

Amin MZ[1]*, Tumu KN[1], Munshi M[1], Jolly YN[2], Rahman MM[3], Satter MA[4]

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Abstract

This study was designed to examine the effect of commercially available poultry feedstuff on the broiler, subsequently, its impact on the experimental animal. The proximate composition as well as concentrations of Pb, Ni, Mn, As and Zn in broiler feed and meat were determined using energy dispersive X-ray fluorescence (EDXRF) spectrometry. Higher levels of Cr, Mn, Zn, Cu, Ni were observed in broiler feed, broiler meat and in the liver of the experimental mice Swiss albino treated with BB1 and BB2. The concentration of these (Cr, Pb and As) metal were 0.182, 0.18, 0.163 µg/g and 0.233, 0.08, 0.158 µg/g, respectively. The blood cholesterol and LDL were significantly higher in the broiler meat treated experimental mice. Remarkable degeneration observed in the liver and kidney of broiler meat-treated mice. It is concluded that although broiler has nutritional benefits the quality of this meat may be compromised as a consequence of contamination through various anthropogenic activities and the presence of toxic metals in commercial poultry feed.

Keywords: Biochemical analysis, Broiler, Feedstuffs, Heavy metal, Histopathology.

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Introduction

Broiler (*Gallus domesticus*) is one of the major sources of protein not only in Bangladesh but also worldwide. A large number of Bangladeshi people consumes broiler meat to fulfill their protein needs due to its low cost and there are no associated religious or cultural taboo when compared to other sources of animal proteins. Thus poultry has become one of the most important and popular dishes for the people of Bangladesh, many commercial producers have given it their special attention to expand this sector in the country's economy.

For proper growing and feeding the broiler, farm owners have to depend on commercially available poultry feed. The raw materials for producing poultry feed are collected from various origins. The exposure of these sources onto various anthropogenic pollutants—especially heavy metals may affect our food chain through the feed. Some heavy metals are ubiquitous also, and day-by-day, the sources, and extents of anthropogenic pollution are increasing in Bangladesh. Heavy metals are especially regarded as toxic as well as carcinogenic elements. It has been reported that various heavy metals like Cu, Mn, and Zn are added to broiler diets to enhance their body weight gain (Hala *et al*., 2009). As these terrifying heavy metals are bio-accumulated and bio-concentrated in broiler and by rotation entered into the food chain, so human being will be distressed by these heavy metals. Therefore, special concern needs to diminish these problems; otherwise, these persistent pollutants will demolish human health by causing damages in kidney, liver, brain, heart and so on. The aim of this study was to conscious people about the available and rapidly growing commercial broiler (*Gallus domesticus*) which accumulate heavy metals in their body in turns human being consume it as a protein source.

[1]Department of Genetic Engineering and Biotechnology, Jessore University of Science and Technology, Jessore, Bangladesh

[2]Chemistry Division, Atomic Energy Centre, Kazi Nazrul Islam Avenue, Dhaka, Bangladesh

[3]Institute of Nuclear Science and Technology, Atomic Energy Research Establishment, Bangladesh Atomic Energy Commission, Savar, Dhaka, Bangladesh

[4]Institute of Food Science and Technology, BCSIR, Dhanmondhi, Dhaka, Bangladesh.

Corresponding Author: Amin MZ, Department of Genetic Engineering and Biotechnology, Jessore University of Science and Technology, Jessore, Bangladesh, Phone: +8801726034288, e-mail: aminziajstu@yahoo.com

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Materials And Methods

Sample Collection and Preparation

Two commonly broiler feed treated *Gallus domesticus* were collected from a particular poultry farm. The collected samples were dressing and washed with distilled water to remove any contaminated particles. This was followed by the samples being cut into small pieces using a clean knife, and then they were washed with distilled water several times. Samples were dried in sun for several days until a constant

weight was achieved. After drying the samples were ground into a fine powder using a ceramic mortar and stored in polyethylene bags until required for heavy metal analysis, biochemical analysis and the preparation of the diet for experimental mice.

Preparation and Design of the Animal Experiment

This work was carried out at the Department of Genetic Engineering and Biotechnology, Jessore University of Science and Technology, Bangladesh. To study the effects of broiler feed on the biochemical composition of *Gallus domesticus* and its impact on lipid profiles, liver and kidney functions of Swiss albino mice. Eighteen male *Swiss albino* mice (weighing between 35 g and 40 g) were collected from ICDDR, B (Dhaka, Bangladesh). The mice were fed *ad libitum* on a basal diet (BD) and water for 15 days as the preferred adaptation period. They were housed individually in stainless steel cages and divided into six groups of 3 animals in each group. The most common poultry feed was purchased from a local market and served as a diet for the experimental broiler chicken. The used poultry feed was designated as BF. This feed was used as a diet for the two different age group of broiler chicken; feeding continue for 30 days. A total of 30 kg of poultry feed were provided on each group of broiler chicken thrice in a day. To observe the effects of different parts of the broiler on experimental mice, healthy and disease-free broiler chicken (*Gallus domesticus*)of 15–24 days old (1–1.2 kg) and 29–36 days old (2–2.8 kg) and their respective feed (collected randomly from the local farm) were used as diet for the experimental mice. Only the breast and leg part with the bone of the broiler (15–24 days old and 29–36 days old) meat were taken to prepare the diet for experimental mice. The flesh was cut into small pieces and sun-dried for seven days before crushing. The ground samples were then stored in sampling bottles. The samples BB1 (15–24 days old broiler meat with bone), B1 (15–24 days old broiler meat without bone), BB2 (29–36 days old broiler meat with bone), B2 (29–36 days old broiler meat without bone) and BF (broiler feed) were used as experimental diets for mice throughout the study period. Eighteen *Swiss albino* mice from 4–5 weeks old with an initial weight of 35–40 g were randomly divided into six groups of 3 animals in each group and fed: powdered broiler meat samples (BB1, B1, BB2 and B2); and broiler feed samples (BF) of selected amounts (6 gm of body weight). Three mice were in the control group and they were fed normal parched rice, cereal, etc. Their food intake was monitored daily, and all the mice fasted before blood sampling. The mice were anesthetized using diethyl ether. The weight gains of the mice were recorded weekly.

Proximate Composition Analysis

Proximate compositions of the bone with meat and bone without meat of the broiler chicken were determined using AOAC methods (2005). All analyses were conducted in triplicate. Moisture content was measured by weighing differences before and after oven drying at 100– 105°C for 16 hours. Lipid content determination was carried out using the modified Bligh and Dyer procedure (Bligh *et al*., 1959), and the ash content was determined by igniting the sample at 550°C for 5–6 hours until the sample was completely free from carbon particles in a carbolite muffle furnace. The total nitrogen was determined by the Kjeldahl method as described by AOAC (1995) and a factor of 6.25 was used for converting the total nitrogen to the crude protein of the different broiler chicken parts examined here.

Analysis of Heavy Metals

The heavy metals (V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Sr, Pb) contents in respective commercial poultry feedstuffs, in broiler meat and in various mice organs treated with broiler meat as a feed were determined using energy dispersive X-ray fluorescence (EDXRF) spectrometry.

Sample preparation for heavy metals analysis and method validation: The feed samples, broiler samples and treated mice organs with broiler meat were dried in an oven at 60°C until a constant weight was obtained, and the dried samples were finely pulverized in a carbide mortar with a pestle and preserved in desiccators. To prepare the samples for analysis, the dried material was transformed into pellets by applying hydraulic pressure of approximately 3 tons for 25 min. The powdered material (0.1g) was pressed to make a pellet using a pellet maker (Specac Ltd., UK), preserved in polyethylene bags, and retained in desiccators for subsequent analysis using Energy Dispersive X-ray Fluorescence (EDXRF) Spectrometry. EDXRF analysis was carried out on the basis of direct comparison methods, where standards were employed to construct the calibration curves. The main concern in this method is that both standard and sample should have a similar matrix so that they can produce identical sensitivity and hence nullify the matrix effects. To make this possible, three fish standards (Tuna-1, Tuna-2, and Tuna-3) were used to construct calibration curves for the elemental analysis.

DORM-2 dogfish muscle (National Research Council, Canada) served as the certified reference material (CRM) to check the accuracy and precision of the constructed calibration curve or to validate the instrument. This CRM was prepared and analyzed under the same conditions as the real samples that were prepared for analysis. Results obtained for the elements of interest and the certified values for their corresponding elements are documented in Table 1. The obtained values were found to agree well with certified values; the recoveries ranging from 86.66% to 109.29%. The resulting relative error and coefficient of variance (CV) were less than 10% for most of the elements tested, thus suggesting that the proposed method was valid for determining the heavy metals in the feed samples, broiler meat samples and broiler meat-treated organs of mice.

Blood Sampling for Biochemical Analysis

Blood samples were collected in a tube after mice were fed by broiler meat for 30 days and then centrifuged at 3000 rpm for 20 minutes to obtain serum, which was kept frozen until required for analysis. After collecting the serum from mice, serum concentrations of total cholesterol (TC), triglyceride (TG) and HDL-cholesterol (HDL-c) were measured by enzyme-assay using commercial kits (Randox lipid reagents; Randox

Table 1: Comparison between experimental results and certified values (mg kg1, dry weight, DORM-2)

Element	*Results obtained*	*Certified values*	*Relative error (%)*	*CV (%)*	*Recovery (%)*
As	15.80 ± 0.569	18.0	5.89	5.84×10^{-5}	93.72
Cr	30.87 ± 0.9863	34.70	9.34	3.8×10^{-4}	86.66
Pb	0.0503 ± 0.1184	0.065	7.69	4.04×10^{-4}	109.23
Hg	4.916 ± 0.825	4.64	4.56	4.08×10^{-4}	104.95
Co	0.253 ± 0.0375	0.182	1.89	3.43×10^{-4}	104.40

Laboratories Ltd, United Kingdom). According to Kikuchi *et al*. (1998), LDL–cholesterol was calculated as consisting of total cholesterol–(HDL cholesterol + triglycerides /5). The photoelectric colorimeter was used to undertake these biochemical analyses (AP-101; APEL Co., Ltd, Japan).

Statistical Analysis

The recorded data were subjected to two-way analysis of variance (ANOVA) to assess the influence of different variables on the concentrations of heavy metals in the broiler feed, broiler meat, and different organs of the experimental mice. Analysis of variance (ANOVA) for each group of tested samples was performed separately using variables such as sites. All the statistical analyses were computed with the help of STATA software version 8.

Histopathological Examination

For the histopathology of the vital organs like liver and kidney of mice, tissue specimens from liver and kidney were collected from all experimental groups at the end of the experiment. They were subsequently fixed in 10% neutral buffered formalin, dehydrated in ascending concentration of ethanol and cleared in xylene. The fixed tissues were embedded in paraffin wax and sectioned into thicknesses of 4–5 µm, then stained with hematoxylin and eosin (H&E) method (Bancroft *et al*., 1996). Then the sections were examined under light microscopy at 400 X magnification (DP72, Olympus). The results were compared to the control group.

Results and Discussion

To investigate the extent of broiler (*Gallus domesticus*) meat causing health problems, Swiss albino mice were used as an experimental model in this study. This study conducted a proximate analysis of poultry feed (BF), broiler meat, biochemical analysis and determination of heavy metal concentration in meat with bone, meat without the bone of the two groups of the broiler.

Comparison of Heavy Metals and Trace Element between Experimental Results and Certified Values

Table 1 shows the concentration of heavy metals and trace element recoveries from the standard reference materials (DORM-2) were close to the provided certified values by the manufacturers. Recoveries for DORM-2 ranged from 86.66–109.23%. The measured values of SRM 1640 used as an ICP check solution were also close to the certified values reported by NIST (data not reported).

Proximity of Commercial Poultry (Broiler) Feed and Different Parts of the Poultry Feed-treated Broiler Meat

The percentages of moisture, ash, crude fiber, crude protein, crude fat, sodium and vitamin C contents of the BF poultry feed and BF treated two groups of broiler chicken are recorded in (Tables 2 and 3). Results indicated that moisture, ash and crude fiber of the experimental feed BF were slightly lower as compared to the certified values. However, the values of other parameters of the BF was virtually the same as compared to certified values. From Table 2, it is observed that crude protein and crude fiber contents of the broiler feed were 1.427% and 3.721%, respectively, these values are much lower than the standard value, but the sodium (Na) contents (1.56%) is much higher than the standard value. Whereas, in the case of commercial feed treated broiler (*Gallus domesticus*) chicken, it is observed that moisture and ash content ranged from 72.42–75.48% and 4.10–8.87%, respectively (Table 3). A large amount (0.39%) of crude fiber was found only in the three weeks' old broiler meat, but the sodium contents in all broiler meat groups ranged from 1.50 mg/100–2.37 mg/100 g (Table 3). The highest protein content emerged in the three weeks old broiler meat sample without bone meat (B1) sample, yet the moisture, ash and Na contents of all types of broiler meats were within the acceptable limit.

Table 2: Proximity of commercial poultry (broiler) feed (% on DM basis)

Name and nature of the feed samples	*BF (Broiler feed) (M±SE)*	*Standard value*
Moisture	9.2764 ± 0.167	12%
Ash	6.4643 ± 0.167	20%
Crude fiber (CF)	3.7217 ± 0.1792	15%
Crude protein (CP)	1.4275 ± 0.2689	9%
Crude fat (EE)	7.1033 ± 0.4746	8%
Sodium (Na)	1.5603 ± 0.1882	0.15%
Vitamin C	0.0435 ± 0.014	–

BF = Broiler feed (Broiler grower pellet)
M = Mean; SE = Standard error

Table 3: Proximity in the different parts of the poultry feed–treated broiler meat

Sample code	*BB1*	*B1*	*BB2*	*B2*	*Certified value*
Moisture	75.209 ± 0.207	75.476 ± 0.131	73.117 ± 0.89	72.4163 ± 1.06	70.3 ± 1.7
Ash	8.87 ± 0.207	4.101 ± 0.168	8.6394 ± 0.650	4.9060 ± 0.175	–
Crude fiber (CF)	0.3926 ± 0.093	0.288 ± 0.089	0.2667 ± 0.112	0.1091 ± 0.008	–
Crude protein (CP)	36.4443 ± 0.275	38.483 ± 0.283	36.18 ± 1.18	36.4346 ± 1.24	13.9 ± 0.3
Crude fat (EE)	26.67 ± 0.478	26.184 ± 0.354	28.08 ± 0.321	29.05 ± 0.292	–
Sodium (Na)	2.370 ± 0.17	1.50 ± 0.16	1.5766 ± 0.090	2.1290 ± 0.149	60.5 ± 8.5
Vitamin C	0.03 ± 0.056	0.02062 ± 0.064	0.0293 ± 0.007	0.0248 ± 0.005	–

BB1 = Broiler meat with bone; 15–24 days old; 1–1.2kg
B1 = Broiler meat without bone; 15–24 days old; 1–1.2kg
BB2 = Broiler meat with bone; 29–36 days old; 2–2.8kg
B2 = Broiler meat without bone; 29–36 days old; 2–2.8kg
M = Mean; SE= Standard error

Nonetheless the vitamin C contents were found to be very low. Protein contents are slightly higher than the standard value, a finding that is identical to earlier studies on chickenfeed materials (Oyedeji *et al*., 2005; Waldroup 2001). From Table 3, it is also observed that the crude fat content in all groups of meat sample was ranged from 26.18% to 29.05%, which was much higher than that documented in previous studies (Imaobong *et al*., 2015; Lonergan *et al*., 2003).

Analysis of heavy metals and trace elements in poultry (broiler) feed and in different parts of the poultry (broiler) treated broiler: A summary of some heavy metals and trace elements contents in the broiler feedstuffs and different groups of broiler meats are presented in Tables 4 and 5. These data revealed that the levels of chromium, zinc, copper in the analyzed broiler feedstuffs were higher than the recommended values, but the other trace elements were within the recommended value range. The concentration of lead was 0.25 µg/g (Table 4), which is identical to the value reported by Islam *et al.* (2007). From Table 5, it is investigated that the concentration of V (Vanadium) was too low in the B1 sample. On the other hand, 1.25 µg/g, 0.89 µg/g and 0.79 µg/g were found in BB1, BB2, and B2. The concentration of Cr (Chromium) in the BB1 and B1 samples and these were 15.59 µg/g and 12.94 µg/g, respectively, but in BB2 and B2 sample its concentration was very low, and it was below 0.5 µg/g. The concentration of arsenic and cobalt in the meat with bone and meat without the bone of the two groups of the sample were found to be the same as in broiler feed (BF) in (Table 4).

The level of Cr, Mn, Ni, Zn and Sr contents in all types of studied samples were much higher in comparison to the control and these concentrations in BB1 sample was 15.59 ± 8.17 µg/g, 7.03 ± 5.62 µg/g, 3.93 ± 1.86 µg/g, 86.86 ± 3.61 µg/g and 20.82 ± 1.29 µg/g, respectively (Table 5). A similar result has been reported by Hameed *et al.* (2013). This study revealed that the broiler meat product was contaminated by Cr, Pb, Zn, Cu, and Ni.

Analysis of heavy metals (Cr, As, Pb) present in the liver of mice treated with different parts of broiler meat: The heavy metals

Table 4: Analysis of heavy metals and trace elements (V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Sr, Pb) in poultry (broiler) feed samples on dry weight basis (µg/g)

Element	*BF (commercial feed) concentration µg/g (M±SE)*	*Standard value concentration (µg/g)*
V	<0.38	10
Cr	19.18±8.19	1
Mn	59.54±6.06	75
Fe	138.30±6.46	60
Co	<0.28	10
Ni	<100	250
Cu	10.38±0.48	6
Zn	182.19±4.18	65
As	<0.41	0.3
Se	7.33±1.60	0.1
Sr	32.01±1.39	0.1
Pb	0.25±0.06	0.5

M = Mean; SE = Standard error

(Cr, Pb, and As) accumulation in the liver of the experimental mice treated with different groups of broiler meat are summarized in Table 6. Levels of Cr and Pb contents were higher in the liver of the experimental mice treated with all groups of the studied sample (broiler meat sample) in comparison to the control with As being the exception. Although all groups of broiler meat sample treated mice liver contents high amount of Cr and Pb, the BB1 sample treated mice liver contents higher amount in comparison to others (B1, BB2, and B2). It may be due to the high contents of Cr and Pb in the 15–24 days old broiler meat with bone sample (BB1) (Table 5).

Analysis of lipid profile and glucose level in the blood serum of broiler meat for mice treated with different parts of the broiler meat: The biochemical analysis results indicated that the cholesterol, TG, LDL and HDL levels were remarkably higher

Table 5: Analysis of heavy metals and trace elements (V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Sr, Pb) present in different parts of the poultry (broiler) treated broiler

Element	*BB1 Con.µg/g (M±SE)*	*B1Con. µg/g (M±SE)*	*BB2Con. µg/g (M±SE)*	*B2 Con. µg/g (M±SE)*	*Standard Con. µg/g (M±SE)*	*Certified value µg/g (M±SE)*
V	1.25 ± 0.57	<0.38	0.89 ± 0.56	0.79 ± 0.58	10	
Cr	15.59 ± 8.17	12.94 ± 5.14	<0.5	<0.5	0.1	
Mn	7.03 ± 5.62	8.11 ± 5.62	18.15 ± 5.70	8.11 ± 5.62	5	5
Fe	81.51 ± 6.07	111.52 ± 6.27	102.22 ± 6.13	104.60 ± 6.27	80	44
Co	<0.28	<0.28	<0.28	<0.28	10	0.033
Ni	3.93 ± 1.86	5.09 ± 1.83	2.86 ± 1.83	3.91 ± 1.83	0.5	
Cu	1.19 ± 0.43	1.47 ± 0.42	1.39 ± 0.42	1.93 ± 0.43	2	
Zn	86.86 ± 3.61	89.36 ± 3.61	98.29 ± 3.68	106.02 ± 3.68	35	35
As	<0.41	<0.41	<0.41	<0.41	0.5	0.035
Se	2.82 ± 1.29	2.83 ± 1.58	2.86 ± 1.60	5.21 ± 1.60	0.3	0.35
Sr	20.82 ± 1.29	9.87 ± 1.21	22.14 ± 1.31	12.90 ± 1.30	0.3	
Pb	0.35 ± 0.05	0.31 ± 0.05	0.33 ± 0.06	0.32 ± 0.06	0.5	0.5

M = Mean; SE = Standard error

Table 6: Analysis of heavy metals (Cr, As, Pb) present in liver of mice treated with different parts of broiler meat

Element	*BB1Conc.µg/g (M±SE)*	*B1 Conc. µg/g (M±SE)*	*BB2 Conc. µg/g (M±SE)*	*B2 Conc.µg/g (M±SE)*	*Control*	*Certified value*
Cr	0.182 ± 0.05	0.132 ± 0.11	0.233 ± 0.18	0.146 ± 0.07	0.09 ± 0.02	0.3
Pb	0.18 ± 0.01	0.18 ± 0.03	0.08 ± 0.03	0.07 ± 0.02	0.07 ± 0.01	0.47 ± 0.024
As	0.163 ± 0.13	0.158 ± 0.35	0.158 ± 0.49	0.156 ± 0.87	0.16 ± 0.02	

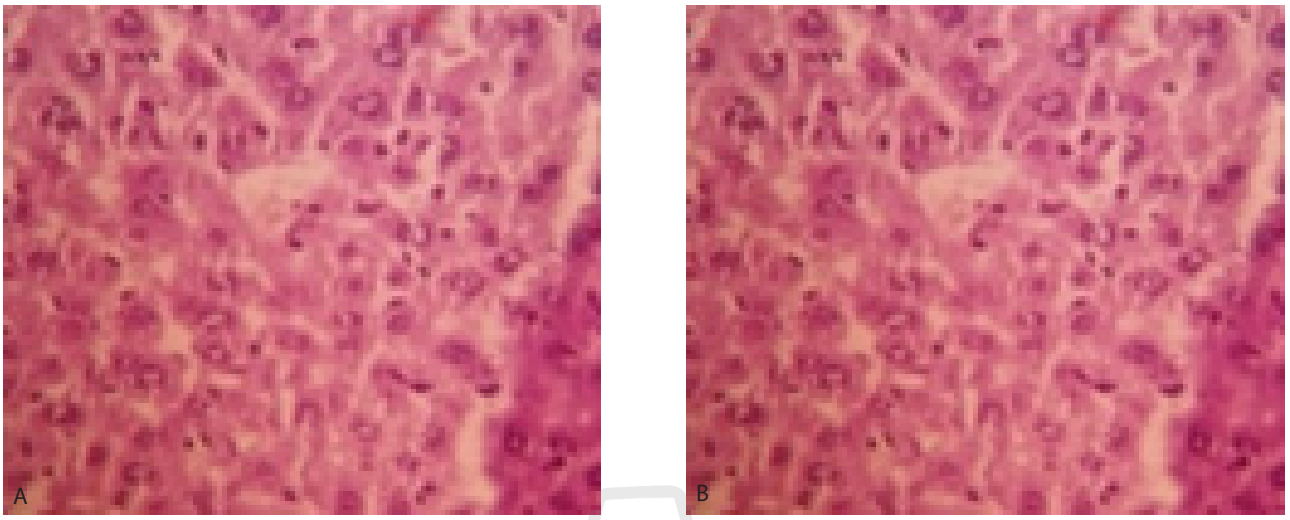
M = Mean; SE = Standard error

Table 7: Determination of lipid profile (cholesterol, triglycerides, HDL and LDL) and glucose level in the blood serum of broiler meat for mice treated with different broiler meat samples

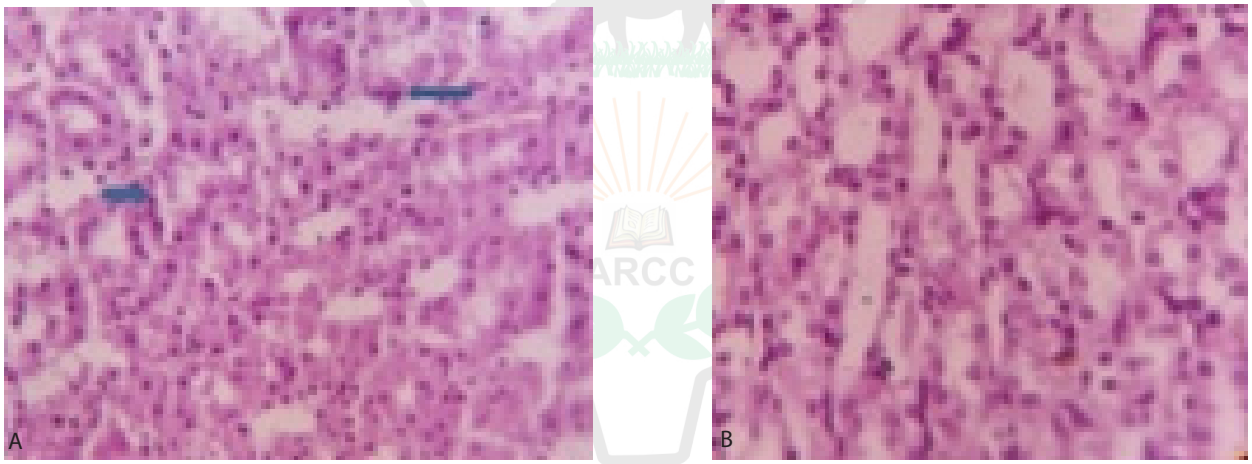
Biochemical parameter mmol/L (M±SE)	*Sample code*						
	Control	*BB1*	*B1*	*BB2*	*B2*	*BF*	*Certified value*
Cholesterol	3.91 ± 0.09	8.661 ± 0.859	7.534 ± 0.639	6.743 ± 0.206	7.519 ± 0.098	7.074 ± 0.506	<5.17
Triglycerides	2.215 ± 0.17	3.470 ± 0.690	2.387 ± 0.310	2.502 ± 0.30	2.613 ± 0.127	2.283 ± 0.044	<1.71
HDL	1.318 ± 0.13	2.912 ± 0.582	2.33 ± 0.77	1.165 ± 0.291	1.456 ± 0.291	2.33 ± 0.582	>1.31
LDL	2.149 ± 0.11	5.005 ± 0.33	4.727 ± 0.39	5.078 ± 0.25	5.540 ± 0.45	4.349 ± 0.37	<3.35
Glucose	5.62 ± 0.22	8.40 ± 2.32	6.540 ± 0.27	4.904 ± 0.43	4.725 ± 0.106	7.074 ± 0.506	3.5-5.5

M = Mean; SE= Standard error
HDL = High density lipoprotein
LDL = Low density lipoprotein

in BB1 and B1 compared to the control group (Table 7). It is interesting to note that the LDL level was higher in the BB2 and B2 samples, but the HDL level was remarkably lower when compared to the control. This may have occurred due to the high content of crude fat, Mn, Cu, Zn, Se and Sr in the BB2 and B2 sample groups. Therefore, the biochemical analysis results indicated that the large amounts of crude fat, protein and some trace elements like Se, Zn, Cr and Cu present in broiler meat samples could be agents causing high levels of cholesterol, LDL and glucose in the broiler meat-treated mice. In our previous study, it has been found high level of Cholesterol, TG, LDL and glucose in mice that fed a diet supplemented with *Anabas testudineus* (Munshi *et al.* 2018). Similarly, high levels of triglyceride and HDL have been found in mice that were fed a diet supplemented with broiler (Das *et al.*, 2014) and ostrich meat (Edvaldo *et al.*, 2011).



Figs 1A and B: Effect of heavy metal content boiler meat on the liver of the mice (A) A photomicrograph of a liver section of a mice (treated with 5 g of BB1 broiler meat sample as diet for 5 weeks) showing atrophic degeneration predominantly in mid-zone. Arrow indicates this; (B) A photograph of the liver section from control mice (treated with 5 g of normal parched rice as diet for 5 weeks) showing no degenerative changes



Figs 2A and B: Effect of heavy metal content in boiler meat on the kidney of a mice (A) Photomicrograph of a kidney section of a mice (treated with 5 g of BB1 broiler meat sample as diet for 5 weeks) showing mild degenerative changes in the straight proximal tubules. Arrow indicates nuclei with inclusions; (B) A photograph of the kidney section from control mice (treated with 5 g of normal parched rice as diet for 5 weeks) showing no degenerative changes

In a similar experiment, Das *et al.* (2014) observed the blood cholesterol levels were also significantly higher, and their finding is consistent with that reported in this study.

Histopathological study: The feeding impact of broiler meat (BB1) on the liver and kidney of the experimental mice (Swiss albino) as shown in (Figs 1 and 2). The photomicrographic histopathology results of liver and kidney revealed no significant change in the control group when treated with normal parched rice and cereal (Figs 1B and 2B). In contrast, referring to the broiler meat treat experimental mice, atrophic degeneration was observed in the mid-zone of liver shown in (Fig. 1B) and mild degenerative change did occur in the kidney shown in (Fig. 2A). The degenerative changes found in the liver and kidney may be the result of the accumulation of heavy metals (Cr, Ni, Zn) when fed broiler meat that had these in large quantities. However, the control group that received a normal diet showed normal central vein, hepatocytes, nucleus, and sinusoid (Figs 1B and 2B). A similar result has been reported by Ahmed *et al.* (2016).

Conclusion

This study suggested that poultry feeds producers and poultry farmers should, firstly, take much care to avoid contamination of heavy metals during the production of feeds; and secondly, increase its nutritive value by eliminating as much as possible those ingredients that promote harmful cholesterol levels. Finally, this study may help poultry feed manufacturers and poultry farmers to provide nutrient-balanced, healthy, safe and cost-effective broiler flesh that continues to be a major source of protein for consumers.

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