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Heavy metals in meat with health implications in Bangladesh

Research

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CONFLICTS OF INTEREST

There are no conflicts of interest for any of the authors.

ABSTRACT

Concentrations of six toxic heavy metals in meat samples (four items like beef, mutton, chicken, and duck) were measured by inductively coupled plasma mass spectrometer (ICP–MS) followed by microwave digestion. The ranges of Chromium (Cr), Nickel (Ni), Copper (Cu), Arsenic (As), Cadmium (Cd) and Lead (Pb) in the investigated items of meat were 0.533–6.55, 0.005–7.70, 0.581–15.99, 0.080–11.34, 0.001–0.22 and 0.061–13.52 mg/kg (on fresh weigh basis), respectively. The estimated levels of most of the heavy metals were higher than the maximum allowable concentration (MAC) for dietary foods. The target hazard quotients (THQ) and carcinogenic risk (TR) of As for both the adults and children suggest that the consumers are exposed chronically to metal pollution with carcinogenic and non-carcinogenic health consequences.

Key words: Heavy metals, Meat, Health risk, Urban area, Bangladesh

INTRODUCTION

Environmental pollution with heavy metals and metalloids is now being considered as a major problem in both developed and developing countries (Ahmed et al. 2015; Islam et al. 2014, 2015). Heavy metals are important from the viewpoint of their toxicity and essentiality and have been widely studied for their toxic effects and bio-accumulation in food chains (Tao et al. 2012). In addition to their essentiality for human nutrition, some micronutrients (e.g. Cu, Cr, and Ni) might be toxic at elevated concentrations (Rahman et al. 2014). However, other metals such as As, Cd and Pb might also in advertently enter the food chain and pose risks to the human and animals (Rahman et al. 2014). Heavy metals like Cr, Ni, As, Cd and Pb have been considered as the most toxic elements in the environment by the US Environment Protection Agency (EPA) (Lei et al. 2010). Toxic elements can be very harmful even at low concentration when ingested over a long time period. For instance, Cr and Cu are essential but may become toxic at higher levels, while Ni are known to cause a variety of pulmonary adverse health effects, such as lung inflammation, fibrosis, emphysema, and tumors (Forti et al. 2011). Lead has been associated with pathological changes in organs and the central nervous system, leading to decrements in intelligence quotients (IQ) in children. Cadmium is toxic to the cardiovascular system, kidneys, and bones while inorganic As, a human carcinogen, is the most toxic form of arsenic (Ahmed et al. 2015).

Non-piscine protein source foodstuffs, e.g. meat, milk and eggs originated from the livestock and poultry sectors are very important for human diet in many parts of the world. These foodstuffs are functioning as a major contributor to solve the global food problem and provide the well-known proteins, minerals, vitamins and essential and non-essential elements (Alturiqi and Albedair 2012). Meat is an important source for some micronutrients such as iron, selenium; vitamins A, B12 and Folic acid which are either not present in plant derived food or have a poor bioavailability. Moreover, meat as a protein-rich and low-carbohydrate product contributes to a low glycemic index which is assumed to be ''beneficial'' with respect to obesity, diabetes development and cancer (insulin resistance hypothesis). Consequently, meat is an important nutrient for human health and development. As an essential part of a mixed diet, meat ensures adequate delivery of essential micronutrients and amino acids and is involved in the regulatory processes of energy metabolism (Cabrera and Saadoun 2014).

In Bangladesh, the evaluation of risks and benefits of the consumption of non-piscine foodstuffs especially meat is extremely important because these foodstuffs (approximately 10% of total food intake per day per individual) supply 30–40% of the animal protein needs of the country (BBS 2011), as well as being a key source of essential minerals, vitamins and fatty acids, act as a very important factor for development of children and adult health (Nriagu et al. 2009). Moreover, elements accumulated in meat can be passed on to people who consume meat and can become a health hazard to the consumers. Therefore, the objectives of this study are to measure the concentrations of Cr, Ni, Cu, As, Cd, and Pb in commonly consumed items of meat in Bangladesh and to evaluate the carcinogenic and non-carcinogenic health risks from consumption of meat from different sources.

2. Materials and methods

2.1. Study area and sampling

This study area is located at the northern part of Bangladesh. The area of Bogra district about 71.56 km² and the population of this district is about 350,397. The per-capita per day intake of meat was used to characterize the consumption pattern for adults and children in Bangladesh (BBS 2011; Islam et al. 2014). About 100 fresh samples of meat (beef, mutton, chicken, and duck) were collected from farms and markets of Bogra district, Bangladesh (Fig. 1). From each sampling site a composite sample for each item of meat (about 200 g) was prepared and homogenized using rotary type food processor. The pre-treated samples were homogenized and then oven-dried at 105 °C for 24 h to attain constant weight. About 20–30 g of dried samples was stored at –20 °C in the laboratory of the Institute of Nutrition and food Science (INFS), University of Dhaka, Bangladesh. The processed samples were brought to Yokohama National University, Japan for chemical analysis.

2.2. Sample extraction procedure

All solutions were prepared with analytical reagent-grade chemicals and MilliQ water (Elix UV5 and MilliQ, Millipore, Billerica, MA, USA). Standard stock solutions containing 10 µg/L of each element (Cd, As, Pb, Cr, Ni and Cu) and internal standard solutions containing 1.0 mg/L of indium, yttrium, beryllium, telium, cobalt and titanium were purchased from Spex Certi Prep® USA. Digestion reagents that were used included 5 ml 69% HNO_3 and 2 ml 30% H_2O_2. The weighed powdered samples of 0.5 g were then placed into the digestion reagent in a Teflon vessel. After digestion samples were then transferred into a Teflon beaker and total volume was made up to 50 ml with MilliQ water. The digested solutions were then filtered (DISMIC® – 25HP PTFE syringe filter (pore size = 0.45 mm); Toyo Roshi Kaisha Ltd., Tokyo, Japan), and stored in crew cap plastic tube.

2.3. Instrumental analysis

Elements in samples were analyzed using inductively coupled plasma mass spectrometer (ICP-MS, 7700 series, Santa Clara, California, USA). All test batches were evaluated using an internal quality approach and validated if they satisfied the defined internal quality controls (IQCs). For each experiment, a run included blank, an internal standard in samples and samples analyzed in triplicate to eliminate any batch-specific error. Multi-element standard solution was used to prepare standard curve. Before starting the sequence, RSD (< 5%) was checked by using tuning solution purchased from Agilent Company (Tokyo, Japan). Each analytical procedure was accompanied with a quality assurance program to ensure the quality of the data.

2.4. Data calculations

2.4.1. Estimated daily intakes (EDIs) of metals

Estimated daily intakes (EDIs) of heavy metals from the consumption of meat depend on the element concentration in meat samples (on fresh weight basis), daily consumption rate and body weight of the consumers, which was calculated by using the formula:

$$EDI = \frac{DFC \times MC}{BW} \tag{1}$$

Where, DFC is the daily meat consumption rate (g/day) for Bangladeshi population (for adults and children in this study, presented in Table 3). This figure was obtained from The "Report of the household income and expenditure survey 2010” (BBS 2011). MC is the mean metal concentration in the composite samples of individual item of meat (mg/kg). BW is the body weight (60 kg for adult and 16 kg for children).

2.4.2. Non-carcinogenic and carcinogenic risks

In this study, the non-carcinogenic health risks associated with the consumption of meats were assessed based on the target hazard quotients (THQs) and calculations were made using the standard assumption for an integrate USEPA risk analysis as follows (USEPA 1989),

$$THQ = \frac{EFr \times ED \times FIR \times MC}{RfD \times BW \times AT} \times 10^{-3} \quad (2)$$

Where, THQ is the target hazard quotient (dimensionless), *EFr* is the exposure frequency (365 days/year), *ED* is the exposure duration (70 years for adult and 14 years for children) equivalent to the average human life time, *FIR* is the food ingestion rate (g/person/day), *MC* is the element concentration in samples (mg/kg, fresh weight), *BW* is the average body weight (adult, 60 kg; children, 16 kg), *AT* is the averaging time for non-carcinogens (365 days/year × number of exposure years), *RfD* is the oral reference dose (mg/kg/day). RfDs are based on 0.001, 0.0003, 0.004, 1.5, 0.02, and 0.04 mg/kg bw/day for Cd, As, Pb, Cr, Ni, and Cu respectively (USEPA 2010). The RfDs represent an estimate of the daily exposure to which the human population may be continually exposed over a lifetime without an appreciable risk of deleterious effects. If the THQ is equal to or higher than 1, there is a potential health risk (Islam et al. 2014, Ahmed et al. 2015), and related interventions and protective measurements should be taken. It has been reported that exposure to two or more toxic elements may result in additive and/or interactive effects (Ahmed et al. 2015). The total THQ (TTHQ, individual meat item) of heavy metals for individual meat was treated as the mathematical sum of each individual metal THQ value:

$$TTHQ = THQ_{toxicant\ 1} + THQ_{toxicant\ 2} + \ldots\ldots\ldots.. + THQ_{toxicant n} \quad (3)$$

To assess the overall potential risk for non-carcinogenic effects posed by more than one element, Hazard Index (HI) approach has been developed by USEPA (1989). HI for a specific receptor/pathway combination (e.g., diet) was calculated as follows:

$$HI = TTHQ_{meat\ 1} + TTHQ_{meat\ 2} + \ldots\ldots\ldots\ldots\ldots + TTHQ_{meat n} \quad (4)$$

When the HI exceeds unity, there may be concern for potential health risks.

For carcinogens, risks were estimated as the incremental probability of an individual to develop cancer over a lifetime exposure to that potential carcinogen (i.e., incremental or excess individual lifetime cancer risk) (USEPA 1989). Acceptable risk levels for carcinogens range from 10^{-4} to 10^{-6}. The equation used for estimating the target cancer risk (lifetime cancer risk) is as follows (USEPA 1989),

$$TR = \frac{EFr \times ED \times FIR \times MC \times CSFo}{BW \times AT} \times 10^{-3} \quad (5)$$

Where, TR represents the target cancer risk or the risk of cancer over a lifetime; *CSFo* is the oral carcinogenic slope factor from the Integrated Risk Information System (USEPA 2010) database was 1.5 $(mg/kg/day)^{-1}$ for As and 0.0085 $(mg/kg/day)^{-1}$ for Pb.

2.5. Statistical analysis

The data were statistically analyzed using the statistical package, SPSS 22.0 (SPSS, USA). The means and standard deviations of the metal concentrations in samples were calculated. Multivariate Post Hoc Tukey tests were employed to examine the statistical significance differences among mean concentrations of heavy metals among meat items. Multivariate methods in terms of principal component analysis (PCA) were used to obtain the detailed information of the data-set and gain insight into the distribution of heavy metals by detecting similarities or dissimilarities in samples. The PCA was performed using Varimax-normalized rotation on the data set using Ward’s method.

3. Results and discussion

3.1. Levels of heavy metals in meats

The concentrations of Cr, Ni, Cu, As Cd and Pb (mg/kg fw) were determined in the most commonly consumed four items of meat in Bangladesh and presented in Table 1. Average concentrations of heavy metals among the four items of meat showed the descending order of: chicken > duck > beef > mutton. For the investigated meat items, a considerable variability in metal concentrations was observed which could be due to variation in species, and growth period (), variable capabilities of absorption and accumulation of heavy metals (Saha and Zaman 2013). In an attempt of rough comparison, the concentration data of heavy metals and metalloids of this study were compared to the data reported in other studies conducted in Bangladesh and/or other regions in the world and presented in Table 2.

Table 1: Concentrations (mg/kg, fresh weight) of heavy metals in four items of meat collected from Bogra district urban area,

	Scientific name		Cr	Ni	Cu	As	Cd	Pb
Chicken	*Gallus gallus domesticus*	Mean± SD	3.6 ± 1.3^{a}	1.4 ± 1.7^{a}	7.2 ± 4.2^{a}	2.9 ± 3.6^{a}	0.018 ± 0.026^{a}	1.9 ± 3.0^{a}
		Range	1.5-6.7	0.003-7.1	1.2-14	0.59-14	0.001-0.075	0.24-14
Duck	*Anas platyrhynchos*	Mean± SD	2.9 ± 0.79^{a}	1.8 ± 1.3^{a}	6.0 ± 4.5^{a}	2.4 ± 1.0^{a}	0.056 ± 0.069^{a}	1.2 ± 0.84^{a}
		Range	2.2-5.5	0.005-4.5	0.93-16	0.93-3.7	0.001-0.22	0.20-2.4
Beef	*Bos primigenius*	Mean± SD	3.5 ± 1.1^{a}	0.95 ± 1.9^{a}	5.9 ± 3.2^{a}	1.4 ± 0.90^{a}	0.017 ± 0.025^{a}	1.2 ± 0.96^{a}
		Range	2.2-5.5	0.025-7.7	0.76-13	0.54-2.8	0.001-0.083	0.15-3.5
Mutton	*Capra aegagrushircus*	Mean± SD	2.2 ± 1.3^{b}	1.6 ± 1.2^{a}	3.2 ± 1.7^{b}	1.3 ± 1.2^{a}	0.045 ± 0.053^{a}	0.78 ± 0.61^{a}
		Range	0.53-4.7	0.12-3.7	0.58-6.5	0.08-3.3	0.001-0.15	0.06-2.0
Maximum allowable concentration (mg/kg, fw)			1*	0.5*	0.1**	0.1*	0.1*	0.1*

Note: Vertically, different letters a,b and c indicate significant different ($P < 0.05$) among the four items of meat.

*JECFA 2005
**JECFA 2012

Table 2: Comparison of heavy metals (mg/kg, fw) in selected items of meat with the reported values in the literatures.

Region	Cr	Ni	Cu	As	Cd	Pb	References
Beef							
Bangladesh	1.3	0.1	1.2	0.042	0.005	0.17	Islam et al. 2015
Belgium	NA	NA	2.2	0.017	0.004	0.004	Waegeneers et al. 2009
Pakistan	NA	NA	81.5	46.5	0.33	2.19	Mariam et al. 2004
Bangladesh	2.02	1.34	2.1	0.57	0.12	0.48	This study
Mutton							
Bangladesh	1.2	1.5	2.5	0.042	0.046	0.45	Islam et al. 2015
Pakistan	NA	NA	5.01	42.4	0.37	4.25	Mariam et al. 2004
China	7.08	1.5	6.06	2.36	24.11	0.21	Sun et al. 2011
Nigeria	NA	NA	10.44	NA	0.69	0.47	Okoye and Ugwu 2010
Bangladesh	1.47	1.29	2.31	0.14	0.14	0.15	This study
Chicken meat							
Bangladesh	1.4	0.39	2.5	0.032	0.03	0.17	Islam et al. 2015
Pakistan	NA	NA	12.86	44.09	0.31	3.1	Mariam et al. 2004
Bangladesh	2.17	1.48	1.99	0.43	0.23	0.37	This study
Duck meat							
Poland	NA	0.014	5.62	NA	0.002	0.018	Kalisinska et al. 2004
Bangladesh	NA	NA	NA	0.033	NA	0.005	Islam et al. 2014
Taiwan	NA	NA	NA	0.012	0.036	0.046	Chen et al. 2013
Bangladesh	1.57	1.37	2.13	0.16	0.16	0.15	This study

Table 3 : Consumption rates and estimated daily intakes of heavy metals from consumption of meat by Bangladeshi population.

Foods	Consumption rate (g/day)*		Estimated daily intake (EDI)											
	Adult	Children	Cr		Ni		Cu		As		Cd		Pb	
			Adult	Children	Adult	Children	Adult	Children	Adult	Children	Adult	Children	Adult	Children
Chicken	17.4	8.3	0.063	0.030	0.025	0.012	0.13	0.06	0.050	0.024	0.0003	0.0002	0.033	0.0155
Duck	7.3	1.7	0.022	0.005	0.013	0.003	0.04	0.01	0.018	0.004	0.0004	0.0001	0.009	0.0021
Beef	12.6	3.1	0.045	0.011	0.012	0.003	0.07	0.02	0.018	0.004	0.0002	0.0001	0.016	0.0039
Mutton	0.9	0.3	0.002	0.001	0.001	0.001	0.003	0.001	0.001	0.001	0.0000	0.0000	0.001	0.0003
Total intake from foods	38.200	13.400	0.132	0.047	0.052	0.019	0.247	0.090	0.087	0.033	0.001	0.0003	0.058	0.022
Maximum tolerable daily intake (MTDI)				2.8[a]	4.3[b]			30[c]	1.8[c]		0.66[c]			3.0[c]

*BBS 2011
[a]RDA 1989; [b]WHO 1996; [c]JECFA 2003

Table 4 : Carcinogenic (TR) and Non-carcinogenic (THQ) health risks of heavy metals due to consumption meat in Bangladesh.

Meat items	Target Hazard Quotients (THQ)												Total TTHQ		Target carcinogenic risk (TR)			
	Cr		Ni		Cu		As		Cd		Pb				As*		Pb	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child
Chicken	0.00070	0.00126	0.021	0.037	0.052	0.094	**2.762**	**4.941**	0.002	0.003	0.155	0.277	2.993	5.354	6.2E-04	1.1E-03	4.6E-06	8.2E-06
Duck	0.00025	0.0002	0.011	0.010	0.019	0.016	**1.000**	0.862	0.002	0.002	0.043	0.037	1.075	0.926	5.3E-04	9.5E-04	3.0E-06	5.4E-06
Beef	0.00050	0.0005	0.010	0.009	0.031	0.029	0.993	0.916	0.001	0.001	0.075	0.069	1.111	1.025	3.1E-04	5.5E-04	3.1E-06	5.5E-06
Mutton	0.00002	0.0000	0.001	0.002	0.001	0.002	0.067	0.084	0.000	0.000	0.003	0.004	0.073	0.091	2.9E-04	5.2E-04	1.9E-06	3.4E-06
Total	0.001	0.002	0.043	0.058	0.103	0.140	4.823	6.803	0.005	0.006	0.276	0.387	**5.252**	**7.396**	2.2E-03	3.9E-03	1.6E-05	2.8E-05

*Assuming 50% inorganic As in foods (Islam et al. 2015); Bold indicates THQ > 1

3.1.1. Chromium (Cr)

The amount of Cr in the diet is of great importance as Cr is involved in insulin function and lipid metabolism. The mean concentration of Cr in four items of meat followed the descending order of: chicken> beef > duck > mutton. The highest mean concentration of Cr was observed in chicken meat (3.6±1.3 mg/kg) and the lowest was found in duck meat (2.2±1.3 mg/kg) (Table 1). Statistical significant differences (*$p < 0.05$*) were observed for Cr concentrations for mutton than with the other items of meat (Table 1). The observed elevated levels of Cr in the chicken meat samples might be due to the use of tannery waste as poultry feed which contain a very high level of Cr (Mahmud et al. 2011). The concentrations of Cr in all meat items were higher than the maximum allowable concentration (MAC) of Cr in foods (Table 1), indicating severe Cr contamination in meat. However, results of Cr content in non-piscine foodstuffs obtained in this study were higher than the result obtained by Islam et al. (2015) and lower than the result obtained by Sun et al. (2011) (Table 2).

3.1.2. Nickel (Ni)

Nickel normally occurs at very low levels in the environment and it can cause variety of pulmonary adverse health effects, such as lung inflammation, fibrosis, emphysema and tumours (Forti et al. 2011). The mean concentration of Ni in the analyzed foodstuffs followed the descending order of: duck > mutton > chicken > beef. The highest mean concentration of Ni was observed in duck meat (1.8±1.3 mg/kg) and the lowest was found in mutton (0.95±1.9 mg/kg) (Table 1). The concentrations of Ni in all items of meat samples were higher than the maximum allowable concentration (MAC) of Ni in foods (Table 2), indicating severe Ni contamination in meat and not suggested for human consumption.

Fig. 1. Map of the study area in Bangladesh.

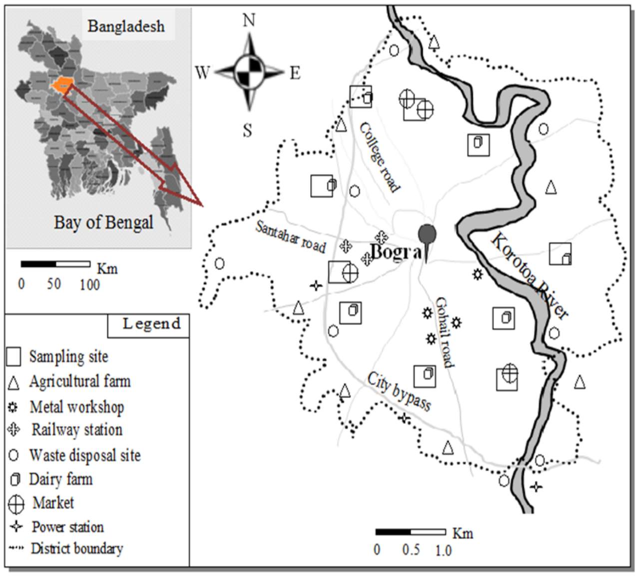
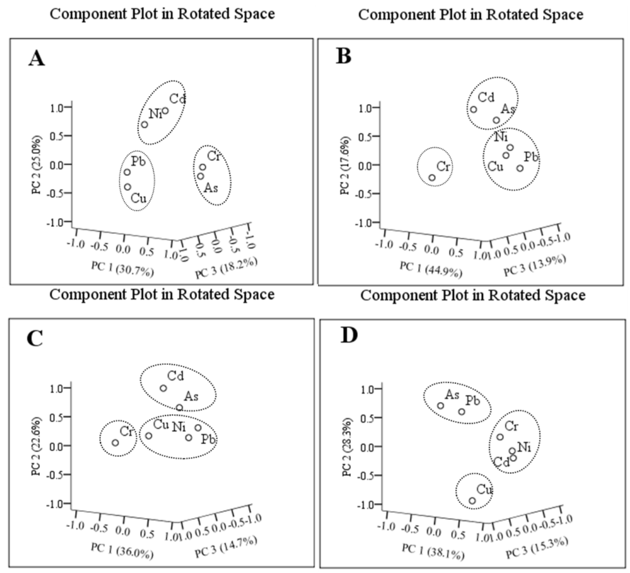


Fig. 2. Principal component analysis (PCA) of heavy metals in meat chicken (A), duck (B), beef (C) and mutton (D) collected from Bogra district, Bangladesh.



3.1.3. Copper (Cu)

Among the analyzed items of meat, the mean concentrations of Cu followed the descending order of: chicken > duck > beef > mutton. The highest mean concentration of Cu was observed in chicken meat (7.2±4.2 mg/kg) and the lowest was found in mutton (3.2±1.7 mg/kg) (Table 1). Statistical significant differences ($p < 0.05$) were observed for Cu concentrations in mutton compared with the other item of meat samples. The concentrations of Cu in analyzed meat samples were higher than the maximum allowable concentration (MAC) of Cu in foods (Table 2), indicating these meats are contaminated by Cu and might pose risk to the consumers. However, results from this study regarding Cu concentrations were lower than those obtained by Mariam et al. (2004), Waegeneers et al. (2009), Okoye and Ugwu (2010), Sun et al. (2011), Kalisinska et al. (2004), Islam et al. (2015) for meat samples (Table 2).

3.1.4. Arsenic (As)

Chronic exposure to As can lead to dermatitis, mild pigmentationkeratosis of the skin, vasospasticity, gross pigmentationwith hyperkeratinization of exposed areas, wart formation, decreased nerve conduction velocity, and lung cancer (Occupational Safety and Health Administration 2004). The mean concentration of As in foodstuffs followed the descending order of: chicken > duck > beef > mutton. The highest mean concentration of As was observed in chicken meat (2.9±3.6 mg/kg) and the lowest was found in mutton (1.3±1.2 mg/kg) (Table 1). The concentrations of As in all of the analyzed foodstuffs were higher than the maximum allowable concentration (MAC) of As in foods (Table 2), indicating these meat items are contaminated by As and might pose risk to the consumers. Results of As content in four items of meat obtained in this study were higher than those obtained by Islam et al. (2015), Waegeneers et al. (2009), Chen et al. (2013) , Islam et al. (2014) and lower than those obtained by Mariam et al. (2004), Sun et al. (2011) (Table 2). The present study revealed that meat samples showed elevated levels of As which might be attributed to the use of As contaminated ground water for irrigation (Neumann et al. 2010) and rice straw for feeding the cattle. It is well documented that grazing cattle involuntarily ingest a certain amount of soil (up to 18%) which can lead to a significant exposure to non-essential elements that may be present in the soil (Blanco-Penedo et al. 2010). Moreover, some farmers also use certain arsenic enriched fertilizers and pesticides (Islam et al. 2015) with feeds for the cattle to make them very healthy (fattening) in a short period of time.

3.1.5. Cadmium (Cd)

Food, rather than air or water, represents the major source of Cd exposure (Rahman et al. 2013). Cadmium is a highly toxic metal with a natural occurrence in soil which might be transported in the food chain by “soil-plant-animal” and/or “soil-water-animal” pathways of the ecosystems. Cadmium may accumulate in the human body and may give rise to renal, pulmonary, hepatic, skeletal, reproductive effects and cancer (Zhu et al. 2011). The mean concentration of Cd in the analyzed meat items followed the descending order of: duck > mutton > chicken > beef. The highest mean concentration of Cd was observed in duck meat

(0.056±0.069 mg/kg) and the lowest was found in beef (0.017±0.025 mg/kg) (Table 1). The concentrations of Cd in meat samples were lower than the maximum allowable concentration (MAC) of Cd in foods (Table 1). However, results of Cd content in meat samples obtained in this study were higher than the results obtained by Kalisinska et al. (2004), Waegeneers et al. (2009), Chen et al. (2013), Islam et al. (2015) and lower than those obtained by Mariam et al. (2004), Okoye and Ugwu (2010), Sun et al. (2011) (Table 2).

3.1.6. Lead (Pb)

Lead is a toxic metal that enters into the human body through air, water and foods and cannot be removed by washing and cooking of foods (Sharma et al. 2007). Lead is a non-essential element and it is well documented that Pb can cause neurotoxicity, nephrotoxicity, and many others adverse health effects (Garcia-Leston et al. 2010). Among the analyzed meat items, the mean Pb concentrations followed the descending order of: chicken > beef > duck > mutton. The highest mean concentration of Pb was observed in chicken meat (1.9±3.0 mg/kg) and the lowest was found in mutton (0.78±0.61 mg/kg) (Table 1). The concentrations of Pb in analyzed meat samples were higher than the maximum allowable concentration (MAC) of Pb in foods (Table 2), indicating severe contamination by Pb. The elevated levels of Pb in meat samples may be attributed to the high bioaccumulative characteristics of Pb in muscle tissues of animals. However, results from this study regarding Pb concentrations were higher than the result obtained by Kalisinska et al. (2004), Waegeneers et al. (2009), Chen et al. (2013), Islam et al. (2014, 2015) and lower than the result obtained by Mariam et al. (2004), Okoye and Ugwu (2010), Sun et al. (2011) (Table 2). The results of the present study indicate that the problem of Pb in all items of meat is more widespread.

3.2. Multivariate analysis

Multivariate principal component analysis (PCA) in respect of cumulative variance for the studied heavy metals in samples about 83.9%, 76.4%, 73.3% and 81.7% for chicken, duck, beef and mutton, respectively (Fig. 2). In the PCA analysis, first three components were computed and the variance explained by them was 30.7%, 25.0% and 18.2% for chicken, 44.9%, 17.6% and 13.9% for duck, 36.0%, 22.6% and 14.7% beef and 38.1%, 28.3% and 15.3% for mutton (Fig. 2). Overall, PCA revealed three major groups of the studied six metals in four items of meat samples. One group comprised of Ni, Cu and Pb for duck and beef, Cr and As for chicken and Cr, Ni and Cd for mutton indicating that these were mostly contributed by anthropogenic activities (Manzoor et al. 2006). Second group showed mutual association of Cu-Pb for chicken and mutton, Cr for duck and beef which were mostly contributed by the lithogenic sources (Iqbal and Shah 2011). Third group revealed similar loadings of Ni-Cd for chicken, Cd-As for duck and beef and As-Pb for mutton which were mostly contributed by the industrial emissions in the vicinity of the sampling sites (Manzoor et al. 2006).

3.3. Health risk assessment

3.3.1. Estimated daily intake (EDI) of heavy metals

The dietary exposure approach of heavy metals from the consumption of meat is a reliable tool for investigating a population's diet in terms of intake levels of nutrients, bioactive compounds, and contaminants. The intake data can then be used to examine a specific element of interest to assess the health risk in terms of maximum tolerable daily intake (MTDI). The MTDI is the upper limit of a metal ingested through food that has no or negligible cumulative adverse effects on human health (JECFA 2003). This study provides an estimate of the dietary intake and examines the dietary exposure to six trace elements (Cr, Ni, Cu, As, Cd and Pb) through consumption of meat in the population's daily diet. Data are then compared to the respective MTDI of studied metals.

The estimated daily intakes (EDIs) of heavy metals were evaluated according to the average concentration of each element in each item of meat and the respective consumption rate (Islam et al. 2014). The EDI of heavy metals for both adults and children from consumption of meat and maximum tolerable daily intake (MTDI) are shown in Table 3. For adults and children, the EDI showed the descending order of Cu > Cr > As > Pb > Ni > Cd. However, the total EDI from consumption of chicken meat was higher than that of other meat for both the adults and children which may be attributed to the higher consumption rate of chicken as well as higher levels of metal contamination in chicken meat. Overall, the intake levels of studied heavy metals through consumption of investigated meat items were lower than the permissible limit for adults and children (Table 3).

3.3.2. Non-carcinogenic health hazard and carcinogenic risk

Risk assessment is the process that evaluates the potential health effects from doses to humans of one contaminant received through one or more exposure pathways. The non-carcinogenic risks from consumption of meats by the adults and children were assessed based on the target hazard quotients (THQ). The THQ is a ratio of determined dose of a pollutant to the reference dose level. If the ratio is greater than 1, the exposed population is likely to experience obvious adverse effects (Wang et al. 2005). The methodology for estimation of THQs although does not provide a quantitative estimate on the probability of an exposed population experiencing a reverse health effect, but it offers an indication of the risk level due to contaminant exposure. The estimated THQs of studied heavy metals are shown in Table 4, indicated that THQ values of As were above 1 for both the adults through consumption of chicken and duck meat, suggesting that the exposed population would experience significant health risks in case of ingesting As from chicken and duck meat. Given all the metals in consideration, TTHQ (sum of individual metal THQ) for the consumption of the studied items of meat were in the range of 0.073 to 2.993 and 0.091 to 5.354 for adults and children, respectively (Table 4). Potential health risks from exposure to heavy metals through consumption of selected meats are therefore of some concern. Different metals could have similar damage on some health endpoints, such as Cu and Pb on cognitive impairments, motor disorders, gastrointestinal tract, and cardiovascular system, and Cd and Pb on the reproductive system. Therefore, the total THQ (TTHQ) is reliably helpful to assess and compare their combined risks from different foods, and have been widely employed in recent literature (Wang et al. 2005). It is noteworthy that the TTHQ value is a highly conservative and relative index. The TTHQ > 1 may not in reality show consumers actually experiencing the adverse health effects (Islam et al. 2015).

The hazard index (HI) value expresses the cumulative non-carcinogenic effects of multiple elements exposed from consumption of one or more foods. In Table 4, HI values through consumption of investigated meats were 5.252 and 7.396 for adults and children, respectively, indicating that consumers of studied items of meat may experience adverse health effects. The element specific contributions of the studied metal to HI were the descending order of: As > Pb > Cu > Ni > Cd > Cr for adults and children. Hence, this study reveals that exposure to As from consumption of meat might pose significant non-carcinogenic health risks for both the adults and children in Bangladesh.

The target carcinogenic risks (TR) derived from the intake of As and Pb were calculated since these elements may promote both non-carcinogenic and carcinogenic effects depending on the exposure dose. Inorganic As is classified as a known carcinogen (USEPA Group A) and Pb as probable carcinogen based on animal studies (USEPA Group B2). The TR values of As and Pb for both adults and children due to exposure from consumption of four items of meat are listed in Table 4. The TR values from exposure of As were found in the range of 2.9E-04 to 6.2E-04 and 5.2E-04 to 1.1E-03, whereas for Pb, it was 1.9E-06 to 4.6E-06 and 3.4E-06 to 8.2E-06 for adults and children, respectively. In general, the excess cancer risk lower than 10^{-6} are considered to be negligible, cancer risk above10^{-4} are considered unacceptable and risks lying between 10^{-6} and 10^{-4} are generally considered an acceptable range (USEPA 1989, 2010). The carcinogenic risk for Pb was within the acceptable to the negligible range ($<10^{-6}$ to 10^{-4}), whereas for As, it was in the unacceptable range ($>10^{-4}$) to the acceptable range (10^{-6} to 10^{-4}). Considering the specific exposure from meat, it was found that TR values of As from consuming of meat were 22 times (adults) and 39 times (children) higher than the acceptable value (10^{-4}), which might be attributed to relatively higher consumption rate of meat for children in terms of body weight compared to the adults. Our findings also suggest that children are more susceptible to toxic or non-essential element exposure through daily meat consumption than the adults in Bangladesh. Therefore, the potential health risk to the consumers due to the exposure of heavy metals through meat consumption should not be ignored. In addition, there are also some other sources of metal exposures, such as consumption of other foodstuffs (e.g. rice, vegetables, fish, etc.) and dust inhalation, which are not included in this study. It is thus suggested that constant monitoring of both toxic and essential elements in all food commodities is needed in order to evaluate if any potential health risk to the consumers does exist in the study area.

4. CONCLUSIONS

Heavy metals and metalloids play important roles in human body. In this study, concentrations of six heavy metals (Cr, Ni, Cu, As, Cd, and Pb) in four items of meat (four items like beef, mutton, chicken, and duck) in Bogra district, Bangladesh were assessed. This study revealed that metals were mostly contributed by anthropogenic activities. The estimated levels of most of the heavy metals were higher than the maximum allowable concentration (MAC) in dietary foods. Single element target hazard quotient (THQ) and combined elements hazard index (HI) revealed that exposure to As from consumption of meat might pose significant non-carcinogenic health risks for both the adults and children. Also, the estimation showed that the carcinogenic risk (TR) of Pb was within the acceptable to the negligible range ($<10^{-6}$ to 10^{-4}), whereas for As, it was in the unacceptable range ($>10^{-4}$) to the acceptable range (10^{-6} to 10^{-4}). From the health point of view, this study showed that the consumers are exposed chronically to elemental pollution with carcinogenic and non-carcinogenic consequences. This study recommended that the Government of Bangladesh should ensure the food safety for the citizens by regular monitoring the contamination levels of toxic heavy metals and metalloids in their daily diets for the enforcement of regulatory standards and assessing the risk for long-term exposure.

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REFERENCES

1. Ahmed, M.K., Shaheen, N., Islam, M.S., Al-Mamun, M.H., Islam, S., Mohiduzzaman, M., & Bhattacharjee, L. (2015). Dietary intake of trace elements from highly consumed cultured fish (*Labeorohita, Pangasius pangasius* and *Oreochromis mossambicus*) and human health risk implications in Bangladesh. Chemosphere, 128, 284–292.
2. Alturiqi, A.S., & Albedair, L.A. (2012). Evaluation of some heavy metals in certain fish, meat and meat products in Saudi Arabian markets. Egyptian Journal of Aquatic Reserch, 38, 45–49.
3. BBS (2011). Report of the household income and expenditure survey 2010. Bangladesh Bureau of Statistics, Statistics division, Ministry of Planning, Dhaka, Bangladesh.
4. Blanco-Penedo, I., Lopez-Alonso, M., Miranda, M., Hernandez, J., Prieto, F., & Shore, R.F. (2010). Non-essential and essential trace element concentrations in meat from cattle reared under organic, intensive or conventional production systems. Food Additives and Contaminants: Part A, 27(1), 36–42.
5. Cabrera, M.C., & Saadoun, A. (2014). An overview of the nutritional value of beef and lamb meat from South America. Meat Science, 98, 435–444.
6. Chen, S.S., Lin, Y.W., Kao, Y.M., & Shih, Y.C. (2013). Trace elements and heavy metals in poultry and livestock meat in Taiwan. Food Additives and Contaminants: Part B, 6, 231–236.
7. Forti, E., Salovaara, S., Cetin, Y., Bulgheroni, A., Pfaller, R.W., & Prieto, P. (2011). In vitro evaluation of the toxicity induced by nickel soluble and particulate forms in human airway epithelial cells. Toxicology in Vitro, 25, 454–461.
8. Garcia-Leston, J., Mendez, J., Pasaro, E., & Laffon, B. (2010). Genotoxic effects of lead: an updated review. Environment Inernational, 36, 623–636.
9. Iqbal, J., & Shah, M.H. (2011). Distribution, correlation and risk assessment of selected metals in urban soils from Islamabad, Pakistan. Journal of Hazardous Materials, 192, 887–898.
10. Islam, M.S., Ahmed, M.K., Al-Mamun, M.H., & Masunaga, S. (2015). Assessment of trace metals in foodstuffs grown around the vicinity of industries in Bangladesh. Journal of Food Composition and Analysis, 42, 8–15.
11. Islam, M.S., Ahmed, M.K., Al-Mamun, M.H., Islam, K.N., Ibrahim, M., & Masunaga, S. (2014). Arsenic and lead in foods: a potential threat to human health in Bangladesh. Food Additives and Contaminants: Part A, 31, 1982–1992.
12. JECFA (2003). In: summary and conclusions of the 61st Meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA). JECFA/61/SC, Rome, Italy.
13. JECFA (2005). Codex General Standard for Contaminants and Toxins in Food and Feeds. In: 64th Meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA), JECFA/64/CAC/RCP 49-2001.
14. JECFA (2012). Working document for information and use in discussions related to contaminants and toxins in the GSCTFF. Joint FAO/WHO Food Standards Programme, Codex Committee on Contaminants in Foods, Sixth Session, Maastricht, the Netherlands, CF/6 INF/1, 2012. Available at: <ftp://ftp.fao.org/codex/meetings/cccf/cccf6/cf06_INFe.pdf>
15. Kalisinska, E., Salicki, W., Myslek, P., Kavetska, K.M., & Jackowski, A. (2004). Using the Mallard to biomonitor heavy metal contamination of wetlands in north-western Poland. Science of the Total Environment, 320, 145–161.
16. Lei, M., Zhang, Y., Khan, S., Qin, Pu., & Liao, Bo. (2010). Pollution, fractionation and mobility of Pb, Cd, Cu, and Zn in garden and paddy soils from a Pb/Zn mining area. Environmental Monitoring and Assessment, 168, 215–222.
17. Mahmud, T., Rehman, R., Ali, S., Anwar, J., Abbas, A., Farooq, M., & Ali, A. (2011). Estimation of Chromium (VI) in various body parts of Local Chicken. Journal of the Chemical Society of Pakistan, 33, 339–342.
18. Manzoor, S., Shah, M.H., Shaheen, N., Khalique, A., & Jaffar, M. (2006). Multivariate analysis of trace metals in textile effluents in relation to soil and groundwater. Journal of Hazardous Materials, 137, 31–37.
19. Mariam, I., Iqbal, S., & Nagra, S.A. (2004). Distribution of Some Trace and Macrominerals in Beef, Mutton and Poultry. International Journal of Agriculture and Biology, 5, 816–820.
20. Neumann, R.B., Ashfaque, K., Badruzzaman, A.B.M., Ali, M.A., Shoemaker, J., & Harvey, C. (2010). Anthropogenic influences on groundwater arsenic concentrations in Bangladesh. Nature Geoscience, 3, 46–52.
21. Nriagu, J., Boughanen, M., Linder, A., Howe, A., Grant, C., Rattray, R., Vutchkov, M., & Lalor, G. (2009). Levels of As, Cd, Pb, Cu, Se and Zn in bovine kidneys and livers in Jamaica. Ecotoxicology and Environmental Safety, 72, 564–571.
22. Occupational Safety and Health Administration (2004). Toxic metals, occupational safety and health administration. US Department of Labor, 200 Constitution Avenue, NW, Washington, DC, available at: <http://www.osha.gov>
23. Okoye, C.O.B., & Ugwu, J.N. (2010). Impact of Environmental Cadmium, Lead, Copper and Zinc on Quali-

ty of Goat Meat in Nigeria. Bulletin of the Chemical Society of Ethiopia, 24, 133–138.

24. Rahman, M.M., Asaduzzaman, M., & Naidu, R. (2013). Consumption of arsenic and other elements from vegetables and drinking water from an arsenic-contaminated area of Bangladesh. Journal of Hazardous Materials, 262, 1056–1063.
25. Rahman, M.A., Rahman, M.M., Reichman, S.M., Lim, R.P., & Naidu, R. (2014). Heavy metals in Australian grown and imported rice and vegetables on sale in Australia: Health hazard. Ecotoxicology and Environmental Safety, 100, 53–60.
26. RDA (1989). Recommended Dietary Allowance, 10th ed. National Academic Press, Washington, DC.
27. Saha, N., & Zaman, M.R. (2013). Evaluation of possible health risks of heavy metals by consumption of foodstuffs available in the central market of Rajshahi City, Bangladesh. Environmental Monitoring and Assessment, 185, 3867–3878.
28. Sharma, R.K., Agrawal, M., & Marshall, F.M. (2007). Heavy metals contamination of soil and vegetables in suburban areas of Varanasi, India. Ecotoxicology Environmental Safety, 66, 258–266.
29. Sun, S., Guo, B., Wei, Y., & Fan, M. (2011). Multi-element analysis for determining the geographical origin of mutton from different regions of China. Food Chemistry, 124, 1151–1156.
30. Tao, Y., Yuan, Z., Xiaona, H., & Wei, M. (2012). Distribution and bioaccumulation of heavy metals in aquatic organisms of different trophic levels and potential health risk assessment from Taihu Lake, China. Ecotoxicology and Environmental Safety, 81, 55–64.
31. USEPA (1989). Risk assessment guidance for superfund, vol. I: Human Health Evaluation Manual. EPA/540/1–89/002. Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, DC.
32. USEPA (2010). Risk-Based Concentration Table. U.S. Environmental Protection Agency, Washington DC. Available at <http://www.epa.gov/reg3hwmd/risk/human/index.htm>
33. Waegeneers, N., Pizzolon, J.C., Hoenig, M.De., & Temmerman, L. (2009). Accumulation of trace elements in cattle from rural and industrial areas in Belgium. Food Additives and Contamination: Part A, 26 (3), 326–332.
34. Wang, X., Sato, T., Xing, B., & Tao, S. (2005). Health risks of heavy metals to the general public in Tianjin, China via consumption of vegetables and fish. Science of the Total Environment, 350, 28–37.
35. WHO (1996). Guidelines for Drinking-Water Quality, 2nd ed., vol. 2. World Health Organization, Geneva, Switzerland.
36. Zhu, F., Fan, W., Wang, X., Qu, L., & Yao, S. (2011). Health risk assessment of eight heavy metals in nine varieties of edible vegetable oils consumed in China. Food and Chemical Toxicology, 49, 3081–3085.