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Effects of Processing Methods on the Heavy Metal Contents of Yam (*Dioscorea spp.*) Produced in Benue State

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Abstract

In this paper, effects of processing methods on heavy metal contents of yams (*Dioscorea* spp.*)* produced in Benue State was investigated. The study analysed chemical content of samples of yam tubers to determine the effectiveness of cooking methods on heavy metal reduction. Results showed that while, cooking methods can reduce heavy metal content, the levels of the mean concentration of Arsenic, chromium and lead often exceeded international safety standards. Findings also revealed that among the methods, frying demonstrated the most significant reduction, followed by boiling and roasting. Peeling yams before boiling and rinsing, further enhanced heavy metal reduction. Boiling was particularly effective due to mechanisms of solubility enhancement, diffusion, leaching and water discard. Fertilizer residues, which can carry heavy metals, contributed to the elevated levels in yams. Based on these results, the study recommends that regulation on agrochemical use should be enforced along with farmer education on proper application and disposal. Implementing best practices throughout the yam cultivation, storage, transportation, and preparation processes can help mitigate heavy metal contamination and associated health risks

***Keywords**: Cooking methods, Residue content, Heavy metals, Yam tubers.*

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Introduction

Yam is a tropical tuber crop that plays an important role in the social, economic, and cultural lives of various African societies. Approximately 90% of the total yam production occurs in West Africa. Although yam cultivation in Nigeria is still largely unmechanised, there is an increased use of farm inputs such as fertilizers, herbicides, and pesticides. These agrochemicals are employed to boost production, mitigate losses, and increase the shelf-life of yam products [1]. Agrochemicals contain trace amounts of heavy metals, which are absorbed and bio-accumulated in the yam tubers and in the food chains. Other potential sources of heavy metal contamination include illegal mining activities, crude oil refining, plastic, textile, and paper processing, high-tension power lines, and nuclear power stations [1]. Heavy metals exist as compounds in nature and are non-biodegradable. Their toxicities are a result of the complexes they form with oxygen, sulfur, or nitrogen compounds in biological systems. These complexes inactivate enzymes and structural proteins, resulting in cellular dysfunction and damage, which cause various organ system failures, including cancer [2]. The absorption of heavy metals by crops from the soil depends solely on the physicochemical properties of the soil, including pH, mineral composition, organic matter content, and binding capacity [3]. Currently, there are no regulations or training programs by the government of Nigeria on the use of agrochemicals in order to improve food safety. This is compounded by the fact that heavy metal contamination in yam tubers is multifactorial and occurs at any point from cultivation to transportation, processing, and storage [4]. Methods and technologies have been researched and developed to help reduce heavy metal content in food crops. These methods include the use of *Saccharomyces cerevisiae* in the bio-mediation of heavy metals and the use of food processing methods [5]. The use of food processing methods will have immense benefits in low-resource societies such as Nigeria.

Food processing involves transforming harvested agricultural goods into consumable food products. Conventional food processing methods include drying, boiling, roasting, and frying [6]. Yam provides three types of meal per day [7]. They include pounded, boiled, roasted yam, and yam flour meal. These meals are said to be tasty, delicious and meet characteristic dietary requirements of traditional eating habits of the people of Benue State. Yam production is thus a variable source of food sufficiency which supports a healthy agrarian population growth [7]. A previous study has shown that tubers of yam *Dioscorea alata* and *D. rotundata* produced in Benue State were contaminated with the residues of Arsenic, Cadmium, Chromium and Lead [8]. Moreover, information on whether food processing methods can reduce the heavy metal content of yams produced in Benue State, Nigeria, will be important in the formulation of policies to help mitigate the adverse health implications of heavy metal contaminants in food crops in our society. For this reason, effects of processing methods on the heavy metal contents of yams *Dioscorea* spp.*)* produced in Benue state was investigated.

Materials and Method

Study Area

Benue State is one of the seven States of the North Central geopolitical zones of Nigeria [8]. 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 (Fig; 1 and 2). The choice of these areas were based on the fact that yam farming is the most predominant activity in these places [8].

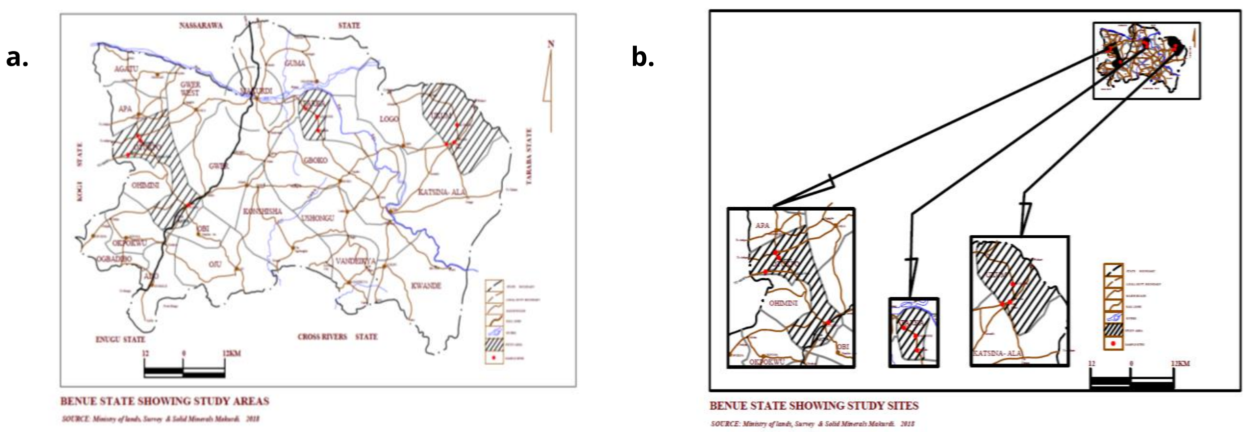

Figure 1. Map of Benue State showing the study areas

Sample Collection

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

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 [10].

Multistage, random and purposive sampling techniques were adopted in the sampling of the respondents and yam tubers [11]. These techniques were involved in this study, because, in multistage sampling, in which the large or total population is divided into relatively smaller heterogeneous groups or clusters which were progressively divided until the smallest unit were obtained. To attain the genuine representation of the population, a simple random sampling or purposive sampling technique was adopted to select the particular unit of the population as the sample(s) [11]. Random or chance sampling permits an equal chance of inclusion of units in the sample. Samples are selected solely subject to the choice of the researcher [11].

Sampling procedure

In stage one of the sampling, the three local government areas; Ukum, Tarka and Otukpo, were purposively picked to represent the three senatorial geo-political zones A, B and C respectively of Benue State. At the second stage, nine (9) yam producing communities were randomly selected with 3 from each local government areas. At the third stage, twenty seven farmers (3 from each of the 9 yam producing communities) were chosen from the sampled yam producing communities to take part in the random sampling of the yam tubers across the three zones. The purposive and reasoned sampling frame used at this stage was to help the interpretation of results from the farmers who have been engaged in yam cultivation for at least the past five years and were willing to supply required information and other necessary inputs. In the fourth stage, 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 fourth sampling took place in the Soil Science Laboratory, Department of soil science Federal University of Agriculture, Makurdi, Benue State.

Laboratory Chemical Analyses

The data on the levels of heavy metals and agrochemical residues 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 analysed 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, JS Tarka University, 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.

Sample Size Determination for Laboratory 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 (*D. rotundata* and *D. alata*). Six (6) discrete samples were made from the representative aggregate composite samples of *D. rotundata* and *D. alata* per LGA as follows:

Samples and the Sample Codes.

The samples were labeled by codes each according to the treatments which consisted of: peeled boiled Pbt, boiled unpeeled Bupt, roasted Rt, raw dried Rdt, as in yam flour, fried Ft and fresh grated treatment Fgt (which is usually moulded and fried as yam balls (akara) or pan cake or to thicken vegetable soup. The treatments were according to the major forms in which yams are processed for consumption in Benue State. Samples (*D. rotundata* and *D. alata*) to differentiate the respective LGAs of the samples by the first letter of the LGA name first written, followed by the species identification letter(s) and then the treatment codes. The procedure was repeated thrice for the three seasons namely storage, milk and late harvest.

Precisely, eighteen samples were made each from *D. rotundata* and *D. alata* tubers taken from selected farmers' farms in each of the three LGAs. On the whole, a total number of 162 samples of yam tubers were taken for the laboratory analyses for the residues of fertilizers (NPK, Urea and Biuret impurities in urea fertilizer), heavy metals (Arsenic, Cadmium, Chromium and Lead).

The sampling sites and their corresponding samples were represented by codes, namely; OtyPbt (Otupko yam peeled boiled treated samples), OtyUpbt (Otupko yam unpeeled boiled treated samples), OtyFrt (Otukpo yam fried treated samples), OtuFst (Otupko yam fresh treated samples) OtyRdt (Otupko yam dried raw treated samples), OtyRtt (Otupko yam roasted treated samples), OtyPbt (Otupko water yam Peeled boiled treated samples), OtyUpbt (Otupko Water Yam unpeeled boiled treated samples), OtwyFst (Otupko Water yam Fresh treated samples), OtyFrt (Otupko water Yam fried treated samples), OwyRdt (Otupko Water yam dried raw samples), OTyRtt (Otupko water yam roasted treated samples); TayPbt (Tarka yam peeled boiled treated samples),TaUpbt (Tarka yam unpeeled boiled treated samples), TayFst (Tarka yam fresh treated samples) TayFrts (Tarka yam fried treated samples), TayRdt (Tarka yam dried raw treated samples), TayRtt (Tarka yam roasted treated samples),TawyPbt (Tarka water yam peeled treated samples), TawyUpbt (Tarka water yam unpeeled boiled treated samples),TawyFst (Tarka water yam fresh treated samples), TawyFrt (Tarka water yam fried treated samples), TawyRdt (Tarka water yam raw dried treated samples), TawyRtt (Tarka Water Yam Roasted); UkyPbt (Ukum yam peeled boiled treated samples), UkyUpt (Ukum yam unpeeled boiled treated samples), UkyFst (Ukum yam fresh treated samples), UkyFrt (Ukum yam fried treated samples), UkyRdt (Ukum yam raw dried treated samples), UyRtt (Ukum yam roasted treated samples), UkwyPbt (Ukum water yam Peeled boiled treated samples), UkwyUpt (Ukum water yam unpeeled boiled treated samples), UkwyFst (Ukum water yam fresh treated samples), UkwyFrt (Ukum water yam fried treated samples) , UkwyRdt (Ukum water yam raw dried treated samples), UkwyRtt (Ukum water yam roasted treated samples). On the whole, a total number of 324 samples,108 each were subjected to the laboratory chemical analysis for the residues of fertilizers, heavy metals and pesticides respectively.

Sample preparation and preservation

The standard methods and procedures as highlighted by AOAC (1965) were adopted. The Laboratory samples of *D. rotundata* and *D. alata* for Pbts, Frts, Fsts and Rdts were peeled with a stainless steel knife and cut into 3×3cm pieces. They were placed in labelled draining bowls according to treatments and washed under running distilled water and subsequently stored in a well- appropriately labelled and covered bowls. The samples for Pbts were placed each in a stainless steel pressure pot containing ½ liter of water and cooked for 5 minutes at 105^oc over gas burner. The Frts were transferred each into a stainless frying pan containing ½ liter olive vegetable oil (the most commonly used among most commercial yam fryers in Benue State) and fried over gas burner for 10 minutes. The samples were drained using draining bowl, allowed 15 minutes to cool.

The samples for Fs were grated with the aid of stainless kitchen grater and stored in the label storage bottles.

Samples for Rdts were sliced into 2mm chips using stainless kitchen knife, spread on stainless steel tray and sun dried for 2 - 5 days.

The Upbts were cut into 3cm cube and placed in a stainless steel pressure pot containing ½ liter of water and cooked for 5 minutes at 105^oc over gas burner. Each of the samples were peeled and stored in a separate labelled bottle.

The samples for Rtts were roasted for 15-20 minutes over charcoal 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 minutes. Each of the treated samples were placed in the appropriately labelled containing vessels.

Samples for fertilizer and heavy metal analysis were air dried for three days, then oven dried to constant weight at 105 ^oC for 6 hours, disaggregated in a ceramic mortar and pestle, ground to powder, and sieved [11]. About 10g of the dried yam samples were each placed in a crucible and ashed in a furnace for about 12–14 hours at 550 ^oC, until the samples turned into white ash mineral (dry treatment process).

Acid Digestion of Yam Samples: Heavy Metal Analyses

The ash samples were placed in a 250-ml volumetric flask, 5 ml each of concentrated HNO_3/H_2O_2 was added to it, and it was 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 100-ml volumetric flask by filtration through What No. 2 filter paper. The flask and the filter paper were washed several times with deionized water, and the volume was made to the mark of 100 ml with the deionized water. The filtrate was used for elemental analysis [12]. The **dry** and **wet** (acid) digestion methods were employed in the digestion of samples to ensure that the 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 samples for heavy metals; Arsenic, Cadmium, Chromium and Lead were determined using an atomic absorption spectrometer (AAS), AA-6800 (Shimadzu, Japan). The monochromator was set at the respective resonance lines and appropriate wavelengths for each of the metals. The atomic absorption spectrophotometry (AAS) AA-680 (Shimadzu, Japan) was chosen because of its accessibility, specificity, wide range of application, low detection capacity and cost effectiveness [2].

Determination of Arsenic Residues in Yam Sample by Atomic Absorption Spectrophotometry (AAS) (Hydride Generation Accessory with a Background Correction System- Deuterium Lamp used as Radiation Source)

Determination of Nitrate-nitrogen Residues in Yam Samples using The Kjeldahl Method [13-14].

Determination of Urea- Nitrogen residue in sampled yam tubers using Urease Method [13-14].

Determination of Phosphorus/Phosphate by Gravimetric quinolinium [13-14].

Determination of Potassium Residues in Yam Sample by Gravimetric and Volumetric Sodium Tetraphenyl Boron (STPB) Method [13-14].

The results were programmed and displayed on the standard calibration curve, with the corrected ion concentrations expressed in mg/L (ppm).

To confirm the precision and accuracy of the mineral analysis, a standard reference material (SRM) was obtained from the National Institute of Standards and Technology (NIST SRM 1577b).

The contents and levels of heavy metals (As, Cd, Cr, and Pb) in the samples were compared to the International Food Standard Levels, in the Food and Agricultural Organization (2020), and the World Health Organization's permissible limits.

The use of a 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 the result data.

Results and Discussion

The concentration of heavy metals in yam tubers

The results of the chemical analyses on the heavy metal contents of the yam tubers produced in Benue State were presented in Tables 1 and 2.

Table 1 showed the presence and levels of the four detected residues of heavy metals—Arsenic, Cadmium, Chromium, and Lead—in the sampled tubers (unprocessed) of *Dioscorea* spp. produced in Benue State. Also included in the table were: Potassium, Urea-Nitrate, Phosphorus, and Biuret, all of which were contaminated from the use of fertilizers in yam production (all values in Mg/Kg).

Arsenic recorded the highest and Cadmium the lowest mean values among the metals. The mean values of Arsenic (1.38975.39) and Chromium (0.45220.10), were all greater than the WHO/FAO MRLS (maximum residual limits) of 0.1000, 0.1000, respectively, while Cadmium (0.01270.01) and Lead (0.02870.00) were below their set limits (0.1000 and 0.1000) respectively. of the fertilizer residues, Urea Nitrate recorded the highest value and the only value that was above the set standard by WHO/FAO.

Effects of Cooking Treatment on Concentration Mean Values of Heavy Metal Residues in the Sampled Tubers of *Dioscorea* Spp

Table 2 presented the mean values of the concentrations of residues of heavy metals and fertilizers in the treated sampled tubers of *Dioscorea* spp. produced in Benue State. All the treated samples recorded equal number of the detected residues of heavy metals with approximately equal mean values (Table 1).

The same table showed the mean concentration of heavy metals in unprocessed and treated yam tubers produced in Benue State. The values of arsenic in fresh (Frts), fried (Fsts), peeled and boiled (Pbts), roasted (Rdts), raw and dried (Rtts), and the unpeeled and boiled (Upbts) were 1.3838 5.82, 1.3873 5.83, 1.3990 5.82, 1.3862 5.83, 1.3957 5.82, and 1.3859 5.82, respectively. There was a reduction in the content of arsenic in the Upbts and Rtts samples, respectively. The greatest reduction was observed in fresh and boiled samples. There was no significant reduction in both Pbts and Rdts yam tubers (Table 2).

The values of Cadmium in Frts, Fsts, Pbts, Rdts, Rtts, and Upbts were 0.01220.01, 0.01190.01, 0.01240.01, 0.01150.01, 0.01790.03, and 0.01020.01. A significant reduction was noticed in Pbts, Upbts, and Rtts yam samples. The greatest reduction in cadmium concentration was obtained in the boiled samples.

The values of chromium in Frts, Fsts, Pbts, Rdts, and Rtts and Upbts were 0.01220.01, 0.01190.01, 0.01240.01, 0.01150.01, 0.01790.03, and 0.01020.01. There was a significant reduction in the content of chromium in the Fsts and Pbts yam tubers. The highest degree of reduction in chromium content was seen in the fried samples.

The values of lead in Frts, Fsts, Pbts, Rdts, Rtts and Upbts were 0.02880.05, 0.03620.07, 0.01750.01, 0.02730.05, 0.01540.0118, and 0.04730.08, respectively. There was a reduction in the content of lead in Rtts followed by Pbts yam tubers (Roasted samples revealed the greatest reduction in lead levels).

Effects of Processing Methods on the Heavy Metal Contents of Yam Tubers

Differences were observed in the reduction of heavy metal contents in yam tubers. Frying was the most effective, followed closely by boiling and then roasting. This is similar to the results obtained in an earlier study by [15].

Table 1. The levels of residues in Mg/Kg of heavy metals and fertilizers measured in sampled tubers of *Dioscorea* spp produced in Benue State.

S/N	Residue	Value Range Min. – Max.	Mean ± SD	P Value	CODEX WHO/FHO MRL
1	Arsenic	00000 – 24.7153	1.3897±5.39 ^{c}	0.059	0.1000
2	Cadmium	0.0000 – 0.0318	0.0127±0.01 ^{a}	0.748	0.1000
3	Chromium	0.1120 – 1.3333	0.4522±0.10 ^{d}	0.061	0.1000
4	Lead	0.0000 – 0.305	0.0287±0.00 ^{ab}	0.748	2.000
5	Nitrogen-Nitrate	0.3650 – 0.5700	0.5074±0.00 ^{dc}	0.061	10.0000
6	Phosphorous	2.6018 – 2.9552	2.8601±0.00 ^{f}	1.000	5.0000
7	Potassium	0.0903 – 0.6017	0.2544±0.01 ^{c}	0.056	2.0000
8	Urea-Nitrate	0.3665 – 26.2824	4.7706±44.41 ^{e}	0.336	4.0000
9	Biuret	0.0570 – 0.2632	0.1305±0.01 ^{bc}	0.063	5.0000
	Total		0.1489±0.22		

Heavy metals and fertilizers $F_{(8,3.391)}$ = 159.317, P<0.001

Means with similar superscript letters are not significantly different from each other according to Duncan's Multiple Range Test at P ≤0.05.

Keys: ± = Plus, Minus

SD = Standard deviation from the mean MRL = Maximum residue limit

Mg/Kg = Milligram/Kilogram

CODEX WHO = World Health Organization

FAO = Food Agriculture Organization

< = Less then

> = Greater than

Table 2. Effects of treatments on the uptake and accumulation of residues of heavy metals in Mg/Kg sampled tubers of *D. alata* and *D. rotundata* produced in Benue State.

Heavy Metal and Fertilizer Residues	Total Mean ± SD	Treatments and X̄ ± SD						P-Value
		Frts	Fsts	Pbts	Rdts	Rtts	Upbts	
Arsenic	1.389657± 5.68 ^{c}	1.3838±5.82	1.3873±5.83	1.3990±5.82	1.3862±5.83	1.3957±5.82	1.3859±5.82	0.059
Cadmium	0.0127± 0.01 ^{a}	0.0122±0.01	0.0119±0.01	0.0124±0.01	0.0115±0.01	0.0179±0.03	0.0102±0.01	0.748
Chromium	0.4537± 0.58 ^{d}	0.4502±0.61	0.4402±0.61	0.4417±0.5223	0.4646±0.59	0.4515±0.67	0.4539±0.60	0.061
Lead	0.0288± 0.05 ^{ab}	0.0288±0.05	0.0362±0.07	0.0175±0.01	0.0273±0.05	0.0154±0.0118	0.0473±0.08	0.064

Nitrogen-Nitrate	0.5074±0.08 ^{de}	0.5028±0.08	0.5228±0.06	0.4939±0.0658	0.5172±0.08	0.4983±0.08	0.5094±0.08	0.061
Phosphorus	2.8602±0.23 ^{f}	2.8246±0.27	2.8408±0.25	2.8849±0.20	2.8738±0.22	2.8777±0.22	2.8792±0.22	1.000
Potassium	0.2544±0.32 ^{c}	0.1421±0.05	0.3526±0.51	0.2511±0.29	0.3019±0.36	0.2742±0.33	0.2046±0.22	0.059
Urea-Nitrate	4.7706±44.41 ^{e}	0.4893±0.08	0.5681±0.26	0.4701±0.12	26.1408±108.78	0.4864±0.08	0.4688±0.13	0.336
Biuret	0.1305±0.20 ^{bc}	0.1067±0.031	0.1833±0.30	0.1827±0.29	0.1436±0.23	0.0798±0.0432	0.0870±0.04	0.059
Total	**1.1564±14.94**	**0.6600±2.09**	**0.7048±2.10**	**0.6815±2.09**	**3.5430±36.30**	**0.6774±2.09**	**0.6718±2.10**	

Heavy metal & fertilizer residue $F_{(8,961)}$ = 160,475 P<0.001
Location $F_{(2,961)}$ = 4.46, P = 0.0125
Means with similar letters are not significantly different. Means with different letters are significantly different.
Keys: ± = Plus, Minus
SD = Standard deviation from the mean MRL = Maximum residue limit
mg/kg= milligram/kilogram CODEX WHO- World Health Organization
FAO=Food Agriculture Organization
< = Less then
> = Greater than

Mean value of heavy metal and fertilizer residues showed statistically significant differences at P ≤0.0001 less than the set value. Treatment revealed statistically significant differences among means of the treated samples with P = 0.0125 implying that cooking methods or treatments affected the accumulation of residues of heavy metals in the sample tubers of the yams.

Comparatively [16] showed lowest content of 0.007 μg/g of cadmium in raw potato (equivalent to Fsts in this work) followed by boiling (Pbts) 0.008 μg/g and the highest in fried samples with 0.012 μg/g. [6] demonstrated the effects of washing, unwashed and drying on metal content on yam tubers sold in Benin and showed statistically significant differences in the means of Cadmium, Chromium and Lead for boiled and unpeeled yam tubers.

Reduction was more prominent in Cadmium. In this order of increasing reduction in heavy metal content the yams observed Arsenic>Chromium>Lead> Cadmium.

Peeling the yams before boiling also proved to be more effective in reducing the heavy metal content than boiling the yam tubers without peeling them first.

Drying was ineffective as a method of reducing the heavy metal contents in yam tubers, as there was no significant reduction in raw dried samples as compared to unprocessed (Fsts) yam tubers. Oil frying method of cooking yam tuber is more effective than roasted treated yam tuber.

Heavy metals are held within foodstuffs by various surface forces. Food processing methods could be effective in reducing the heavy metal contents through mechanisms that alter the integrity of plant cell walls and disrupt the surface forces. These mechanisms involve the transfer of mass and heat [17].

Boiling is an effective method of reducing the heavy metal contents of food items. The latent heat of vaporization of the liquid (mainly water) results in mass and heat (energy) transfer. Boiling can help reduce the heavy metal contents of food through the following mechanisms:

i. Solubility: boiling makes heavy metals such as lead and cadmium more water-soluble by interfering with the surface forces that bind them in foods.
ii. Diffusion: the heat transfer from boiling disrupts the cell membranes of plants rendering them more permeable. The result is the net movement (diffusion) of solutes (including heavy metals) out of the cells into the interstitial fluid.
iii. Leaching: boiling leads to the migration of soluble form of heavy metals out of the food into the boiling water.
iv. Discarding the boiled water: the boiled liquid contains the leeched heavy metals. Discarding the water after cooking is known to remove a significant portion of the heavy metals present in the foodstuff.

These mechanisms might account for the reason why boiling was more effective in reducing the heavy metal contents of all four metals assayed in this study.

Peeling and rinsing the yams before boiling can help further reduction in the heavy metal contents.

Frying which is a form of dry processing of food as it involves the removal of water or fluid which the oil replaces in the tissues, it is not as effective as boiling, as seen in the results of the study, even though it caused the highest heavy metal reduction in the samples.

Roasting is also a form of dry processing, it results in the shrinkage of tissues as it damages the epidermal cell walls. This affects its ability to reduce the heavy metal contents in yams as the cell wall destruction limits the ability of the heavy metals to diffuse or move out of the cells, this could explain why not much heavy metals were removed from samples using this method.

The variations in the mechanisms of action of the various methods of food processing might explain the differences in the degree to which they were able to reduce the heavy metal content of yam tubers examined in this work.

Conclusion

The study revealed that the concentrations of Arsenic, Cadmium, Chromium, and Lead can be reduced by common food processing methods such as frying, boiling, and roasting. However, the concentrations of heavy metals such as Arsenic and Chromium in the treated samples were still greater than the WHO/FAO Maximum Residual Limits (MRLs). The unacceptable level of fertilizer residue in Urea Nitrate in both the unprocessed and treated yam samples might account for the high levels of heavy metals in the yams. This is because heavy metals can be found as impurities in Nitrate-Urea fertilizer, Potassium and Phosphate fertilizers. The abnormal value of Urea-Nitrate in Rdts-yam chips, sun dried in open air may have arisen from air drifts loaded with particulate nitrates and nitrites, through conscious efforts should be made to check the use of heavy metals containing agricultural inputs. This is essentially so we can mitigate the presence of Arsenic in our environment, food and water that can constitute to type II Diabetics [17-18 and Cadmium which though the values below the set limits can bio-accumulate in human body and overtime lead to various bone disorders as *Osteoporosis, Osteomalacia* [18] and others. Moreover, Arsenic exposure and contamination in human being through food injection can lead to insulin sensitivity reduction, contributing to type II Diabetes [18-19]. Lead could have resulted from air drift, rain and soil deposition and have ability to bio-accumulate in human body [1, 18]. The study thus recommends controlled use of these agrochemicals through education, awareness creations and information dissemination to our farmers.

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