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Seasonal Variation in Heavy Metal Contamination of African Spinach

Article by Oche Joseph Otorkpa[1], Abiodun Paul Olaiya[2], Stephen Emmanuel[3]
[1]*University of Central Nicaragua*
[2]*University of Central Nicaragua*
[3]*Kogi State University, Nigeria*
E-mail: Ochejoseph@yahoo.com

Abstract

Access to sufficient amounts of safe and nutritious food is vital to sustaining life and promoting good health. Seasonal variation in disease causing agents such as dietary heavy metals can negatively influence morbidity and mortality. The purpose of this study was to investigate the seasonal variation in lead, cadmium, manganese, copper, chromium, cobalt, nickel, and zinc in African Spinach a staple food in Nigeria. The method employed was atomic absorption spectrophotometry and the results indicates that the mean concentration of levels of Cd, Cu, Mn in the food crop increased during the rainy season while the mean concentration of Cr, Co, Pb, Ni, and Zinc were either higher or vary slightly during the dry season. With the exception of Cd and Co all other heavy metals were within maximum permissible limits set by the Joint FAO/WHO Expert Committee on Food Additives and the Agency for toxic substance disease registry (ATSDR), although slightly higher levels of lead were recorded in some dry seasons samples they still fell within permissible limits. Understanding the seasonal variation of heavy metal contamination in staple foods can possibly explain the seasonal variation in prevalence of some non communicable diseases, save lives and reduce healthcare costs.

Keywords: *Dietary exposure, Heavy metal, Contamination, Vegetables, Food Additives.*

Introduction

Vegetables are vital for human health because of the minerals, vitamins, phytochemical compounds, dietary fiber and anti-antioxidant they provide. However, contamination of these rich sources of nutrients by heavy metal presents one of the biggest challenges for food safety and public health. Rapid industrialization, urbanization, haphazard use of variety of chemicals agents and pollution of agricultural lands has resulted in increased accumulation of unacceptable levels of heavy metal in the environment, resulting in the uptake, transformation and bio-accumulation of these non-biodegradable elements by food crops with a corresponding negative impact on food quality, safety and ultimately the health of the population that consume such food (Khanna, 2011).

Dietary exposure to low levels of heavy metals may contribute much more toward the causation of chronic disease and impaired functioning than previously thought. (Orisakwe, 2014).Food safety is unique among the various aspects of public health due to its pluridisciplinary and multi-sectoral nature, As a component of the ‘Health for All’ strategy of the World Health Organization, the food safety programme is given significant priority in both design and implementation of national plans of action for nutrition (Miyagishima *et al*.,1995). Access to sufficient amounts of safe and nutritious food is vital to sustaining life and promoting good health. Unsafe food containing harmful parasites, bacteria, viruses or substances like heavy metals cause over 200 different diseases including diarrhoea and cancers. Globally, around 600 million - almost 1 in 10 people – fall sick after consuming contaminated food each year, leading to 420 000 deaths and the loss of 33 million healthy life years (DALYs) (WHO, 2019).

Amaranthus hybridus is a plant with high affinity for heavy metals and as such could be easily contaminated. A study which analyzed the heavy metal uptake by two edible *Amaranthus* herbs grown on soils contaminated with Lead, Mercury, Cadmium, and Nickel was carried out to investigate the abilities of 2 species of the plant *Amaranthus hybridus* (green herbs) and *Amaranthus dubius* (red herbs) and measure their response and ability to accumulate and tolerate varying levels of heavy metals in their roots and shoots. Both herbs (red and green) were grown in soil pots contaminated with three mixtures of Cd (II), Ni (II), Pb (II), and Hg (II). The control treatment for the experiment was plants grown in the absence of the heavy metal's mixture. The distribution of Cd, Ni, Pb, and Hg in the plant's roots, stems, and leaves were analyzed in two stages.

The first stage was after 5 weeks of plant growth while the second stage was at 10 weeks of growth. In the red herbs, the Cd concentration in the leaves at the second stage was 150 ppm and was present in higher concentrations than Ni, Hg, and Pb. At the highest contamination level, while in the green herbs plant, the concentration of Hg was the highest in the root, i.e., 336 ppm at the first stage, while the level in the leaves was 7.12 ppm. The study concluded that both the green and red herbs species of Amaranthus showed an affinity for Ni and Cd with moderate to high levels detected in the leaves, respectively (Chunilall *et al*., 2005). This affinity of the plant for heavy metal accumulation as reported by this study is very vital because it debunks the claim that long period of exposure time is required for sufficient bio accumulation.

A study that assessed the bioaccumulation of heavy metals in spinach sold at vegetable farms in Katsina, North west Nigeria, conducted using atomic absorption spectrometer VPG 210 model reported that cadmium was the heavy metal with the highest concentration, this was followed closely by chromium, and zinc.

The findings from the study revealed the following; Kofar Marusa site, cadmium 12.5±2.5mg/kg > chromium and zinc both had 4.7±0.62mg/kg, while Kofar Durbi site Zinc 13.2±4.21mg/kg > cadmium 12.5±2.5mg/kg > chromium 4.71 ± 0.62mg/kg. Similarly, at Kofar/Sauri, study site, Zinc had 13.2±4.21mg/kg > Cadmium 12.5± 2.5mg/kg > Chromium 4.71±0.62mg/kg. However, concentrations of heavy metals in the soil of the study sites show chromium had high mean value of 10.19±0.41mg/kg > Zinc 6.13± 0.87mg/kg > Cadmium 5.84±0.83mg/kg: Plant concentration factor (PCF) in the study ranges between 1.40-2.8Mg/l at K/Marusa for Cd, Cr and Zn, K/Durbi 0.45-2.11 and K/Sauri with 0.3-4.0 respectively. (Abba and Ibrahim, 2017). A comparative assessment of some heavy metals in *Gongronema latifolium, Amaranthus hybridus, Talinum triangulare, Telfairia occidentalis ,Piper guineense* and *Ocimum gratissimum* commonly used for making local dishes in Yenagoa metropolis, Nigeria reported that the concentration of cobalt, lead, and cadmium were below detection level while the concentration of other heavy metals in the vegetables ranged from 1.85 - 3.55mg/kg for copper, 1.63 – 14.98 mg/kg for zinc, 5.83 – 186.59 mg/kg for manganese, 8.12 – 31.72 mg/kg for chromium, 5.01 – 16.03 mg/kg for nickel and 307.60 – 1051.31 mg/kg for iron.

An analysis of variance indicated that there was significant variation ($P<0.05$) among the vegetables analyzed. The study also reported that the concentrations of the heavy metals in the vegetables were found to be below Food and Agricultural Organization/World Health Organization maximum limit with the exception of iron and chromium (Izah and Aigberua, 2017).

The assessment of seasonal variation in heavy metal contamination of African Spinach (Amaranthus hybridus) using atomic absorption spectrophotometry provides valuable platform for the synthesis and processing of vital information that was hitherto unavailable to public health officials and food safety experts considering the large-scale consumption of the plant and its affinity for heavy metals.

Methodology

Data collection instrument

Atomic Absorption Spectrometry (AAS) determines the presence and concentration of metals in liquid samples. When they are excited by heat in their elemental form, heavy metals will absorb ultraviolet light. Each heavy metal has a unique wavelength that will be absorbed. The Atomic Absorption Spectrophotometer looks for a particular metal by focusing a beam of uv light at a particular wavelength through a flame and into a detector (García and Báez 2012).

Validation of data collection instrument

Atomic Absorption Spectrometry (AAS) is the most widely recommended instrument utilized in analytical procedures for heavy metal. It is a validated, simple, reliable, sensitive and convenient method for quantitative estimation of trace metals and heavy metals in dried vegetables (Rawar, and Rohman2016) (Sharma *et al.*,2009). Standard solutions were frequently run to check the sensitivity of the instrument and the operation conditions used to operate AAS instrument were as recommended by the manufacturer.

Sample processing

Approximately 0.5 g of the powdered *Amaranthus hybridus* was transferred to a 25 ml conical flask; 5 ml of concentrated Tetraoxosulphate (VI) Acid (H_2SO_4) was then added followed by 25 ml of concentrated Nitric acid (HNO_3) acid, and 5 ml of concentrated hydrochloric acid (HCl). The contents of the tube were then heated at 200° C for 1 hour in a fuming hood, and then cooled to room temperature. After this, 20 ml of distilled water was added and the resulting mixture filtered using filter paper No.1 (11cm) to complete the digestion of organic matter. Finally, the mixture was transferred to a 50 ml volumetric flask, filled to the mark, and let to settle for at least 15 hours. The resultant supernatant was thereafter analyzed for heavy metal using atomic absorption spectrophotometer Model No: AAS-6800N Shimadzu at National Research Institute for Chemical Technology (NARICT) Zaria Nigeria (Atayese, *et al.*, 2008).

Results

Table 1

Heavy Metal	Mean Concentration (ppm) and SD of Heavy Metal in African Spinach (Dry Season)	Mean Concentration (ppm) and SD of Heavy Metal in African Spinach (Rainy Season)	Maximum Permissible Limits (ppm) WHO/ FAO, *ATSDR*
Cd	Leaf: 0.0347 ± 0.0602	Leaf: 0.8799 ±1.3181	0.1
	Stem: 0.07108 ± 0.1335	Stem 0.4558 ± 0.6672	
Cr	Leaf: 0.2087 ± 0.2661	Leaf: 0.0113 ± 0.0073	2.3
	Stem: 0.2171 ± 0.4379	Stem:0.0145 ± 0.0101	
Cu	Leaf: 0.0157 ± 0.0091	Leaf: 0.0912 ± 0.0765	40.0
	Stem:0.01395 ± 0.0075	Stem:0.0935 ± 0.0505	
Co	Leaf: 0.2662 ± 0.1009	Leaf: 0.1197 ±0.1912	*0.05- 0.1*
	Stem: 0.2728 ± 0.0833	Stem: 0.0865 ±0.0734	
Pb	Leaf: 0.0717 ± 0.0515	Leaf: 0.0522 ± 0.0360	*0.3*
	Stem: 0.10377 ± 0.058	Stem:0.0494 ± 0.0232	
Mn	Leaf :1.0322± 0.9571	Leaf:1.8033 ± 2.1183	500
	Stem: 1.2432 ± 0.8401	Stem:1.8944 ±1.8404	
Ni	Leaf: 0.0207± 0.0124	Leaf:0.0124 ± 0.0087	1.5
	Stem: 0.0127 ± 0.0077	Stem 0.0242 ± 0.0101	
Zn	Leaf: 0.0864 ± 0.1220	Leaf: 0.0189 ± .0192	0.6
	Stem: 0.0508 ± 0.1061	Stem: 0.0577 ±0.0549	

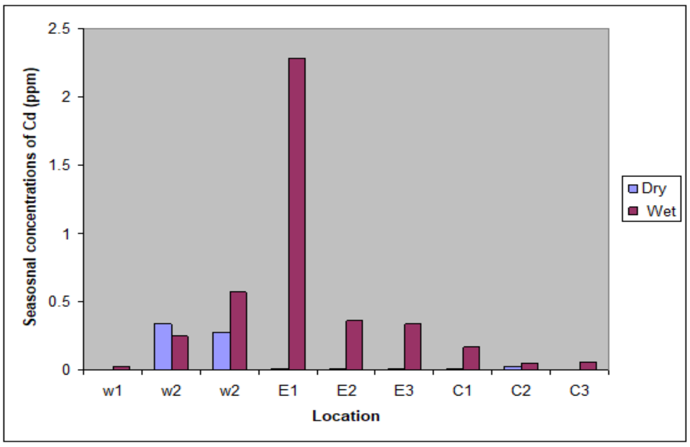

Figure 1. Showing the seasonal variation of cadmium contamination in the food crop

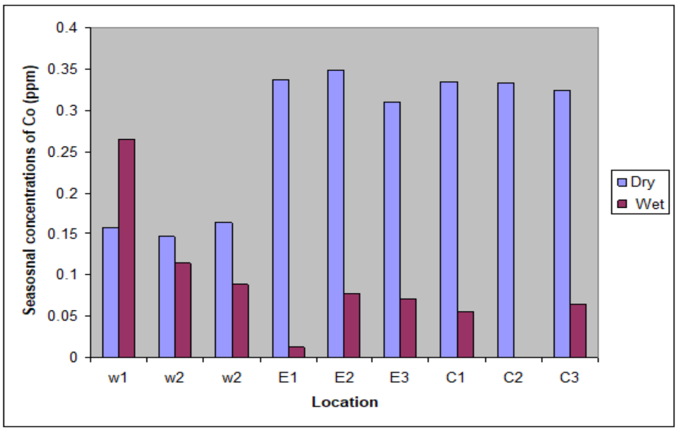

Figure 2. Showing the seasonal variation of cobalt contamination in the food crop

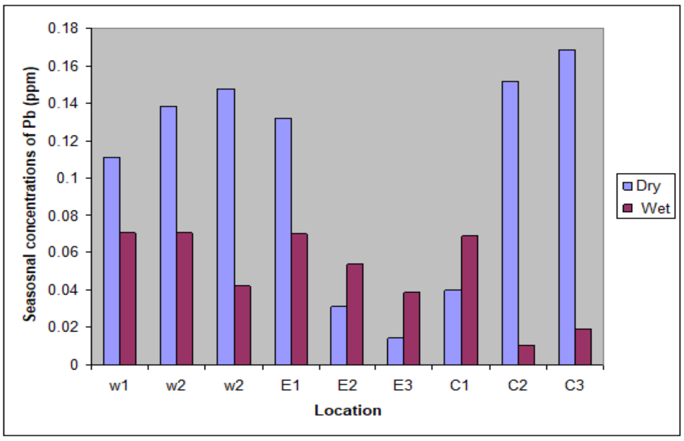

Figure 3. Showing the seasonal variation of lead contamination in the food crop

Discussion

Spectrophotometry offers the best way to objectively measure the quantity of heavy metal in food crops. This validated method of heavy metal assessment provides a useful tool for assessing foods and production processes that undermines health and negatively impact wellbeing. The results of the analysis of African Spinach for heavy metals using atomic absorption spectrophotometer showed that higher levels of lead were observed in the dry season which is a cause for concern, despite the fact that they still fell within the maximum permissible limits.

The results show that the mean concentration of Cadmium during the rainy season (Leaf: 0.8799 and 0.4558) is higher than those recorded in the dry season, it was also far above the FAO/WHO maximum limit of 0.1ppm (Tasrina et al.,2015). This finding is in agreement with the results of a study on heavy metal contamination of Amaranthus grown along major highways in Lagos which reported that the concentration of Cd in Amaranthus at 4.0 ppm above maximum limit of 0.1ppm (Atayese, et al., 2008). Heavy metal contamination of foods crops is a major public health issue because of the resultant toxicity and diseases it produces in humans and animals who consume them. Cadmium toxicity can result in renal dysfunction with both tubular and glomerular damage with resultant proteinuria. In contrast, a comparative study of trace element levels in some local vegetable varieties which included Amaranthus hybridus reported that Cadmium was not detected in the vegetables produced during wet season, while the concentration recorded for the dry season is within maximum permissible set by some the World Health Organization (Dosumu et al.,2003). This variation could be due to the low Cd, and Pb that has been reported to be associated with Ilorin where this particular study was conducted (Abdus-Salam, 2009)

The values for Cobalt recorded during this study is another public health concern because most of the values recorded were above the maximum permissible limit set by the Agency for Toxic Substance Disease Registry (ATSDR) in both wet and dry seasons. The maximum permissible limits for the heavy metals in vegetables set by (ATSDR) is between 0.05 to 0.1ppm 0.1ppm (Tasrina et al., 2015). The results indicate higher levels of Co in the dry season with a mean concentration of 0.2662 and 0.2728 in the leaf and stems respectively as compared with a mean concentration of 0.1197 and 0.0865 obtained in the rainy season. The dry season values are about twice the maximum acceptable limit for this heavy metal in vegetables. This is in harmony with the findings of an assessment of cobalt levels in wastewater, soil and vegetable samples including African spinach which reported that the highest cobalt (4.07 mg/Kg) were recorded during dry season, followed by 3.74 mg/Kg also during the dry season. (Oladeji *et al.*, 2015). In contrast, another study conducted in Tanzania reported a slightly different result which indicates that cobalt was only found in the roots at an average concentration of 0.14 ppm but was undetectable in the edible parts (Stem and leaves) of plant (Sahu and Kacholi, 2016). This variation could be due to natural and anthropogenic factors, the accumulation and distribution of heavy metals in the plant depend on the plant species, the levels of the metals in the soil and air, the element species and bioavailability, pH, cation exchange capacity, climacteric condition, vegetation period and multiple other factors as reported by (Filipović-Trajković,2012). Evaporation of water from soil and dehydration of plant leaves by transpiration also increase metal concentration in roots (Oyedele *et al.*, 2008).

The discovery of seasonal variation of cobalt is of immense public health concern because Cobalt is toxic to the heart muscle. It can cause heart muscle disease (toxic cardiomyopathy). Too much cobalt in foods can also cause deafness, nerve problems, ringing in the ears (tinnitus), and thickening of the blood, thyroid problems and vision problems. A spike in the levels of dietary cobalt during the dry season could lead to increase in number of these conditions.

Conclusion

The need for public health and food safety officials to constantly monitor the quality of food produced and sold for human consumption needs not to be overemphasized. Nevertheless, understanding the seasonal variation of heavy metal contamination in staple foods is critical if the goals of public health are to be achieved in any population.

Understanding the pattern of spike in concentration of toxic heavy metals especially for foods crops widely consumed by the population can possibly explain the seasonal variation in prevalence of some non communicable diseases. Knowledge of this can save lives and cost for health departments and also reduce healthcare costs significantly because increases in disease causing agents such as dietary heavy metals will continue to negatively influence morbidity and mortality rates and consequently increase the burden of disease including health care cost in communities if left unchecked.

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