MINERAL AND ANTINUTRIENT CONTENT OF HIGH QUALITY CASSAVA-TIGERNUT COMPOSITE FLOUR EXTRUDED SNACK

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ABSTRACT

This study investigated the mineral and antinutrient composition of extruded snack produced from different blends of high quality cassava and tigernut flour. The extruded snacks were produced using a single-screw laboratory extruder at constant feed moisture (27%), screw speed (60 rpm) and barrel temperature (80C). It was observed that the extrudates had higher values for mineral composition (phosphorus, calcium, magnesium, potassium and iron) than the composite flour which showed that extrusion cooking improves the absorption of the minerals. The antinutrient (tannin, phytate, saponin, oxalate, alkaloids and total phenolic) contents of all the flour blends significantly ($P < 0.05$) increased with tigernut flour inclusion. Extrusion cooking resulted in significant ($P < 0.05$) reduction in the antinutrients of the extrudates. The study showed that extrusion cooking reduced the antinutritional factors thereby increasing the bioavailabilty of minerals. Also, the minerals were not affected by the extrusion cooking process probably because minerals are heat stable.

PRACTICAL APPLICATIONS

Findings from this study have potentials to increase the productivity and value addition to tigernut, an underutilized plant specie. The snack produced is also a good alternative gluten free product.

INTRODUCTION

Consumption of food that are safe, nutritious and hygienically prepared is now on the increase in most part of the world. In food processing, extrusion cooking combines heating with the act of extrusion to create a shaped cooked product. With the help of shear energy, exerted by the rotating screw, and additional heating of the barrel, the food material is heated to its melting point or plasticating point. Some essential nutrients can be retained or enhanced through the process of extrusion cooking. Extrussion cooking have also been reported to partially/totally eliminate or inactivate many antinutritional components of plant foods (Shimelis and Rakshit 2007; Anton *et al.* 2009; Batista *et al.* 2010). It also reduces the operating costs and higher productivity than other cooking process, combining energy efficiency and versatility.

In the developing world, cassava (*Manihot esculenta* Crantz) is a major root crop and an important staple food for over 500 million people (Falade and Akingbala 2010). It has been regarded as a chief source of dietary food energy for the majority of the people living in the lowland tropics, and much of the subhumid tropics of West and Central Africa (Tsegai and Kormawa 2002). High quality cassava flour (HQCF) is unfermented, smooth, odorless, white or creamy flour, bland with no gluten. As a result of increase in the price of wheat in the international market and unfavorable exchange rates in West Africa, HQCF was introduced and is now gradually gaining popularity in the subregion. Commercial production of HQCF is relatively new in Africa and is still being used mainly by small and medium-scale processors (Dziedzoave *et al.* 2006).

Tigernut (*Cyperus esculentus*) is an underutilized crop in the family of *Cyperaceae*, which produces rhizomes from the base, and tubers that are somewhat spherical. It grows mainly in the middle belt and in the northern regions of Nigeria. It is a root crop which grows widely in wet places as a grass and is sometimes cultivated for its small and sweet tubers (Eteshola and Oraedu 1996). It has been recognized for their health benefits as they are rich in fiber, protein and natural sugars, minerals (phosphorus, potassium) (Belewu and Belewu 2007). Tigernut flour has a distinct sweet taste, which is ideal for wide uses. It is a good alternative to many other flours like wheat flour, as it is gluten free and good for people who cannot take gluten in their diets.

Good nutrition indicates that all the nutrients are provided and utilized in adequate amount to maintain optimal health and well-being (Thomas 2006). The ability of extrussion cooking to process various plant food commodities (either alone or in blends) into foods of high-nutritional value has been reported (Anuonye *et al.* 2010). Antinutrients are natural or synthetic compounds that interfere with the absorption of nutrients. Extrusion cooking has been reported to be a useful process for the reduction of the activity of some antinutritional factors (Mouquet *et al.* 2003). These antinutrients such as tannin, alkaloids, phytates and saponins might produce adverse effects in humans and animals nutrition (Martin-Cabrejas *et al.* 2004; Anton *et al.* 2009; Batista *et al.* 2010). Hence, this study was aimed at determining the mineral and antinutritional factor content of extruded snack from high quality cassava and tigernut composite flour.

MATERIALS AND METHODS

Yellow variety of tigernut seeds were purchased from an open market in Abeokuta, Ogun state, Nigeria while yellow-flesh cassava roots (clone 01/1368) were obtained from the Research Farm of the International Institute of Tropical Agriculture (IITA), Ikenne, Nigeria.

TIGERNUT SEED FLOUR AND HQCF PROCESSING

Tigernut seeds were sorted to remove unwanted materials prior to washing with clean water. The cleaned seeds were dried in a cabinet dryer (Genlab, DC500, UK) at 60C for 72 h to reduce moisture to 13% (modified method of Ade-Omowaye *et al.* 2008). Dry seeds were milled using a laboratory hammer mill and then sieved using a 600 μm screen. The tigernut flour was then packed in zip-lock polyethylene bag and stored at 4C until used.

Yellow fleshed cassava roots were peeled, washed, grated, dewatered and then dried in a cabinet dryer (Genlab, DC500, UK) at 50C for 6 h, the dried grits were milled and then sieved using 250 μm screen (Dziedzoave *et al.* 2003). The flour was packaged in zip-lock polyethylene bag and stored at 4C until used. The HQCF and tigernut flour obtained were blended together in different proportions using a laboratory blender (Philip, HR2020/50, UK) as shown in Table 1.

TABLE 1. FORMULATION OF DIFFERENT BLENDS OF HQCF-TIGERNUT FLOUR

HQCF (%)	Tigernut flour (%)
100	0
90	10
80	20
70	30
60	40
50	50
40	60
30	70
20	80
0	100

Processing of Extruded Snacks

This was processed following the procedure of Kareem *et al.* (2015). One hundred grams (100 g) each of the various composite flour samples (Table 1) were mixed with other ingredients (i.e., 0.75% dried onion powder, 0.3% dried ginger powder, 0.75% iodized salt, 7.5% sugar, 21% milk powder and 0.3% dried chilli pepper powder). The mixture (feed samples) were preconditioned to 27% (wb) moisture content with the addition of 50 mL hot water (80–90C), mixed and allowed to stand for 2 min to uniformly hydrate the raw material in order to eliminate any dry core. A laboratory scale single-screw extruder with screw length per diameter, screw diameter and length of 16.43:1, 18.5 mm and 304 mm, respectively, was used. The extruder composed of two sections: the transmission and the die zones. The barrel section was heated with band heater (Sobukola *et al.* 2012). It was operated at full speed in all runs under the following constant conditions: barrel and die temperature (80C), screw speed (60 rpm) and feed moisture (27% wb). Flat die of 15 mm width was used to produce nonexpanded extrudates. The extrudates were cut into small pieces of 2 cm length and dried in a hot air oven (Genlab, OV/50/DIG, UK) at 60C for 3 h to obtain the HQCF-tigernut seed composite flour extruded snacks. The snack was cooled to room temperature, packaged in zip-lock polyethylene bags and stored at 4C for further analysis.

DETERMINATION OF THE MINERAL COMPOSITION OF THE COMPOSITE FLOUR AND EXTRUDED SNACKS

The mineral contents of the samples were determined by the procedure of AOAC (2000). Calcium, potassium,

magnesium, phosphorus and iron elements were measured with Atomic Absorption Spectrophotometer (Thermo scientific S Series Model GE 712354) after digesting with perchloric-nitric acid mixture (AOAC 2000). Prior to digestion, 0.5 g of the samples were weighed into a 125 mL Erlenmeyer flask with the addition of perchloric acid (4 mL), concentrated HNO_3 (25 mL) and concentrated sulfuric acid (2 mL) under a fume hood. The contents were mixed and heated gently in a digester (Buchi Digestion unit K-424) at low to medium heat on a hot plate under perchloric acid fume hood and heating was continued until dense white fume appeared. Heating was continued strongly for half a minute and then allowed to cool followed by the addition of 50 mL distilled water. The solution was allowed to cool and filtered completely with a wash bottle into a Pyrex volumetric flask and then made up with distilled water. The solution was then read on Atomic Absorption Spectrophotometer.

DETERMINATION OF ANTINUTRITIONAL FACTOR COMPOSITION

Alkaloids. This was done by the alkaline precipitation gravimetric method described by Harborne (1973). A measured weight of the sample was dispersed in 10% acetic acid solution in ethanol to form a ratio of 1:10 (10%). The mixture was allowed to stand for 4 h at 28C. It was later filtered via Whatman No. 1 filter paper. The filtrate was concentrated to one quarter of its original volume by evaporation and treated with drop wise addition of concentrated aqueous NH_4OH until the alkaloid was precipitated. The precipitated alkaloid was received in a weighed filter paper, washed with 1% ammonia solution and dried in the oven at 80C. Alkaloid content was calculated and expressed as a percentage of the weight of sample analyzed.

Tannins. The method of Swain (1979) was used for the determination of tannin contents of the composite flour and extrudates. About 0.2 g of finely ground sample was measured into a 50 mL beaker. Then, 20 mL of 50% methanol was added, covered with parafin and placed in a water bath at 77–80C for 1 h with continuous stirring using a glass rod to prevent lumping. The extract was quantitatively filtered using a double-layered Whatman No.1 filter paper into a 100 mL volumetric flask using 50% methanol to rinse. This was made up to mark with distilled water and thoroughly mixed. Then, 1 mL of sample extract was pipetted into 50 mL volumetric flask, 20 mL of distilled water, 2.5 mL of Folin-Denis reagent and 10 mL of 17% Na_2C0_3 were added and mixed properly. The mixture was made up to mark with distilled water, mixed well and allowed to stand for 20 min when a bluish-green coloration developed. Standard tannic acid solutions of range 0–10 ppm were treated similarly as 1 mL of the sample. The absorbance of the tannic acid standard solutions as well as samples was read after color development on a Spectronic 21D Spectrophotometer at a wavelength of 760 nm.

Percentage tannin was calculated using the formula below:

$$\text{Tannin } (\%) = \frac{\textit{Absorbance of sample} \times \textit{Average gradient} \times \textit{Dilution factor}}{\textit{weight of sample} \times 10,000} \quad (1)$$

Saponin. The spectrophotometric method of Brunner (1984) was used for saponin analysis. One gram of finely ground sample was weighed into a 250 mL beaker and 100 mL isobutyl alcohol was added. The mixture was shaken on a UDY shaker for 5 h to ensure uniform mixing. Thereafter, the mixture was filtered through a Whatman No. 1 filter paper into a 100 mL beaker and 20 mL of 40% saturated solution of magnesium carbonate added. The mixture obtained with saturated $MgCO_3$ was again filtered through a Whatman No. 1 filter paper to obtain a clear colorless solution. Then, 1 mL of the colorless solution was pipetted into 50 mL volumetric flask and 2 mL of 5% $FeCl_3$ solution was added and made up to mark with distilled water. It was allowed to stand for 30 min for blood red color to develop. Then, 0–10 ppm standard saponin solutions were prepared from saponin stock solution. The standard solutions were treated similarly with 2 mL of 5% FeCl solution. The absorbance of the sample as well as standard saponin solutions were read after color development on a T60 UV-visible spectrophotometer, U.K. at a wavelength of 380 nm. Percentage saponin was calculated using the formula below:

$$\text{Saponin } (\%) = \frac{\textit{Absorbance of sample} \times \textit{Average gradient} \times \textit{Dilution} \text{ factor}}{\textit{weight of sample} \times 10,000} \quad (2)$$

Total Phenol. The total phenol content of the samples was determined using the method described by Malick and Singh (1980). Each sample (1 g) was taken and ground in 10 mL of 80% ethanol using a pestle and mortar. This homogenate was centrifuged at 10,000 rpm for 20 min. Supernatant was saved and residue was reextracted with 10 mL of 80% ethanol, centrifuged and the supernatant was saved. The supernatant was evaporated to dryness. The residue was dissolved in 5 mL distilled water. Different quantities of samples (0.2–2 mL) were taken in the test tubes. Volume of each tube was made to 3 mL with distilled water. Folin–Ciocalteu reagent (0.5 mL) was added in each tube. After 3 min, 2 mL sodium carbonate (20%) solution was added to each tube. The contents of the tubes were mixed thoroughly and the tubes were placed in boiling water bath exactly for 1 min, cooled and the absorbance was measured at 650 nm against a blank reagent. Standard curve was prepared by using different concentrations of catechol.

Oxalate. Oxalate was determined using method described by Day and Underwood (1986). One gram of the sample was weighed into 100 mL conical flask after which 75 mL of 3 N H_2SO_4 was added and stirred intermittently with a magnetic stirrer for 1 h. It was then filtered using Whatman No. 1 filter paper. From the filtrate, 25 mL aliquot was taken and titrated while hot (80–90C) against 0.1 N $KMnO_4$ solution until a faint pink color persisted for at least 30 s.

$$\text{Oxalate content} = \frac{T \times (Vme)(Df) \times 105}{ME \times M_f} \text{ mg/100 g} \quad (3)$$

T = titre of $KMnO_4$ (mL), Vme = volume-mass equivalent, Df = dilution factor ($V_T/A \times 2.4$, where V_T is the total volume of titrate and A is the aliquot used), ME is the molar equivalent of $KMnO_4$ in oxalate, M_f = mass of flour.

Phytate. Phytate was determined using the method described by Maga (1982). Two grams of each finely ground flour sample was soaked in 20 mL of 0.2 N HCl for 3 h and filtered. After filtration, 0.5 mL of the filtrate was mixed with 1 mL ferric ammonium sulfate solution in a test tube, boiled for 30 min in a water bath, cooled in ice for 15 min and centrifuged at 3000 rpm for 15 min. One milliliter of the supernatant was mixed with 1.5 mL of 2,2-pyridine solution and the absorbance read in a spectrophotometer at 519 nm. The concentration of phytic acid was obtained by extrapolation from a standard curve using standard phytic acid solution.

Hydrogen Cyanide. Quantitative determination of hydrogen cyanide was carried out using the method described by Essers *et al.* (1993). An extract was made from the flour blends and extrudates using cold orthophosphoric acid. The extract was treated with an excess amount of exogenous linamarase; the pH was raised to convert all cyanohydrins and hydrogen cyanide to cyanide ions. Cyanide ions were quantified using a specific and stoichiometric reaction with chloramine T, isonicotinate and dimethyl barbituric, which produces a colored dye. The absorbance of the color produced is proportional to the concentration of cyanide ions in the reaction mixture.

Statistical Analysis

Data obtained were subjected to Analysis of Variance (ANOVA) using SPSS version 16.0 and the differences between significant mean values were evaluated at $P < 0.05$ probability level using Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Mineral Composition of Composite Flour and Extruded Snack

Tables 2 and 3 show the result of mineral composition of composite flour and extrudate. It was observed that the mineral content of the extrudates was generally higher than that of the flour blends. It has been reported that increase in extrusion temperature could lead to increase in amount of trace elements in extruded products (Anuoye *et al.* 2010). The 100% HQCF had the lowest value while 100% tigernut flour had the highest value for all the minerals. The Potassium content of the flour ranged from 45.98 ± 0.43 to 121.1 ± 1.54 mg/100 g while that of the extrudates ranged from 55.55 ± 2.89 to 125.29 ± 2.62 mg/100 g. The magnesium content of the flour blends ranged from 9.40 ± 0.86 to 10.58 ± 0.10 mg/100 g, while that of the extrudates ranged from 9.68 ± 0.42 to 19.53 ± 0.97 mg/100 g. The phosphorus content of the flour blends ranged from 55.0 ± 14.14 to 171.4 ± 1.94 mg/100 g while that of the extrudates ranged from 85.0 ± 0.02 to 185.0 ± 7.01 mg/100 g. The phosphorus content of 100% tigernut flour (171.4 mg/100 g) was higher than the value of 121 mg/100 g reported by Oladele and Aina (2007). The value obtained for 100% HQCF (55 mg/100g) was higher than the value of 52 mg/100 g reported by Sarkiyayi and Agar (2010). Minerals are heat stable and unlikely to be lost during extrusion. The phosphorus content of high quality cassava-tigernut flour and extruded samples were higher than the daily requirement for adults (30 mg/100 g).

The calcium content of the flour blends ranged from 138.0 ± 6.81 to 214.3 ± 7.44 mg/100 g while that of the extrudates ranged from 305.0 ± 21.2 to 382.0 ± 7.07 mg/

TABLE 2. MINERAL COMPOSTION OF HIGH QUALITY CASSAVA-TIGERNUT FLOUR BLENDS (mg/100 g)

Sample	P	Ca	Mg	K	Fe
100%CF	55.0 ± 14.14^{b}	138.0 ± 6.81^{f}	9.40 ± 0.86^{a}	45.98 ± 0.43^{f}	1.67 ± 0.24^{b}
90%CF:10%TF	60.0 ± 7.07^{b}	154.8 ± 2.66^{e}	10.42 ± 0.58^{a}	54.05 ± 6.20^{ef}	1.71 ± 0.20^{b}
80%CF:20%TF	87.1 ± 4.18^{ab}	169.0 ± 10.39^{d}	10.36 ± 0.66^{a}	64.31 ± 7.05^{def}	1.79 ± 0.20^{b}
70%CF:30%TF	101.0 ± 4.24^{ab}	176.1 ± 4.37^{cd}	10.52 ± 0.56^{a}	73.35 ± 9.52^{cdef}	1.84 ± 0.13^{b}
60%CF:40%TF	105.0 ± 12.8^{ab}	179.5 ± 5.34^{bcd}	10.22 ± 1.08^{a}	82.50 ± 16.63^{bcde}	1.84 ± 0.14^{b}
50%CF:50%TF	116.4 ± 1.94^{ab}	181.2 ± 14.18^{bcd}	10.15 ± 0.15^{a}	94.62 ± 9.58^{abcd}	2.10 ± 0.25^{ab}
40%CF:60%TF	132.6 ± 3.5^{ab}	181.9 ± 2.41^{bcd}	10.19 ± 1.12^{a}	99.31 ± 15.85^{abc}	2.14 ± 0.30^{ab}
30%CF:70%TF	144.6 ± 6.4^{ab}	189.5 ± 5.43^{bc}	10.33 ± 0.52^{a}	101.0 ± 14.85^{abc}	2.28 ± 0.28^{ab}
20%CF:80%TF	145.2 ± 7.26^{ab}	193.6 ± 4.91^{b}	10.48 ± 0.08^{a}	109.0 ± 16.92^{ab}	2.38 ± 0.51^{ab}
100%TF	171.4 ± 1.94^{a}	214.3 ± 7.44^{a}	10.58 ± 0.10^{a}	121.1 ± 1.54^{a}	2.72 ± 0.53^{a}

Mean values with different superscripts within the same column are significantly different ($P < 0.05$).
CF – HQCF, TF – tigernut flour, P – phosphorus, Ca – calcium, Mg – magnesium, K – potassium, Fe – iron.

100 g. The calcium content of 100% tigernut flour (214.3 mg/100 g) was higher than the value of 155 mg/100 g reported by Oladele and Aina (2007). This may probably be due to the differrent location where the sample was cultivated since it has been reported that genetic and environment interactions affects nutritional composition of plant materials (Sanni *et al.* 2008). The value obtained for 100% HQCF (138 mg/100 g) was higher than the value (33 mg/100 g) reported by Sarkiyayi and Agar (2010). This may likely be due to the improved variety of cassava that was used in this study. The result obtained for calcium was high and this could be due to low level of oxalic acid and phytic acids being the major chelators of calcium, hence releasing calcium for biological activities.

The iron content of the flour ranged from 1.67 ± 0.24 to 2.72 ± 0.53 mg/100 g while that of the extrudates ranged from 1.98 ± 0.69 to 4.68 ± 0.56 mg/100 g. The iron content of 100% tigernut flour (2.72 mg/100 g) was higher than the value of 0.65 mg/100 g reported by Oladele and Aina (2007). The value obtained for 100% HQCF (1.67 mg/100 g) was higher than the range of values (0.16–0.24 mg/100 g) reported by Emmanuel *et al.* (2012). Iron is required for the synthesis of hemoglobin and myoglobin, which are oxygen carriers in the blood and muscle, respectively. The extrudates had higher values for mineral composition than individual raw samples which showed that extrusion cooking significantly reduced the antinutritional factors especially the chelating agents thereby making more mineral to be available for analysis. It was also reported that minerals content before and after extrusion cooking was significantly ($P < 0.05$) different by Murekatete *et al.* (2010). This can also be attributed to a high-temperature, short-time process of extrusion cooking, thereby yielding a better product. This trend is in conformity with earlier reports of Harper (1988) and Anuonye *et al.* (2009).

Antinutritional Composition of Composite Flour and Extruded Snack

The data on antinutritional composition of the high quality cassava-tigernut flour and its extruded snack are shown in Tables 4 and 5, respectively. It was observed that extrusion cooking caused significant ($P < 0.05$) decrease in these antinutrients. The hydrogen cyanide of high quality cassava-tigernut composite flour ranged from 1.13 ± 0.06 to 1.22 ± 0.01% while that of extrudates ranged from 0.75 ± 0.01 to 0.87 ± 0.03%. The value of hydrogen cyanide

TABLE 3. MINERAL COMPOSTION OF HIGH QUALITY CASSAVA-TIGERNUT EXTRUDATES (mg/100 g)

Sample	P	Ca	Mg	K	Fe
100%CF	85.0 ± 0.02^{a}	305.0 ± 21.21^{a}	9.68 ± 0.42^{c}	55.55 ± 2.89^{e}	1.98 ± 0.69^{c}
90%CF:10%TF	90.0 ± 0.01^{a}	325.0 ± 28.57^{a}	10.70 ± 1.84^{bc}	59.41 ± 2.85^{e}	2.16 ± 0.63^{c}
80%CF:20%TF	110.0 ± 0.00^{b}	339.8 ± 16.99^{a}	11.70 ± 0.94 ^{bc}	61.14 ± 3.78^{e}	2.28 ± 0.52^{c}
70%CF:30%TF	110.0 ± 0.01^{b}	358.0 ± 20.62^{a}	11.34 ± 0.69^{bc}	71.75 ± 3.81^{de}	2.84 ± 0.47^{bc}
60%CF:40%TF	115.0 ± 7.07^{b}	345.4 ± 28.16^{a}	10.51 ± 1.41^{bc}	78.98 ± 3.25^{cd}	2.87 ± 0.23^{bc}
50%CF:50%TF	135.0 ± 0.17^{c}	360.1 ± 19.03^{a}	11.00 ± 1.32^{bc}	83.96 ± 3.35^{cd}	2.96 ± 0.41^{bc}
40%CF:60%TF	140.0 ± 6.10^{cd}	356.6 ± 16.80^{a}	12.07 ± 0.71^{bc}	86.71 ± 2.85^{cd}	3.11 ± 0.09^{bc}
30%CF:70%TF	145.0 ± 3.02^{cd}	371.2 ± 15.40^{a}	12.50 ± 0.17^{bc}	94.16 ± 1.78^{bc}	3.64 ± 0.13^{ab}
20%CF:80%TF	150.0 ± 2.18^{d}	370.9 ± 10.49^{a}	12.88 ± 0.75^{b}	108.60 ± 2.44^{b}	3.84 ± 0.44^{ab}
100%TF	185.0 ± 7.01^{e}	382.0 ± 7.07^{a}	19.53 ± 0.97^{a}	125.29 ± 2.62^{a}	4.68 ± 0.56^{a}

Mean values with different superscripts within the same column are significantly different ($P < 0.05$).
CF – HQCF, TF – tigernut flour, P – phosphorus, Ca – calcium, Mg – magnesium, K – potassium, Fe – iron.

TABLE 4. ANTINUTRITIONAL FACTORS OF FLOUR BLENDS (%)

Sample	HCN	Oxalate	Phytate	Tannin	Saponin	Phenolic	Alkaloids
100%CF	1.15 ± 0.01^{cd}	0.12 ± 0.01^{i}	0.32 ± 0.01^{g}	3.62 ± 0.04^{e}	0.42 ± 0.04^{f}	0.57 ± 0.01^{f}	0.94 ± 0.06^{i}
90%CF:10%TF	1.13 ± 0.06^{d}	0.22 ± 0.02^{h}	0.58 ± 0.04^{f}	3.64 ± 0.08^{e}	0.47 ± 0.05^{ef}	0.67 ± 0.04^{e}	1.13 ± 0.08^{h}
80%CF:20%TF	1.15 ± 0.01^{cd}	0.33 ± 0.02^{g}	0.67 ± 0.01^{f}	4.27 ± 0.08^{d}	0.48 ± 0.04^{ef}	0.85 ± 0.03^{d}	1.25 ± 0.03^{gh}
70%CF:30%TF	1.17 ± 0.03^{bc}	0.41 ± 0.02^{f}	0.97 ± 0.04^{d}	4.38 ± 0.05^{cd}	0.57 ± 0.04^{e}	0.89 ± 0.01^{cd}	1.35 ± 0.01^{fg}
60%CF:40%TF	1.14 ± 0.01^{d}	0.47 ± 0.01^{e}	0.83 ± 0.05^{e}	4.40 ± 0.01^{cd}	0.76 ± 0.05^{d}	0.89 ± 0.05^{cd}	1.47 ± 0.03^{ef}
50%CF:50%TF	1.18 ± 0.06^{b}	0.53 ± 0.03^{de}	1.03 ± 0.01^{d}	4.46 ± 0.08^{c}	1.02 ± 0.06^{c}	0.90 ± 0.04^{cd}	1.49 ± 0.04^{def}
40%CF:60%TF	1.22 ± 0.01^{a}	0.56 ± 0.06^{cd}	1.02 ± 0.01^{d}	4.49 ± 0.09^{c}	1.23 ± 0.04^{b}	0.91 ± 0.06^{c}	1.56 ± 0.10^{cde}
30%CF:70%TF	1.19 ± 0.01^{b}	0.59 ± 0.05^{c}	1.38 ± 0.06^{c}	5.27 ± 0.06^{b}	1.21 ± 0.04^{b}	0.91 ± 0.05^{c}	1.73 ± 0.07^{ab}
20%CF:80%TF	1.17 ± 0.03^{bc}	0.73 ± 0.03^{b}	1.49 ± 0.03^{b}	6.09 ± 0.10^{a}	1.23 ± 0.06^{b}	0.99 ± 0.01^{b}	1.87 ± 0.12^{a}
100%TF	1.15 ± 0.02^{cd}	0.83 ± 0.03^{a}	1.90 ± 0.02^{a}	6.05 ± 0.10^{a}	1.24 ± 0.06^{a}	1.13 ± 0.01^{a}	1.68 ± 0.06^{abc}

Values are means of trplicate determination.

Mean values with different superscripts within the same column are significantly different ($P < 0.05$).

CF – HQCF, TF – Tigernut flour.

of all the high quality cassava-tigernut flour and extruded samples were below the Nigerian Industrial Standard (10 mg/kg) for cassava and cassava products (NIS 344:2004) maximum specification for HQCF (Sanni *et al.* 2005). Initial processing of the raw samples (cassava roots and tigernut seeds) reduced their hydrogen cyanide below the NIS maximum specification before extrusion cooking which further reduced the cyanide content. It has been reported that extrusion cooking affected the hydrogen cyanide content of (shreaded cassava chips) *Ighu/AYB* (Africa Yam Bean) blends (Omeire *et al.* 2012). Hydrogen cyanide is heat labile and hence can volatilize while subjecting the sample to extrusion process (Iorgyer *et al.* 2009).

The oxalate content of high quality cassava-tigernut flour blends ranged from 0.12 ± 0.01 to 0.83 ± 0.03% while that of the extrudates ranged from 0.11 ± 0.01 to 0.63 ± 0.11%. The oxalate content of 100% tigernut flour (0.83%) was higher than the range of values (0.41–0.52%) reported by Nwaoguikpe (2010). The value obtained for 100% HQCF (0.12%) was higher than the value 0.02% reported by Sarkiyayi and Agar (2010). Oxalates can remove calcium in the form of calcium oxalate in the blood and thus may result to kidney damage and they also exhibit structure dependent biological activity (Savage 1993).

The phenolic content of high quality cassava-tigernut flour blends ranged from 0.57 ± 0.01 to 1.13 ± 0.01% while that of the extrudates ranged from 0.37 ± 0.01 to 1.00 ± 0.18%. The phenolic content of 100% tigernut flour (1.13%) was higher than the value of 1.00 ± 0.07% reported by Oladele *et al.* (2009). Recent finding has shown that phenolic compounds are powerful antioxidants that can protect the human body from free radicals, the formation of which is associated with the normal metabolism of aerobic cells (Oboh and Rocha 2007).

Alkaloids, saponins and tannins are known to have antimicrobial activity, as well as other physiological activities in human system (Sofowora 1993; Evans 2005). The alkaloids content of high quality cassava-tigernut flour blends ranged from 0.94 ± 0.06 to 1.87 ± 0.12% while that of the extrudates ranged from 0.87 ± 0.06 to 1.74 ± 0.03%. The result obtained for alkaloids content of 100% tigernut (1.89%) was low compared to the value (2.63%) reported by Oladele *et al.* (2009) and this may likely be due to varietal differences. Alkaloids are known for their toxicity, but not all

TABLE 5. ANTINUTRITIONAL FACTORS OF HIGH QUALITY CASSAVA-TIGERNUT EXTRUDATES (%)

Sample	HCN	Oxalate	Phytate	Tannin	Saponin	Phenolic	Alkaloids
100%CF	0.87 ± 0.03^{a}	0.11 ± 0.01^{g}	0.27 ± 0.02^{f}	2.68 ± 0.01^{c}	0.34 ± 0.05^{d}	0.37 ± 0.01^{d}	0.87 ± 0.06^{e}
90%CF:10%TF	0.84 ± 0.01^{a}	0.18 ± 0.03^{fg}	0.47 ± 0.03^{ef}	2.46 ± 0.10^{c}	0.38 ± 0.04^{d}	0.51 ± 0.05^{d}	1.12 ± 0.06^{de}
80%CF:20%TF	0.81 ± 0.01^{b}	0.30 ± 0.01^{ef}	0.61 ± 0.01^{de}	3.19 ± 0.04^{ab}	0.43 ± 0.04^{d}	0.61 ± 0.11^{bcd}	1.22 ± 0.05^{d}
70%CF:30%TF	0.78 ± 0.03^{b}	0.33 ± 0.06^{def}	0.76 ± 0.02^{cd}	3.32 ± 0.08^{ab}	0.52 ± 0.08^{cd}	0.64 ± 0.12^{bcd}	1.28 ± 0.07^{cd}
60%CF:40%TF	0.75 ± 0.01^{a}	0.40 ± 0.03^{cde}	0.79 ± 0.02^{cd}	3.72 ± 0.03^{ab}	0.71 ± 0.08^{c}	0.75 ± 0.05^{abc}	1.37 ± 0.05^{cde}
50%CF:50%TF	0.82 ± 0.01^{b}	0.43 ± 0.02^{bcde}	0.88 ± 0.01^{cd}	3.85 ± 0.01^{abc}	0.93 ± 0.05^{b}	0.77 ± 0.07^{abc}	1.40 ± 0.06^{bcde}
40%CF:60%TF	0.85 ± 0.02^{a}	0.49 ± 0.02^{abcd}	1.01 ± 0.01^{bc}	4.38 ± 0.04^{ab}	1.04 ± 0.04^{b}	0.86 ± 0.03^{ab}	1.52 ± 0.05^{abcd}
30%CF:70%TF	0.86 ± 0.01^{a}	0.51 ± 0.07^{abc}	1.21 ± 0.05^{b}	4.77 ± 0.01^{ab}	1.04 ± 0.04^{b}	0.89 ± 0.03^{ab}	1.62 ± 0.06^{abc}
20%CF:80%TF	0.80 ± 0.02^{b}	0.60 ± 0.10^{ab}	1.29 ± 0.02^{ab}	5.30 ± 0.02^{a}	1.12 ± 0.02^{ab}	0.94 ± 0.05^{a}	1.74 ± 0.03^{a}
100%TF	0.81 ± 0.03^{b}	0.63 ± 0.11^{a}	1.54 ± 0.05^{a}	5.37 ± 0.17^{a}	1.31 ± 0.10^{a}	1.00 ± 0.18^{a}	1.67 ± 0.07^{bc}

Values are means of triplicate determination.

Mean values with different superscripts within the same column are significantly different ($P < 0.05$).

CF – HQCF, TF – Tigernut flour.

alkaloids are toxic. Some affect glucagon and thyroid stimulating hormones, while some have been reported to be carcinogenic (Okaka *et al.* 1992). They have also been used either as an analgesic, antispasmodic or bactericidal agents (Frantisek 1991).

The value of 1.47% saponin recorded by 100% tigernut flour used in this study was high compared to that (0.64–0.78) reported by Nwaoguikpe (2010). The saponin content of high quality cassava-tigernut flour blends ranged from 0.42 ± 0.04 to 1.24 ± 0.06% while that of the extrudates ranged from 0.34 ± 0.05 to 1.31 ± 0.10%. Saponins have been reported to be useful in reducing inflammation of upper respiratory passage and also mainly as foaming and emulsifying agents (Frantisek 1991). It has also been found that saponin reduces the uptake of certain nutrients including glucose and cholesterol in the gut through intralumenal physicochemical interaction (Price *et al.* 1987).

The tannin content of high quality cassava-tigernut flour blends ranged from 3.62 ± 0.04 to 6.09 ± 0.10% while that of the extrudates ranged from 2.46 ± 0.10 to 5.37 ± 0.17%. The tannin content of 100% tigernut flour (6.04%) obtained in this study was low compared to the values (7.21–9.52%) reported by Nwaoguikpe (2010). Nwaoguikpe (2010) worked on brown and yellow tigernut variety while only yellow variety was used in this study. Tannins have astringent properties that hasten the healing of wounds and prevention of decay. The phytate content of high quality cassava-tigernut flour blends ranged from 0.32 ± 0.01 to 1.90 ± 0.02% while that of the extrudates ranged from 0.27 ± 0.02 to 1.54 ± 0.05%. The result obtained for phytate content of 100% tigernut flour (1.90%) was lower than the values (2.11–2.33%) reported by Nwaoguikpe (2010). The value obtained for 100% HQCF (0.32%) was higher than the values (0.22–0.30%) reported by Sarkiyayi and Agar (2010). The presence of phytates in biological systems may chelate divalent metals like calcium, magnesium, or block the absorption of essential minerals in the intestinal tract (Dan 2005). It would be expected that lowering these antinutritional compounds should enhance the bioavailability of such minerals as zinc and iron in the extrudates since phytic acid has been implicated in making these minerals unavailable (Anuonye *et al.* 2009). The reduction in these antinutrients can be explained by the partial degradation of the molecules of phytate. Although many findings have considered phytic acid as an antinutrient, recent findings have pointed out that phytic acid is an important antioxidant and additive, with applications in the manufacture of many novel food products such as pasta, bread, fish paste, meat, fruits and vegetables (Oatway *et al.* 2001; Batista *et al.* 2010).

CONCLUSION

The study showed that extrusion cooking reduced the antinutritional factors thereby increasing the bioavailabilty of minerals. Also, the minerals were not affected by the extrusion cooking process probably because minerals are heat stable. This implies that the usage of HQCF-tigernut flour blends and its extruded snacks for human food may not have any toxic effect to the consumers.

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