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Assessment of Heavy Metal Levels of Green Leafy Vegetables Sourced from Different Markets in Lokoja, Kogi State, Nigeria

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Abstract

care rich sources of vitamins, minerals, and fibers, and 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 five vegetables (*Vernonia amygdalina*, *Ocimum gratissimum*, *Talinum triangulare*, *Telfairia occidentalis*, and *Solanum marcrocarpon*) 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 five different markets and Atomic absorption spectrophotometry 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 Organization (WHO). All the metals were detected in the vegetables (except Chromium) and their levels were found to be well below the WHO 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 an important result as human health is directly affected by the consumption of vegetables.

Keywords: Vegetables, heavy metals, markets, Atomic absorption spectrophotometry.

1.0 Introduction

Green leafy vegetables are popular around the world. In recent years their consumption is increasing gradually, particularly among the urban community. These vegetables are valuable sources of vitamins A and C, iron, calcium, folic acid, and dietary fibre.

Vegetables also contain both essential and toxic elements over a wide range of concentrations. Metals in vegetables pose a direct threat to human health. Plants and vegetables take up elements by absorbing them from contaminated soils and waste water used for irrigating them as well as from deposits on different parts of the plants exposed to the air from polluted environment (Funtua *et al.*, 2008). Absorption capacity of heavy metals depends upon the nature of vegetables and some of them have a greater potential to accumulate higher concentrations of heavy metals than others (Akan *et al.*, 2009).

The use of green leafy vegetables for the preparation of soups cuts across different cultures in Nigeria and other parts of West Africa (Ladipo and Doherty, 2011). However, intake of heavy metal contaminated vegetables may pose a risk to the human health. Prolonged human consumption of unsafe concentrations of heavy metals in food stuffs may lead to the disruption of many biological and biochemical processes in the human body (WHO, 1992; Jarup, 2003). Regular monitoring of these metals in vegetables and in other food materials is essential for preventing excessive buildup of the metals in the food chain. This study was carried out to determine the levels of Copper (Cu), Zinc (Zn), Lead (Pb), Cadmium (Cd), Chromium (Cr), Manganese (Mn) and Iron (Fe) in some selected vegetables that are consumed regularly by inhabitants of Lokoja metropolis.

2.0 Materials and Methods

2.1. Sample Collection

The vegetables used in this study were Bitter leaf (*Vernonia amygdalina*), Basil leaf (*Ocimum gratissimum*), water leaf (*Talinum triangulare*), fluted pumpkin (*Telfairia occidentalis*) and Eggplant (*Solanum marcrocarpon)* (Figure 1). These vegetables were obtained from each of 5 different Markets- International Market (M1), Old Market (M2), Mami Market (M3), Kpata Market (M4) and Lokongoma Market (M5) in Lokoja, Kogi State, Nigeria. The samples were collected in polyethene bags for transport to the laboratory.

Figure 1: Pictures showing the leaves of [A] *Vernonia amygdalina* [B] *Ocimum gratissimum* [C] *Talinum triangulare* [D] *Telfairia occidentalis* [E] *Solanum marcrocarpon*

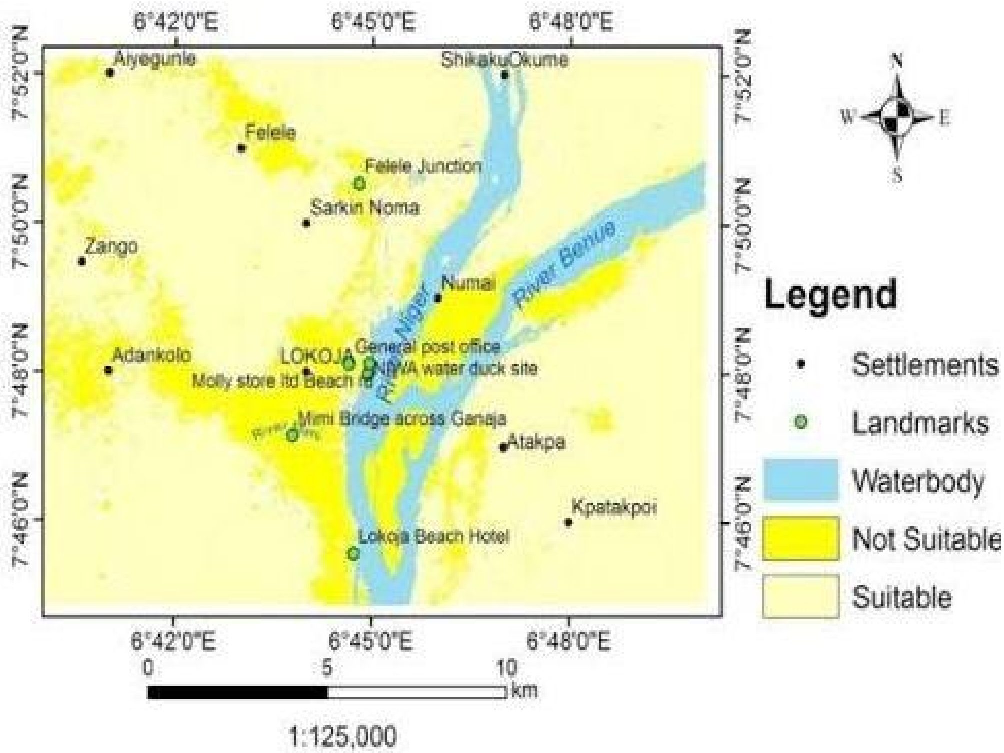

Figure 2: Map of the Studied Area

2.2. 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 fruit samples was weighed into 50 ml platinum crucibles. The crucibles were then placed in a muffle furnace operating at 500 ^{o}C 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 (HNO_3), 5 ml of 20% (v/v) perchloric Acid ($HClO_4$) and 2 ml of 10% (v/v) sulphuric acid (H_2SO_4) at 100^{o}C 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.

2.3. Analytical Procedure

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

2.4 Data Analysis

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

3.0 Results and Discussion

3.1. Copper (Cu)

Copper was present in all the vegetables sourced from the different markets (M1-M5) 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 *V. amygdalina*, the highest Cu concentration was found in those sourced from M1 and M4 (0.65 mg/ kg) followed by M5 (0.57 mg/ kg), M2 (0.43 mg/ kg) and *V. amygdalina* from M3 had the least Cu concentration (0.42 mg/ kg). For *O. gratissimum*, the Cu concentration ranged between 0.51 mg/ kg (M1) and 0.34 mg/ kg (M5). In between this, *O. gratissimum* sourced from M2, M4 and M3 had values of 0.48, 0.45 and 0.35 mg/ kg respectively. The Cu concentration of *T. triangulare* sourced from M4 had the highest (0.73 mg/ kg) value followed by M1 (0.51 mg/ kg) and M3 (0.41 mg/ kg). *T. triangulare* sourced from M2 and M5 had the least Cu concentration (0.40 mg/ kg). For *T. occidentalis*, the Cu concentration ranged between 0.81 mg/ kg (M1) and 0.31 mg/ kg (M3). In decreasing order of Cu- concentration, *T. occidentalis* sourced from M5, M4 and M2 had values of 0.75, 0.45 and 0.43 mg/ kg respectively. *S. marcrocarpon* sourced from M1 had the highest Cu concentration (0.56mg/ kg) followed by those from M2 and M4 (0.45 mg/ kg), M3 (0.42 mg/ kg) and *S. marcrocarpon* sourced from M5 had the least Cu concentration (0.41 mg/ kg) (Table 1).

The Cu- concentrations of all the vegetables from each market were also compared. The Cu- concentration of the vegetables were in the following order for M1 (*T. occidentalis>V. amygdalina> S. marcrocarpon> T. triangulare> O. gratissimum).* For M2, it was *O. gratissimum> T. occidentalis> S. marcrocarpon> V. amygdalina> T. triangulare.* For M3, (*S. marcrocarpon and V. amygdalina > T. triangulare> O. gratissimum> T. occidentalis*) For M4, (*T. triangulare> V. amygdalina> O. gratissimum and S. marcrocarpon>.T. occidentalis*) and For M5, (*T. occidentalis> V. amygdalina >S. marcrocarpon > T. triangulare O. gratissimum*).

Table 1: Concentration of Copper (Cu) (mg/ kg) in Green Leafy Vegetables Sourced from Different Markets

Vegetables	M1	M2	M3	M4	M5
V. amygdalina	0.65 ±0.06^{bB}	0.43±0.33^{aA}	0.42±0.06^{aB}	0.65±0.04^{bB}	0.57±0.13^{bB}
O. gratissimum	0.51 ±0.10^{bA}	0.48±0.04^{aB}	0.35 ±0.06^{aAB}	0.45 ±0.04^{bA}	0.34 ±0.04^{bA}
T. triangulare	0.51 ±0.06^{bA}	0.40 ±0.03^{aA}	0.41 ±0.05^{aB}	0.73 ±0.05^{bC}	0.40 ±0.06^{aA}
T. occidentalis	0.84 ±0.07^{dC}	0.45 ±0.02^{bAB}	0.31 ±0.02^{aA}	0.43 ±0.05^{bA}	0.75 ±0.08^{cB}
S. marcrocarpon	0.56 ±0.10^{bAB}	0.45 ±0.04^{aAB}	0.42 ±0.05^{aB}	0.45 ±0.04^{aA}	0.41 ±0.05^{aA}
WHO Safe Limit	**73.00**				

Data are presented as mean ± SD. Data was analysed by one- way ANOVA followed by Duncan post- hoc test for multiple comparisons, (n=5), M1= International Market, M2= Old Market, M3= Mami Market, M4= Kpata Market, M5= Lokongoma Market

Mean values having different lower case alphabets as superscripts are considered significant (p< 0.05) across the rows. Mean values having different upper case alphabets as superscripts are considered significant (p< 0.05) across the columns.

Cu is an essential trace metal, vitally important for both physical and mental development in human, usually found in many food types particularly vegetarian foods such as nuts, seeds and grains. It is important for energy production in cells and is required for women's fertility in relation to estrogen metabolism amongst others. This study did not reveal any risk of acute Cu toxicity and any possibility of chronic toxicity. Although Cu accumulates easily in the body hence, chronic low level intakes have damaging effects on human beings and other animals, since there is no good mechanism for their elimination. Conditions associated with increased copper body burden are arthritis, fatigue, insomnia, scoliosis, osteoporosis, heart disease, cancer, migraine, heart seizures, gum diseases, skin and hair problems. Reported also are mental and emotional disorders such as depression mood swings, fears, anxiety, panic attacks, violence and memory loss (Schuhmacher *et al.*, 1993; Conti and Carcea, 2000).

3.2. Zinc (Zn)

Table 2 shows the Zinc concentration of the vegetables sourced from different markets (M1-M5). 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 vegetable sourced from different markets. For *V. amygdalina*, the highest Zn concentration was found in those sourced from M3 (0.41 mg/ kg) followed by M2 (0.37 mg/ kg), M4 (0.34 mg/ kg), M5 (0.34 mg/ kg) and *V. amygdalina* from M1 had the least Zn concentration (0.31 mg/ kg). For *O. gratissimum*, the Zn concentration ranged between 0.35 mg/ kg (M3) and 0.19 mg/ kg (M1). In between this, *O. gratissimum* sourced from M4, M5 and M2 had values of 0.26, 0.25 and 0.23 mg/ kg Zn concentration respectively. The Zn concentration of *T. triangulare* sourced from M3 had the highest (0.41 mg/ kg) value followed by M2 (0.40 mg/ kg) and M1 (0.36 mg/ kg). *T. triangulare* sourced from M4 and M5 had the least Zn concentration (0.35 mg/ kg). For *T. occidentalis*, the Zn concentration ranged between 0.43 mg/ kg (M2) and 0.26 mg/ kg (M1). In decreasing order of Zn- concentration, *T. occidentalis* sourced from M3, M5 and M4 had values of 0.35, 0.55 and 0.33 mg/ kg respectively. *S. marcrocarpon* sourced from M2 had the highest Zn concentration (0.39 mg/ kg) followed by M4 (0.39 mg/ kg), M1 (0.29 mg/ kg) and *S. marcrocarpon* sourced from M3 and M5 had the least Zn concentration (0.25 mg/ kg).

The Zn- concentrations of all the vegetables from each market were also compared. The Zn- concentration of the vegetables were in the following order for M1 (*T. triangulare*> *V. amygdalina*> *S. marcrocarpon*> *T. occidentalis*> *O. gratissimum).* For the vegetables from M2, it was *T. occidentalis*> *T. triangulare*> *S. marcrocarpon*> *V. amygdalina*> *O. gratissimum*. For M3 it was *V. amygdalina*> *T. triangulare*> *O. gratissimum*> *T. triangulare*> *S. marcrocarpon*. For M4 it was *S. marcrocarpon*> *T. triangulare*> *V. amygdalina*> *T. occidentalis*> *O. gratissimum* while for M5 it was in this order- *T. occidentalis*> *T. triangulare*> *V. amygdalina* >*S. marcrocarpon* > *O. gratissimum.*

Zn is the least toxic and an essential element in human diet as it is required to maintain the functioning of the immune system. Zn deficiency in the diet may be highly detrimental to human health than too much Zn in the diet. The recommended dietary allowance for Zn is 15 mg/day for men and 12 mg/day for women according to Agency for Toxic Substances and Disease Registry (ATSDR), but high concentration of Zn in vegetables may cause vomiting, renal damage, cramps etc.

The contents of Zn in this study were within the permissible level of 100.00 mg/kg by the FAO/WHO in vegetables. The concentrations are not enough acute toxic but long term consumption of low concentrations of Zn could lead to chronic toxicity. Chronic elevated intake of Zn could also result to impaired Cu uptake in humans. This implies that some of the effects of Zn may be secondary to impaired copper utilization (Codex Alimentarius Commission, 2011).

Table 2: Concentration of Zinc (Zn) (mg/ kg) in Green Leafy Vegetables Sourced from Different Markets

Vegetables	M1	M2	M3	M4	M5
V. amygdalina	0.31 ±0.04^{aC}	0.37±0.03^{bcB}	0.41±0.03^{cC}	0.34±0.02^{abBC}	0.33±0.02^{abB}
O. gratissimum	0.19 ±0.02^{aA}	0.23±0.03^{bA}	0.35 ±0.04^{cB}	0.26 ±0.04^{bA}	0.25 ±0.03^{bA}
T. triangulare	0.36 ±0.05^{abD}	0.40 ±0.30^{bcBC}	0.41 ±0.04^{cC}	0.35 ±0.04^{aBC}	0.35 ±0.03^{Ab}
T. occidentalis	0.26 ±0.04^{aB}	0.43 ±0.03^{cC}	0.35 ±0.02^{bB}	0.33 ±0.03^{bB}	0.35 ±0.04^{bB}
S. marcrocarpon	0.29 ±0.02^{bBC}	0.39 ±0.25^{cBC}	0.25 ±0.03^{aA}	0.38 ±0.03^{cC}	0.25 ±0.05^{aA}
WHO Safe Limit	**100.00**				

Data are presented as mean ± SD. Data was analysed by one- way ANOVA followed by Duncan post- hoc test for multiple comparisons, (n=5), M1= International Market, M2= Old Market, M3= Mami Market, M4= Kpata Market, M5= Lokongoma Market

Mean values having different lower case alphabets as superscripts are considered significant ($p< 0.05$) across the rows. Mean values having different upper case alphabets as superscripts are considered significant ($p< 0.05$) across the columns.

3.3. Lead (Pb)

Lead was detected only in the vegetables sourced from M1 but in concentrations that are within the WHO's safe limit. The highest Pb concentration was detected in *T. occidentalis* (0.08 mg/ kg) while *O. gratissimum* and *T. triangulare* had the least Pb concentration (0.05 *V. amygdalina* and *S. marcrocarpon* both had Pb concentration of 0.08 mg/ kg (Table 3).

This study revealed that Pb was only detected in the vegetables sourced from M1 (International market). The detection of Pb in the vegetables from this market may be attributed to the pollution from automobiles due to the proximity of the market to a highway. 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 the vegetables is however not enough to cause acute toxicity as they fall within WHO recommended permissible limit. Chronic consumption of low concentration of Pb in edible plants poses a health risk to consumers. The absorption of Pb is influenced by food intake with higher rates of absorption after fasting than when it is ingested with a meal. Age is also another factor that influences Pb absorption. The absorption rate in infants is five times greater than that of adults. After Pb absorption and distribution in blood, it is initially distributed to soft tissues throughout the body. Eventually, bone accumulates Pb over much of the human life span and may serve as an endogenous source of Pb. The half-life for Pb in blood and other soft tissues is about 28-36 days, but it is much longer in the various bone compartments. The percentage retention of Pb in body stores is higher in children than adults. Lead that is not distributed is mainly excreted through the kidney (WHO, 2000). Lead is a classical chronic or cumulative poison. In humans, Pb is known to cause a lot effects in the body system depending on the level and duration of exposure (Idakwoji, 2016). Many of the effects observed in humans ranges from hematological, neurological, behavioral; renal to cardiovascular effects. Due to the rapid rate of absorption in children, they are often more vulnerable to the effects of lead than adults. Pb has been implicated in the impairment of neurobehavioral functioning in children and this is thought to be the most critical effect (Mottet, 1980).

Table 3: Concentration of Lead (Pb) (mg/ kg) in Green Leafy Vegetables Sourced from Different Markets

Vegetables	M1	M2	M3	M4	M5
V. amygdalina	0.06 ± 0.06^{B}	ND	ND	ND	ND
O. gratissimum	0.05 ± 0.02^{A}	ND	ND	ND	ND
T. triangulare	0.05 ± 0.01^{A}	ND	ND	ND	ND
T. occidentalis	0.08 ± 0.02^{C}	ND	ND	ND	ND
S. marcrocarpon	0.06 ± 0.01^{B}	ND	ND	ND	ND
WHO Safe Limit	**0.30**				

Data are presented as mean ± SD. Data was analysed by one- way ANOVA followed by Duncan post- hoc test for multiple comparisons, (n=5), ND= Not detected, M1= International Market, M2= Old Market, M3= Mami Market, M4= Kpata Market, M5= Lokongoma Market

Mean values having different upper case alphabets as superscripts are considered significant ($p < 0.05$) across the columns.

3.4. Chromium (Cr)

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

Table 4: Concentration of Chromium (Cr) (mg/ kg) in Green Leafy Vegetables Sourced from Different Markets

Vegetables	M1	M2	M3	M4	M5
V. amygdalina	ND	ND	ND	ND	ND
O. gratissimum	ND	ND	ND	ND	ND
T. triangulare	ND	ND	ND	ND	ND
T. occidentalis	ND	ND	ND	ND	ND
S. marcrocarpon	ND	ND	ND	ND	ND
WHO Safe Limit	**30.00**				

ND= Not detected, M1= International Market, M2= Old Market, M3= Mami Market, M4= Kpata Market, M5= Lokongoma Market

3.5. Cadmium (Cd)

Table 5 shows the Cadmium concentration of the vegetables. Cadmium was detected only in the vegetables sourced from M1 and M4 but in concentrations that are within the WHO's safe limit. For *V. amygdalina* sourced from M1 and M4, the Cd concentration detected was 0.15 mg/ kg each while for *O. gratissimum,* it was 0.11 and 0.15 mg/ kg for M1 and M4 respectively. *T. triangulare* sourced from M1 had Cd concentration of 0.11 mg/kg and 0.15 mg/kg for *T. triangulare* sourced from M4. For *T. occidentalis* sourced from M1 and M4, the Cd concentration detected was 0.14 and 0.15 mg/ kg respectively while for *S. marcrocarpon,* it was 0.16 and 0.15 mg/ kg for M1 and M4 respectively.

The Cd concentrations of all the vegetables from each market were also compared. For vegetables sourced from M1, The Cd- concentration was in the following order - *S. marcrocarpon> V. amygdalina> T. triangulare > T. occidentalis> O. gratissimum)* while for vegetables sourced from M4, it was *amygdalina> O. gratissimum> T. occidentalis, T. triangulare and S. marcrocarpon.*

The estimated concentrations of Cd in the vegetables were below the WHO permissible limit. With that, there is no fear of acute toxicity when the vegetables are consumed. However, in the long term, toxicity might however, arise from chronic accumulation of Cd if these vegetables are continuously consumed. The kidneys and liver store about 50 to 85% of Cd in the body with 30 to 60% being stored in the kidneys (Anyakora *et al.*, 2011). Cd has no known biological functions in the body but it interferes with some essential function of Zn, thereby inhibiting enzyme reactions and nutrient utilization. It catalyzes oxidation reactions, generating free-radical tissue damage (WHO, 1992). Zinc, an essential trace element is more toxic in salt form than in elemental form. Its ingestion causes gastrointestinal toxicity, pulmonary toxicity, nephrotoxicity and neurotoxicity (Conti, 2000; Codex Alimentarius Commission, 2003). Though there has been paucity of information on reported carcinogenicity by oral route, most classifications are based on occupational exposure to cadmium with inhalation as the primary route of exposure.

Table 5: Concentration of Cadmium (Cd) (mg/ kg) in Green Leafy Vegetables Sourced from Different Markets

Vegetables	M1	M2	M3	M4	M5
V. amygdalina	0.15 ±0.06^{C}	ND	ND	0.15±0.04^{B}	ND
O. gratissimum	0.11 ±0.10^{A}	ND	ND	0.15 ±0.04^{B}	ND
T. triangulare	0.11 ±0.06^{A}	ND	ND	0.13 ±0.05^{A}	ND
T. occidentalis	0.14 ±0.07^{B}	ND	ND	0.13 ±0.05^{A}	ND
S. marcrocarpon	0.16 ±0.10^{C}	ND	ND	0.15 ±0.04^{B}	ND
WHO Safe Limit	**0.2**				

Data are presented as mean ± SD. Data was analysed by one- way ANOVA followed by Duncan post- hoc test for multiple comparisons, (n=5), ND= Not detected, M1= International Market, M2= Old Market, M3= Mami Market, M4= Kpata Market, M5= Lokongoma Market

Mean values having different upper case alphabets as superscripts are considered significant ($p< 0.05$) across the columns.

3.6. Manganese (Mn)

Manganese was present in all the vegetables sourced from the different markets (M1-M5) in concentrations that are within the safe limit as recommended by WHO. There were variations in Mn concentration among the vegetables and also among the same vegetable obtained from the different markets. The highest Mn concentration was found in *V. amygdalina* sourced from M3 (0.50 mg/ kg) followed by M5 (0.47 mg/ kg), M2 (0.39 mg/ kg), M4 (0.38 mg/ kg) and *V. amygdalina* from M1 had the least Mn concentration (0.37 mg/ kg). For *O. gratissimum*, the Mn concentration ranged between 0.89 mg/ kg (M1) and 0.31 mg/ kg (M5). In between this, *O. gratissimum* sourced from M2, M3 and M4 had values of 0.48, 0.45 and 0.33 mg/ kg Mn concentration respectively. The Mn concentration of *T. triangulare* sourced from M1 had the highest (0.52 mg/ kg) followed by M2 (0.44 mg/ kg), M5 (0.40 mg/ kg) and M4 (0.38 mg/ kg). *T. triangulare* sourced from M3 had the least Mn concentration of 0.37 mg/ kg. For *T. occidentalis*, the Mn concentration ranged between 0.65 mg/ kg (M1/M2) and 0.34 mg/ kg (M4). Mn- concentration of *T. occidentalis* sourced from M3 and M5 had values of 0.56 and 0.39 mg/ kg respectively. *S. marcrocarpon* sourced from M4 had the highest Mn concentration (0.37 mg/ kg) followed by M3 (0.33 mg/ kg), M2 (0.29 mg/ kg) and *S. marcrocarpon* sourced from M5 had the least Mn concentration (0.24 mg/ kg).

The Mn- concentrations of all the vegetables from each market were compared. The Mn- concentration of the vegetables were in the following order for M1 (*O. gratissimum*> *T. occidentalis*> *T. triangulare*> *V. amygdalina*> *S. marcrocarpon*>*)*. For the vegetables sourced from M2, it was *T. occidentalis* > *O. gratissimum*> *T. triangulare*> *V. amygdalina* > *S. marcrocarpon.* For vegetables sourced from M3 the Mn- concentration was in the following order- *T. occidentalis*> *V. amygdalina*> *O. gratissimum*> *T. triangulare*> *S. marcrocarpon*. For M4 it was *T. triangulare/ V. amygdalina*> *S. marcrocarpon*> *T. occidentalis*> *O. gratissimum* while for M5 it was in this order- *V. amygdalina*> *T. triangulare*> *T. occidentalis*> *O. gratissimum* > *S. marcrocarpon.*

Manganese is an essential plant mineral nutrient, playing a key role in several physiological processes, particularly photosynthesis. Manganese deficiency is a widespread problem, most often occurring in sandy soils, organic soils with a pH above 6 and heavily weathered, tropical soils. Mn is readily transported from root to shoot through the transpiration stream, but not readily remobilized through phloem to other organs after reaching the leaves (Loneragan, 1988).

Table 6: Concentration of Manganese (Mn) (mg/ kg) in Green Leafy Vegetables Sourced from Different Markets

Vegetables	M1	M2	M3	M4	M5
V. amygdalina	0.37 ±0.03^{aB}	0.39±0.04^{aB}	0.50±0.05^{bC}	0.38±0.04^{Aa}	0.47±0.09^{bC}
O. gratissimum	0.89 ±0.04^{cE}	0.48±0.05^{bC}	0.45 ±0.30^{bB}	0.33 ±0.04^{Aa}	0.31 ±0.04^{aA}
T. triangulare	0.52 ±0.02^{cC}	0.44 ±0.34^{bBC}	0.37 ±0.05^{aA}	0.38 ±0.04^{aA}	0.40 ±0.04^{abBC}
T. occidentalis	0.65 ±0.06^{cD}	0.65 ±0.05^{cD}	0.56 ±0.40^{bC}	0.34 ±0.04^{Aa}	0.39 ±0.04^{aB}
S. marcrocarpon	0.19 ±0.03^{aA}	0.29 ±0.04^{bA}	0.33 ±0.03^{cA}	0.37 ±0.05^{Da}	0.24 ±0.03^{abA}
WHO Safe Limit	**500.00**				

Data are presented as mean ± SD. Data was analysed by one- way ANOVA followed by Duncan post- hoc test for multiple comparisons, (n=5), M1= International Market, M2= Old Market, M3= Mami Market, M4= Kpata Market, M5= Lokongoma Market

Mean values having different lower case alphabets as superscripts are considered significant (p< 0.05) across the rows. Mean values having different upper case alphabets as superscripts are considered significant (p< 0.05) across the columns.

3.7. Iron (Fe)

Iron was also present in all the vegetables sourced from the different markets (M1-M5) in safe concentrations. The highest Fe concentration was found in *V. amygdalina* sourced from M4 (0.32 mg/ kg) followed by M3 and M5 (0.30 mg/ kg), M1 (0.31 mg/ kg) and *V. amygdalina* from M2 had the least Fe concentration (0.27 mg/ kg). For *O. gratissimum,* the Fe concentration ranged between 0.35 mg/ kg (M1) to 0.28 mg/ kg (M2). In between this, *O. gratissimum* sourced from M3, M4 and M5 had values of 0.33, 0.31 and 0.31 mg/ kg Fe concentration respectively. The Fe concentration of *T. triangulare* sourced from M5 had the highest (0.34 mg/ kg) followed by M3 (0.31 mg/ kg), M2 and M1 (0.28 mg/ kg). *T. triangulare* sourced from M1 had the least Fe concentration (0.24 mg/ kg). For *T. occidentalis,* the Fe concentration ranged between 0.34 mg/ kg (M1) and 0.26 mg/ kg (M3). In decreasing order of Fe- concentration, *T. occidentalis* sourced from M5 and M1/ M2 had values of 0.31 and 0.27 mg/ kg respectively. *S. marcrocarpon* sourced from M4 had the highest Fe concentration (0.34 mg/ kg) followed by M5 (0.33 mg/ kg), M3 (0.31 mg/ kg) and *T. triangulare* sourced from M1 and M2 had Zn concentration of 0.28 and 0.27 mg/ kg respectively.

The Fe- concentrations of all the vegetables from each market were also compared. The Fe- concentration of the vegetables were in the following order for M1 (*O. gratissimum> V. amygdalina> S. marcrocarpon> T. occidentalis> T. triangulare*). For the vegetables from M2, it was *O. gratissimum> T. occidentalis> T. triangulare/ S. marcrocarpon/ V. amygdalina.* For M3 it was *O. gratissimum> S. marcrocarpon/ T. triangulare> V. amygdalina> T. occidentalis.* For M4 it was *S. marcrocarpon/ T. occidentalis> V. amygdalina > O. gratissimum >T. triangulare* while for M5 it was in this order- *T. triangulare >S. marcrocarpon > O. gratissimum/ T. occidentalis> V. amygdalina.*

Fe is a fundamental component for every single living life form and is important for keeping up cell homeostasis. It is essential for the synthesis of chlorophyll and activates a number of respiratory enzymes in plants. The deficiency of Fe results in severe chlorosis of leaves in plants. High levels of exposure to Fe dust may cause respiratory diseases such as chronic bronchitis and ventilation difficulties. This study revealed the presence of Fe in the vegetables in concentrations that are within the WHO permissible limit, hence there is no fear of acute toxicity.

Table 7: Concentration of Iron (Fe) (mg/ kg) in Green Leafy Vegetables Sourced from Different Markets

Vegetables	M1	M2	M3	M4	M5
V. amygdalina	0.31 ±0.07[aAB]	0.27±0.08[a]	0.30±0.06[a]	0.32±0.07[a]	0.30±0.05[a]
O. gratissimum	0.35 ±0.03[bB]	0.28±0.05[a]	0.33 ±0.07[ab]	0.31 ±0.07[a]	0.31 ±0.03[ab]
T. triangulare	0.24 ±0.04[aA]	0.28±0.03[ab]	0.31 ±0.04[b]	0.28 ±0.05[ab]	0.34 ±0.06[b]
T. occidentalis	0.27 ±0.04[aA]	0.27 ±0.06[a]	0.26 ±0.06[a]	0.34 ±0.03[b]	0.31 ±0.03[ab]
S. marcrocarpon	0.28 ±0.08[aAB]	0.27 ±0.05[a]	0.31 ±0.01[a]	0.34 ±0.03[a]	0.33 ±0.05[a]
WHO Safe Limit	**425.00**				

Data are presented as mean ± SD. Data was analysed by one- way ANOVA followed by Duncan post- hoc test for multiple comparisons, (n=5), M1= International Market, M2= Old Market, M3= Mami Market, M4= Kpata Market, M5= Lokongoma Market

Mean values having different lower case alphabets as superscripts are considered significant ($p< 0.05$) across the rows. Mean values having different upper case alphabets as superscripts are considered significant ($p< 0.05$) across the columns.

4.0 Conclusion

Our 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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