Human Health Risk of Chromium Intake From Consumption of Poultry Meat and Eggs in Dhaka, Bangladesh

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Introduction

Food safety has been a major public health concern worldwide in recent years due to the presence of toxic heavy metals in food of animal origin.1,2 Heavy metal contamination in the food chain is a serious threat to human health due to the toxicity, biomagnification and bioaccumulation capacities of heavy metals.3 These heavy metals may cause direct physiological toxic effects as they are accumulated in tissues, sometimes permanently.4,5 Heavy metals such as lead, cadmium, chromium (Cr), copper, zinc and cobalt are commonly ingested through food in the human diet, although their levels vary from place to place depending on dietary habits, level of environmental pollution and recycling of poultry food.2

During the last two decades, many developing countries have adopted intensive poultry production to meet the demand for animal protein. Intensive poultry farming is seen as a way to quickly increase the supply of economical, palatable and healthy food protein for growing urban populations. The poultry industry is now the largest sector of agriculture throughout the world and is rapidly increasing in South Asia. In Bangladesh, poultry farming has an increasing share in the national economy.6 There is a rapid increase in consumption of chicken due to its lower purchase cost compared to mutton and better nutritional value and health benefits than beef. In order to meet the

Background. Heavy metal contamination of food is a serious threat. Long term exposure may lead to human health risks. Poultry and eggs are a major source of protein, but if contaminated by heavy metals, have the potential to lead to detrimental effects on human health.

Objectives. The objective of this study is to determine chromium concentrations in poultry meat (flesh and liver) and eggs collected from poultry farms in Dhaka, Bangladesh, to calculate the daily intake of chromium from the consumption of poultry meat and eggs for adults, and to evaluate their potential health risk by calculating the target hazard quotients (THQ).

Methods. All samples of poultry feed, meat (flesh and liver) and eggs were analyzed by a graphite furnace atomic absorption spectrometer (AAS) (GFA- EX- 7i Shimadzu, Japan).

Results. Chromium concentrations were recorded in the range of not detected (ND) to 1.3926±0.0010 mg kg⁻¹ and 0.0678±0.0001 mg kg⁻¹ to 1.3764±0.0009 mg kg⁻¹ in the liver of broiler and layer chickens, respectively. Chromium concentrations were determined in the range of 0.069±1.0004 mg kg⁻¹ to 2.0746±0.0021 mg kg⁻¹ and 0.0362±0.0002 mg kg⁻¹ to 1.2752±0.0014 mg kg⁻¹ in the flesh of broiler and layer chicken, respectively. The mean concentration of chromium in eggs was 0.2174-1.08 mg kg⁻¹. The highest concentration of chromium 2.4196±0.0019 mg kg⁻¹ was found in egg yolk. Target hazard quotients values in all poultry flesh, liver and eggs samples were less than one, indicating no potential health risks to consumers.

Conclusions. The estimated daily intake values of chromium were below the threshold limit. Thus, our results indicate that no adverse health effects are expected as a result of ingestion of chicken fed with tannery waste.

Competing Interests. The authors declare no competing financial interests.

Keywords. heavy metal, chromium, poultry, eggs, target hazard quotient

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increasing demand for chicken meat, suppliers and poultry farm owners have attempted to facilitate this demand through an uninterrupted supply of feed production. In the last few years, tannery waste in the form of tanned skin-cut wastes, which contain a large amount of heavy metals, especially Cr, have been used for the manufacture of poultry feed in many developing countries such as Bangladesh. This is the most direct source of chromium contamination in the food chain. There are two forms of chromium: Cr (III) is an essential trace mineral nutrient and Cr (VI) is regarded as a hazardous carcinogen.

In some cases, leather shaving dusts are directly used as poultry feed. There is high possibility for the transport of chromium from skin-cut wastes and leather shaving dusts to poultry, as well as the human body through ingestion of poultry, and this poses a risk of causing serious diseases, including cancer. Although the use of tannery wastes as poultry feed is rapidly increasing, few studies have been carried out assessing the human health risk of heavy metals intake via dietary consumption of poultry meat and eggs in Bangladesh. The aim of this study is to quantify the concentration of chromium in chicken, eggs and poultry feed made from waste products from tanneries, in order to assess the risk to human health.

**Methods**

**Study Area and Sampling**

Six layer chickens from six different poultry farms and four broiler chickens from four different poultry farms were collected from the Gazipur district of Bangladesh, a major source of poultry supply in Dhaka city. Chickens were slaughtered and the liver and flesh were collected using sterile techniques.

There were a total of 20 samples from poultry meat (6 liver and 6 flesh samples from layer poultry, and 4 liver and 4 flesh samples from broiler poultry meat). All collected organ parts were kept in separate sterile airtight plastic bags, labeled, and stored at 4°C until analysis within 24 hours.

Egg samples were collected from 6 different poultry farms from the Gazipur district of Bangladesh which are the main supply of eggs in Dhaka city. Three eggs from each farm were mixed to prepare one representative sample. Albumen, yolk and eggshell were separated carefully in a Pyrex petri dish. There were 18 samples from eggs (6 albumen, 6 yolk and 6 eggshell). All collected samples were kept in separate sterile Pyrex petri dishes, labeled and stored at 4°C until analysis within 24 hours.

Three poultry feed samples (500 g of each sample) were also collected from three different brands commonly used as both broiler and layer chicken feed to determine the concentration of chromium in poultry feed.

**Ethics Approval**

This study was approved by the Biosafety, Biosecurity and Ethical Committee of Jahangirnagar University on biosafety, biosecurity and ethical issues of animal subject research.

**Chemical Analysis**

All the samples were air dried. Chicken liver and flesh were chopped into small chunks with a sterile stainless steel knife and the samples were made into a semi-liquid state. All the samples were oven-dried in an oven at 80°C for 48 hours to remove all moisture. Dried samples were powdered using a pestle and mortar and sieved through muslin cloth.

For each sample, three powdered samples (1 g each) were accurately weighed and placed in crucibles to produce three replicates for each sample. The powder samples were digested with perchloric acid and nitric acid (1:4) solution. The samples were left to cool and contents were filtered through Whatman filter paper No. 42. Each sample solution was made up to a final volume of 25 ml with distilled water and analyzed by a graphite furnace atomic absorption spectrometer (GFA- EX- 7i Shimadju, Japan).

**Quality Assurance and Quality Control Analysis**

Quality assurance and quality control were incorporated into the analysis. The instrument was first
where CE is the experimental concentration determined from the calibration curve and CM is the spiked concentration.

Control samples were processed along with spiked ones. The average percent recoveries ranged from 91.42 to 103.12% for chromium with precisions ranging from 1.81 to 4.41% (Table 1).

**Table 1 — Recovery Percentage of Metals Analyzed at Three Spiking Levels**

### Table 2 — Chromium Concentration in Poultry Feed

| Sample | Brand | Chromium concentration in mg/kg |
|--------|-------|---------------------------------|
| Feed   | Brand 1 | 0.07                            |
|        | Brand 2 | 0.271                           |
|        | Brand 3 | 0.127                           |

**Determinination of Estimated Daily Intake and Target Hazard Quotient**
The average estimated daily intake (EDI) of heavy metals by human subjects was calculated using Equation 2, recommended by the United States Environmental Protection Agency (USEPA).^8^  

**Equation 2**

\[ EDI = C \times IR \times EF \times ED/BW \times AT \]

Where EDI is the average daily intake (mg/kg bw/day); C is the heavy metal concentration in the exposure medium (mg/kg); IR is the ingestion rate (kg/day); EF is the exposure frequency (260 days/year for people who eat chicken and eggs five times a week); ED is the exposure duration (70 years, equivalent to the average lifespan); BW is body weight (kg) and AT is the average exposure time for non-carcinogens (365 day/year × ED).

Average body weight (BW) was 60 kg for adults.^9^ Ingestion rate (IR) was 0.1 kg/day for flesh, 0.02 kg/day for liver, and 0.0372 kg/day for eggs.^10,11^ The human health risk posed by heavy metal exposure from consuming contaminated chicken meat and eggs is usually characterized by the target hazard quotient (THQ), the ratio of the average estimated daily intake resulting from exposure to contaminated chicken and eggs to the oral reference dose obtained by the USEPA. The oral reference dose (RfD) for chromium was 11 mg/kg/day for the essential form of Cr (III) (permitted maximum tolerable daily intake): tolerable intake suggested by the Food and Agriculture Organization of the United Nations/World Health Organization (FAO/WHO).^9,12^ The THQ based on non-carcinogenic toxic risk is determined by Equation 3.

**Equation 3**

\[ THQ = \frac{EDI}{RfD} \]

If the value of THQ is less than 1, the risk of non-carcinogenic toxic effects is assumed to be low. When it exceeds 1, there may be concerns for potential health risks associated with overexposure.^

**Statistical Analysis**
All analyses were performed in triplicate. Results were expressed as means ± (standard deviation [SD]). The statistical software package Statistical Package for Social Sciences...
version (SPSS) 17.0 was used for the data analysis.

**Results**

**Chromium in Poultry Feeds**
Chromium concentrations in poultry feed are presented in Table 2. Chromium was determined in feeds from three different brands commonly used as both broiler and layer feed. Chromium was found in poultry feed in concentrations ranging from 0.07 mg/kg to 0.271 mg/kg.

**Chromium in Poultry Meat**
Table 3 describes the chromium concentrations found in poultry meat. Chromium concentrations were determined in liver and flesh body parts in two types of poultry samples (broiler and layer).

In the broiler sample, chromium concentrations were recorded in the range of not detected (ND) up to 1.3926±0.0010 mg kg⁻¹ in poultry liver. The highest Cr concentration in liver (1.3926±0.0010 mg kg⁻¹) was found in sample broiler farm 4 (BF4) and the lowest Cr concentration in liver ND was found in BF2. In poultry flesh, the chromium concentration was determined to be in a range of 0.069±1.0004 mg kg⁻¹ to 2.0746±0.0021 mg kg⁻¹. The highest Cr concentration in flesh (2.0746±0.0021 mg kg⁻¹) was found in BF3 and the lowest Cr concentration in flesh (0.069±1.0004 mg kg⁻¹) was found in BF4.

In the layer sample, chromium concentrations were recorded in the range of 0.0678±0.0001 mg kg⁻¹ to 1.3764±0.0009 mg kg⁻¹ in the liver of poultry. The highest Cr concentration in liver of 1.3764±0.0009 mg kg⁻¹ was found in layer farm 1 (LF1) and the lowest Cr concentration in liver of 0.0678±0.0001 mg kg⁻¹ was found in LF2. Chromium concentrations in the range of 0.0362±0.0002 mg kg⁻¹

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**Table 3 — Chromium Concentration in Poultry Meat (Broiler and Layer)**

| Sample (Broiler + Layer) | Farm          | Body part (Liver & Flesh) | Chromium concentration in mg/kg±SD |
|--------------------------|---------------|----------------------------|-----------------------------------|
| BF1                      | Flesh         |                            | 0.0746±0.0002                    |
| BF2                      | Liver         |                            | 0.0418±0.0001                    |
| BF3                      | Flesh         |                            | 1.4448±0.0020                    |
| BF4                      | Liver         |                            | 2.0746±0.0021                    |
|                        | ND            |                            | 0.0978±0.0002                    |
| LF1                      | Flesh         |                            | 0.069±1.0004                     |
| LF2                      | Liver         |                            | 1.3926±0.0010                    |
| LF3                      | Flesh         |                            | 1.2752±0.0014                    |
| LF4                      | Liver         |                            | 1.3764±0.0009                    |
| LF5                      | Flesh         |                            |                                         |
| LF6                      | Liver         |                            |                                         |

Abbreviations: SD, standard deviation.

**Table 4 — Chromium Concentration in Poultry Eggs**

| Sample      | Farm          | Chromium concentration (mg/kg)±SD |
|-------------|---------------|-----------------------------------|
| Albumen     | EF1           | 0.3484±0.0005                     |
|            | EF2           | 0.0006±0.0002                     |
|            | EF3           | 0.8356±0.0008                     |
|            | EF4           | 0.0198±0.0003                     |
|            | EF5           | 1.5406±0.0015                     |
|            | EF6           | 0.5926±0.0005                     |
| Yolk        | EF1           | 0.7574±0.0002                     |
|            | EF2           | 0.3676±0.0006                     |
|            | EF3           | ND                               |
|            | EF4           | 1.7474±0.0026                     |
|            | EF5           | 0.0978±0.0001                     |
|            | EF6           | 2.496±0.0019                      |
| Shell       | EF1           | ND                               |
|            | EF2           | 0.284±0.0006                      |
|            | EF3           | 0.388±0.0003                      |
|            | EF4           | 0.3374±0.0007                     |
|            | EF5           | 0.3182±0.0003                     |
|            | EF6           | 0.2278±0.0003                     |

Abbreviations: SD, standard deviation.
Concentrations of chromium in flesh of poultry were found ranging from ND to 1.2752±0.0014 mg kg⁻¹. The highest Cr concentration in flesh (1.2752±0.0014 mg kg⁻¹) was found in sample LF1 and the lowest Cr concentration in flesh (0.0362±0.0002 mg kg⁻¹) was found in LF2.

**Chromium in Eggs**

Using the composite sampling method, six albumen, six shell and six yolk samples were collected from six different farms. The concentration of chromium in poultry egg samples is presented in Table 4. Chromium concentrations in egg samples were recorded at the range of ND to 2.4196±0.0019 mg kg⁻¹. The highest concentration of chromium of 2.4196±0.0019 mg kg⁻¹ was found in yolk. The chromium content in albumen was determined in concentrations ranging from 0.0006±0.0002 mg kg⁻¹ to 1.5406±0.0015 mg kg⁻¹. Chromium contents in eggshell were found in concentrations ranging from ND to 0.388±0.0003 mg kg⁻¹. In comparison with albumen and yolk, lower concentrations of chromium were recorded in eggshell in this study.

**Discussion**

For the last decade, solid tannery waste containing a high chromium concentration has been converted into protein concentrate and widely used as a poultry feed ingredient due to its easy availability. Chromium may enter into the edible parts of poultry through feed. Therefore, there is a high possibility of chromium contamination in the edible portion of poultry and possible transfer to humans via dietary consumption of poultry.

Among three feed brands investigated, the highest concentration of chromium was found in brand 2 and the lowest found in brand 1. Islam et al. reported chromium concentrations in the range of 5.7875 mg/kg to 0.0926 mg/kg in feeds widely used as both broiler and layer feed. In that study, chromium concentrations were found ranging from 0.27 mg/kg to 0.98 mg/kg, which were higher than the results of this study.

Chromium concentrations were recorded in the range of ND to 1.3926±0.0010 mg kg⁻¹ in the liver of chicken and ranged between 0.0362±0.0002 mg kg⁻¹ to 2.0746±0.0021 mg kg⁻¹ in the flesh of chicken. The order of increasing chromium concentration among four broiler poultry farms were BF3>BF2>BF1>BF4 in flesh and BF4>BF3>BF1>BF2 in liver. The order of increasing chromium concentration among six layer poultry farms were LF1>LF5>LF6>LF3>LF4>LF2 in flesh and LF1>LF4>LF3>LF6>LF5>LF2 in liver. Khan et al. found chromium concentrations ranging from 0.08-0.11 mg/kg in liver and 0.06 mg/kg in thigh and breast muscle, lower than...
the results of this study. On the other hand, Iwegbue et al. recorded chromium concentrations of 0.01–3.43 mg kg⁻¹ in poultry meat, similar to the findings of this study. Chromium concentrations were determined ranging from 0.202-0.780 mg kg⁻¹ in broiler chicken, 0.138-0.440 mg kg⁻¹ in Deshi chicken and 0.111-1.400 mg kg⁻¹ in free range chicken. Higher chromium content was recorded in the flesh than liver, in contrast to the findings of the previous study conducted by Parvin and Rahman. Chromium concentration levels in most of the samples from both flesh and liver were above the WHO permissible limit level of 0.05 mg/kg.

The results revealed that the mean concentration of chromium in eggs was 0.2174–1.08 mg kg⁻¹ (Table 6). The highest level of chromium of 1.08 mg kg⁻¹ was recorded in sample egg farm 6 (EF6). Parvin and Rahman revealed that chromium concentrations were ND to 1.03±0.327 mg/kg in albumin and ND to 0.36 mg/kg in yolk of eggs in Bangladesh. Chromium concentrations in the range of 1.2-12.4 mg/kg were recorded by Basha et al., which were much higher than the values determined in this study. Chromium levels in egg yolk and egg white were determined ranging from 0.01-0.06 µg/g in Turkey and 0.03-0.09 mg/kg in Pakistan. Levels of chromium ranging from 3.24±2.45 µg/g have been determined in domestic chicken eggs in Malaysia. Most of the albumen, yolk and shell samples showed higher concentrations than the WHO permissible level of 0.05 mg/kg.

Target Hazard Quotients
To determine the health risks associated with chromium contamination of poultry meat and eggs, the daily intake of chromium and target hazard quotients for the essential form of Cr (III) were calculated. There are several possible pathways of exposure to humans, but the food chain is the most important. The daily intake of chromium was calculated according to the average poultry meat (liver and flesh) and egg consumption for adults. The daily intake of chromium and target hazard quotients for poultry meat (flesh and liver) and eggs are presented in Table 5 and Table 6, respectively. Estimated daily intakes (EDI) were recorded in the range of 0.000043 to 0.000247 mg/kg/day and 0.00001 to 0.000334 mg/kg/day in the flesh and liver, respectively. The highest daily intake of chromium of 0.00247 mg/kg/day was recorded in flesh and the lowest intake of 0.00001 mg/kg/day was determined in liver. In eggs, EDIs were recorded at the range of 0.000096 to 0.000475 mg/kg/day (Table 6).

Khan et al. determined a daily intake of chromium ranging between 0.16 to 0.26 mg/person through commercial chicken eggs assuming consumption of two eggs per person per day. On the other hand, a daily intake of 0.19 mg/day was calculated assuming consumption of one egg per day. THQ values in all of the flesh, liver and eggs samples were less than 1 (Tables 5 and 6). A THQ of less than one indicates that no toxic effects are expected to occur. The results revealed that adult consumers in the study area are not expected to experience adverse health risks by ingestion of chromium via the consumption of flesh, liver and eggs of poultry.

Study Limitations
The main limitation of this study is that it was not able to differentiate between chromium (VI) and chromium (III) due to the lack of appropriate analytical methods and instruments as chromium concentrations were determined by graphite furnace atomic absorption spectrometry.

Conclusions
The estimated daily intake values as calculated by the target hazard quotient indicated no excess health risk to consumers through consumption of chicken meat and eggs from chicken farms in the Gazipur district in Bangladesh. However, the study results indicated the presence of chromium accumulation in poultry meat and eggs. Further research is required to differentiate between chromium (VI) and chromium (III) and to assess their eventual health risks separately.
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