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Full Length Research Paper

Heavy metal levels in selected green leafy vegetables obtained from Katsina central market, Katsina, North-western Nigeria

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The levels of Lead (Pb), Cadmium (Cd), Iron (Fe), Zinc (Zn) and Copper (Cu) were determined in four different samples of vegetables purchased from Katsina central market using atomic absorption spectrometer. The mean concentrations of metals ranged from 0.071 mg/kg Pb to 0.632 mg/kg Cu. The relative abundance of metals in vegetables followed the sequence Cu (0.483 mg/kg) > Zn (0.268 mg/kg) > Fe (0.260 mg/kg) > Pb (0.095 mg/kg). The levels of Pb and other metals were below the FAO/WHO recommended limits for metals in vegetables. Low concentrations of Pb and absence of Cd in all the samples are indications that these plants contribute less toxic effects of metals. The results showed that, these vegetables are the main sources of essential trace elements. The daily human intakes of metals have also been computed and were observed below recommended values by the FAO/WHO.

Key words: Heavy metals, vegetables, Katsina, spectrometry.

INTRODUCTION

The term vegetable applies to edible part of the plant that stores food in roots, stems, or leaves. Vegetables are green and leafy-like in appearance bearing edible stems or leaves and roots of plants (Sharma, 2004). Vegetables constitute essential diet components by contributing carbohydrates, proteins, vitamins, iron, calcium and other nutrients that are in short supply.

Vegetables also contain both essential and toxic elements over a wide range of concentrations. Metals in vegetables pose a direct threat to human health. Plants and vegetables take up elements by absorbing them from contaminated soils and waste water used for irrigating them as well as from deposits on different parts of the plants exposed to the air from polluted environment (Funtua et al., 2008).

Vegetables, especially those of leafy vegetables grown in heavy metals contaminated soils, accumulate higher amounts of metals than those grown in uncontaminated soils because of the fact that they absorb these metals through their roots (Muhammad et al., 2008). Vegetables accumulate heavy metals in their edible and non-edible parts. Absorption capacity of heavy metals depends upon the nature of vegetables and some of them have a greater potential to accumulate higher concentrations of heavy metals than others (Akan et al., 2009). Atayese et al. (2009) investigated heavy metal contamination of Amaranthus grown along major highways in Lagos, Nigeria. Ladipo and Doherty (2011) studied heavy metal levels in vegetables from selected markets in Lagos, Nigeria.

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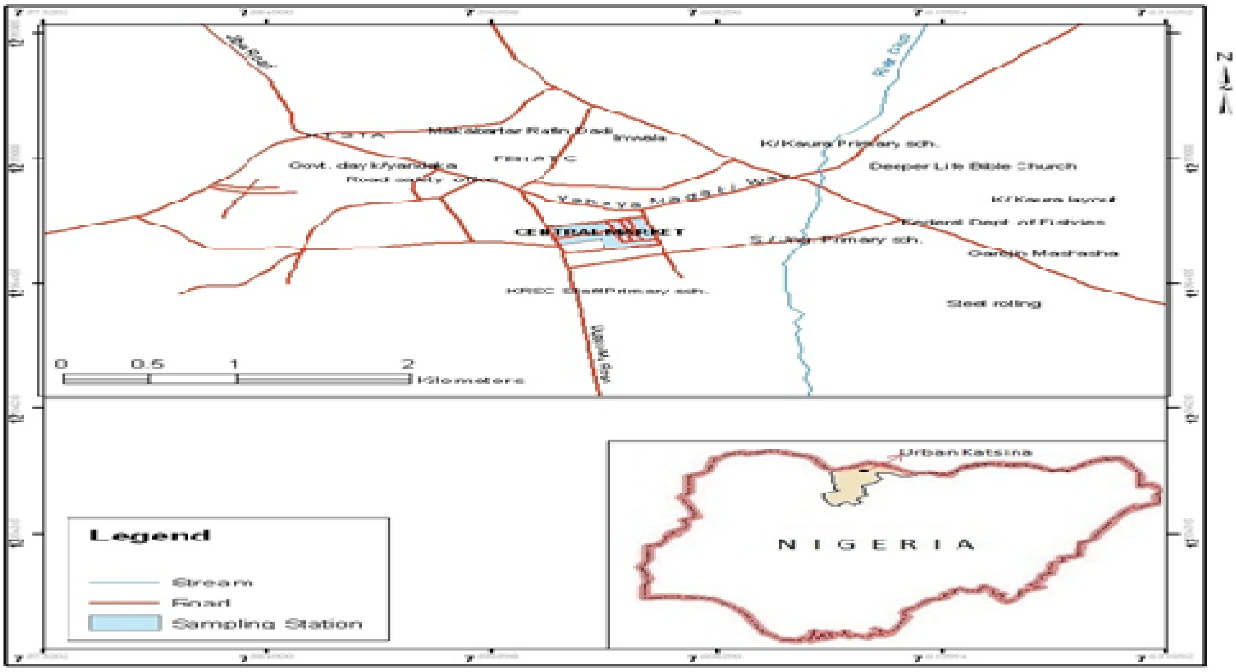

Figure 1. Map of the studied area showing sampling station (Katsina central market).

The use of green leafy vegetables for the preparation of soups cuts across different cultures in Nigeria and other parts of West Africa (Ladipo and Doherty, 2011; Akan et al., 2009). Intake of vegetables is an important path of heavy metal toxicity to human being and based on persistent nature and cumulative behaviour as well as the probability of potential toxicity effects of heavy metals as a result of consumption of leafy vegetables, this study was carried out to determine the dry matter levels of Pb, Cd, Fe, Zn, and Cu in some selected vegetables that are consumed regularly by inhabitants in Katsina metropolis. These vegetables serve as food sources and thus offer rapid and ideal means of providing adequate vitamins, mineral salts, trace essential elements and fibre as suggested by Ihekeronye and Ngoddy (1995).

MATERIALS AND METHODS

Chemicals of analytical grade purity and distilled deionized water were used. All glass wares and plastic containers used were washed with detergent solution followed by (20% v/v) nitric acid and then rinsed with tap water and finally with distilled deionized water. Also, standard solutions of the metal salts and other reagents were prepared.

Study area

The study area covered in this research was Katsina, a city in North-western Nigeria. It is the capital of Katsina state, one of Nigeria's 36 states. It is also the headquarters of Katsina Local Government Area. The city is located on the latitude 12° 59′ N and longitude 7° 36′ E with an average area of 142 km^2 and a population of 318,459 as of 2006 (Figure 1).

Sample and sampling

A total of 120 samples of four different vegetables that is, Foetid cassia (*Cassia tora*), Kenaf (*Hibiscus cannabinus*), Tossa jute (*Corchorus olitorius*) and Wild jute (*Corchorus tridens*) were purchased from Katsina Central Market.

Sample treatment

The vegetables were washed with 20% (v/v) nitric acid and then rinsed with distilled deionized water. These samples were cut into pieces with knife and were air-dried in the laboratory for 4 days before oven-dried at 105°C for about 24 h. The samples were crushed into powder in a mortar with a pestle. The samples were then sieved through a 2 mm nylon sieve and transfer into a labeled polyethylene container for analysis.

Sample digestion

The procedure according to Awofolu (2005) was used for digestion of plant sample. 0.5 g of sieved leaf samples were then weighed into 100 cm^3 beaker. A mixture of 5 cm^3 concentrated HNO_3 and 2 cm^3 $HClO_4$ were added to dissolve the sample. The beaker was heated at moderate temperature of 110°C on a hot plate for 1 h in a fume hood until the content was about 2 cm^3.

The digest was allowed to cool, filtered into 50 cm^3 standard volumetric flask and mad e up to the mark with distilled deionized water.

Table 1. Concentrations of the heavy metals (mg/kg) in green leafy vegetables.

Plant sample	Pb	Cd	Fe	Zn	Cu
Foetid Cassia	0.118 ± 0.071	ND	0.242 ± 0.050	0.227 ± 0.060	0.333 ± 0.034
Kenaf	0.095 ± 0.000	ND	0.250 ± 0.000	0.250 ± 0.020	0.467 ± 0.000
Tossa jute	0.071 ± 0.022	ND	0.334 ± 0.014	0.221 ± 0.031	0.500 ± 0.017
Wild jute	0.095 ± 0.010	ND	0.214 ± 0.050	0.375 ± 0.015	0.632 ± 0.022
Mean ± SD	0.095 ± 0.026		0.260 ± 0.029	0.268 ± 0.032	0.483 ± 0.018
Range	0.071 - 0.118		0.214 - 0.334	0.221 - 0.375	0.333 - 0.632
FAO/WHO Safe limit (2001) [a]	0.300	0.2	425.00	99.40	73.00

ND = Not detected; SD = standard deviation; source: *a* = Adu et al. (2012).

Sample analysis

A serial dilution method was used to prepared the working standards and the concentrations of the metals in each sample digest were determined using Atomic Absorption Spectrophotometer (Buck Model 210 VGP) equipped with a digital readout system.

Data analysis

Data obtained were analyzed using Microsoft Excel and results were expressed as mean ± standard deviation.

Daily intake of heavy metals from vegetables

The daily intake of heavy metals through the consumption of vegetables tested was calculated according to the equation (Cui et al., 2004):

Daily intake of metals (DIM) = DVC × VMC

DVC = daily vegetable consumption; VMC = mean vegetable metal concentrations (mg/day, fresh weight).

Where daily vegetable consumption was taken as 98 g of vegetables per person per day as set by the FAO/WHO (1999), for heavy metal intake based on body weight for an average adult (60 kg body weight).

RESULTS AND DISCUSSION

The metal contents obtained from each vegetable from the central market site are listed in Table 1. Among the 4 different vegetables examined, Wild jute recorded highest level of Cu and Zn which are 0.632 mg/kg and 0.375 mg/kg, respectively. Tossa jute recorded highest level of Fe which is 0.334 mg/kg and Foetid cassia recorded highest level of Pb which is 0.118 mg/kg. Similarly, Tossa jute recorded the lowest mean levels for lead (0.071 mg/kg) and zinc (0.221 mg/kg).

The mean levels of the metals examined in Foetid cassia, Kenaf and Tossa jute samples were found to be in the order: Cu > Fe > Zn > Pb. These trends suggest that Foetid cassia, Kenaf and Tossa jute samples have a high retention capacity for Cu followed by Fe and then Zn and Pb. However, the mean levels of the metals in Wild jute are found to be in the order: Cu > Zn > Fe > Pb. This trend indicates that Wild jute has a high retention capacity for Cu followed by Zn and then Fe and Pb. However, it could be observed that all vegetables have higher retention capacities for essential metals (Cu, Zn, and Fe) than the toxic ones (Pb and Cd).

Pb is a toxic element that can be harmful to plants, although plants usually show ability to accumulate large amounts of lead without visible changes in their appearance or yield. In many plants, Pb accumulation can exceed several hundred times the threshold of maximum level permissible for human consumption (Muhammad et al., 2008). The high levels of Pb in some plants may probably be attributed to pollutants in irrigation water, farm soil or due to pollution from the highways traffic (Qui et al., 2000). Wong et al. (1996) reported that Chinese cabbage picks up Pb more readily compared to other heavy metals such as Cd, Cu, Ni, and Zn. The level of Pb in this study is found highest in the leaf of Foetid cassia (0.118 mg/kg) and lowest in the leaf of Tossa jute (0.071 mg/kg). Both Kenaf and Wild jute have recorded the same Pb content of 0.095 mg/kg in their leaves. The levels of Pb reported in this study are higher when compared to that reported in the leaves of lettuce (0.01 mg/kg) by Adu et al. (2012). The Pb contents of the plants in this study are lower when compared to the FAO/WHO (2001) safe limit of 0.3 mg/kg. The study showed that, in the plant, Pb contents are within the permissible limit. Thus, the Pb level in the leafy parts of the vegetables examined seems not to be alarming except in a case of excessive consumption.

Cd is a non-essential in foods and natural waters and it accumulates principally in the kidney and liver (Divrikli et al., 2006). Various sources of environmental contamination have been reported for its presence in foods and various values have been reported for leafy vegetables which include 0.090 mg/kg for fluted pumpkin by Sobukola et al. (2010), 0.049 mg/kg for lettuce by Muhammad et al. (2008). In contrast, no Cd was detected in all vegetable samples examined in this study and hence are within safe limit, regular monitoring is required

Table 2. Estimation of heavy metal intake through consumption of vegetables in Katsina Metropolis.

Heavy metal	Mean conc. (mg/kg)	Daily intake (µg/day)	WHO/FAO limit (µg)[b]
Pb	0.095	9.31	214
Cd	0.000	0.00	60
Fe	0.260	25.48	-
Zn	0.268	26.26	60000 (60 mg)
Cu	0.483	47.33	3000 (3 mg)

Source: b = Elbagermi et al. (2012).

over a long period as the vegetables are transported from different sources.

Fe is essential for the synthesis of chlorophyll and activates a number of respiratory enzymes in plants. The deficiency of Fe results in severe chlorosis of leaves in plants. High levels of exposure to iron dust may cause respiratory diseases such as chronic bronchitis and ventilation difficulties. Fe content is found highest in the leaves of Tossa jute (0.334 mg/kg) and lowest in the leaves of Wild jute (0.214 mg/kg). Substantial amounts were recorded in the leaves of Foetid cassia and Kenaf which are 0.242 and 0.250mg/kg respectively. These values are far below the mean value of 12.873mg/kg in the leaves of lettuce as reported by Adu et al. (2012). The Fe contents of these plants are lower than the FAO/WHO (2001) safe limit of 425.00 mg/kg. These vegetables could be good supplement for Fe.

Zn is the least toxic and an essential element in human diet as it is required to maintain the functioning of the immune system. Zn deficiency in the diet may be highly detrimental to human health than too much Zn in the diet. The recommended dietary allowance for Zn is 15 mg/day for men and 12 mg/day for women Agency for Toxic Substances and Disease Registry (ATSDR, 1994), but high concentration of Zn in vegetables may cause vomiting, renal damage, cramps etc. Wild jute recorded the highest level of Zn which is 0.375 mg/kg and the least concentration was recorded by Tossa jute which is 0.221 mg/kg. Both Foetid cassia and Kenaf recorded moderate amounts of zinc which are 0.227 and 0.250 mg/kg respectively. These values are higher when compared to those reported in available literature. Sobukola et al. (2010) have reported Zn levels of 0.011, 0.070 and 0.050 mg/kg in the leaves of bitter leaf, water leaf and cabbage, respectively. The contents of Zn in all the plants examined are generally lower than the permissible levels by the FAO/WHO in vegetables as shown in Table 1. Regular consumption of these four vegetables may assist in preventing the adverse effect of zinc deficiency which results in retarded growth and delayed sexual maturation because of its role in nucleic acid metabolism and protein synthesis (Barminas et al*.,* 1998).

Cu is an essential micronutrient which functions as a biocatalyst, required for body pigmentation in addition to Fe, maintains a healthy central nervous system, prevents anaemia and interrelated with the functions of Zn and Fe in the body (Akinyele and Osibanjo, 1982). However, most plants contain the amount of Cu which is inadequate for normal growth which is usually ensured through artificial or organic fertilizers (Itanna, 2002). Among all heavy metals, Cu is the most abundant element, which recorded highest concentration of 0.632 mg/kg in the leaves of Wild jute. The least concentration of 0.333 mg/kg was recorded in the leaves of Foetid cassia. Moderate amounts of Cu were recorded by Kenaf and Tossa jute which are 0.467 and 0.500 mg/kg, respectively. The results obtained here were observed to be lower compared to other published results. Elbagermi et al. (2012) reported values of 5.00, 5.75 and 5.32 mg/kg for the concentration of Cu in carrot, cucumber and spinach. The contents of Cu in this study and from other published works are within the permissible level of 73.00 mg/kg by the FAO/WHO in vegetables.

The exposure of consumers and the related health risks are usually expressed in terms of the provisional tolerable daily intake .The FAO/WHO (1999) have set a limit for the heavy metal intake based on the body weight for an average adult, namely, 60 kg body weight. The average diet per person per day of vegetables is 98 g. If the mean levels of Pb (0.095 mg/kg), Cd (0.000 mg/kg), Fe (0.260 mg/kg), Zn (0.268 mg/kg) and Cu (0.483 mg/kg) found here are consumed daily, the contribution of heavy metal intake for an average human being from the vegetable diets were calculated and presented as shown in Table 2. It can therefore be concluded that our estimated daily intakes for heavy metals studied here are below those reported by the FAO/WHO, which had set a PTDI limit for heavy metal intake based on body weight for an average adult (60 kg body weight) for Pb, Cd, Zn, and Cu as shown in Table 2.

Conclusion

The results reported here confirm that the vegetables obtained from the central market site contained substantial amounts of the metals with exception of Cd which recorded zero concentrations or Cd concentrations were found to be below the detection limit of the machine. Levels of the metals are found to be within the safe limits prescribed by the FAO/WHO. This is an important result as human health is directly affected by consumption of vegetables. The monitoring of heavy metals in vegetables needs to be continued; because these are the main sources of food for humans in many parts of the world and are considered as bioindicators of environmental pollution.

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