Heavy Metal Contents of Some Common Tubers Sold in Benin Metropolis, Benin City, Nigeria

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Abstract

This study was conducted to determine the concentration of heavy metal in tuber crops bought at two different markets in Benin metropolis. A total of 12 yam and potato tubers were bought at two markets in Benin City with 6 samples each from Ikpoba Hill market and Uselu market. Samples of tubers which include Hausa yam, native yam and yellow yam varieties, white potato, red potato and Irish potato varieties were obtained. The samples were washed, dried, digested and the concentration of iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), cadmium (Cd), chromium (Cr), lead (Pb), nickel (Ni) and Arsenic (As) were analysed using Atomic Absorption Spectroscopy (Bulk Scientific 210 VGP). It was observed that the peeled samples were having less concentration of metals than the unpeeled samples. Fe dominated all heavy metals analysed in both the yam and potato varieties. The concentrations of Zn, Cu, Cr and Pb showed significant difference in the unpeeled to peeled yam while Fe, Mn, Zn, Cr and Pb concentrations showed significant difference in the unpeeled to peeled potato. Processing (peeling) brought about reduction in the levels of the heavy metals. Cd and Pb concentrations in the unpeeled yam and potato varieties were above the international food standards (CODEX). The high concentrations of heavy metals in this study can be linked to atmospheric deposition of exhaust fumes and other farming practices where these tubers were grown, transported and are been sold. However, further study is needed to determine the soil characteristics where food crops are grown.

Keywords: Heavy metals, Atomic Absorption Spectroscopy, Yam tuber, Potato tuber

INTRODUCTION

The nutritional health and well-being of humans are majorly dependent on foods of plant origin. Plants are critical components of the dietary food chain as they provide almost all essential mineral and organic nutrients to humans (Grusak and Penna, 1999). Tropical tuber crops including yam and potato are raw materials for small-scale industries, and consumed as staple foods especially in the less developed countries (Ravi *et al*., 1996). Tubers are critical components in the diet during the early evolution of humankind and were the most important food crops of very ancient origin in the tropics and sub-tropic (Asha and Nair, 2002). Apart from providing basic food security and a source of income and diversity in diet, tuber crops also serve as additional source of essential vitamins and minerals (Asha and Nair, 2002). Tuber crops are found in a wide variety of production systems and do well under various levels of management from low to high input systems (Aregahegn *et al*., 2013). This is a distinctive feature, which makes them important for improving the productivity and richness of agro-systems. Even though their agronomic properties have been well documented, their food and industrial quality characteristics have not been studied extensively (Aregahegn *et al*., 2013). The full potential of these staples is being realized in developing countries and they would continue to contribute to energy and nutrient requirements for the increasing population (Aregahegn *et al*., 2013).

Uptake and accumulation of heavy metals by plants is either via the roots and foliar surfaces (Sawidis *et al*., 2001). Some factors which affect metal uptake include soil pH, metal solubility, conductivity, stages of plant growth, plant species, soil type and fertilizers (Ismail *et al*., 2005; Sharma *et al*., 2006). Previous work by Kaplan *et al*. (2005) showed that individual plants have different capacity to absorb and accumulate heavy metals which leads to contamination of the food chain. This situation causes varying degrees of illness based on acute and chronic exposures (Demirezen and Ahmet, 2006). Metals such as cadmium and copper are cumulative poisons, which cause environmental hazards and are reported to be exceptionally toxic (Ellen *et al*., 1990). Accurate and adequate food composition data are however invaluable for estimating the adequacy of intakes of essential nutrients and assessing exposure risks from intake of toxic non-essential elements. Heavy metals are significant in nutrition, either for their essential nature or their toxicity. Heavy metals analysis is an important part of environmental pollution studies and the level of their concentrations in foods such as tubers have been of considerable interest because of their toxic effect (Asaolu, 1995). This study aims to determine the concentration of heavy metal in tuber crops bought at two different markets in Benin metropolis, Southern Nigeria in a view to ascertain human risk exposure.

MATERIALS AND METHODS

Study Area

This research was conducted in Benin City, Edo State situated at 6^{o}20’00N, 5^{o}37’20E (Figure 1). The Yam and Potato samples were bought at two popular and most visited markets in Benin City and their geographic coordinates recorded with a global positioning system (GPS). The markets are Ikpoba Hill market (6^o 21’ 1’’ N 5^o 39’ 32’’ E) and Uselu market (6^o 22’ 32’’ N 5^o 36’ 49’’ E).

Sample Collection and Preparation

A total of 12 yam and potato tubers were bought at two popular and most visited markets in Benin City with 6 samples each from the Ikpoba Hill market and Uselu market.

The samples include

1. Hausa Yam – *Dioscorea spp*
2. Native Yam – *Dioscorea rotundata*
3. Yellow Yam – *Dioscorea cayenensis*
4. Irish Potato – *Solanum tuberosum*
5. Red Potato – *Ipomoea batatas*
6. White Potato - *Ipomoea batatas*

The samples were washed with distilled water to remove dirt; each variety of tubers was divided into two portions. The skin of one portion was peeled and that of other was left unpeeled. All samples (both peeled and unpeeled) were sliced into smaller sizes using a stainless steel knife into different aluminum plates and labeled properly prior to digestion.

Species Identification

The various yam and potato species were identified by the Department of Crop Science and the Department of Plant Biology and Biotechnology, Faculty of Agriculture and faculty of Life Sciences, University of Benin, Benin City.

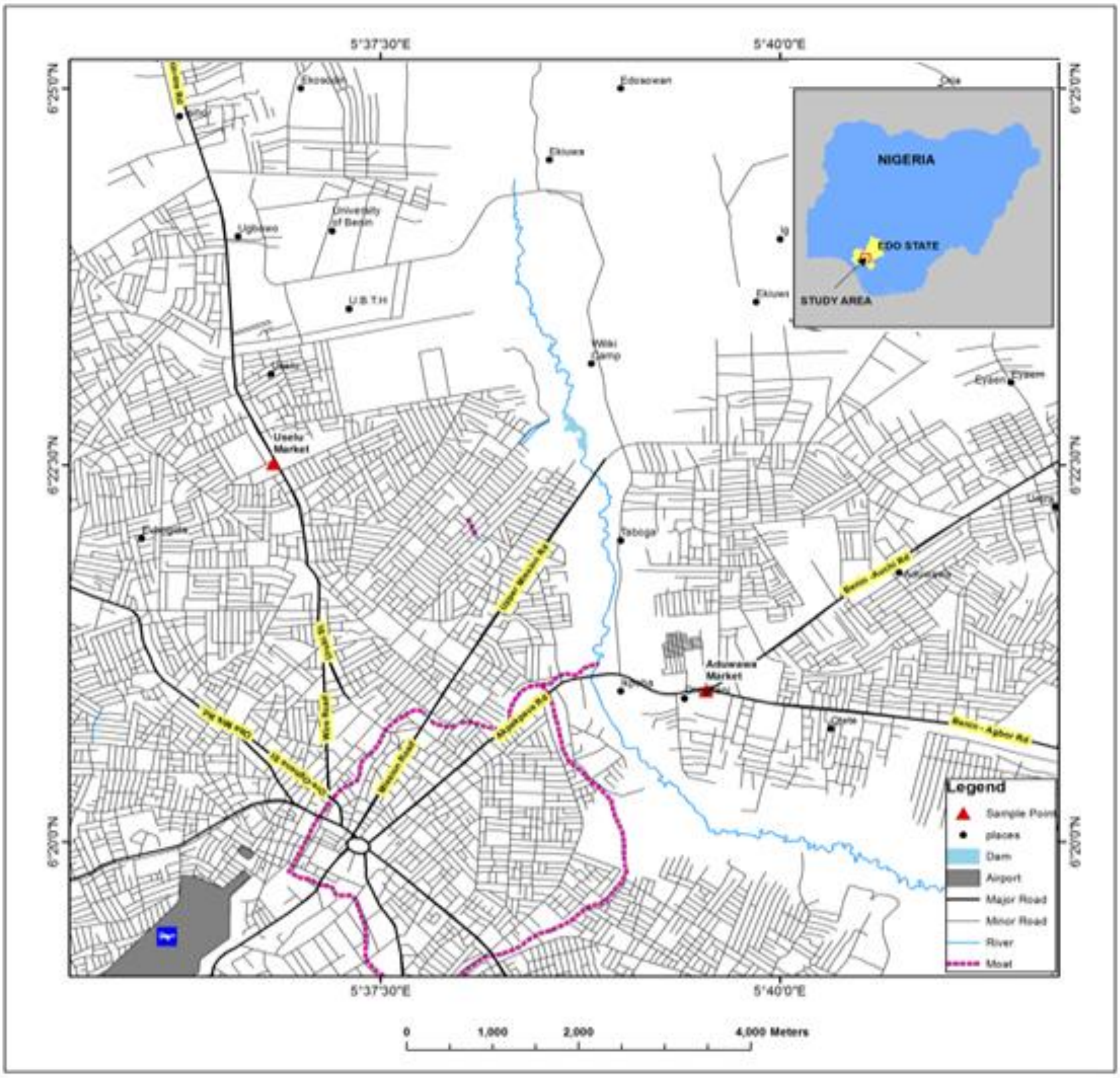


Figure 1: Map showing the location of the study area (red triangles).

Digestion of Samples

Digestions of the samples were done adopting procedure from Radojevic and Bashkin (1999). 5g of the yam samples (peeled and unpeeled) were placed in an oven at 105^oC for 1 hour and then 1g of yam samples were weighed into a 50ml Pyrex beaker and put in a crucible with cover. The beaker was then placed in a muffle furnace set at 500^oC and the material was left to ash for 3 hours. The ash was dissolved in 10ml 10% HNO_3 and it was stirred to dissolve the ash completely using a glass stirring rod. The resulting solution was heated gently on a hot plate for 20 minutes. The solution was then cooled and filtered into a 250ml flask with the aid of filter paper (Whatman No.1) and further diluted to mark with distilled Water. The same procedure was carried out for the potato samples.

Heavy Metals Analysis

Heavy metals were determined in the Ecotoxicology laboratory, University of Benin, Benin City. After cooling the digested samples, the mixture was diluted with distilled water to 100 ml and subsequently analysed by using Atomic Absorption Spectrophotometer (AAS Bulk

Scientific 210 VGP) to determine the concentrations of Copper (Cu), Manganese (Mn), Lead (Pb), cadmium (Cd), Zinc (Zn), Iron (Fe), Chromium (Cr) and Nickel (Ni) in the digest of yam and potato samples (AOAC).

Data Analyses

All statistical tests were carried out using Microsoft Excel software. If significant value ($p<0.05$) were obtained, Duncan multiple range (DMR) tests were performed to determine the point of significant differences using the computer SPSS 20.0 window application.

RESULTS

Yam (*Dioscorea* spp.)

Table 1 shows the summary of heavy metal concentration in yam varieties which includes Hausa yam, native yam and yellow yam. The varieties of yam were analyzed in two forms – peeled and unpeeled. The mean concentrations and standard deviation of the replicated samples were presented in the table. The following yam varieties such as Hausa yam, native yam and yellow yam recorded significant difference ($p < 0.05$) from unpeeled to peeled in the concentration of Zn, Cu, Cd, Cr, and Pb while Fe, Mn, Ni and As showed no significant difference ($p > 0.05$) in the various yam varieties. This indicates that the concentration of heavy metals were higher in the unpeeled yam varieties than in the peeled yams. Iron (Fe) was recorded as the most dominant heavy metal.

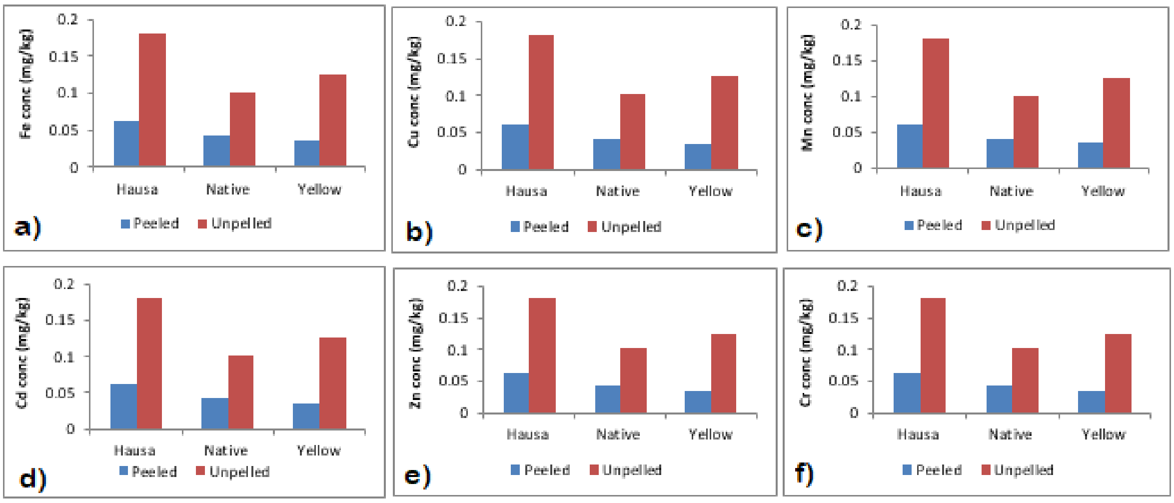
Table 1: Summary of heavy metal concentrations in the various yam varieties

Heavy Metals	Hausa Yam Peeled $\bar{x}$±SD	Native Yam Peeled $\bar{x}$±SD	Yellow Yam Peeled $\bar{x}$±SD	Hausa Yam Unpeeled $\bar{x}$±SD	Native Yam Unpeeled $\bar{x}$±SD	Yellow Yam Unpeeled $\bar{x}$±SD	P-Value
Fe (mg/Kg)	206.80±122.90	146.50±44.97	112.95±19.45	283.10±187.95	261.80±1.13	152.40±23.90	p>0.05
Mn (mg/Kg)	1.03±0.25	0.54±0.05	0.33±0.16	1.21±0.43	0.75±0.14	0.98±0.27	p>0.05
Zn (mg/Kg)	40.00^{c} ±3.54	50.65^{b} ±6.43	29.20^{d} ±3.96	71.90^{a} ±5.80	57.90^{b} ±8.34	47.45^{b} ±4.31	p<0.05
Cu (mg/Kg)	1.16^{a} ±0.50	0.25^{b} ±0.07	0.10^{c} ±0.01	1.96^{a} ±0.79	0.65^{b} ±0.12	0.31^{b} ±0.02	p<0.05
Cd (mg/Kg)	0.06^{c} ±0.01	0.05^{c} ±0.02	0.10^{b} ±0.00	0.25^{a} ±0.07	0.22^{a} ±0.10	0.16^{a} ±0.02	p<0.05
Cr (mg/Kg)	0.08^{b} ±0.06	0.07^{b} ±0.04	0.07^{b} ±0.01	0.38^{a} ±0.13	0.15^{b} ±0.02	0.10^{b} ±0.03	p<0.05
Pb (mg/Kg)	0.06^{b} ±0.02	0.04^{b} ±0.03	0.04^{b} ±0.02	0.18^{a} ±0.03	0.10^{a} ±0.04	0.13^{a} ±0.05	p<0.05
Ni (mg/Kg)	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	p>0.05
As (mg/Kg)	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	p>0.05

p>0.05 – No significant difference
p<0.05 – Significant difference

Potato (*Solanum tuberosum*)

Table 2 shows the summary of heavy metal concentrations in potato varieties which include white potato, red potato and Irish potato. The varieties of potatoes were analyzed in two forms – peeled and unpeeled. The mean concentrations and standard deviation of the replicated samples were presented in the table 4.2. The following potato varieties such as white potato, red potato and Irish potato recorded significant difference ($p < 0.05$) from peeled to unpeeled in the concentration of Fe, Mn, Zn, Cr and Pb while Cu, Cd, Ni and As showed no significant difference ($p > 0.05$) in the various potato varieties. This indicates that the concentration of heavy metals were higher in the unpeeled potato varieties than in the peeled potatoes.



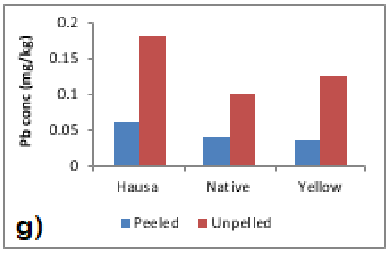


Figure 2: Variation in concentration of heavy metals in the various Yam varieties and their processed forms. The metals are Fe, Cu, Mn, Cd, Zn, Cr and Pb (as identified from a-g).

Table 2: Summary of heavy metal concentrations in the various potato varieties

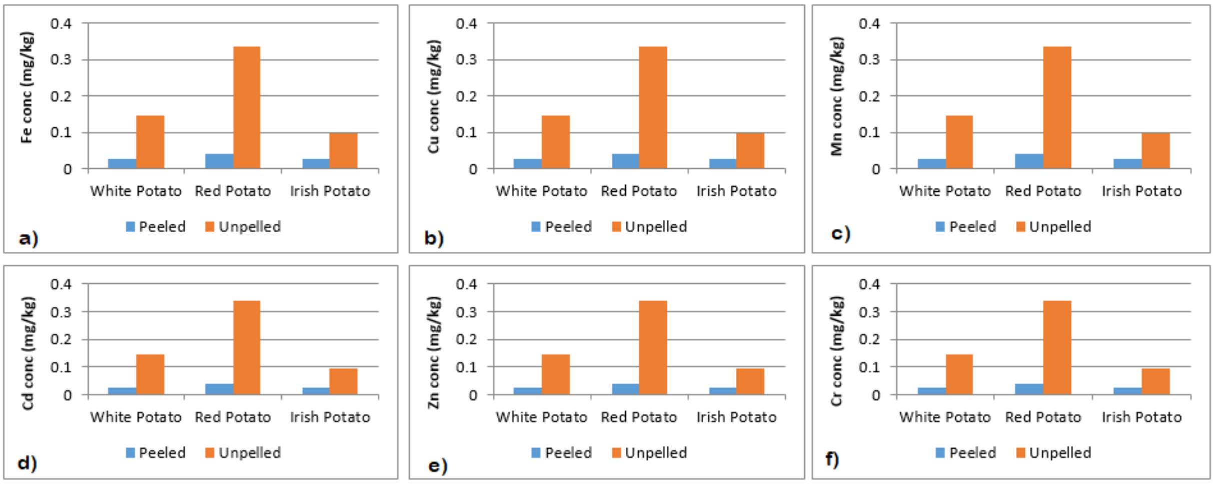
Heavy Metals	White Potato Peeled X̄±SD	Red Potato Peeled X̄±SD	Irish Potato Peeled X̄±SD	White Potato Unpeeled X̄±SD	Red Potato Unpeeled X̄±SD	Irish Potato Unpeeled X̄±SD	P-Value
Fe (mg/Kg)	114.00^{b} ±14.99	129.75^{b} ±0.91	113.70^{b} ±38.47	211.45^{a} ±47.31	337.08^{a} ±2.37	195.70^{a} ±122.33	$p<0.05$
Mn (mg/Kg)	0.17^{c} ±0.05	0.78^{b} ±0.01	0.23^{c} ±0.07	0.50^{b} ±0.24	1.39^{a} ±0.01	0.74^{b} ±0.30	$p<0.05$
Zn (mg/Kg)	25.05^{b} ±11.38	43.52^{b} ±0.31	24.65^{b} ±5.87	47.45^{b} ±17.04	71.66^{a} ±0.50	42.80^{b} ±9.48	$p<0.05$
Cu (mg/Kg)	0.11±0.01	0.31±0.00	0.36±0.23	0.19±0.01	0.94±0.01	0.77±0.54	$p>0.05$
Cd (mg/Kg)	0.09±0.00	0.03±0.00	0.09±0.10	0.20±0.12	0.11±0.00	0.27±0.14	$p>0.05$
Cr (mg/Kg)	0.04^{d} ±0.03	0.07^{c} ±0.00	0.05^{d} ±0.02	0.11^{b} ±0.02	0.12^{b} ±0.00	0.18^{a} ±0.01	$p<0.05$
Pb (mg/Kg)	0.03^{c} ±0.00	0.04^{c} ±0.00	0.03^{c} ±0.01	0.15^{b} ±0.05	0.34^{a} ±0.00	0.10^{b} ±0.01	$p<0.05$
Ni (mg/Kg)	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	$p>0.05$
As (mg/Kg)	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	$p>0.05$

$p>0.05$ – No significant difference
$p<0.05$ – Significant difference

DISCUSSION

Heavy Metal Status in Yam Varieties

The soil, water and air are contaminated by heavy metals, which directly affect agricultural crops through cultivation. Heavy metals in contaminated cultivatable land will on a long-term accumulate in plant and therefore in animals which consume the crops (Mee-Young *et al.*, 2013). The concentration of Fe in the peeled Hausa yam, native yam and yellow yam were 206.80, 146.50 and 112. 95 (mg/kg) respectively while the concentrations of Fe in the unpeeled yam varieties such as Hausa yam, native yam and yellow yam were 283.10, 261.80 and 152.40 (mg/kg) respectively. Lower concentration was recorded for peeled yellow yam while the highest concentration was recorded for unpeeled Hausa yam. Mn is a micro nutrient required by plants and man and it is found in the organic matter in the soil (Orhue and Usi, 2015).



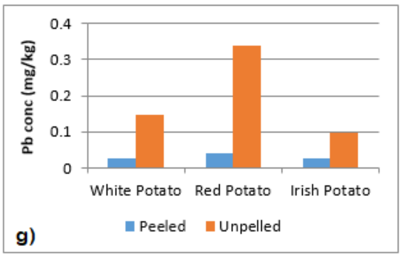


Figure 3: Variation in concentration of heavy metals in the various Potato varieties and their processed forms. The metals are Fe, Cu, Mn, Cd, Zn, Cr and Pb (as identified from a-g).

The concentration of Mn in the peeled Hausa yam, native yam and yellow yam were 1.03, 0.54 and 0.33 (mg/kg) respectively while the concentrations of Mn in the unpeeled yam varieties such as Hausa yam, native yam and yellow yam were 1.21, 0.75 and 0.98 (mg/kg) respectively. The highest concentration of Mn was recorded for unpeeled Hausa yam while the lowest concentration was recorded for peeled yellow yam.

The concentration of Zn in the peeled Hausa yam, native yam and yellow yam were 40.00, 50.65 and 29.20 (mg/kg) respectively while the concentrations of Zn in the unpeeled yam varieties such as Hausa yam, native yam and yellow yam were 71.90, 57.90 and 47.45 (mg/kg) respectively. Lower concentration was of Zn was recorded for peeled yellow yam while the highest concentration was recorded for unpeeled Hausa yam. The prevalence of Zn, though the least toxic among all heavy metals is indicative of the significance of zinc in our ecosystem (Ladipo and Doherty, 2011).

The concentration of Cu in the peeled Hausa yam, native yam and yellow yam were 1.16, 0.25 and 0.10 (mg/kg) respectively while the concentrations of Cu in the unpeeled yam varieties such as Hausa yam, native yam and yellow yam were 1.96, 0.65 and 0.31 (mg/kg) respectively. Lower concentration was of Cu was recorded for peeled yellow yam while the highest concentration was recorded for unpeeled Hausa yam.

The concentration of Cd and Cr in the peeled Hausa yam, native yam and yellow yam were 0.06, 0.05 and 0.10 (mg/kg) for Cd and 0.08, 0.07 and 0.07 (mg/kg) for Cr respectively while the concentrations of Cd and Cr in the unpeeled yam varieties such as Hausa yam, native yam and yellow yam were 0.25, 0.22 and 0.16 (mg/kg) for Cd and 0.38, 0.15 and 0.10 (mg/kg) for Cr respectively. The highest concentration of Cd and Cr was recorded for unpeeled Hausa yam while the lowest concentration of Cd and Cr was recorded for peeled native yam and yellow yam respectively. The concentration of Pb in the peeled Hausa yam, native yam and yellow yam were 0.06, 0.04 and 0.04 (mg/kg) respectively while the concentrations of Pb in the unpeeled yam varieties such as Hausa yam, native yam and yellow yam were 0.18, 0.10 and

0.13 (mg/kg) respectively. Lower concentration was of Pb was recorded for peeled native yam and yellow yam while the highest concentration was recorded for unpeeled Hausa yam followed by unpeeled yellow yam.

The result of this study showed that concentrations of the heavy metals differed in relation to the yam varieties and processed forms. Relating to yam varieties, Hausa yam contained the highest concentrations of all the heavy metals analyzed in the unpeeled yam varieties, while in the peeled variety, Hausa yam contained the highest levels of Fe, Mn, Cu, Cr, and Pb. It can also be attributed to the farming systems and the use of phosphate fertilizer which are applied in growing tubers for commercial purpose in Nigeria.

Furthermore, among the peeled yam variety, the highest concentrations of Zn and Cd were recorded in native yam and yellow yam respectively. This can be attributed to the farming systems of the local farmers in Benin City where the native yam and yellow yam are grown. Generally higher concentrations of heavy metals were recorded in unpeeled yam varieties than the peeled varieties. This kind of variation had earlier been reported by Divya *et al*. (2015) in their study of heavy metal contamination of some common tubers sold in local markets of Ernakulam District, Kerala, India. The high values of heavy metal in the unpeeled varieties of these tubers products can be attributed to heavy metal adsorption to the skin of food crops analyzed because higher concentrations were recorded in unpeeled when compared to the peeled. The outer skin tissues had more metal contamination than the inner part of the tubers (Fiona *et al*., 2003).

It was also observed in this study that by peeling the yam skin, the amount of heavy metal concentration can be reduced as this can also reduce the amount of metal entry into human body. Most of the tubers used for cooking are peeled and hence a great amount of contamination can be avoided using this peeling procedure. Divya *et al*. (2015) opined that the concentration of heavy metals in many plants can be reduced up to 20-50% by proper washing of the tubers. Washing practices should be done as it is recommended to reduce small amount of heavy metals that could be attached to the skin of the yam tuber.

The concentrations of Pb and Cd in the unpeeled Hausa yam, yellow yam and native yam respectively exceeded the value of 0.1 mg/kg as recommended by joint FAO/WHO food standards programme CODEX committee on contaminants in foods by the joint FAO/WHO food standards (CODEX. 2011).
The levels of Cd in peeled and unpeeled yellow yam variety were approximately 0.1 mg/kg and 0.16 mg/kg respectively. Furthermore, no suitable and applicable standard was found for other heavy metals analysed in this study. The occurrence of Pb, As, Hg, Cd, Cr and Ni in our ecosystem can endanger public health when they find their way into the food chain (Adepoju-Bello *et al*., 2009).

Heavy Metal Status of Potato Varieties

Heavy metal concentrations in potato also varied in relation to varieties and processed form. The variation recorded in the unpeeled potato varieties generally recorded higher levels of the heavy metals than peeled potato. Unpeeled red potato had the highest value of Fe, Mn, Zn, Cu and Pb while unpeeled Irish potato had the highest concentration of Cd and Cr. The concentration of Fe in the peeled white potato, red potato and Irish potato were 114.00, 129.75 and 113.70 (mg/kg) respectively while the concentrations of Fe in the unpeeled potato varieties such as white potato, red potato and Irish potato were 211.45, 337.08 and 195.70 (mg/kg) respectively.

Lower concentration was recorded for peeled Irish potato while the highest concentration was recorded for unpeeled red potato. Statistical analysis showed a significant difference ($P<0.05$) between the unpeeled and peeled potato varieties. The concentration of Mn in the peeled white potato, red potato and Irish potato were 0.17, 0.78 and 0.23 (mg/kg) respectively while the concentrations of Mn in the unpeeled potato varieties such as white potato, red potato and Irish potato were 0.50, 1.39 and 0.74 (mg/kg) respectively. The highest concentration of Mn was recorded for unpeeled red potato while the lowest concentration was recorded for peeled white potato. The concentration of Zn in the peeled white potato, red potato and Irish potato were 25.05, 43.52 and 24.65 (mg/kg) respectively while the concentrations of Zn in the unpeeled potato varieties such as white potato, red potato and Irish potato were 47.45, 71.66 and 42.80 (mg/kg) respectively. Lower concentration of Zn was recorded for peeled Irish potato while the highest concentration was recorded for unpeeled red potato. Statistical analysis showed a significant difference ($P<0.05$) between the unpeeled and peeled potato varieties.

The concentration of Cu and Cd in the peeled white potato, red potato and Irish potato were 0.11, 0.31 and 0.36 (mg/kg) for Cu and 0.09, 0.03 and 0.09 (mg/kg) for Cd respectively while the concentrations of Cu and Cd in the unpeeled potato varieties such as white potato, red potato and Irish potato were 0.19, 0.94 and 0.77 (mg/kg) for Cu and 0.20, 0.11 and 0.27 (mg/kg) for Cd respectively. The highest concentration of Cu and Cd was recorded for unpeeled red potato and unpeeled Irish potato while the lowest concentration of Cu and Cd was recorded peeled white potato and peeled red potato. Statistical analysis showed no significant difference ($P>0.05$) between the unpeeled and peeled potato varieties for Cu and Cd.

The concentration of Cr and Pb in the peeled white potato, red potato and Irish potato were 0.04, 0.07 and 0.05 (mg/kg) for Cr and 0.03, 0.04 and 0.03 (mg/kg) for Pb respectively while the concentrations of Cr and Pb in the unpeeled potato varieties such as white potato, red potato and Irish potato were 0.11, 0.12 and 0.18 (mg/kg) for Cr and 0.15, 0.34 and 0.10 (mg/kg) for Pb respectively. The highest concentration of Cr and Pb was recorded for unpeeled Irish potato and unpeeled red potato respectively while the lowest concentration of Cr and Pb was recorded in the peeled white potato and peeled red potato respectively.

Statistical analysis showed a significant difference ($P<0.05$) between the unpeeled and peeled potato varieties for Cr and Pb potato varieties. The levels of Pb and Cd in all the unpeeled potato varieties exceeded joint FAO/WHO food standards recommended value of 0.1 mg/kg (CODEX, 2011). In relation to Cd, concentrations was greater than 0.1 mg/kg in unpeeled red and Irish potatoes while in the peeled forms of the same varieties, the observed concentrations were less than 0.1 mg/kg. Thus Cd was mostly adsorbed to the skin of the potatoes and by peeling off the skin of the potato; the concentration of heavy metal can actually be reduced to non-harmful level. Cadmium is a nonessential element in foods and natural waters, and it accumulates principally in the kidneys and liver. Cadmium in foods is mostly derived from various sources of environmental contamination (Öztürk *et al*., 2011). This result is similar to the study carried out by Öztürk *et al*. (2011) when they determined the concentrations of heavy metal in potato cultivars.

CONCLUSION

Tubers play a significant role in human diet. The findings from this study concluded that the concentration of heavy metals for unpeeled yam and potato varieties were more than the peeled samples. Fe was the most dominant heavy metals in this study. The process of peeling brought about reduction in the concentrations of the various heavy metals present in the tubers. Cd and

Pb concentrations in the unpeeled yam and potato were generally above the international food standards (CODEX). Heavy metals can enter into agricultural food products normally by using fertilizers and addition of pesticides and wastewater to grow crops. However, further study is needed to determine the soil characteristics where these tubers are grown.

References

Ahmad, I. M., Makama, S. A., Kiresur, V. R. and Amina, B. S. (2014). Efficiency of sweet potato farmers in Nigeria: Potentials for food security and poverty alleviation. *IOSR Journal of Agriculture and Veterinary Science*, 7(9): 01-06

Amienyo, C. A. and Ataga, A. E. (2007). Use of indigenous plant extracts for the protection of mechanically injured sweet potato (*Ipomoea batatas* (L.) Lam) tubers. *Scientific Research and Essay*, 2(5): 167–170.

Apau, J., Acheampong, A., Appiah, J. A. and Ansong, E. (2014). Levels and health risk assessment of heavy metals in tubers from markets in the Kumasi Metropolis, Ghana. *International Journal of Science and Technology*, 3 (9): 534-539.

Aregahegn, A., Chandravanshi, B. S. and Atlabachew, M (2013). Levels of major, minor and toxic metals in tubers and flour of *Dioscorea abyssinica* grown in Ethiopia. African Journal of Food, Agriculture, Nutrition and Development. 13(3): 7870-7887

Arora, M., Kiran, B., Rani, A., Kaur, B., and Mittal, N. (2008). Heavy metal accumulation in vegetables irrigated with water from different sources. *Food Chem*, 11: 811-815.

Asaolu, S. S. (1995). Lead content of vegetables and tomatoes at Erekesan Market, Ado-Ekiti. *Pak. J. Sci. Ind. Res.*, 38: 399.

Asha, K. I. and Nair, M. C. (2002). Ethnic knowledge system on wild Dioscorea (yams) by the Kanikkars of Southern Western Ghats, Kerala. *Indian J. Plant Genetics Res*.15: 146–49.

Chibowski, S., (2000) Studies of radioactive contaminations and heavy metal content in vegetables and fruit from Lubin, Poland, *Polish Journal of Environmental Studies*., 9: 249

Cieslinski, G., Van-Rees, K. C. J., Huang, P. M., Kozak, L. M., Rostad, H. P. W. and Knott, D. R. (1996). Cadmium uptake and bioaccumulation in selected cultivars of durum wheat and flax as affected by soil type. *Plant and Soil*, 182: 115-124.

Clark, R. B. (1992). *Marine Pollution*. Oxford, UK: Cleavendo Press. 61-79 pp.

CODEX. (2011). Working document for information and use in discussions related to contaminants and toxins in the GSCTFF. Codex Alimentarius Commission. Rome, Italy. p 13, 15.

Colak, H., Soylak, M. and Turkoglu, O. (2005). Determination of trace metal content of various herbal and fruit teas produced and marketed from Turkey. *Trace. Elem. Electrolytes*, 22: 192-195.

Demirezen, D., and Ahmet, A. (2006). Heavy metal levels in vegetables in turkey are within safe limits for Cu, Zn, Ni and exceeded for Cd and Pb. *J. Food Qual.*, 29, 252-265.

Divya, L., Jessen, G. and Midhun, G. (2015). Heavy metal contamination of some common tubers sold in local markets of Ernakulam District, Kerala, India. *International Research Journal of Biological Sciences*, 4(3): 49-52.

Ellen, G., Loon, J. W. and Tolsma, K. (1990). Heavy metals in vegetables grown in the Netherlands and in domestic and imported fruits. *Z.Lebensm. Unters. Forsch.*, 190: 34-39.

Emurotu, J. E., Salehdeen, U. M. and Ayeni, O. M. (2012). Assessment of heavy metals level in cassava flour sold in Anyigba Market Kogi State, Nigeria. *Advances in Applied Science Research*, 3(5): 2544-2548.

Fairweather-Tait, S. J. (1988). Zinc in human nutrition. *Nutrition Research Review*, 1: 23-37.

FAO. (1997). Report on the inter-center review of root and tuber crops research in the CGIAR. Rome: Food and Agriculture Organization.

Fiona, M. A., Ravi, A., Dolf, T. L., Bhupal, D. S., Rana, P. B., Neela, M., Chandra, S., Nigel, P., Madhoolika, A. and Singh, S. D., (2003). Heavy metal contamination of vegetable in Delhi. *Indian Agricultural Research Institute*, 3, 121-125.

Goyal, P., Sharma, P., Srivastava, S., and Srivastava, M. M. (2008). *Saraca indica* leaf powder for decontamination of Pb: Removal, recovery, adsorbent characterization and equilibrium modeling. *International Journal of Environmental Science Technology*, 5 (1): 27-34.

Grusak, M. A. and Penna, D. D. (1999). The nutrient composition of plants to enhance human nutrition and health. Ann. Rev. Plant Physiol. *Plant Mol. Biol*. 50: 133–161.

Ike, P. C. and Inoni, O. E. (2006). Determinants of yam production and economic efficiency among small-holder farmers in South-eastern Nigeria. *Journal of Central European Agriculture*, 7(2): 337–342.

Ismail, B. S., Farihah, K., and Khairiah, J. (2005). Bioaccumulation of heavy metals in vegetables from selected agricultural areas. *B. Environ. Contain. Tax.*, 74: 320-327.

Kalagbor, I. A., Adooh, D. L. and James, R. (2015). Determination of five heavy metals in white yam (Dioscorea Rotundata) and three- leaved yam (Dioscorea Dumetorum) from farms in Khana, Rivers State. *Environment and Pollution*; 4(4): 18-23

Kaplan, M., Orman, S., Kadar, I., and Koncz, J. (2005). Heavy metal accumulation in calcareous soil and sorghum plants after addition of sulphur-containing waste as a soil amendment in Turkey. Agric. *Ecosyst. Environ*., Ill: 41-46.

Kim, K. R., Kim, J. G., Park, J. S., Kim, M. S., Owens, G., Youn, G. H. and Lee, J. S. (2012). Immobilizer-assisted management of metal-contaminated agricultural soils for safer food production. *J. Environ. Manage*. 102: 88-95.

Mee-Young, S., Young-Eun, C., Chana, P., Ho-Yong, S., Jae-Hwan, L., and In-Sook, K. (2013). The contents of heavy metals (Cd, Cr, As, Pb, Ni, and Sn) in the Selected commercial yam powder products in South Korea. *Prev. Nutr. Food Sci.* 18(4): 249-255

Mendil, D., Tuzen, M., Yazici, K. and Soylak, M. (2005). Heavy metals in lichens from roadsides and an industrial zone in Trabzon, Turkey. *Bull. Environ. Contam.Toxicol*., 74: 190-194.

Narin, I., Tuzen, M., Sari, H., and Soylak, M. (2005). Heavy metal content of potato and corn chips from Turkey. *Bull. Environ. Contam. Toxicol*., 74: 1072-1077.

National Bureau of Statistics - NBS. (2012). LSMS – Integrated surveys on agriculture: general household survey panel 2010/11. Available at: www.nigerianstat.gov.ng/pages/download/194.

Nouri, J., Khorasani, N., Lorestani, B., Yousefi, N., Hassani, A. H. and Karami, M. (2009). Accumulation of heavy metals in soil and uptake by plant species with phytoremediation potential. *Environmental Earth Science*, 59(2): 315-323.

Nteranya, S. (2015). *Root and Tuber Crops (Cassava, Yam, Potato and Sweet Potato)*, An Action Plan for African Agricultural Transformation. United Nations Economic Commission for Africa.

Obighesan C. O. (1976). Report on potato production in Nigeria. In: Report of participants of international course on potato production. Wageningen, the Netherlands PP 64-71.

Okereke, C. J., Essien, E. and Wegwu M. O. (2016). Human health risk assessment of heavy metal contamination for population via consumption of selected vegetables and tubers grown in farmlands in Rivers State, South-South Nigeria. *Journal of Analytical & Pharmaceutical Research*, 3(6): 1-10.

Oktem, F., Yavrucuoglu, H., Turedi, A., and Tunc, B. (2005). The effect of nutritional habits on hematological parameters and trace elements in children. SuleymanDemirel Univ. *Tip Fak.Der.* 12: 6-10.

Onyedika, G. O. and Nwosu, G. U. (2008). Lead, Zinc and Cadmium in Root Crops from Mineralized Gelena-Sephalerite Mining Areas and Environment. *Pakistan Journal of Nutrition* 7(3): 418-420.

Osuocha, U. K., Chukwu, E. C., Ezekwe, A. S., Imo, C., Charles, S. U., Ibe, C., Ikpo, J. C. (2014). Heavy metal bioaccumulation of selected tuber crops from Ishiagu, Ebonyi State, South East, Nigeria. *Journal of Biodiversity and Environmental Sciences,* 5(2): 136-140

Oti, J. O. W. (2015) characterized heavy metal accumulation in tubers crown in a lead-zinc derelict mine and their significance to health and phytoremediation. *American Chemical Science Journal*, 8(3): 1-9.

Oti, W. J. O. (2016). Heavy metals in tapioca locally processed by sun-drying method along Enugu-Abakaliki highway in Ezilo, Ebonyi State, Nigeria. *Journal of Environmental Science, Toxicology and Food Technology* 10(7): 85-87

Oti, W. J. O. and Nwabue, F. I. (2013). Uptake of heavy metals by *Dioscorea rotundata* (White Yam) and *Ipomoea batatas* (Sweet Potato) from Enyigba lead-zinc Derelict. *Environment and Pollution*, 2(2): 79-84

Öztürk, E., Atsan, E., Polat, T. and Kara, K. (2011). Variation in heavy metal concentrations of potato (*Solanum tuberosum* L.) cultivars. *The Journal of Animal & Plant Sciences*, 21(2): 235-239

Petr, M., Fernanda, Z. C., Lourdes, Z. Z., Anderson, F., José R., Valter, A. N. (2016). Trace elements in common potatoes, sweet potatoes, cassava, yam and taro. *International Journal of Medicinal Plants and Natural Products* 2(2): 8 – 12

Radojevic, M. and Bashkin, V. N. (1999). *Practical environmental analysis*. Royal school of chemistry, Thomas Graham house, science park Cambridge, UK. 645pp

Rajković, M. B. Perić, L. and Kovačević, D. (2002). Quality of potatoes grown in various regions of Serbia as influenced by heavy metal and pesticide residues concentrations. *Journal of Agricultural Sciences*, 47(2): 161-177

Raphael, E. C., Opia, E. E. and Frank, E. O., (2010). Trace metals distribution in some common tuber crops and leafy vegetables grown in the Niger Delta region of Nigeria, *Pakistan Journal of Nutrition*., 9(10): 957-961

Ravi, V., Ked, J. and Balagopalan, C. (1996). Review on tropical root and tuber. In: Critical Reviews. Food Sci. Nutr. 36: 360–730.

Sawidis, T., Chettri, M. K., Papaionnou, A., Zachariadis, G., and Stratis. J. (2001). A study of metal distribution from lignite fuels using trees as biological monitors. *Ecotox. Environ. Safe*, 48: 27-35.

Sharma, R. K., Agrawal, M., and Marshall, F. (2006). Heavy metals contamination in vegetables grown in wastewater irrigated areas of Varanasi. *India B. Environ. Contain. Tax.,* 77: 312-318.

Shin, M., Cho, Y., Park, C. Sohn, H., Lim, J. and Kwun, I. (2013). The contents of heavy metals (Cd, Cr, As, Pb, Ni, and Sn) in the selected commercial yam powder products in South Korea. Prev. *Nutr. Food Sci*. 18(4): 249-255.

Singh, B. (2001). Heavy Metals in Soils: Sources, Chemical Reactions and Forms. In: GeoEnvironment: Proceedings of the 2nd Australia and New Zealand Conference on Environmental Geotechnics: Newcastle, New South Wales. pp. 77-93

Tewe, O. O., Ojeniyi, F. E., and Abu, O. A. (2003). Sweetpotato Production, Utilization, and Marketing in Nigeria. Lima, Peru. p. 44

Ugonna, C. U, Jolaoso, M. O, Onwualu, A. P. (2013). A technical appraisal of potato value chain in Nigeria. *International Research Journal of Agricultural Science and Soil Science*. 3(8): 291-301.

WHO, Europe (2007). Health risks of heavy metals from long-range transboundary air pollution.

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