



Heavy Metals Content of Common Tubers from Selected Farm Locations in Enugu North District, South East, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author FCA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors EP and GWU managed the analyses of the study while author CJA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The concentration of heavy metals (Cd, Pb, Ni, As, Cr, Mn, Cu, and Zn) in sweet potato (*Ipomoea batatas*), yam (*Dioscorea ssp*), and cassava (*Manihot esculenta*) in four farm locations in some local government areas of Enugu North District was determined. Samples were prepared following standard procedure and digested with a 5:1:1 mixture of trioxonitrate (V) acid, tetraoxosulphate (VI) acid, and perchloric acid as previously reported. Metal concentration was determined using Atomic Absorption Spectrophotometer (Perkin Elmer 1100B model). The range of heavy metals concentration recorded for sweet potato in the four farm locations were 60.26±2.30-312.66±31.24 mg/kg, 20.06±1.27-40.55±4.08 mg/kg, 12.60±2.00-32.06±3.20 mg/kg, 8.20±3.00-15.00±1.07 mg/kg, 0.05±0.07-0.80±1.27 mg/kg, 0.07±0.42-0.18±0.42 mg/kg, 0.01±0.20-0.09±0.03 mg/kg and

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0.02±0.07-0.03±0.08 mg/kg respectively for Mn, Ni, Cu, Zn, Cr, Pb, As and Cd while the range in yam was 18.46±2.05-380.20±10.97 mg/kg, 44.20±4.99-66.30±3.87 mg/kg, 17.80±2.18-56.08±6.73 mg/kg, 12.00±2.00-42.30±0.06 mg/kg, 0.01±0.32-0.42±0.27 mg/kg, 0.02±0.07-0.20±0.12 mg/kg, 0.04±2.03-0.10±0.00 mg/kg and 0.01±0.07-0.08±0.47 mg/kg for Mn, Cu, Zn, Ni, Cr, Pb, As and Cd respectively. In cassava, the concentration range was 74.20±10.97-312.20±31.20 mg/kg, 14.20±1.29-38.22±6.07 mg/kg, 10.88±3.03-32.00±0.70 mg/kg, 3.20±0.20-11.20±1.09 mg/kg, 0.01±0.20-0.18±1.27 mg/kg, 0.02±0.03-0.12±0.07 mg/kg, 0.01±0.03-0.10±0.07 mg/kg and 0.03±0.00-0.05±0.42 mg/kg for Mn, Ni, Zn, Cu, Cr, Pb, Cd and As respectively. While Cd was not detected in farm location B and D in all the tuber samples, arsenic was detected in all the samples except in cassava cultivated in farm location B. All the heavy metals analyzed were each below the World Health Organization (WHO) permissible concentration except chromium which was slightly higher than the recommended limit of 0.05 mg/kg. Apart from 0.80±1.27 mg/kg Cr recorded for sweet potato cultivated in location C, the concentration of chromium in all the tubers were below the China's State Environmental Protection Administration (SEPA) permissible limit of 0.5 mg/kg. Hence, risk assessment of Cr intake was recommended to ascertain the level of human exposure to Cr through the consumption of these tubers in the study area

Keywords: Heavy metals; food safety; tubers; Enugu north district; permissible limit; risk assessment.

1. INTRODUCTION

Progressive food safety check and monitoring of the environment is necessary, especially in developing countries. This is due to their inadequate implementation and enforcement of food safety guidelines and environmental legislation. This monitoring of food and the environment is again necessary due to the dynamic nature of human and industrial activities. Heavy metals conversely refer to metallic elements with relatively high atomic mass and toxic even at low concentrations. Heavy metals constitute a major source of food poisoning apart from the microorganism. Although metals and microorganisms occur in nature, the presence of a pathogen is an indicator of the hygienic and sanitary conditions of both the human and operational environment; heavy metals are toxic and find their way into the food chain through several means. Most notably, is the mining activities, agricultural practices like the use of inorganic fertilizers, sewage sludge for soil amendment, and pest control. Indiscriminate dumping of refuse especially electronic waste, batteries, and packaging materials are also major sources of heavy metals into the soil and the environment.

Research has shown that these metals are distributed in the environment through erosion, transportation, grazing, and irrigation with wastewater, industrial activities, and atmospheric deposition [1] due to emitting factories. The uptake of heavy metals by plants is dependent upon factors such as soil pH, microorganism, and plant species. Previous work [2] and [3]

respectively explained the process of metal availability in the soil, the role of microorganism in metal soluble organic complex formation, translocation ability, and storage of metals in the cell wall by plants. Microorganisms in the soil need certain mineral elements for development and bioactivity, but at increased concentration, heavy metals pose danger to these important microorganisms which are evident from the enzymes the plant produces [4].

The gross effect of elevated doses of heavy metals in the soil is either phytotoxicity or bioaccumulation depending on plant species and pH among other factors. Among the poisonous metals cadmium (Cd), mercury (Hg), and lead (Pb) are of utmost concern as they pose severe health challenges to both adults and children. Elevated levels of cadmium in the body causes kidney malfunction, skeletal damage, and reproductive impairments [5]. High concentration of lead in the body is the major cause of liver, brain, and nervous system complication [6]. It has been considered a carcinogen in human by the United States Environmental Protection Agency (USEPA). Previous report as well indicates that accumulated nickel causes respiratory problems [6].

Although potato was neglected, underutilized, and considered as food for the low-income earners [7] in the last few years, it has recently been elevated to play major roles in mitigating against food and diet shortages [8] sequel to its carbohydrate (energy) content and physiological benefits from the leaves and edible tubers [9]. Sweet potatoes (*Ipomoea batatas*) are a huge

source of carbohydrate, protein, and minimal fat [7]. It has been reported to be rich in β -carotene, vitamin C, phenols, and fiber. Both the root (tuber) and the leaves are rich in antioxidants [7,10]. It is ranked the second most starchy root crop, after cassava (*Manihot esculenta*) and over 130 million tons are produced annually [11]. Sweet potatoes are now a major root crop consumed in most African countries because it is relatively cheap compared to other tubers like yam (*Dioscorea ssp.*) [12]. Yam is common and favorite to many households not only in Enugu North District but Nigeria and many African countries. It is prepared in different recipes easily with vegetables, cooked with different varieties of beans, pounded and eaten with melon or okra soup, and as fries. Cassava (*Manihot esculenta*) is widely cultivated on a commercial scale in Enugu North District of Enugu State. There is an increasing demand for cassava tubers not only because it is a staple food for most households but because it is processed into the cassava flour required in the bakery and other food industries. It is also processed into gari and tapioca and served in different recipes in restaurants. It is, therefore, necessary to frequently monitor the contamination levels of heavy metals; Cd, Pb, Ni, As, Cr, Mn, Cu, and Zn in these tubers cultivated, consumed, and shipped from Enugu North District, Nigeria.

2. MATERIALS AND METHODS

2.1 Sample Collection

Fresh samples of sweet potato (*Ipomoea batatas*), yam (*Dioscorea ssp.*), and cassava (*Manihot esculenta*) root tubers were collected from four farm locations in some local government areas that supply the major markets; Nkwo Ibagwa- Aka, Igbo-Eze South, Obollo-Afor, Udeno and Ogige market in Nsukka metropolis, Enugu State.

2.2 Sample Preparation

The usual household practice was followed in preparing the sample except for the use of distilled or deionized water in place of tap water. The tubers from each farm were washed with distilled water to remove soil particles and impurities. They were peeled with a Teflon knife to separate the edible portion from the back. Edible parts were sliced into pieces, air-dried for a few hours, and oven-dried for 72 hrs at 105°C until a constant weight is obtained. Dried samples were ground to a fine powder using a

clean porcelain mortar and pestle. Particles were sieved through a 2.00 mm mesh and labeled A, B, C, and D to represent samples from each farm location.

2.3 Sample Digestion

The wet digestion method was carried out according to a previously reported procedure [13]. Each sample (1.00 g) was digested by adding 15 ml of an acid mixture (5:1:1) of HNO_3 : H_2SO_4 : HClO_4 in a 250 ml conical flask and heated above 90°C in a fume cupboard until a transparent solution is obtained. The solution was allowed to cool, followed by filter with Whatman No. 1 filter paper. The filtrate was diluted to 50 ml with deionized water in a volumetric flask.

2.4 Atomic Absorption Spectrophotometric Analysis

Heavy metals were analyzed in triplicates using a Perkin Elmer model 1100B atomic absorption spectrophotometer. Measurements were made using a hollow cathode lamp and at corresponding wavelengths for each metal. The calibration curves were prepared from standards by dissolving appropriate amounts of the metal salts in purified nitric acid and diluted with deionized water. These stock solutions were each stored in quartz flask. Fresh working solutions were then made by serial dilution of the stock solutions.

2.5 Data Analysis

Data was analyzed using SPSS version 21. The significance of variation of heavy metals in the tubers was determined using a one-way analysis of variance (ANOVA) and data presented as mean \pm SD.

3. RESULTS AND DISCUSSION

Figs. 1–3 respectively show the concentration of heavy metals in sweet potato, yam, and cassava tubers in different farm locations (A–D). The order of heavy metals concentration in sweet potato from location A was $\text{Mn} > \text{Ni} > \text{Cu} > \text{Zn} > \text{Cr} > \text{Pb} > \text{As} > \text{Cd}$. The same order of concentration of heavy metals; $\text{Mn} > \text{Cu} > \text{Zn} > \text{Ni} > \text{Cr} > \text{Pb} > \text{As} > \text{Cd}$ was recorded for both yam and cassava. The concentrations followed the same trend for Mn, Ni, Cu, and Zn in farm locations B, C and D. Results showed that all the sweet potato samples from the four farm

locations had heavy metals concentration below the WHO permissible limits except for chromium. Whereas the farm location A contained 0.05 ± 0.07 mg/kg Cr which is within the allowable concentration, location C contained 0.80 ± 1.27 mg/kg Cr which is higher than the WHO and China's State Environmental Protection Administration (SEPA) permissible limit of 0.05 mg/kg [14] and 0.5 mg/kg [15] respectively. Again location B and D each contained 0.50 ± 1.29 mg/kg Cr which is also higher than the WHO acceptable limit but within China's SEPA guidelines. The range of heavy metals concentration recorded for sweet potato in the four farm locations (Fig. 1) were 60.26 ± 2.30 - 312.66 ± 31.24 mg/kg, 20.06 ± 1.27 - 40.55 ± 4.08 mg/kg, 12.60 ± 2.00 - 32.06 ± 3.20 mg/kg, 8.20 ± 3.00 - 15.00 ± 1.07 mg/kg, 0.05 ± 0.07 - 0.80 ± 1.27 mg/kg, 0.07 ± 0.42 - 0.18 ± 0.42 mg/kg, 0.01 ± 0.20 - 0.09 ± 0.03 mg/kg and 0.02 ± 0.07 - 0.03 ± 0.08 mg/kg respectively for Mn, Ni, Cu, Zn, Cr, Pb, As and Cd. Chromium is important in human metabolism for the absorption of fat,

sugar, and protein. However, higher doses of Cr can lead to kidney problems like necrosis of tubules and gastrointestinal bleeding [16,17] in humans and sometimes fatalities in children. The 0.80 ± 1.27 mg/kg of Cr obtained in this study agrees with previous work although lower than 1.50 mg/kg reported by Haladu *et al* [18]. Again, Wilberforce [14] studied both the bioaccumulation factor (BAF) and the translocation factor (TF) for cocoyam, yam, cassava, Irish and sweet potato. The result showed that while yam is a potential hyperaccumulator of Cu, sweet potato is a hyperaccumulator of Cr. This fact, therefore, explains why there is a relatively higher amount of Cr in the sweet potato sample than other metals.

The range of concentration of heavy metals in yam from the four farm locations (Fig. 2) was 18.46 ± 2.05 - 380.20 ± 10.97 mg/kg, 44.20 ± 4.99 - 66.30 ± 3.87 mg/kg, 17.80 ± 2.18 - 56.08 ± 6.73 mg/kg, 12.00 ± 2.00 - 42.30 ± 0.06 mg/kg,

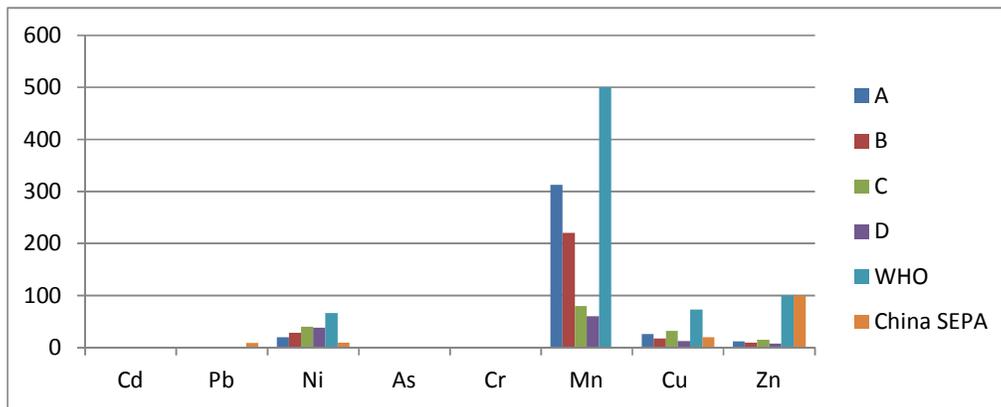


Fig. 1. Concentration of heavy metals in sweet potato tubers (mg/kg)

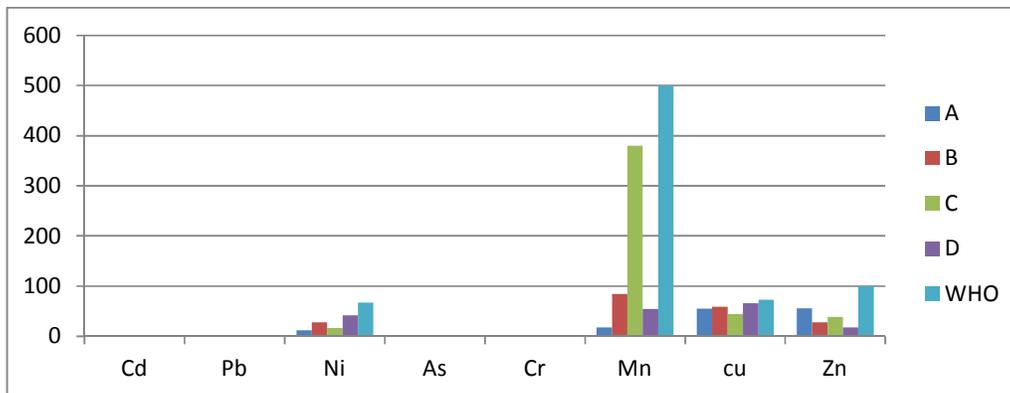


Fig. 2. Concentration of heavy metals in yam (mg/kg)

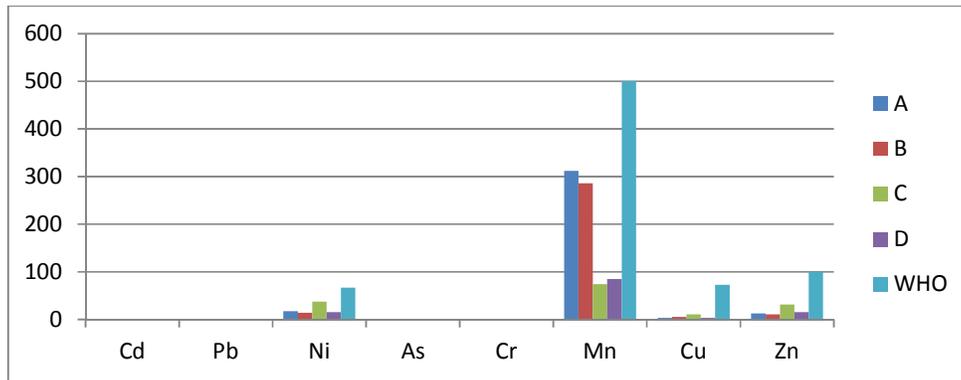


Fig. 3. Concentration of heavy metals in cassava tubers (mg/kg)

0.01±0.32-0.42±0.27 mg/kg, 0.02±0.07-0.20±0.12 mg/kg, 0.04±2.03-0.10±0.00 mg/kg and 0.01±0.07-0.08±0.47 mg/kg respectively for Mn, Cu, Zn, Ni, Cr, Pb, As and Cd. These values were below the WHO permissible limit. Hence, by this result, the consumption of yam cultivated in Enugu North District poses no human health risk for heavy metals contamination. Cadmium and lead among others are the heavy metals of utmost concern for environmental, water, and food poisoning. In this study, Cd was not detected in location B and D in all the tuber samples analyzed. Again, all the metals detected in yam were below the WHO standard limit of 0.05 mg/kg except Cr which was slightly higher (0.42±0.03 mg/kg) and (0.20±0.12 mg/kg) respectively for locations B and C.

Comparatively, the result of the present study for Cd and Pb; 0.02±0.03 and 0.07±0.42 mg/kg respectively found in sweet potato in location A were lower than 0.20 and 4.40 mg/kg reported respectively for sweet potato in Cochin, Ernakulam District, India [19]. The same study reported 1.0 and 14.40 mg/kg of Cd and Pb in yam sample from the same locality as against the 0.08 and 0.04 mg/kg respectively reported for these metals in this study.

Fig. 3 showed that the range of heavy metals concentration in cassava tubers was 74.20±10.97-312.20±31.20 mg/kg, 14.20±1.29-38.22±6.07 mg/kg, 10.88±3.03-32.00±0.70 mg/kg, 3.20±0.20-11.20±1.09 mg/kg, 0.01±0.20-0.18±1.27 mg/kg, 0.02±0.03-0.12±0.07 mg/kg, 0.01±0.03-0.10±0.07 mg/kg and 0.03±0.00-0.05±0.42 mg/kg for Mn, Ni, Zn, Cu, Cr, Pb, Cd and As respectively. These values were again lower than the WHO allowable limit for human consumption except for Cr in location C. The

concentration of chromium in all the samples; sweet potato (0.80±1.27 mg/kg), yam (0.20±0.03 mg/kg) and cassava (0.18±0.03 mg/kg) from location C were higher than the WHO allowable limit of 0.05 mg/kg [14]. Although, heavy metals are potentially toxic, some of them in moderate amount (Zn, Cu, Ni, Mn, and Fe) are micronutrients required by plants and animals for optimum biochemical and physiological functions.

4. CONCLUSION

The present study showed that the heavy metals (Cd, Pb, Ni, As, Mn, Cu, and Zn) concentration in common tubers (yam, sweet potato, and cassava) cultivated in selected farm locations in Enugu North District of Enugu State were below the WHO recommended limit and hence pose no danger to consumers of such food. However, risk assessment of chromium intake through the consumption of these tubers is recommended to ascertain the level of human exposure to chromium in the study area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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