# HEALTH RISKS ASSOCIATED WITH CONSUMPTION OF ANTI-NUTRIENTS AND ELEVATED HEAVY METALS LEVEL IN LEAFY VEGETABLES MARKETED IN UYO, AKWA IBOM STATE

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## ABSTRACT

This study investigated the health risks associated with the consumption of anti-nutrients and heavy metals laden leafy food vegetables - *Talinum triangulare*, *Murraya koenigii*, *Colocasia esculenta*, *Piper guineense* and *Amaranthus viridis* commonly marketed in Uyo, Nigeria. Standard analytical methods were used and the results indicated that apart from the rich proximate properties of the leafy vegetables, some contained anti-nutrients and elevated levels of heavy metals. *Talinum triangulare* had high moisture content (93.4%), ash (19.1%), crude fibre (0.65%), soluble oxalate (78.0 mg/100g), and Cu (19.8 mg/kg).*Murraya koenigii* was rich in crude protein (30.1%), and contained tannin (30.9 mg/100g), phytate (90.68 mg/100g) and elevated levels of Cd (5.65 mg/kg), Fe (480 mg/kg) and Pb (1.25 mg/kg). *Colocasia esculenta* was rich in total carbohydrate (64.1%) while *Piper guineense* contained high levels of crude fat, energy content and Cr (10.4%, 406 kcal/100g and 0.05 mg/kg, respectively). On the other hand, *Amaranthus viridis* was rich in HCN (49.2 mg/100g), total oxalate (86.2 mg/100g), Ni (0.20 mg/100g) and Zn (145 mg/kg). The levels of Cd and Pb in *Murraya koenigii*, *Piper guineense, Amaranthus viridis* exceeded the WHO safe limits of 0.02 mg/kg and 0.30 mg/kg, respectively. The mean EDI values of metals in all the vegetables were lower than the maximum tolerable daily intake MTDI. Hazard Quotient (HQ) of all metals analyzed were<1, indicating no health risk for adults, except for Cd in *Murraya koenigii* (3.55) and *Amaranthus viridis* (2.42); while HI was>1 for metals in *Murraya koenigii*, *Piper guineense* and *Amaranthus viridis*, an indication of adverse non-carcinogenic health risk to adult population. *Talinum triangulare* and *Colocasia esculenta* were safe for consumption (HQ and HI <1). The findings revealed that consumption of some leafy vegetables marketed in Uyo may be risky due to heavy metals contamination, hence the need for routine monitoring.

## INTRODUCTION

The FAO reports that edible wild plants form part of the diet of about one billion people, especially in the developing countries. The peculiar resource-poor setting allows no option than dependence on consumption of the rather cheap plant foods, especially the traditional leafy vegetables that supply the much-needed macro- and micro- nutrients. Vegetables possess immense health benefits attributable to their richness in vitamins, fatty acids, minerals, amino acids and dietary fibre, and various essential bioactive compounds (Siegel *et al.*, 2014). However, it is worth noting that while some of the groups of chemical compounds in vegetables have health benefits, others can be very harmful and fatal to human when consumed. These undesirable chemical substances are called anti-nutrients.

Anti-nutrients are natural compounds that interfere with the absorption of nutrients, hence reduce nutrient availability to human and animal (Agbaire, 2012; Udousoro and Akpan, 2014). These include oxalate, tannin, phytate and cyanide, among others. A much serious nutritional challenge is apparent if vegetables are cultivated in contaminated soil environment such as done in the Niger Delta region of Nigeria including Akwa Ibom State. On contaminated soil, vegetables grow and accumulate heavy metals, which can also be toxic to human health when consumed (Jolly *et al.* 2013). Heavy metals are not biodegradable, and there is no effective mechanism by which the body eliminates them. The water-soluble nature of most of these metals ensures their distribution in all parts of the body (Arora *et al.*, 2008). Despite the toxicity of some of the metals even at low concentrations, the potential for accumulation in the body makes the long-term exposure to this group of metals extremely hazardous (Ametepey *et al*., 2018). Human exposure to heavy metals has been associated with increased blood acidity, kidney damage, various cancers, interference with essential elements, and even death (Bortey-Sam *et al.* 2015).

If vegetables, for their prized value, are to fill nutritional gaps, traditional leafy vegetables should be investigated, and periodically too. The present study therefore, aims to determine the proximate compositions, levels of anti-nutrients and levels of toxic heavy metals in five leafy vegetables namely: waterleaf (*Talinum triangulare*), cocoyam leaf (*Colocasia esculenta*), curry leaf (*Murraya koenigi*i), guinea black pepper (*Piper guineense*), and African spinach (*Amaranthus viridis*); and to further assess the hazard index associated with the intake of these metals in adults.

## MATERIALS AND METHODS

### Sample Collection and Treatment

The leaves of Piper guineense, *Talinum triangulare, Colocasia esculenta, Murraya koenigii and Amaranthus viridis* were purchased from Akpan Andem market in Uyo, Akwa Ibom state, Nigeria. The samples were shredded with knife and air-dried. The dried samples were ground into powder with a mortar and pestle. The powder of each sample was sieved through 0.5 mm mesh sieve and stored in air-tight plastic containers for analysis.

### Proximate Analysis

Powdered vegetables were analyzed for their proximate composition - moisture, ash, crude fat, crude fiber, crude protein, total carbohydrate and energy using the AOAC (1990) method. Total carbohydrate and energy contents were estimated as follows:

Total Carbohydrate content =100 – (% moisture + % proteins + % lipids + % ash + % fibres) (Udousoro and Ekanem, 2013).

The caloric value = [(9 x fat) + (4 x carbohydrate) + (4 x protein)] (Agbaire and Emoyan, 2012).

### Determination of Anti-nutrient Composition

Oxalate was determined using the method described by Aina *et al.*, (2012); hydrocyanide by the spectrophotometer-alkaline picrate method described by Njoku *et al.*, 2014; tannin using the Follin-Dennis spectrophotometric method (Nair *et al.*, 2015); and phytate by the method described by Annor *et al.* (2016). The absorbance was measured with spectrometer (721D) at 500 nm.

### Determination of Heavy Metals Concentration

Precisely 2g of each sample was ashed at 550˚C in a muffle furnace. The ash was digested in 6M HCl (20 ml) on a steam bath to near dryness. It was transferred quantitatively into 50 ml volumetric flask and made up to volume with de-ionized water, and stored in plastic vials for metal analyses with Unicam 939/959 Atomic Absorption Spectrophotometer. The metals analyzed were Cd, Cr, Cu, Fe, Ni, Pb and Zn. The wavelengths used for the different metals were 228.8 nm (Cd), 57.9 nm (Cr), 324.8 nm (Cu), 248.3 nm (Fe), 232 nm (Ni), 217 nm (Pb) and 213.9 nm (Zn).

### Quality Control

Analytical grade reagents (BDH, UK) were used. Glassware and sample containers were thoroughly washed and soaked in 10% $HNO_3$ before use. Analyses were done in duplicates. Standard solutions of elements for calibration curves were prepared from 1000 ppm stock solutions of each element (Cd, Cr, Cu, Fe, Ni, Pb and Zn). Spiked recoveries were used to validate analytical procedures and the recoveries (%) obtained from equation 1.

$$\%\,Recovery = \frac{C_{spiked} - C_{unspiked}}{C_{standard}} \times 100 \qquad - \quad - \quad - \qquad \text{eqn 1}$$

where: $C_{spiked}$, $C_{unsiiked}$, and $C_{standard}$ are the concentrations in the spiked sample; unspiked sample; and concentration in standard.

The mean recoveries (%) from four replicates were 98±0.46, 80±1.98, 93±0.55, 85±0.32, 100±0.17, 86±1.01 and 94±0.11 for Cd, Cr, Cu, Fe, Ni, Pb and Zn, respectively.

Data are presented as means, standard deviation, minimum and maximum. Statistical analyses of data were processed using IBM SPSS Statistics 20 and Microsoft Excel.

**Health Risk Estimation of Heavy Metals through the Consumption of Vegetables**

**Estimated Daily Intake (EDI):**

Estimated daily intake calculated from equation 2 (Xin *et al.*, 2012) was used to evaluate the long-term exposure of adult population to heavy metals (Cd, Cr, Cu, Fe, Ni, Pb and Zn) from consumption of the studied vegetables.

$$EDI = \frac{C_{metal} \times IR \times CF \times EF \times ED}{BW \times AT} \quad - \; - \quad - \quad - \quad - \qquad \text{eqn 2}$$

where: $C_{metal}$ is the heavy metal concentration in vegetables (mg/kg); CF is the conversion factor (0.085); EF is the exposure frequency (365 days/year); ED is the exposure frequency (70 years); IR is the ingestion rate (0.55 g/days); BW is the body weight (70 kg); and AT is the averaging time (for non-carcinogens, AT= ED x 365 days).

**Hazard Quotient:**

The level of risk associated with the consumption of contaminated food can be assessed using the hazard quotient (US Environmental Protection Agency, 1989). Hazard Quotient (HQ) of individual heavy metals through the consumption of contaminated vegetables by the adult population was assessed by the ratio of estimate daily intake (EDI) to the oral reference dose (RfDo), equation 3. If the value of HQ is less than one, then the vegetable is safe for consumption by the exposed adult population; if HQ is equal to or higher than one, it is considered as not safe, implying potential health risk may occur, hence appropriate interventions and protective measures should be put in place. Oral reference doses (mg/kg/day) for metals have the values 0.001(Cd), 0.003 (Cr), 0.04 (Cu), 0.7 (Fe), 0.02 (Ni), 0.004 (Pb) and 0.3 (Zn) (Chauhan and Chauhan, 2014).

$$HQ = \frac{EDI}{RfD_o} \quad - \quad - \quad - \quad - \quad - \quad - \qquad \text{eqn 3}$$

**Hazard Index (HI):**

To assess risk to human health through consumption of more than one heavy metal, the hazard index (HI) has been developed (USEPA, 1989); it estimates the potential non-carcinogenic human risk from consumption of more than one metal. The hazard index is the sum of the hazard quotients for all heavy metals, and calculated using equation 4 (Chauhan and Chauhan, 2014).

$$HI = \sum HQ \quad - \quad - \quad - \quad - \quad - \quad - \quad - \qquad \text{eqn 4}$$

## RESULTS AND DISCUSSION

**Proximate Properties of the Vegetables**

The proximate properties of the leafy vegetables are presented in Table 1. High moisture, ash and crude fibre levels were recorded for *Talinum triangulare*; *Murraya koenigii* was rich in protein and *Colocasia esculenta* in carbohydrate. *Piper guineense* contained high levels of crude fat and energy. The mean moisture content ranged from 75.7±1.1% (*Amaranthus viridis*) to 93.4±9.8% (*Talinum triangulare*).These values are comparable to the range (79.1-83.6%) reported by Rehman *et al.*, (2013) for different edible vegetables. High moisture content of vegetables is responsible for their shorter shelf life (Kwenin, 2011). Ash measures the mineral content of foods, and vegetables are good sources of minerals. The ash content values recorded for the vegetables analyzed ranged from 8.8±0.37% in *Murraya Koenigii* to 19.1±0.46% in *Talinum triangulare*.

Table 1: Proximate composition (%) of leafy vegetables marketed in Uyo, Akwa Ibom State

| Sample | Moisture | Ash | Crude protein | Crude fat | Crude fibre | Total carbohydrate | Energy (kcal) |
|---|---|---|---|---|---|---|---|
| *Talinum triangulare* | 93.4±9.80 | 19.1±0.46 | 27.6±0.51 | 5.65±0.11 | 0.65±0.06 | 47.6±0.89 | 346±1.2 |
| *Murraya Koenigii* | 82.4±0.30 | 8.80±0.37 | 30.1±0.22 | 3.10±0.09 | 0.30±0.02 | 57.7±1.01 | 379±1.8 |
| *Colocasia esculenta* | 84.1±0.40 | 9.10±0.41 | 27.7±0.46 | 5.00±0.15 | 0.10±0.04 | 64.1±0.91 | 388±0.9 |
| *Piper guineense* | 82.8±0.10 | 11.1±0.28 | 20.0±0.25 | 10.4±0.08 | 0.35±0.08 | 58.2±0.84 | 406±2.0 |
| *Amaranthus viridis* | 75.7±1.10 | 15.7±0.52 | 27.3±0.44 | 8.55±0.16 | 0.55±0.02 | 47.9±0.75 | 378±0.8 |
| Min | 82.4 | 8.80 | 20.0 | 3.10 | 0.10 | 47.6 | 346 |
| Max | 93.4 | 19.1 | 30.1 | 10.4 | 0.65 | 64.1 | 406 |

The values are higher than 0.95-1.75% reported for vegetables grown in Zaria (Mohammed *et al.*, 2012). Some of the vegetables marketed in Uyo contained high crude protein. The crude protein values obtained varied between 20.0±0.25% in *Piper guineense* to 30.1±0.22 in *Murraya koenigii* and are higher than the values observed by Effiong *et al.*, (2009), but comparable to those reported by Rehman *et al.*, 2013. This finding indicated that the vegetables are also good sources of protein. The crude fat content of the vegetables varied from 3.10±0.09% in *Murraya koenigii* to 10.35±0.08% in *Piper guineense*; and are higher than the levels recorded for vegetables from Pakistan (Hussain *et al.*, 2009). Crude fibre ranged 0.10±0.04 (*Colocasia esculenta*) to 0.65±0.06 (*Talinum triangulare*). The values are lower compared to values obtained by other workers for edible leafy vegetables (Effiong *et al.*, 2009, Mohammed and Mann, 2012, Oulai *et al.*, 2014). Total carbohydrate content ranged from 47.6±0.89 in *Talinum triangulare* to 64.1±0.91 in *Colocasia esculenta.* Carbohydrate content of vegetables in Uyo is higher than levels (26.19-59.99%) reported by Oulai *et al.* (2014) for vegetables in Côte D'ivoire. Energy values (kcal) of vegetables marketed in Uyo were high and ranged from 346±1.2 (*Talinum triangulare*) to 406±2.0 (*Piper guineense*), higher than values (95.3-140 kcal) obtained for vegetables in Bida, Nigeria (Mohammed and Mann, 2012); an indication that the vegetables marketed in Uyo are important sources of dietary calorie.

**Anti-nutrients of Leafy Vegetables in Uyo Market**

The anti-nutrients in vegetables marketed in Uyo are listed in Table 2. Tannin content of the vegetables ranged from 1.18±0.06 mg/100g in *Talinum triangulare* to 30.9±0.10mg/100g in *Murraya koenigii.* With the exception of *Talinum triangulare*, which contained 1.18 ±0.06 mg/100g of tannin, tannin levels in other vegetables analyzed were higher than values reported by Unuofin *et al.* (2017) but lower than values (402-519.4 mg/100g) obtained by Singh *et al.* (2015). Unuofin *et al.* (2017) recorded 3.23 mg/100g of tannin in *Talinum triangulare.*). Tannins are known to inhibit the activities of such enzymes as trypsin, amylase, chymotrypsin and lipase; and interfere with iron absorption, growth rate and protein digestibility in humans (Umaru *et al.*, 2007). The hydrocyanic acid (HCN) content in the vegetable samples ranged from 0.40±0.19mg/100g to 49.2±0.34mg/100g, and was lower than the levels previously reported by Udousoro and Akpan (2014) in edible vegetables. The HCN levels in the leafy vegetables however was within the permissible limit of 200 mg /100 mg (Musa and Ogbadoyi, 2014). This indicated that HCN content in vegetables marketed in Uyo does not pose any danger to consumers.

All the vegetables in this study contained low levels of phytate. The phytate ranged from 0.02±0.02mg/100g in *Piper guineense* to 0.68±0.03mg/100g in *Murraya koenigii*.

Table 2: Anti nutrient composition in leafy vegetables (mg/100g dw) marketed in Uyo, Akwa Ibom State

| Sample | Tannin | HCN | Phytate | Soluble oxalate | Total oxalate |
|---|---|---|---|---|---|
| *Talinum triangulare* | 1.18±0.06 | 4.68±0.21 | 0.25±0.01 | 78.0±0.45 | 81.8±0.02 |
| *Murraya Koenigii* | 30.9±0.10 | 13.2±0.30 | 0.68±0.03 | 28.2±0.22 | 38.7±0.01 |
| *Colocasia esculenta* | 7.37±0.55 | 0.61±0.08 | 0.28±0.02 | 46.6±0.19 | 53.7±0.02 |
| *Piper guineense* | 4.61±0.09 | 0.40±0.19 | 0.20±0.02 | 59.8±0.31 | 72.2±0.03 |
| *Amaranthus viridis* | 11.8±0.08 | 49.2±0.34 | 0.54±0.04 | 70.4±0.30 | 86.2±0.04 |
| Min | 1.18 | 0.40 | 0.20 | 28.2 | 38.7 |
| Max | 30.9 | 49.2 | 0.68 | 78.0 | 86.2 |

dw is dry weight

This range was lower than 10.6-57.3mg/100g obtained by Singh *et al.*, (2015) hence the vegetables are wholesome and of no health risk. It has been reported that a dietary intake of 1-6% phytate over a long period reduced the bioavailability of mineral elements to monogastric animals (Unuofin *et al.*, 2017). Soluble oxalate levels obtained in this study ranged from 28.16±0.22mg/100g in *Murraya koenigii* to 78.0±0.45 mg/100g in *Talinum triangulare*, while total oxalate levels ranged from 38.7±0.01mg/100g to 86.2±0.04mg/100g in *Murraya koenigii* and *Amaranthus viridis*, respectively. The values were lower than those obtained by Singh *et al.*, (2015). Oxalate binds to Ca and the consequences of loss of Ca include impairment of blood clotting processes, degeneration of bones and teeth, and kidney stones (Unuofin *et al.*, 2017).

**Heavy Metals Burden of the Leafy Vegetables**

The levels of heavy metals (Table 3) in vegetables indicated that some might have been harvested from contaminated environment. Metals in the vegetables followed the pattern iron>zinc>copper>cadmium>lead>nickel>chromium. The study revealed the accumulation of Cr, Ni and Cu in all the vegetables analyzed, Cd and Pb in *Talinum triangulare* and *Colocasia esculenta*, Zn in *Piper guineense*, and Fe in all the vegetables (except *Murraya koenigii*), but all were below the WHO permissible limits (Table 3). However, Cd and Pb in *Murraya koenigii*, *Piper guineense* and *Amaranthus viridis* were three times higher than the safe limit, and would have negative impact on human and animal health. Excess Cd and Pb ingestion is linked with renal failure, nervous, and cardiovascular diseases (Shaheen, *et al.*, 2016). Previous studies on leafy vegetables from the eastern district of Saudi Arabian market have reported Cd, Cu, Fe, Pb, and Zn in range of 0.94-4.02, 4.24-11.4, 124-496, 2.19-5.31, and 21.5-35.5, respectively (Ali *et al.*, 2012). In another study, the lowest and highest levels of Cr, Cu, Ni, and Zn in leafy vegetables were 1.55-3.52, 9.15-18.7, 2.84-7.30, 11.5-44.6 (Rehman *et al.*, 2018).

Table 3: The level of heavy metal concentration (mg/kg, dw) in leafy vegetables marketed in Uyo, Akwa Ibom State

| Sample | Cd | Cr | Cu | Fe | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|
| *Talinum triangulare* | BDL | BDL | 19.8±0.02 | 300±4.1 | BDL | BDL | 69.1±0.16 |
| *Murraya Koenigii* | 5.65±0.02 | 0.001±0.00 | 11.6±0.03 | 480±3.9 | 0.05±0.00 | 1.25±0.03 | 62.8±0.69 |
| *Colocasia esculenta* | 0.001±0.00 | BDL | 10.9±0.09 | 249±2.6 | BDL | 0.05±0.01 | 70.2±1.00 |
| *Piper guineense* | 1.55±0.01 | 0.05±0.00 | 8.65±0.11 | 206±2.2 | 0.10±0.00 | 0.75±0.06 | 40.4±0.83 |
| *Amaranthus viridis* | 3.85±0.02 | 0.001±0.00 | 10.8±0.07 | 406±2.9 | 0.20±0.04 | 1.05±0.01 | 145±0.8 |
| Min | BDL | BDL | 8.65 | 206 | BDL | BDL | 40.4 |
| Max | 5.65 | 0.05 | 19.8 | 480 | 0.20 | 1.25 | 145 |
| **WHO (1984*, 2002) permissible limit** | **0.02** | **2.30** | **40.0** | **450*** | **1.00** | **0.30** | **60.0** |

**Non-carcinogenic Health Risk of Heavy Metals in Leafy Vegetables**

***Estimated daily intake (EDI) of heavy metals:***

EDI (mg/kg/day) of heavy metals from consumption of leafy vegetables varied with the vegetables and metals analyzed. The EDI values for Cd ranged from 0.00E+00 in *Talinum triangulare* to 3.551E-03 in *Murraya koenigii*, Cr from 0.00E+00 in *Talinum triangulare* and *Colocasia esculenta* to 1.048E-02 in *Piper guineense*, Cu from 1.359E-01 in *Piper guineense* to 3.111E-01 in *Talinum triangulare* and from 1.85E-01 in *Piper guineense* to 4.310E-01 in *Murraya koenigii* for Fe; also, for Ni from 0.00E+00 in *Talinum triangulare* and *Colocasia* *esculenta* to 6.286E-03 in *Amaranthus viridis*, Pb from 0.00E+00 in *Talinum triangulare* to 1.964E-01 in *Murraya koenigii* while a range of 8.465E-02 in *Piper guineense* to 3.038E-01 in *Amaranthus viridis* was recorded for Zn. EDI of Cd in *Amaranthus viridis*, Cr in *Piper guineense*, Cu in all vegetables, and Pb in all vegetables except *Talinum triangulare* were greater than the oral reference doses of the heavy metals; while Fe, Ni and Zn were below (Table 4). On the other hand, the EDI of all the metals that may be accumulated from the consumption of the leafy vegetables was lower than the maximum tolerable daily intake (MTDI). The mean values of EDI in vegetables decreased in the order Fe>Cu>Zn>Pb>Ni>Cr>Cd.

Table 4: Estimated daily intake of heavy metals in leafy vegetables (mg/kg/day)

| Sample | Cd | Cr | Cu | Fe | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|
| *Talinum triangulare* | 0.00E+00 | 0.00E+00 | 3.111E-01 | 2.694E-01 | 0.00E+00 | 0.00E+00 | 1.448E-01 |
| *Murraya Koenigii* | 3.551 E-03 | 2.100 E-04 | 1.823E-01 | 4.310E-01 | 1.571 E-03 | 1.964E-01 | 1.316E-01 |
| *Colocasia esculenta* | 6.290E-07 | 0.00E+00 | 1.713E-01 | 2.236 E-01 | 0.00E+00 | 7.857E-03 | 1.471E-01 |
| *Piper guineense* | 9.740E-04 | 1.048E-02 | 1.359E-01 | 1.850E-01 | 3.143 E-03 | 1.179E-01 | 8.465E-02 |
| *Amaranthus viridis* | 2.420E-03 | 2.100E-04 | 1.700E-01 | 3.646E-01 | 6.286E-03 | 1.650E-01 | 3.040E-01 |
| Min | 0.00E+00 | 0.00E+00 | 1.359E-01 | 1.850E-01 | 0.00E+00 | 0.00E+00 | 8.465E-02 |
| Max | 3.551E-03 | 0.010476 | 0.311143 | 4.310E-01 | 6.286E-03 | 1.964E-01 | 3.040E-01 |
| Mean | 1.390E-03 | 2.180E-03 | 1.940E-01 | 2.950E-01 | 2.200E-03 | 9.74E-02 | 1.620E-01 |
| SD | 0.001563 | 0.004639 | 0.067708 | 0.10149 | 0.00263 | 0.08986 | 0.08297 |
| **RfDo*** | **0.001** | **0.003** | **0.04** | **0.7** | **0.02** | **0.004** | **0.3** |
| **MTDI**** | **0.021** | **0.2** | **30** | **-** | **0.3** | **0.21** | **60** |

* (Chauhan and Chauhan, 2014) ** (Shaheen *et al*., 2016)

***Hazard Quotient and Hazard Index:***

Hazard quotient (HQ) and Hazard index (HI) were used to evaluate the non-carcinogenic health effect of metals (Cd, Cr, Cu, Fe, Ni, Pb and Zn) through consumption of the leafy vegetables. When HQ or HI>1, the population would be exposed to adverse health effects (Shaheen, 2016). The HQ of individual heavy metals (Table 5) and the HI values of the combined non-carcinogenic effects of multiple heavy metals in each vegetable are presented in Table 5.

The HQ of Cd in *Murraya koenigii* (curry leaf, HQ=3.55) and *Amaranthus viridis* (African spinach, HQ=2.42) was >1, suggesting the population could be exposed to non-carcinogenic health risk through ingestion of the vegetables. The mean HQ of metals in the vegetables investigated decreased in the order Cd>Fe>Cu>Zn>Pb>Ni>Cr (Table 5).

Table 5: Hazard quotient of leafy vegetables

| Sample | HQ | | | | | | | HI |
|---|---|---|---|---|---|---|---|---|
| | Cd | Cr | Cu | Fe | Ni | Pb | Zn | |
| *Talinum triangulare* | 0 | 0 | 0.31114 | 0.26939 | 0 | 0 | 0.14478 | 0.72532 |
| *Murraya Koenigii* | 3.55143 | 0.00021 | 0.18229 | 0.43102 | 0.00157 | 0.19643 | 0.13158 | 4.49452 |
| *Colocasia esculenta* | 0.00063 | 0 | 0.17129 | 0.22359 | 0 | 0.00786 | 0.14709 | 0.55045 |
| *Piper guineense* | 0.97429 | 0.01048 | 0.13593 | 0.18498 | 0.00314 | 0.11786 | 0.08465 | 1.51132 |
| *Amaranthus viridis* | 2.42 | 0.00021 | 0.16971 | 0.36457 | 0.00629 | 0.1650 | 0.30381 | 3.42959 |
| Min | 0 | 0 | 0.13593 | 0.18498 | 0 | 0 | 0.08465 | 0.55045 |
| Max | 3.55143 | 0.01048 | 0.31114 | 0.43102 | 0.00629 | 0.19643 | 0.30381 | 4.49452 |
| Mean | 1.38927 | 0.00214 | 0.19407 | 0.29471 | 0.0022 | 0.09743 | 0.16238 | 2.14224 |
| SD | 1.56269 | 0.00464 | 0.06771 | 0.10149 | 0.00263 | 0.08986 | 0.08297 | 1.74141 |

The HI values of heavy metals in vegetables ranged from 0.55 in *Talinum triangulare* to 4.49 in *Murraya koenigii*. The HI recorded in *Murraya koenigii* (4.49), *Piper guineense* (1.51) and *Amaranthus viridis* (3.43), indicated that the combined contribution of heavy metals (Cd, Cr, Cu, Fe, Ni, Pb and Zn) from ingestion of contaminated vegetables could result in aggregate health risk

Therefore, the high HI values of heavy metals in *Murraya koenigii* (curry leaf), *Piper guineense* (guinea black pepper) and *Amaranthus viridis* (African spinach) have great probability to pose health risk to the adult consumers. *Talinum triangulare* (HQ=0.72) and *Colocasia esculenta* (HQ=0.55), (HI<1) were found safe for consumption. The HI decreased in the order *Murraya koenigii*>*Amaranthus viridis*>*Piper guineense*>*Talinum triangulare*>*Colocasia esculenta*.

## CONCLUSION AND RECOMMENDATION

Study findings have revealed the varied levels of nutrients, anti-nutrients and heavy metals in the vegetables analyzed. It also shows that the vegetables are rich sources of minerals, protein, fat, carbohydrate and energy. Very low crude fibre (0.10-0.65%) and high moisture content (82.4-93.9) were recorded for the vegetable samples. Low concentrations of HCN (0.40 mg/100g) and phytate (0.20mg/100g) were found in *Piper guineense*, oxalate – [soluble (28.2) and total (38.7)] in *Murraya koenigii*, and Tannin (1.18 mg/100g) in *Talinum triangulare*. *Talinum triangulare* contained very low levels of Cd, Cr, Ni, and Pb while *Piper guineense* had minimal concentrations of Cu, Fe, and Zn. Cr, Cu, Ni, and Fe. In all cases except *Murraya koenigii*, the metals were below WHO safe limits for vegetables. The estimated daily intake (EDI) of metals through the ingestion of all the vegetables in the study were found to be lower than the maximum tolerable daily intake (MTDI). The order of decrease for EDI was Fe>Cu>Zn>Pb>Ni>Cr>Cd. Hazard quotient (HQ) of Cd through consumption of *Murraya koenigii* and *Amaranthus viridis*, the hazard index (HI) of combined contribution from consumption of all metals in *Murraya koenigii*, *Piper guineense* and *Amaranthus viridis* were >1. This suggests that the adult consumers in Uyo, Akwa Ibom State of Nigeria are exposed to non-carcinogenic adverse health risk from consumption of the three vegetables. The research work has further revealed that the vegetables though important sources of nutrients contain varying levels of anti-nutrients and heavy metals. The later may reduce the quality of some of the vegetables, as well as pose health risk. There is therefore need for continuous monitoring of edible leafy vegetables in a constantly impacted human environment

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