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Assessment of Heavy Metal Concentration of Common Non-Leafy Vegetables Sourced from Major Markets across Lokoja, Kogi State, Nigeria

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Abstract

Vegetables are rich sources of vitamins, minerals, and fibres. They also have beneficial anti-oxidative effects. Ingestion of vegetables containing heavy metals is one of the main routes through which these elements enter the human body and when the metals accumulate over time, they could cause an array of diseases. In this study, we investigated the concentrations of Copper (Cu), Zinc (Zn), Lead (Pb), Cadmium (Cd), Chromium (Cr), Manganese (Mn), and Iron (Fe) in four vegetables *Cucumis sativa*, *Caucus Clarita*, *Solanus lycopersicum* and *Abelmoschus esculentus* that are frequently consumed by the inhabitants of lokoja, a city in the north central region of Nigeria. The vegetables were sourced from each of four different markets (International market, Old market, Adankolo market, and Mami market) and atomic absorption spectrophotometer was used to estimate the levels of the metals in them. The mean concentration for each heavy metal in the samples was calculated and compared with the permissible levels set by the World Health Organisation rganisation (W.H.O). All the metals were detected in the vegetables (except Chromium) and their levels were found to be well below the World Health Organization (W.H.O) recommended limits for metals in vegetables. The low concentration of these metals in all the vegetables is an indication that these plants contribute less toxic effects of metals. This was important result as human health is directly affected by the consumption of vegetables containing heavy metals.

Keywords: Heavy Metals, Market, Vegetables, Atomic Absorption Spectrophotometer

Introduction

Non-leafy vegetables are popular around the world. In recent years their consumption is increasing rapidly, particularly among the urban community. These vegetables are valuable sources of vitamins A and C, iron, calcium, folic acid, and dietary fibre. Metals in Non-leafy vegetables pose a direct threat to human health. In addition to absorbing these elements from contaminated soil, plants and vegetables can also be contaminated via waste water used for irrigating them as well as deposits on different parts of the plant such as root and stems that are exposed to the air from polluted environment. (Funtua *et al*., 2008). The rate of absorption absorption by heavy metals depend on the nature of vegetables and some of them have a higher potential to accumulate heavy metals than others. (Akan *et al*., 2009). In Nigeria and other parts of West Africa, Non-leafy vegetables are common in the preparation of soups among different cultures. (Ladipo and Doherty, 2011). Consumption of vegetables that are contaminated by an unsafe concentration of these heavy metals for a long period of time may lead to the disruption of many biological and biochemical processes in humans. (Jarup, 2003). Occurrence of uncontrolled urban sewage farming is a common site in African cities which exposes consumers of such produce to poisoning from heavy metals (Ebong et al., 2008). Open dumps are a source of various environmental and health hazards. The decomposition of organic materials produces methane, which may cause explosions and produce leachates, which causes surface and ground water pollution. It ruins the aesthetic quality of the land (Oyelola et al., 2009).

Pollution is defined in various ways. It is considered as the release of unwanted substances to the environment by man in quantities that damage either the health or the resource itself (Tripati et al., 2007).

Heavy metals are generally referred to as those metals which possess a specific density of more than 5 g/cm^3 and adversely affect the environment and living organisms (Järup, 2003). Heavy metal contamination of the food items is one of the most important aspects of food quality assurance (Khan et al., 2008). Human activities such as industrial production, mining, agriculture and transportation, release high amounts of heavy metals into surface/ ground water, soils and ultimately to the biosphere. Heavy metals enter the human body mainly through two routes which are inhalation and ingestion. Ingestion is the main route of exposure to these elements in human population (Türkdogan et al., 2003). Environmental pollution by heavy metals has been on the rise in recent times. Cement manufacture is one of such activities that contribute to environmental pollution through the emission of gasses and cement dust (El-Abssawy A, Hassanien MA et al., 1995).

Materials and Methods

Materials

Atomic Absorption Spectrophotometer (AAS), Electrical blender, 2mm nylon sieve, 50ml platinum crucibles, What man No1 filter paper

Methods

Sample collection

The vegetables used in this study were okro (*Abelmoschus esculentus*), Tomato (*Solanum lycopersicum*), Carrot (*Caucus carota*), Cucumber (*Cucumis sativa*) (figure 1). These vegetables were obtained from each of 4 different markets- International Market (M1), Old market (M2), Adankolo Market (M3), Mami Market (M4) in lokoja, kogi state, Nigeria. The samples were collected in polyethene bags for transport to the laboratory.

Sample Preparation

The vegetables were washed with distilled water and deionized water, sun dried and ground into uniform powder using electrical blender. The samples were then sieved through a 2 mm nylon sieve and 0.5 g of each of the dried vegetables samples was weighed into 50 ml platinum crucibles. The crucibles were then placed in a muffle furnace operating at 500oC and the samples were allowed to ash for 3 hours. The ashed samples in each crucible were then digested by mixing them with 5 ml of 10% (v/v) nitric acid (HNO3), 5 ml of 20% (v/v) perchloric Acid (HClO4) and 2 ml of 10% (v/v) sulphuric acid (H2SO4) at 100oC on a hot plate for two hours in a fume cupboard. The resulting solution was left to cool for twelve hours and then transferred to 250 ml flasks, after which they were diluted with 88 ml of distilled water to make it up to the 100 ml mark. The content of each flask was filtered with Whatman No. 1 filter paper into appropriate sample bottles and then stored for subsequent analysis.

Analytical Procedure

The concentration of elements was carried out using an Atomic Absorption Spectrophotometer (AAS Solar 969 Unicam Series) (Schuhmacher et al., 1993).

Data Analysis

All data were expressed as Mean ± SEM and statistical differences between means were determined by one- way ANOVA followed by Duncans post hoc test for multiple comparison tests using SPSS version 20. Values were considered significant at P< 0.05.

Results and Discussion

Table 1: Concentration of Copper (Cu) (mg/kg) in non-leafy vegetables sourced from Different Markets.

	S. lycopersicum	*A. esculentus*	*C. sativa*	*C. carota*
M1	0.94±0.06b	0.84±0.04a	1.09±0.02b	0.83±0.03a
M2	0.88±0.08a	0.76±0.07a	0.71±0.05a	0.74±0.03a
M3	0.66±0.02a	0.86±0.04a	0.71±0.04a	0.72±0.02a
M4	0.72±0.04a	0.82±0.02a	0.76±0.03a	0.84±0.03a

WHO Safe Limit **73.00**

Data are presented as mean ± SD. Data analysed by one-way ANOVA followed by Duncan post-hoc test for multiple comparison. Values with same alphabets are not significantly different when compared down the column at (p<0.05). M1 = International Market, M2 = Old Market, M3 = Adankolo Market, M4 = Mami Market.

Table 2: Concentration of Lead (Pb) (mg/kg) in non-leafy Vegetables Sourced from Different Market.

	S. lycopersicum	*A. esculentus*	*C. sativa*	*C. carota*
M1	0.09±0.01a	1.07±0.07a	0.11±0.01a	0.09±0.07a
M2	0.08±0.01a	0.07±0.01b	0.43±0.029a	0.12±0.02a
M3	ND	ND	0.09±0.02a	0.06±0.01a
M4	ND	ND	ND	ND

WHO Safe Limit **0.30**

Data are presented as mean ± SD. Data analysed by one-way ANOVA followed by Duncan post-hoc test for multiple comparison. Values with same alphabets are not significantly different when compared down the column at (p<0.05). M1 = International Market, M2 = Old Market, M3 = Adankolo Market, M4 = Mami Market.

Table 3: Concentration of Zinc (Zn) (mg/kg) in non-leafy Vegetables Sourced from Different Markets.

	S. lycopersicum	*A. esculentus*	*C. sativa*	*C. carota*
M1	0.43±0.02a	0.54±0.01a	0.53±0.02a	0.38±0.03a
M2	0.51±0.02a	0.44±0.01a	0.42±0.02a	0.52±0.02a
M3	0.52±0.01a	0.56±0.02a	0.42±0.02a	0.54±0.02a
M4	0.46±0.03a	0.54±0.02a	0.61±0.03b	0.46±0.02a

WHO Safe Limit **100.00**

Data are presented as mean ± SD. Data analysed by one-way ANOVA followed by Duncan post-hoc test for multiple comparison. Values with same alphabets are not significantly different when compared down the column at ($p<0.05$). M1 = International Market, M2 = Old Market, M3 = Adankolo Market, M4 = Mami Market

Table 4: Concentration of chromium (Cr) (mg/kg) in non-leafy vegetables Sourced from Different Markets. Chromium was not detected in any of the vegetables from the different markets.

	S. lycopersicum	*A. esculentus*	*C. sativa*	*C. carota*
M1	ND	ND	ND	ND
M2	ND	ND	ND	ND
M3	ND	ND	ND	ND
M4	ND	ND	ND	ND

WHO Safe Limit **30.00**

Data are presented as mean ± SD. Data analysed by one-way ANOVA followed by Duncan post-hoc test for multiple comparison. Values with same alphabets are not significantly different when compared down the column at ($p<0.05$). M1 = International Market, M2 = Old Market, M3 = Adankolo Market, M4 = Mami Market, ND=Not Detected

Table 5: Concentration of Cadmium (Cd) (mg/kg) in non-leafy Vegetables Sourced from Different Markets.

	S. lycopersicum	*A. esculentus*	*C. sativa*	*C. carota*
M1	0.17±0.02a	0.14±0.02a	0.19±0.01a	0.16±0.02a
M2	0.18±0.01a	0.17±0.02a	0.13±0.02b	0.13±0.02a
M3	ND	ND	ND	ND
M4	ND	ND	ND	ND

WHO Safe Limit **0.2**

Data are presented as mean ± SD. Data analysed by one-way ANOVA followed by Duncan post-hoc test for multiple comparison. Values with same alphabets are not significantly different when compared down the column at ($p<0.05$). M1 = International Market, M2 = Old Market, M3 = Adankolo Market, M4 = Mami Market.

Figure 6: Concentration of Manganese (Mn) (mg/kg) in non-leafy Vegetables Sourced from Different Markets.

	S. lycopersicum	*A. esculentus*	*C. sativa*	*C. carota*
M1	0.46±0.03a	0.83±0.02b	0.57±0.03a	0.62±0.01a
M2	0.56±0.02a	0.65±0.02b	0.55±0.04a	0.64±0.02a
M3	0.84±0.04b	0.75±0.01b	0.63±0.03a	0.62±0.02a
M4	0.58±0.02a	0.43±0.02a	0.65±0.01a	0.71±0.02a

WHO Safe Limit **500.00**

Data are presented as mean ± SD. Data analysed by one-way ANOVA followed by Duncan post-hoc test for multiple comparison. Values with same alphabets are not significantly different when compared down the column at ($p<0.05$). M1 = International Market, M2 = Old Market, M3 = Adankolo Market, M4 = Mami Market.

Table 7: Concentration of Iron (Fe) (mg/kg) in non-leafy Vegetables Sourced from Different Markets.

	S. lycopersicum	*A. esculentus*	*C. sativa*	*C. carota*
M1	0.48±0.02a	0.38±0.01a	0.45±0.03a	0.48±0.02a
M2	0.26±0.03a	0.33±0.01a	0.45±0.02a	0.44±0.02a
M3	0.55±0.03b	0.51±0.02b	0.37±0.03a	0.42±0.03a
M4	0.48±0.02a	0.31±0.05a	0.44±0.01a	0.61±0.02b

WHO Safe Limit **425.00**

Data are presented as mean ± SD. Data analysed by one-way ANOVA followed by Duncan post-hoc test for multiple comparison. Values with same alphabets are not significantly different when compared down the column at ($p<0.05$). M1 = International Market, M2 = Old Market, M3 = Adankolo Market, M4 = Mami Market.

Copper was present in all the vegetables sourced from the different markets (M1-M4) in concentrations that are within the safe limit as recommended by WHO. However, there were variations in the Cu concentrations across the vegetables and also within the same vegetable sourced from different markets. For *Solanus lycopersicum*, the highest Cu concentration was found in those sourced from M1 and M2 (0.94 mg/ kg and 0.88mg/kg) followed by M4 (0.72 mg/ kg), and Tomato from M3 had the least Cu concentration (0.66 mg/ kg). For *Abelmoschus lycopersicum*, the highest Cu concentration is sourced from M3 (0.86mg/kg) and the lowest is from M2 (0.76mg/kg). *Abelmoschus esculentus* sourced from M1, and M4 had values of 0.84 and 0.82 respectively. The Cu concentration of *Cucumis sativa* sourced from M1 had the highest (1.09mg/kg) value followed by M4 (0.76mg/kg). *Cucumis sativa* sourced from M3 (0.76mg/kg) and M4 (0.76mg/kg) had the least Cu Concentration. For *Caucus carota*, the highest Cu Concentration were sourced from M4 (0.84mg/kg), followed by M1 (0.83mg/kg) and M2 (0.74mg/kg). M3 had the least Cu Concentration (0.72mg/kg).

The Cu Concentration of all vegetables sourced from each market was also compared. The Cu Concentration of the vegetables were in the following order M1 (*Cucumis sativa>Solanus lycopersicum>Abelmoschus esculentus>Caucus carota*). For M2 (*Solanus lycopersicum>Abelmoschus esculentus>Caucus carota>Cucumis sativa*). For M3 (*Abelmoschus esculentus>Caucus carota>Cucumis sativa>Solanus lycopersicum*). For M4 (*Caucus* *carota*>*Abelmoschus esculentus*>*Cucumis sativa*>*Solanus lycopersicum*) (Table 1).

Lead was detected in all the vegetables sourced from M1 and M2. In M3, it was detected only in *Cucumis sativa* and *Caucus carota*. But are all within the WHO' s safe limit. It was not detected in vegetable sourced from M4. The highest Pb lead Concentration was detected in M2 (0.43mg/kg) while M3 had the least Pb Concentration (0.06mg/kg) (Table 2).

This study revealed that Pb was not detected in all the Vegetables sourced from M4 (Mami Market). This may be attributed to the less pollution from automobiles and anthropogenic effect. Other less likely sources of Pb are pollutants in irrigation water or farm soil on which the vegetables were grown (Qui et al., 2000). The Concentration of Pb In Vegetables sourced from M1 (International Market), M2 (Old Market), and some in M3 (Adankolo Market), is however not enough to cause acute toxicity as they fall within WHO recommended permissible limit. The Pb concentration of all vegetables sourced from each market was compared. The Pb concentration of the vegetables were in the following order: M1 (*Abelmoschus esculentus*>*Cucumis sativa*> *Solanus lycopersicum*>*Caucus carota*), M2 (Cucumis sativa>*Caucus carota*>*Solanus lycopersicum*>*Abelmoschus esculentus*), M3 (*Cucumis sativa*>*Caucus carota*) (Table 2).

Table 3 shows the Zinc Concentration of the vegetables sourced from different markets (M1-M4). Zn was present in all the vegetables in safe concentrations. However, like Cu, there were variations in the Zn concentrations across the vegetables and also within the same vegetables sourced from different markets. For *Solanus lycopersicum*, the highest Zn concentration was found in those sourced from M3 (0.52mg/kg) followed by M2 (0.51mg/kg), M4 (0.46mg/kg), and M1 had the least Pb concentration (0.43mg/kg). For *Abelmoschus esculentus*, the Zn concentration ranged between 0.56mg/kg (M3) and 0.44mg/kg (M3). The Zn concentration of *Cucumis sativa* sourced from M4 had the highest Zn concentration (0.61mgkg) followed by M1 (0.53mg/kg). M2 and M3 had the least Zn concentration (0.42mg/kg). For *Caucus carota*, the Zn concentration ranged between 0.54mg/kg (M3) and 0.38mg/kg (M1). The Zn concentration of all the vegetables from each market were also compared. The Zn concentration of the vegetables were in the following order for M1 (*Abelmoschus esculentus*>*Cucumis sativa*>*Solanus lycopersicum*>Caucus carota). Vegetables sourced from M2 it was (*Caucus carota*>*Solanus lycopersicum*>*Abelmoschus esculentus*>*Cucumis sativa*). For M3 it was (*Abelmoschus esculentus*> *Caucus carota*>*Solanus lycopersicum*>*Cucumis sativa*). For M4 it was (*Cucumis sativa*>*Abelmoschus esculentus*> *Caucus carota*>*Solanus lycopersicum.*

Chromium was not detected in any of the vegetables from the different markets (Table 4)

Table 5 shows the cadmium concentration of the vegetables. Cadmium was detected only in the vegetables sourced from M1 and M2 but is in concentrations that are within the WHO' s safe limit. For *Solanus lycopersicum* sourced from M1 and M2, the Cd concentration detected was 0.17mgkg and 0.18mg/kg, while *Abelmoschus esculentus* sourced from M1 and M2, the Cd concentration detected was 0.14mg/kg and 0.17mg/kg. For *Cucumis sativa*, the Cd concentration detected from M1 and M2 was 0.19mg/kg and 0.13mg/kg, while for Caucus carota, the Cd concentration detected from M1 and M2 was 0.16mg/kg and 0.13mg/kg respectively.

The Cd concentration of all vegetables from each market were also compared. For vegetables sourced from M1, the Cd concentration was in the following order (*Cucumis sativa*>*Solanus lycopersicum*>*Caucus carota*>*Abelmoschus esculentus),* while from vegetables sourced from M2, the Cd concentration was (*Solanus lycopersicum*>*Abelmoschus esculentus*>*Cucumis sativa* >*Caucus carota*).

This study revealed that Cd was not detected in all the vegetables sourced from M3 and M4 (Adankolo Market and Miami Market). This may be attributed to the less pollution in the farm soil to which the vegetables were grown or other less likely sources such as pollutants in irrigation water.

Manganese was present in all the vegetables sourced from the different markets (M1-M4) in concentrations that are within the safe limit as recommended by WHO. This study revealed that Mn was detected in all the vegetables sourced from M1-M4. This may be attributed to the farm soil to which the vegetables were grown.

The highest Mn concentration for *Cucumis sativa* and *Caucus sativa* were sourced from M4 (0.65mg/kg and 0.71mg/kg) respectively. The least Mn concentration for *Solanus lycopersicum* were sourced from M1 (0.46mg/kg), M2 and M4 have values of (0.56mg/kg) and (0.58mg/kg), while the least Mn concentration for *Abelmoschus esculentus* were sourced from M4 (0.43mg/kg), M2 and M3 have values of (0.65mg/kg) and (0.75mg/kg). The least Mn concentration for *Caucus carota* were sourced from M1and M3 each having values of (0.62mg/kg), M2 have value of (0.64mg/kg) (Table 6).

The Mn- concentration of all the vegetables from each market were compared. The Mn-concentration of the vegetables were in the following order for vegetables sourced from M1 (*Abelmoschus esculentus*>*Caucus carota*>*Cucumis sativa*>*Solanus lycopersicum*), for M2 (*Abelmoschus esculentus*>*Caucus carota*>*Solanus lycopersicum*>*Cucumis sativa*), for M3 (*Solanus lycopersicum*>*Abelmoschus esculentus*>*Cucumis sativa*>*Caucus carota*), and for M4 (*Caucus carota*>*Cucumis sativa*>*Solanus lycopersicum*>*Abelmoschus esculentus*).

Iron was also present in all the vegetables sourced from the different market (M1-M4) in safe concentrations. This study revealed that Fe was detected in all the vegetables sourced from M1-M4. This may be attributed to the presence of Fe in the ferric form in the farm soil. The highest Fe concentration for *Solanus lycopersicum* were sourced from M3 (0.55mg/kg) followed by M1 and M4 having a value of (0.48mg./kg) respectively, *Solanus lycopersicum* sourced from M2 have the least Fe concentration (0.26mg/kg). The highest Fe concentration for *Abelmoschus esculentus* were sourced from M3 (0.51mg/kg) followed by M1 (0.38mg/kg), M2 and M4 have values of (0.33mg/kg) and (0.31mg/kg) respectively. For *Cucumis sativa*, the highest Fe concentration were sourced from M1 and M2 having values of (0.45mg/kg) followed by M4 (0.44mg/kg). M3 had the least concentration of Fe (0.37mg/kg). For *Caucus carota*, the concentration of Fe ranges from 0.61mg/kg (M4) to 0.42mg/kg (M3), M2 and M1 have value of (0.48mg/kg) and (0.44mg/kg) respectively (Table 7).

Conclusion

The results showed that all the vegetables obtained from the different markets contained varying amount of the metals with exception of Cd which recorded zero concentrations Levels. The metals detected were found to be within the safe limits as recommended by the FAO/WHO. This observation is important as human health is directly affected by consumption of vegetables. Thus, the need for a continuous monitoring of heavy metal levels in vegetables cannot be over emphasized as these are the main sources of food for humans in many parts of the world

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