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

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ABSTRACT

Thirteen Jamaican-grown food crops – 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 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 (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

Abbreviations: AAS, atomic absorption spectrophotometry; ATSDR, Agency for Toxic Substances & Disease Registry; EDI, estimated daily intake; FAO, Food and Agriculture Organization of the United Nations; GTHQ, global target hazard quotient; HI, hazard index; IAEA, International Atomic Energy Agency; INAA, instrumental neutron activation analysis; JECFA, Joint FAO/WHO Expert Committee on food additives; LOAEL, lowest observed adverse effect level; NATA, National Air Toxics Assessment; NIST, National Institute of Standards and Technology; NOAEL, no observed adverse effect level; PTWI, provisional tolerable weekly intake; RfD, oral reference dose; RSL, regional screening levels; TCR, target cancer risk; THQ, target hazard quotient; US EPA, United States Environmental Protection Agency; WHO, World Health Organization

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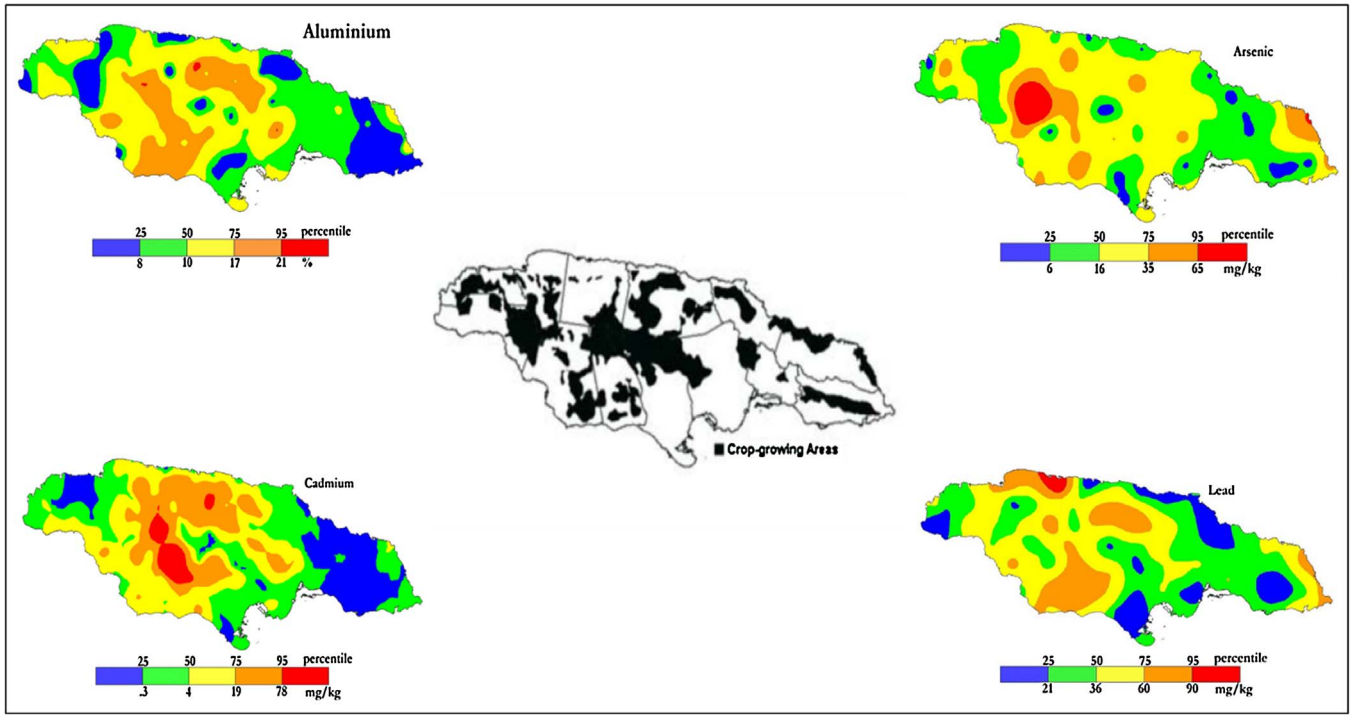

Fig. 1. The relationship between small farmer crop-growing areas and the distribution of aluminium, arsenic, cadmium and lead in Jamaican soils.

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 spectropohotometry

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 ^{28}Al, approximately 0.5 g of sample was weighed out into pre-cleaned double polyethylene bags and heat sealed in pre-cleaned 7 cm^3 polyethylene vials [11]. Each sample was irradiated for 3 min at a neutron flux of 5×10^{11} n $cm^{-2}s^{-1}$ and allowed decay periods of approximately 5 min before counting. For the longer-lived radioisotopes ^{76}As and ^{115}Cd approximately 1 g of sample was weighed out in pre-cleaned polyethylene capsules which were then heat sealed in 7 cm^3 polyethylene vials and irradiated for 4 h at a neutron flux of 10×10^{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.