



Research article

Risk assessment of heavy metals concentration in cereals and legumes sold in the Tamale Aboabo market, Ghana

Abdul-Aziz Adam^a, Lyndon N.A. Sackey^{b,*}, Linda Aurelia Ofori^a^a Department of Theoretical and Applied Biology, Faculty of Biosciences, Kwame Nkrumah University of Science and Technology, PMB, Kumasi, Ghana^b Department of Environmental Science, Faculty of Biosciences, Kwame Nkrumah University of Science and Technology, PMB, Kumasi, Ghana

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ABSTRACT

The greatest risks posed by heavy metals to human health are linked to exposure to hazardous metals, which may be present in staple foods such as cereals and legumes. In this study, the levels of harmful metals and vital minerals like cadmium (Cd), lead (Pb), zinc (Zn), copper (Cu), arsenic (As), and copper (As) in certain cereals and legumes sold in Tamale Aboabo Market in the Northern Region of Ghana were evaluated. A total of twenty-one (21) samples were randomly selected, digested, and analyzed using an atomic absorption spectrophotometer. The samples included three each of cowpea, groundnuts, and soybean (AAS). As concentrations varied from 0.017 mg/kg, Cd concentration was undetectable, Cu concentrations ranged from 0.019 to 0.042 mg/kg, and Zn concentrations were low. The levels of As in the legumes and grains were higher than the 0015 mg/kg FAO/WHO guideline limit. According to the study, there is a risk associated with consuming any of the cereal and legume crops offered in the Tamale Aboabo market that contain any amount of As. The use of pesticides, fertilizers, and runoff from other agricultural fields may have contributed to the higher levels in the cereals. The hazard index via ingestion values for both adults and children were found to be less than 1, indicating no need for potential non-carcinogenic concern. Generally, there is no cancer risk with consumption of the cereals and legumes in terms of all the metals investigated.

1. Introduction

Heavy metals are metallic elements with a density of more than 5 g/cm³ and include, among others, chromium (Cr), cadmium (Cd), copper (Cu), arsenic (As), and lead (Pb). When human beings are exposed to heavy metals such as lead, cadmium, chromium, and arsenic, they have impact on their health [1]. Because of the propensity for heavy metals to accumulate in biosystems through contaminated soil, water, and irrigation water, their poisoning of the food chain has recently gained importance [1]. The primary contributors to metal contamination in soils are crops that are exposed to heavy metals through fertilizers, sewage sludge, municipal waste, and the release of industrial waste, fossil fuels, and industrial waste [2]. Humans' ability to absorb heavy metals through diet has been shown to have serious health implications. As a result of the decrease in labor productivity, this has an impact on economic growth. Affected people are also burdened by the cost of treating illnesses like cancer, kidney disease, reduced intellectual capacity, heart disease, harm to the nervous system, bone fractures, and gastrointestinal issues [3]. Chemical nutrients known as essential minerals are essential for the

healthy growth and development of an organism. Iron, zinc, copper, and manganese are some of the nutrients that are necessary for good health and are used by the body to maintain healthy bones, muscles, hearts, and brains. Living organisms require very little amounts of some trace metals, yet huge concentrations of these same metals can be harmful [2]. Trace metals are elements that typically occur in the environment at very low levels. At large amounts, the trace metals might have harmful effects. They build up in human organs such the liver, kidney, and bones and cause serious health problems [4]. Through a variety of processes, heavy metals bioaccumulate in living things and have negative impacts [1]. Extreme heavy metal absorption from polluted soils through crops may negatively impact the quality and safety of food, which may then have an impact on human health. Food is a vital ingredient needed by all living things to maintain life and its related processes, such as body growth, maintenance, and development [4, 5]. Particularly in Asian diets, cereals and legumes are important staple foods. They are nutrient-rich foods, particularly when consumed as whole grains [6]. The majority of grains are processed, after being cleaned and sorted into final goods that are useful to industry. Because they serve as the foundation for so many food

* Corresponding author.

E-mail address: niiadjiri2004@yahoo.com (L.N.A. Sackey).<https://doi.org/10.1016/j.heliyon.2022.e10162>

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preparations in Ghana, hence cereals and legumes make a significant contribution to reducing food insecurity [6]. Food contamination by heavy metals has become a public health concern, and there is a lack of knowledge about this issue in many developing nations, including Ghana [7]. Cereal crops and legumes are necessary for human nutrition. Because of their significance for wholesome nutrition or because they are hazardous, heavy metals have impact on human health. It is well recognized that copper and zinc are vital nutrients, and they can get into food through soil mineralization by crops or environmental contamination with metal-based insecticides [7]. Due to its significant negative impacts on the environment and human health, heavy metal contamination is one of the main issues for the safety and security of food [8]. Heavy metals can bioaccumulate through biological chains, this make them to be persistent and non-biodegradable, hence resulting in a lengthy biological half-life [8]. Although heavy metals are important in nature as trace elements, their biological toxicity on human biochemistry is a major concern [9]. It was reported that, both adults and children in Iran consumed rice on a daily basis with no appreciable increase in cancer risk possibility due to toxic and estimated trace element intake, which was lower than the safe risk limit [10]. The residents of Tamale consume a lot of cereals and legumes, which suggests that there may be a chance for these metals to bioaccumulate over time and endanger their health. However, no extensive work has been done on the health impact of consumption of cereals and legumes on inhabitants of Tamale. Therefore, the purpose of this study was to evaluate the levels of lead (Pb), zinc (Zn), copper (Cu), arsenic (As), and cadmium (Cd) in a variety of cereals (maize, rice, millet, and sorghum) and legumes (cowpea, groundnuts, and soybean) sold in Tamale Aboabo Market in the Northern Region of Ghana. This will be determined with the aid of Atomic Absorption Spectrophotometer and the potential health risk assessment carried out.

2. Materials and methods

The third-largest city in Ghana, Tamale is located in the Northern Region [11]. According to the 2010 Census [11], there were 371,351 people living in the Metropolitan area. Due to its location in the Northern Region, Tamale Metropolis might be an excellent market for locally produced commodities from the agricultural and commercial sectors of the other districts in the region. The Metropolis also imports goods from markets in the West African sub-region, including those in Niger, Burkina Faso, the northern parts of Togo and Mali, as well as from Ghana's southern region via a route across the region. The vast majority of rural societies serve as the Metropolis's food basket and have plenty of territory for cultivation. The Metropolis has four primary markets: Lamashegu, Kukuo, Central Market, and Aboabo. There are outpost markets in other towns in addition to the ones mentioned [11]. The Tamale Aboabo market was chosen for the study because it provides food for the majority of rural people engaged in agricultural activities, and an evaluation of the amount of heavy metal concentration in market foodstuffs will give a fair depiction of the toxicity of these metals. At Aboabo, there is also a lot of industrial activity, urbanization, and population growth, all of which might generate high metal levels.

2.1. Sampling collection

Twenty-one ($n = 21$) samples were randomly selected from the Tamale Aboabo market in the Tamale Metropolis in December 2017. Three samples of each cereal (maize, rice, millet, and sorghum) and three samples of each legume (cowpea, soybean, and groundnuts) were taken. Before grinding, a composite sample was created by combining each type of sample. The hard samples were ground in a grinding mill and sieved using a 100 μm standard sieve, while the soft samples were ground in a pestle and mortar. Before being digested, the powdered samples were kept in plastic sample bottles.

2.2. Digestion of the cereals and legumes samples

Prior to analysis using an Atomic Absorption Spectrophotometer (AAS) (Shimadzu model AA 6300) by the Shimadzu Corporation in Japan, the samples were digested. 50 ml of the sample was measured into a round bottom flask, and 5 g of the dried sample with constant weight were added to a 100 ml reflux flask. 5 ml of concentrated nitric acid (HNO_3) (LR Traders, Bangalore- India) was added to each sample and the mixture was heated on a hot plate for 20 min at 105 °C (Seal Bd-50 Block Digester- SEAL Analytical, Inc). Using Whatman 0.45 μm membrane filter paper, the sample was filtered after cooling in a water bath at 36 °C for two hours (Buckinghamshire, UK).

2.3. Analysis of heavy metals

With the use of an AAS (Shimadzu model AA 6300) Shimadzu Corporation; Japan, the digests were examined for Zn, Cd, Cu, Pb, and As concentrations at the Council for Scientific and Industrial Research - Water Research Institute (CSIR-WRI) laboratory in Tamale.

2.4. Quality assurance/quality control

To establish accuracy, dependability, and repeatability, all batch isotherm tests were repeated three times with the metal blanks being used as a control group each time. All of the glassware underwent a pre-soaking process in a 5% HNO_3 solution (LR Traders, Bangalore, India), rinsed with deionized water and oven dried. The appropriate modifications were done after running the blanks. After the equipment had been standardized, the wavelength of the food was determined (As-189.0, Cd-228.8, Zn-206.2, Pb-283.3 and Cu-324.5). High percent recovery was observed for all metals calibrated between 0.01 and 3.5 mg/l (92–103%). The individual metals' limits of detection were As-0.02, Cd-0.04, Zn-0.02, Pb-2.0, and Cu-0.3. The measurements were made in triplicate, and the means were recorded.

2.5. Health risk assessment of the foodstuff

Based on the metal concentration, a risk evaluation for carcinogenic and non-carcinogenic effects was performed. Humans are exposed to heavy metals primarily through three routes: inhalation through the nose, ingestion through the mouth, and dermal absorption through skin contacts; dermal absorption and ingestion are frequently associated with water exposure [12, 13]. The United States Environmental Protection Association's Risk Assessment Guidance for Superfund (RAGS) approach was used to derive the words for the human health risk assessment [9]. Eqs. (1) and (2) provides the relationship needed for the calculation.

$$D_{ing} = \frac{C_{food} \times IR \times EF \times ED}{BW \times AT} \quad (1)$$

$$D_{derm} = \frac{C_{food} \times SA \times KP \times ET \times IR \times EF \times ED \times CF}{BW \times AT} \quad (2)$$

$$HQ_{ing/derm} = \frac{D_{ing/derm}}{RfD_{ing/derm}} \quad (3)$$

where $HQ_{ing/derm}$ is hazard quotient via ingestion or dermal contact and $RfD_{ing/derm}$ is oral/dermal reference dose (qg/kg/day). The Rf_{ing} and RfD_{derm} values were obtained from the literature [12, 13].

The Hazard Quotient (HQ) is a numerical assessment of the potential for systemic toxicity posed by a single metal and a single exposure method (Eq. (3)). By integrating the calculated HQs for each metal, the combined non-carcinogenic potential effects of many metals are assessed and expressed as a Hazard Index (HI), as shown in equation (Eq. (4)) [11].

$$HI = \sum_{i=1}^n HQ_{\text{derm}}^{\text{ing}} \quad (4)$$

where $HI_{\text{ing/derm}}$ is hazard index via ingestion or dermal contact. When HQ/HI exceeds unity, there is a need for concern of potential human health risks caused by exposure to non-carcinogenic elements [12].

Chronic Daily Intake (CDI) was calculated using Eq. (5).

$$CDI_{\text{ing}} = C_{\text{food}} \times \frac{DI}{BW} \quad (5)$$

where C_{food} , DI , and BW stand for the body weight, the average daily calorie intake, and the amount of heavy metals present in food in mg/kg, respectively. The parameters used in the exposure assessment of heavy metals in food samples in the study are given in Table 1. Cancer Risk (CR) was also evaluated using Eq. (6).

$$CR_{\text{ing}} = \frac{D_{\text{ing}}}{SF_{\text{ing}}} \quad (6)$$

where SF_{ing} is the cancer slope factor. The SF_{ing} for As is 1.5×10^3 , Pb is $8.5 \mu\text{g/g/day}$ and Cd is 6.1×10^3 [12,14].

3. Results

3.1. Heavy metals levels in maize, rice, millet and sorghum sold in the Tamale Aboabo market

The results show high levels or concentration of As for maize, rice, millet and sorghum in the ranged of 0.048–0.051 mg/kg (0.050 ± 0.002 mg/kg), 0.100–0.200 mg/kg (0.150 ± 0.058 mg/kg), 0.017–0.10 mg/kg (0.059 ± 0.042 mg/kg) and 0.065–0.710 mg/kg (0.068 ± 0.03 mg/kg), respectively (Table 2). Pb, Cd, Cu and Zn concentration levels in cereals were not high as compared to the [3] limit (Table 2).

3.2. Heavy metals levels in cowpea, soybean and groundnuts sold in the Tamale Aboabo market

The results show high levels of As in cowpea, soybean and groundnuts in the ranged of 0.074–0.083 mg/kg (0.079 ± 0.005 mg/kg), 0.049–0.060 mg/kg (0.055 ± 0.006 mg/kg) and 0.060–0.074 mg/kg (0.068 ± 0.007 mg/kg), respectively (Table 3). Pb, Cd, Cu and Zn

Table 1. Estimating factors for heavy metal exposure assessments [12, 13].

Parameters	Unit	Value	
		Adult	Children
Concentration of metals in food (C_{food})	mg/kg		
Food intake rate (IR)	kg/day	2.2	1.8
Exposure frequency (EF)	Days/year	350	350
Exposure duration (ED)	Year	70	6
Average body weight (BW)	Kg	70	15
Average time (AT)	Days	25,550	2,190
Exposed skin area (SA)	cm^2	18,000	6,600
Exposure time (ET)	h/day	0.58	1
Unit conversion factor (CF)	L/cm^3	0.001	0.001
Dermal permeability coefficient (KP)			
As	(cm/h)	0.001	
Pb		0.004	
Cd		0.001	
Cu		0.001	
Zn		0.006	

JMP 10 statistical software (SAS institute) was used for the statistical analysis.

Table 2. Heavy metals concentrations in cereals sampled from Tamale Aboabo market.

Cereals		As	Pb	Cd	Cu	Zn
Maize	Min	0.048	nd	nd	0.037	nd
	Max	0.051	nd	nd	0.041	nd
	Mean	0.050	nd	nd	0.039	nd
	StD	0.002	0.001	0.001	0.002	0.002
Rice	Min	0.100	nd	nd	0.024	nd
	Max	0.200	nd	nd	0.042	nd
	Mean	0.150	nd	nd	0.032	nd
	StD	0.050	0.001	0.003	0.006	0.007
Millet	Min	0.017	nd	nd	0.019	0.003
	Max	0.100	nd	nd	0.030	0.003
	Mean	0.059	nd	nd	0.023	0.003
	StD	0.042	0.005	0.003	0.008	0.009
Sorghum	Min	0.065	nd	nd	0.029	0.029
	Max	0.071	nd	nd	0.041	0.035
	Mean	0.068	nd	nd	0.034	0.033
	StD	0.003	0.006	0.004	0.008	0.019
[12] Limit		0.015	0.200	0.200	73.300	99.400

Note: The concentrations are in mg/kg and nd is not detected.

Table 3. Heavy metals concentrations in legumes sampled from Tamale Aboabo market.

Legumes		As	Pb	Cd	Cu	Zn
Cowpea	Min	0.074	nd	nd	0.029	0.039
	Max	0.083	nd	nd	0.038	0.045
	Mean	0.079	nd	nd	0.034	0.042
	StD	0.005	0.006	0.005	0.007	0.023
Soybean	Min	0.049	-0.020	nd	0.050	0.079
	Max	0.060	-0.015	nd	0.054	0.090
	Mean	0.055	-0.017	nd	0.052	0.086
	StD	0.006	0.006	0.008	0.010	0.035
Groundnuts	Min	0.060	-0.012	nd	0.035	0.068
	Max	0.074	-0.011	nd	0.040	0.080
	Mean	0.068	-0.011	nd	0.037	0.076
	StD	0.007	0.006	0.008	0.009	0.037
[13] Limit		0.015	0.200	0.200	73.300	99.400

Note: the concentrations are in mg/kg, nd-not detected.

concentration levels in legumes were not high as compared to the [15] limit (Table 3).

3.3. Human health risk related to exposure dose via dermal and consumption of cereals and legumes in the Tamale Aboabo market

The non-carcinogenic health risk concerning the consumption of cereals and legumes in terms of the heavy metals for adults and children are presented in Table 4. The As doses for adults' consumption of all products varied from 1.50×10^{-3} to 4.52×10^{-3} . Only consumption of rice has a high dose of 4.52×10^{-3} . Pb, Cd and Cu doses for adult's consumption were not high for all the crops (Table 4). Zn doses for adults' consumption of maize, rice, millet, sorghum, cowpea, soybean and groundnuts were not significant and was $<2.5 \times 10^{-3}$. The As doses for children consumption of maize, millet, sorghum, cowpea, soybean and groundnuts were high with doses ranging from 5.80×10^{-3} to 1.73×10^{-2} . Pb, Cd, Cu and Zn doses for children's consumption of cereals and legumes were not high (Table 4).

The HI_{ing} for adults and children that consumed the cereals and legumes containing As, Pb, Cd, Cu and Zn were not high, as shown in Table 4.

Table 4. Non-carcinogenic health risk assessment for the heavy metals in the food for adults and children through ingestion.

HQ _{ing}		As	Pb	Cd	Cu	Zn	HI
Cowpea	Adult	2.38×10^{-3}	nd	nd	1.02×10^{-3}	1.27×10^{-3}	3.65×10^{-3}
	Child	9.09×10^{-3}	nd	nd	4.78×10^{-3}	4.83×10^{-3}	1.48×10^{-2}
Soybean	Adult	1.66×10^{-3}	nd	nd	1.57×10^{-3}	2.59×10^{-3}	4.50×10^{-3}
	Child	6.33×10^{-3}	nd	nd	5.98×10^{-3}	9.9×10^{-3}	1.72×10^{-2}
Gnut	Adult	2.05×10^{-3}	nd	nd	1.12×10^{-3}	2.29×10^{-3}	4.59×10^{-3}
	Child	7.82×10^{-3}	nd	nd	7.8×10^{-6}	8.75×10^{-3}	1.33×10^{-2}
Maize	Adult	1.50×10^{-3}	nd	nd	1.20×10^{-3}	nd	1.46×10^{-3}
	Child	5.80×10^{-3}	nd	nd	4.50×10^{-3}	nd	5.63×10^{-3}
Rice	Adult	4.52×10^{-3}	nd	nd	9.60×10^{-4}	nd	4.82×10^{-3}
	Child	1.73×10^{-2}	nd	nd	3.70×10^{-3}	nd	1.85×10^{-2}
Millet	Adult	2.08×10^{-3}	nd	nd	6.90×10^{-4}	9.0×10^{-5}	2.65×10^{-3}
	Child	7.90×10^{-3}	nd	nd	2.60×10^{-3}	3.50×10^{-4}	1.00×10^{-2}
Sorghum	Adult	2.05×10^{-3}	nd	nd	1.02×10^{-3}	1.0×10^{-4}	2.18×10^{-3}
	Child	7.82×10^{-3}	nd	nd	4.78×10^{-3}	3.80×10^{-3}	1.26×10^{-2}
	RfD _{ing}	3.0×10^{-3}	3.50×10^{-3}	1.0×10^{-3}	4.0×10^{-2}	3.0×10^{-1}	1.0

nd – not detected.

In the range of 0.048–0.051 mg/kg (0.050–0.002 mg/kg), 0.100–0.200 mg/kg (0.0150–0.058 mg/kg), 0.017–0.10 mg/kg (0.059–0.042 mg/kg), and 0.065–0.710 mg/kg (0.068–0.03 mg/kg, respectively), the results demonstrate high levels or concentrations of As (Table 2). The concentrations of Pb, Cd, Cu, and Zn in grains were below the [3] limit (Table 2). According to Table 5, children's exposure to Pb, Cd, Cu, and Zn from all cereals and legumes was low. The Hiderm for adult and child exposure dose by dermal of the grains and legumes containing As, Pb, Cd, Cu, and Zn was not high (Table 5).

Almost all the Chronic Daily Intake (CDI) values for Zn, Cd, Pb, Cu and As for both adult and children were generally below 1 (Table 6). The day-to-day food intake of As, Pb, Cd, Cu and Zn from cereals and legumes varied from 1.60×10^{-3} to 4.70×10^{-3} mg/(kg-d), 7.20×10^{-4} to 1.60×10^{-3} mg/(kg-d) [16], $<2.70 \times 10^{-3}$ mg/(kg-d) respectively with Pb and Cd were below detection, for an adult in the Tamale Metropolitan (Table 6). The daily dietary intake of As, Pb, Cd, Cu and Zn from cereals and legumes varied from 6.0×10^{-3} to 1.80×10^{-1} mg/(kg-d), 8.70×10^{-4} to 6.20×10^{-3} mg/(kg-d), $<1.03 \times 10^{-3}$ mg/(kg-d) with Pb and Cd below the detectable limit for children in Tamale Metropolitan (Table 6) [16].

The cancer risk of the metals from cereals and legumes varied from 1.10×10^{-6} to 3.0×10^{-6} in As, with Pb and Cd below detection, for

adults in Tamale Metropolitan (Table 7). The cancer risk of metals from cereals and legumes varied from 4.0×10^{-6} to 1.20×10^{-4} in As with Pb and Cd below detection, for children in Tamale Metropolitan (Table 7).

4. Discussion

4.1. Heavy metals levels in maize, rice, millet and sorghum sold in the Tamale Aboabo market

The As content of cereal an essential foodstuff for the human diet, was above the [17] stipulated limits of 0.015 mg/kg in this study. The study revealed that As content of maize, rice, millet and sorghum sold in the Tamale Aboabo market cannot be risk-free after consumption. The elevated concentrations in the cereals can be attributed to the application of arsenic containing pesticides, fertilizer and runoff from other agricultural fields. The present study revealed that Pb content in the maize, rice, millet and sorghum are within [17] permissible limits of 0.2 mg/kg for intake. This result is similar to that of [18] that reported Pb concentration in a range of 0.04–0.23 mg/kg in cereal samples eaten in Finland. However, these results are lower than those reported by [19, 20, 21] where Pb levels in corn, split peas, wheat, lentil, bean and peas, ranged from 0.70 to 1.95 mg/kg, 1.45–2.44 mg/kg, 0.54–4.89 mg/kg,

Table 5. Assessment of the non-carcinogenic health risks of heavy metals in food for both adults and children via dermal pathways.

HQ _{derm}		As	Pb	Cd	Cu	Zn	HI
Cowpea	Adult	2.50×10^{-5}	nd	nd	1.10×10^{-5}	7.90×10^{-5}	1.08×10^{-4}
	Child	6.0×10^{-5}	nd	nd	-2.60×10^{-5}	1.90×10^{-4}	1.58×10^{-4}
Soybean	Adult	1.70×10^{-5}	nd	nd	1.60×10^{-5}	1.60×10^{-4}	1.64×10^{-4}
	Child	4.20×10^{-5}	nd	nd	3.90×10^{-5}	3.9×10^{-4}	3.98×10^{-4}
Gnut	Adult	2.10×10^{-5}	nd	nd	1.20×10^{-5}	1.40×10^{-4}	1.51×10^{-4}
	Child	5.20×10^{-5}	nd	nd	2.80×10^{-5}	3.46×10^{-4}	3.72×10^{-4}
Maize	Adult	1.60×10^{-5}	nd	nd	1.20×10^{-5}	nd	nd
	Child	3.80×10^{-5}	nd	nd	3.0×10^{-5}	nd	nd
Rice	Adult	4.70×10^{-5}	nd	nd	1.0×10^{-5}	nd	2.70×10^{-5}
	Child	1.10×10^{-4}	nd	nd	2.40×10^{-5}	nd	6.0×10^{-5}
Millet	Adult	2.20×10^{-5}	nd	nd	nd	5.70×10^{-6}	1.61×10^{-5}
	Child	5.20×10^{-5}	nd	nd	1.70×10^{-5}	1.40×10^{-5}	-6.10×10^{-5}
Sorghum	Adult	2.10×10^{-5}	nd	nd	1.10×10^{-5}	6.20×10^{-5}	2.8×10^{-5}
	Child	5.0×10^{-5}	nd	nd	2.60×10^{-5}	1.50×10^{-4}	1.55×10^{-4}
	RfD _{derm}	1.23×10^{-4}	5.25×10^{-3}	1.0×10^{-5}	1.20×10^{-2}	6.0×10^{-2}	1.0

nd – not detected.

Table 6. Chronic Daily Intake (CDI) for the heavy metals.

CDI _{ing}		As	Pb	Cd	Cu	Zn
Cowpea	Adult	2.48×10^{-3}	nd	nd	1.10×10^{-3}	1.32×10^{-3}
	Child	9.48×10^{-3}	nd	nd	8.70×10^{-4}	1.60×10^{-3}
Soybean	Adult	1.70×10^{-3}	nd	nd	1.60×10^{-3}	2.70×10^{-3}
	Child	6.60×10^{-3}	nd	nd	6.20×10^{-3}	1.03×10^{-2}
Groundnut	Adult	2.10×10^{-3}	nd	nd	1.20×10^{-3}	2.40×10^{-3}
	Child	8.20×10^{-3}	nd	nd	4.40×10^{-3}	9.10×10^{-3}
Maize	Adult	1.60×10^{-3}	nd	nd	1.23×10^{-3}	nd
	Child	6.0×10^{-3}	nd	nd	4.70×10^{-3}	nd
Rice	Adult	4.70×10^{-3}	nd	nd	1.0×10^{-3}	nd
	Child	1.80×10^{-1}	nd	nd	3.80×10^{-3}	nd
Millet	Adult	2.20×10^{-3}	nd	nd	7.20×10^{-4}	9.40×10^{-4}
	Child	8.30×10^{-3}	nd	nd	2.76×10^{-3}	3.60×10^{-4}
Sorghum	Adult	2.10×10^{-3}	nd	nd	1.10×10^{-3}	1.04×10^{-3}
	Child	8.20×10^{-3}	nd	nd	4.10×10^{-3}	3.96×10^{-3}

nd – not detected.

0.74–1.36 mg/kg, 1.26–2.96 mg/kg and 0.90–3.23 mg/kg, respectively. Also, in Kermanshah Iran, a study by [22] reported Pb levels in different kinds of rice samples varied from 0.99 to 2.30 mg/kg with a mean amount of 1.35 mg/kg. Cd content in the maize, rice, millet and sorghum were within [17] stipulated limits of 0.2 mg/kg for intake. These results are similar to that of [22] that reported Cd amounts in the range of <0.01 mg/kg, and 0.06–0.28 mg/kg by [22] in cereals [17]. reported ranges around 0.1 mg/kg in wheat bran. Cd amount in different types of rice was reported to have ranged from 0.041 to 0.089 mg/kg [22]. Cu levels in the maize, rice, millet and sorghum are within [17] permissible limits of 73.30 mg/kg for intake. Similar studies reported Cu was detected in cereal samples ranging from 0.55 to 6.77 mg/kg [22], 1.59–10.56 mg/kg [22], 1.20–3.10 mg/kg [23], 2.00–14.00 mg/kg [18] and 1.53–3.07 mg/kg [24]. Zn levels in the maize, rice, millet and sorghum are within [17] permissible limits of 99.40 mg/kg for intake. Similar studies reported Zn concentrations of cereals ranged from 3.55 to 23.61 mg/kg [22], 8.50–18.40 mg/kg [25], 6.65–46.99 mg/kg [21], 32.60–70.20 mg/kg [26], 3.54–33.40 mg/kg [24] and 8.00–89.00 mg/kg [18].

4.2. Heavy metals levels in cowpea, soybean and groundnuts sold in the Tamale Aboabo market

It is essential to study the heavy metal content of legumes an essential foodstuff for the human diet, sold in markets. Essential minerals and

Table 7. Risk assessment of the heavy metals' potential for cancer.

CR _{ing}		As	Pb	Cd
Cowpea	Adult	1.70×10^{-6}	nd	nd
	Child	6.32×10^{-6}	nd	nd
Soybean	Adult	1.10×10^{-6}	nd	nd
	Child	4.40×10^{-6}	nd	nd
Groundnut	Adult	1.40×10^{-6}	nd	nd
	Child	5.50×10^{-6}	nd	nd
Maize	Adult	1.10×10^{-6}	nd	nd
	Child	4.0×10^{-6}	nd	nd
Rice	Adult	3.0×10^{-6}	nd	nd
	Child	1.20×10^{-4}	nd	nd
Millet	Adult	1.50×10^{-6}	nd	nd
	Child	6.0×10^{-6}	nd	nd
Sorghum	Adult	1.40×10^{-6}	nd	nd
	Child	5.50×10^{-6}	nd	nd

nd – not detected.

heavy metals occur in contaminated and natural environments and cannot be simply decontaminated through degradation, resulting in their tenacity in the environment. Most metals are carcinogens and are involved in numerous illnesses, including osteoporosis, multiple sclerosis, Parkinson's disease, Alzheimer's disease, developmental disorders and failure of numerous organs or organ systems, for example, heart, immune system, kidney and lungs [27]. Zn and Cu are important minerals that are desired as variety of biomolecules to maintain the normal structure, proliferation and function of cells [25]. The study revealed that As content of cowpea, soybean and groundnut sold in the Tamale Aboabo market cannot be risk-free from consumption because As levels of the legumes in this study were above [17] stipulated limits of 0.015 mg/kg. The elevated levels in the legumes can be attributed to the application of arsenic containing pesticides production stages of the legumes. Pb content in the cowpea, soybean and groundnut were within [17] permissible limits of 0.2 mg/kg for intake, there is no accumulation of Pb in the soil of the area. However, the consumption of these legumes may not pose an immediate health risk. Pb is a very poisonous element and prolonged exposure, even at small concentrations, is related with several health threats [28]. Similar to that of [26] who reported Pb levels that ranged from 0.32 to 0.70 mg/kg in legumes and from 0.14 to 0.39 mg/kg in nuts sold in Spain. Cd is an element capable of generating chronic toxicity even when it is available at levels of about 1 mg/kg [29]. Cd concentration in the cowpea, soybean and groundnut were within [17] permissible limits of 0.20 mg kg⁻¹ for intake, this indicated that there is no presence of Cd in the soil. A similar study by [23] reported Cd content was <0.01 mg/kgⁱⁿ groundnut. Cu levels in the cowpea, soybean and groundnut are within [17] permissible limits of 73.30 mg/kg for intake indicating that there were traces of Cu in the soil. Cu is an essential mineral that is required for several biomolecules to maintain the normal structure, production and function of cells [25]. It may be toxic in excessive amounts, especially in certain genetic disorders [29]. Zn is also an essential mineral that is needed for a variety of biomolecules to maintain the normal structure, function and proliferation of cells [25]. Zn levels in the cowpea, soybean and groundnut were within [17] permissible limits of 99.40 mg/kg for intake.

4.3. Human health risk related to the consumption and dermal contact with cereals and legumes in the Tamale Aboabo market

The rate of adults' ingestion of As in cereals and legumes in this study were within the RfD_{ing} of 3.0×10^{-3} [17] except rice that recorded a higher value whilst for children the RfD_{ing} of 3.0×10^{-3} was generally exceeded. This places the children at risk of consuming the cereals and legumes containing As and the adult consuming the rice sold in the market. The consumption of the legumes and cereals by children and adults in the study location will likely pose no Cd and Pb related health risks as the RfD_{ing} of 1.0×10^{-3} and 3.50×10^{-3} [17], respectively were not exceeded. The children and adults' consumption of the cereals and legumes containing Zn and Cu will pose no health risk as the RfD_{ing} for Zn and Cu were within the thresholds of 3.0×10^{-1} and 4.0×10^{-2} [17] respectively. HI_{ing} values for both children and adults were established to be less than unity. Hence, there is no need for great concerns as there are no potential non-carcinogenic effects. The exposure dose via dermal contact of adults and children of As in cereals and legumes are within the RfD_{derm} of 1.23×10^{-4} [17]. This places no health threat to both children and adults consuming the cereals and legumes containing As. The exposure dose via dermal contact with the cereals and legumes for children and adults will likely pose no Cd and Pb related health risks as the RfD_{derm} of 1.0×10^{-5} and 5.25×10^{-3} respectively were not exceeded. Children and adults consuming cereals and legumes containing Zn and Cu poses no health risk as to the RfD_{derm} for Zn and Cu were within the thresholds of 6.0×10^{-2} and 1.20×10^{-2} [17] respectively. HI_{derm} for As, Pb, Cd, Cu and Zn were less than unity for both children and adults signifying that the dermal adsorption of these metals in the cereals and legumes sold in the market could have little or no health risk.

The Cancer Risk (CR) value for Pb and Cd for both children and adults were generally found to be within the safe limit of cancer risk except As. The US Environmental Protection Agency considers acceptable for regulatory purposes a cancer risk in the range of 1×10^{-6} to 1×10^{-4} [29]. Generally, the residence of Tamale which includes adults and children have no Pb and Cd risk after consuming the cereals and legumes. The ingestion pathway is the likely main contributor to excess lifetime cancer risk than the dermal pathway.

5. Conclusion and future perspectives

High concentration levels of As measured in the various foodstuffs with low concentrations Pb, Cd, Cu and Zn compare to the standard limit. High content of As detected in cereal and legume can be harmful after consumption, but the other metal had lower concentrations which cannot cause any risk after consumption. The elevated concentrations of As in the cereals can be attributable to the application of arsenic containing pesticides, fertilizer and runoff from other agricultural fields. The human health risk for adults and children related to dose through dermal and consumption of cereal and legumes containing As, Pb, Cd, Cu and Zn were not high, Hence, this cannot cause any carcinogenic effect to them. The ingestion pathway is likely the main contributor to excess lifetime cancer threat than the dermal pathway. HI_{derm} for all the metals studied were less than one for both adult and children indicating that dermal adsorption of these metals in cereals and legumes sold on the market could have little or no health risk. All the metals assessed were within the acceptable limit of cancer risk value except As. In Tamale and Ghana at large, cereals and legumes are eaten more than once in a day. Hence, it is required that certified agencies monitor and evaluate the heavy metal levels in these foodstuffs. It is recommended that similar studies should be carried out in some of the rural and urban areas of Ghana since it is essential to study the heavy metals content of cereals and legumes sold in markets. Critical attention is necessary for the implementation of proper ways to regulate and monitor arsenic containing pesticides, fertilizer and runoff from other agricultural fields.

Declarations

Author contribution statement

Abdul-Aziz Adam & Linda Aurelia Ofori: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Lyndon N. A. Sackey: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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