Determination of copper, iron and lead levels in selected vegetables obtained from the three main markets, in Minna, North Central Nigeria

Article · January 2013

DOI: 10.5897/AJFS12.103

4 authors:

Jimoh Tijani Oladejo
Federal University of Technology Minna

Muhammed Ndamitso
Federal University of Technology Minna

Abdullahi Sobola
Rhodes University

Bankole Mercy Temitope
Federal University of Technology Minna

African Journal of Food Science Vol. 6(23) pp. 554-559, 15 December, 2012
Available online at http://www.academicjournals.org/AJFS
DOI: 10.5897/AJFS12.103
ISSN 1996-0794 ©2012 Academic Journals

Full Length Research Paper

Determination of copper, iron and lead levels in selected vegetables obtained from the three main markets, in Minna, North Central Nigeria

Jimoh, T.O*, Ndamitso, M. M., Abdullahi, S. H. and M. T. Bankole

Department of Chemistry, Federal University of Technology, P.M.B. 65, Minna, Nigeria.

Accepted 17 October, 2012

The levels of Cu, Fe and Pb in six selected vegetables in three Minna main markets were determined using Perkin Elmer Analyst 200 atomic absorption spectrophotometer (AAS). The results revealed that average concentrations of Cu, Fe, Pb detected ranged from 24 to 28, 320 to 2140 and 20 to 100 µg/g for Bosso market; 18 to 34, 260 to 720 and 20 to 20 µg/g for Tunga market, and 26 to 34, 260 to 1940 and 20 to 100 µg/g for Central Area market, respectively. The concentrations of the metals were compared with those reported for similar vegetables from other parts of the world and were found to be higher. The high values might be attributed to the combination of factors including the use of untreated water, bad practice in post harvesting handling of the vegetables products with disregard to the food safety guidelines. The physical market environments in these locations surrounded by a heavy urban pollutant deposition might have exacerbated contamination levels of these vegetable samples. The daily intakes of Cu and Pb through these vegetables were also calculated and were found to be above the recommended tolerance levels proposed by FAO, WHO/EU and FAO/WHO. The concentration of Cu, Fe and Pb contents obtained showed that vegetable samples from these markets could put the consumers of these vegetables at health risk, since the levels were above safety baseline contents for human consumption.

Key words: Atomic absorption spectrometry, copper, iron, lead, vegetables, Minna.

INTRODUCTION

Vegetables as reported by IARC (2003) are essential sources of a wide range of vital micronutrients and are usually consumed in relatively small amounts as side-dish or relish with the staple foods. Although a few of them are of global importance, many more are still used as condiments locally, in the regions of their natural occurrence while some are traded in small quantities and used in ethnic restaurants. Several researchers observed that consumption of vegetables could prevent a number of chronic non-communicable diseases such as cardiovascular diseases, kidney, nervous as well as bone diseases and could contribute substantially to protein, mineral, vitamins, fibre and other nutrients which are usually in short supply in daily diets (Mosha and Gaga, 1999; Mepba et al., 2002; IARC, 2003; WHO, 2003; Robertson et al., 2004; Fasuyi, 2006). Adeleke and Abiodun (2010) opined that most vegetables consumed in Nigeria are planted in rural areas and transported to the urban areas for human consumption. The recent trend indicated that there is an increasing awareness on the nutritive value of vegetables in preference to meat (Fasuyi, 2006). Vegetables are now recognized to have some medicinal properties due to antioxidant and antimicrobial action. Also, many of them have been documented to possess anti diabetic, anti inflammatory and anti hypertensive potentials (Okeno et al., 2003; Orech et al., 2005; Smith and Eyzaguirre, 2007). Despite

*Corresponding author. E-mail: jimohishola8@gmail.com. Tel: +2348057344464.

these essential benefits derived from consuming vegetables, most available literature established that when taken as food, vegetables might cause metabolic disturbance if they contain more than the permissible limits of heavy metals. Recently, heavy metal pollution in the environment has increasingly gathered a global interest. In this respect, contamination of vegetables with heavy metals has always been considered a critical challenge among scientific community (Radwan and Salama, 2006). Heavy metal contamination may occur due to irrigation with contaminated water, the addition of chemical fertilizers and metal-based pesticides, industrial emissions, harvesting process, storage and/or sale. These metals, due to their cumulative behaviour and toxicity have potential hazardous effects not only on plants but also on human health (Onianwa et al., 2001; Konofal et al., 2004; Kocak et al., 2005; Audu and Lawal, 2005). For instance, Pb toxicity causes reduction in the haemoglobin synthesis, disturbance in the functioning of kidney, joints, reproductive and cardiovascular systems and chronic damage to the central and peripheral nervous systems (Ogwuegbu and Muhanga, 2005). The high concentration of Fe in vegetable may increase the nutritional health of the people in an area (Fiona et al., 2010) but was also reported to increase the risk of colon cancer (Lund et al., 2001). In addition, studies have proved that apart from having the macronutrients necessary for good nutrition status, Fe has profound effect on the immune system of an individual thus reducing the prevalence and severity of infections and cutting short the infection-malnutrition cycle (FAO, 2004). Cu does occur naturally in vegetables as an essential trace element needed for good health, but could be toxic when its concentration exceeds limits of safe exposure. A large number of symptoms/ailments comprising anaemia, depressed growth, dermatitis, dwarfism, electrolyte-imbalance, gastro-intestinal and neurological disorders, lethargy and nausea has been associated in humans with copper deficiency as well as toxicity due to excessive intake (Akan et al., 2009; Anita et al., 2010).

During the last decades, the increasing demand of the safety level of most vegetables have stimulated research regarding the risk associated with their consumption as a result of contamination by pesticides, heavy metals and/or toxins (Sridhar et al., 2000; Cobb, 2000; Nwoko and Egunjobi, 2002; Fakayode and Owalabi, 2003; D'Mello, 2003; Okoronkwo et al., 2005, Intawongse and Dean, 2006). Heavy metals determination in vegetables is therefore important. Consequently, monitoring programmes for residues and contaminants contribute to improving food safety.

The objectives of this study were to estimate the levels of iron, copper and lead in the selected vegetables sold in selected markets within Minna metropolis in order to provide a baseline data on these metals in the dried vegetables and to establish their daily intake through their consumption.

MATERIALS AND METHODS

Description of the sampling area

The sampling area chosen in this research was Minna, a city in West Central Nigeria. It is the capital of Niger State, one of Nigeria's 36 states. It is also the headquarters of Chanchaga Local Government Area. The town is located on the latitude 9.617°N and longitude 6.5500°E with an average elevation of 299 meters and a population of 291905 people.

Sample collection

Six dried vegetables samples of *Kerstingiella geocarpa, Citrullus lanatus, Brachystegia eurycoma, Adansonia digitata l, Hibiscus esculentus l and Detariium microcapum* were purchased from three markets namely: Tunga, Bosso and Mobil within Minna metropolis. They were then packaged into labeled paper bags and transported to the laboratory awaiting analysis. Sampling was done at least three times from each market for each vegetable.

Sample preparation

The samples were washed with deionized water to remove debris and sand and later air-dried for 24 h. They were oven dried to a consistent weight at a temperature of 105°C. The dried samples were crushed in a mortar and the resulting powders were sieved using 400 µm sieve.

Digestion for heavy metals determination

A 0.5 g of oven-dried, ground and sieved sample was weighed into acid-washed porcelain crucibles and ashed in a muffle furnace for four hours at 500°C. The crucible were removed from the furnace and cooled in a desiccator. 10 ml of 6 M HCl was added to each, covered and heated on a steam bath for 15 min. Another 1 ml of HNO_3 was added and evaporated to dryness by continuous heating for one hour to dehydrate silica and completely digest organic compounds. Finally, 5 ml of 6 M HCl and 10 ml of water were added and the mixtures heated on a steam bath to complete digestion. The mixtures were cooled, filtered and diluted to 100 cm^3 with de-ionized distilled water. The filtrates were then transferred into sample bottles and kept for the analysis of heavy metals. All samples were analysed in duplicates.

Elemental analysis of samples

Copper (Cu), iron (Fe) and lead (Pb) levels were determined on each final solution using atomic absorption spectrophotometer Perkin Elmer Analyst 200.

Daily intake estimate of Cu, Fe and Pb

The daily intake (µg/g/day) was calculated based on these pieces of information;

1) The adult weight is 50 kg and the vegetable intake per day is 20 g.
2) The children weight is 10 kg and the vegetable intake is 15 g.

$$\text{The daily intake } (\mu g/g/day) = \text{metal conc. in vegetable} \times \frac{\text{weight of vegetable}}{\text{Weight of body}}$$

Table 1. Iron, copper and lead content of each vegetable obtained from Bosso market in microgram per gram (µg/g).

Tissue	Fe (µg/g)	Cu (µg/g)	Pb (µg/g)
A	32.0±0.02	24±0.13	10.0±0.07
B	44.0±0.34	26±1.12	ND
C	38.0±1.25	26±0.67	20±1.19
D	21.4±2.31	28±1.27	20±0.58
E	46.0±0.01	28±0.32	ND
F	11.4±6.73	24±1.35	ND
Mean	32.13±1.78	26.00 ±0.81	16.67±0.61
Range	11.4 – 46.0	24 - 28	10 – 20
FAO/WHO limit	0.3 µg/g	0.1 µg/g	0.1 µg/g

A, *Kerstingiella geocarpa*; B, *Citrullus lanatus*; C, *Brachystegia eurycoma*; D, *Adansonia digitata* l.; E, *Hibiscus esculentus* l.; F, *Detariium microcapum*; ND, not detected.

Table 2. Iron, copper, and lead content of each vegetable obtained from Tunga market in microgram per gram (µg/g).

Tissue	Fe (µg/g)	Cu (µg/g)	Pb (µg/g)
A	72.0±1.16	30±0.03	ND
B	34.0±0.30	34±0.08	ND
C	26.0±1.19	18±0.06	ND
D	58.0±2.45	24±1.02	ND
E	38.0±0.01	28±0.02	ND
F	59.0±6.02	39±1.07	20±0.36
Mean	47.83±1.41	28.83±0.38	20±0.36
Range	26 - 72	18 – 39	0 – 20
FAO/WHO limit	0.3 µg/g	0.1 µg/g	0.1 µg/g

A, *Kerstingiella geocarpa*; B, *Citrullus lanatus*; C, *Brachystegia eurycoma*; D, *Adansonia digitata* l.; E, *Hibiscus esculentus* l.; F, *Detariium microcapum*; ND, not detected.

RESULTS

In the Table 1, the lowest Fe level (11.4±6.73 µg/g) was found in sample F (*D. microcapum*) and the highest concentration (46.0±0.01 µg/g) was found in sample E (*H. esculentus l.*). Other samples had values within the range of 21.4±2.31 to 44.0±0.34 µg/g. The concentration of Cu in the investigated samples ranged from 24±0.13 to 28±1.27 µg/g while the level of Pb ranged from 10.0±0.07 to 20±1.19 µg/g. In Table 2, the Fe, Cu and Pb concentrations were similar to those in Table 1, ranging generally from 26 to 72; 18 to 39 and 0 to 20 µg/g, respectively. The Fe contents were at least twice the Cu and Pb contents of the samples. From Table 3, the minimum concentration of Fe (5.6±0.04 µg/g) was found in sample F while the maximum level (50.0±1.34 µg/g) was found in sample C. The Cu contents of both samples F and C follow the same trend as that of Fe. The Pb level in sample A ranged from 6 to 20 µg/g as shown in Table 3.

DISCUSSION

Heavy metal concentrations varied among different vegetables as indicated in Tables 1, 2 and 3. Among the investigated vegetables, samples collected from Tunga market had the highest level of Fe (which ranged from 26 to 72 µg/g) followed by samples purchased from Bosso market with concentration ranging between 11.4 to 46.0 µg/g while Mobil market recorded the least amount of Fe. The observed range of Fe concentration recorded was higher than the range (1.3 to 3.7 µg/g) reported by Sridhar et al. (2000) for lady's finger grown in waste water irrigated areas of Hyderabad, Andhra Pradesh. The result obtained was however, in agreement with Radwan and Salama (2006) who reported that leafy vegetables likely accumulate iron at higher levels compared to other metals. The concentration of Cu was low (39 µg/g; maximum) in all the vegetables from all the markets (Tables 1, 2 and 3) as compared to Cu concentration of 201.75 µg/g recorded by Liu et al. (2004) in tomato collected from waste water irrigated area of Zhengzhou city, China due to atmospheric deposition. Samples A, C and D had relatively high Pb contents (10.0±0.07, 20.0±1.19, 20.0 ±0.58 µg/g) while samples B, E and F had no detectable amounts of Pb. Also, most samples obtained from Tunga market did not contain detectable lead except sample F whose lead content was 20.00±0.36 µg/g. Lead was detected in most of the vegetables purchased from Mobil market except sample

Table 3. Iron, Copper, and Lead level of each vegetable obtained from Mobil market in microgram per gram (µg/g)

Tissue	Fe (µg/g)	Cu (µg/g)	Pb (µg/g)
A	28.0±0.09	26±1.85	ND
B	26.0±1.44	27±0.09	20±0.04
C	50.0±1.34	30±0.80	20±0.08
D	19.4±2.45	26±1.27	10.0±0.05
E	8.2±0.06	34±0.02	20±1.50
F	5.6±0.04	26±0.01	6.0±2.20
Mean	22.87±0.93	28.17±0.55	15.20±0.77
Range	5.6 - 28	26 -34	6 – 20
FAO/WHO limit	0.3 µg/g	0.1 µg/g	0.1 µg/g

A, *Kerstingiella geocarpa*; B, *Citrullus lanatus*; C, *Brachystegia eurycoma*; D, *Adansonia digitata* l.; E, *Hibiscus esculentus* l.; F, *Detariium microcapum*; ND, not detected.

Table 4. Daily intake of heavy metals by urban population of Bosso market through consumption of vegetables.

Tissue	Fe (µg/g)		Cu (µg/g)		Pb (µg/g)	
	Adults	Children	Adults	Children	Adults	Children
A	12.8	48	9.60	36.00	4.00	15.0
B	17.6	66	10.4	39.00	ND	ND
C	15.2	57	10.4	39.00	8.00	30.0
D	8.56	32.1	11.4	42.00	8.00	30.0
E	18.4	69	11.4	42.00	ND	ND
F	4.56	17.1	9.60	36.00	ND	ND
Mean	12.85	48.2	10.47	39.00	6.67	25.0
Safe limit	425 µg/g		0.2 µg/g		0.3 µg/g	

A, *Kerstingiella geocarpa*; B, *Citrullus lanatus*; C, *Brachystegia eurycoma*; D, *Adansonia digitata* l.; E, *Hibiscus esculentus* l.; F, *Detariium microcapum*; ND, not detected.

A. Among the selected samples, the highest concentrations of Pb were noticed in *C. lanatus*, *B. eurycoma, H. esculentus l, A. digitata*, with the least concentration in *D. microcapum* whose respective values were (20.0±0.04, 20.0±0.08, 20.0±1.50, 10.0±0.05, 6.0±2.20 µg/g) obtained from Mobil market. The high concentration of Pb in virtually most of the vegetables purchased from Mobil market compared to Bosso and Tunga markets could be due to the high concentration of traffic which results in vehicular emission of this metal (Devkota and Schmidt, 2000; Frost and Ketchum, 2000; Parveen et al., 2003). This agreed with what were earlier reported by Abou-Arab and Abou-Donia (2000) and Kocak et al. (2005) that heavy metals contents of vegetables vary depending on environmental pollution levels. It was also believed that a combination of factors including the use of polluted water, bad practice in post harvesting handling of the vegetable products with disregard to the food safety guidelines, and the heavy urban pollution depositions around these markets may have exacerbated contamination levels. It was generally observed that the respective concentrations of the heavy metals in all the samples were higher than the FAO/WHO guideline values of 0.3 µg/g Fe, 0.1 µg/g Pb and 0.1 µg/g Cu.

Mohammed and Ahmed (2006) revealed that exposure of consumers and related health risks are usually expressed as provisional tolerable daily intake (PTDI), a reference value established by Joint FAO/WHO (1999). If for instance, the average diet per person per day of all the vegetables was 20 g for adults and 15 g for children, respectively, Tables 4, 5 and 6 show that the respective maximum concentration of Fe^{2+} (12.85 µg/g, adults and 48.2.µg/g, children), Cu^{2+} (10.47µg/g, adults and 39.0 µg/g, children) and Pb^{2+} (6.67 µg/g, adults and 25.0 µg/g, children) were contributed by samples from Bosso market. The respective contributions to the daily intakes of vegetables from Tunga market were Fe^{2+} (19.13 µg/g, adults and 71.75.µg/g, children), Cu^{2+} (11.53 µg/g, adults and 43.25 µg/g, children) and Pb^{2+} (8.00 µg/g, adults and 30.0 µg/g, children) while those samples from Mobil market were Fe^{2+} (9.15 µg/g, adults and 34.3 µg/g, children), Cu^{2+} (11.27 µg/g, adults and 42.25 µg/g, children) and Pb^{2+} (6.00 µg/g, adults and 22.80 µg/g,

Table 5. Daily intake of heavy metals by urban population of Tunga market through consumption of vegetables.

Tissue	Fe (µg/g)		Cu (µg/g)		Pb (µg/g)	
	Adults	children	Adults	Children	Adults	Children
A	28.8	108	12.0	45	ND	ND
B	13.6	51	13.6	51	ND	ND
C	10.4	39	7.2	27	ND	ND
D	23.2	87	9.6	36	ND	ND
E	15.2	57	11.2	42	ND	ND
F	23.6	88.5	15.6	58.5	8.00	30.0
Mean	19.13	71.75	11.53	43.25	8.00	30.0
Safe limit	425 µg/g		0.2 µg/g		0.3 µg/g	

A, *Kerstingiella geocarpa*; B, *Citrullus lanatus*; C, *Brachystegia eurycoma*; D, *Adansonia digitata* l.; E, *Hibiscus esculentus* l.; F, *Detariium microcapum*; ND, not detected.

Table 6. Daily intake of heavy metals by urban population of Mobil market through consumption of vegetables.

Tissue	Fe (µg/g)		Cu (µg/g)		Pb (µg/g)	
	Adults	Children	Adults	Children	Adults	Children
A	11.2	42.0	10.4	39.0	ND	ND
B	10.4	39.0	10.8	40.5	8.00	30.0
C	20.0	75.0	12.0	45.0	8.00	30.0
D	7.76	29.1	10.4	39.0	4.00	15.0
E	3.28	12.3	13.6	51.0	8.00	30.0
F	2.24	8.4	10.4	39.0	2.40	9.0
Mean	9.15	34.3	11.27	42.25	6.00	22.80
Safe limit	425 µg/g		0.2 µg/g		0.3 µg/g	

A, *Kerstingiella geocarpa*; B, *Citrullus lanatus*; C, *Brachystegia eurycoma*; D, *Adansonia digitata* l.; E, *Hibiscus esculentus* l.; F, *Detariium microcapum*; ND, not detected.

children). The results show that except for Fe, all the contribution made by the samples to the daily intake of Cu and Pb exceeded the recommended daily intake. These values were also found to be too higher than those reported by Mohammed and Ahmed (2006) and PTDI level given by Joint FAO/WHO Expert Committee on Food Additives (1999).

Conclusion

The results obtained in this study show that most of the vegetable samples evaluated from the three markets were contaminated by both lead and copper. Hence, consumption of these samples could pose a health hazard when taken for along time. Therefore, concerted effort by the government and other concerned bodies are needed to educate the producers of these vegetables on the health implications of these metals and the need for the use of good agricultural practices required for the production of these essential commodities.

ACKNOWLEDGEMENT

The authors wish to express sincere appreciation to the Science and Technology Education Post-Basic (STEP-B), Federal University of Technology, Minna, Nigeria for sponsoring the research.

REFERENCES

Abou-Arab AA, Abou-Donia MA (2000). Heavy metals in Egyptian spices and medicinal plants and the effect of processing on their levels. J. Agric. Food Chem. 48:2300.

Adeleke RO, Abiodun OA (2010). Chemical Composition of Three Traditional Vegetables in Nigeria. Pak. J. Nutr. 9(9):858-860.

Akan JC, Abdulrahman FI, Ogugbuaja VO, Ayodele JT (2009). Heavy Metals and Anion Levels in Some Samples of Vegetable Grown Within the Vicinity of Challawa Industrial Area, Kano State, Nigeria. Am. J. Appl. Sci. 6(3):534-542.

Anita S, Rajesh KS, Madhoolika A, Fiona MM (2010). Risk assessment of heavy metals toxicity through contaminated vegetable from waste water irrigated area of Varanasi, India. Int. Soc. Trop. Ecol. 51(2s):375-387.

Audu AA, Lawal AO (2005). Variation in metal contents of plants in vegetable garden sites in Kano metropolis. J. Appl. Sci. Environ. 10:105-109.

Devkota B, Schmidt GH (2000). Accumulation of heavy metals in food plants and grasshoppers from the Taigetos Mountains, Greece. J. Agric. Ecosyst. Environ. 78:85-91.

D'Mello JPF (2003). Food safety: Contaminants and toxins. Cambridge: CABI Publishing.

Fakayode SO, Olu-Owolabi BL (2003). Heavy metal contamination of roadside topsoil in Oshogbo, Nigeria. Its relationship to traffic density and proximity to highways. J. Environ. Geol. 44(2):150-157.

FAO (2004). Biological diversity is fundamental to food and agricultural production. Biodiversity for food security, World Foods Day 16th October 2004.

Fasuyi OA (2006). Nutritional potentials of some tropical vegetable leaf meals: Chemical characterization and functional properties. Afr. J. Biotechnol. 5:49-53.

Fiona MM, Singh A, Sharma RK, Agrawal M (2010). Risk assessment of heavy metal toxicity through contaminated vegetables from waste water irrigated area of Varanasi, India. Trop. Ecol. 51(2S):375-387.

Frost HL, Ketchum LH (2000). Trace metal concentration in durum wheat from application of sewage sludge and commercial fertilizer. Adv. Environ. Res. 4:347-355.

IARC (2003). Fruit and vegetables. International Agency for Research on Cancer, Lyon. pp. 22-23.

Intawongse M, Dean JR (2006). Uptake of heavy metals by vegetable plants grown on contaminated soil and their bioavailability in the human gastrointestinal tract. Food Addit. Contam. 23:36-48.

Joint FAO/WHO Expert Committee on Food Additives (1999). Summary and conclusions. 53rd Meeting, Rome, June 1–10.

Kocak S, Tokusoglu O, Aycan S (2005). Some heavy metal and trace essential element detection in canned vegetable foodstuffs by differential pulse polarography (DPP), Electronic J. Environ. Agric. Food Chem. 4:871-878.

Konofal E, Lecendreux M, Arnulf I, Mouren MC (2004). Iron deficiency in children with attention-deficit/hyperactivity disorder. Arch. Pediatr. Adolesc. Med. 158:1113-1115.

Lund EK, Fairweather-Tait SJ, Wharf SG, Johnson IT (2001). Chronic exposure to high levels of dietary iron fortification increases lipid peroxidation in the mucosa of the rat large intestine. J. Nutr. 131:2928-2931.

Mepba HD, Eboh L, Banigo DEB (2002). Effects of processing treatments on the nutritive composition and consumer acceptance of some Nigerian edible leafy vegetables.107:12-26.

Mohammed AA, Ahmed KS (2006). Market basket survey for some heavy metals in Egyptian fruits and vegetables. J. Food Chem. Toxicol. 44:1273-1278.

Mosha TC, Gaga HE (1999). Nutritive value and effect of blanching on trypsin and chymotrypsin inhibitor activities of selected leafy vegetables. Plant Foods Hum. Nutr. 54:271-283.

Nwoko COE, Egunjobi JK (2002). Lead contamination of soil and vegetation in an abandoned battery factory site in Ibadan. Nig. J. Sustain Agric. Environ. 4(1):91-96.

Ogwuegbu MOC, Muhanga W (2005). *Citrullus lanatus*. *In:* Grubben G.J.H, Schippers R.R. (2004). Cucurbitaceae. *In : Légumes africains indigènes : présentation des espèces cultivées.* Wuerzburg, Allemagne : Margraf Publishers/CTA, pp. 113-182.

Okeno JA, Chebet DK, Mathenge PW (2003). Status of indigenous vegetables in Kenya. Acta Hortic, 621:9.

Onianwa PC, Adeyemo AO, Idowu OE, Ogabiela EE (2001). Copper and zinc contents of Nigerian foods and estimates of the adult dietary intakes. J. Food Chem. 72:89-95.

Orech FO, Akenga T, Ochora J, Friis H, Aagaard H (2005). Potential toxicity of some traditional leafy vegetables consumed in Nyang'oma Division, Western Kenya. Afr. J. Food Agric. Nutr. Dev. 5(1):234-235.

Radwan MA, Salama AK (2006). Market based survey for some heavy metals in Egyptian fruits and vegetables. Food Chem.Toxicol. 44:1273-1278.

Robertson A, Tirado C, Lobstein T, Jermini M, Knai C, Jensen J (2004). Food and health in Europe: a new basis for action. European Series, No. 96. WHO Regional Publications, Copenhagen. 12:32-34.

Smith FI, Eyzaguirre P (2007). African leafy vegetables: Their role in the world health organization's global fruit and vegetables initiatives. Afr. J. Food Agric. Nutr. Dev. 7:1-9.

Sridhar MK, Olawuyi JF, Adogame LA, Okekearu CO, Linda A (2000). Lead in the Nigerian environment: Problems and Prospects, in 11th Annual International Conference on Heavy Metals in the Environment. University of Michigan, School of Public Health. 19:12-13.

Parveen Z, Khuhro MI, Rafiq N (2003). Market basket survey for lead, cadmium, copper, chromium, nickel and zinc in fruits and vegetables. Bull. Environ. Contam. Toxicol. 71:1260-1264.

WHO (2003). Diet, Nutrition and the prevention of chronic diseases. Report of a Joint WHO/FAO Expert consultation. WHO Technical Report Series 916. Geneva.