Proximate Composition, Minerals and Heavy Metals Content of Cassava, Plantain and Yam Flour Sold in Some Markets in Port Harcourt, Nigeria

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ABSTRACT

The quality of retailed samples of cassava, yam and plantain flour produced in private homes without adequate monitoring is a concern to consumers. Consequently, this study was aimed at determining proximate composition, minerals and heavy metal content of fifteen (15) packaged and 15 exposed samples of flours obtained from three (3) supermarkets and 3 open markets in Port Harcourt, respectively using standard methods. Control samples were prepared in the laboratory. This study was carried out between April - August, 2017. Results obtained showed significant differences (p=.05) between each of the flours. Protein content of exposed cassava flour (2.3 %) was higher than other cassava flour samples. Meanwhile, that of yam flour (3.22 %) used as control was the highest among all flours. Crude fibre content of the cassava flour (3.12 - 5.46 %) was higher than that of other flour samples. Ash content of the flour samples were lower than that of plantain flour (2.7 - 7.07 %). Both moisture content of plantain flour used as control (13.22 %) and exposed plantain flour (10.3 %) were higher than that of other flour samples. Potassium, sodium, iron and calcium content of the packaged flour samples were higher than their respective control and exposed samples with few exceptions. Interestingly, heavy metals content of all samples were below Codex Alimentarius Commission permissible limits of 1.5, 1.0 and 1.0 mg/Kg for Pb, Cd and As, respectively. Therefore, flour fortification to improve their nutritional qualities as well as retailing only sealed flour samples could increase consumers' confidence.

Keywords: *Minerals, heavy metals, proximate composition, flour, markets.*

1. INTRODUCTION

Cassava (*Manihot esculenta* Crantz), yam (*Dioscorea* spp.) and plantain (*Musa parasidiacal*) are staple foods for millions of people living in Africa [1, 2, 3]. They are ranked among the top three reliable foods consumed in Nigeria. These crops are rich in carbohydrate and also contain essential minerals [4, 5, 6]. Apart from being a staple food for millions of people, diabetic patients in Nigeria rely on unripe plantain meal to reduce post pyramidal glucose level [7].

In order to drastically reduce post harvest losses, increase product shelf life and meet high demand of these staples which have high moisture content, they are usually processed into edible flour [8, 9, 10]. Processing methods and varieties of cassava, plantain and yam could influence proximate composition of flour derived from these crops [11, 12, 13]. In recent times, patronage of edible flours in Nigerian markets is on the increase [14]. Therefore, ascertaining nutritional composition of commercially available edible flours is important.

Essential macroelements and microelements perform important role in biological systems [15, 16]. Due to some health benefits of essential metals (EMs) and adverse health effects of toxic metals (TMs) in food, periodic monitoring of its level in food is important [17]. Heavy metals usually contaminate human body through ingestion of food or exposure to environments that is heavily contaminated. Relevant regulatory bodies have set safe limits of each heavy metal in foods [18]. However, consumption of foods that exceeded the safe limits could cause hematological, cardiovascular, neurological, developmental, respiratory, and gastrointestinal disorders as well as many disease conditions [15, 19, 20, 21].

Edible flours such as cassava, plantain and yam flour in Nigerian markets are either exposed or packaged. Contamination of these products usually occurs during processing and retailing [6]. This could affect their nutritional composition, minerals and heavy metals content. Consequently, patronage of these products over a long period without ascertaining their quality could have health implications on the consumers [22, 23]. Although, some studies had been carried out to evaluate the quality of retailed samples of edible flours, there is need for regular reassessment of these products especially in developing countries like Nigeria because large quantity of edible flours are locally produced in private homes where strict implementation of good manufacturing practices (GMPs) is difficult to enforce. To guarantee customer satisfaction and wellbeing, this study was aimed at evaluating heavy metal content, minerals and proximate composition of packaged and exposed cassava, plantain and yam flour retailed in some supermarkets and open markets in Port Harcourt, Rivers State, Nigeria.

2. MATERIALS AND METHODS

Fifteen (15) samples of packaged cassava flour and also for packaged plantain and yam flour were obtained from ED, SL and SR supermarkets in Port Harcourt, Nigeria. Each of the flour samples weighed 1 Kg. Composite composition of fifteen (15) samples of each of the flours obtained from the supermarkets was prepared. Similarly, fifteen (15) sterile plastic containers were used to collect 1 Kg of exposed cassava flour and also plantain and yam flour from fifteen (15) flour retailers at RO, M3 and OM open markets in Port Harcourt metropolis. Composite composition of fifteen (15) samples of each of the flours obtained from the open markets were also prepared. All the flour samples were transported to Food and Industrial Microbiology Laboratory, University of Port Harcourt for analysis. The control sample of cassava, yam and plantain flour was prepared in the laboratory under hygienic condition. The method described by Onyenwoke and Simonyan [2] with slight modification was adopted during preparation of cassava flour. Slightly modified procedure described by Omohimi [6] was adopted while preparing yam flour. As for preparation of plantain flour, slightly modified procedure described by Ajayi [3] was adopted.

2.1 Determination of proximate composition

The furnace incineration gravimetric method of AOAC [24] as described by Harbers and Nielsen [25] was adopted to determine ash content of the flour samples. Determination of moisture content of the flour samples involved gravimetric method as described by Bradely [26]. Crude fibre content was determined using AOAC [24] method. The Kjeldahl procedure described by AOAC [27] was used to estimate crude protein content of the samples. Fat content was determined using Soxhlet extraction method described by AOAC [24]. Carbohydrate content of the flour samples estimated as amino free substance was determined by mathematical estimation using the proximate variables [24].

2.2 Determination of minerals and heavy metals

Mineral analysis of the samples was done using AOAC [27] method. At 550 ^oC, the samples were ashed. Using a beaker, 5 g of the ashed sample was boiled with 10 ml of 20 % hydrochloric acid which was filtered into a 100 ml flask. The liquid in the flask was made up to the mark using deionized water. Minerals and heavy metals present in the resultant filtrate were determined. To determine sodium and potassium content, standard flame emission photometer was used whereby NaCl and KCl were the standards. Atomic absorption spectrophotometer (AAS Model SP9) was used to determine Ca and Fe content. The values obtained were expressed in mg/100 g.

2.3 Data analyses

All analyses were done in duplicates and expressed as mean± standard deviation. Statistical analyses to compare minerals and heavy metal content of cassava, yam and plantain flour samples that were either exposed or packaged was carried out using analysis of variance (ANOVA) and test of significance at 95 % (P=.05). Statistical Package for the Social Sciences (SPSS) IBM Statistics v.20 software was used to perform statistical analyses.

3. RESULTS

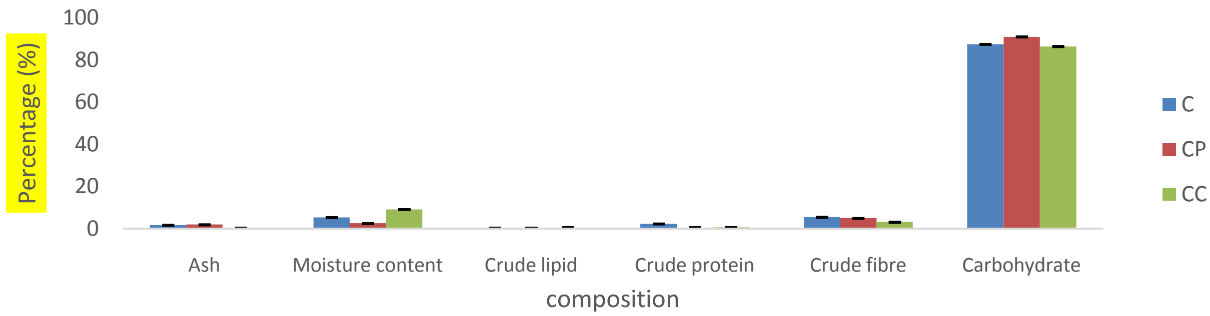

Figure 1. Proximate composition of cassava flour

Key: C - Exposed cassava flour; CP - Packaged cassava flour; CC- Cassava flour as control sample

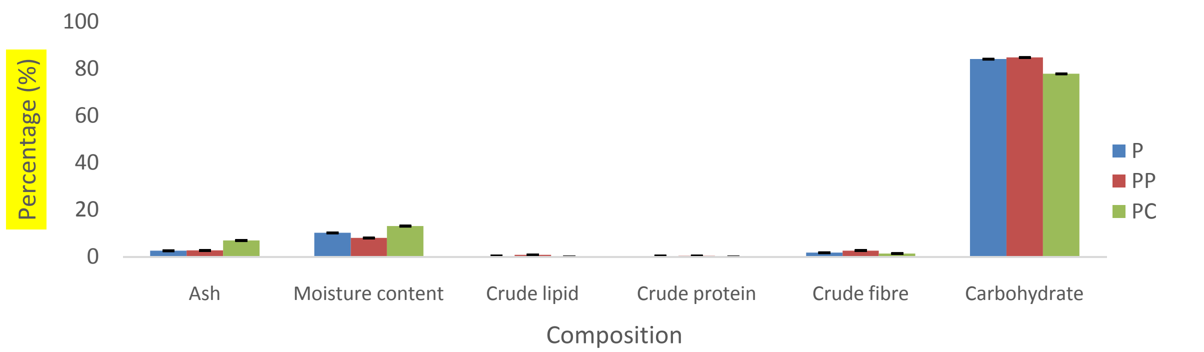

Figure 2. Proximate composition of plantain flour

Key: P - Exposed plantain flour; PP - Packaged plantain flour; PC- Plantain flour as control sample

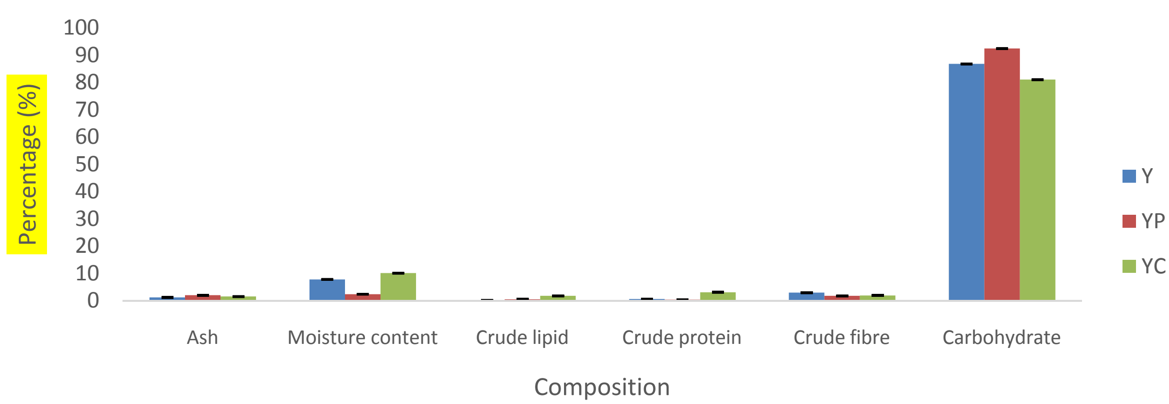

Figure 3 Proximate composition of yam flour

Key: Y- Exposed yam flour; YP - Packaged yam flour; YC - Yam flour as control sample

Table 1. Minerals and heavy metals content of exposed and packaged cassava flour, plantain flour and yam flour and their control samples

Sample	K (mg/kg)	Ca (mg/kg)	Na (mg/kg)	Fe (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	As (mg/kg)
Y	$7.25 + 0.00^{c}$	1.38 ± 0.006^{c}	2.04 ± 0.005^{d}	5.34 ± 0.004^{a}	0.004 ± 0.002^{b}	0.002 ± 0.003^{b}	0.04 ± 0.0002^{d}	0.00011 ± 0.0^{a}
YP	$15.98 + 0.01^{h}$	1.81 ± 0.01^{d}	1.37 ± 0.01^{a}	10.68 ± 0.1^{h}	0.0092 ± 0.001^{c}	0.000 ± 0.000^{a}	0.027 ± 0.01^{e}	0.0043 ± 0.001^{d}
Y (control)	9.31 ± 0.12^{e}	ND	ND	8.2 ± 0.12^{d}	0.0115 ± 0.0002^{d}	<0.0001	0.0025 ± 0.0001^{a}	<0.0001
P	10.14 ± 0.01^{f}	1.06 ± 0.011^{b}	1.53 ± 0.007^{b}	9.86 ± 0.04^{f}	0.003 ± 0.0003^{a}	0.0001 ± 0.00^{a}	0.015 ± 0.0003^{b}	0.0018 ± 0.0001^{b}
PP	8.51 ± 0.003^{d}	1.08 ± 0.33^{b}	2.16 ± 0.001^{d}	11.47 ± 0.09^{i}	0.003 ± 0.0015^{a}	0.003 ± 0.0003^{b}	0.54 ± 0.005^{f}	0.006 ± 0.001^{f}
P (control)	5.11 ± 0.02^{b}	ND	ND	10.2 ± 0.02^{g}	<0.0001	<0.0001	<0.0001	<0.0001
C	5.22 ± 0.01^{b}	0.76 ± 0.003^{a}	1.65 ± 0.043^{b}	6.67 ± 0.05^{b}	0.0052 ± 0.003^{b}	0.003 ± 0.000^{b}	0.52 ± 0.001^{c}	0.0023 ± 0.001^{c}
CP	$13.54 + 0.003^{g}$	$1.42 + 0.11^{c}$	1.84 ± 0.05^{c}	9.57 ± 0.05^{e}	0.005 ± 0.0004^{b}	0.028 ± 0.024^{c}	0.058 ± 0.004^{b}	0.0053 ± 0.001^{e}
C (control)	3.2 ± 0.02^{a}	ND	ND	7.2 ± 0.02^{c}	<0.0061	<0.0001	0.003 ± 0.002^{a}	<0.0001

Values presented in the table are MSE (Mean ± standard Error), Mean values (n = 2) having different superscript alphabets in the same column are significantly different ($p < 0.05$).

Key: Y -Exposed yam flour; YP - Packaged yam flour; P - Exposed plantain flour; PP - Packaged plantain flour; C - Exposed cassava flour; CP - Packaged cassava flour; Control samples were prepared in the laboratory; ND - Not detected.

4. DISCUSSION

4.1 Proximate composition

The proximate composition of packaged and exposed cassava, plantain and yam flour including that of control sample of each of the flour is presented in Figure 1-3. This study showed that moisture content of exposed and packaged plantain flour was 10.3 % and 8.1 %, respectively. Yarkwan and Uvir [12] reported similar results from a related study. According to Omohimi *et al.* [6], moisture content of processed yam flour from different markets range between 9.2-14.61 %. The moisture content of yam flour subjected to different drying methods reported by Hsu *et al*. [28] is in agreement with our result. Low moisture content of flour is an indication of better product shelf life [29]. According to Odentunde *et al*. [4], cassava flours from different markets had moisture content within the range of 9.66-10.54 %. If edible flour is directly exposed to the atmosphere with high relative humidity for a long period, it is most likely to experience increase in moisture content [30]. This study showed that moisture content of each of the flour samples used as control was higher than similar flour sample packaged or exposed. Inadequate drying of the control samples could be a major factor behind their high moisture content. However, lower moisture content of all the packaged flour samples compared with the exposed ones could be as a result of its packaging. Researchers have established that moisture content of any food product is an index of its keeping quality as well as a shelf life indicator [31]. It is quite interesting that moisture content of packaged and exposed yam, cassava and plantain flour obtained from selected markets in Port Harcourt, Rivers State are within 12 - 14 % recommended by Standard Organization of Nigeria (SON) for edible flour or food powder during storage [32].

Results from this study shows that ash content of packaged plantain, yam and cassava flour was 2.8, 2.1 and 1.9 %, respectively. These values were slightly higher than ash content of exposed plantain, yam and cassava flour which was 2.7, 1.3 and 1.7 %, respectively. Abiodun *et al*. [33], reported that ash content of pounded yam flour from *Dioscorea alata* was approximately 1.9 %. According to Arinola *et al.* [13] and Ajibola and Olapade [34], ash content of unripe plantain flour and cassava flour subjected to different drying methods range between 3.11-3.91 % and 0.99-1.39 %, respectively. In a related study, Emurotu *et al*. [22] reported that ash content of cassava flour samples range between 1.03-1.64 %. This result is in agreement with ash content of cassava flour samples (both the exposed and packaged) with the exception of the control sample. Ash content of cassava, plantain and yam flour as control sample was 0.33 %, 7.07 % and 1.63 %, respectively. Different varieties of cassava, plantain and yam processed into flours could have accounted for differences in ash content of the flour samples especially plantain flour. Generally, ash content of food materials is an indication of the level of minerals in a food sample [9]. Prevention of biochemical activities of microorganisms present in the packaged flour samples might be the reason ash content of the products were higher than that of exposed flour samples [32].

The lipid content of packaged and exposed cassava flour was 0.3 %. This result is an indication that exposure or packaging of cassava flour did not influence its lipid content. From a related study, Ajibola and Olapade [34] reported that lipid content of cassava flour range between 0.32-0.56 %. This result is in agreement with lipid content of cassava flour both packaged and exposed as well as control sample. Similarly, crude lipid content of yam flour reported by Hsu *et al.* [28] is in harmony with our result. This study revealed that lipid content of each control sample did not vary widely from that of similar flour sample packaged or exposed with the exception of yam flour. Result from this study shows that lipid content of packaged yam and plantain flour was 0.62 % and 0.93 %, respectively. Also, that of exposed yam and plantain flour was 0.18 % and 0.46 %, respectively. Therefore, lipid content of both packaged flours was higher than similar flours that were exposed. This could be as a result of reduced proteolytic and lipolytic enzymatic activity of microorganisms present in packaged yam and plantain flour. Probably, this prevented huge loss of nutrients such as lipids not to have occurred in packaged yam and plantain flour compared with level of nutrients in similar flour samples that were exposed.

Exposed and packaged cassava flour had a protein content of 2.3 % and 0.51 %, respectively. Relatively high protein content of exposed cassava flour compared with that of packaged flour could be as a result of edible flours from different sources mistakenly mixed with it during retailing of the product in open markets. Ajibola and Olapade [34] reported that protein content of cassava flours subjected to three drying methods range between 1.51-1.89 %. Odetunde *et al.* [35] reported that protein content of cassava flour range between 2.10 - 3.44 %. This result corroborates the protein content of exposed cassava flour. Meanwhile, protein content of plantain flour which range between 4.75 - 9.84 % reported by Ogundare-Akanmu *et al.* [36] is not in agreement with our results. However, protein content of yam flour reported by Obadina *et al*. [37] corroborates the result obtained from this study. It is critical that protein content of all the flour samples were less than 1 % except yam flour (control sample) and exposed cassava flour which protein content were 3.22 and 2.30 %, respectively. Studies have shown that high intake of plant protein could prevent onset of risk factors associated with cardiovascular diseases, reduce risk for stroke, lower body weight, cholesterol and blood pressure levels. It also helps maintain bone and muscle health [38, 39].

According to Yarkwan and Uvir [12], crude fibre content of fresh, sun dried and oven dried plantain flours was 1.40, 10.11 and 10.43 %, respectively. In another related study, Pacheco-Delahaye *et al*. [40] reported that dietary fiber content of unripe plantain flour dehydrated using different methods range between 9.01 - 9.67 %. This result is not in agreement with crude fibre content of packaged and exposed plantain flour which was 2.76 % and 1.87 %, respectively. A study carried out by Obadina *et al.* [37] revealed that fiber content of yam flour was within the range 1.17 - 2.26 %. This result corroborates with the crude fibre content of packaged yam flour which was 1.84 %. The result obtained from a related study by Hsu *et al*. [28] is in agreement with crude fibre content of both exposed and packaged yam flour. According to Eleazu and Eleazu [11], crude fibre content of cassava flour from six cassava varieties range between 1.65 - 2.32 %. Their result is not in agreement with crude fibre content of packaged and exposed cassava flour which was 4.94 % and 5.46 %, respectively. Meanwhile, this study revealed that crude fibre content of each control sample was lower compared with that of similar flour sample either exposed or packaged with the exception of yam flour. Dietary fibre is beneficial to human health because it reduces appetite, alleviates constipation, lowers variance in blood sugar levels and reduces risk of developing heart disease. It could also reduce onset risk or symptoms of metabolic syndrome and diabetes as well as reduce risk of developing colorectal cancers [41, 42].

Findings from this study revealed that carbohydrate content of each packaged flours was slightly higher than that of similar flour sample exposed to the environment. Carbohydrate content of packaged cassava, yam and plantain flour was 90.94 %, 92.52 % and 84.9 % while that of exposed cassava flour was 87.40 %, 86.85 % and 84.2 %, respectively. Lower moisture content for each packaged flours compared with that of similar flour sample exposed to the environment could be responsible for its carbohydrate content being higher than that of exposed flour. This study also showed that carbohydrate content of each control sample was slightly lower when compared with that of similar flour sample that was either exposed or packaged. High carbohydrate content of all the flour samples both the packaged, the exposed and the control samples is in agreement with earlier studies that reported these staples to be a rich source of carbohydrate [4, 5, 6, 7, 43].

4.2 Heavy metals content

Table1 shows the heavy metal content of exposed and packaged cassava, plantain and yam flour including that of control sample of each of the flour. Arsenic (As), cadmium (Cd), lead (Pb) and chromium (Cr) are heavy metals. They are known to be toxic. Arsenic and Cd are teratogenic whereas Cd and Cr are carcinogenic. Although iron (Fe) is a heavy metal, it is an essential micro-element for living things. However, at high concentration Fe becomes toxic to living things [44]. Exposure of humans to Pb could increase blood pressure. Lead is harmful to the cardiovascular system [17]. Damage to bones, kidneys and DNA could be caused by cadmium. mRNA transcriptional changes in the gills of *Mytilus galloprovincialis* has been associated with cadmium. Long period of human exposure to cadmium could result in nephrotoxicity. The limit of Cd in cassava flour stipulated by World Health Organization (WHO) is 0.5 ppm. Also, 0.5 ppm was stipulated as the limit of Pb content in cassava flour [45]. Similarly, Codex Alimentarius Commission (CAC) tolerable limit for Pb and Cd content in flour samples is 0.1-1.5 mg/Kg and 0.05-1.0 mg/kg, respectively. Adebayo-Oyetoro *et al*. [46] reported that quantity of As permissible in cassava flour was between 0.5-1.0 mg/kg. Although, safe limit for quantity of Cr in foods is not specified by the CAC, daily allowance of 1.50 μg/day is recommended [44]. European Union Food Standard recommends that Cd and Pb should not exceed 0.1 mg/kg [36].

This study has shown that the control samples had lower minerals and heavy metals than the ones that were either exposed or packaged. This result is in agreement with a similar study carried out by Yarkwan and Uvir [12]. Processing methods, exposure of retailed flour samples to environment, storage conditions and level of soil contamination with heavy metals where plantain, cassava and yam was grown could have influenced quantity of minerals and heavy metals in their respective flour samples. The exhaust fumes from heavy duty trucks that conveyed bulky goods to the market could also have deposited heavy metals on the exposed flour samples [12]. Therefore, exposure of flour in open markets should be discouraged due to potential health consequences of consuming such products.

Our results revealed that cadmium and lead content in both exposed and packaged flour samples are within International Standard. Adebayo-Oyetoro *et al*. [46] reported that quantity of As and Pb in cassava flour samples obtained from the market were lower than the recommended limit (1.0 mg/kg) except one sample which exceeded approved limits. Based on International Food Standards, Shin *et al*. [18] reported that quantity of Cd, Cr and As in commercial yam powder products in South Korea were within safe level but Pb content exceeded safe limits. The Cd and Cr content of commercial yam powder reported by Shin *et al*. [18] is in agreement with the results obtained from this study but As and Pb content was higher than the results obtained from this study. A related study by Iyabo *et al*. [17] revealed that Cd and Pb content of amala (cassava flour) were 0.03 and 0.14 mg/kg, respectively. They also reported that Cd and Pb content of amala (yam flour) were 0.02 and 0.30 mg/kg, respectively. Analysis results by Emurotu *et al*. [22] revealed that Pb and Cd content of cassava flour were below detection limit. This is not in agreement with the results obtained from this study. Research findings by Lanlokun *et al*. [21] revealed that Cd content between 0.51- 4.51 mg/kg was present in most plantain flour samples obtained from different locations. However, the researchers did not detect Pb in the plantain flour samples. This contradicts the result obtained from this study. Lanlokun *et al*. [21] also reported that As was not detected in plantain flour samples analyzed with the exception of one flour sample which contained 120.23 mg/kg arsenic acid. Obi *et al*. [47] reported that As, Cr, Pb and Cd content of unripe plantain flour are 0.027, 0.053, 0.063 and 0.033 ppm, respectively.

4.3 Minerals content

Shown in Table1 is the mineral content of exposed and packaged cassava, plantain and yam flour including that of control sample of each of the flour. Iron (Fe) is important in formation of heamoglobin, transferrin, ferritin and bone iron-containing enzymes. It is also involved in transport of different substances, DNA synthesis, and electron transport chain [45]. Potassium and sodium are beneficial for human health. These ions are important in the body because they are associated with many physiologic and pathophysiologic processes [48]. Calcium is important in human body because of its role in muscle contraction, blood clotting, nerve impulse, transmission, building strong teeth and bones [49].

Gomes *et al*. [16] reported that Fe content of cassava flour range between 2.95-15.45 mg/kg is in agreement with the results obtained from this study. According to Emurotu *et al*. [22], safe level of potassium, calcium and iron content of cassava flour should be 4.84-6.71 µg/g, 1.18-1.53 µg/g and 0.66-1.27 µg/g, respectively. The limit for Fe content in cassava flour recommended by World Health Organization (WHO) is 300 ppm [45]. According to Gomes *et al.* [16], the concentration of calcium in four cassava flour samples from Nigeria ranged between 1.18-1.53 mg/kg. This result is in agreement with calcium content of packaged cassava flour which was 1.42 mg/kg. Potassium and calcium content of exposed and packaged yam flour was lower than the values reported by Nina *et al*. [9] from a similar study. In another related study, Emurotu *et al*. [22] reported that cassava flour contains calcium, potassium and iron which range between 1.36 - 1.53, 4.84 - 6.71 and 0.66 - 1.27 µg/g, respectively. The quantity of minerals in both exposed and packaged plantain flour is higher than that of fresh unripe plantain, sun dried and oven dried unripe plantain flours reported by Yarkwan and Uvir [12] from a related study. The variety of plantain processed into plantain flour and processing methods adopted could be responsible for the differences in its mineral content.

CONCLUSION

Based on proximate composition and minerals content of packaged and exposed cassava, yam and plantain flour samples from selected open markets and supermarkets in Port Harcourt, Nigeria, fortification of the products is suggested. An interesting result from this study shows that heavy metals content of the flour samples did not exceed safe limits recommended by relevant international regulatory bodies. To further minimize heavy metal contamination of cassava, plantain and yam flour placed in open markets, the products should be bagged and sealed.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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REFERENCES

1. Montagnac, J. A., Davis, C. R. and Tanumihardjo, S. A. Nutritional value of cassava for use as a staple food and recent advances for improvement. *Comprehensive Reviews in Food Science and Food Safety*. 2009, 8: 181-194.
2. Onyenwoke, C. A. and Simonyan, K. J. Cassava post-harvest processing and storage in Nigeria: A review. Afri. *Journal of Agricultural Research*. 2014, 9 (53): 3853-3863.
3. Ajayi, A. O. Microbiological quality of plantain (*Musa paradisiacal*). *Nigerian Journal of Microbiology*. 2016, 30(2): 3962-3969.
4. Odetunde, S. K., Adebajo, L. O., Lawal, A. K. and Itoandon, E. E. Investigation of microbiological and chemical characteristics of cassava flour in Nigeria. *Global Advanced Research Journal of Microbiology*. 2014, 3 (3): 031-040.
5. Aruwa, C. E. and Ogundare, O. Microbiological quality assessment of pupuru and plantain flours in an urban market in Akure, Ondo state, south western Nigeria. *Open Access Library Journal*; 2017, 4: 1-11.
6. Omohimi, C., Piccirillo, C., Ferraro, V., Roriz, M. C., Omemu, M. A., Santos, S. M., Ressurreição, S. D., Abayomi, L., Adebowale, A., Vasconcelos, M. W., Obadina, O., Sanni L. and Pintado, M. M. E. Safety of yam-derived (*Dioscorea rotundata*) foodstuffs-chips, flakes and post-processing conditions. *Foods*. 2019, 8(12):1-19.
7. Ayodele, O. H. and Godwin, E. V. Glycemic indices of processed unripe plantain (*Musa paradisiaca*) meals. *African Journal of Food Science* 2010, 4 (8): 514-521.
8. OOye, D. A., Oso, G. K. and Olalumade, B. B. Effects of different processing methods on the proximate and cyanogenic composition of flour from different cassava varieties. Research and Reviews: *Journal of Agriculture and Allied Sciences*. 2014, 3 (3):1-6.
9. Nina, K. C. J., Ghislaine, D. C., Hubert, K. K., Patrice, A. Y. D., Patrice, K. L. and Alphonse, K. Biochemical and functional properties of yam flour during the post-harvest conservation of *Dioscorea alata* Cultivar 'Azaguié'. *Current Journal of Applied Science and Technology*. 2017, 21(6): 1-10.
10. Omowunmi, O. O. and Motunrayo, E. L. Effect of different sun drying surfaces on the functional properties and microbial loads of unripe plantain flours. *Frontiers in Environmental Microbiology*. 2017, 3 (3): 50-55.
11. Eleazu, C. O. and Eleazu, K. C. Determination of the proximate composition, total carotenoid, reducing sugars and residual cyanide levels of flours of 6 new yellow and white cassava (*Manihot esculenta* Crantz) varieties. *American Journal of Food Technology*. 2012; 7 (10): 642-649.
12. Yarkwan, B. and Uvir, R. H. Effects of drying methods on the nutritional composition of unripe plantain flour. *Food Science and Quality Management*. 2015, 41:5-10.
13. Arinola, S. O., Ogunbusola, E. M. and Adebayo, S. F. Effect of drying methods on the chemical, pasting and functional properties of unripe plantain (*Musa paradisiacal*) flour. *British Journal of Applied Science and Technology*. 2016, 14 (3): 1-7.
14. Kenechukwu, A. O. and Ndidi, O. L. Public health significance of food borne pathogens in edible flours. *African Journal of Microbiology Research*. 2015, 9(8): 509-514.

15. Apau, J., Acheampong, A., Appiah, J. A. and Ansong, E. Levels and health risk assessment of heavy metals in tubers from markets in the Kumasi metropolis, Ghana. *International Journal of Science and Technology*. 2014, 3 (9): 534-539.
16. Gomes, B. S., Pereira Junior, J. B, Nunes, P. O., Lemos, M. S., Dantas Filho, H. A., Dantas, K. G. F. Assessment of the concentration of trace elements in cassava flour (*Manihot esculenta* Crantz) by inductively coupled plasma optical emission spectrometry. *Revista Virtual de Quimica.* 2017, 9 (4): 1-13.
17. Iyabo, O. O., Ogundiran, M. B. and Adebayo, O. L. Toxic and essential metals in staple foods commonly consumed by students in Ekiti state, South West, Nigeria. *International Journal of Chemistry*. 2015, 7 (1): 155-160.
18. Shin, M. Y., Cho, Y. E., Park, C., Sohn, H. Y., Lim, J. H. and Kwun, I. S. The contents of heavy metals (Cd, Cr, As, Pb, Ni and Sn) in the selected commercial yam powder products in South Korea. *Preventive Nutrition and Food Science*. 2013, 18 (4): 249-255.
19. Alissa, E. M. and Ferns, G. A. Heavy metal poisoning and cardiovascular disease. *Journal of Toxicology*. 2011, 1-21.
20. Izah, S. C., Inyang, I. R., Angaye, T. C. N. and Okowa, I. P. A review of heavy metal concentration and potential health implications of beverages consumed in Nigeria. *Toxics*. 2017, 5 (1): 2-15.
21. Lanlokun, O. A., Bankole, M. O., Shittu, O. B., Henshaw, F. O. and Akinrotoye, K. P. Heavy metal assessment of unripe plantain flour sold in some markets in Osun state, Nigeria. *Biotechnological Research*. 2018; 4(4): 114-118.
22. Emurotu, J. E., Salehdeen, U. M. and Ayeni, O. M. Assessment of heavy metals level in cassava flour in Anyigba market Kogi State, Nigeria. *Advances in Applied Science Research*. 2012, 3 (5): 2544-2548.
23. Chukwu, O. and Abdullahi, H. Effects of moisture content and storage period on proximate composition, microbial counts and total carotenoids of cassava flour. *International Journal of Innovative Science, Engineering and Technology*. 2015, 2 (11):753-763.
24. A. O.A. C. (2000). Official method of analysis, 14th edition, the William Byrd press, Richmond VA USA. 332-333.
25. Harbers, L. H. and Nielsen, S. S. Ash analysis in food analysis 3rd edition Kluwer Academic/Plenum Publishers NY. 2003, p. 103-111.
26. Bradely, R. L. Moisture and total solids analysis. In food analysis 3rd edition. Eds. Harbers, L. H. and Nielsen, S. S. 2003, p. 81-101.
27. A.O.A.C. (2005). Association of analytical chemist. Official method of analysis 17th edition of A.O.A.C. Washington, D. C, U.S.A. 210-215.
28. Hsu, C. L., Chen, W., Weng, Y. M. and Tseng, C. Y. Chemical composition, physical properties , and antioxidant activities of yam flours as affected by different drying methods. *Food Chemistry*. 2003, 83: 85-92.
29. Butt, M. S., Nasir, M., Akhtar, S. and Sharif, K. Effect of moisture and packaging on the shelf life of wheat flour. *Internet Journal of Food Safety*. 2004, V (4): 1-6.
30. Nasir, M., Butt, M. S., Anjum, F. M., Sharif, K. and Minhas, R. Effect of moisture on the shelf life of wheat flour. *International Journal of Agriculture and Biology*. 2003, 5 (4): 458-459.
31. Kyere, G. The effect of various drying methods on drying characteristics, sensory and nutritional qualities of yam. Master of Science thesis submitted to College of Science, Department of Food Science and Technology, Kwame Nkrumah University of Science and Technology, Ghana. 2015, 1-103.
32. Adebowale, A. A., Owo, H. O., Sobukola, O. P., Obadina, O. A., Kajihausa, O. E., Adegunwa, M. O., Sanni, L. O. and Keith, T. Influence of storage conditions and packaging materials on some quality attributes of water yam flour. *Cogent Food and Agriculture*. 2017, 1-59.
33. Adeola, A. A., Otegbayo, B. O. and Ogunnoiki S. Preliminary studies on the development and evaluation of instant pounded yam from *Dioscorea alata*. *Journal of Applied Science and Environmental Management.* 2012; 16 (3): 287-290.
34. Ajibola, G. O. and Olapade, A. A. Effects of drying methods on nutritional quality of pro-vitamin A cassava (*Manihot esculenta* Crantz) flours. *Annals, Food Science and Technology*. 2017, 18 (3): 355-363.
35. Odetunde, S. K., Adebajo, L. O., Lawal, A. K. and Itoandon, E. E. Investigation into microbiological and chemical characteristics of cassava flour in Nigeria. *Global Advanced Research Journal of Microbiology.* 2014, 3 (3): 031-040.
36. Ogundare-Akanmu, O. A., Inana, M. E. and Adindu, M. N. Preliminary quality evaluation of selected plantain flour (*Musa paradisiacal*) sold in Port Harcourt markets, Nigeria. *Food Science and Quality Management*. 2015, 35:7-10.

37. Obadina, A. O., Babatunde, B. O. and Olotu, I. Changes in nutritional composition, functional, and sensory properties of yam flour as a result of presoaking. *Food Science and Nutrition*. 2014, 1-6.
38. Chalvon-Demersay, T. C., Azzout-Marniche, D., Arfsten, J., Egli, L., Gaudichon, C., Karagounis, L. G. and Tomé, D. A systematic review of the effects of plant compared with animal protein sources on features of metabolic syndrome [1-3]. *The Journal of Nutrition*. 2017, 281-292.
39. Richter, C. K., Skulas-Ray, A. C., Champagne, C. M. and Kris-Etherton, P.M. Plant protein and animal proteins: Do they differentially affect cardiovascular disease risk?[1-2]. *American Society for Nutrition. Advances in Nutrition*. 2015, 6: 712-728.
40. Pacheco-Delahaye, E., Maldonado, R., Pérez, E. and Schroeder, M. Production and characterization of unripe plantain (*Musa paradisiacal* L.) flours. *Interciencia*. 2008, 33 (4): 290-296.
41. Dhingra, D., Michael, M., Rajput, H. and Patil, R. T. Dietary fibre in foods: a review. *Journal of Food Science and Technology.* 2012, 49 (3): 255-266.
42. Lattimer, J. M. and Haub, M. D. Effects of dietary fiber and its components on metabolic health. *Nutrients*. 2010, 2: 1266-1289.
43. Chandrasekara, A. and Kumar, T. J. Roots and tuber crops as functional foods: A review on phytochemical constituents and their potential health benefits. *International Journal of Food Science*. 2016, 1-15. Article ID 3631647.
44. Ogbonna, I. O., Agbowu, B. I. and Agbo, F. Proximate composition, microbiological safety and heavy metal contaminations of garri sold in Benue, North-Central Nigeria. *African Journal of Biotechnology.* 2017, 16 (18): 1085-1091.
45. Ezeh, E., Okeke, O., Aburu, C. M. and Anya , O. U. Comparative evaluation of the cyanide and heavy metal levels in traditionally processed cassava meal products sold within Enugu metropolis. *International Journal of Environmental Sciences and Natural Resources*. 2018, 12 (2):01-06.
46. Adebayo-Oyetoro, AO., Oyewole, OB., Obadina, AO., Omemu, MA. 2013. Cyanide and heavy metal concentration of fermented cassava flour (lafun) available in the markets of Ogun and Oyo states of Nigeria. World Academy of Science, Engineering and Technology. *International Journal of Nutrition and Food Engineering.* 2013, 7 (7): 645-648.
47. Obi, T. E., Henshaw, O. F. and Atungwu, J. J. Evaluation of heavy metals and anti-nutrient contents of flour and noodles produced from unripe plantain from fields undergoing conversion to organic systems. *Journal of Organic Agriculture and Environment*. 2017, 5 (1):73-82.
48. Pohl, H. R., Wheeler, J. S. and Murray, H. E. Sodium and potassium in health and disease In: Interrelations between essential metal ions and human diseases, metal ions in life sciences. Sigel, A., Sigel, H. and Sigel, R. K. O. (eds.). 2013; 13: 29-47.
49. Pravina, P., Sayaji, D. and Avinash, M. Calcium and its role in human body. *International Journal of Research in Pharmaceutical and Biomedical Sciences.* 2013, 4 (2): 659-668.