European Journal of Nutrition & Food Safety

13(1): 1-14, 2021; Article no.EJNFS.65143
ISSN: 2347-5641

Assessment of Heavy Metal Contents, and Probable Health Risks of Some Staple Vegetables in Enugu Metropolis

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Authors' contributions

This work was carried out in collaboration among all authors. Author EEI designed the study and wrote the protocol. Authors DIM and AEA managed the analyses of the study. Author DIM performed the statistical analysis, and wrote the first draft of the manuscript. Authors CEN and AV managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/EJNFS/2021/v13i130341
Editor(s):
(1) Dr. Rasha Mousa Ahmed Mousa, University of Jeddah, Saudi Arabia.
Reviewers:
(1) Hamid Sodaeizadeh, Natural Resources Yazd University, Iran.
(2) Tamara Myslyva, Belarusian State Agricultural Academy, Belarus.
Complete Peer review History: http://www.sdiarticle4.com/review-history/65143

Original Research Article

Received 27 November 2020
Accepted 09 January 2021
Published 10 January 2021

ABSTRACT

Heavy metals naturally are non-biodegradable constituents of the earth's crust that accumulate and persist indefinitely in the ecosystem as a result of both human and natural activities. Their contamination of vegetables remains an issue of public health interest due to the frequency, and quantity of consumption. The over exposure to these heavy metals continues to pose serious health threat globally. This study was aimed to assess the heavy metal contents of staple vegetables *[Telfairia occidentalis*, *Amaranthus hybridus* and *Ocimum gratissimum]* within Enugu metropolis; the leaves were screened for heavy metals [Arsenic As, Lead Pb, Cadmium Cd, Nickel Ni, Chromium Cr and Cobalt Co], by atomic absorption spectroscopy (AAS). Results (Mean±SD, mgkg-1) showed that *Amaranthus hybridus:* contained [Pb-0.109±0.350, Cr -0.161±0.004]; *Ocimum gratissimum*: [Ni-0.179±0.028, Cd-0.033±0.006, Cr-0.176±0.036], and *Telfairia occidentalis*: [Pb-0.153±0.139, Co-0.198±0.148]; of which some values were slightly above

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WHO/FAO standards. Although, the estimated daily intakes (EDIs) were below referenced tolerable daily intakes (TDIs). The hazard quotients (HQs) were below 1 (HQ<1), but As and Cd, were exceptions; while the hazard index (HI) values were all above 1 (HI>1). The slightly above standard references of some of these heavy metals, and HI>1 values in this study are a concern, as potential health risks may arise amidst the population over a period of time, therefore, there is need to eliminate the likely sources of the latent contamination.

Keywords: Heavy metals; Telfairia occidentalis; Amaranthus hybridus; Ocimum gratissimum; health risk; Enugu.

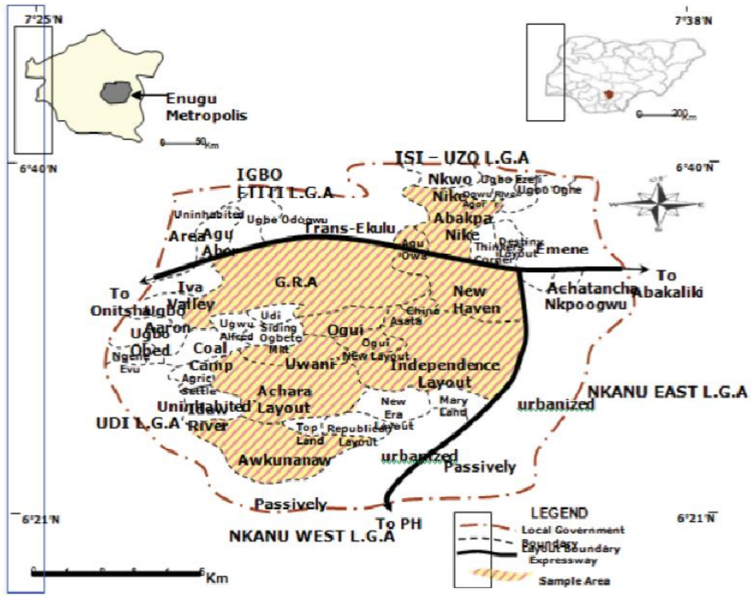
1. INTRODUCTION

The benefits of vegetables as sources of foods cannot be overemphasized; they are important constituents of human diets [1], and can effectively buffer some toxic metabolites in the course of food digestion [2]. But possible association with toxicants -like heavy metals- is one issue that brings concerns about their enormous consumptions. Vegetables as food sources are consumed daily; therefore, could be a source of health risk when inadvertently contaminated by toxicants like heavy metals; which deleterious effects on exposure, only manifest after a prolonged period of time [3]. Heavy metals contamination of vegetables is mostly as a result of pollution of agricultural soil, which natural events such as weathering, erosion, atmospheric fall-out etc. are the known factors [4]. Also the activities of humans that include but not limited to irrigation with contaminated water, the addition of fertilizers and metal-based pesticides, industrial wastes-emissions and effluents. Other sources include during transportation, the harvesting process, storage and at the point of sale [5,6,7]. Heavy metals like Cd, Pb and As are non-biodegradable, therefore, their accumulation in human tissues could lead to progressive toxicity [8]. Pb, Cd and As are amongst the heavy metals that are mostly present in foods with highest toxic potential [9]. Studies have shown that some of these metals exceeded WHO recommended standards in leafy vegetables, for example, chromium in *Telfairia occendentalis* [10,11] and Nickel in *Ocimum gratissimum* [12]. Contamination of vegetables with heavy metals poses a great threat to human health and could result in a number of disease conditions; such as renal and neurological damages, developmental challenges in neonates, amongst others [13,14]. Food consumption is known to be one of the major pathways for human exposure to certain environmental contaminants [15], therefore, sources of food contaminants and measures to eliminate them are constantly a focus of research [16,17]. With the understanding of the potential health risks attributed to consumption of heavy metal contaminated vegetables, it is necessary to analyze these food items often, to ensure that their levels are not above acceptable set standards. There are many indigenous vegetables that are consumed in Enugu metropolis, which cultivation and trade are sources of livelihood for many that depend on subsistent or commercial agriculture; from which millions of Naira are generated annually. This study is necessary in this location also, because research has shown that soils around coal mines are contaminated with lots of heavy metals [18], the city is known for coal mining though the coal mining activities have long declined. *Telfairia occidentalis*, *Amaranthus hybridus* and *Ocimum gratissimum* are amongst the staple vegetables in Enugu, therefore are consumed every day by large percentage of the population, but very little is known about their heavy metal contents. The aim of this study was therefore to assess the levels of heavy metals content (As, Pb, Cd, Ni, Cr and Co) in staple vegetables (*Telfairia occidentalis*, (*Cucubitaceae*); *Amaranthus hybridus* (*Amaranthaceae*), and *Ocimum gratissimum (Lamiaceae)* sold in the Enugu markets and to determine their potentially harmful effects with calculating the hazard quotient for the child and adult population of the city.

2. MATERIALS AND METHODS

2.1 Study Area

Enugu is a cosmopolitan city known for coal mining; with sparse industrial sites while markets are common sights. It is situated in the southeast of Nigeria, and was the capital of the old eastern region of Nigeria. There are many water channels, several high and low lands across the city, with a population of about 722,664; a total area of 556 km^2 and is situated between the latitudes and longitudes of 6.4584ºN, 7.5464ºE, this city has a warm climate of average annual temperature of 26.3º C and rainfall of 1730mm. The map Fig. 1 [19] shows the area where the vegetables were purchased.



Source: Town Planning Authority, ENUGU, 2009

Fig. 1. Map of Enugu Metropolis

2.1.1 Sample collection and preparation

To assess the heavy metals [As, Pb, Cd, Ni, Cr and Co] content of staple vegetables within Enugu metropolis, three species -*Telfairia occidentalis*, *Amaranthus hybridus* and *Ocimum gratissimum*- were randomly purchased from different markets within the city during raining season; (a total of 12 samples each were purchased), three of which were bought at each market anytime the purchase was made, that lasted for a duration of 6 weeks. The leaves were clicked and used while the stems were discarded. The leaves were left in an open air in the laboratory for 24hrs before they were oven dried at 40°C for 10 hrs. with Gallenkamp oven. The crispy leaves were crushed, and similar amounts of each vegetable were screened for the heavy metals; using Buck model 205 atomic absorption spectroscopy (AAS). as described [20].

2.1.2 Hazard quotient determination and hazard index

$$DIM\ (mgkg^{-1}Day^{-1}) = \frac{A(mgkg^{-1})xB(kg)}{C(kg)} \qquad (Eqn..1)[21]$$

Where DIM is Dietary intake of metal, A is concentration of the metal, B is ingestion rate, C is the average weight of individuals involved [child and adult taken to be 24 and 60 respectively] [21]; Vernonia amygdalina consumption rate in the study by Orisakwe et al. [21], equates to the consumption rate of the leafy vegetables in this study, therefore was used as a proportional injection rate for the vegetables in this study, which were 345 gday^{-1} for adults, and 232gday^{-1} for children [21].

The hazard quotient (HQ) was determined as a ratio of daily intake of metal (DIM) to the oral reference dose for the heavy metal (USEPA 2010)

$$Hazard\ quotient = \frac{Daily\ intake\ of\ metal}{R_fD} \qquad \text{(Eqn...2) [22]}$$

Where: R_fD is the oral reference dose for each heavy metal considered.

The hazard index (HI) was expressed as the total sum of the hazard quotients (HQs) of the heavy metals [23]

$$Harzard\ index = HQ1 + HQ2 + HQ3 \ldots\ldots + HQn\ \ Eqn \ldots 3\ \ [23]$$

2.2 Statistical Analysis

Data were analyzed with SPSS version 20. ANOVA was used to determine mean differences, and when significant (LSD) was used for the post-ANOVA test, p was considered significant at< 0.05. Other statistical analyses were determined with descriptive statistics (frequencies).

3. RESULTS AND DISCUSSION

This study presents results of levels of heavy metals - As, Pb, Cd, Co, Ni and Cr - assessed in different species of staple vegetables consumed in Enugu metropolis as purchased from different markets within the city. In order to determine possible contamination, this study results were considered to be of potential toxic effect when values were above set reference standards. The results showed that Pb ranged from 0.085 mgkg-1 in *O. gratissimum* to 0.153 mgkg-1 in *T. occidentalis*, As ranged from 0.046 mgkg-1 in *T. occidentalis* to 0.055 mgkg-1 in *A. hybridus*, Co ranged from 0.116 mgkg-1 in O.gratissimum to 0.198 mgkg-1 in *T. occidentalis*, Ni ranged from 0.161 mgkg-1 *A. hybridus* to 1.385 mgkg-1 in *T. occidentalis*, Cd ranged from 0.030 mgkg-1 in *T. occidentalis* to 0.033 mgkg-1 in *O. gratissimum*, and Cr ranged from 0.135 mgkg-1 in *T. occidentalis* to 0.176 mgkg-1 in O.gratissimuim Table 1. The amounts of Ni and Cr were higher in *A. hybridus* followed by Co, and least was in Cd. Cd was highest in *O.gratissimum* followed by Ni, and As had the least while in *T. occidentalis* Ni was highest followed by Co and the least was Cd. The thresholds Table 2 for heavy metals in leafy vegetables were exceeded in some vegetables in this study. As threshold of the 0.5 mgkg-1 was slightly exceeded in *A. hybridus* and *O. gratissimum.* Pb was higher than 0.1 mgkg-1 threshold in *T. occidentalis* and *A. hybridus*. Cd was higher than prescribed threshold of 0.03 mgkg-1 in *O. gratissimum*, while Ni exceeded the 0.3 mgkg-1 permissible concentration in *T.occidentalis* Table 1.

There were no statistically significant differences between the heavy metal contents in *A. hybridus* compared to *O.gratissimum* ($p>0.05$), comparison of heavy metal contents in *A. hybridus* and *T. occidentalis* showed statistically significant differences in As and Ni contents ($p<0.05$), while *O.gratissimum* and *T.occidentalis* comparison showed statistically significant differences in Ni and Cr ($p<0.05$) Table 3. The heavy metal concentrations in the vegetables [*O.gratissimum (O.g); A. hybridus* (*A.h*); *T. occidentalis (T.o)*] varied as follows *Pb:T.o>A.h>O.g; Co: T.o>A.h>O.g; As:A.h>O.g>T.o; Ni:T.o>O.g>A.h; Cr:O.g>A.h>T.o; Cd:O.g>A.h>T.o* Figs:2,3,&4.

Table 1. Statistical characteristics of the of heavy metals content in the vegetables (mg/kg) [n =12]

Heavy metal	Heavy metal content value			Sd	Cv, %	Med	Kurtosis	Skewness
	min	max	mid					
Amaranthus hybridus								
Pb	0.071	0.194	0.133	0.035	32.00	0.108	2.163	0.637
As	0.042	0.070	0.056	0.009	1.60	0.055	-0.489	0.188
Co	0.093	0.518	0.306	0.119	83.50	0.110	11.796	3.423
Ni	0.105	0.212	0.159	0.036	22.30	0.161	-1.412	-0.064
Cd	0.020	0.043	0.032	.0009	25.80	0.031	-1.564	-0.062
Cr	0.078	0.215	0.147	0.045	27.70	0.169	-0.382	-0.716
Ocimum gratissimum								
Pb	0.069	0.131	0.100	0.018	21.50	0.078	2.996	1.795
As	.0435	0.063	0.053	0.006	11.60	0.051	-0.153	0.441
Co	0.100	0.133	0.117	0.009	8.00	0.119	0.204	-0.462
Ni	0.135	0.221	0.178	0.029	15.90	0.181	-1.118	-0.183
Cd	0.022	0.044	0.033	0.007	18.18	0.033	-0.735	-0.051
Cr	0.110	0.220	0.165	.036	20.50	0.189	-0.755	-0.764
Telfairia occidentalis								
Pb	0.081	0.590	0.336	0.139	90.84	0.119	11.540	3.370
As	0.030	0.060	0.045	0.008	17.30	0.046	0.708	-0.414
Co	0.107	0.647	0.377	0.148	74.75	0.145	9.468	2.967
Ni	0.149	2.275	1.212	0.712	51.40	1.378	-0.398	-0.650
Cd	0.019	0.037	0.028	0.006	23.08	0.026	-0.810	0.422
Cr	0.101	0.203	0.152	0.025	18.70	0.132	4.641	1.775

Note: Sd is the standard deviation; Cv is the coefficient of variation; Med is the median

Table 2. Standard references of permissible levels of heavy metals for vegetables

Heavy metal	NEPA-China [a]	FAO/WHO (CODEX)[b, *b]	Threshold[f]	[c]Recommended Max. limit
Pb	0.2	0.5(2001) 0.3(2015)	0.2	0.3
As	0.5	0.2(2015),0.1(2011)[d]	-	0.43
Co	-		0.5[e]	50
Ni	0.3	10(2011)[d]	2	67.9
Cd	0.05	0.02(2001) 0.2(2015)	0.05	0.2
Cr	0.5	2-3(2011)[d]	0.5	2.3

*[a]National Environmental Protection Agency-China (NEPA-China) 2001 [24], [b]Food and Agriculture Organization [FAO]. 2001 [25],[*b]Food and Agriculture Organization [FAO] 2015 [26]. [c]Itanna 2002 [27], [d]Shaheen et al. 2016 [28]: ,[e]Murtaza et al. 2008 [29], [f]Hu et al [30].*

Co, Pb and Ni values were highest in *T. occidentalis* Figs. 2&3; Cr and Cd in *O. gratissimum* Fig. 4 while As in *A. hybridus* Fig. 3. *T. occidentalis* may have been cultivated in an area contaminated with the heavy metals; alternatively fertilizers application could be a source of the slightly above normal referenced values in the vegetables as observed in this study. Also there could be a possibility that some of these vegetables could have been grown along sewage sites or poor water effluents from domestic activities by those that live in the suburb of the city, thereby contaminating them with these metals, also Enugu seats on coal, though mining activities have long declined but its effects may still be affecting crop production, as it has been reported that soils around coal mines are contaminated with many heavy metals [18].

Some research findings on heavy metal evaluation of these vegetables in other places where they are also cultivated and consumed have been documented. Evaluation of *T. occidentalis* in some studies has showed that Cd and Cr concentrations of 0.55 mgkg-1 and 1.4 mgkg-1 respectively were reported by Njoku-Tony et al. [31] in Rivers state, while Egwu et al. [11] reported Cd and Cr of 0.14 mgkg-1 and 0.71 mgkg-1 respectively in Niger state. Cd and Cr values in this study were lower Table 1 than those reported from studies in Niger sate and Rivers state. $^{-1}$

Okereke et al. [32] findings showed that Ni of 0.12 mgkg-1 and 2.7 mgkg-1 were found in a similar study in Ebonyi and Rivers respectively, while that of Ebonyi state was lower than the concentration found in this study (Table 1), the value of the study in Rivers state was higher. Co of 1.75 mgkg-1 and 0.14 mgkg-1 were reported by Kalagbor et al. [33] and Ukpabi et al. [34] respectively in Rivers state. Egwu et al. [11] reported Pb value of 4.27 mgkg-1 in Niger state while Nwoko et al. [35] showed in their study that the vegetable contained 0.727 mgkg-1 in Imo state, both of which were higher than our findings. As of 0.42 mgkg-1 was reported by Uka et al. [36] in Ebonyi state while Adepoju-Bello et al. [37] showed that the vegetable in their study contained 1.183 ug/g in Lagos, which is lower than the value obtained in our study.

In *Ocimum gratissimum,* Cd of 0.08 mgkg-1 was found in the vegetable collected around residential area in Lagos [38], Vaikosen and Alade [39] reported a concentration of 0.41 mgkg-1 in Bayelsa, while Adedokun et al. [40] reported a value of 0.20 mgkg-1 in Lagos. Cr of 1.68 mgkg-1 was reported by Abdurahman et al. [41] in Borno state, while Patrick-Iwuanyanwu and Chioma [12] reported a value of 1.369 mgkg-1 in Bayelsa state. Ni of 3.625 mgkg-1 and 0.093 mgkg-1 in two different locations in Bayelsa state were also reported by Patrick-Iwuanyanwu and Chioma, [12], and in Abuja Ojo et al. [38] showed that the vegetable contained Ni of 1.08 mgkg-1 in residential area. Co of 3.5 mgkg-1 was reported by Kalagbor et al. [33] in Rivers state. Alexander [42] reported a Pb concentration of 0.005 mgkg-1 in Adamawa, but Kalagbor et al. [33] reported 6.25 mgkg-1 in Rivers while in Lagos Adedokun et al. [40] reported a range of 9.34 mgkg-1 to 5.44 mgkg-1. In Ghana, Annan et al. [43] reported As of <0.001 ugg^{-1}, this is lower than the value found in our study Table 1. The concentration of Cd found in *O.gratissimum* in this study was higher than that found in the vegetable in Lagos, but lower than that found in the vegetable in Bayelsa state. Also the value found in our study was higher than that found in Adamawa state but lower than that found in Lagos and Rivers states, this may not be unexpected as Lagos is a great commercial city and Rivers a crude oil exploration state.

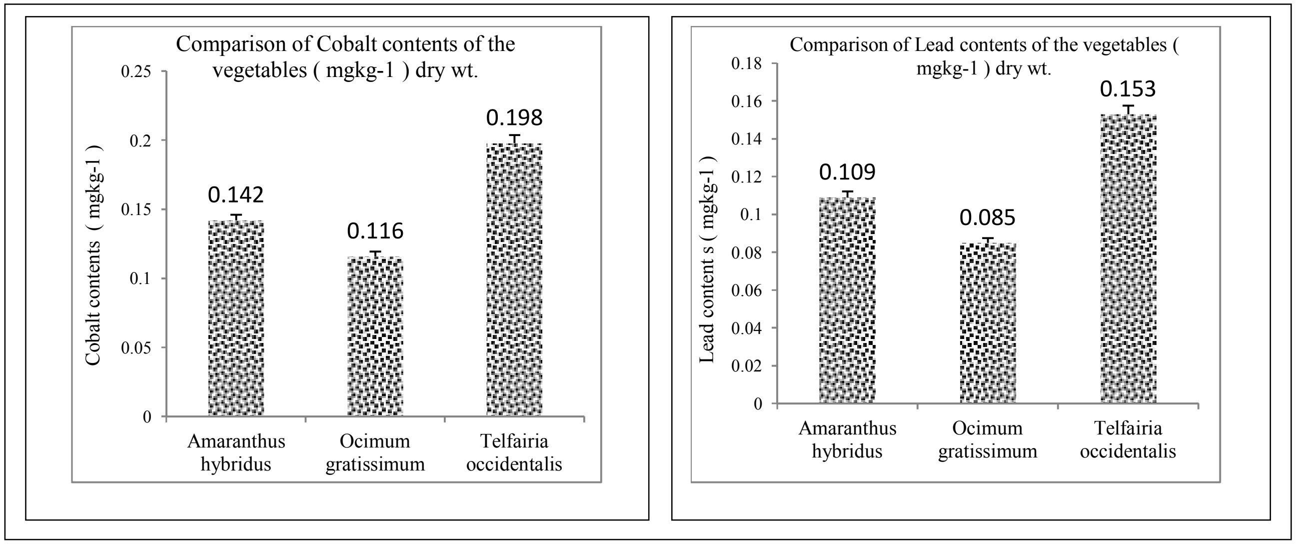


Fig. 2. Comparison of heavy metal contents of the vegetables- cobalt: lead

Table 3. p-values of post ANOVA tests of comparisons of the heavy metals content of the vegetables

Heavy metal	*Amaranthus hybridus/ Ocimum gratissimum*	*Amaranthus hybridus/Telfairia occidentalis*	*Ocimum gratissimum Telfairia occidentalis*
Pb	0.767	0.452	0.149
As	0.491	0.024*	0.255
Co	0.846	0.473	0.207
Ni	0.993	0.001*	0.001*
Cd	0.993	0.113	0.090
Cr	0.629	0.233	0.036*

**Value is significant at P<0.05 when each vegetable's heavy metals was compared one to another*

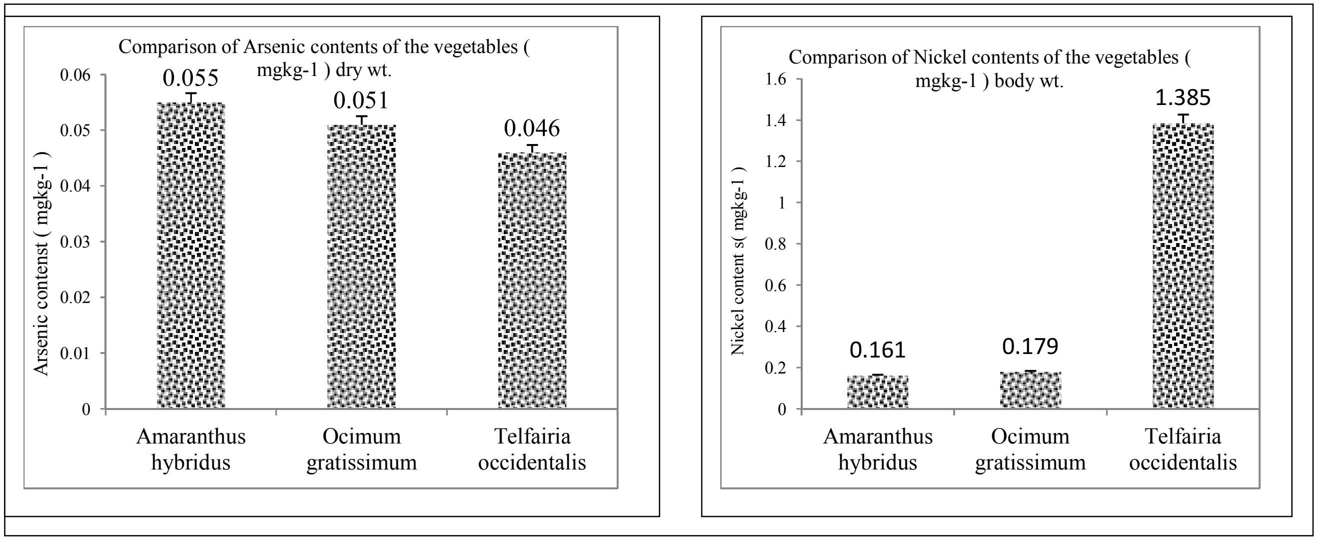


Fig. 3. Comparison of heavy metal contents of the vegetables-arsenic: nickel

Table 4. Estimated daily intake of *Amaranthus hybridus, Ocimum gratissimum and Teliferia occidentalis*

Heavy metal	A.hybridus (mgkg-1)	EDI in A	EDI in C	O.gratiss-imum (mgkg-1)	EDI in A	EDI in C	T.occide-talis (mgkg-1)	EDI in A	EDI in C
Lead	0.109	6.27E-04	1.05E-03	0.085	4.89E-04	8.22E-04	0.153	8.80E-04	1.48E-03
Arsenic	0.055	3.16E-04	5.32E-04	0.051	2.93E-04	4.93E-04	0.046	2.65E-04	4.45E-04
Cobalt	0.142	8.17E-04	1.37E-03	0.116	6.67E-04	1.12E-03	0.198	1.14E-03	1.19E-03
Nickel	0.161	9.26E-04	1.56E-03	0.179	1.03E-03	1.73E-03	1.385	7.96E-03	1.34E-02
Cadmium	0.032	1.84E-04	3.09E-04	0.033	1.90E-04	3.19E-04	0.026	1.50E-04	2.51E-04
Chromium	0.161	9.26E-04	1.56E-03	0.176	1.01E-03	1.70E-03	0.135	7.76E-04	1.31E-03

EDI=Estimated Daily intake, A=Adults, C= Children

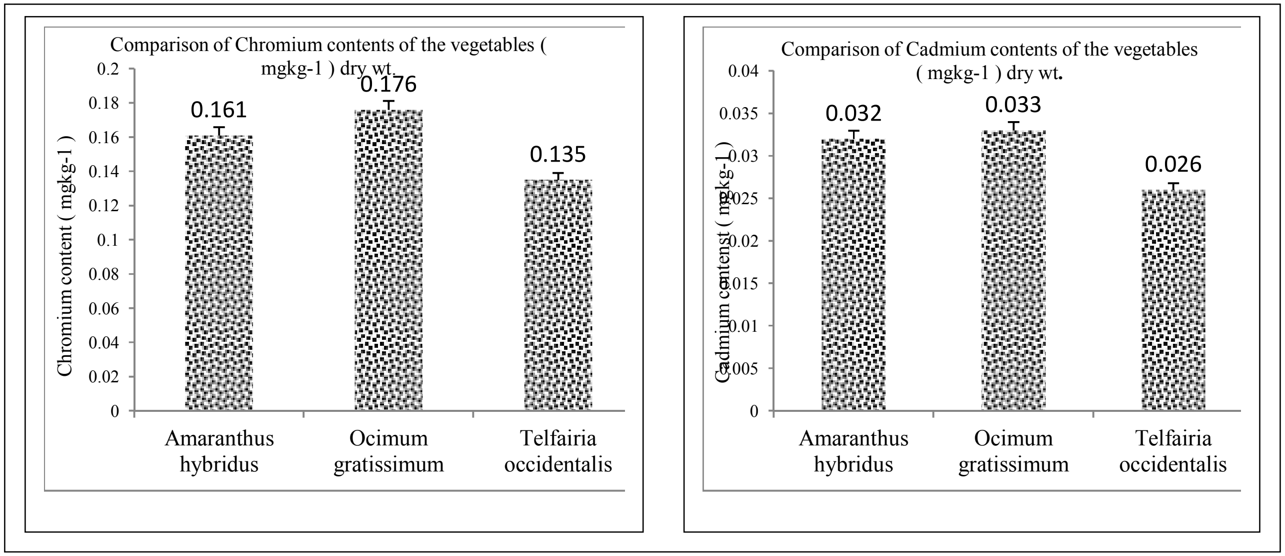


Fig. 4. Comparison of heavy metal contents of the vegetables- Chronium: Cadmiunm

Table 5. Hazard quotient (HQ) and hazard index (HI) of *A. hybridus*, *O. gratissimum* and *T. occidentalis* (Adults and Children)

	R_fD	A.h(A)	A.h(C).	O.g (A)	O.g(C)	T.o(A)	T.o(C)
Lead	0.0035	1.79E-01	3.00E-01	1.40E-01	2.35E-01	2.51E-01	4.23E-01
Arsenic	0.0003	1.05E+00	1.77E+00	9.77E-01	1.64E+00	8.83E-01	1.48E+00
Cobalt	0.02	4.09E-02	6.85E-02	3.34E-02	5.60E-02	5.70E-02	9.55E-02
Nickel	*0.02	4.63E-02	7.80E-02	5.15E-02	8.65E-02	3.98E-01	6.70E-01
Cadmium	0.001	1.84E-01	3.09E-01	1.90E-01	3.20E-01	1.50E-01	2.50E-01
Chromium	0.003	3.09E-01	5.20E-01	3.37E-01	5.67E-01	2.59E-01	4.37E-01
HI		1.81E+00	3.05E+00	5.14E+00	8.64E+00	3.95E+00	6.63E+00

*RfD= Oral reference dose [66] *[67]; A.h=A. hybridus; O.g=O. gratissimum; T.o=T. occindentalis; A= Adults; C= Childr*

In some evaluation studies with *A. hybridus*, Gbaye et al. [44] reported Cd range of 0.03 - 0.06 mgkg-1 in Ondo state, Ogoko [45] reported 0.48 mgkg-1 in a study in Abia state while in Kaduna, Akubugwo et al. [46] reported a Cd range of 0.04-1.19 mgkg-1 . Izah and Aigberua [47] reported Cr value of 8.08 mgkg-1 in their study. Ogoko [45] reported Pb of 4.43 mgkg-1 in Abia state while Gbaye et al. [44] reported 0.07 mgkg-1 of Pd also in Ondo state. Ni of 0.29 mgkg-1 and As of 0.08 mgkg-1 were found in the vegetable in a similar study in Abia state [45], and in Burkina Faso, Bakary et al. [48] reported 0.145 mgkg-1 of As in the vegetable, Oyelola and Banjoko (2015) showed that the vegetable contained Co of 0.52 mg/100 g in a study in Lagos, while Ani et al. [49] also, reported a Co of 0.042 mgkg-1 in Mgbowo, Enugu. In another related study, Oladeji and Saeed 2015 [50] found that the vegetable contained a Co ranged 6.25-8.45 mgkg-1 in Kaduna state. The reported values of heavy metal in *A. hybridus* elsewhere were higher than values found in our study Table 1, an indication that level of the vegetable contamination in our study area was minimal compared to other regions. Clearly, reports from other places suggest differences in the concentrations of these heavy metals in the vegetables; this disparity could largely be due to environmental, cultural and industrial factors.

Generally, heavy metals can cause severe problems for humans, for example, exposure to high concentration of Pb has been shown to cause a number of deleterious human conditions like brain injury, damages to nervous system, red blood cells; and renal system; induces low IQ and impairs development, causes loss of memory, nausea, insomnia, anorexia, weakness of the joints and reduces fertility [51]. Cadmium has toxic effects on the kidneys as well as the skeletal and respiratory systems [52] and has also been classified as a human carcinogen [53]. High intake of cadmium on the other hand can lead to disturbances in calcium metabolism, and may contribute to smoking-related lung disease [53,54,55]. Allergic reactions are the most common harmful health effect of nickel, which mostly occur through skin contact that could result in chronic bronchitis, reduced lung function, and cancer of the lung, and nasal sinus [56]. The harmful effect of long-term exposure to high levels of inorganic arsenic is usually observed in the skin, which includes pigmentation changes, skin lesions and hard patches on the palms and soles of the feet (hyperkeratosis) that can be as a result of acute or chronic exposure [57]. Other deleterious health effects associated with long-term ingestion of inorganic arsenic include developmental effects, diabetes, pulmonary disease, and cardiovascular disease [57]. Arsenic exposure has also been related with adverse pregnancy outcomes and infant mortality, also with impacts on child health [58], and exposure in utero and in early childhood has been linked to increases in mortality in young adults due to multiple cancers, lung disease, heart attacks, and kidney failure [59]. Cobalt has both beneficial and harmful effects on human health; this is beneficial because it is a component of vitamin B12, Its concentration of 0.16–1.0 mgkg-1 body weight has been found useful in treatment of anaemia. It also increases red blood cell production in healthy individuals, but only at very high exposure levels [60]; it can also enhance the kinetics of some enzymes, such as heme oxidase in the liver [61]. Excessive exposure to cobalt however, can lead to harmful health effects such as difficulty in breathing, and serious side effects on the lungs, including asthma, pneumonia, and wheezing, this also interferes with and depresses iodine metabolism, resulting in reduced thyroid activity [60,61]. Chromium is an essential nutrient required by the human body to promote the action of insulin for the sugars, proteins and fats utilization [62,63]. But high doses of chromium over a long period of time can give rise to various cytotoxic and genotoxic reactions that can affect the immune system [62]. Occupational exposure to Cr(VI) compounds in a number of industries has been associated with increased risk of respiratory system cancers [64].

Health risk assessment was carried out to evaluate the possible association of the vegetables consumption to the wellbeing of the study population. The EDIs of the heavy metals as a result of the consumption of the vegetables are as presented Table 4. The EDI ranged from 4.89E-04 in *O. gratissimum* [adults] to 1.12E-03 in *T. occindentalis* [children]. All the EDIs were below the TDIs [65], an indication that the individual consumption of the vegetables may present no health risks amongst the population.

The HQs of all the heavy metals in this study were less than 1 (HQ<1), with exception of As and Cd (Table 5). HQ values less than 1 (HQ<1) indicates that the cumulative consumption of that substance will not induce an adverse effect but with tendency of adverse effect when it is above 1 (HQ>1); the same applies also to HI. HQ of As in all the three (3) vegetables ranged from 9.77E-

01 to 1.77E+00, and were above 1 in all, except in *O. gratissimum* [children] Table 5; also HQs of Cd in *O. gratissimum* in adults and children were 1.87E+00 and 3.15E+00 respectively with values above 1 (HQ>1) (Table 5) The HI of the heavy metals in each vegetable were above 1(HI>1); also the HIs of all the heavy metals in the three (3) vegetables were above 1, which ranged from 1.81E+00 in *A. hybridus* [adults] to 5.74E+00 in *O. gratissimum* [children] Table 5, which presents a tendency of deleterious side effect.

Since source of food contaminants and measures to eliminate them had been described as a constant focus of research [16,17], also considering the high HI of the heavy metals in the vegetables in our study, there is therefore, the need for a review of the vegetables for these heavy metals from time to time to checkmate a possible chronic heavy metal toxicity amongst the population.

4. CONCLUSION

Our findings showed that some of the heavy metals like Pb and Cr, were slightly above the FAO/WHO set standard references, and all the determined heavy metals' HIs in all the vegetables were above 1 (HI>1), there is then the need to trace and curb the latent source of contamination of the vegetables to avoid the adverse implications of heavy metals to healthy living of the population.

Declaration of interest: we have no conflict of interest to declare

5. FUNDING

This study received no funding.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/65143