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Levels and Health Risk Assessment of Heavy Metals in Tubers from Markets in the Kumasi Metropolis, Ghana

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ABSTRACT

Tubers play a significant role in human diet. Samples of tubers were obtained from five different markets from Kumasi. Pulvurised samples were digested with concentrated nitric acid. Heavy metals Zn, Fe, Cu and Cd were analysed using Atomic Absorption Spectroscopy in four tubers which include yam, cassava, cocoyam and sweet potatoes. The metals were analysed using Atomc Absorption Spectrophotometer 220. The concentration ranges were 0.862 to 2.144 mg/kg for Cu, 0.476 to 0.778 mg/kg for Cd, 11.246 to 58.728 mg/kg for Zn and 27.918 to 45.872 mg/kg for Fe. Health risk assessment showed that consumers are not in danger as far as these metals are concerned.

Keywords: *Tubers, Atomic Absorption Spectroscopy, Heavy Metals, Health Risk.*

1. INTRODUCTION

Heavy metals have been excessively released into the environment due to rapid industrialization and have created a major global concern. These metals have important positive and negative roles in human life (Divrikli *et al*., 2003; Dundar and Saglam, 2004; Colak *et al*., 2005; Oktem *et al*., 2005). Unlike organic wastes, heavy metals are non-biodegradable and can be accumulated in living tissues, causing various diseases and disorders. Metals such as cadmium and copper are cumulative poisons, which cause environmental hazards and are reported to be exceptionally toxic (Ellen *et al*., 1990). Iron, copper, and zinc are essential metals for humans, since they play an important role in biological systems, but these essential heavy metals can produce toxic effects when their intake is excessively elevated (Mendil *et al*., 2005; Narin *et al*., 2005).
Human activities such as industrial production, mining, agriculture and transportation release high loads of heavy metals to the biosphere. Accumulation of heavy metals in crop plants is often of great concern due to its potential for food contamination through the soil-root interface (Cieslinski *et al*., 1996). Cadmium exposures are associated with kidney and bone damage. Cadmium has also been identified as a potential human carcinogen, causing lung cancer (WHO 2007). Toxicity of zinc due to excessive intake, may lead to electrolyte imbalance, nausea, anaemia and lethargy (Fairweather-Tait, 1988).

Accurate and adequate food composition data are however invaluable for estimating the adequacy of intakes of essential nutrients and assessing exposure risks from intake of toxic non-essential elements. In many less-developed countries such data are not readily available (Burk & Pao, 1980; Bruce & Bergstrom, 1983; Hoover & Pelican, 1984). Trace heavy metals are significant in nutrition, either for their essential nature or their toxicity. Copper, iron and zinc are known to be essential and may enter the food materials from soil through mineralization by crops, food processing or environmental contamination, as in the application of agricultural inputs, such as copper-based pesticides which are in common use in farms in some countries.
Due to the fact that trace metals analysis is an important part of environmental pollution studies (Loska *et al*., 2000; Solecki and Chibowski, (2000); Chibowski, 2000; Czarrnowska and Milewska, 2000), and that the consequence of trace metals in foods such as tubers have been of considerable interest because of their toxic effect which are important in human beings (Asaolu, 1995), it is imperative to know the levels of heavy metals (such as Cu, Cd, Zn and Fe) in tubers (such as yam, cocoyam, potato, cassava) from some selected Ghanaian markets to ascertain the risk posed by these metals to consumers.

2. MATERIALS AND METHODS

Description of the Study Area

The samples investigated in this work were collected from various markets in the Kumasi Metropolis of the Ashanti region of Ghana. The markets are Ayeduase, Kejetia, Bantama, Oforikrom and Asafo. Kumasi is the Ashanti regional capital and is the second largest city in Ghana. Kumasi is approximately 483 km north of the equator and 161 km north of the Gulf of Guinea. With over 2.5 million inhabitants, the city spans a radius of about 29 to 32 km (Ghana Statistical Service, 2000). Samples were taken between the months of December 2009 and February 2010.

Reagents

All the reagents were of analytical grade. The glasswares were washed with detergent and rinsed with deionised water before they were soaked in potassium permanganate solution overnight. They were then rinsed with distilled water before use.

Sample Collection and Analysis

Samples of tubers comprising of yam, cocoyam, sweet potatoes and cassava were collected randomly from five different market places.

Table I: English, local (Akan) and scientific names of samples studied

English name	Local name (Akan)	Scientific name
Yam	Bayere	*Dioscorea sp*
Cocoyam	Mankani	*Xanthosoma sp*
Sweet Potatoes	Abrodwomaa	*Ipomea batatas*
Cassava	Bankye	*Manihot esculenta*

The samples were washed with distilled water to remove dirt, peeled to remove their coats and sliced into smaller sizes using a stainless steel knife. They were put on aluminium trays and dried in an electric oven to a constant weight. The dried samples were ground into powder using mortar and pestle. Approximately 2 g each of the grounded sample was weighed and placed in a 50 ml beaker. 20 ml of concentrated nitric acid was added and shaken vigorously. The beaker was swirled gently and heated on an electric heating plate placed in a fume hood at a temperature of 120 ^{o}C till a clear solution was obtained. A dropwise addition of concentrated nitric acid was carried out to ensure that all the organic matter was digested. The digested samples were left to cool and then filtered through Whatman No. 42 filter paper. The resulting solutions were transferred into 50 ml graduated flask and made up to the mark with distilled water. Treated samples were then analysed using Atomic Absorption Spectrophotometer (AAS) 220.

Recovery

The reliability was obtained by performing the recovery of standard Zn, Cd, Cu, and Fe solution. Approximately 20 ml of each standard was taken through the process described above and their concentrations measured.

Table II: Recovery of Zinc, Copper, Cadmium and Iron

	Zn	Cu	Cd	Fe
Amount added (mg/L)	0.50	5.00	0.50	5.00
Amount recovered/(mg/L)	0.48	4.99	0.49	4.99
% recovery	96	99	99	99

Estimation of Dietary Exposure and Health Risk Assessment

Estimated average daily intakes (EADIs) of a metal in food and food consumption assumption were used to determine long term health risks to consumers. The food consumption rates for yam, cocoyam and cassava in Ghana is quoted to be 50.0 kg/person/year, 38.0 kg/person/year, and 154.0 kg/person/year, respectively (Ministry of Agriculture of Ghana, 2013). For each type of exposure, the EADI was obtained by using the following equation:

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$$\text{EADI} = \frac{\text{C x F}}{\text{W x D}}$$

where C is the concentration of metal in each commodity (mg/kg), F is mean annual intake of food per person, D is number of days in a year (365) and W is the mean body weight (60 kg).

The health risk indices were obtained by dividing the estimated average daily intake (EADI) by the acceptable daily intakes (ADI) established by Codex Committee (FAO/WHO, 2011)

$$\text{Health index (HI)} = \frac{\text{EADI}}{\text{ADI}}$$

When the HI is more than 1; the food involved is considered a risk to the concerned consumers. When the HI is less than 1, the food involved is considered as acceptable (no concern) to the concerned consumers (USEPA, 2002). The calculated values can be found in Table IV in the discussion.

3. RESULTS AND DISCUSSION

Human exposure to toxic heavy metals such as cadmium, iron, copper and zinc is known to be responsible for many human health problems. Contaminated foods are however a major source of such heavy metals to man (Ward 1995). Contamination of food may also take place during harvesting, transportation, storage, processing and preparation. The results of the study are shown by Figure 1 to Figure V. The concentration ranges for copper were: yam (1.48-2.70 mg/kg), cocoyam (1.18-2.70 mg/kg), potato (1.10-2.30mg/kg) and cassava (0.50-1.18 mg/kg). Also the concentration of Cd for the various tubers ranged from yam (0.33-0.63 mg/kg), cocoyam (0.28-1.18 mg/kg), potato (0.38-0.98 mg/kg) and cassava (0.25-0.7 mg/kg). Zn concentration were in the range of yam (4.93-90.00 mg/kg), cocoyam (6.05-19.10 mg/kg), potato (9.78-121.78 mg/kg) and cassava (6.68-38.25 mg/kg); whilst the concentration of Fe ranges from yam (25.53-46.28 mg/kg), cocoyam (16.63-38.80 mg/kg), potato (34.30-53.80 mg/kg) and cassava (23.03-36.13 mg/kg). Among the metals studied in the tubers, Zn had the highest mean in potato. However Cd had the lowest mean concentration in cassava.
Generally, the mean concentration of metals in tubers from the selected markets gave a general sequence as follows Fe>Zn>Cu>Cd with the exception of potato which recorded Zn as the highest mean concentration of the metals (Table III). Zurera and co-workers have reported that the differences in metal contents present in food samples depended on the physical and chemical nature of the soil and absorption capacity of each metal by the plant, which is altered by various factors like environmental and human interference, and the nature of the plant (Zurera et al., 1989).

Table III: Mean concentration (mg/kg) and standard deviation of metals in tubers

	Mean concentration and standard deviation			
Sample	Cu	Cd	Zn	Fe
Yam	2.062±0.450	0.508±0.118	30.772±36.254	34.434±8.111
Cocoyam	2.144±0.608	0.778±0.395	11.246±5.414	27.918±9.351
Potato	1.768±0.505	0.614±0.224	58.728±53.256	45.872±8.310
Cassava	0.862±0.278	0.476±0.178	22.258±11.181	29.908±5.099

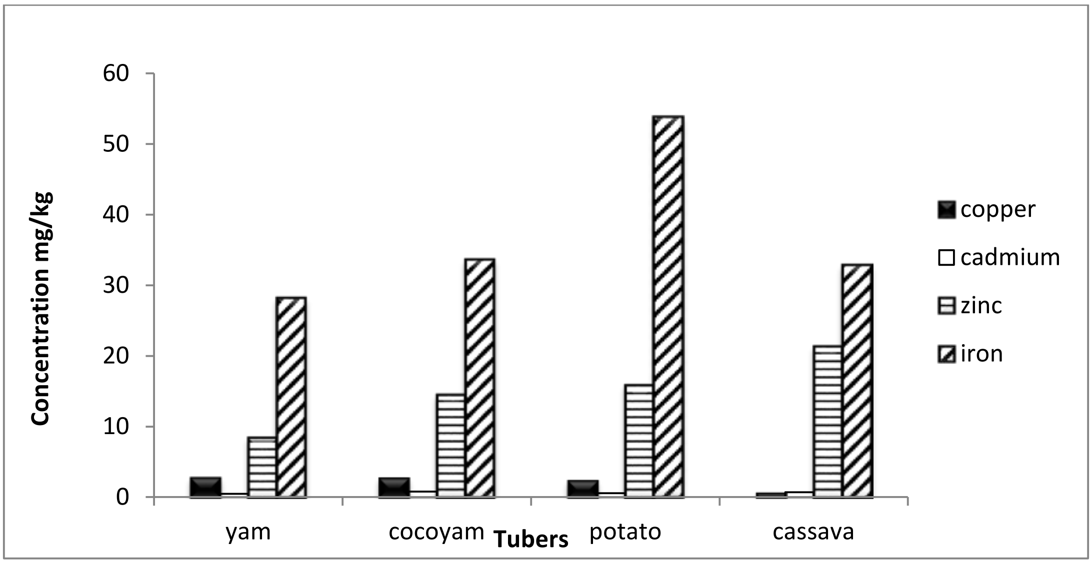

Fig. 1: Concentration of metals in tubers from Ayeduase market

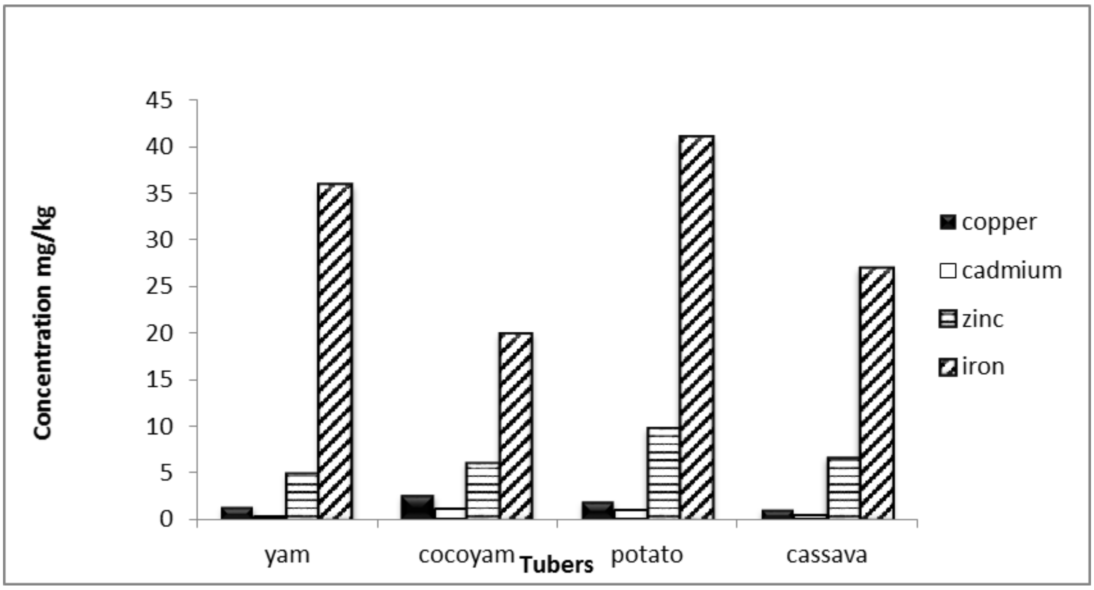

Fig. 2: Metal concentration in tubers from Kejetia market

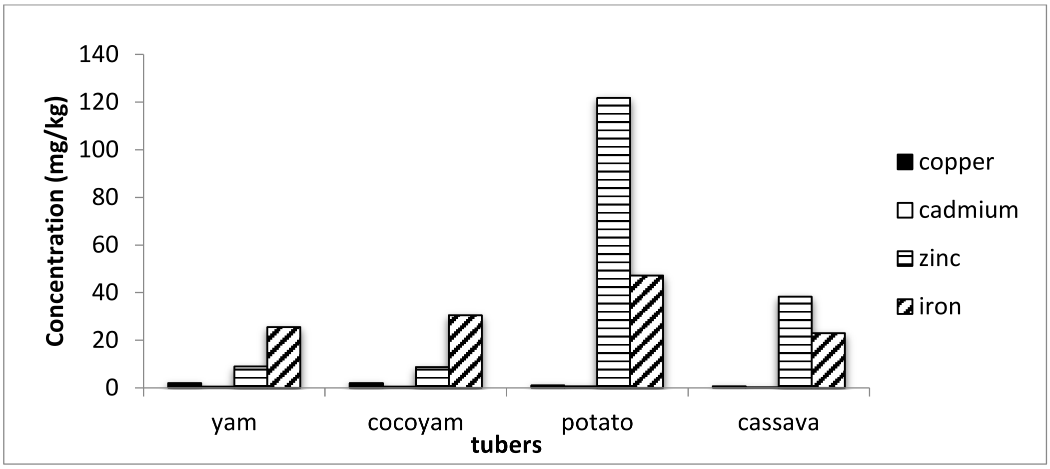

Fig. 3: Metal concentration in tubers from Bantama Market

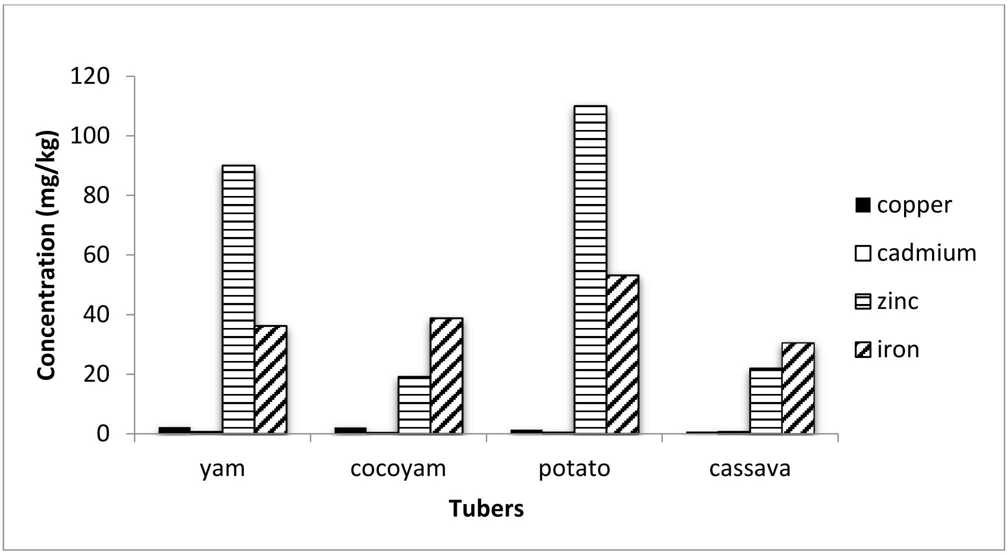

Fig. 4: Metal concentration in tubers from Asafo Market

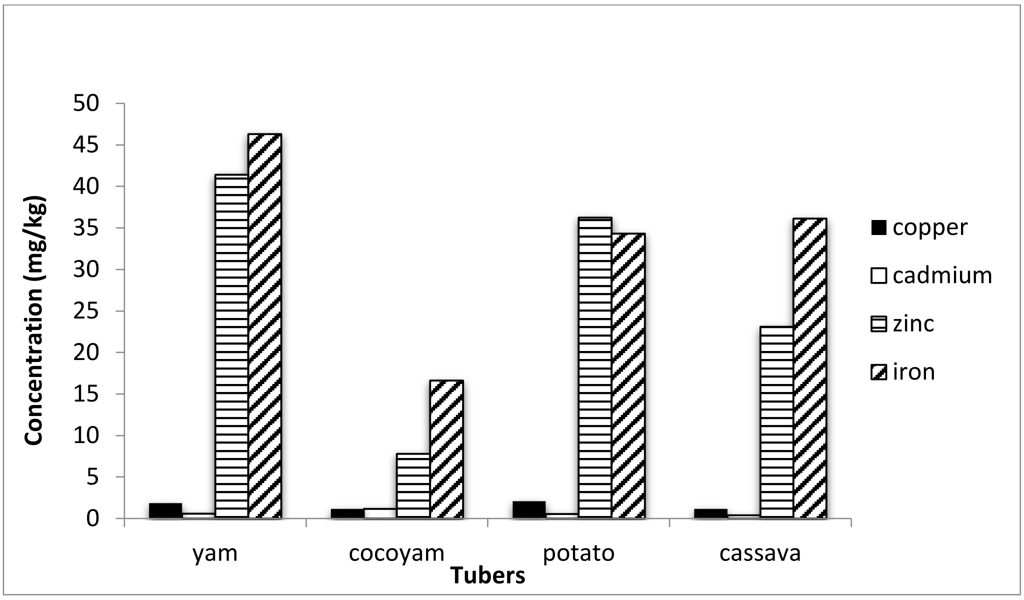

Fig. 5: Metal concentration in tubers from Oforikrom Market

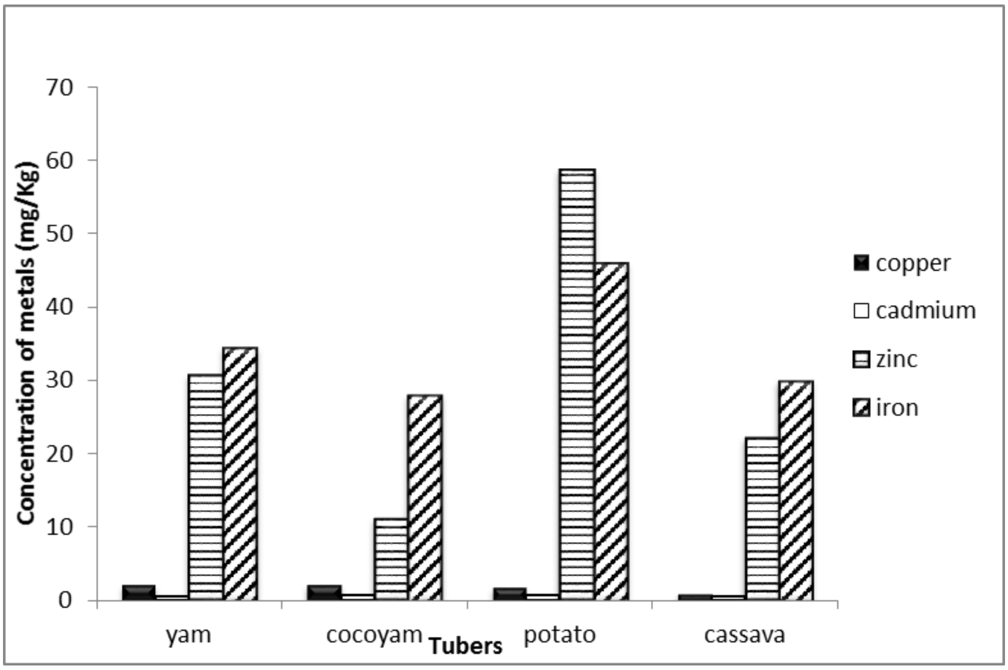

Fig.6: Mean concentration of metals in tubers

Human's activities like mining, farming, manufacturing and the dumping of wastes in landfills are common sources of heavy metal contamination and any or all of these could be ascribed to the exceptionally high levels for some of the heavy metals found in these food samples analyzed.

The results obtained from the analysis revealed the levels of these heavy metals to be from background levels for some metals to excess levels when compared with the standard for maximum acceptable limits of WHO standards for heavy metals in food. The results indicated that higher levels of Cd, Zn and Fe were recorded in all samples analyzed when compared to the FAO/WHO permissible limits for food. The levels of Cu were found to be within safe limits of the WHO standard. People especially those within the Kumasi metropolis stand a risk of Cd, Zn and Fe toxicity since the tubers used for the analysis are the most common and affordable of the foods consumed in Ghana.

The health risk assessment for systemic effects associated with metals encountered in yam, cocoyam and cassava are summarized in Table IV. The toxicological assessment of metals in potato could not be evaluated, since the assumption consumption rate for potato was not available. The results showed that the EADIs calculated ranged between 0.001 to 0.471 mg kg-1day-1, while the hazard indices ranged from 0.001 to 3.000 for the tested metals. The hazard indices of all the metals analysed were less than 1, indicating no direct hazard to human health, in spite of their presence in the food.

Table IV: Acceptable and estimated daily intakes for metals found in yam, cocoyam and cassava

Metal		Yam		Cocoyam		Cassava	
	ADI (mg $kg^{-1}d^{-1}$)	EADI (mg $kg^{-1}d^{-1}$)	HI	EADI (mg $kg^{-1}d^{-1}$)	HI	EADI (mg $kg^{-1}d^{-1}$)	HI
Copper	3.00	0.471	0.016	0.004	0.001	0.006	0.002
Cadmium	0.0001	0.001	0.100	0.001	0.100	0.003	0.033
Zinc	20.00	0.070	0.004	0.019	0.001	0.157	0.009
Iron	17.00	0.079	0.005	0.048	0.003	0.210	0.012

4. CONCLUSION

The results obtained from the analysis of copper, cadmium, zinc and iron in yam, cocoyam potato and cassava from five selected markets in the Kumasi metropolis of Ghana showed that the levels of cadmium, zinc and iron in all the food samples analyzed were above the WHO standard of maximum permissible limits (FAO/WHO, 1991) with the exception of copper. Cadmium is a very toxic metal with no known biological function and higher levels may cause health hazards. Heavy metals are dangerous to plants and animals as well as the entire environment. However, the estimated health index indicates that the tubers pose no health treat as far as the metals analysed are concerned.

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