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RESEARCH ARTICLE

Health risk assessment for selected heavy metals in *Telfairia occidentalis* (fluted pumpkin) leaf retailed in markets within Lokoja metropolis

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Abstract

This study investigated the levels of selected heavy metals and their potential health risks to consumers within Lokoja metropolis, Kogi State, Nigeria. Fresh pumpkin (*Telfairia occidentalis*) leaves, obtained from major (International, Old Market, Kpata and Lokongoma) markets within Lokoja, were analyzed for copper (Cu), zinc (Zn), lead (Pb), cadmium (Cd), Nickel (Ni) and manganese (Mn) using standard atomic adsorption spectrophotometer. Daily intake of metals (DIM), target hazard quotient (THQ)/hazard index (HI) and target cancer risk (TCR), were then determined to assess the potential health risks of the metals. Concentrations of Cd (0.18 ± 0.02 and 0.16 ± 0.02 mg/kg), Pb (0.08 ± 0.11 mg/kg and 0.05 ± 0.10 mg/kg) and Zn (1.82 ± 0.04 mg/kg and 1.76 ± 0.01 mg/kg) were significantly highest ($p<0.05$) in vegetable samples from International and Old Markets when compared with Lokonguma and Kpata Markets which were not significantly different ($p>0.05$) from each other. There were insignificant non-carcinogenic risks for the metals except for Cd which could pose risks when the daily ingestion rate is tripled. Target cancer risks were in the increasing order Pb<Cd<Ni<Cu, suggesting moderate cancer risks for Cd and Pb, and high cancer risks Ni and Cu over a life time period of exposure to heavy metal contaminated vegetables within the study location. This study has shown that the heavy metals in *T. occidentalis* poses subantantilly low health risks when consumed moderately except for Cd, Ni and Cu when the daily consumption rate is significantly increased over a life time period. Hence, intensive awareness campaigns are recommended to enlighten farmers/retailers on safer ways of cultivation/handling of green leafy vegetables.

Keywords: Bioaccumulation; Health risk; Heavy metals; *Telfairia occidentalis*.

1. Introduction

Plant is the major sources of food to humans. Most plants derive their energy directly from sunlight using some inorganic compounds. Plants grow very well in mineral rich environments where they synthesize and store their foods in their stems, roots and leaves. Of all the edible parts of plants, the leaves have been exploited by man for food, medical, economic and aesthetic values. One of such edible leafy plant is green leafy vegetable. Currently, green leafy vegetables are the most popular plants consume globally because of their valuable nutrients (Ali *et al.*, 2020). According to Dada *et al*. (2021) leafy vegetables are rich sources of vitamins A, C, K, carotenes, iron, calcium, zinc, potassium folic acid and other antioxidants, which are indispensable in human diets.

Fluted pumpkin (*Telfairia occidentalis*) is one of the most extensively cultivated and commercial green leafy vegetables with wide acceptance in

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many Nigerian communities (Nwosu *et al*., 2012) Scientists and dieticians attributed the wide preference to its ease of cultivation, palatability, affordability, availability and nutritious constituents (Ishiekwene and Dada, 2019). The minerals and vitamins in fluted pumpkin leaves help in blood production, maintenance of strong bones, health skins and as antioxidant (Effiong *et al.*, 2009).

The soil environment where most leafy green vegetables are cultivated and harvested in Nigeria exposes them to contaminations by diverse heavy metals which are abundant in dumpsites containing wastes from agrochemicals wastewater and automobile spent engines. This has continued to generate attention considering the fact that these heavy metals can absorb and accumulate in the vegetable leaves over a period of time. Studies have shown that most edible leafy vegetable sourced from dumpsites, along road sides and swampy areas harbor heavy metals in their leaves. For example, Idakwoji *et al*. (2018) reported the presence of Copper (Cu), Zinc (Zn), Lead (Pb), Cadmium (Cd), Manganese (Mn) and Iron (Fe) in five vegetables (*Vernonia amygdalina*, *Ocimum gratissimum*, *Talinum triangulare*, *Telfairia occidentalis*, and *Solanum marcrocarpon*) cultivated and sold within Lokoja, Kogi State. Similarly, *Telfairia occidentalis* cultivated along roadsides in Calabar, were found to harbor seventeen (17) different heavy metals in their leaves (Okon *et al.*, 2015). In the same vein, heavy metal accumulations in vegetables have been reported from Lagos (Adesuyi *et al.*, 2015; Afolami *et al*., 2010), Yola (Chiroma *et al.*, 2003) and Kano (Akan *et al*., 2009). The potential health risks associated with consumption of these vegetables is worrisome and needs urgent attention globally. Exposure to heavy metals above the permissible limits in food and water has been found to cause an array of tissues and organ toxicity (Jaishankar *et al.*, 2014). Some of the metals, such as the non-essential elements (Pb, Cd and Hg), when they enter the food chain or human body, are non-biodegradable, instead, accumulate and damages tissues and organs even at minute level (Tchounwou *et al.*, 2012; Jaishankar *et al.*, 2014). Considering the detrimental health effects of exposure to vegetables contaminated by heavy metals, it is crucial to frequently examine public health risk associated with short and long-term detrimental effects of metal accumulations in commonly consumed vegetables. Hence, this study was aimed at investigating the levels of some heavy metals and their potential health risk to exposed consumers within Lokoja metropolis, Kogi State, Nigeria.

2. Materials and methods

2.1. Study area

The study location was some major markets in Lokoja, the capital of Kogi State (Figure 1). It is situated at latitude $7^0$45’’N and longitude $6^0$45’’E. Being a confluence town where Rivers Niger and Benue linked each other in Nigeria, it is characterized by wet and dry season with annual rainfall and temperature of between 1016 mm to 1524 mm and 27 ^{0}C, respectively. It has an estimated land area of about 3,180 km^2 with a projected population density rise from 634,000 (2018) to 791,000 in the year 2021 (Anon, 2022). Lokoja is a hub of trade center and well known for lots of agricultural produce including fruits, vegetables, yams, fishes among others, which gave rise to several markets within the metropolis. The well-known markets are namely; International Market, Old Market, Mami Market, Kpata Market and Lokongoma Market.

2.2. Collection of vegetable samples

Fresh leaves of fluted pumpkin (*Telfairia occidentalis*) (Figure 2) were purchased from four (4) Markets, namely; International, Old, Kpata and Lokongoma Markets, within Lokoja, Kogi State, Nigeria. The samples were properly placed in clean back polyethylene bags and transported immediately to the laboratory for analysis

studies were executed to study the toxicity effect of many chemical and non-chemical compounds against immature stages (nymphs) of the cottony cushion scale, *I. purchasi* on citrus leaves, under laboratory conditions at Plant Protection Dept., Faculty of Agriculture, South Valley University, Qena governorate, Egypt.

Figure 1. Map of Nigeria showing Lokoja, the capital of Kogi State.

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Figure 2. Fresh leaf sample of fluted pumpkin (*Telfairia occidentalis*)

2.3. Digestion and determination of heavy metals

The procedure reported earlier (Adedokun *et al.,* 2016) was adopted. Each of the vegetable samples was weighed and 0.5 g was weighed out into a digestion glass beaker containing 10 mL of acidic mixture of $HNO_3/HClO_4$ in ratio 2:1. After thorough manual mixing, the digestion beaker was placed in a fume chamber set at a temperature of 150 °C for 2 h to ensure complete digestion. The solution was cooled, filtered and stored at low temperature for further analysis. A series of blank solutions was prepared for quality control. The filtrate was used to determine the presence of lead (Pb), Cadmium (Cd), Manganese (Mn), Nickel (Ni), Zinc (Zn) and Copper (Cu) using a graphite furnace atomic absorption spectrophotometer (GBS Scientific Equipment Sens AAS 1175, Australia. The concentrations of heavy metals were expressed as mg/kg wet weight.

2.4. Health risk analysis

The potential health risk analysis via consumption of heavy metal contaminated vegetable was determined by calculating the estimated daily intake, non-carcinogenic and target cancer risk according to previous reports (Adedokun *et al.,* 2016; Ogu and Akinnibosun, 2020). The parameters and formula are:

2.4.1. Estimated daily intake

This was done using equation 1.

Daily intake of metal (D_{IM}) = $\frac{Cm \times Cf \times Dv}{Bwt}$ (1)

Where:

Cm: Concentration of heavy metal in vegetable (mg/kg)
Cf: Conversion factor (0.085, from fresh to dry weight)
Dv: Daily intake of vegetable (65 g/kg)
Bwt: Average body weight in kg per individual (65 kg).

2.4.2. Non-carcinogenic risk

The risk that is not associated with cancer was determined by calculating the target hazard quotient and hazard ration or quotient using equations 2 and 3.

Target hazard quotient (THQ) =

$$\frac{EF \times ED \times IR \times CM}{BWA \times ATn \times RfD \times 1000} (2)$$

Where:

EF: Exposure frequency (365 days/year),
ED: Exposure duration (30 years for non-cancer risk as suggested by the USEPA),
IR: Vegetable ingestion rate (about 65g/person/day)
C: Concentration of metal in vegetable (mg/kg);
BWA: Average adult body weight (65 kg)
Atn: Average exposure time for non-carcinogens for 30 years (10,950 days)
RfD: Reference oral dose (given as Cu, Cd, Pb, Zn, Mn, Ni for 0.040, 0.001, 0.004, 0.300, 0.020 and 0.140 mg/kg bodyweight/day respectively) (Ogu and Akkinibosun, 2020).

Hazard Index (HI) $= \sum (THQ\ (Pb + Cd + Cu + Zn + Ni + Mn)$ (3)

Where:

$\sum$: Summation
THQ: Target hazard quotient or hazard ratio

2.4.3. Target cancer risk

The risk of cancer when an individual is exposed to some of the heavy metals such as Pb, Cd, Cu, and Ni was determined using the carcinogenic risk formula shown in equation 4

Carcinogenic risk = $EDI \times CPSo$ (4)

Where:

EDI: Estimated daily intake of each heavy metal (mg/kg/day)
CPSo: Carcinogenic potency slope (mg/kg body weight/day) (given as 0.0085, 0.38, 1.5 and 1.7 for Pb, Cd, Cu and Ni, respectively (USEPA, 2018).

2.5. Data analysis

The mean values obtained by descriptive statistics were presented as means ± standard deviations (SD). ANOVA was used to analysed the results and Duncan's test was used to compare the means with statistical level of significance set at $p<0.05$.

3. Results and discussions

The mean concentration of the six (6) heavy metals analyzed (Table 1) reveled they were detected in all the samples from the four (4) different markets. This is an indication that all the vegetables in the different sampling sites harbor heavy metal in their leaves. This finding is in disagreement with earlier report from Lokoja (Idakwoji *et al.,* 2018), which detected Pb and Cd in *Telfairia occidentalis* leaves from only International Market. The rise in environmental pollution from increase in human, vehicular and waste generations from constructions of roads, agrochemicals/pesticides, auto-mechanics and incinerations must have contributed to widespread heavy metal pollutions of these vegetables during cultivation, harvesting, and or retiling. Hence, the observed differences observed with the previous study. Cadmium (Cd) concentration was significantly highest ($p<0.05$) in vegetable samples from International Market (0.18 ± 0.02 mg/kg) and Old Market (0.16 ± 0.02 mg/kg) when compared with Lokonguma Market (0.01 ± 0.01 mg/kg) and Kpata Market (0.02 ± 0.00 mg/kg) which were not significantly different ($p>0.05$) from each other. A similar trend was observed for the concentrations of Pb and Zn. However, the concentrations of Cu, Mn and Ni were significantly different ($p<0.05$) in each of the four (4) markets. Vegetable samples from Old Market recorded the highest concentration of Cu (1.82 ± 0.06 mg/kg) and Ni (1.15 ± 0.01 mg/kg), while Lokuonguma (0.68 ± 0.22 mg/kg) and Kpata Market (0.19 ± 0.03 mg/kg) recorded least respectively. On the other hand, Mn level was highest and lowest in vegetables from International Market (0.72 ± 0.22 mg/kg) and Lokonguma Market (0.56 ± 0.02 mg/kg) respectively. The variations observed could be linked to the differences in locations of the marketing environment and the extent of pollution of the irrigation water and soil around the farms were the vegetables were cultivated. Similar observations were reported previously (Chiroma *et al.,* 2003; Doherty *et al.,* 2012; Okon *et al.,* 2015; Adedokun *et al.,* 2016; Ara *et al.,* 2018; Idakwoji *et al.,* 2018; Kamkara *et al.,* 2021).

Table 1. Concentration of heavy metals in fresh Telfairia occidentalis leaf samples.

Heavy metal (mg/kg)	International Market	Lokonguma Market	Kpata Market	Old Market
Cd	0.18 ± 0.02^{aE}	0.01 ± 0.01^{cF}	0.02 ± 0.00^{cD}	0.16 ± 0.02^{bE}
Cu	1.25 ± 0.12^{bB}	0.68 ± 0.22^{dB}	0.79 ± 0.03^{cA}	1.82 ± 0.06^{aA}
Pb	0.08 ± 0.11^{aF}	0.03 ± 0.13^{cE}	0.02 ± 0.11^{cD}	0.05 ± 0.10^{bF}
Mn	0.72 ± 0.22^{aC}	0.56 ± 0.02^{dC}	0.69 ± 0.05^{bB}	0.64 ± 0.02^{cD}
Zn	1.82 ± 0.04^{aA}	0.75 ± 0.01^{cA}	0.68 ± 0.01^{cB}	1.76 ± 0.01^{bB}
Ni	0.24 ± 0.03^{bD}	0.21 ± 0.11^{cD}	0.19 ± 0.03^{dC}	1.15 ± 0.01^{aC}

*Mean values with dissimilar lower case alphabets as superscripts are reported significant ($p< 0.05$) across the rows, while mean values having dissimilar upper case alphabets as superscripts are noted significant ($p< 0.05$) across the columns.

The results of estimated daily intake (EDI) of heavy metals in *T. occidentalis* leaf samples as presented in Table 2 showed values that were well below the daily recommend levels for heavy metals in food. This finding suggest that there is no associated health risk with respected to the daily recommended concentrations for Cd, Cu, Pb, Mn, Zn and Ni in the studied vegetable.

This observation is at variance with the report of Adedokun *et al*. (2016), who observed that the EDI of Cd (0.004 – 0.017 mg/kg) and Pb (0.046 – 0.182 mg/kg) exceeded the recommended daily intake of metal but fall within the upper tolerable daily level. However, our findings are in line with the report of Onyedikachi *et al.* (2021) and Ara *et al*. (2021).

Table 2. Estimated daily intake (EDI) of heavy metals in *Telfairia occidentalis* leaf samples

Heavy metal (mg/kg)	EDI (mg/person/day)				Recommended level*	
	International Market	Lokonguma market	Kpata market	Old Market	Daily intake	Upper tolerable
Cd	0.0153	0.0009	0.0017	0.0136	0.0000	0.0640
Cu	0.1063	0.0578	0.0672	0.0012	0.9000	10.0000
Pb	0.0068	0.0026	0.0017	0.0043	0.0000	0.2400
Mn	0.0612	0.0476	0.0587	0.0544	3.0000	11.0000
Zn	0.1547	0.0638	0.0578	0.1496	8.0000	40.0000
Ni	0.0204	0.0018	0.0162	0.0978	0.5000	1.0000

*(FDA, 2001; Garcia-Rico, 2007)

Analysis of the target and hazard quotient was carried out to determine the non-carcinogenic health risk associated with ingestion of vegetables contaminated with the individual and combined heavy metals. The target quotient and hazard index are two absolute parameters used in estimating non-carcinogenic lifetime effects of humans exposure to heavy metals in food metal via consumptions. According to Kigigha *et al*. (2018), an estimated THQ or HI values of greater than or equal to one (1), suggests potential adverse health hazard to heavy metal exposures. As shown in Table 3, adults who ingested about 65 g up to 130g of the vegetables revealed THQ or HI values of less than one, indicating that none of the heavy metals could cause non-carcinogenic toxicity in the exposed adults. However, human exposure to about 195 g of the vegetable could lead to some health associated with Cd (Table 3). The non-carcinogenic hazards associated with exposure to Cd in food are toxicity to the heart, kidney, gastrointestinal, reproductive, respiratory and neurological systems (Jaishankar *et al*., 2014). Similar studies of heavy metals polluted vegetables with THQ or HI values for Cd > 1 have been reported previously (Yaacob *et al*., 2018, Ara *et al*., 2021). Moreover, the low levels of THQ and HI values in our study is in agreement with the work of Adedokun (2016) and disagreement with the study of Singh *et al*. (2010) with Higher THQ for Cd, Pb, and Ni in vegetables sourced from environment irrigated using wastewater. The soil environment and water used to irrigate cultivated vegetables are probably linked to variations observed.

The risk associated exposure with carcinogenic chemical elements could increase as the individual constantly and continuously gets exposed with time. Hence, the life time health risk was evaluated in this study. According to food scientists, TCR value of $\leq 10^{-6}$ has a low risk of cancer, while values of 10^{-5} to 10^{-3} has moderate cancer risk and values 10^{-3} to 10^{-1} has high risks (Doh, 2007; USEPA, 2018). The results on the target cancer risks (TCR) for Cd, Pb, Cu and Ni in vegetable samples (Table 4) revealed varying incremental lifetime cancer risks (ILCR) in the increasing order Pb<Cd<Ni<Cu. This finding suggests that potential cancer risks associated with Cd and Pb in the vegetable studied are moderate, while Ni and Cu are high over a life time period of exposure to heavy metal contaminated vegetables within the study location.

Table 3. Target hazard quotient (THQ/HI) of heavy metals in *Telfairia occidentalis* leaf samples

Heavy metal (mg/kg)	Vegetable ingestion (g)	International Market	Lokonguma market	Kpata market	Old Market	HI
	65	0.1800	0.0100	0.0200	0.1600	0.3700
Cd	130	0.3600	0.0200	0.0400	0.3200	0.7400
	195	0.5400	0.0300	0.0600	0.4800	1.1100*
	65	0.0313	0.0170	0.0196	0.0455	0.1134
Cu	130	0.0626	0.0340	0.0392	0.0910	0.2268
	195	0.0939	0.0510	0.0588	0.1365	0.3402
	65	0.0200	0.0075	0.0050	0.0125	0.0450
Pb	130	0.0400	0.0150	0.0100	0.0250	0.0900
	195	0.0600	0.0225	0.015	0.0375	0.1350
	65	0.0360	0.0280	0.0345	0.0320	0.1305
Mn	130	0.0720	0.0560	0.0690	0.0640	0.2610
	195	0.1080	0.0840	0.1035	0.0960	0.3915
	65	0.0061	0.0025	0.0023	0.0059	0.0168
Zn	130	0.0122	0.0050	0.0046	0.0118	0.0336
	195	0.0183	0.0075	0.0069	0.0177	0.0504
Ni	65	0.0017	0.0015	0.0014	0.0082	0.0128
	130	0.0034	0.0030	0.0028	0.0164	0.0256
	195	0.0051	0.0045	0.0042	0.0246	0.0384

**THQ or HI > 1= Potential adverse non-carcinogenic effects.*

Table 4. Target Cancer risks for heavy metals in *Telfairia occidentalis* leaf samples

Heavy metal (mg/kg)	Incremental lifetime cancer risks (ILCR)				∑ILCR
	International Market	Lokonguma market	Kpata market	Old Market	
Cd	$5.8E^{-3}$	$3.4E^{-4}$	$6.5E^{-4}$	$5.2E^{-3}$	$1.2E^{-2}$
Cu	$1.6E^{-1}$	$8.7E^{-2}$	$1.0E^{-1}$	$1.8E^{-3}$	$3.5E^{-1}$
Pb	$5.8E^{-5}$	$2.2E^{-5}$	$1.4E^{-5}$	$3.7E^{-5}$	$1.3E^{-4}$
Ni	$3.5E^{-2}$	$3.1E^{-3}$	$2.8E^{-2}$	$1.7E^{-1}$	$2.3E^{-1}$

4. Conclusion

This study has shown that fluted pumpkin (*T. occidentalis*) leaves from major markets in Lokoja, Kogi State, harbored various levels Cu, Zn, Pb, Cd, Ni and Mn in concentrations well below the daily recommended intake in food. The health risks associated with consumption of the vegetable from all the four markets were substantially low for the analyzed metals except for Cd which could pose non-carcinogenic risks when the daily ingestion rate is tripled. Target cancer risks were in the increasing order Pb<Cd<Ni<Cu, suggesting moderate cancer risks for Cd and Pb, and high cancer risks Ni and Cu over a life time period of exposure to heavy metal contaminated vegetables within the study location. Hence, intensive awareness campaign is recommended to enlighten the populace on proper waste managements and safer ways of cultivation/handling of green leafy vegetables without exposure to heavy metal contaminations.

Authors' Contributions

All authors are contributed to this research.

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Institutional Review Board Statement

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Data presented in this study are available at fair request from the respective author.
Ethics Approval and Consent to Participate
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Consent for Publication
Not applicable.
Conflicts of Interest
Nil.

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