HEAVY METAL CONTAMINATION OF YAMS PRODUCED IN BENUE STATE

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Abstract

Yam production play a vital role in the socio-economical scene of Benue State. This study seeks to determine the concentration of heavy metal in Yam tubers produced in Benue State. Two species of Yams Dioscorea rotundata and Dioscorea alata were selected as they are the most cultivated species in Benue state. Yams were sampled from nine sampling stations; three farming communities from Oturkpo, Ukum, and Tarka Local Government Areas (LGAs). A total number of 324 yam tubers were sampled for laboratory analyses of heavy metals (Arsenic (As), Cadmium (Cd), Chromium (Cr), and Lead (Pb), and residues of fertilizers (NPK, Urea, and Biuret impurities). The concentration of the heavy metals were analyzed using Atomic Absorption Spectrophotometry (AAS) 6800. The mean concentration of As, Cd, Cr, and Pb in the yams were 1.3887, 0.0126, 0.0452, and 0.0286 Mg/kg. The concentration of As, Cd, Cr, and Pb in Dioscorea alata were 2.7657, 0.0125, 0.03570, and 0.0251 while the concentration of the heavy metals in Dioscorea rotundata were 0.0136, 0.0129, 0.0550, and 0.0325 Mg/Kg respectively. Arsenic dominated al heavy metals analyzed in the yam varieties and the concentration of the heavy metals varied between the two sampled yam species. It was observed that the concentration of As, Cd, and Pb were greater than the Maximum Residual Limits (MRLs) of the World Health Organization (WHO) and Food and Agriculture Organization (FAO).

INTRODUCTION

Yam is a tropical tuber crop that is cultivated in Africa, Asia, South America, South Pacific islands, and the Caribbean. Yam is a member of the genus *Dioscorea* (Family *Dioscoreaceae).* There are more than 600 species in the genus but only about 6 species are socially, economically, and culturally important on the basis of food, cash, and medicine. (IITA, 2009). It is a rich source of carbohydrates and a major constitute of the diet of many African countries. It also occupies an important position in the cultures of some yam producing communities in Nigeria in the form of new yam festivals. More than 90% of the world's production of yam is cultivated in West Africa on about 4 million hectares of land annually. This constitute about 58.8 million tons of yams. (FAOSTAT, 2014)

Yam is the second most cultivated/harvested tuber crop in Nigeria, after cassava. It is also the fifth most harvested crop in Nigeria, after cassava, maize, guinea corn, and beans. Yam is a major cash crop and is among the most consumed food crops in the country. Yam production in Nigeria is a profitable enterprise despite the labour intensive costs of productions and the fluctuations in the price of the commodity due to seasonal rainfall patterns/ climate change, economic inflation, and insecurity (in the form of farmer-herder clashes). It is estimated that the average profit per seed yam, after harvest and storage is over US$ 13,000 per hectare of yams harvested. (IITA, 2013).

Nigeria is the largest producer of yams in the world, constituting about 65% of the world's production (38 million metric tons) and a production valve of about $7.75 billion. This is cultivated on about 2.9 million hectares of land as at 2012. The yield potential ranges from 20-50 tons per hectares and during poor harvest seasons 10 tons per hectares (FAO, 1985). Yam production in Nigeria has been transformed in recent years, although still largely un-mechanized. Modern farm inputs such as agrochemicals have been employed in the production of yam in Nigeria; with an increasing number of farmers utilizing agrochemicals in production.

The Food Agriculture Organisation (FAO 1970) estimated an annual crop loss of 30-50% worldwide, with a greater severity in tropical countries of Africa. The losses in yam tubers was estimated at between 20-67%. This figure is still relevant in present day Nigeria as agriculture is still largely un-mechanized and most cases sustenance. This has necessitated agrochemicals in the forms of

fertilizers, pesticides, and herbicides as essential inputs in yam production to mitigate losses and boost production.

The compounds employed to supply these agrochemicals contain trace amounts of heavy metals (e.g. Cadmium, Lead) as impurities which accumulate in the soil over time. Industrial sources of heavy metal contamination include: mining, high temperature processing of metals, crude oil refining, petroleum combustion, nuclear power stations and high tension electric lines. Other industrial sources are the processing of textiles, plastics, paper, and wood preservation. Yam tubers absorb nutrients simultaneously with heavy metals from the soil during growth. The accumulation of these heavy metals in the tubers of yam lead to contamination of the food chain and various ecological, nutritional and economic adverse complications.

Heavy metal toxicities result in stunted plant growth through leaf chlorosis, necrosis, and a crippled photosynthetic apparatus. The consumption of heavy metal contaminated yam tuber leads to the bioaccumulation of these metals over a period of time resulting in the displacement/depleted on essential nutrients in the human body leading to immunological deficient, intrauterine growth retardation in fetuses, impaired psychosocial behaviors and intellect, and a high prevalence of cancers of the gastrointestinal tract.

The knowledge of the potential deleterious health effects of heavy metal toxicities on human lead to the adoption of Maximum Residual Limits (MRLS) which is the highest concentration of an agrochemical/heavy metal residue that is legally allowed in a food product in keeping with best agricultural practices.

MRLs help enforcement agencies monitor whether an agrochemical has been used as directed in food production, processing or storage and if the concentration of heavy metals in food products are within the safety levels. Agricultural communities such as Benue state are under threat of heavy metals contamination as a result of anthropogenic activities and other natural phenomena that cause environmental pollution. Therefore, heavy metal analysis is an essential part of environmental pollution studies and the levels of their concentration in yam tubers is of significant socio-economic importance due to their potential adverse health effects. This study aims to determine the concentration of heavy metals in yam tubers produced in Benue State in a view to ascertain the human risk exposure.

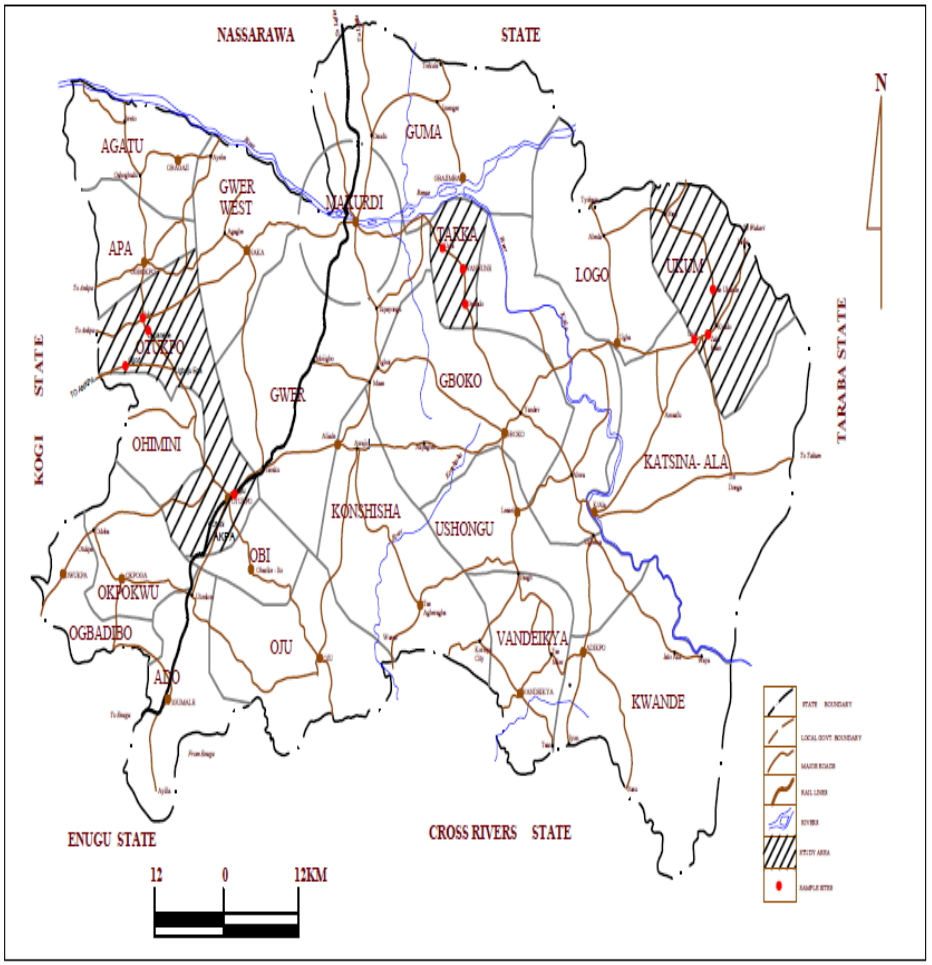
MATERIALS AND METHODS

Study Area

Benue State is one of the seven States of the North Central geopolitical zones of Nigeria (Kwanga and Kerenku, 2007; Okpage, 2007 and Verter and Bečvářová, 2014). The Study was carried out in three local government areas (LGAs) namely; Otukpo (OT) [Latitude 6°50' 10N, Longitude 8°40' 46E]; Ukum (UK) [Latitude 7°64 Longitude 9°56'] and Tarka (TA) [Latitude 7^{0}30' 70N, longitude 8^{0}45' 90E] in the state, North central Nigeria.

Nine sampling stations were chosen for the study. Three farming communities from each sampling location or LGAs- Otukpo, Ukum and Tarka participated in the study. They included Upu Otukpo, Ogoli-ugboju, and Okpanche- Adoka all of Otukpo L.G.A; Zaki-biem, Tse- Uvia and Ukande Tse-Uli of Ukum LGA, and Untenger, Wannune and Mbajir Uchi in Tarka LGA. The choice of these areas were based on the fact that yam farming is the most predominant activity in these places (BNARDA, 2000; Yina, 2007; Adogwu, 2014; Verter, and Bečvářová, 2014).

The three local government areas gave a fair representation of the three senatorial zones of the State. (Ukum, Tarka and Otukpo (study locations (fig 3)) represents zones A, B and C respectively of Benue State).



BENUE STATE SHOWING STUDY AREAS

SOURCE: Ministry of lands, Survey & Solid Minerals Makurdi. 2018

SAMPLE COLLECTION

Three yam farmers' fields from each of the 9 farming communities (27 yam farms) formed the yam tuber sampling sites (Fig. 4) and provided the yams for laboratory analysis for Agrochemical residues.

SAMPLING TECHNIQUES

Study Samples

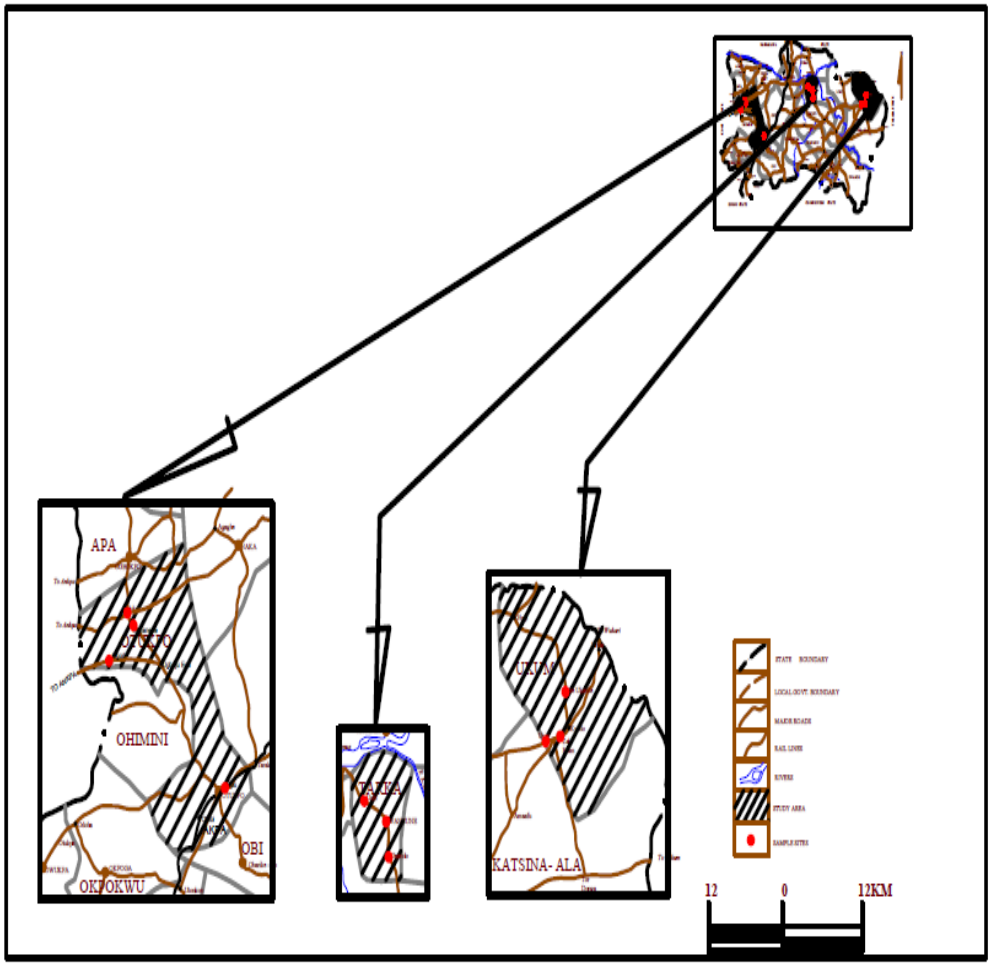
Two categories of Dioscorea (yam) species and respondents who were yam farmers in Benue State were involved in the study. The two species of Dioscorea were Dioscorea rotundata and D alata which were selected are the most cultivated species in Benue State due to their cultural acceptance, nutritional and medicinal values, adaptation to the environmental and soil conditions for good growth and high yield in the areas (Ogboji, 2008; Adogwu, 2014; erter and Bečvářová, 2014).

Sample collection

Three yam farmers' fields from each of the 9 farming communities (27 yam farms) formed the yam tuber sampling sites (Fig. 4) and provided the yams for laboratory analysis for Agrochemical residues. 162 yam tubers, each of D. rotundata and D. alata were randomly sampled from the yam farmers' farms as follows; 6 yam tubers each of D. rotundata and D. alata from the 9 sampling sites each of otukpo: (54 yam tuber each of D.rotundata and D.alata); the same in Tarka and Ukum sampling sites.

The first sampling, which was for the storage season took place in December 2014, and January/ February 2015- the late harvesting period of 2014. The second sampling and harvesting was done during the milk or early harvest in the months of August and September 2015 when most Benue farmers and inhabitants eat the new yam. The third sampling took place in the month of December 2015, January and February 2016. A total number of sampled yam tubers were 486 each for D. rotundata and D. alata for the three seasons.

Sampled yam tubers of D. rotundata and D. alata from each study location were added together to form the 3 bulk samples respectively during sampling season



BENUE STATE SHOWING STUDY SITES

SOURCE: Ministry of lands, Survey & Solid Minerals Makurdi. 2018

Laboratory Chemical Analyses

The data on the levels agrochemical residue in Benue State were determined by chemical analyses. Sampled yam tubers were processed for chemical analysis accordingly. A set of 36 samples were tested for fertilizers (NPK and Urea as well as impurity-Biurets) and heavy metals (Arsenic (As), Cadmium (Cd), Chromium (Cr) and Lead (Pb). Levels of fertilizer residues and impurities were also analyzed as these constitute a major source of heavy metal contamination in the soil.

Fertilizer residual analysis was done at the Soil Science laboratory, Department of Soil Science, Federal University of Agriculture, Makurdi, Benue State, and that of heavy metals took place at the Chemistry Departments, Nasarawa State University, Keffi, Nasarawa State and Chemistry Department, Usman Danfodio University, Sokoto, Sokoto State. The use of the laboratories outside the University of Agriculture, Makurdi, Benue State was duely approved by the Federal University of Agriculture, Makurdi and the necessary cooperation of the respective authorities for the use of their laboratories were obtained.

Laboratory / Field Analysis

In the Soil Science Laboratory of the Department of Soil Science, Federal University of Agriculture Makurdi, sub-samples were taken purposively from different portions (the head, middle and tail regions) of each yam tuber from each of the bulk samples per location (LGA) per species of D. rotundata and D. alata. This was done to get the representative aggregate composite samples. Six (6) discrete samples were made from the representative aggregate composite samples of D. rotundata and D. alata per LGA and were labeled by codes according to the treatments each was subjected to: boiled peeled (BP), boiled unpeeled (BUP), roasted (RT), raw dried (RD), as in yam flour, fried (FR) and fresh (FS) as in yam balls (akara) or pan cake. The treatments were according to the major forms in which yams are processed for consumption in Benue State. Samples of *D. rotundata* and *D. alata* to differentiate the respective LGAs of the samples, the first letters of the name of the LGAs were first written, followed by the species identification letter(s) and then the treatment codes. The procedure was repeated thrice for the 3 seasons namely storage, milk and late harvest.

Precisely, eighteen samples were made each from *D. rotundata* and *D. alata* tubers sampled from selected farmers' farms in each of the 3 LGAs. On the whole, a total number of 324 samples of yam tubers were employed for the laboratory analyses for the residues of fertilizers (NPK, Urea and Biuret impurities in urea fertilizer), heavy metals (Arsenic, Cadmium, Chromium and Lead).

Sample Preparation and Preservation

The Laboratory samples of *D. rotundata* and *D. alata* for Boiled peeled (BP), fried (FR), Fresh (FS) and raw dried (RD) treatments were peeled with a stainless steel knife and cut into 3×3cm pieces. They were placed in labeled draining bowls according to treatments and washed under running distilled water and subsequently stored in a well covered bucket. The samples for BP treatment were placed each in a stainless steel pressure pot containing ½ liter of water and cooked for 5 minutes at 105^{o}c over gas burner. The samples was allowed to cool for 15 minutes. With the aid of a weighing balance (Shimadzu Corporation INC), 20g each in 3 places were taken from the Laboratory samples and labeled for pesticide, fertilizer and heavy metal analyses respectively. The samples FR treatment were transferred each into a stainless frying pan containing ½ liter olive vegetable oil (the most commonly used among most commercial yam friers in Benue State) and fried over gas burner for 15 minutes. The samples were drained using draining bowl and allowed 15 minutes to cool.

The samples for FS treatment were grated with the aid of usual stainless kitchen grater, and 20g each was weighed and separated according to the parameters for residue determination as described previously. (*state*)

Samples for RD treatmet were grated with stainless kitchen grater, spread on stainless steel tray and sun dried for 2- 3 days after which they were weighed and separated as described before. (*state*)

The Boiled unpeeled (BUP) samples were boiled and cooled as described for BP samples. Each of the samples were peeled and separately weighed as mentioned before. (*state*)

The RT samples were roasted for 30 minuets over char coal heat according to the local method of roasting yam in Benue State. Each roasted piece was peeled to remove the burnt layer and allowed to cool for 15 minuets. They were weighed and separatly treated as earlier described.(*state*)

.The carefully labeled samples for fertilizer and heavy metal residue determination were subjected to drying and wet treatments prior to chemical quantification.

Laboratory Analysis

All yam samples for determinations of fertilizer residue and heavy metal content were air dried for 3 days, to remove excess moisture and then oven dried to constant weight at 105^{o}c for 6 hours. Each set of the respective samples were cooled for about 1 hour and disintegrated in a ceramic morta and pestle, ground to a powdered form before being sieved through a 0.5mm sieve (Menham et al., 2006; Ndimele and Jimoh, 2011). A 10g of the individual dried yam samples were seperately placed in crucibles and ashed in a furnace for 12 hours at 550^{o}c, until the sample turned into white ash mineral. The individual samples were allowed to cool and kept in labeled sample bottles for acid digestion.

Acid Digestion of Yam Samples for Fertilizer and Heavy Metal Analyses

The ashed samples were placed in a 250ml volumetric flask, 5ml of concentrated HNO_3/H_2O_2 added to it and heated gently on a hot plate until fumes disappeared, then 5 ml of deionized water was added and heated until a clear solution was formed. The solution was transferred into a 100ml volumetric flask by filtration through What No. 2 Filter paper. The flask and the filter paper were washed several times with deionised water and the volume was made to the mark of 100ml with the deionised water. The filtrate was used for elemental analysis (Kisamo, 2003; Pearson 2006). The **dry** and **wet** (acid) digestion method were employed in the digestion of samples, to ensure that ions to be determined were free and not bonded to other ions or fragments of an organic matrix.

Determination of heavy metal residue in sampled yam tubers by Atomic Absorption Spectrophotometry (AAS)

The heavy metal samples were determined using an atomic absorption spectrometer (AAS), AA – 6800 (Shimadzu, Japan). The atomic absorption spectrophotometry (AAS), AA-680 (Shimadzu Japan) was because of its accessibility, specificity, wide range of application, low detection limit, and cost effectiveness (Ademoroti, 1996). Samples for fertilizer and heavy metal analysis were air dried for three days, then oven dried to constant weight at 105^{o}c for 6 hours, disaggregated in a ceramic motar and pestle, ground to powder and sieved (Ndimele and Jimoh, 2011). About 10g of the dried yam samples were placed in a crucible and ashed in a furnace for about 12-14 hours at 550^{o}c, until the sample turned into white ash mineral (dry treatment process).

To confirm the precision and accuracy for the mineral analysis, a standard reference material (SRM) was obtained from the National Institute of Standards and Technology (NIST SRM 1577b). The contents/levels of heavy metals (As, Cd, Cr and Pb) in the samples were compared to the International Food Standard Levels; the Food and Agricultural Organisation and the World Health Organisation standards permissible limits. The use of blank (a solution containing the solvent and all of the reagents used in analysis, without the sample to be analysed), and internal standard reference materials were employed in the process of quality assurance to ascertain the reliability of result data.

Statistical Analysis

All the data obtained in the course of the experiments were represented in Tables and Charts as appropriate. The data collected from the respondents were analyzed using descriptive statistics of frequency, means and simple percentages. Chi-square test and analyses of variance (ANOVA) were also employed to test hypothesis. Statistics was used to analyze the relationship between two or more variable, and could be used for quantitative prediction or forecast the behavior of the large population. The statistical techniques used in this study were Chi-square and Analysis in Variance (ANOVA) using excel. These techniques were used to determine the level of significance of variations in the demographic characteristics of the respondents (farmers) and the study locations and residues quantified from the laboratory measurement of the sampled yam tubers. The p – values provides information on the significance of variables. The results were considered statistically significant when $p < 0.05$ as the p – value $p < 0.05$ gets lower, the

variables in considered more or strongly significant. Result obtain from samples analyzed were expressed as mean values with their standard deviation

Results

The results of chemical analysis of the sampled tubers of *Diocorea alata* and *D. Rotundata* for heavy metal contamination of the yams cultivated in Benue State were presented in Tables. The heavy metals analysed were Arsenic, Cadmium, Chromium and lead.

Table 1: The residues of fertilizer and heavy Metals measured in sampled tubers of *Dioscorea alata* and *D. rotundata* produced in Benue state (All values in Mg/Kg).

S/no	Parameter or Residue	Value Range Min	max	Mean ±SD	> Or <	CODEX WHO/FAO MRL
1	Arsenic	00000 – 24.7153		1.3887±5.39	>	0.0100
2	Cadmium			0.0126±0.01	>	0.0010
3	Chromium	0.0000 – 0.0318		0.0452±0.10	<	0.1000
4	Lead	0.1120 – 1.3333		0.0286±0.00	>	0.0200
5	Nitrate – Nitrogen	0.0000 – 0.305		3	<	10.0000
	Phosphorus	0.3650 – 0.5700		0.5085±0.00		
6	Potassium			2	<	5.0000
7	Urea- Nitrate	2.6018 – 2.9552			<	2.0000
8	Biuret	0.0903 – 0.6017		2.8526±0.00	>	4.0000
9		0.3665 – 13.2824		2	<	5.0000
				0.2535±0.01		
		0.0570 – 0.2632		4.7706±44.4		
				1		
				0.1228±0.01		

Arsenic concentrations measured in all the samples of tubers of yam species were as presented in Table 1. The recorded values, ranged from 0.000-24.7153, and the state mean was 1.3890. The mean was greater than the recommended WHO/FAO MRL of 0.0100**.** Cadmium concentrations recorded for the all samples as shown in Table 1 included values ranged from 0.0000-0.0318 and the mean 0.0126. The mean was greater than the WHO/FAO recommended MRL of 0.0010 Chromium's total values, ranged from 0.1120-

1.3333 and the mean, 0.0452 was less than the set MRL, 0.1000 set by WHO/FAO (Table 1). Lead concentration measured for all samples ranged 0.0000-0.1305 while the mean values was 0.0286±0.003. The mean was greater than the WHO/FAO MRL of 0.02

Table 2: Mean Values and Standard Deviation (X±SD) of heavy metal and fertilizer residues measured in the samples of yam (*Dioscorea rotundata and D. alata*) tubers produced in Benue State.

Heavy Metal & Fertilizer Residues	**Total Mean ±SD**	***Discorea alata*(X±SD)**	***D.rotundata* (X±SD)**
Arsenic [c]	1.3897±5.68	2.7657±7.8333	0.0136±0.01
Cadmium [a]	0.0127±0.01	0.0125±0.02	0.0129±0.01
Chromium [d]	0.0453±0.58	0.0357±0.40	0.0550±0.70
Lead [ab]	0.0288±0.05	0.0251±0.04	0.0325±0.06
Nitrogen-Nitrate [de]	0.5074±0.08	0.5083±0.07	0.5064±0.08
Phosphorus [f]	2.8601±0.23	2.8676±0.21	2.8528±0.24
Potassium [c]	0.2544±0.32	0.2441±0.28	0.2647±0.37
Urea-Nitrate [e]	4.7706±44.41	0.5110±0.17	9.0302±62.80
Biuret [bc]	0.1305±0.20	0.1496±0.24	0.1114±0.1416
Total	**1.1564±14.9437**	**0.8268±2.81**	**1.4861±20.95**

Heavy Metal and Fertilizer Residues $F_{(8,962)} = 159.317$, $P<0.001$

Species $F_{(1, 0.962)} = 0.962$, $P>0.05$

All the means with similar letters are not significantly different, while those with different letters are significantly different.

Arsenic level was found to be very high in the tubers of *Dioscorea alata* with a mean value of 2.7657, while *D. rotundata* had the mean value, 0.0136. The residue was absent or below instrumental detection in 17 samples each of *D. alata* and *D. rotundata*.

The mean value of cadmium in *Dioscorea alata* 0.0125 was slightly higher than the mean of that of *Dioscorea rotundata* with a mean of 0.0129. The residue was undetected in 11 and 17 samples of *D. alata* and *D. rotundata* respectively.

The mean value of Chromium's concentration was 0.0550 in *D. rotundata* was greater than that of *D. alata* (0.0357). The residue was not detected in only 4 samples of *D. alata*.

The mean value of Lead concentration in *D. rotundata* had a higher mean value, 0.0325 than *D. alata* with the mean value, 0.0251. Lead residue was not instrumentally detected in 17 samples each of *D. alata* and *D. rotundata*.

The gross mean value for all the samples was 1.1564±14.9437 and the mean values for the species were 0.8268±2.81 and 1.4861±20.95 for *D. alata* and *D. rotundata* respectively. When the data were subjected to ANOVA analysis, the results showed that the mean values of Heavy metals and fertilizer residues were significantly different at $P<0.001$, while those of species were not at $P = 0.327>0.05$. Meanwhile, all the means with similar letters were not significantly different, while the means with different letters were significantly different.

Discussion

Chemical analysis of yam tubers produced in Benue State is essential to ascertain the safety level of agrochemical residues and heavy metal contamination. This is a direct consequence of the increasing use of agrochemicals in crop production to increase productivity, improve quality, and profitability while minimalizing loss from pests, diseases and storage. (Owoicho, 2022). The heavy metals in farmlands are absorbed from the soil and bio-accumulate in the yam tubers and contaminate the food chain.

The essence of heavy metal contamination monitoring in Yam tubers in Benue State is to ensure that the concentration of heavy metals (components of agrochemical impurities) does not exceed the set Maximum Residual Limits (MRLs) allowed by food regulatory agencies, to prevent the misuse of agrochemicals, and to ensure that good agricultural practices are maintained. Keikotlhaile and Spanoghe, 2011). The mean concentration of arsenic in the sampled yam tubers in Benue State was 1.3887±5.39 which is greater than the WHO/FAO MRL of 0.0100. Lower concentration was recorded

for D.rotundata while the highest concentraton of arsenic was recorded for D.alata. The concentration of Arsenic in yam tubers was significant in this study than the sudy by Biose et al (2020) on heavy metal contamination of yams tubers sold in Benin.

According to the WHO (2022), the inorganic forms of arsenic (e.g. in water) are highly toxic where organic compounds of arsenic (found in foodstuffs) are less harmful to health. The International Agency for Research on Cancer (IARC) has classified arsenic and arsenic compounds as carcinogenic to human. Exposure to high levels of arsenic is for a minimum is a precursor to the development of skin cancer. (WHO, 2022). Other adverse health outcomes associated with Arsenic poisoning include diabetes, pulmonary diseases, and cardiovascular diseases. Arsenic is also linked to adverse pregnancy outcomes, and have been demonstrated to have negative impacts on cognition, intelligent, and memory.

The concentration of cadmium in *D. alata* and *D. rotundata* were 0.0127 and 0.0129 respectively and a mean concentration of 0.0126 which was greater than the WHO/FAO set MRL of 0.001 Mg/Kg. Cadmium have significant effect on cell proliferation, differentiation, and apoptosis (cell death) which result in reduced bone density and increased fracture risks, renal damage, reducted in reproductive potential through decrease libido, fertility and increased rate of spontaneous abortions (Rafati et al; 2017). The mean concentration of Lead in the yam tubers was 0.0286 mg/kg which was greater than the WHO/ FAO MRL of 0.0200. Lead toxicity is associated with decreased cognitive performance, anemia, decreased fertility in adults. Infants and children are highly sensitive to low levels of lead and Lead toxicity in this group is associated with behavioural problems, learning deficient and lowered Intelligent Quotient (IQ) (Wani et al 2015).

The result of this study showed the concentration of heavy metals in yam tubers produced in Benue state was high and differed in relation to the yam variety. Arsenic was found to have very high concentration in the tubers of *D. alata.* The high concentration of heavy metals in the yam tubers produced in Benue State is related to the farming practices such as the extensive use of agrochemicals such as fertilizers and pesticides in the production, processing, and storage of yam tubers. This study alos revealed that the concentration of urea-nitrate residue in yams tubers produced in Benue State was higher than the WHO/FAO MRLs. The study by Biose et al (2020) revealed that peeling of yam tubers reduced the concentration of heavy metals in yam tubers as much as 79.23%.

The concentration of Arsenic, Cadmium, and Lead in the yam tubers were all greater than the WHO/FAO maximum residual limits (MRLs). This result is of Public Health significance due to the numerous potential adverse health effects of heavy metals on human health.

CONCLUSION

The findings from this study concludes that the concentration of heavy metals in yam tubers produced in Benue state is significant high and varies with the variety of yam produced. Arsenic was the most important heavy metal assayed in this study. The concentrations of Arsenic, cadmium, and Lead were greater than the WHO/FAO MRLs. The high concentration of heavy metals in yam tubers produced in Benue State is linked to the extensive use of agrochemicals as farm inputs in the production of yams. The high concentration of heavy metals in the yam tubers can also be associated with the soil characteristics, and atmospheric deposition of heavy metals.

Further studies are required to determine the locational distribution and, seasonal variations of heavy metal contaminations of yam tubers produced in Benue State. Studies on how processes such as peeling, boiling, drying can affect the concentration of heavy metals in yam tubers are necessary.

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