BAJOPAS Volume 15 Number 1, June, 2022
http://dx.doi.org/10.4314/bajopas.v15i1.17

Bayero Journal of Pure and Applied Sciences, 15(1): 125 - 130
Received: March, 2022
Accepted: April, 2022
ISSN 2006 – 6996

HEALTH RISK INDICES ASSOCIATED WITH HEAVY METALS FROM VEGETABLES CULTIVATED IN TSAGERO DISTRICT, RIMI LOCAL GOVERNMENT AREA, KATSINA STATE, NIGERIA

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ABSTRACT
Local preservation of vegetables involves drying to enhance shelf life. The drying processes could, in turn, contaminate the vegetables with environmental heavy metals. Ingestion of foods contaminated with heavy metals may lead to an increase in the chances of incurring cancer and other health disorders in the consumer population. This study investigated heavy metals contaminations and health risks associated with the consumption vegetables from Turaji, Tsagero District, Rimi Local Government Katsina State, North west Nigeria. The vegetables were three samples of Solanum lycopersicum L. (tomato) as fresh tomato, tomatoes sun-dried along tarred road side, and tomatoes air-dried on farmland soil; three samples of Capsicum annuum (sweet pepper) as fresh sweet pepper, sweet pepper sun-dried along tarred road side and sweet pepper air-dried on farmland soil. The samples were grinded, ashed and digested with HNO_3 and HCl separately using standard methods. The heavy metals (Cu, Ni, Fe, Cr, Cd, Mn, Zn, and Pb) contents of the samples were analyzed using atomic absorption spectrophotometry. Daily intake, non-carcinogenic and carcinogenic risks as well as hazard indices of the heavy metals were determined. Results of the study showed that the vegetables analyzed generally have low levels of the heavy metals, with Ni being below detection level (BDL) in all the samples. All of the detected heavy metals concentrations were below the maximum permissible limits as set by the regulatory agencies. The calculated target hazard quotient (THQ) Health risk indices (HRIs) of the evaluated heavy metals in all the samples were therefore, less than 1. The Incremental Life time Cancer Risk (ILCR) to the population from consumption of the samples lies within the safe limit ($\leq 10^{-4}$). From the results, these vegetables are hence, safe for human consumption.
Keywords: Heavy metals, Katsina, Nigeria, Health risk, Vegetables.

INTRODUCTION

Vegetables are great sources of nutrients that are essential for human nutrition and health. In particular, they are source of vitamin C, folic acid, minerals, niacin, thiamine, pyridoxine and dietary fiber. These nutrients possess enormous biochemical roles including antioxidative effects (Siegel *et al*., 2014). Mostly lethal to humans at low concentrations, heavy metals are natural components of the Earth's crust metallic elements with relatively high density. One of the most essential aspects of food quality assurance is heavy metal contamination of the food items (Wang *et al.,* 2005). Vegetables absorb metals from contaminated soils; besides from deposits on the parts of the vegetables exposed to polluted air (Haiyan and Stuanes 2003). Heavy metals can be readily absorbed by vegetable roots, and can be accumulated in the edible parts of vegetables at high levels, regardless of the heavy metal concentration in the soil (Jolly *et al.,* 2013). Anthropogenic activities are a major source of heavy metal contamination which includes agricultural crop residue, emission from industries and vehicular emissions. Generally, wastewater contains significant amounts of useful nutrients and heavy metals that create opportunities and problems in terms of agricultural production (Chen *et al.,* 2005).

The consumption of vegetables contaminated with heavy metals may pose a risk to the health of humans. Heavy metals are deleterious due to their long biological half-lives, non-biodegradable nature, and their ability to accumulate in different body parts (Heidarieh *et al.,* 2013).

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). 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 (Huang *et al.,* 2007; Liu *et al.,* 2013; Bortey-Sam *et al.,* 2015).

Heavy metals are deleterious due to their long biological half-lives, non-biodegradable nature, and their ability to accumulate in different body parts (Heidarieh *et al*. 2013). Therefore, consumption of vegetables contaminated with heavy metals may pose a grave risk. This study determined the levels of some selected heavy metals concentration and their associated human health risk in vegetables from Turaji, Tsagero ward, Rimi Local Government, Katsina State.

MATERIALS AND METHODS

Study area

The study was carried out during irrigation time of 2022 in Turaji, Tsagero ward, Rimi local government area of Katsina state Nigeria. The area is located between latitude 12.530° N and longitude 7.460° E, in the North West zone of Nigeria. It is among the location associated with the water body of the Ajiwa Dam where irrigation farming is taking place.

Sampling

Vegetables were obtained from a farmer that preserves the samples through drying in the study area. The vegetables were designated as indicated Table 1.

Table 1: Acronyms of the Assessed Samples

***Solanum lycopersicum* (tomato)**	**Acronym**	***Capsicum annum* (sweet pepper)**	**Acronym**
fresh	SLF	fresh	CAF
air dried under the shade	SLAD	air dried under the shade	CAAD
sun dried along the road side	SLSD	sun dried along the road side	CASD

Heavy Metals Determination

Heavy metals in the samples were determined using atomic absorption spectrophotometry (AA210RAP BUCK Atomic Absorption Spectrometer flame emission spectrometer filter GLA-4B Graphite furnace), according to standard methods (AOAC, 1995) after ashing and digestion as described by Yaradua *et al.* (2019a) and the results were presented in mg/kg.

Determination of daily intake of heavy metals (DIM)

The daily intake of metals was calculated using the following equation:

$$DIM = \frac{C_{metal} \times C_{factor} \times D_{intake}}{B_{weight}} \text{ ....equation (1)}$$

Where, Cmetal, Cfactor, Dintake and Bweight represent the heavy metal concentrations in the samples, the conversion factor, the daily intake of the sample and the average body weight, respectively. The conversion factor (CF) of 0.085 (Jan *et al*., 2010) was used for the conversion of the samples to dry weights. The average daily intake of the samples were 0.527 kg person^{-1} d^{-1} (Bhalkhair and Ashraf, 2015) and the average body weight for the adult and children population was 60 kg (Orisakwe *et al*., 2015) and 24 kg (*Ekhator et al*., 2017) respectively; these values were used for the calculation of HRI as well.

Determination of non-carcinogenic risk index

The non-carcinogenic risk assessments are performed in order to estimate the potential health risks of pollutants using the target hazard quotient (THQ). The target hazard quotient values through the consumption of vegetables were assessed for each heavy metal and calculated using the standard assumption for an integrate USEPA risk analysis.

THQ=DIM/RfD……………………………….eqn.2

where: DIM is the daily intake of metals (Mg/Kg/person) RfD is the oral reference dose (mg kg^{-1} d^{-1}) RfDs are based on 0.04, 0.02, 0.03, 0.7, 0.003, 0.001, 0.014, 0.3 and 0.004 mg kg^{-1} d^{-1} for Cu, Ni, Fe, Cr, Cd, Mn, Zn, and Pb, respectively (USEPA, 2011). It should be noted that if the THQ value is less ,than 1, the exposed population is unlikely to experience adverse health hazard. Conversely, if the THQ is equal to or greater than 1 (≥ 1), there are chances that potential health risk may occur. Thus, interventions and protective approach could be taken (Wang *et al*., 2005).

Determination of hazard index (HI)

In order to estimate the risk to human health with more than one heavy metal (HM), the hazard index (HI) developed by the USEPA (2005) was adopted. The hazard index is the sum of the hazard quotients for all the heavy metals evaluated(Guerra *et al*., 2012).

HI=THQ1+THQ2+⋯+THQn………………eqn. (3)

Determination of carcinogenic risk

Carcinogenic metals (Ni, Cr, Cd, and Pb) have all been associated with DNA damage through deletion, base pair mutation and/or attack by oxygen radical on animal's DNA (Tchounwou, *et al.,* 2012). Carcinogenic risk (CR) indicates an incremental chance of an individual developing cancer over an extended life time due to exposure to a potential carcinogen. The risk of incurring cancer by a consumer of heavy metals - Ni, Cr, Cd, and Pb contaminated vegetable was obtained using cancer slope factor (CSF), provided by (USEPA, 2000).

CR = CSF × EDI ………………………… eqn.4

Where, CSF is the oral carcinogenic slope factor of 0.0085, 0.38, 0.5, 1.7 (mg/kg/day) $^{-1}$ for Pb, Cd, Cr, and Ni respective (Kamunda*et al*., 2016; Yang *et al*., 2018; Javed and Usmani, 2016). EDI is the estimated daily intake of heavy metals. Acceptable risk levels for carcinogens range from 10^{-4} (risk of developing cancer over a human lifetime is 1 in 10000) to 10^{-6} (risk of developing cancer over a human lifetime is 1 in 1000000).

RESULTS AND DISCUSSION

The results for the mean concentrations of the evaluated heavy metals in the study samples are displayed in Table 1. From the results, the mean values of the metals that were detected in the samples were within levels viewed as acceptable by the regulatory agencies (WHO, 2004; FAO/WHO, 2011) for heavy metals in fruits vegetables. Also as can be seen from the Table, the heavy metal Ni was below detection level (BDL) in all the samples analysed,while the heavy metal Pb was only detected in the SLAD sample (Table 1). Previous studies conducted on heavy metals in pepper, tomato and onion have reported similar observation of Ni values below detection levels, but differed with the current study by reporting the mean concentrations of the heavy metal Pb to beabove permissible values (Yaradua *et al*., 2019a, b; Yaradua *et al*., 2020).

Table 2: Mean concentration of heavy metals (mg/kg) invegetable samples cultivated in Tsagero district, Rimi local government area Katsina state, Nigeria

Sample	Heavy metal							
	Cu	Fe	Mn	Zn	Pb	Cd	Cr	Ni
CAAD	0.207±0.005	6.630±0.210	0.227±0.009	0.551±0.004	BDL	0.028±0.006	0.272± 0.008	BDL
CASD	0.150±0.008	3.630±0.033	0.261±0.008	0.513±0.005	BDL	0.025±0.005	0.181± 0.008	BDL
SLAD	0.437±0.005	12.320±0.185	0.135±0.007	0.833±0.004	0.163± 0.028	0.026±0.005	0.062± 0.025	BDL
SLSD	0.153±0.005	16.130±0.212	0.063±0.005	0.371±0.005	BDL	0.024±0.006	BDL	BDL
CAF	0.407±0.005	3.390±0.099	0.073±0.005	0.625±0.005	BDL	0.023±0.006	BDL	BDL
SLF	0.183±0.005	1.263±0.091	0.058±0.006	0.317±0.005	BDL	0.027±0.005	BDL	BDL

Values are expressed as Mean ± Standard deviation.

The estimated DIM in children and adult population from consumption of the vegetable samples are displayed in Tables 2 and 3. The results were similar to DIM values reported for fruit vegetables samples in studies from Katsina state, Nigeria (Yaradua *et al*., 2019a, b; Yaradua *et al*., 2020). From the tables the estimated daily intake of the heavy metals in the consumer population were lower than the tolerable daily intake limit set by the USEPA (2005) in the samples.

Table 3: Daily metal intake in adults from consumption of the vegetable samples cultivated in Tsagero district, Rimi local government area Katsina state, Nigeria

Samples	Cu	Fe	Mn	Zn	Pb	Cd	Cr	Ni
CAAD	1.545E-04	4.950E-03	1.695E-04	4.114E-04	BDL	2.090E-05	2.031E-04	BDL
CASD	1.120E-04	2.710E-03	1.995E-04	3.830E-04	BDL	1.867E-05	1.351E-04	BDL
SLAD	3.263E-04	9.198E-03	1.008E-04	6.219E-04	1.217E-04	1.941E-05	4.629E-05	BDL
SLSD	1.142E-04	0.012	4.704E-05	2.770E-04	BDL	1.792E-05	BDL	BDL
CAF	3.039E-04	2.531E-03	5.450E-05	4.666E-04	BDL	1.717E-05	BDL	BDL
SLF	1.366E-04	9.429E-04	4.330E-05	2.367E-04	BDL	2.016E-05	BDL	BDL

Values are expressed as Mean ± Standard deviation.

Table 4: Daily metal intake in children from consumption of the vegetable samples cultivated in Tsagero district, Rimi local government area Katsina state, Nigeria

Samples	Cu	Fe	Mn	Zn	Pb	Cd	Cr	Ni
CAAD	3.864E-04	0.012	4.237E-04	1.028E-03	BDL	5.226E-05	5.077E-04	BDL
CASD	2.800E-04	6.775E-03	4.872E-04	9.575E-04	BDL	4.666E-05	3.378E-04	BDL
SLAD	8.156E-04	0.023	2.520E-04	1.555E-03	3.042E-04	4.853E-05	1.157E-04	BDL
SLSD	2.856E-04	0.030	1.176E-04	6.925E-04	BDL	4.480E-05	BDL	BDL
CAF	7.597E-04	6.327E-03	1.363E-04	1.167E-03	BDL	4.293E-05	BDL	BDL
SLF	3.416E-04	2.357E-03	1.083E-04	5.917E-04	BDL	5.039E-05	BDL	BDL

Values are expressed as Mean ± Standard deviation.

To estimate the heavy metal non-cancer health risks that may arise from the consumption of the samples to the population, the target hazard quotient (THQ) and hazard index (HI) were used. From Tables 4 and 5, the results of the THQs and HIs for both adults and children were all below 1, an indication that there was no potential health risk to the children and adult population. These results were in concordat with what was earlier reported for vegetable samples from Katsina state (Yaradua *et al*., 2019a, b; Yaradua *et al*., 2020). The THQ and HI in all the samples differ from the THQ and HI values reported for vegetables from Tamale metropolis, Ghana that showed that the THQ and HI for both adult and children exceeded 1 (Ametepey *et al.,* 2018) and the THQ and HI values of more than 1 for cabbage and tomato from Mojo, Ethiopia (Gebeyehu and Bayissa, 2020).

Table 5: Target hazard quotient (THQ) and health risk index (HRI) in adults from consumption of the vegetable samples cultivated in Tsagero district, Rimi local government area Katsina state, Nigeria

Sample	THQ								HRI
	Cu	Fe	Mn	Zn	Pb	Cd	Cr	Ni	
CAAD	3.864E-03	7.071E-03	0.012	1.371E-03	BDL	4.181E-05	6.769E-04	BDL	0.025
CASD	2.800E-03	3.872E-03	0.014	1.277E-03	BDL	3.738E-05	4.504E-04	BDL	0.022
SLAD	8.157E-03	0.013	7.199E-03	2.073E-03	2.028E-04	3.882E-05	1.543E-04	BDL	0.031
SLSD	2.856E-03	0.017	3.360E-03	9.233E-04	BDL	3.584E-05	BDL	BDL	0.024
CAF	7.597E-03	3.616E-03	3.893E-03	1.555E-03	BDL	3.434E-05	BDL	BDL	0.017
SLF	3.416E-03	1.347E-03	3.093E-03	7.889E-04	BDL	4.032E-05	BDL	BDL	8.685E-03

Values are expressed as Mean ± Standard deviation.

Table 5 Target hazard quotient (THQ) and health risk index (HRI) in children from consumption of the vegetable samples cultivated in Tsagero district, Rimi local government area Katsina state, Nigeria

Sample	THQ								HRI
	Cu	Fe	Mn	Zn	Pb	Cd	Cr	Ni	
CAAD	9.659E-03	0.018	0.030	3.428E-03	BDL	1.045E-04	1.692E-03	BDL	0.063
CASD	6.999E-03	9.679E-03	0.033	3.192E-03	BDL	9.332E-05	1.126E-03	BDL	0.056
SLAD	0.020	0.033	0.018	5.183E-03	5.071E-04	9.706E-05	3.857E-04	BDL	0.078
SLSD	7.139E-03	0.043	8.399E-03	2.308E-03	BDL	8.959E-05	BDL	BDL	0.061
CAF	0.019	9.039E-03	9.732E-03	3.888E-03	BDL	8.586E-05	BDL	BDL	0.042
SLF	8.539E-03	3.368E-03	7.733E-03	1.972E-03	BDL	1.008E-04	BDL	BDL	0.022

Values are expressed as Mean ± Standard deviation.

The possibility of cancer risks to the population in the present study were estimated using the incremental lifetime cancer risk (ILCR), (Liu *et al*., 2013). The risk assessment for carcinogenic exposure effect has revealed that the incremental lifetime cancer risk (ILCR) and the cumulative lifetime cancer risks (∑ILCR) were all within the safe limit for cancer in the children and the adults population for all the vegetable samples evaluated (Tables 6 and 7). The results are similar to the results for vegetables from some selected communities from ONELGA Rivers State, Nigeria that reported non carcinogenic cancer risks from the vegetable samples in the study (Ogbo and Patrick-Iwuanyanwu, 2019), but differ from carcinogenic risk vegetables reported in earlier studies from Katsina state, Nigeria (Yaradua *et al*., 2019a, b; Yaradua *et al*., 2020).

Table 6 Incremental lifetime cancer risk (ILCR) in adults from consumption of the vegetable samples cultivated in Tsagero district, Rimi local government area Katsina state, Nigeria

Samples	ILCR			∑ILCR
	Pb	Cd	Cr	
CAAD	BDL	7.944E-06	1.015E-04	1.095E-04
CASD	BDL	7.093E-06	6.757E-05	7.466E-05
SLAD	1.034E-06	7.376E-06	2.314E-05	3.156E-05
SLSD	BDL	6.809E-06	BDL	6.809E-06
CAF	BDL	6.525E-06	BDL	6.525E-06
SLF	BDL	7.660E-06	BDL	7.660E-06

Values are expressed as Mean ± Standard deviation.

Table 7 Incremental lifetime cancer risk (ILCR) in children from consumption of the vegetable samples cultivated in Tsagero district, Rimi local government area Katsina state, Nigeria

Samples	ILCR			∑ILCR
	Pb	Cd	Cr	
CAAD	BDL	3.972E-05	8.462E-04	8.859E-04
CASD	BDL	3.546E-05	5.631E-04	5.985E-04
SLAD	4.310E-06	3.688E-05	1.929E-04	2.341E-04
SLSD	BDL	3.404E-05	BDL	3.404E-05
CAF	BDL	3.263E-05	BDL	3.263E-05
SLF	BDL	3.830E-05	BDL	3.830E-05

Values are expressed as Mean ± Standard deviation.

CONCLUSION

Health risks associated with the consumption of heavy metals in *Capsicum annum* and *Solanum lycopersicum* cultivated in Turaji, Tsagero District, Rimi Local Government Katsina State, North west Nigeria were investigated. Results of the study showed all of the detected heavy metals concentrations were below the permissible limits as set by the regulatory agencies. The calculated target hazard quotient (THQ) Health risk indices (HRIs) of the evaluated heavy metals in all the samples were less than 1 an indication of non cancer risk to the consumer population, With the Incremental Life time Cancer Risk (ILCR) to the population from consumption of the samples within the safe limit ($\leq 10^{-4}$). Thus it can be concluded that the study vegetables are safe for consumption to the population as par the evaluated heavy metals.

Conflict of interest

Authors declare no conflict of interest.

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