HEAVY METAL CONTENT IN SOME COMMONLY CONSUMED VEGETABLES FROM KARIAKOO MARKET, DAR ES SALAAM, TANZANIA

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ABSTRACT
This work reports on the levels of cadmium, lead, copper, manganese and zinc in 174 samples from eight varieties of green vegetables (amaranth, Chinese cabbage, cowpea leaves, green pepper, leafy cabbage, lettuce, okra and pumpkin leaf) commonly grown in Dar es Salaam and marketed at Kariakoo, Tanzania. The amount of cadmium and lead ranged between 3-42 and 11-60 µg/kg respectively. The amount of copper, manganese and zinc ranged between 0.35 - 2.12, 1.01 - 7.57, and 1.19 - 6.33 µg/kg respectively. On average consumption pattern, the contribution of these vegetables to the recommended daily intakes (RDI) for cadmium and lead ranges from 0.5 - 10.8% and 0.1 - 4.0%, respectively. The contribution of these vegetables for copper, manganese and zinc to the recommended daily intake is observed to mostly be less than 20%. The estimated dietary intakes through these vegetables show that they may be considered as an appreciable source of both heavy metals and essential trace elements due to their extensive consumption.

Keywords: Heavy metals, Vegetables, Daily intake, Kariakoo market, Food safety

INTRODUCTION

Heavy metals are important environmental pollutants and their presence in the atmosphere, soil, water and in food chain can cause serious problems to living things. Heavy metal contamination of vegetables cannot be ignored because vegetables are important components of human diet as they are rich sources of vitamins, minerals, fibres, and antioxidants. However, intake of heavy metal-contaminated vegetables may pose risk to the human health. In humans, heavy metals enter the body mainly through dietary intake (Calderon *et al*. 2003; Roychowdhury *et al*. 2003). Although living organisms need heavy metals for metabolic processes, excess concentrations have a lethal effect (Girisha and Ragavendra 2009). Due to their importance, the intake of these metals by humans through food chain has been of great concern and has recently been of intense interest by several workers (Aremu and Undoessien 1990, Bahemuka and Mubofu 1999, Ellen *et al.* 1990, Gardea-Torresdeya *et al.* 2009, Li *et al.* 2009, Marshall *et al.* 2009, Mei *et al*. 2009, Radwan and Salama 2006, Sridhara Chary *et al*. 2008, Voegborlo 1993, Zurera *et al.* 1989). The thresholds of dietary toxicity of heavy metal in soil-crop system is affected by factors such as soil type which includes soil pH, organic matter content, clay mineral and other soil chemical and biochemical properties; and crop species or cultivars regulated genetically for heavy metal transport and accumulation. In addition, the interactions of soil-plant root-microbes play important roles in regulating heavy metal movement from soil to the edible parts of crops. Agronomic practices such as fertilizer and water managements as well as crop rotation system can affect bioavailability and accumulation of heavy metals in crops, thus influencing the thresholds for assessing dietary toxicity of heavy metals in the food chain.

The size of the urban area of Dar es Salaam is 165 km^2 and of this, about 650 ha (about

4%) is used for vegetable production on open spaces (Dongus 2001). In a study on vegetable production in Dar es Salaam, Dongus (2001) reported that major share of productive open spaces in Dar es Salaam's urban area is situated between settlements, along river valleys, near industrial areas and along railway lines. Although this information is known, little is known on the safety and levels of metals in these vegetables. In previous works (Bahemuka 1996, Bahemuka and Mubofu 1999), high levels of lead and cadmium were observed in some vegetables grown at Sinza and Buguruni areas in Dar es Salaam. Because it is difficult to establish amounts of heavy metals from each area of Dar es Salaam, commonly consumed vegetables were sampled from Kariakoo, the biggest and dependable vegetable market in Dar es Salaam. Varieties of fresh vegetables and fruits are sold at Kariakoo but the most common vegetables include African spinach (*Amaranth sp*.), Chinese cabbage (*Brassica chinensis*), Cabbage (*Brassica oraceae*), Cowpea leaves (*Vigna unguiculata*), leafy cabbage (*Brassica rapa*) and lettuce (*Lectuca sativa*). The increasing level of activities related to metal processing and the haphazard disposal of domestic wastes, calls for a research on the heavy metal pollution in vegetables marketed in Kariakoo because some of the vegetables sold at Kariakoo are grown near metal polluted areas. A study on the levels of lead from effluents discharged from factories in Dar es Salaam contacted by Mashauri *et al.* (1991) showed that lead was above the stipulated standards for industrial effluents.

The main objective of this study was to determine the concentrations of cadmium, lead, copper, manganese and zinc from eight green vegetable varieties (amaranth, Chinese cabbage, cowpea leaves, green pepper, leafy cabbage, lettuce, okra and pumpkin leaf) that are commonly marketed at Kariakoo market. Moreover, the estimate for the contribution of standard portions of vegetables to the allowable daily intakes of these metals in some edible green vegetables from Kariakoo market was evaluated.

MATERIALS AND METHODS

Reagents

All reagents were used without further purification and all were analytical grade obtained from Aldrich, BDH, May and Baker Dagenham, all from England.

Sample collection

The vegetable samples in this study were bought from Kariakoo market situated at the centre of Dar es Salaam. It is important to note that most vegetables marketed at Karakoo are produced in Dar es Salaam. It is established that periurban vegetable production in Dar es Salaam is mainly on non-leafy vegetables, whereas leafy vegetables are almost exclusively originating in the (inner) urban areas (Stevenson *et al.* 1996).

The vegetable samples were African spinach (*Amaranth sp*.), Chinese cabbage (*Brassica chinensis*), Cabbage (*Brassica oraceae*), Cowpea leaves (*Vigna unguiculata*), leafy cabbage (*Brassica rapa*), lettuce (*Lectuca sativa*), green pepper, okra and pumpkin leaves (*Moschata cucurbita*). The samples were bought over the period of six months and in each case they were packed and stored in polythene bags according to their types and brought to the laboratory for preparation.

Sample preparation

The samples were washed with distilled water to eliminate air-borne pollutants. Leafy stalks were removed according to the common household practices. Excess moisture was removed by drying samples on the sheet of paper. The samples were then sliced, weighed and oven dried at 60 °C to a constant weight. Each oven-dried sample was ground in a mortar to pass through a 60-

mesh sieve. Each determination was carried out by accurately weighing a sample of 1 g of a ground sample in a crucible before placing it in a muffle furnace and ashed at 450 ^{o}C for 12 h. The ash was then digested with 5 ml of 20% (v/v) analar HCl following the procedure described by Perkin-Elmer (1982). The residue was then filtered into a 50 ml volumetric flask using Whatman filter paper No. 41, and the solution was made to the mark with deionised water. AAS was used for the determination of the heavy metals. Each sample solution was run in duplicate to ensure the repeatability of the obtained results. The same procedure was followed for each sample and the appropriate dilution factors were used in the calculation.

Atomic absorption spectrophotometric (AAS) analysis

The ash solution was aspirated into the instrument after all necessary set-up and standardization procedures. All metals were determined with a Perkin-Elmer Model 2380 atomic absorption spectrophotometer at the Department of Chemistry, University of Dar es Salaam. For analytical quality assurance, the result of each metal was corrected by subtracting the value from the blank. Also, after every five sample readings, standards were run to make sure that the obtained results were within range. A 10 cm long slot-burner head, a lamp and a standard air-acetylene flame were used. Other AAS conditions employed in these determinations are as reported in the previous study (Bahemuka and Mubofu, 1999).

RESULTS AND DISCUSSION

Levels of heavy metals in vegetables

Apart from affecting the nutritive values of vegetables, heavy metals may have harmful effects on consumers of the vegetables. The regulations on food quality have lowered the maximum permissible levels of toxic metals in human food and this call for a good and vigorous food quality control on the concentrations of trace metals in food. The mean and range of heavy metals concentrations in eight green vegetable samples are summarized in Tables 1 and 2. Results in Table 1 show high levels of cadmium between 42 µg/kg in lettuce and 3 µg/kg in okra with range of 22-56 and 1-18 µg/kg, respectively. The highest concentrations of cadmium that are greater than a mean value of 10 µg/kg were recorded in lettuce (42 µg/kg), cowpea leaves (27 µg/kg), Chinese cabbage (10 µg/kg) and Leafy cabagge (10 µg/kg. Amaranth, pumpkin leaves and okra had mean cadmium levels of 9 µg/kg, 4 µg/kg and 3 µg/kg, respectively. Within the studied vegetables, the highest concentrations of lead greater than a mean value of 46 µg/kg were noticed in okra followed by pumpkin leaves, lettuce and amaranth. The remaining vegetables had mean lead levels ranging from 11 µg/kg to 19 µg/kg. Variation in the contents of heavy metals in these vegetables is probably due to the absorption of these metals from the soil that is influenced by factors such as pH of the soil (Streat *et al*, 1977), the organic matter content (Jaakkola and Ylaranta, 1976), and the interaction of other metals such as selenium, in the growing areas. The concentration of these metal elements in the soil, the absorption capacity of metal elements by vegetable species may also cause the differences in the contents. The high levels of heavy metals found in some vegetables might also be closely related to the pollutants found in irrigation water, farm soil or due to pollution from the highways traffic. Moreover, the variation may be due to differences in crop species or cultivars that are expected to be genetically regulated in their heavy metal transport and accumulation. Agronomic practices such as fertilizer and water managements on growing these vegetables could be affecting the accumulation of heavy metals. This is supported by the findings that vegetable production in Dar es Salaam, is situated in between settlements, along river valleys, near industrial areas and near along railway lines (Dongus, 2001). These vegetable growing areas are not environmentally safe and hence prone to heavy metal contamination. The levels of these toxic heavy metals (Cd and Pb) are in contrast to our recent results where the levels of these metals in oranges from Muheza, Tanga, Tanzania were below the detection limits (Mbogo *et al*., 2010).

Table 1: Contents of cadmium and lead in 174 samples of vegetables

Type of vegetable	N	Cadmium		Lead	
		Mean	Range	Mean	Range
		µg/kg			
Amaranth	22	9	3 - 18	46	20 - 51
Chinese cabbage	21	10	7 - 28	16	10- 22
Cowpea leaves	22	27	5 - 42	11	10 - 16
Green pepper	20	14	5 - 20	17	11 - 32
Leafy cabbage	20	10	4 - 22	19	10 - 42
Lettuce	21	42	22 - 56	52	20 - 72
Okra	25	3	1 - 18	60	15 - 81
Pumpkin leaves	23	4	2 - 21	59	21 - 68
Mean		14.9		35	
Standard deviation		±0.001		±0.02	
Permissible levels in food as per WHO & FAO		30		30	

N = number of samples. Values are mass/fresh mass of the edible portion.

The maximum lead limit for human health set by WHO for edible parts of vegetables is 0.3 µg/g. Data in Table 1 shows that lead concentration in studied vegetables, are in the range of 0.011 to 0.06 µg/g. The lead levels in these vegetables are below the maximum WHO permissible levels and are comparable to those observed in earlier studies in vegetables consumed in Dar es Salaam (Bahemuka and Mubofu, 1999). Other investigations have also reported similar levels of lead content in vegetables sampled from markets (Al Othman, 2010, Radwan and Salama, 2006). Generally, a comparison with other previously reported results on heavy metals in vegetables from other parts of the world show that the amounts of cadmium obtained in this study are within the range of concentrations reported by others (Zurera *et al.* 1989, Ellen *et al.* 1990, Girisha *et al.* 2009). On the other hand, levels of lead are extremely lower than those reported by Zurera *et al.* (1989), but are in agreement with those reported by Ellen *et al.* (1990).

The levels of copper, manganese and zinc are shown in Table 2. The highest level of copper was found in amaranth with a mean value of 2.12 µg/kg while the lowest level of copper was recorded in lettuce with mean amount of 0.35 µg/kg. In general, 50% of studied vegetables had mean copper levels below 0.50 µg/kg. The mean level of manganese was highest in pumpkin leaves (7.57 µg/kg) and lowest in green pepper (1.01 µg/kg). Overall, about 75% of vegetables studied had mean manganese content greater than 2 µg/kg. Zinc concentration in these vegetables ranged from 1.19 µg/kg in Chinese cabbage to 6.33 µg/kg in amaranth. Out of the eight vegetables studied, slightly over 60% of vegetables showed the mean amount of zinc above 2 µg/kg. It is worth noting that the levels of zinc in 60% of similar green vegetables studied had higher amounts than the 1.46 µg/100 g reported by Voegborlo, 1993 from central Sahara. The variation of metals found in different vegetables might be due to the pollutants found in irrigation water, soil type differences and crop species differences in regulating their metal accumulation. The levels of copper obtained in this study are comparable to those reported by Ellen *et al.* (1990), although are higher than those reported by Zurera *et al.* (1989). The levels of manganese were higher than those reported by both Zurera *et al.* (1989) and Ellen *et al.* (1990). For zinc, the values obtained are extremely lower than those reported by Ellen *et al.* (1990), but comparable to those of Zurera *et al.* (1989).

Table 2: Contents of copper, manganese and zinc in 174 samples of vegetables

Type of vegetable	*N*	Copper		Manganese		Zinc	
		Mean	Range	Mean	Range	Mean	Range
		µg/kg					
Amaranth	22	2.12	1.57 - 2.72	2.22	1.15 - 2.38	6.33	1.89 - 11.2
Chinese cabbage	21	0.38	0.23 - 0.60	3.88	3.21 - 4.61	1.19	0.77 - 1.36
Cowpea leaves	22	0.41	0.31 -0.63	5.81	4.48 - 6.98	1.96	0.95 - 1.39
Green pepper	20	0.46	0.26 - 0.52	1.01	1.03 -1.17	1.33	0.82 - 1.71
Leafy cabbage	20	0.56	0.45 - 0.71	1.80	1.12 - 2.35	4.18	3.80 - 4.96
Lettuce	21	0.35	0.10 - 0.46	4.48	4.20 - 4.56	2.07	1.67 - 2.52
Okra	25	1.22	1.34 - 1.74	5.94	5.09 - 6.97	3.59	1.38 - 5.78
Pumpkin leaves	23	1.61	1.57 - 1.72	7.57	6.69 - 8.23	3.39	0.77 - 25.0
Mean		0.89				3.01	
Standard deviation		±0.002		4.09		±0.002	
Permissible levels in vegetables as per WHO & FAO		73.3		±0.002		9.4	

N = number of samples. Values are mass/fresh mass of the edible portion.

In order to estimate the contributions of vegetables to tolerable or recommended daily intakes of the heavy metals/metals (WHO 1972, WHO 1989, FAO/WHO–Codex 2001, Reilly 1991) the approach of combining mean levels with a standardized portion is utilized. In Tables 3 and 4, the calculated contributions of standard portion of vegetables to the acceptable and allowable daily intakes (ADI) are reported. As noted in Table 3, a normal consumption of vegetables does not contribute significant amount (except cowpea leaves) of cadmium with respect to the tolerable intake. The pollution of lead due to the consumption of the vegetables in most cases is less than 2% of the tolerable daily intake. The exception is however noted in amaranth and pumpkin leaves whose mean lead levels are 4.0% and 3.3% for amaranth and pumpkin leaves respectively. It can also be seen that cowpea leaves contribute large amount of cadmium whereas amaranth contributes large amount of lead. An interesting observation is noted in okra that contributes the same amounts of cadmium and lead.

Table 3: Estimation of the contribution of standard portions of vegetables to the allowable daily intakes of cadmium, lead

Kind of vegetable	Standard portion (g)	Contributions to daily intake of			
		Cadmium		Lead	
		Daily intake		Daily intake	
		(μg)	% of ADI	(μg)	% of ADI
Amaranth	378	3.4	5.7	17.4	4.0
Chinese cabbage	182	1.8	3.0	2.9	0.7
Cowpea leaves	244	6.5	10.8	2.7	0.6
Green pepper	38	0.5	0.8	0.6	0.1
Leafy cabbage	244	2.4	4.0	4.6	1.1
Lettuce	92	3.7	6.2	4.9	1.1
Okra	38	0.3	0.5	2.3	0.5
Pumpkin leaves	244	0.9	1.5	14.4	3.3

Table 4: Estimation of the contribution of standard portions of vegetables to recommended daily intakes of copper, manganese and zinc

Kind of vegetable	Standard portion (g)	Contributions to daily intake of					
		Copper		Manganese		Zinc	
		Daily intake		Daily intake		Daily intake	
		(mg)	% of ADI	(mg)	% of ADI	(mg)	% of ADI
Amaranth	378	0.80	20 - 40	0.84	16.8 - 42	2.39	15.9
Chinese cabbage	182	0.05	1.7 - 3.5	0.71	14.2 - 35.5	0.22	1.5
Cowpea leaves	244	0.10	2.5 - 5	1.42	28.4 - 71	0.48	3.2
Green pepper	38	0.20	5 - 10	0.04	0.8 - 2	0.05	0.3
Leafy cabbage	244	0.14	3.5 - 7	0.44	8.8 - 22	1.02	6.8
Lettuce	92	0.03	0.7 - 1.5	0.41	8.2 - 20.5	0.19	1.3
Okra	38	0.05	1.2 - 2.5	0.23	4.6 - 11.5	0.14	0.9
Pumpkin leaves	244	0.39	9.7 - 19.5	1.85	37 - 92.5	0.83	5.5

The trace elements like copper and zinc are essential in our bodies. Copper, a biocatalyst, is also essential in the maintenance of healthy central nervous system, pigmentation, prevention of anaemia and is interrelated with the function of zinc (Akinyele and Osibanjo, 1982). Zinc has a role as an anti-oxidant, wound healer and as a co-factor of several enzymes in energy metabolism and thus needed by humans.Vegetables examined in this study are found to be good sources of essential trace elements. For instance, amaranth showed a contribution of 40% of copper, 42% of manganese and 15.9% of zinc to the recommended daily intake. Most vegetables had a contribution of less than 7% of zinc (with exception of amaranth that had 15.9%) to the recommended daily intake. The study shows that the contribution of manganese from these vegetables is more than 20% of the recommended daily intakes. The highest contribution to the recommended daily intake of manganese is found in pumkin leaves which contribute up to 92.5%.

CONCLUSION

Results obtained in this study compare favourably with findings of other researchers elsewhere. Generally, the levels of copper, manganese and zinc obtained in all vegetables do not pose any health hazard but the study has helped to show that vegetables from Kariakoo market serve as good dietary sources for essential trace metals. Indeed results from this study shows that mineral deficiency would not occur in people consuming these vegetables. Furthermore, the study has established the levels of very toxic metals *i.e* lead and cadmium content in representative vegetables sold at the Kariakoo market in Dar es Salaam. This information is useful for consumers and policy makers.

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