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Phyto-Accumulation of Lead and Chromium in Common Edible Green-Leafy Vegetables Consumed in Dutse Metropolis, Jigawa State, Nigeria

I. Mohammad[1], A. K. Daniel[2], S. A. Kiyawa[3,*], A. S. Kutama[4]

[1]Department of Environmental Sciences, Federal University, Dutse, Nigeria
[2]Department of Biological Sciences, Federal University, Dutse, Nigeria
[3]Department of Chemistry, Northwest University, Kano, Nigeria
[4]University Coordinator of Examinations, Federal University, Wukari, Taraba State, Nigeria

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Abstract

Several researches have shown that the accumulation of heavy metals in green-leafy vegetables is of increasing concern due to food safety threat and potential health risks. Therefore, the aim of this research was to analyze the amount of heavy metals accumulated in three green-leafy vegetables consumed in Dutse metropolis, Jigawa state, Nigeria. Three (3) samples of each of the vegetables were collected randomly from two (2) different markets in Dutse Metropolis. The sample collection was replicated twice at a week interval. The concentration of lead (Pb) and chromium (Cr) in the vegetables were estimated using the atomic absorption spectrophotometric technique. It has been found statistically that out of the two metals analyzed, only Cr levels in SPI-UMM, CAB-UMM and LET-YTF (1.48 mg/kg - 2.22 mg/kg) did not exceed the permissible limit (2.30 mg/kg); whereas Cr levels in CAB-YTF, SPI-YTF, and LET-UMM (2.96 mg/kg - 4.44 mg/kg) exceeded the permissible limit. Conversely, the concentration of Pb in all the vegetables from the two sampling locations (0.87 mg/kg - 1.74 mg/kg) exceeded the permissible limit (0.30 mg/kg) set by FAO/WHO.

Keywords: Vegetables, heavy metals, phyto-accumulation, atomic absorption spectrophotometer

1. Introduction

According to the Food and Agricultural Organization [1], food security exists when all people, at all times have physical, social and economic access to sufficient, safe and nutritious food that meet their dietary needs and food preferences for an active and healthy life. Vegetables are highly vital in the maintenance of health and prevention of diseases; they provide high amounts of micro-minerals which play vital roles in nutrient metabolism and retard degenerative diseases [2]. Green-leafy vegetables such as spinach, cabbage, and lettuce contain vitamins, carbohydrates, proteins, minerals, some trace elements and fibers which are essential to the human body [3]. Vitamins and minerals repair damaged cellular organelles and boost the immune system by producing blood cells and other hormones. Carbohydrates release energy; proteins repair worn-out tissues and promote growth while fibers prevent constipation, decrease the risk of coronary heart diseases and some elements like calcium promote strong bone formation. Despite the numerous advantages of vegetable, phytoaccumulation of heavy metals in its tissues may pose threats to human health. Accumulation of heavy metals in green-leafy vegetables is of increasing concern due to food safety threat and potential health risks [4]. Heavy metal toxicity is due to

* Corresponding author:
salihukiyawa@yahoo.com
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long term or high level of exposure to pollutants in soil, air, water, food, and numerous vegetables such as cabbage, lettuce and spinach [5]. The use of excessive fertilizer and indiscriminate application of pesticides may lead to the phytoaccumulation of heavy metals in plants. Madyiwa et al. [6] suggested that most of the deleterious metals such as lead (Pb), mercury (Hg) and chromium (Cr) in wastewater irrigated soils accumulate in plants thereby making the plants a potential source of contamination. Vegetables are the most important sources of biomagnifications/bioconcentration of heavy metals into the human biological systems. Exposure to very low level of elements such as Pb, cadmium (Cd), Hg have a cumulative effects on human health due to the absence of homeostatic mechanisms that regulate the level of these toxic substances [7]. Pb is linked with miscarriage, reduced fertility in men and women, hormonal changes, menstrual irregularities and delays in puberty onset in girls [8].

Kiyawa [9] determined the level of Pb in plants grown near heavy machinery activities in a semi - arid zone of Bagwai, Kano - Nigeria. The result showed that the Pb concentration in *calotropis procera was* 4.6012 µg/g, *Commelina sp* 1.7053 µg/g, *Colocynthis bulgaris* 1.4971 µg/g, *Cucurbita pepo* 1.754 µg/g, *Haemanthus sp* 0.1645 µg/g, *Hibiscus esculenta* 0.5357 µg/g, *Mitracarpus scaber* 0.3313 µg/g, and *Lactuca taraxacifolia* 4.1067 µg/g. Kiyawa [10] determined the amount of total Cr and manganese (Mn) contents of some soils and naturally fully - grown plants of sub-Saharan region of Bagwai, Kano - Nigeria. The results obtained indicated that the highest amount (6.38 µg/g) was observed in *Calotropis procera*. This was followed by *Colocynthis bulgaris* (3.78 µg/g), *Lactuca taraxacifolia* (3.46 µg/g), *Hibiscus esculenta* (3.16µg/g) and *Haemanthus sp* (0.96 µg/g). To ascertain the level of heavy metals exposure, the concentration of heavy metals in spinach (*Spinacia oleracea*), cabbage (*Brassica oleracea*) and lettuce (*Lactuca sativa*) consumed by the people in Dutse Metropolis, Jigawa state, Nigeria was determined and the results compared with the safety limit set by World Health Organization (WHO) and Food and Agricultural Organization (FAO). The result of this study will provide a Consumer Risk Assessment Data (CRAD) that could be used to take preventive measures. It will serve as baseline information for monitoring studies. The results could assist the government in enacting laws, adequate policies, regulations and assure compliance to the principles of good Agricultural practices and environmentally - based regulatory bodies.

2. Materials and Methods

2.1. Description of the Study Area

Dutse, the Jigawa State capital is located on latitude 11°46'39" North, and longitude 9°20'3" East with a population of 290, 320 [11]. The inhabitants are mostly farmers (about 80% of the population). Millet and sorghum form the staple food crops while the cultivated cash crops are peanuts, beans, sugar cane, cotton, dates, potatoes, mangoes, vegetables (such as spinach, cabbage, and lettuce) and several other fruits.

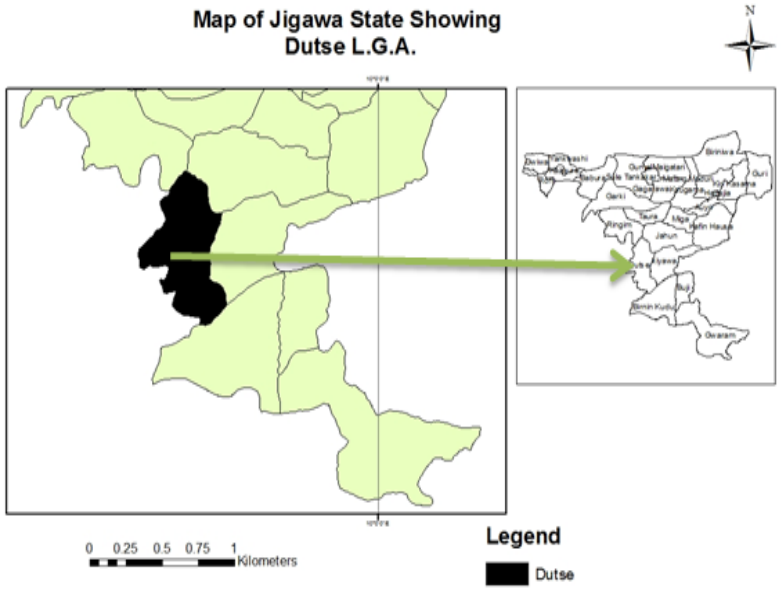

Figure 1. Map of Jigawa State showing Dutse LGA. *Source:* GIS Lab., Federal University Dutse, Nigeria

2.2. Plant Samples and Reagents

The plants utilized as samples in this study were the commonly consumed green leafy vegetables namely; spinach, cabbage and lettuce. All chemicals used were of analytical grade including Pb, Cr, HCl acid, concentrated nitric acid, silica gel and potassium permanganate (BDH).

2.3. Sample Collection

Three (3) samples from each of the green-leafy vegetables were collected randomly from two (2) different markets in Dutse Metropolis (Dutse Ultra-Modern Market (DUMM) and 'Yan-Tifa Mini-Market (YTMM)). The sampling points and their codes are presented in Table 1. Sample collection was replicated twice at a week interval. Sample of same vegetables were separated, cut into smaller portions and mixed together in order to get a composite sample of each of the vegetables. The samples were identified at the point of collection using standard botanical keys and descriptions [12] in addition to the identification by botanists in the Department of Biological Sciences, Federal University Dutse, Nigeria. Moreover, precautionary measures were taken to avoid contamination.

Table 1. Three Green-Leafy Vegetable Samples from the Sampling Points and their Codes

Sample	Sampling location	Sample code
Spinach	Ultra-Modern Market	SPI-UMM
	'Yan-Tifa Mini-Market	SPI-YTF
Cabbage	Ultra-Modern Market	CAB-UMM
	'Yan-Tifa Mini-Market	CAB-YTF
Lettuce	Ultra-Modern Market	LET-UMM
	'Yan-Tifa Mini-Market	LET-YTF

2.4. Sample Preparation

Samples were prepared according to the modified procedure of Shuaibu et al. [13] and Bukola [14]. Sampled vegetables were separated into its various tissues of leaves, stems and roots, cut into pieces with knife and properly washed with 20 % nitric acid and rinsed with distilled water. It was oven-dried at 70^0C for 24 h until it attained a steady weight. It was ground with mortar and pestle to fine powder and sieved through a 2 mm nylon sieve. The sieved samples were transferred into labeled containers for easy identification and laboratory analysis.

2.5. Digestion

The digestion of the samples was done as described by Bukola [14]. The glasswares were washed, properly cleaned and rinsed with distilled water. A 2.5 g vegetable sample was weighed into a beaker. 5 mL nitric and 10 mL Hydrochloric acid with 1 mL of sulphuric acid were mixed into a separate beaker. The acid mixture was added to the samples in the beaker and stirred continuously for few minutes. A 5.0 mL of distilled water was added and stirred again. The beaker was heated at 110 °C on a hot plate for 1 h in a fume hood until the content was about 2 mL, and the digest was allowed to cool. The solution was filtered through a Whatman No. 1 filter paper into 50 mL volumetric flask and diluted to volume with distilled water before aspiration into the instrument. The same procedure was repeated for digestion of the remaining samples prior to analysis of heavy metals (Pb and Cr) using the atomic absorption spectrophotometer (AAS; Buck Scientific VGP210) [15]. The digested samples were aspirated in with regular interval of standards to maintain a check on the instrument stability.

2.6. Data Analysis

The replicate values for levels of Pb and Cr in the samples were compared by one-way analysis of variance (ANOVA) at 95% confidence or greater than or equal to the level using software Excel 2010 and IBM SPSS Statistics 20 for windows. Significant differences were taken for $p < 0.05$; whenever a significant difference was found, the means were represented with standard error [16].

3. Results and Discussion

The WHO and FAO standards and permissible levels for Pb and Cr are 0.30 mg/kg and 2.30 mg/kg, respectively. The Statistical result of one-way ANOVA test has shown that variation in metals concentrations were significant ($p < 0.05$) between and among the sampled vegetables. The result obtained in this research from Table 2 and Figure 2 indicated that the analyzed metals; Pb (0.87 mg/kg - 1.74 mg/kg) and chromium (1.48 mg/kg - 4.44 mg/kg) were present in all the samples.

The concentrations of Pb and Cr in vegetables differ from one sampling location to the other and vary from one species of vegetable to the other. Among the two (2) heavy metals analyzed, the concentration of Cr (4.44mg/kg) detected in Spinach from 'Yan-Tifa Mini Market (SPI-YTF) was the highest. Also, the highest concentration for Pb (1.74mg/kg) was detected in spinach (SPI-YTF) and cabbage (LET-YTF) both from 'Yan Tifa. The lowest values were obtained for Cr in spinach (1.48 mg/kg) from Ultra modern market (SPI-UMM) while for Pb, 3 similar values (0.87 mg/kg) in spinach (SPI-UMM), cabbage (CAB–UMM) and lettuce (LET-UMM) were recorded. With the exception of Cr the levels of Pb detected in all the samples analyzed in this research were higher than the stipulated permissible levels in vegetables by FAO/WHO guidelines as shown in Figures 2 and 3, respectively.

Table 2. Comparison of Mean Concentrations of Pb and Cr (mg/kg) against the Permissible Limit Set by WHO/FAO

	Metals (X±SE, n=3)	
Sample code	**Cr (mg/kg)**	**Pb (mg/kg)**
SPI-YTF	4.44±0.00	0.87±0.00
SPI-UMM	1.48±0.02	0.87±0.00
CAB-YTF	2.96±0.03	1.74±0.00
CAB-UMM	2.22±0.00	0.87±0.00
LET-YTF	2.22±0.00	1.74±0.00
LET-UMM	2.96±0.03	0.87±0.00
WHO/FAO	2.30	0.30

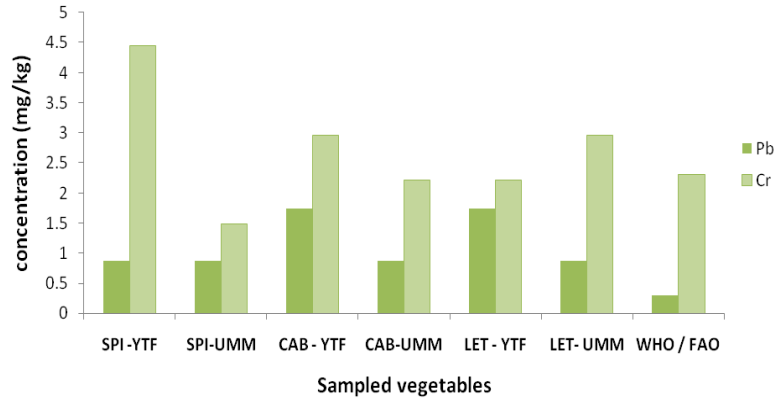

Figure 2. Mean Concentrations of Pb and Cr (mg/kg) obtained from the Analysis of Three Green Leafy Vegetables

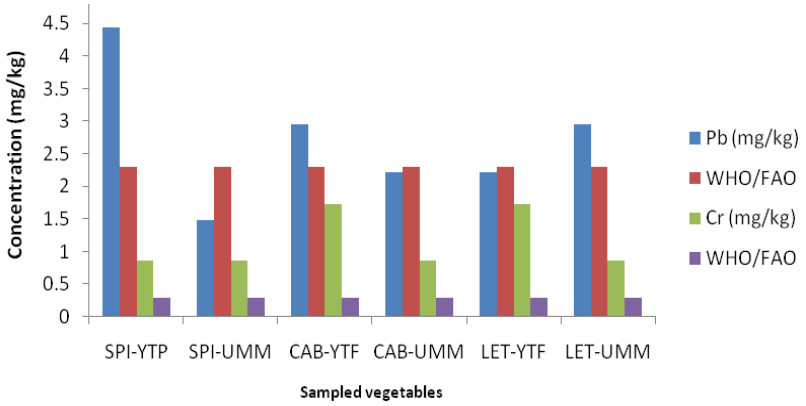

Figure 3. Comparison of the Concentration of Pb and Cr (mg/kg) obtained from the Locations against the Permissible Limit in Green-Leafy Vegetables set by WHO/FAO

These results were in agreement with that obtained by Sharma et al. [19] which reported the high Pb concentrations (17.54 mg/kg - 25.00 mg/kg) in vegetables grown in industrial areas. Muchuweti et al. [20] reported the level of Pb (6.77 mg/kg) in vegetables irrigated with mixtures of wastewater and sewage from Zimbabwe to be higher than the WHO safe limit (0.3mg/kg). Al Jassir et al. [21] studied six washed and unwashed green leafy vegetables from Saudi Arabia and noted the highest concentrations of Pb in coriander and purslane. The quality of food has now become an important issue in all the countries especially with respect to vegetables consumptions.

Since the levels of Pb in all the vegetable samples were above the permissible level, continuous consumption of these vegetables can cause several health effects such as; kidney damage, brain damage and rise in blood pressure. At higher concentration, Pb has been revealed to have serious negative effects. Cancerous breast biopsies show higher accumulation of Pb than non-cancerous biopsies and several metals act like oestrogen in the presence of some breast cancer cells [22]. Pb is a neurotoxin linked to learning, language, behavioral problems, miscarriage, reduced fertility in men and women, hormonal changes, menstrual irregularities and delays in puberty onset in girls. Boys developing testes (at puberty), pregnant women and young children may be particularly vulnerable to Pb because the metal crosses the placenta and may enter into the feotal brain [23].

The low levels of Cr recorded in this study are comparable to the levels recorded by Dayan and Paine [24] which ranged from 1.48 mL to 4.44 mL. The difference in the levels of Cr may be attributed to the difference in the environmental conditions where the constituent plant was grown [25]. Skin contact with Cr is reported to cause skin ulcers; allergic reactions consisting of severe redness and swelling of the skin whereas long term exposure causes damage to liver, kidney circulatory, nerve tissues and skin irritation [26]. Breathing high levels of Cr causes irritation to the lining of the nose, nose ulcers, running nose and breathing problems such as asthma, cough, shortness of breath, or wheezing, Cr(VI) compounds are toxins and human carcinogens [24].

4. Conclusion

The study has shown the presence of Pb and Cr in the three (3) green-leafy vegetables consumed in Dutse Metropolis. Different concentrations of the metals were determined using the atomic absorption spectrophotometric technique. It has been shown statistically that only Cr levels in SPI-UMM, CAB-UMM, and LET-YTF (1.48 mg/kg - 2.22 mg/kg) did not exceed the permissible limit of (2.30 mg/kg); whereas Cr levels in CAB-YTF, SPI-YTF, and LET-UMM (2.96 mg/kg - 4.44 mg/kg) exceeded the permissible limit of 2.30 mg/kg. Conversely, the concentration of Pb in all the samples (0.87 mg/kg - 1.74 mg/kg) exceeded the permissible limit of 0.30 mg/kg set by FAO/WHO. Even though, some of the Pb and Cr concentrations in the sampled plants were less significant at 95% confidence level when compared with the standards. It is therefore concluded that some of the vegetables sold in Dutse Metropolis are not fit and safe for human consumption. It is recommended that more researches should be made to ascertain the concentrations of other heavy metals in other vegetable samples and measures should be taken to reduce the concentration of heavy metals in farms, soils and open market practices due to vehicular emissions to protect the safety of vegetable consumers and the environment. Also, measures should be taken to reduce the practices of cultivating the vegetables near dumpsites.

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