Concentration of Heavy Metals in Selected Commercial Dry Yam and Yam Powder Products Sold at Oja Oba and Bodija Market, Ibadan, Nigeria

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Abstract*— In vitro propagation is a plant tissue culture technique that provides a way to increase the rapid production of disease-free and non-contaminated planting materials, which boosts economic growth and support good health of the citizens. Being an aseptic procedure, it often helps to overcome constraints related with availability of both high-quality planting material and non-contaminated food production. The different yield of agronomic crops resulting from the contemporary agriculture practices, are often contaminated with pollutants such as heavy metals; especially during the course of their cultivation and occasionally during post-harvest processing procedures. Dioscorea sp. (Yam) is an important staple food in Nigeria with many health benefits but the presence of such noxious contaminants as heavy metals in its tubers and products renders its consumption highly detrimental to the health of its different consumers particularly human. This study was designed to conduct a comparative assessment of selected heavy metals concentrations in the dry tubers and powders originating from tissue culture hardened D. rotundata and D. alata with their respective market samples. Samples of tubers originating from yield of hardened in vitro propagated of D. rotundata and D. alata were collected from an Ibadan based Tissue Culture laboratory over a period of 28 days. Also, samples of the retailed dry tubers of both yam species were purchased concurrently from two renowned markets in Ibadan for comparison. These yam samples were all subjected to digestion and heavy metal analysis using Flame Atomic Absorption Spectrometer (AAS) to determine the levels of Pb, Cr, Cd and Ni in the digestates. The results obtained were also analyzed using XLSTAT analytical tool while pollution load indices and contamination factor were calculated. The results obtained showed that the levels of Pb, Cr, Cd and Ni in the dry tubers of in vitro yam samples (Cr=Ni=Pb=Cd; Cr = 0.000 mg/l) were significantly less than ($p<0.005$) those purchased from the two markets (Cr>Ni>Pb=Cd; Cr = 0.018± 0.025 - 0.030± 0.037 mg/l). Yam cultivation via micro-propagation and screen-house environments prevent undue exposure of the resulting tubers to heavy metal toxicity and as such reduces human exposure to heavy metal contaminated foodstuffs.

***Index Terms*— In vitro propagation, Dioscorea rotundata, Dioscorea alata, Pollutants, Heavy metals, Tissue Culture, Toxicity.**

I. INTRODUCTION

Dioscorea sp. is an edible starchy tuber, with cultural economic and nutritional importance in the tropical and subtropical regions of the world (1). It is an excellent source of carbohydrate, energy, vitamins, minerals and protein (2). It can either be boiled, fried, roasted, cooked and pounded before eating or be processed into yam flour (3), (4). The process of producing yam flour involves: slicing, parboiling, drying and milling of the yam to yield flour (5), (6), (7), (8). Heavy metals have often been associated with contamination and potential toxicity (9). Although, majority of the heavy metals are toxic only if taken in excess or encountered in certain forms, others are known to be toxic if their permissible threshold is exceeded (10). Heavy metals contamination of soil, water and air often directly affect agricultural crops through cultivation (11), (12). It is well known that soil contamination by heavy metals can transfer to food and ultimately to consumers (13). Plants or crops grown on such contaminated soil are likely to absorb these metals from the soil through the roots (14, 15). That is why root crops and tubers easily get contaminated with heavy metals (16).

Prolong human consumption of unsafe concentration of heavy metals in food stuff may lead to the disruption of numerous organs, gastrointestinal tissues and biochemical processes in human body because heavy metals are bio-accumulative and persistent (17), (18), (19). Consequently, due to the fact that the sign and symptoms of contamination by heavy metals do not appear early or easily, especially in humans, heavy metal contamination of the human body system has been of great concern. Based on this, this study was designed to carry out a comparative assessment of heavy metals concentrations in dried tubers and powders originating from hardened micropropagated *Dioscorea rotundata* and *Dioscorea alata* with their respective contextual market samples from two important markets in ibadan; so as to ascertain that the commercial yam products being sold for public consumption are safe.

II. Materials and Methods

2.1 Description of Study Site

The first sampling in this study involved the collection of processed yam from Oja-Oba and Bodija markets in Ibadan city. Ibadan is the capital and most populous city of Oyo state, Nigeria. It is situated at 7.39°N Latitude, 3.9°E Longitude. Oja-Oba market is located along Ibadan South-West Local Government Area of Oyo State. It is one of the biggest foodstuffs market in Ibadan. It is composed of thousands of independent sellers who compete for sales of major food items like Yam and its different products, Maize, Cowpea or Beans, Rice, Vegetables, Palm and Vegetable Oils, Cassava products, Onions, Tomatoes, Pepper, Millet, Sorghum, fruits etc. The distribution pattern of the market is mostly on-street/roadside trading.

Bodija market is located close to the University of Ibadan Campus, along Oyo-Ogbomoso-Ilorin interstate road network. It is a region in Ibadan North Local Government Area of Oyo State. It is an open-air market, which is most reputable when it comes to various fresh and dried food products. It is made up of a series of buildings, which are arranged in blocks. The market is designed in such a way that every farm produce: namely Rice, Beans, Pepper, Yam, Garri, dried Maize, Groundnuts, Tomatoes etc. has its own row stalls, well arranged and lined. The market can also be described as a mixture of open space trading, concrete and wooden stalls. The Tissue Culture Unit of NACGRAB is part of the Biotechnology Department and is involved in the micropropagation of different crop species using the *in vitro* techniques. It is the control area for this study.

2.2 Collection of Samples

At the Oja- Oba market, samples of dry yam (Figure 1) and yam powder products were randomly collected by purchasing the products from those selling them over the period of four weeks. The selected and purchased dry yam and yam powder products were of the dry white yam type and the dry water yam type along with their different ground products.

At Bodija Market, four (4) samples of dry yam and their powdered products were collected by purchasing them from those selling them along 7.4358o N latitude and 3.9192o E longitude for a period of four weeks. The samples collected include dry white, dry water yam and their pulverized products. The native nomenclatures for the different dried yam tubers and their products, which are being sold at the two markets (Figure 2) are highlighted in Table 1.

Figure 1: Different processed yam products being sold at (a and b) Oja- Oba (c) Bodija Market

Figure 2: (a) Dried White Yam Tubers (b) Dried Water Yam Tubers (c) Pulverized Yam Flour

Table 1: The Different Yam Products Sampled and Their English Names

S/N	Different Yam Products	English Names	Scientific Names	Yoruba Names
1	Elubo isu gidi	Dried white yam (Tubers and Pulverised)	*Dioscorea rotundata*	Elubo gidi: Kiayomo, Ipokoro and Gbararo
2	Kunube (Elubo isu gidi)	Dried white yam (Peel)	*Dioscorea rotundata*	Elubo gidi: Kiayomo, Ipokoro and Gbararo
3	Elubo Ewura	Dried water yam (Tubers and Pulverised)	*Dioscorea alata*	Elubo Ewura

All the control white and water yam were collected from National Centre for Genetic Resources and Biotechnology, Moor Plantation, Apata, Ibadan, latitude 7°23′31.5″N and longitude 3°50′46.5″E and they are tubers origination from in vitro propagation (Figure 3) namely Tropical Dioscorea rotundata (TDr 89/02665) and Tropical Dioscorea alata (TDa 2014/TDa 98/02565).

Figure 3: Different processes involved in raising in vitro control yam products

2.3 Processing and Analysis of Samples

The heavy metals namely Pb, Cd, Cr and Ni in the dry yam and pulverized yam products were analyzed using two processes: Acid digestion and heavy metal analysis using Atomic Absorption Spectrophotometer (AAS). Firstly, the collected dry white yam and dry water yam tuber samples were pounded into fine particles to homogenize the different samples. Afterwards, 0.5g of each of the dry white yam tubers, dry water yam tubers and their pulverized products were digested in concentrated nitric acid (HNO3) inside a digestive block for a period of one hour (1hr) at 100oC. The digestate of the samples were later diluted in 25ml of distilled water. The second process involved the determination of the heavy metals in the digested samples using Atomic Absorption Spectrophotometer (AAS) and ASS Buck Scientific Model 210 was employed.

Quality control of metal analysis was performed by analyzing reference samples of both white yam and water yam. The quality assurance scheme for the reagents included blank reagents.

The results's data were analyzed using Microsoft Office Excel workbook 2013 by finding mean and standard deviation. Histograms charts were used to plot the data where applicable to identify patterns of relationship within them.

III. Results

3.1. Concentrations of Pb, Cd, Cr and Ni in the dry yam and pulverized yam products collected from the Oja-Oba market:

The concentrations of the four heavy metals namely Pb, Cd, Cr and Ni analyzed from the first week to the fourth week in the dry yam and pulverized yam products are shown in Figures 4-7. The results obtained showed that the Pb, Cd and Ni concentrations were not detected in all the yam samples collected from the Oja-Oba market (0.000 mg/L). From these results, the concentrations of Pb, Cd and Ni was completely absent in the dry yam and pulverized yam product collected from the studied market. However, the results showed that Cr was present in all the samples. In Figure 4, Cr concentration present in the dry white yam collected from Oja- Oba market ranges from 0.000- 0.060 mg/L, while Figure 5 showed the Cr concentration present in the pulverized white yam collected from Oja- Oba market ranges from 0.000- 0.053 mg/L. However, Figure 6 showed that the Cr concentration present in the dry water yam collected from Oja- Oba market ranges from 0.000- 0.053 mg/L while, Figure 7 showed that the Cr concentration present in pulverized water yam collected from Oja-Oba market ranges from 0.000- 0.072 mg/L. From the result of the analysis done, the highest Cr concentration was found in the pulverized water yam collected.

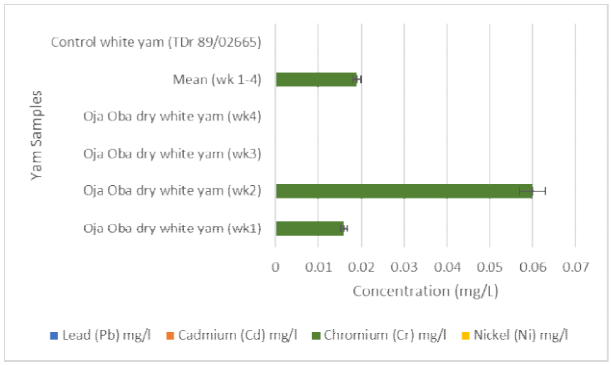

Figure 4: Concentration of Pb, Cd, Cr and Ni in Dry White Yam collected from Oja-Oba Market (From week 1-4)

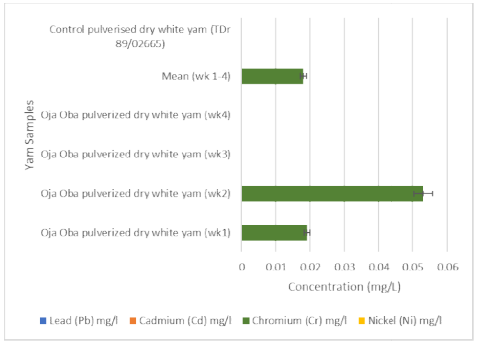

Figure 5: Concentration of Pb, Cd, Cr and Ni in Pulverized Dry White Yam collected from Oja-Oba Market (From week 1-4)

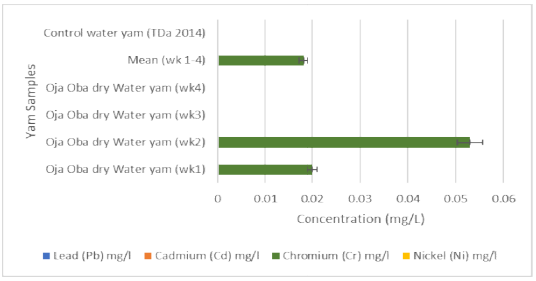

Figure 6: Concentration of Pb, Cd, Cr and Ni in Dry Water Yam collected from Oja-Oba Market (From week 1-4)

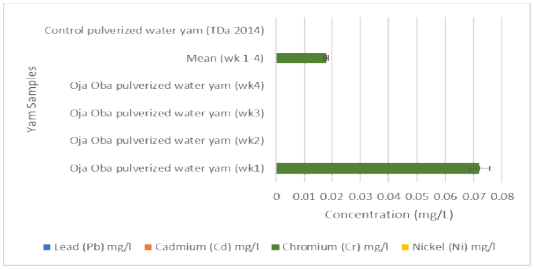

Figure 7: Concentration of Pb, Cd, Cr and Ni in Pulverized Dry Water Yam collected from Oja-Oba Market (From week 1-4)

3.2. Mean Concentrations of Pb, Cd, Cr and Ni in the dry yam and pulverized yam products collected from the Oja-Oba market:

The mean concentration of the studied heavy metals that was present in the dry white yam, dry water yam and pulverized white and water yam products, compared with the concentration of each of the heavy metal present in the control dry white yam (TDr 89/02665), control pulverized white yam products (TDr 89/02665) and control dry water yam (TDa 2014), control pulverized water yam products (TDa 2014) for four weeks are shown in Figures 8. The results obtained indicated that Pb, Cd and Ni are completely absent in the analyzed white yam samples while the mean concentration of Cr present in both the dry white yam (0.019 ± 0.028 mg/L) and pulverized white yam (0.018 ± 0.025 mg/L) was higher than those in control yam samples (0.000 ± 0 mg/L) (Figure 8). Also, Pb, Cd and Ni were not detected in the analyzed dry water yam and pulverized water yam samples while only concentration of Cr was detected and the mean concentration found in both the dry water yam (0.018 ± 0.025 mg/L) and pulverized water yam (0.018 ± 0.025 mg/L) was higher than those in control water yam samples (0.000 ± 0 mg/L) (Figure 8).

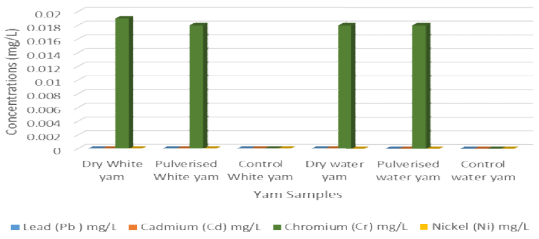

Figure 8: Mean Concentration of Pb, Cd, Cr and Ni in White and Water Yam Products at Oja Oba Market compared with Controls

3.3. Heavy Metals Concentrations in White and Water Yam Products at Oja Oba Market compared with Controls, NESREA and WHO Standard Limits

In Table 2 below, the NESREA standard regulatory limits for food beverage and tobacco in Nigeria has been indicated.

Table 2: NESREA and WHO Heavy Metals Standard Regulator Limits for Food, Beverage and Tobacco

METALS	UNIT	MAXIMUM PERMISSIBLE LIMIT (NESREA)	MAXIMUM PERMISSIBLE LIMIT (WHO)
Lead	mg/l	0.05	2.00
Cadmium	mg/l	1.00	0.02
Chromium (hexavalent)	mg/l	0.05	-
Nickel	mg/l	0.05	10.00
Total Chromium	mg/l	1.0	1.30

The results obtained for samples taken at Oja Oba was also compared with the Standard Limits of NESREA and WHO. The outcome of the comparison indicated that all the results obtained were very much below the standard regulatory limits of NESREA (Figures 9 and 10) and WHO (Figures 11 – 13).

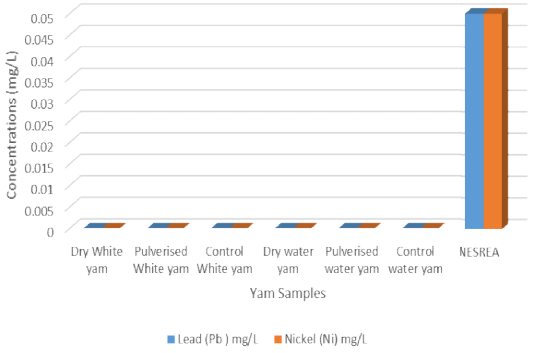

Figure 9: Mean Concentration of Pb and Ni in White and Water Yam Products at Oja Oba Market compared with Controls and NESREA Standard Limits

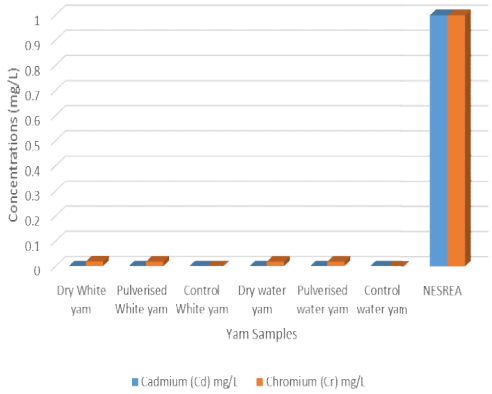

Figure 10: Mean Concentration of Cd and Cr in White and Water Yam Products at Oja Oba Market compared with Controls and NESREA Standard Limits

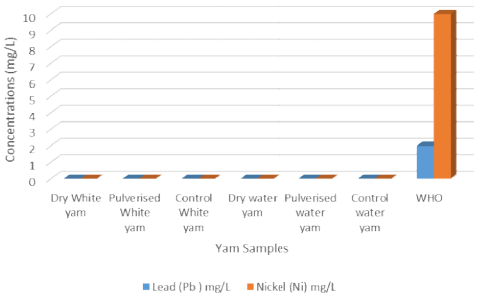

Figure 11: Mean Concentration of Pb and Ni in White and Water Yam Products at Oja Oba Market compared with Controls and WHO Standard Limits

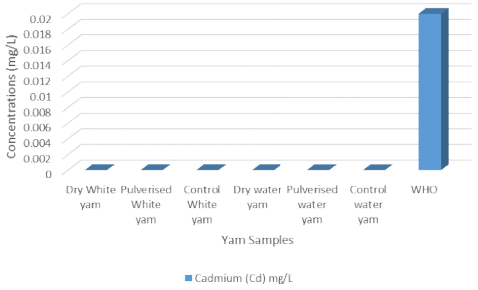

Figure 12: Mean Concentration of Cd in White and Water Yam Products at Oja Oba Market compared with Controls and WHO Standard Limits

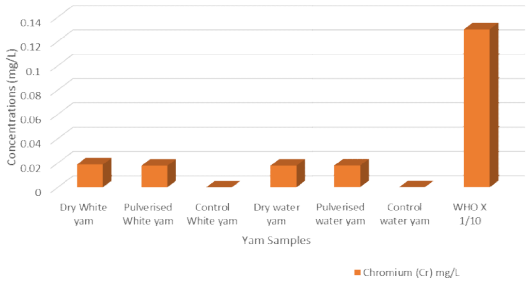

Figure 13: Mean Concentration of Cr in White and Water Yam Products at Oja Oba Market compared with Controls and WHO Standard Limits

(Note: The actual value of WHO is divided by 10 to allow for values of chromium to be seen).

3.4. Concentrations of Pb, Cd, Cr and Ni in the dry yam and pulverized yam products collected from the Bodija market:

Pb, Cd, Cr and Ni concentrations from the first week to the fourth week in the dry yam and pulverized yam products are shown in Figures 14-17. The results obtained showed that while Pb and Cd concentrations were not detected in all the yam samples collected from the Bodija market (0.000 mg/L). From these results, the concentrations of Pb and Cd was completely absent in the dry yam and pulverized yam product collected from the studied market. However, the results further showed that Cr and Ni were present in all the samples. In Figure 14, Cr concentration present in the dry white yam collected from Bodija market ranges from 0.000 - 0.077 mg/L while Ni concentration present in the dry white yam from the same market ranges from 0.000 - 0.023 mg/L. Figure 15 showed the Cr concentration present in the pulverized white

yam collected from Bodija market ranges from 0.000- 0.063 mg/L while Ni concentration present in the pulverized white yam from the same market ranges from 0.000- 0.008 mg/L. However, Figure 16 showed that the Cr concentration present in the dry water yam collected from Bodija market ranges from 0.000- 0.061 mg/L while Ni concentration was not detected in the dry water yam collected from Bodija market. Figure 17 showed that the Cr concentration present in pulverized water yam collected from Bodija market ranges from 0.000- 0.083 mg/L while Ni concentration was also not detected in the pulverised water yam collected from Bodija market. From the result of the analysis done, the highest Cr concentration was found in the pulverized water yam collected from Bodija market while the highest Ni concentration was found in the dry white yam.

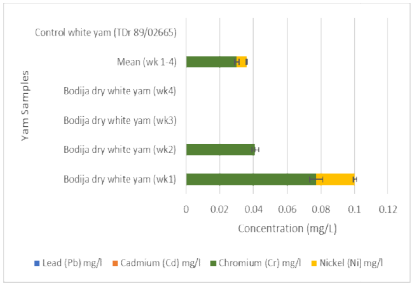

Figure 14: Concentration of Pb, Cd, Cr and Ni in Dry White Yam collected from Bodija Market (From week 1-4)

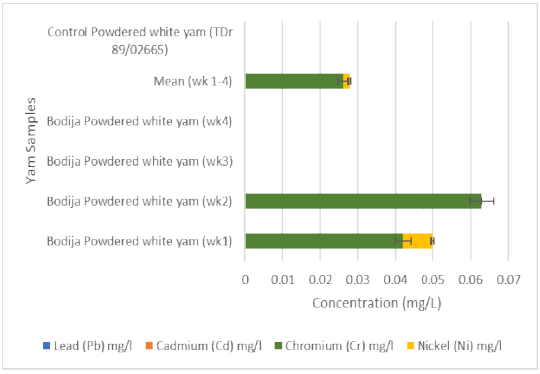

Figure 15: Concentration of Pb, Cd, Cr and Ni in Pulverized Dry White Yam collected from Bodija Market (From week 1-4)

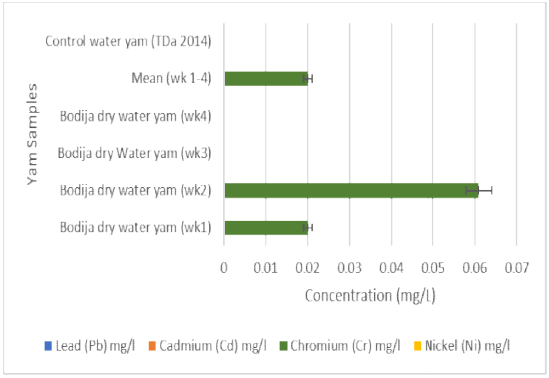

Figure 16: Concentration of Pb, Cd, Cr and Ni in Dry Water Yam collected from Bodija Market (From week 1-4)

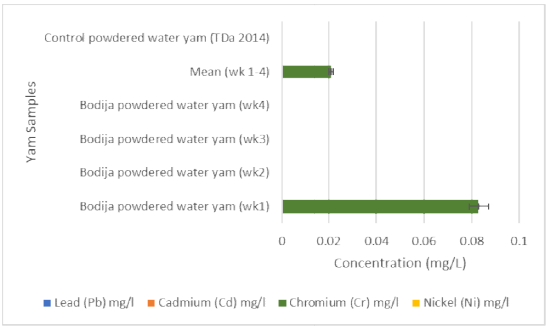

Figure 17: Concentration of Pb, Cd, Cr and Ni in Pulverized Water Yam collected from Bodija Market (From week 1-4)

3.5. Mean Concentrations of Pb, Cd, Cr and Ni in the dry yam and pulverized yam products collected from the Bodija market:

The mean concentration of the studied heavy metals that was present in the dry white yam, dry water yam and pulverized white and water yam products, compared with the concentration of each of these heavy metal present in the control dry white yam (TDr 89/02665), control pulverized white yam products (TDr 89/02665) and control dry water yam (TDa 2014), control pulverized water yam products (TDa 2014) for four weeks are shown in Figures 18. The results obtained indicated that Pb and Cd are completely absent in the analyzed white yam samples while the mean concentration of Cr present in both the dry white yam (0.030± 0.037 mg/L) and pulverized white yam (0.026± 0.032 mg/L) was higher than those in control yam samples (0.000 ± 0 mg/L) (Figure 18). Also, the mean concentration of Ni present in the dry white yam (0.006± 0.012 mg/L) and pulverized white yam (0.002± 0.004 mg/L) was higher than those in control yam samples (0.000 ± 0 mg/L) (Figure 18).

Pb, Cd and Ni were not detected in the analyzed dry water yam and pulverized water yam samples while only concentration of Cr was detected and the mean concentration found in both the dry water yam (0.020± 0.030 mg/L) and pulverized water yam (0.021± 0.042 mg/L) was higher than those in control water yam samples (0.000 ± 0 mg/L) (Figure 18).

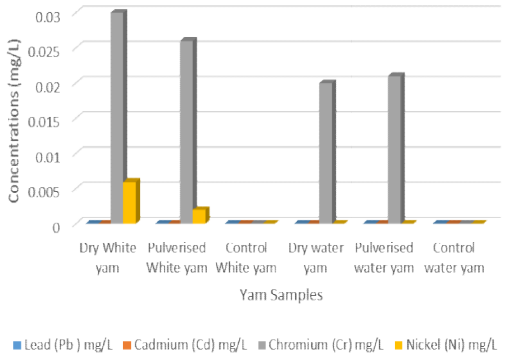

Figure 18: Mean Concentration of Pb, Cd, Cr and Ni in White and Water Yam Products at Bodija Market compared with Controls

3.6. Heavy Metals Concentrations in White and Water Yam Products at Bodija Market compared with Controls, NESREA and WHO Standard Limits:

The results obtained for samples taken at Bodija was also compared with the Standard Limits of NESREA and WHO. The outcome of the comparison indicated that all the results obtained were very much below the standard regulatory limits of NESREA (Figures 19 and 20) and WHO (Figures 21 – 23).

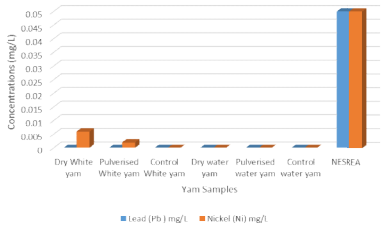

Figure 19: Mean Concentration of Pb and Ni in White and Water Yam Products at Bodija Market compared with Controls and NESREA Standard Limits

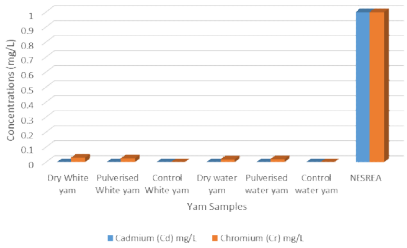

Figure 20: Mean Concentration of Cd and Cr in White and Water Yam Products at Bodija Market compared with Controls and NESREA Standard Limits

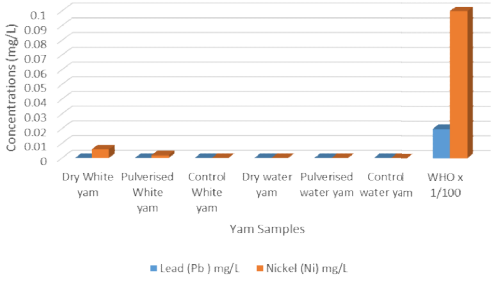

Figure 21: Mean Concentration of Pb and Ni in White and Water Yam Products at Bodija Market compared with Controls and WHO Standard Limits

(NB: the actual value of WHO is divided by 100 to allow for values of Nickel to be seen).

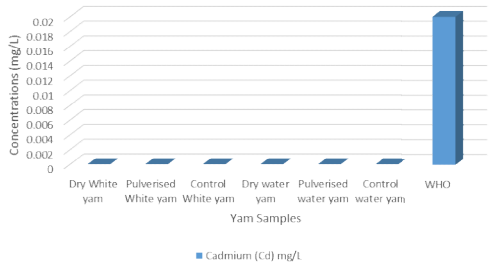

Figure 22: Mean Concentration of Cd in White and Water Yam Products at Bodija Market compared with Controls and WHO Standard Limits

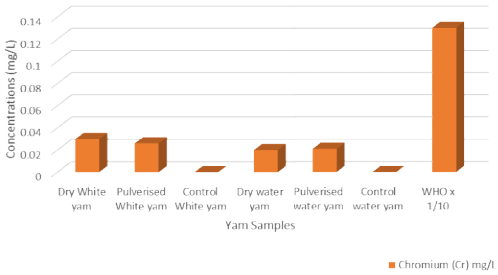

Figure 23: Mean Concentration of Cr in White and Water Yam Products at Bodija Market compared with Controls and WHO Standard Limits

IV. Discussion

Yam tuber is a root crop that is used for some of the diets of Nigerians. The pulverised yam gives rise to the flour, which is used in the preparation of semi-solid and cooked flour paste known as "Amala", which is eaten by most Nigerians but mostly by Yoruba tribe. Being a native food, it is consumed by people of all ages from infant to aged. It is eaten by children as a weaning diet that mothers used to graduate their growing babies from breast milk to normal food types. It is usually accompanied by vegetables such as Cochorus sp, Okra sp, and other leafy vegetables like Amaranthus sp, Telfaria sp (flutted pumpkin) etc. Amala has been said to be rich in carbohydrates and some other nutrients and vitamins. However, it can be easily contaminated with heavy metals through its different preparative process, which include drying the yam tubers by the road side (a popular method of processing adopted by rural farmers); grinding of the dried yam with metal soldered grinder and exposure to atmospheric pollutant during display at the open market among others. Thus, if such heavy metal contamination occurs, the consumption of such contaminated yam flour over a long period of time could be the route through which traces of those heavy metals enter into and accumulate within the human consumer's body over the period of many years. Heavy metals have been known to be bioaccumulative and non-biodegradable in nature. Hence, consumption of such contaminated food substance over a long period of time could lead to a higher body-burden for the heavy metal and the symptom of heavy metals contamination, which do not often appear easily or early in humans would lead to more chronic side effect in human consumer's body over the period of its accumulation.

In this study, the result of analysis of the dry white yam and dry water yam alongside their pulverized products collected from the Oja–Oba and Bodija markets indicated that Lead and Cadmium were not detected in the different samples analyzed from the two markets throughout the study period. When this was compared with the results of analyses for control yam samples from NACGRAB Tissue Culture laboratory, there was no presence of Pb and Cd within the different control yam samples. Also, when compared with the national food standard regulatory limits of NESREA, the mean concentrations of Pb and Cd in the different yam samples and their pulverized products from both markets as well as the control yam were far less than the 0.05 mg/l and 1.00 mg/l recommended

standard limit for Pb and Cd respectively in food by NESREA. The results were compared also with the recommended standard values for Pb in food by WHO (28) and the mean concentration of Pb and Cd in all the different yam samples and their pulverized products from the two market and control were below the 2.0 mg/L and 0.02 mg/l standard regulatory values of WHO respectively.

A similar result was obtained in the studies of Oladebeye (26), who carried out a study on the assessment of heavy metals in Nigeria vegetables and soils within Owo and Edo axes of Ondo state using X-ray Fluorescence (XRF) techniques. The study could not detect nickel, cadmium, cobalt and copper in both vegetables and soil samples. The result of this study was also compared to the mean concentration of lead and cadmium obtained by Mee- Yong et al. (8), who studied the content of heavy metals (Cr, Cd, As, Pb, Ni and Sn) in the selected commercial pulverized yam product in South Korea. The range of lead (0.198-0.740mg/l) obtained in their study was higher than the values obtained in this study and even higher than the standard recommended value of 0.1mg/l by food Safety Department in Korea while the ranged obtained for Cadmium (0.031-0.047mg/l) was higher than the values obtained in this study but lower than the standard recommended value of 0.1mg/l by Food Safety Department in Korea. Their results, which was found to be several folds higher than the results of this study, further indicate that there is possibility that if the preparation of dried yam product were not carefully handled, it may result in heavy metal contamination. Furthermore, in the study of Okereke et al. (27) on human health risk assessment of heavy metal contamination for population via consumption of selected tubers grown in farmland in Rivers State, Nigeria; the mean of concentration of lead obtained in some selected tubers ranged from 0.005-0.550 mg/l and was higher than the results of this study but less than the standard recommended values of NESREA, WHO and European Union. Likewise, the mean concentration of cadmium that the study obtained ranged from 0.00-0.46mg/l and this was also higher than the results of this study, standard recommended values of NESREA, WHO and European Union. This results also further corroborate the possibility of yam products' contamination with heavy metals if the environment is polluted. However, the non-detectability of lead and cadmium in this study, indicates that the dry yam and pulverized yam products were not contaminated by lead and cadmium at all. This makes the consumption of the dry white yam, dry water yam and their pulverized products safe. Hence, the consumers are free from adverse effect of lead and cadmium. It also certifies that these products could be consumed by human and their livestock without any fear of being exposed to heavy metals toxicity.

The concentrations of Chromium found in the different yam samples and their pulverized products from the two markets were much higher than the concentrations in the control yam samples as there was no Cr in the control yam samples. Comparing this results with the values for the national standard regulatory limits for food, though the concentration of Cr found in Bodija Samples were higher than those obtained for Oja-Oba market samples, the concentration of Cr in all the different yam samples and their pulverized products from the two markets were below NESREA recommended standard limit of 1.0 mg/l for Cr in food. Also, when the result was compared to WHO (1996) recommended standard values of 1.30 mg/l for Cr in food, the mean concentration of all the different yam samples and their pulverized products from the two market were below the WHO standard values. These results were compared to the results obtained by Mee-Yong et al. (8) and they are lower than the mean concentration obtained. The mean concentration of Chromium in this study was lower than the concentration obtained by Okereke et al. (27) who studied human health risk assessment of heavy metal contamination for population via consumption of selected tubers grown in farmland in Rivers state, Nigeria and his study obtained the mean concentration of Chromium as a range of 0.00-1.26 mg/L, which he said was higher than the standard recommended value of 1.0 mg/L by European Union. Therefore, the result obtained in this study for Chromium has indicated that the concentration of Chromium in all the yam products is still within the safety level and different yam samples and their pulverized products from the two markets are safe for human consumption. However, there could be possibility of bio-accumulation if the consumers are continually exposed to the chromium contaminated yam products and if this occurs, chromium toxicity and its respective effects may commence.

The results obtained from this study showed that Ni concentration was not detected (0.000±0 mg/L) in all the different yam samples and their pulverized products from the two markets. Except for the dry white yam and powdered white yam collected at Bodija market, which ranges from 0.002±0.004 to 0.006±0.012 mg/L. Comparing this to the control yam samples, the results is the same as the concentration in control for most of the different yam samples and their pulverized products except for the dry white yam and powdered white yam collected at Bodija market, which is much higher than control. However, the concentration of Ni in all the different yam samples and their pulverized products from the two markets were below NESREA standard recommended values of 0.05 mg/l Ni in food. Also, when compared to the recommended standard values of 10 mg/L for Ni in food by WHO (28), the mean concentrations in all the different yam samples and their pulverized products from the two markets were below the WHO standard values.

V. CONCLUSIONS

The concentration of Lead and Cadmium were not detected all the different yam samples and their pulverized products from the two markets while the concentration of Chromium and Nickel was very low, when compared with the permissible limit recommended by NESREA and WHO (28). In general, based on the permissible limit recommended by NESREA and WHO (28), the result of the analysis of these selected heavy metals in the dry yam and pulverized yam products shows that

they are safe for human consumption in Nigeria and would pose no harmful effects if consumed. However, due to the fact that consumption of the heavy metal contaminated-agricultural products is directly contaminating the human body, caution should be exercised while purchasing food items from the market and necessary standard analysis should be carried out from time to time to establish the safety status of food items. From the current study, it is vital to avoid heavy metal contamination during yam cultivation and the different stages of processing yam into its different products. Likewise, local food processors should be enlightened to avoid contamination of the farm produce and its respective products during food processing processes.

VI. Conflicts of Interests

The authors wish to indicate that there are no conflicts of interest (s) with respect to this research work.

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