Assessment of the potential health risks associated with the aluminium, arsenic, cadmium and lead content in selected fruits and vegetables grown in Jamaica

Johann M.R. Antoine⁎, Leslie A. Hoo Fung, Charles N. Grant

International Centre for Environmental and Nuclear Sciences, 2 Anguilla Close, University of the West Indies, Mona Campus, Kingston 7, Jamaica

Abstract

Thirteen Jamaican-grown food crops — ackee (Blighia sapida), banana (Musa acuminata), cabbage (Brassica oleracea), carrot (Daucus carota), cassava (Manihot esculenta), coco (Xanthosoma sagittifolium), dasheen (Colocasia esculenta), Irish potato (Solanum tuberosum), pumpkin (Cucurbita pepo), sweet pepper (Capsicum annuum), sweet potato (Ipomoea batatas), tomato (Solanum lycopersicum) and turnip (Brassica rapa) — were analysed for aluminium, arsenic, cadmium and lead by atomic absorption spectrophotometry and instrumental neutron activation analysis. The fresh weight mean concentrations in these food crops were all below 4.25–93.12 mg/kg for aluminium; 0.001–0.104 mg/kg for arsenic; 0.015–0.420 mg/kg for cadmium; 0.003–0.100 mg/kg for lead) were used to calculate the estimated daily intake (EDI), target hazard quotient (THQ), hazard index (HI) and target cancer risk (TCR) for arsenic, associated with dietary exposure to these potentially toxic elements. Each food type had a THQ and HI < 1 indicating no undue non-carcinogenic risk from exposure to a single or multiple potentially toxic elements from the same food. The TCR for arsenic in these foods were all below 1 × 10⁻⁴, the upper limit used for acceptable cancer risk. There is no significant health risk to the consumer associated with the consumption of these Jamaican-grown food crops.

1. Introduction

The primary method of exposure to trace elements from the non-occupationally exposed population is through diet. In the case of nutrition, iron deficiency is considered the most prevalent nutritional deficiency [1]. Inadequate zinc intake is also prevalent as well; it has been estimated that 17.3% of the global population is at risk of zinc deficiency [2]. From a food safety standpoint, the intakes of several trace elements are strictly regulated by several international bodies including the Codex Alimentarius and the Joint FAO/WHO Expert Committee on Food Additives (JECFA), as well as numerous regional and national bodies. In the year 2011, JECFA withdrew the provisional tolerable weekly intake (PTWI) for both lead and inorganic arsenic with the recommendation that the previously established PTWIs could no longer be considered health protective [3,4]. JECFA has since not re-established a PTWI for either element.

Geochemical investigations of Jamaican soils have revealed the enrichment of several elements, in some cases to a degree that is an order of magnitude higher than world averages. These include, arsenic, cadmium, chromium, copper, lead, mercury, uranium and zinc [5]. Several of these elements are of toxicological concern. The higher mass fractions of some of the potentially toxic elements are associated with bauxitic and terra rosa soils and intersect with the growing regions for several crops (see Fig. 1). Although this mineralization has occurred through natural surface processes [5], the implications for uptake by food crops are nonetheless of concern irrespective of origin.

The elemental content, including trace elements, of several Jamaican food crops, has been presented in a previous study [6]. The potential health risks associated with the consumption of these food stuffs was never fully investigated however. This study was undertaken to evaluate the risk from exposure to aluminium, arsenic, cadmium and lead through the consumption of Jamaican-grown foods, some of which
are exported, using target hazard quotient (THQ) and hazard index (HI). Additionally, the target cancer risk (TCR) was also calculated for arsenic to determine the risk of cancer posed by the content of this element in these crops. The methodologies for THQ, HI and TCR have been used in several studies [7,8,9,10] for various food types but sparingly if ever in foods from Latin America and the Caribbean.

2. Materials and methods

2.1. Sampling and preparation

Samples of ackee (Blighia sapida), banana (Musa acuminate), cabbage (Brassica oleracea), carrot (Daucus carota), cassava (Manihot esculenta), coco (Xanthosoma sagittifolium), dasheen (Colocasia esculenta), Irish potato (Solanum tuberosum), pumpkin (Cucurbita pepo), sweet pepper (Capsicum annuum), sweet potato (Ipomoea batatas), tomato (Solanum lycopersicum) and turnip (Brassica rapa) were collected from markets and farms island-wide. These samples were collected in labelled paper or plastic bags and transported to the food preparation laboratories at the International Centre for Environmental and Nuclear Sciences (ICENS). Samples were brushed to remove surface soil and any other potential sources of surface contamination, washed with tap water and carefully patted dry using clean paper towels. Peel and other non-edible portions were removed and the edible portion of each sample cut into smaller pieces. Samples were dried to constant weight at a temperature not exceeding 60 °C in an analytical laboratory oven and thereafter ground and homogenized using an automated agate mortar and pestle. Moisture content was determined using a subsample that was dried to constant weight. Ackee samples were treated in a similar manner as other samples with a notable exception. The edible portion of the ackee fruit is the fleshy extension of the seed referred to as the aril which was separated from the seed. This was analysed fresh.

2.2. Analysis

Samples were analysed by atomic absorption spectrophotometry (AAS) and instrumental neutron activation analysis (INAA).

2.2.1. Atomic absorption spectrophotometry

Samples were prepared for analysis by Flame-AAS (Al), Graphite Furnace-AAS (Cd, Pb) and Hydride Generation-AAS (As) by acid digestion. 20 ml of 1:3 HCl:HNO₃ was added to 1 g of sample in a 70 ml graduated polyethylene vial and allowed to stand overnight. The following day the samples were digested at 110 °C for 2 h using a ModBlock (CPI International) and made up to 50 ml. For ackee samples for the analysis of lead, 10 mL of HNO₃ was added to 0.5 g of sample in an EasyPrep Teflon vial and allowed to stand for 1 h before digestion using a CEM MARS 5 microwave system (CEM Corporation, NC, USA). After cooling, samples were made up to 25 mL using deionized water. Acid digested samples were analysed using a PerkinElmer 5100PC Spectrophotometer (PerkinElmer, MA, USA) with Zeeman Background Correction. Calibration standards were prepared using Certiprep solutions (SPEX Certiprep, NJ, USA) in 2% HNO₃. A matrix modifier was added to samples for the GFAAS analyses. The limits of detection (LODs) on a fresh weight basis ranged from 0.722–15.0 mg/kg for aluminium, 0.007–0.150 mg/kg for arsenic, 0.001–0.020 mg/kg for cadmium and 0.003–0.065 mg/kg for lead.

2.2.2. Instrumental neutron activation analysis

Samples were analysed by INAA using the SLOWPOKE-2 nuclear reactor. For the determination of the short-lived radioisotope ²⁵Al, approximately 0.5 g of sample was weighed out into pre-cleaned double polyethylene bags and heat sealed in pre-cleaned 7 cm³ polyethylene vials [11]. Each sample was irradiated for 3 min at a neutron flux of $5 \times 10^{11}$ n cm⁻² s⁻¹ and allowed decay periods of approximately 5 min before counting. For the longer-lived radioisotopes ⁷⁶As and ¹¹⁵Cd approximately 1 g of sample was weighed out in pre-cleaned polyethylene capsules which were then heat sealed in 7 cm³ polyethylene vials and irradiated for 4 h at a neutron flux of $10 \times 10^{11}$ n cm⁻² s⁻¹ and allowed decay periods of 4 days. Samples were counted on hyper-pure germanium (HPGe) detectors with relative efficiencies ranging from 15% to 71%. The limits of detection (LODs) were 0.5 mg/kg for aluminium, 0.0005 for arsenic and 0.01 mg/kg for cadmium on a fresh weight basis. Lead was not analysed for by INAA.
2.3. Quality control

Approximately 10% of the samples were analysed in duplicate, with the differences between duplicates being less than 15%; at least one reagent blank was analysed in each batch in the case of AAS, and a certified reference material was also included in each analysis batch. Reference materials used for analysis of the elements were NIST (National Institute of Standards and Technology, MD, USA) 1573a – Tomato Leaves, NIST 1547–Peach Leaves and IAEA (International Atomic Energy Agency, Vienna, Austria) 336–Lichen. Recovery for reference materials used were within 10%.

2.4. Health risk assessment: estimated daily intake, target hazard quotient, hazard index and target cancer risk

2.4.1. Estimated daily intake

The estimated daily intake (EDI) of the elements of interest (Al, As, Cd and Pb) were determined based on their average concentration in each food sample type and the daily intake in grams of the respective food items. Consumption data was estimated by accessing FAOSTAT (see Table 2). Food Balance/Food Supply-Crops primary equivalent data for Jamaica was retrieved for 2013, the year for which data was most recently compiled (see Table 2). For example, sweet potatoes were selected for the year 2013 which returned a food supply value of 12.96 kg/capita/year. This food supply value was divided by 365 (the number of days in the year) and the result multiplied by 1000 for conversion to grams. The result is an intake of 35.51 g/capita/day which is the food ingestion rate (FIR) of sweet potato in Jamaica. The following equation was used for EDI:

\[ \text{EDI} = \left( \frac{C \times \text{FIR}}{\text{BWa}} \right) \]

Where C is the fresh weight concentration of the element in the food type in mg/kg, FIR is the daily food ingestion rate in grams per day and BWa is the reference body weight of 70 kg.

2.4.2. Target hazard quotient

The target hazard quotient (THQ) is defined as the ratio of exposure to the toxic element and the reference dose which is the highest level at which no adverse health effects are expected. The reference dose is specific to the trace element being assessed. The THQ describes the non-carcinogenic health risk posed by exposure to the respective toxic element. If the THQ is < 1 then non-carcinogenic health effects are not expected. If, however, the THQ is > 1 then there is a possibility that adverse health effects could be experienced. A THQ exceeding 1 is not a statistical probability that adverse non-carcinogenic health effects will occur. The THQ was estimated using the United States Environmental Protection Agency (US EPA) methodology based on the Region III risk-based concentration table.

\[ \text{THQ} = \frac{E_{\text{Rg}} \times \text{Ed} \times F_{\text{IR}} \times C}{\text{RfD} \times \text{BWa} \times \text{ATc}} \times 10^{-3} \]

Where E_{\text{Rg}} is the exposure frequency to the trace element, Ed is the exposure duration (70 yrs), F_{\text{IR}} is the food ingestion rate in grams per day for the respective food item, C is the concentration in wet weight of the trace element in the given food item, RfD is the oral reference dose for inorganic arsenic of 1.5 (mg/kg)/day, BWa is the reference body weight of 70 kg, ATc is the averaged exposure time to the carcinogen (365 days*70yrs) and 10^{-3} is the unit conversion factor (see Table 2). The carcinogenicity of aluminium has not been established at this point [12] and so no oral cancer slope factor has been established. Currently no oral slope factor currently exists for cadmium and the US EPA has never established one for lead [13].

3. Results and discussion

3.1. Estimated daily intake, target hazard quotient, hazard index and global target hazard quotient

The aluminium, arsenic, cadmium and lead concentrations for the thirteen foodstuffs analysed are presented in Table 1. The aluminium content ranges from 2.58 mg/kg found in pumpkins to a high of 93.12 mg/kg in bananas. The arsenic content ranged from 0.001 mg/kg in cabbages to 0.104 mg/kg also in bananas. The cadmium content was close to this value at 0.266 and 0.248 mg/kg respectively. Cabbage samples had the lowest mean content of lead at 0.003 mg/kg with cassava samples having the highest mean content of lead at 0.100 mg/kg. All values are reported as fresh weight.

The calculations and results for the EDI (see Table 3) are based on a number of parameters; the uncertainty associated with the use of these individually the cumulative effect of consumption may result in adverse health effects. If the HI is > 1 there is the potential for adverse non-carcinogenic health effects. The equation for HI is:

\[ \text{HI} = \sum_{n=1}^{N} \text{THQ}_n \]

2.4.4. Target cancer risk for arsenic

The target cancer risk (TCR) is used to assess the potential risk associated with exposure to carcinogenic agents throughout the lifetime exposure period. Instead of an oral reference dose, as is used for the determination of THQ, an oral slope factor is utilized. This factor determines, along with the dose of the carcinogen, the probability of excess cancer risk over the lifetime of the exposed individual. The equation for TCR is:

\[ \text{TCR} = \frac{E_{\text{Rg}} \times \text{Ed} \times F_{\text{IR}} \times C \times \text{CPSO}}{\text{BWa} \times \text{ATc}} \times 10^{-3} \]

Where E_{\text{Rg}} is the exposure frequency to arsenic, Ed is the exposure duration (70 yrs), F_{\text{IR}} is the food ingestion rate in grams per day for the respective food item, C is the concentration in wet weight of the trace element in the given food item, CPSO is the oral cancer slope factor for inorganic arsenic of 1.5 (mg/kg)/day, BWa is the reference body weight of 70 kg, ATc is the averaged exposure time to the carcinogen (365 days*70yrs) and 10^{-3} is the unit conversion factor (see Table 2). The carcinogenicity of aluminium has not been established at this point [12] and so no oral cancer slope factor has been established. Currently no oral slope factor currently exists for cadmium and the US EPA has never established one for lead [13].

Table 1

| Food           | Al (mg/kg) | As (mg/kg) | Cd (mg/kg) | Pb (mg/kg) |
|----------------|------------|------------|------------|------------|
| ackee          | 6.89       | 0.011      | 0.248      | 0.033      |
| banana         | 93.12      | 0.104      | 0.057      | 0.010      |
| cabbage        | 8.49       | 0.001      | 0.041      | 0.003      |
| carrot         | 4.25       | 0.004      | 0.031      | 0.006      |
| cassava        | 13.44      | 0.019      | 0.063      | 0.100      |
| coco           | 3.28       | 0.006      | 0.079      | 0.017      |
| dasheen        | 5.04       | 0.008      | 0.024      | 0.021      |
| Irish potato   | 22.04      | 0.003      | 0.073      | 0.010      |
| pumpkin        | 2.58       | 0.014      | 0.015      | 0.006      |
| sweet pepper   | 7.27       | 0.002      | 0.157      | 0.005      |
| sweet potato   | 34.23      | 0.006      | 0.096      | 0.054      |
| tomato         | 12.89      | 0.012      | 0.266      | 0.021      |
| turnip         | 36.69      | 0.007      | 0.286      | 0.006      |
for both inorganic arsenic and lead has left it necessary to food frequency questionnaires has long been questioned[17,18] and so consumption. These sources of error notwithstanding, the validity of food supply quantity for bananas specifically. To calculate the EDI and THQ an oral reference dose is necessary. As defined in the US EPA’s[19] A Review of the Reference Dose and Reference Concentration Processes, this is the “estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from the No Observed Adverse Effect Level (NOAEL), the Lowest Observed Adverse Effect Level (LOAEL), or benchmark dose, with uncertainty factors generally applied to reflect limitations of the data used”[19]. The oral reference doses used in this study were downloaded from the US EPA’s Regional Screening Level’s Generic Tables of May 2016[20].

Aluminium has an oral reference dose of 1 mg/kg day−1. Food comprises greater than ninety percent (90%) of the non-occupational human exposure to aluminium[12]. Several studies have indicated neurotoxicity associated with long term exposure to aluminium although in many cases these are animal studies. The human studies tend to focus on the subset of patients undergoing dialysis and dialysis encephalopathy[21]. Although the association of aluminium with Alzheimer’s disease seems to be only a correlation, this element has been associated with brain aging and some neurodegenerative diseases such as Parkinson’s disease[21,22]. The oral reference dose for inorganic arsenic is 0.0003 mg/kg day−1. As is the case with aluminium, the primary source of arsenic is through food for the non-occupationally exposed consumer[21]. Arsenic is more bioavailable in water than in food but can still be a significant contributor to the level of dietary exposure[23]. Seafood tends to have high levels of arsenic although the majority of this tends to be the less toxic organic species of arsenic. Larger percentages of inorganic arsenic have been found in market basket studies and the accumulation of inorganic arsenic in grains and produce may be very significant[24,25,26]. The oral reference dose for dietary cadmium is 0.001 mg/kg day−1. Cadmium is well known as a nephrotoxin with the incidence of renal tubular induced osteomalacia known as Itai Itai disease, a well-known example of the consequences of extreme dietary exposure to this metal[27]. Cadmium also has several effects on other systems of the human body[28]. The Integrated Risk Information System (IRIS) of the US EPA has the oral reference dose for lead and it compounds at 0.002 mg/kg day−1. Lead is a well-known neurotoxin that can accumulate in tissue including blood and bone causing a range of deleterious health effects[24].

It is notable that no individual THQ for any of the foodstuffs analysed for any of the four elements is > 1 (see Table 4). This indicates that in and of themselves consumption of the thirteen foods analysed...

variables have possibly resulted in an overestimation of the non-carcinogenic risk posed by the consumption of the elements assessed in this study. The EDI in this study is based on the food balance sheets of the most recent data available from the Food and Agriculture Organization[14]. Food balance sheets have inherent limitations. They may not consider food consumption by tourists, non-human consumption of food such as animal feed or industrial use of crops[15]. Food balance sheets assume uniform consumption without assumption that availability equals consumption. This does not account for plate waste, spoilage, etc. which means the amount consumed is for this category resulting in an error in the estimate of consumption. These sources of error notwithstanding, the validity of food frequency questionnaires has long been questioned[17,18] and so food balance sheets were selected as the more objective option.

The withdrawal of the provisional tolerable weekly intake (PTWI) for both inorganic arsenic and lead has left it necessary to find other methodologies to evaluate the risk associated with consumption of foods with significant levels of these and other potentially toxic...
presents no undue risk of non-carcinogenic health effects. For aluminium the THQ values range from 0.001 in cassava to 0.046 in bananas (Table 4). It is of interest that bananas exceed the aluminium content of other foodstuffs as shown in Table 1. In fact, bananas account for over 28% of the global hazard quotient of all foods for Al (Fig. 2). By comparison the root vegetables coco and dasheen only account for a cumulative 15% of the global target hazard quotient. Altogether, four crops account for 64% of the global target hazard quotient (see Fig. 2). Examining the individual contribution of each food crop to the global target hazard quotient for arsenic, indicates that banana contributes about 38%. With dasheen and coco contributing 19% and 14% respectively. Cumulatively these three crops contribute 71% of the global target hazard quotient for arsenic (see Fig. 2). In contrast to the previous elements cadmium shows a somewhat more even distribution. Coco accounts for 20% of the total THQ with ackees contributing 14%, cabbage at 13%, carrots at 11%, tomatoes at 9% and turnips at 8%. Still, these six food crops account for 75% of the GTHQ. The root crops coco and dasheen account for 54% of the GTHQ for lead with 24% and 30% respectively. With sweet potatoes at 13% and ackees at 11% these four crops contribute 78% of the GTHQ for lead.

The HI which considers the cumulative effect of the consumption of several potentially hazardous elements also does not exceed 1 (Table 4). The HI for the foods analysed for the four elements range from 0.016 for cassava to a high of 0.340 for coco (see Table 4). The estimated consumption patterns indicate cadmium contributing 63% to the HI of the foods analysed. This is followed by arsenic with 23% and then aluminium with 8% and lead with 6% (see Fig. 3). The EDI is evaluated against the oral reference dose or RfD. If one considers the average consumption patterns of the above elements, it becomes clear that the EDI does not exceed the RfD, thereby indicating no risk of non-carcinogenic health effects. For arsenic the EDI values range from 0.014 in tomatoes to 0.171 in sweet potatoes (Table 4). For aluminium the EDI values range from 0.002 in tomatoes to 0.046 in bananas (Table 4). For cadmium the EDI values range from 0.001 in turnips to 0.012 in sweet peppers (Table 4). For lead the EDI values range from 0.002 in turnips to 0.017 in tomatoes (Table 4).
inorganic and therefore the risk presented is also likely to be mined. It is unlikely that the entire arsenic content of the various foods are total arsenic rather than inorganic arsenic, which was not determined.

4. Conclusions

The food crops analysed presented no undue risk of adverse health effects, whether non-carcinogenic in the case of THQ for aluminium, arsenic, cadmium and lead or for cumulative health effects in terms of HI. The individual food crops analysed fall within the range of acceptable cancer risk for inorganic arsenic although the results are for total arsenic. It is possible that with the addition of targeted food surveys supplemental to the food balance sheets the estimated daily intake of these and other elements can be refined to more accurately represent the exposure of the Jamaican population. These targeted food studies could also be tailored to address special groups such as vegetarians and vegans whose consumption of these foods may be higher than the general public and for whom other foods will have to be considered. Future investigations are necessary to more accurately estimate the THQ and TCR for inorganic arsenic, to understand the risk of cadmium and its contribution to the total HI and to expand the food types for a comprehensive look at the safety of Jamaican food.

Table 5

| Food     | TCR          |
|----------|--------------|
| ackee    | 1.14E-05     |
| banana   | 7.70E-05     |
| cabbage  | 7.48E-06     |
| carrot   | 2.19E-06     |
| cassava  | 2.43E-06     |
| coco     | 2.88E-05     |
| dasheen  | 3.77E-05     |
| irish potato | 1.95E-06   |
| pumpkin  | 1.40E-05     |
| sweet pepper | 1.88E-06   |
| sweet potato | 4.69E-06   |
| tomato   | 7.61E-06     |
| turnip   | 3.19E-06     |

As previously stated the only element evaluated in this study for which the US EPA has established an oral cancer slope is arsenic. The TCR values range from 1.88E-06 in sweet peppers to 7.70E-05 in bananas (see Table 5). As is the case with the calculations for EDI, THQ and HI, the TCR for arsenic is based on the oral cancer slope for inorganic arsenic. Considering that the calculation was made using total arsenic it is likely that the TCR for inorganic arsenic is lower. Following on publications using $10^{-6}$ to $10^{-4}$ as the range for acceptable risk of developing cancer [32,33], $10^{-4}$ was accepted as the upper limit for acceptable risk of developing cancer. No TCR result for any food type analysed exceeded $10^{-4}$. It is possible that if the TCR was based on inorganic arsenic content rather than total the TCR results would be lower. By summing the individual TCRs the result is $2.00 \times 10^{-4}$. This cumulative TCR risk would exceed the $10^{-4}$ threshold and be cause for some concern. Terrestrial foods may have a wide range of inorganic arsenic content [26]. Chen et al. [34] assumed an inorganic content of 50% and following on this the cumulative TCR would be $10^{-4}$. With the possible overestimation in consumption data it is also likely that the cumulative TCR is actually under $10^{-4}$. The potential closeness to $10^{-4}$ means, however that further investigation may be warranted.

References

[1] WHO, World Health Organization. Micronutrient Deficiencies, Iron Deficiency Anaemia, (2017) http://www.who.int/nutrition/topics/ida/en/ (Accessed 16 November 2016).
[2] K.R. Wessells, K.H. Brown, Estimating the global prevalence of zinc deficiency: results based on zinc availability in national food supplies and the prevalence of stunting, PLoS One 7 (2012) e050568, http://dx.doi.org/10.1371/journal.pone.0050568.
[3] JECFA, Joint FAO/WHO Expert Committee on Food Additives, Evaluation of Certain Contaminants in Food: Seventy-second Report of the Joint FAO/WHO Expert Committee on Food Additives. WHO Technical Report Series; No. 959, (2011).
[4] JECFA, Joint FAO/WHO Expert Committee on Food Additives, Evaluation of Certain Contaminants in Food: Seventy-third Report of the Joint FAO/WHO Expert Committee on Food Additives. WHO Technical Report Series; No. 960, (2011).
[5] G. Lalor, A Geochemical Atlas of Jamaica, Canoe Press, Kingston, Jamaica, 1996.
[6] A. Hewie, L. Hoo Fung, G. Lalor, R. Rattray, M. Vutukhov, Elemental composition of Jamaican foods. 1: a survey of five food crop categories, Environ. Geochem. Health 27 (2005) 19–30.
[7] C. Copat, G. Arena, M. Fiore, C. Ledda, R. Fallico, S. Sciacca, M. Ferrante, Heavy metals concentrations in fish and shellfish from eastern Mediterranean Sea: consumption advisories, Food Chem. Toxicol. 53 (2013) 33–37.
[8] M.U. Khan, R.N. Malik, S. Muhammad, Human health risk from heavy metal via food crops consumption with wastewater irrigation practices in Pakistan, Chemosphere 93 (2013) 2230–2238, http://dx.doi.org/10.1016/j.chemosphere.2013.07.067.
[9] A. Cherfi, S. Abdoun, O. Gaci, Food survey levels and potential health risks of chromium, lead, zinc, and copper contents in fruits and vegetables consumed in Algeria, Food Chem. Toxicol. 70 (2014) 48–53.
[10] T. Sarkar, M. Masihul Alam, N. Parvin, Z. Fardous, A.Z. Chowdury, S. Hossain, M.E. Haque, N. Biswas, Assessment of heavy metals contamination and human health risk in shrimp collected from different farms and rivers at Khulna-Satkhira region, Bangladesh, Toxicol. Rep. 3 (2016) 346–350.
