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Research Paper

Health Risk Assessment of Selected Vegetables Grown By Local Farmers in Akungba Akoko Ondo State Nigeria.

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Abstract
Vegetables are important edible crops that are rich in nutrients and form essential part of the human diet. Heavy metals can be readily taken up by vegetable roots, and accumulated at high levels in its edible parts. A study to investigate some heavy metals such as lead (Pb), cadmium (Cd), zinc (Zn) and chromium (Cr) in three selected vegetables namely Corchorusolitorus, Amaranthushybridusand Abelmoschusesculentus; and the consequent health risks connected with ingestion of the vegetables were determined. Vegetable samples were obtained from two farms within AkungbaAkoko in Ondo State, Nigeria and analyzed for Pb, Cd, Zn and Cr concentrations. Health risk parameters such as daily intake of metal (DIM), health risk index (HRI), target health quotient (THQ), and total diet target health quotient (TTHQ) were evaluated. The analyzed metals in the vegetables were all below the permissible level set by FAO/WHO. DIMs of Cd, Pb and Zn for children were higher than 0.001, 0.0035 and 0.300 mg/kg/day respective values of oral reference doses (RFD). HRI >1 for Pb in children, Cd in adult and children and Zn in children indicated health risks in connection with the ingestion of the selected vegetables. THQ and TTHQ for the analyzed metals are less than 1. From the outcome of this study, it can be concluded that children were more vulnerable to the adverse effects of heavy metal ingestion through vegetables than adults. Hence, strict monitoring of local farm vegetables should be done in order to safeguard the public.

Keywords: vegetable, *heavy metal, health risk, children, adult.*

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I. Introduction

The use of leafy vegetable is part of Africa's cultural heritage and they play significant roles in the customs, traditions and food ethos of the African homes (Mensah *et al*., 2008).Vegetables are essential for human nutrition and health as they play an important biochemical and antioxidant role (Siegel *et al.*, 2014) and as source of vitamin C, vitamin B and as dietary fiber. They are edible herbaceous plants whose part or parts are eaten as supporting food or main food and they may be sweet-smelling, bitter or tasteless.

Nigeria is endowed with a range of traditional vegetables such as *Amaranthushybridus, Corchorus olitorius* and *Abelmoschusesculentus* that are consumed by the various racial groups for different reasons. *A. hybridus* is a common species of waste places, cultivated fields and barnyards known to contain considerable amount of squalene, a compound that has both health and industrial benefits (He and Corke, 2003). In Nigeria, it leaves combined with condiments are used to prepare soup (Oke, 1983; Mepha*et al*., 2007). *Abelmoschusesculentus* is native to the tropics of the Eastern Hemisphere and cultivated or naturalized in subtropics of the Western Hemisphere. As a vegetable, it may be prepared sauteed, or pickled, and it is also an ingredient in various stews in the gumbos of the southern United States. In some places it is use as a thickener for broths and soups.

Heavy metals and metalloids (such as Zinc, lead, cadmium, chromium, cobalt, etc.) are elements in the natural and structural part of the earth's crust with a density greater than 5 g/cm^3. Many of them are non-degradable contaminants which persist in the environment. Initially, they are deposited on the soil surface, then absorbed by plant roots and further distributed and accumulated into it edible and non-edible parts, posing an impending danger to the food chain (Ahmad *et al*., 2019; Alsafran*et al.*, 2021). Natural as well as anthropogenic sources of heavy metals including industrial emissions and the application of fertilizer and sewage sludge to farm land which may lead to contamination of soils, and increase their uptake by crops and vegetablesgrown for

human consumption. While Chromium and lead are relatively abundant element in the earth's crust, their bioaccumulation and uptake could become noxious when they exceed certain threshold concentrations. Among the heavy metals, zinc is the least toxic and a vital element in human diet as it is required to maintain the functioning of the immune system.

The contamination of vegetables by heavy metals cannot be ignored due to their significance in food quality assurance.Among environmental contaminants, heavy metals due to anthropogenic activities have attracted numerous attentions due to their serious health implication to humans when accrued in a preeminent concentration above body requirements (Wang *et al.,* 2018). It is evident that prolonged consumption of foodstuff with unsafe concentrations of heavy metals may lead to chronic accumulation of heavy metals in the kidney and liver of human beings causing various disorders in numerous biochemical processes, leading to cardiovascular, bone, kidney and nervous diseases (Jarup,2003).

The human health risk associated with consumption of vegetables depends on the quantity of vegetables consumed and the weight of the individual. Prolonged ingestion of heavy metals with low concentrations has a negative consequence on human health, and after several years of exposure the detrimental effect becomes apparent (Liu *et al*.,2005; Huang *et al*.,2007; Bortey-Sam *et al*.,2015). Since vegetable consumers are exposed to heavy metals via consumption, this present study tends to investigate health risk involved in the consumption of three selected vegetables grown in two farms within Akungba-Akoko metropolis in Akoko South West Local Government Area of Ondo State, Nigeria.

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II. Materials and Methods

Fresh samples of three (3) selected vegetables: *Corchorus olitorius, Amaranthushybridus*and *Abelmoschusesculentus,* were obtained from AdekunleAjasin University Permanent Site farm (PSF) and Akunmi Community farm (ACF) within Akungba-Akoko metropolis. The vegetables were collected from the four (4) cardinal points on the farm, tagged accordingly and kept in polyethylene bags for onward transfer to the laboratory at the Department of Plant Science and Biotechnology, AdekunleAjasin University, Akungba-Akoko.

The vegetable samples were washed under tap water and de-ionized water to remove air pollutants and oven dried at 70℃ for 48 hours to a constant weight. The dried samples were pulverized, using agate pestle and mortar and stored in a bagging envelop for further investigation.

The pulverized samples were digested using the Aqua-regia method of digestion.Briefly, two grams of each of the pulverized vegetable sample were treated with 4 ml of $HNO_3$and 1ml of HCl. The digestion was carried out on hotplate inside fume cupboard. The digest was allowed to cool to room temperature, then filtered and made up to 25 ml of solution. The samples were then subjected to Atomic Absorption Spectrophotometer (AAS) using GBC A Vanta PM Version 2.02 for determination of zinc, cadmium, chromium and lead.

Data obtained were subjected to one-way ANOVA. Statistical means were separated using Duncan Multiple Range (DMR) test with the Statistical Package for Social Sciences (SPSS) version 21.0 software.

The heavy metals risk to humans were determined by estimating the daily intake of metal (DIM) calculated using Eq. 1 (Ramteke*et al.,* 2016; Edogbo*et al.,* 2020), health risk index (HRI) determined using Eq. 2(Osu*et al.,* 2015; Rehman*et al.,* 2017; USEPA, 2006); target health quotient (THQ) determined using Eq. 3 (Zhou *et al.,* 2016; Edogbo*et al.,* 2020); and total diet THQ (TTHQ) calculated using Eq. 4 (Zhou *et al.,* 2016; Storelli, 2008).

$$\text{DIM} = \frac{Chm\ x\ Cft\ x\ Dvi}{Abv} \quad (1)$$

$$\text{HRI} = \frac{DIM}{RFD} \quad (2)$$

$$\text{THQ} = \frac{EF \times ED \times FIR \times Chm \times 10-3}{RFD \times WAB \times TA} \quad (3)$$

$$\text{TTHQ} = \sum i = 1n(THQ)i \quad (4)$$

where Chm is the HM (heavy metals) in vegetables, Cftis the fresh to dry weight conversion factor of vegetables considered as 0.085. (Rattan *et al.,* 2005). Dvi(187 g/p/d (gram/person/day) for adults and 130 g/p/d for children)is the daily vegetable ingestion (Atikpo*et al*., 2021). A_{bw} is the average body weight estimated as 71.3 kg for adults and 22.5 kg for children (Atikpo*et al*., 2021).RFD denotes the reference oral dose which according to USEPA (2006), Edogbo*et al.* (2020).is 0.001, 0.300, 0.0035 and 1.5 mg/kg/day for Cd, Zn, Pb and Cr respectively.

EF is exposure frequency (350 days/year). ED is exposure duration (60 years). FIR is the ingestion rate of vegetables (130 g/p/d for children and 187g/p/d for adults). WAB denotes mean body weights (22.5 kg for children and 71.3 kg for adults). TA denotes non – carcinogens mean time of exposure (ED x 365 days/year).
A THQ >1 is an indication that the intake of a particular metal through vegetable diet is of potential health risk (Zhou *et al.,* 2016; Chauhan and Chauhan, 2014). (TTHQ) > 1 indicates negative health risk from total diets of the vegetables (Zhou *et al.,* 2016; Edogbo*et al.,* 2020)

III. Results and Discussion

The mean concentration of the analyzed heavy metals in *Corchorus olitorius*, *Amaranthushybridus*and *Abelmoschusesculentus*from the two farms are shown in Table 1 and 2. The mean concentration of Cd ranged from 0.008 ± 0.110 mg/kg to 0.029 ± 0.030 mg/kg from the two farms. The least concentration (0.008±0.010 mg/kg) was found in *A. hybridus*from ACF while the highest concentration (0.029±0.030 mg/kg) was found in *C. olitorius* from both farm sites. The Cd concentrations in the three selected vegetables from the two farms were lower than the 0.2 mg/kg (maximum limit) specified standards by WHO/FAO. In Ghana, a study conducted by Lente *et al*. (2012) reported cadmium values below detection limit of 0.006 mg kg^{-1} in vegetables grown in long-term wastewater irrigated urban farming sites in Accra. Similar study conducted by Hang*et al*. (2016) on vegetables grown on contaminated soil report Cd values higher than these present study.

The mean concentration of Cr ranged from 0.133 ± 0.059 mg/kg to 0.178 ± 0.081 mg/kg from the two farms (Table 1 and 2). The least concentration was found in *A. esculentus*from PSF while the highest concentration was found in *A. hybridus* from PSF. The Cr concentrations in the three selected vegetables from the two farms were lower than the 2.3 mg/kg (maximum limit) specified standards by WHO/FAO. Samuel *et al.* (2018) and Ekundayo*et al* (2020) reported lower values for Cr while conducting their research on heavy metal loads in various vegetables in Ghana and Nigeria respectively.

The mean concentration of Pb ranged from 0.004 ± 0.005 mg/kg to 0.026 ± 0.037 mg/kg from the two farms (Table 1 and 2). The least (0.004±0.005 mg/kg) and highest (0.026±0.037 mg/kg) concentrations were found in *A. esculentus*and *A. hybridus* respectively from ACF. The Pb concentrations in the three selected vegetables from the two farms were lower than the 0.3 mg/kg (maximum limit) specified standards by WHO/FAO. The concentrations of Pb in the vegetables in this study were lower than the concentrations recorded in vegetables studied in Pakshi, Bangladesh (Tasrina*et al.,* 2015). The current Pb concentrations were also lower than the concentrations in vegetables studied by Edogbo*et al* (2020) and Ekundayo*et al* (2020).

The mean concentration of Zn ranged from 0.923 ± 0.195 mg/kg to 1.019 ± 0.296 mg/kg from the two farms (Table 1 and 2). The least concentration (0.923±0.195 mg/kg) was found in *A. esculentus*from PSF while the highest concentration (1.019±0.296 mg/kg) was found in *A. hybridus* from PSf. The Zn concentrations in the three selected vegetables from the two farms were higher than the 0.6 mg/kg (maximum limit) specified standards by WHO/FAO. In Ghana, a study conducted by Lente *et al*. (2012) reported Zn values below 10 mg/kg in vegetables grown in long-term wastewater irrigated urban farming sites in Accra.

Table 1: Concentration of heavy metals (mg/kg) analyzed inselected vegetables from PSF.

Metals/Vegetables	Cd	Cr	Pb	Zn
Corchorus olitorius	0.029 ± 0.09^{a}	0.176 ± 0.067^{b}	0.007 ± 0.010^{a}	0.981 ± 0.390^{b}
Amaranthushybridus	0.023 ± 0.018^{a}	0.178 ± 0.081^{b}	0.008 ± 0.011^{a}	1.019 ± 0.296^{c}
Abelmoschusesculentus	0.020 ± 0.017^{a}	0.138 ± 0.059^{a}	0.024 ± 0.009^{b}	0.923 ± 0.195^{a}

Note: Values are mean ± standard deviation for four (4) replicate. Means with same superscript along the column are statistically same at p≤0.05 (Duncan Multiple Range Test).

Table 2: Mean concentration of heavy metals (mg/kg) analyzed in selected vegetables from ACF. (n = 4)

Metals/Vegetables	Cd	Cr	Pb	Zn
Corchorus olitorius	0.029 ± 0.030^{c}	0.175 ± 0.074^{b}	0.014 ± 0.012^{b}	0.963 ± 0.156^{ab}
Amaranthushybridus	0.008 ± 0.010^{a}	0.114 ± 0.0038^{a}	0.026 ± 0.037^{c}	0.942 ± 0.166^{a}
Abelmoschusesculentus	0.012 ± 0.019^{b}	0.169 ± 0.078^{b}	0.004 ± 0.005^{a}	0.999 ± 0.380^{b}

Note:Note: Values are mean ± standard deviation for four (4) replicate. Means with same superscript along the column are statistically same at p≤0.05 (Duncan Multiple Range Test).

Health Risk Assessment

There are many pathways of heavy metals exposure to humans. Ingestion of vegetables contaminated with significant amounts of heavy metal could cause harm to the human health. Intake of metals even at low concentrations is of adverse health consequences which become obvious after exposure for many years. The vegetables harvested from the studied farms are sold in the community's and other communities' markets. For this purpose, it became imperative to look into the health risks attached to the vegetables ingestion. The daily intake of metal (DIM) values for adult and children are presented in Table 3.The minimum Cd intake by adults and children were 0.0018 and 0.004 mg/kg/day respectively through the consumption of *A. hybridus* sourced

from ACF, while the maximum intakes were 0.0067 and 0.015 mg/kg/day respectively through diet of *C. olitorius* sourced from PSF. These values exceed the standard (0.001 mg/kg/day) RfD of Cd. DIMs in this study were lower than the DIMs recorded in a study conducted by Rehman*et al.,* (2017) in Pakistan, but exceed DIMs documented by Zhou *et al.,* (2016) and Edogbo*et al.,* (2020). DIM range of 0.11–0.67 mg/kg/day for some selected vegetables studied in India were also reported by Ramteke*et al.,* (2016).

The minimum Cr DIM for adults and children were 0.026 and 0.057 mg/kg/day respectively. These values were in connection with ingestion of*A. hybridus* sourced from ACF, while the maximum intakes were 0.041and 0.089 mg/kg/day respectively through the ingestion of*A. hybridus* sourced from PSF. Cr DIM values for all vegetables intake by adults and children from the two farms were lower than the (1.5 mg/kg/day)RfD of Cr. Cr DIM range of 0.4–7.2 mg/kg/day was documented by Ramteke*et al.,* (2016) for some vegetables in India. Respective Cr DIMs of 0.14, 7.23 and 0.03 mg/kg/day for lettuce, tomato and onion for adults and 0.004, 0.19 and 0.007 mg/kg/day for children were recorded in Challawa, Nigeria (Edogbo*et al.,* 2020).

The minimum DIM ofPb recorded for adults was 0.00092 mg/kg/day, the minimum for children was 0.002 mg/kg/day observed in *A. esculenthus* sourced from ACF, while the maximum DIM of Pb for adults was 0.006 mg/kg/day, and the maximum for children was 0.013 mg/kg/day observed in *A. hybridus* sourced from PSF. These values were lower than the RfD of Pb and also lower than the values documented by Zhou *et al.* (2016) and Edogbo*et al.* (2020). DIM range (0.26–2.00 mg/kg/day) was discovered for some vegetables in India by Ramteke*et al.* (2016).

Zn minimum DIM for adults and children were 0.21 and 0.46 mg/kg/day respectively which were observed in *A. esculenthus* sourced from PSF while the maximum DIM value for adults was 0.23 mg/kg/day observed in *C. olitorus*and *A. hybridus*both from PSF and *A. esculenthus* from ACF the maximum for children was 0.51 mg/kg/day observed in *A. hybridus* from PSF. These Zn DIMs were lower than the RfD of Zn and also lower than the Zn DIMs for some vegetables in India recorded by Ramteke*et al.* (2016). Respective DIMs of 6.14, 13.9 and 11.7 mg/kg/day for lettuce and tomato were reported in Challawa, Nigeria Edogbo*et al.* (2020).

Table 3: Daily intake of metal values from selected vegetables for adult and children in mg/kg

	PSF			**ACF**		
Metals/Vegetables	***Corchorus olitorius***	***Amaranthushybridus***	***Abelmoschusesculentus***	***Corchorus olitorius***	***Amaranthushybridus***	***Abelmoschusesculentus***
Cd: Adult	0.0067	0.0053	0.0046	0.0067	0.0018	0.0028
Children	0.015	0.012	0.01	0.012	0.004	0.006
Cr: Adult	0.04	0.041	0.032	0.04	0.026	0.039
Children	0.088	0.089	0.067	0.086	0.057	0.085
Pb: Adult	0.0016	0.0018	0.0055	0.0032	0.006	0.00092
Children	0.0035	0.004	0.012	0.007	0.013	0.002
Zn: Adult	0.23	0.23	0.21	0.22	0.22	0.23
Children	0.49	0.51	0.46	0.48	0.47	0.50

The human health risk (HRI) associated with the average daily dose was determined using the mean concentrations of Cd, Cr, Pb, and Zn in the three selected vegetables and their results are presented in Table 4. It is evident that HRIs were less than 1 in Cr for both adults and children from both farms, for Pb in *C. olitorius* and *A.hybridus* from PSF in adults and in *C. olitorius* and *A. esculentus*from ACF in adults and *A. esculentus* in children from ACF, and also less than 1 in Zn for adults from both farm. The HRIs were greater or equal to 1 in Cd for all the three vegetables for both adults and children from both farm, Pb in *A. esculentus* and *A. hybridus*in children from both farm and all the vegetables except *A. esculentus*in children from both farm, and in Zn in all the vegetables in children from the two farms. Hence, there is need for concern regarding the continuous consumption of the vegetables in terms of potential health risk. When HRI exceeds 1, there is concern for potential health effect (Huang *et al*., 2008). When the health risk index is <1, it poses no health effect but when the ratio is ≥ 1 it indicates that the population will experience health risk (Osu*et al.,* 2015; Khan *et al.,* 2009).

The difference in HRI values for adults and children are usually attributable to the differences in the ingestion of the heavy metals, body weight between adults and children, and exposure time (Ramteke*et al.,* (2016); Rehman*et al.,* (2017). Similar, studies conducted by Harmanescu*et al*. (2011) and Zhou *et al*. (2016) observed differences in HRI values through vegetable consumption in Banat Country in Romania, Shizhuyuan area in China.The HRIs for children were generally higher. These are signals of greater risks for children. Rehman*et al*. (2017) and Edogbo*et al*. (2020) also reported higher HRI values for children.

Like the impacts of Cd and Pb, Zn also shows higher health risks for children. The order of constituting health hazard was discovered to be Cd >Pb> Zn > Cr. This implied that Cd has higher adverse impact on human health while Cr has the least health risk in this study. Study conducted by Zhou *et al.* (2016) showed metals adverse health impact in the order of Cd >Pb> Zn > Cu > As.

Table 4: Health Risk Index for Children and Adults

	PSF			ACF		
Metals/Vegetables	***Corchorus olitorius***	***Amaranthushybridus***	***Abelmoschusesculentus***	***Corchorus olitorius***	***Amaranthushybridus***	***Abelmoschus esculentus***
Cd: Adult	6.7	5.3	4.6	6.7	1.8	2.8
Children	15	12	1	12	4	6
Cr: Adult	0.027	0.027	0.021	0.027	0.017	0.0026
Children	0.059	0.059	0.045	0.057	0.038	0.057
Pb: Adult	0.46	0.51	1.6	0.091	1.7	0.27
Children	1	1	3	2	3.7	0.57
Zn: Adult	0.77	0.77	0.7	0.73	0.73	0.77
Children	1.6	1.7	1.5	1.6	1.6	1.7

The occurrence of health effect of non-carcinogenic nature with years was also assessed with the THQ of the metals. The THQs of the metals were calculated and presented in Table 5. The THQs in all the vegetables were all less than 1 as well as the TTHQ. The principles of usage of THQ is that if THQ >1, the ingestion of such metal is likely to cause health problems with time (Edogbo*et al.*, 2020).Edogbo*et al*. in (2020) discovered THQ >1 for Cd, Cr and Pb except for Zn in their study in Challawa, Nigeria. However, their study discovered (TTHQ >1) for Zn which implied that Cd, Cr,Pb and Zn were of potential health concern in Challawa, Nigeria. This current study showed that the use of these vegetables as diet for a long time might cause the children and adults health challenges.

Table 5: Target Health Quotient (THQ) and Total THQ (TTHQ)

	PSF					ACF				
Metals/Vegetables	**Cd**	**Cr**	**Pb**	**Zn**	**TTHQ**	**Cd**	**Cr**	**Pb**	**Zn**	**TTHO**
Corchorus olitorius	0.075	0.0003	0.051	0.0017	0.128	0.075	0.0003	0.1	0.0016	0.177
Amaranthushybridus	0.06	0.0003	0.058	0.0017	0.119	0.021	0.00019	0.19	0.0016	0.213
Abelmoschusesculentus	0.052	0.00022	0.18	0.0016	0.233	0.031	0.00029	0.029	0.0017	0.062

IV. Conclusion

Vegetables are major part of human diet as they are being consumed by several families in tropical Africa especially in Nigeria. The present study was performed to assess heavy metal levels of commonly consumed vegetables and their associated health risks in AkungbaAkoko Ondo State. Generally, the heavy metals concentrations in the three selected vegetables were all below the permissible limit set by WHO / FAO. Health risk assessment showed potential health effect based on health risk index of the heavy metals under study. HRI >1 indicate health risks in relation to the ingestion of these vegetables, and the health risks were higher for children than adults. Based on the findings of this study; it is recommended that further research work should be carried out to study the levels of heavy metals in vegetables in and around Akungba-Akoko in order to maintain and/or improve measures to reduce their levels in vegetables and ultimately prevent these avoidable health problemsto the consumer of these vegetables in the near future.

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