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Evaluation of nutritional and functional properties of plantain (*Musa paradisiaca* L.) and tigernut (*Cyperus esculentus* L.) flour blends for food formulations

M. O. Adegunwa[1], E. O. Adelekan[2], A. A. Adebowale[2], H. A. Bakare[1] and E. O. Alamu[3]*

Abstract: Some individuals are intolerant to gluten of wheat and other cereals like oats, rye and barley used for food formulations and this intolerance seriously impairs intestinal absorption. There is need to develop alternative gluten-free flours for baking and confectioneries. This research therefore aimed at determining the chemical and functional properties of plantain–tiger nut composite flour to be able to explore its potentials in food formulation. The flours made from matured plantains and tiger nuts were blended at the ratio of 100:0, 70:30, 60:40, 50:50, 40:60, 30:70 and 0:100 to make different plantain–tiger nuts flours and these were analysed using standard methods. The results revealed that protein ranged from 4.55 to 6.78/100 g, fat (2.25–32.75/100 g), crude fibre (3.50–6.13/100 g), bulk density (0.81–0.92 g/cm^3), swelling power (38.38–2.37/g), Mg (30.65–49.08 mg/100 g), P (3.65–120.65 mg/100 g), K (71.62–212.08 mg/100 g), Vitamin C (3.18–5.30 mg/100 g) and Vitamin A (1.71–51.31 μg/100 g). There were significant differences ($p < 0.05$) in the pasting profile of the plantain–tiger nut flour blends and in functional properties of composite flour except for bulk density. Addition of tiger nut flour improved the

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E. O. Alamu, is a postdoctoral fellow in Food Science/Technology for IITA. He holds a PhD in Food Chemistry. He has experienced in carrying out nutrition-sensitive agricultural research using different tools and techniques. He has many publications in local and foreign journals to his credit. His research areas covered physicochemical and functional properties, processing and nutrients retention, sensory and consumer testing, bioactive compounds, anti-oxidant activities, bioavailability, bioefficacy and nutrition survey.

PUBLIC INTEREST STATEMENT

Plantain flour has a good potential for use as a functional agent in bakery products on account of its high water absorption capacity and it has recorded success when used in addition to the conventional wheat flour. Tiger nut flour has a unique sweet taste, which is ideal for different uses. Both are gluten-free and considered good flour or additive for the bakery industry, as their natural sugar content is fairly high, avoiding the necessity of adding too much extra sugar. Tiger nut is potentially a commercial source of high-oleic acid vegetable oil and high-carbohydrate tuber cakes. Its content of vitamin E and oleic acid was reported to have positive effect on cholesterol thereby preventing heart problems, thrombosis and activates blood circulation and blood content of soluble glucose, responsible for preventing and treating urinary tract and bacterial infection, assist in reducing the risk of colon cancer.

proximate, mineral and vitamin composition of the composite flour and the study concluded that inclusion of tiger nut flour is a good protein, fat, mineral and vitamin supplement for plantain flour.

Subjects: Environment & Agriculture; Bioscience; Food Science & Technology; Food Additives & Ingredients; Food Chemistry

Keywords: plantain; tiger nut; composite flour; chemical composition; functional properties

1. Introduction

Nigeria has been completely dependent on imported wheat for the manufacture of baked goods and deep fat frying products. But, local climatic conditions in tropical countries such as Nigeria are not suitable for profitable wheat production. On the other hand, some individuals are intolerant to gluten of wheat and other cereals like oats, rye and barley. This intolerance, celiac disease, seriously impairs intestinal absorption and can lead to severe malnutrition (*1, 2*). Therefore, research efforts in tropical countries were currently aimed at steps to identify those non-wheat sources that could be used as an alternative to wheat flours, thus affects saving in foreign exchange by limiting wheat importation. Such non-wheat flours are obtained from other cereals, legumes, tubers and root crops, for example, maize, rice, soybean, sorghum, cassava, sweet potato, potato and plantain (*3–8*).

Nigeria is one of the largest Plantains (*Musa paradisiaca*)-producing countries in the world (*9*). FAO (*10*) has reported that more than 2.5 million metric tons of plantains are produced in Nigeria annually, but about 40–60% post-harvest losses had been reported which is attributed to lack of storage facilities and inadequate technologies for food processing. In Nigeria and many African countries, plantains (*Musa paradisiaca*) are used as an inexpensive source of calories (*11*). It is one of the most important sources of food energy in West and Central Africa, where about 70 million people derive more than 25% of their carbohydrates from plantains (*12, 13*). When processed into flour it is used traditionally for preparation of gruel which is made by mixing the flour with appropriate quantities of boiling water to form a thick paste. It is also consumed as snacks in form of chips, “dodo ikire”, etc. It is, however, gradually finding applications in weaning food formulation and composite flour preparations (*4, 14*). It is recommended to produce plantain flour from green fruits, since it has high starch content of about 35% on wet weight basis (*15*). Akubor (*16*) has shown that plantain flour has a good potential for use as a functional agent in bakery products because its high water absorption capacity (WAC) and it has recorded success when used in addition to the conventional wheat flour, but currently there is need to investigate the application of whole *Musa* flour in baking and confectioneries from the point of view of their pasting properties (*17*). Furthermore, Ogazi et al. (*18*) reported that feeding mainly on plantain cannot meet up with the daily protein requirement, therefore protein supplementation is essential.

Tiger nut (*Cyperus esculentus*), an underutilized crop (*19, 20*) are valued for their highly nutritious starch content, and digestible carbohydrate (*21, 22*). The nut was reported to be rich in sucrose, fat (which are resistant to peroxidation) and protein (*23, 24*). It is also an excellent source of some useful minerals such as iron and calcium which are essential for body growth and development (*25*). It is also rich in sodium, phosphorous, potassium, magnesium, zinc and traces of copper (*26*) and rich in vitamins E and C. Tiger nut has been demonstrated to contain higher essential amino acids (such as lysine, cystine, arginine and histidine) than those proposed in the protein standard by the FAO/WHO (*27*) for satisfying adult needs (*28, 29*). It also contains a reasonable amount of methionine lacking in plantain, making it a good supplement for plantain (*18*). It was reported to be high in dietary fibre content, which could be effective in the treatment and prevention of many diseases including colon cancer, coronary heart diseases, obesity, flatulence, indigestion, diarrhoea, dysentery, excessive thirst, diabetics and gastrointestinal disorders (*30, 31*). Tiger nut has been cultivated as a livestock food and for human consumption; it can be eaten raw, roasted, grated, baked or used for ice cream and beverage making for its many useful benefits (*26, 32*). Wheat-based composite flour was substituted with plantain and tiger nut flours to enhance its protein, fibre, minerals, antioxidants and resistant starch contents (*33*). Bamigbola *et al.* (*33*) reported that the optimum blends obtained were runs 2 (70% wheat, 20% plantain and 10% tiger nut flours), 13 (77% wheat, 20% plantain and 3% tiger nut flours) and 15 (65.66% wheat, 29% plantain and 5.33% tiger nut flours) with overall best ash, fibre, protein and mineral contents. Tiger nut flour has a unique sweet taste, which is ideal for different 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. Apparently, the inclusion of tiger nut flour could serve as a good protein supplement for plantain flour and a naturally gluten-free alternative to wheat flour. This research therefore aimed at determining some quality attributes of plantain–tiger nut composite flour to be able to explore its potentials in food formulation.

2. Materials and methods

Tiger nuts (*Cyperus esculentus*) yellow variety, black pepper, matured, green, ripe and wholesome fruits of plantain was purchased from Kuto market, Abeokuta.

2.1. Tiger nut flour processing

The method of Oladele and Aina (*25*) was used in the preparation of tiger nut flour with slight modification. Dry tiger nuts were sorted to remove unwanted materials like stones, pebbles and other foreign seeds, before washing with tap water and then drained and dried in a cabinet dryer at 60°C for 24 h to a moisture content of about 13%. The dried nuts were milled and sieved through 600-μm mesh size sieve. The resultant flour was packed and sealed in polythene bags until analysed.

2.2. Plantain flour processing

The method of Mepha (*14*) was used to prepare the plantain flour with slight modification. Plantain heads were cut into separate bunches which were subsequently de-fingered. The fingers were washed to remove adhering soil particles, peeled, cut into thin slices of about 2-cm thick and blanched in 1.25% $NaHS0_3$ solution at 80°C for 5 min. Blanched plantain slices were drained and dehydrated in the cabinet dryer at 60°C for 24 h. The dried plantain slices were milled into flour using Hammer mill. Flour obtained was sifted through a 250-μm aperture sieve. The flour was packed and sealed in polyethylene bags until ready for analyses.

The blending of both plantain and tiger nut flours was prepared in different formulations as presented in Table 1.

2.3. Determination of functional properties

2.3.1. Emulsion activity and stability

Emulsion activity and stability was evaluated using a method by Yasumatsu et al. (*34*). A mixture of 1-g flour sample, 10-ml distilled water and 10-ml oil was prepared in a calibrated centrifuged tube. The emulsion was centrifuged at 2000 rpm for 5 min. The ratio of the height of emulsion layer to the total height of the mixture was calculated as emulsion activity in percentage. The emulsion stability was estimated after heating the emulsion contained in calibrated centrifuged tube at 80°C for

Table 1. Formulations of plantain–tiger nut composite flour

Treatment	Plantain flour (%)	Tiger nut flour (%)	Sample code
T1	100	0	A
T2	0	100	B
T3	70	30	C
T4	60	40	D
T5	50	50	E
T6	40	60	F
T7	30	70	G

30 min in a water-bath, cooling for 15 min under running tap water and centrifuging at 2,000 rpm for 15 min. The emulsion stability expressed as percentage was calculated as the ratio of the height of emulsified layer to the total height of the mixture.

$$\text{Emulsion activity } (\%) = \frac{\text{Height of emulsion layer}}{\text{Height of whole mixture}}$$

2.3.2. Foam capacity and stability

Foaming capacity was evaluated using Narayana and Narasinga, (35) method with slight modification. One gram of flour sample was added to 50 ml of distilled water at 30 ± 2°C in a graduated cylinder. The suspension was mixed and shaken for 5 min to foam. The volume of foam at 30 s after whipping was expressed as foam capacity using the formula:

$$\text{FC } (\%) = \frac{\text{Volume of foam after whipping} - \text{Volume of foam before whipping}}{\text{Volume of foam before whipping}} \times 100$$

The volume of foam was recorded one hour after whipping to determine foam stability as per cent of initial foam volume.

2.3.3. Bulk density

A 50-g flour sample was put into a 100-ml measuring cylinder. The cylinder was tapped continuously until a constant volume was obtained. The bulk density (g/ cm^3) was calculated as weight of flour (g) divided by flour volume (cm^3) (36)

$$\text{Bulk density } \left(\text{g/cm}^3\right) (\%) = \frac{\text{Weight of Sample}}{\text{Volume of Sample after tapping}}$$

2.3.4. Water absorption capacity

The water absorption capacity of the flours was determined by the method of Sosulski et al. (15). One gram of flour sample was mixed with 10 ml of distilled water and allowed to stand at ambient temperature (30 ± 2°C) for 30 min, then centrifuged for 30 min at 3000 rpm. The clear supernatant was decanted. Water absorption was expressed as per cent water bound per gram flour.

2.3.5. Oil absorption capacity

The oil absorption capacity was determined by the method of Sosulski et al. (37). One gram of flour sample mixed with 10 ml of oil and allowed to stand at ambient temperature (30 ± 2°C) for 30 min, then centrifuged for 30 min at 3,000 rpm. The clear supernatant was decanted. The oil absorption was calculated as per cent oil bound per gram flour.

2.3.6. Swelling power and solubility index

Swelling power and solubility index were determined using the method described by Takashi and Sieb, (23). It involved weighing 1 g of the sample into a 50-ml centrifuge tube. About 50 ml of distilled water was added and mixed gently. The slurry was heated in a water bath at 80°C for 15 min. During heating, the slurry was stirred gently to prevent clumping of the flour. On completion of 15 min, the tube containing the paste was centrifuged at 3,000 rpm for 10 min. The supernatant was decanted immediately after centrifuging. The weight of the sediment was taken and recorded. The moisture content of the sediments gel was, therefore, determined to get the dry matter content of the gel.

$$\text{Swelling power} = \frac{\text{Weight of wet mass sediment}}{\text{Weight of dry matter in the gel}}$$

$$\text{Solubility index } (\%) = \text{Weight of dry solid after drying} \times 100$$

2.4. Pasting analysis

This was determined using the Rapid Visco Analyzer (RVA) (New point Scientific). About 3.5 g of the experimental products were weighed into the text canister, then 25 ml of distilled water dispensed into the canister containing the sample. The solution was thoroughly mixed and the canister was fitted into the RVA. The slurry was heated at 50°C with 2-min holding time. The rate of heating and cooling at a constant rate of 11.2,550°C/min was recorded, where peak viscosity, trough, breakdown, final viscosity, set back, peak time and pasting temperature were read from the pasting profile with the aid of thermo cline for windows software connected to a computer (*38, 39*).

2.5. Determination of proximate composition
Proximate composition of protein, ash, moisture content, crude fat, crude fibre and carbohydrate were determined according to the official method of analysis described by the Association of Official and Analytical Chemist (*40*).

2.6. Mineral analyses
Five grams (5g) of each sample was heated gently over a Bunsen burner flame until most of the organic matter was destroyed. This was further heated strongly in a muffle furnace for several hours until white-grey ash was obtained. The ash material was cooled. About 20 ml of distilled water and 10 ml of dilute hydrochloric acid was added to the ash material. This mixture was boiled, filtered into a 250-ml volumetric flask, washed thoroughly with hot water, cooled and made up to volume. Mineral content of each sample was analysed using Atomic Absorption Spectrophotometer (PYE Unicon, UK, model SP9) (*41*). Some mineral elements determined include: potassium, magnesium, phosphorus, calcium and iron.

2.7. Vitamin analyses
Vitamin A (Retinol) and B1 (Thiamine) was determined using (*40*) method, while Vitamin E (Tocopherol) was determined using AOAC (*41*) method. Standards and samples are saponified in basic ethanol–water solution, neutralized and diluted. This process converts fats to fatty acids, and retinyl esters to retinol and the corresponding fatty acids. Extract clean-up is carried out with a C18 cartridge and vitamin A is concentrated eluting with a smaller volume of isopropanol than the aliquot taken to clean. Retinol is quantified in an LC system, using UV detection at 326 nm. Thiamin is extracted in an autoclave with diluted sulphuric acid. After enzyme hydrolysis, thiamin is oxidized with potassium ferricyanide in sodium hydroxide to form the thiochrome, which is fluorescent. The extract is injected into a HPLC onto a reverse phase column (C18) with fluorescence detection: excitation at 370 nm and emmision at 430 nm. Concentration is calculated by comparison of peak heights or peak areas of retinol in test samples with those of standards.

2.8. Ascorbic acid (Vitamin C)
Ascorbic acid was determined by dyestuff titration method, (*42*). Sample (5 g) was digested with 0.4/100 g oxalic acid. The aliquot was titrated against dyestuff, which was previously standardized by standard ascorbic acid solution, and the ascorbic acid content was calculated using the following expression.

$$\text{Vitamin C}\left(\text{mg}/100\,g\right)=\frac{\text{Titre value}\times 0.606\times 100}{\text{Weight of Sample}}$$

3. Statistical analysis
The mean ± standard deviation of the results from the experiment was calculated and analysed using single-factor ANOVA in the statistical package for social science software (SPSS version 17.0 for windows). The Duncan's multiple range test was used to separate the differences in the mean scores at significant level of $p = 0.05$.

4. Results and discussion
Table 2 showed the results of chemical composition of plantain–tiger nut flour. Significant ($p < 0.05$) differences existed in the percentage moisture, ash, protein, fat and total carbohydrate contents among the flour blends. As expected, the ash, protein, fat and crude fibre increased as the percentage of tiger nut flour increases, while moisture and carbohydrate increased with increase in plantain flour substitutions. The ash content for the flour ranged from 1.33 ± 0.00/100 g to 2.00 ± 0.00/100 g. Ash gives an indication of inorganic elements that are present in a food as minerals. Ash contents of

Table 2. Proximate composition of plantain–tiger nut composite flour (g/100 g)

Sample	Moisture	Crude protein	Crude fat	Ash	Crude Fibre	CHO
A	$10.00 \pm 0.00^{a*}$	4.45 ± 0.28^{d}	2.25 ± 0.02^{g}	1.33 ± 0.00^{d}	3.50 ± 0.71^{a}	78.48 ± 0.45^{a}
B	9.67 ± 0.00^{ab}	5.07 ± 0.14^{c}	7.88 ± 0.45^{f}	1.50 ± 0.24^{cd}	4.96 ± 1.00^{a}	70.93 ± 0.17^{b}
C	9.33 ± 0.00^{bc}	5.16 ± 0.13^{c}	14.03 ± 0.10^{e}	1.67 ± 0.00^{bc}	5.01 ± 0.93^{a}	64.80 ± 0.71^{c}
D	9.17 ± 0.23^{c}	5.32 ± 0.16^{c}	17.03 ± 0.12^{d}	1.67 ± 0.00^{bc}	$5.25 \pm 1.06^{a}6$	1.57 ± 0.55^{cd}
E	6.84 ± 0.23^{d}	5.41 ± 0.16^{c}	21.05 ± 1.21^{c}	1.67 ± 0.00^{bc}	5.89 ± 1.11^{a}	59.16 ± 2.40^{d}
F	6.67 ± 0.00^{d}	6.28 ± 0.18^{b}	26.38 ± 0.46^{b}	1.84 ± 0.23^{ab}	5.84 ± 1.18^{a}	53.01 ± 1.22^{e}
G	6.50 ± 0.24^{d}	6.73 ± 0.23^{a}	32.75 ± 1.06^{a}	2.00 ± 0.00^{a}	6.13 ± 1.24^{a}	46.07 ± 2.52^{f}

Notes: Sample: A: 100% plantain flour, B: 70% plantain flour and 30% Tiger nut flour, C: 60% plantain flour and 40% Tiger nut flour, D: 50% plantain flour and 50% Tiger nut flour, E: 40% plantain flour and 60% Tiger nut flour, F: 30% plantain flour and 70% Tiger nut flour, G:100% Tiger nut flour. CHO = Carbohydrate.

Results are expressed as mean ± standard deviation.

*Values followed by different letters in each column are significantly different at $p < 0.05$.

the flour blends were high, indicating that the flours were likely to be good sources of mineral elements. The ash content of 100% tiger nut flour obtained in this study was lower compared to the value of 3.97/100 g reported for tiger nut flour by Oladele and Aina (25). These differences can be attributed to the different locations where the sample was cultivated since it has been reported that gene and environment interactions affects nutritional composition of plant materials (43). The ash content of 100% plantain flour was comparable to the value of 0.98 ± 0.43/100 g reported for plantain flour by Adegunwa et al. (44).

The moisture content for the flour ranged between 6.50 ± 0.24 and 10.0 ± 0.00/100 g. Moisture provides a measure of the water content and an index of storage stability of the flour. High-moisture products (>12/100 g) usually have shorter shelf stability compared with lower moisture products (<12/100 g), as reported by Ashworth and Draper, (45). Therefore, the low moisture content of all the flour blends makes them less liable to microbial attack than the raw material (plantain and tiger nut) and would have longer shelf stability. The protein content for the flour ranged from 4.45 ± 0.28 to 6.73 ± 0.23/100 g. The protein content of 100% tiger nut flour (6.73 ± 0.23/100 g) was comparable to the value (7.15/100 g) reported by Oladele and Aina, (25). Similarly, the protein content of 100% plantain flour (4.45 ± 0.28/100 g) was comparable to the values (4.54 ± 0.02/100 g) obtained by Abioye et al. (46).

The fat content of the composite flour ranged from 2.25 ± 0.02 to 32.75 ± 1.06/100 g. It has been reported that the fat content of tiger nut varies between 22.8 and 32.8/100 g (47), which is in accordance with the value for fat of 100% tiger nut flour (32.75%) obtained in this study. The fat content of 100% plantain flour (2.25 ± 0.02/100 g) was comparable to the value of 2.27 ± 0.01/100 g reported by Adegunwa et al. (48). Increased substitution of tiger nut flour increased the fat content of the flour blends, which could be of nutritional concern, however, tiger nut fat has been reported to have health benefits (20, 49). Tiger nut oil has been reported to reduce low-density lipoprotein cholesterol (LDL-C) and increases high-density lipoprotein cholesterol (HDL-C), hence, reduces levels of triglycerides in the blood and then risk of forming bloody clots, thereby preventing arteriosclerosis (49). It also stimulates the absorption of calcium in bones and the production of new bony material due to presence of short and medium chain fatty acids, oleic acid and essential fatty acids. It has a high oleic acid and low polyunsaturated fatty acid (linoleic acid and linolenic acid) (50, 51). It also has higher oxidative stability than other oils, due to the presence of polyunsaturated fatty acids and gamma-tocopherol (51). The oil was found to contain 18% saturated (palmitic acid and stearic acid) and 82% unsaturated (oleic acid and linoleic acid) (52). Tiger nut oil has a monounsaturated profile (>60% monounsaturated fatty acids (MUFA)), with a similar fatty acid (FA) profile to olive oil (49). Tiger nut oil was considered a generally healthier alternative.

The crude fibre content of the composite flour ranged from 3.50 ± 0.71 to 6.13 ± 1.24/100 g. The crude fibre of 100% tiger nut flour was 6.13 ± 1.24/100 g comparable to the value (6.26/100 g) reported by Oladele and Aina (*25*). The value of crude fibre obtained in 100% plantain flour (3.50 ± 0.71/100 g) is comparable to the values (3.50/100 g) reported by Mepba et al. (*14*). Nutritional claims for dietary fibre foods (*53*) recommended that for a product to be labelled as "source of fibre" it must contain >3 g dietary fibre/100 g food. Since the plantain–tiger nut composite flours obtained in this study all contain more than 3 g dietary fibre/100 g, it implies that the flour blends can be regarded as "source of dietary fibre".

The carbohydrate content of the flour samples ranged from 46.07 ± 2.52 to 78.48 ± 0.45/100 g; 100% plantain flour had the highest value, while 100% tiger nut flour (46.07 ± 2.52/100 g) had the lowest mean value. The results showed that the carbohydrate content decreased with increasing level of tiger nut flour substitution. The result (46.07 ± 2.52/100 g) of carbohydrate for 100% tiger nut flour obtained in this study was comparable to the result (46.99/100 g) reported by Oladele and Aina (*25*).

Functional characteristics are required to evaluate and possibly help to predict how new proteins, fat, fibre and carbohydrates may behave in specific systems as well as demonstrate if such protein can be used to stimulate or replace conventional protein (*54, 55*). The results for functional properties of plantain–tiger nut flour are shown in Table 3. Apart from bulk density, there were significant differences *($p > 0.05$)* in other functional properties of all the flour samples. Bulk density values ranged from 0.81 ± 0.06 to 0.92 ± 0.02 g/cm^3. The100% tiger nut flour had the highest bulk density, while 100% plantain flour had the lowest bulk density. However, there was no significant difference in bulk density of all the samples. The bulk density is affected by the particle size and the density of the flour which is very important in determining the packaging requirements, material handling and the application in wet processing in food industry (*56*). Generally, higher bulk density is desirable for it great ease of dispersibility and reduction of paste thickness which is an important factor in convalescent child feeding (*57*). On contrast, low bulk density would be an advantage in the formulation of complementary foods (*58*).

The water absorption capacity (WAC) ranged from 131.75 ± 8.84 to 78.75 ± 8.13/100 g The WAC was observed the highest in 100% plantain flour and the lowest in tiger nut flour. Water absorption capacity or characteristics represent the ability of a product to associate with water under conditions where water is limited. The highest WAC of plantain flour could be attributed to the presence of higher amount of carbohydrates (starch) and fibre in this flour, this could be because starch and

Table 3. Functional properties of Plantain–Tiger nut CompositeFlour (g/100 g)

Sample	A	B	C	D	E	F	G
BD (g/cm^3)	0.81 ± 0.06^{a,*}	0.82 ± 0.06^a	0.84 ± 0.06	0.86 ± 0.05^a	0.89 ± 0.02^a	0.90 ± 0.01^a	0.92 ± 0.02^a
WAC	131.75 ± 8.84^a	103.90 ± 5.80^b	97.85 ± 1.20^b	95.40 ± 1.99^{bc}	93.93 ± 1.31^{bc}	84.82 ± 2.57^{cd}	78.75 ± 8.13^d
OAC	129.73 ± 0.39^a	102.88 ± 4.07^b	95.40 ± 4.81^c	90.73 ± 2.44^c	82.50 ± 0.71^d	78.00 ± .0.00^d	71.62 ± 0.88^e
EA	3.25 ± 0.35^g	3.39 ± 0.47^f	4.60 ± 0.14^e	6.11 ± 0.15^d	8.05 ± 0.07^c	11.35 ± 0.01^b	13.22 ± 0.04^a
ES	2.18 ± 0.32^c	2.21 ± 0.30^c	2.33 ± 0.46^c	2.55 ± 0.21^c	3.26 ± 0.37^b	5.18 ± 0.03^a	5.76 ± 0.06^a
SP (g/g)	38.38 ± 0.27^a	29.37 ± 0.14^b	24.82 ± 0.03^c	18.26 ± 0.06^d	12.41 ± 0.01^e	9.53 ± 0.06^f	2.37 ± 0.14^g
SI	6.72 ± 0.40^g	8.06 ± 0.15^f	9.71 ± 0.08^e	11.38 ± 0.18^d	13.29 ± 0.01^c	14.13 ± 0.04^b	14.99 ± 0.01^a
FC	3.25 ± 1.06^d	4.48 ± 0.32^d	4.65 ± 0.50^d	6.26 ± 0.59^c	7.94 ± 0.90^b	8.54 ± 0.40^b	10.30 ± 0.13^a
FS	6.48 ± 0.74^f	16.64 ± 2.18^e	22.18 ± 2.31^{de}	27.94 ± 4.01^{cd}	32.67.95 ± 5.90^{bc}	38.96 ± 6.06^b	51.80 ± 1.62^a

Notes: Sample: A: 100% plantain flour, B: 70% plantain flour and 30% Tiger nut flour, C: 60% plantain flour and 40% Tiger nut flour, D: 50% plantain flour and 50% Tiger nut flour, E: 40% plantain flour and 60% Tiger nut flour, F: 30% plantain flour and 70% Tiger nut flour, G:100% Tiger nut flour. BD—Bulk Density, WAC—Water Absorption Capacity, OAC—Oil Absorption Capacity, EA—Emulsion activity, ES—Emulsion Stabibity, SP—Swelling Power, SI—Solubility Index, FC—Foaming Capacity and FS—Foaming Stability.

Results are expressed as mean ± standard deviation.

*Values followed by different letters in each column are significantly different at $p < 0.05$.

fibre having good ability to associate with water under limited water condition (high hydration properties). Water absorption capacity is a critical function of protein in various food products like soups, dough and baked products (*59*). The highest value of oil absorption capacity (OAC) was observed for plantain flour (129.73 ± 0.39/100 g) and lowest for tiger nut flour (71.62 ± 0.88/100 g). The water and oil binding capacity of food protein depend upon the intrinsic factors like amino acid composition, protein conformation and surface polarity or hydrophobicity. Plantain flour having highest OAC could be better to tiger nut flour as flavour retainer. The ability of the proteins of these flours to bind with oil makes it useful in food system where optimum oil absorption is desired. The OAC also makes the flour suitable in facilitating enhancement in flavour and mouth feel when used in food preparation. Due to these properties, the protein probably could be used as functional ingredient in foods such as whipped toppings, sausages, chiffon dessert, angel and sponge cakes. These results agreed with the findings of Bamigbola et al. (*33*) who reported that substitution of wheat flour with plantain and tiger nut flours reduces the swelling capacity and foaming capacity but substitution of wheat flour with plantain and tiger nut however increases the water absorption capacity.

The values for emulsifying activities (EA) ranged from 3.25 ± 0.35 to 13.22 ± 0.04/100 g. The flour samples showed increase in emulsifying activity as the substitution of tiger nut increases. Difference in the EA of protein may be related to their solubility. Hydrophobicity of protein has been attributed to influence their emulsifying properties (*60*). These properties are influenced by many factors among which are solubility, pH and concentration. The capacity of protein to enhance the formation and stabilization of emulsions is important for many applications in food products like cake, coffee whiteners and frozen desserts. In these products, varying emulsifying and stabilizing capacity are required because of their various compositions and processes (*61*). Highest ES was also observed for tiger nut flour (5.76 ± 0.06/100 g), and lowest for plantain flour (2.18 ± 0.32/100 g). Increasing emulsion activity (EA), emulsion stability (ES) and fat binding during processing are primary functional properties of protein in such foods as comminuted meat products, salad dressing, frozen desserts and mayonnaise.

The results of the Swelling Power as shown above revealed that, 100% plantain flour had the highest mean value of 38.38 ± 0.27/100 g, while 100% tiger nut flour had the lowest mean value of 2.37 ± 0.14/100 g. The solubility index mean value of the flour samples ranged from 14.99 ± 0.01/100 g for 100% tiger nut flour to 6.72 ± 0.40/100 g for plantain flour.

The highest foam capacity was observed for 100% tiger nut flour (10.30 ± 0.13/100 g) and lowest for 100% plantain flour (3.25 ± 1.06/100 g). The highest foam stability was also observed for tiger nut flour (51.80 ± 1.62/100 g) and lowest for plantain flour (6.48 ± 0.74/100 g). This shows that increase in tiger nut substitution increased the values of both foaming capacity and stability. Tiger nut flour obtained the highest foam capacity due to higher protein content. Protein in the dispersion may cause a lowering of the surface tension at the water air interface, thus always been due to protein which forms a continuous cohesive film around the air bubbles in the foam (*60*).

The pasting properties of starch are used in assessing the suitability of its application as functional ingredient in food and other industrial products (*62*). The results of the pasting properties of plantain–tiger nut composite flour are shown in Table 4. There were significant differences ($p < 0.05$) in the pasting profile of the flour samples. Peak viscosity is the ability of the starch to swell freely before its physical breakdown (*63*) and it ranged from 12.30 ± 0.18 to 509.09 ± 1.53 RVU. The results of pasting properties of the samples indicated that the substitution of tiger nut flour reduced the peak viscosity. Peak viscosity is often correlated with the final product quality. It also provides an

Table 4. Pasting properties of plantain–tiger nut composite flour

Sample/ parameters	Peak 1 (RVU)	Trough 1 (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback (RVU)	Peak time min	Pasting temp°C
A	509.09 ± 1.53[a*]	312.50 ± 2.48[a]	196.59 ± 0.94[a]	462.33 ± 4.24[a]	149.83 ± 1.77[a]	4.83 ± 0.05[g]	82.38 ± 0.04[c]
B	210.50 ± 0.59[b]	164.71 ± 0.18[b]	45.80 ± 0.77[b]	260.50 ± 1.06[b]	95.80 ± 1.24[b]	5.23 ± 0.05[f]	82.33 ± 0.04[c]
C	154.79 ± 5.71[c]	131.92 ± 2.00[c]	22.88 ± 3.71[c]	195.80 ± 7.96[c]	63.88 ± 5.95[c]	5.57 ± 0.14[e]	83.15 ± 0.00[b]
D	115.46 ± 1.82[d]	105.75 ± 1.30[d]	9.71 ± 0.52[d]	150.38 ± 2.30[d]	44.63 ± 1.00[d]	6.00 ± 0.09[d]	83.20 ± 0.00[b]
E	75.29 ± 1.00[e]	72.46 ± 0.65[e]	2.83 ± 0.35[e]	105.08 ± 0.71[e]	32.63 ± 0.06[e]	6.50 ± 0.05[c]	83.18 ± 0.04[b]
F	48.63 ± 0.18[f]	46.13 ± 0.06[f]	2.50 ± 0.24[e]	79.88 ± 1.83[f]	33.75 ± 1.77[e]	7.00 ± 0.00[b]	83.28 ± 0.04[a]
G	12.30 ± 0.18[g]	11.67 ± 0.12[g]	0.63 ± 0.06[e]	28.88 ± 0.29[g]	17.21 ± 0.41[f]	7.23 ± 0.05[a]	83.33 ± 0.04[a]

Notes: Sample: A: 100% plantain flour, B: 70% plantain flour and 30% Tiger nut flour, C: 60% plantain flour and 40% Tiger nut flour, D: 50% plantain flour and 50% Tiger nut flour, E: 40% plantain flour and 60% Tiger nut flour, F: 30% plantain flour and 70% Tiger nut flour, G:100% Tiger nut flour. RVU = Rapid Viscosity Unit.

Results are expressed as mean ± standard deviation.

*Values followed by different letters in each column are significantly different at $p < 0.05$.

indication of the viscous load likely to be encountered during mixing (*64*). Higher swelling index is indicative of higher peak viscosity, while higher solubility as a result of starch degradation or dextrinization results in reduced paste viscosity (*65*).

Trough is the minimum viscosity after the initial peak and occurs after the commencement of the sample cooling. The trough which ranged from 11.67 ± 0.12 to 312.50 ± 2.48 RVU is the viscosity value that measures the ability of the paste to withstand breakdown during cooling. Plantain flour had the highest trough value of 312.50 ± 2.48 RVU. The results indicate that the substitution of tiger nut flour reduced the trough viscosity. The breakdown is regarded as a measure of the degree of disintegration of granules or paste stability (*66*). Breakdown is the peak viscosity minus trough viscosity. The breakdown viscosities of the flour samples range between 0.63 ± 0.06 to 196.59 ± 0.94 RVU and the plantain flour had the highest breakdown viscosity value of 196.59 ± 0.94 RVU. Large values indicate little breakdown of sample starches.

Final viscosity is the viscosity at the end of the test. The final viscosity values range from 28.88 ± 0.29 to 462.33 ± 4.24 RVU. It indicates the ability of the flour to form a gel or viscous paste after cooking and cooling as well as the resistance of the viscous paste to shear stress during stirring (*61*). The final viscosity of the flour samples increased with an increase in plantain substitution. The viscosity after cooling to 50°C represents the setback or viscosity of cooked paste. It is a stage where retrogradation or reordering of starch molecules occurs. It is a tendency to become firmer with increasing resistance to enzymic attack. It also has effect on digestibility. Higher setback values are synonymous to reduced dough digestibility (*39, 65*). The setback value of the flour samples ranged from 17.21 ± 0.41 to 149.83 ± 1.77 RVU. The setback values decreased with increase in tiger nut substitution levels, indicating the higher the substitution level, the more the retrogradation during cooling and the higher the staling of the products made from the flour.

The peak time (min) is a measure of the cooking time (*61*). It is the time at which the peak viscosity occurred and it ranged from 4.83 ± 0.05 to 7.23 ± 0.05. 100% Plantain flour had the highest mean value of 7.23 ± 0.05 min, while 100% tiger nut flour had the lowest mean value of 4.83 ± 0.05 min. The pasting temperature is an indication of the gelatinization time during processing. It is the temperature at which the first detectable increase in viscosity is noted and is an index associated with

Table 5. Mineral composition of plantain–tiger nut composite flour

Sample/ Component	Magnesium (mg/100 g)	Phosphorus (mg/100 g)	Potassium (mg/100 g)	Iron (mg/100 g)	Calcium (mg/100 g)
A	30.65 ± 1.49^{d*}	32.65 ± 0.50^{g}	71.62 ± 1.97^{g}	0.25 ± 0.01^{f}	6.92 ± 0.04^{a}
B	32.75 ± 0.50^{d}	55.55 ± 0.64^{f}	103.53 ± 1.59^{f}	0.30 ± 0.01^{e}	5.63 ± 0.01^{b}
C	35.70 ± 0.28^{c}	64.32±1.53^{e}	130.05 ± 0.11^{e}	0.41 ± 0.00^{d}	4.87 ± 0.04^{c}
D	35.90 ± 0.14^{c}	74.16 ± 1.35^{d}	144.91 ± 0.49^{d}	0.48 ± 0.01^{c}	3.98 ± 0.01^{d}
E	37.63 ± 1.17^{c}	89.63 ± 0.53^{c}	156.51 ± 0.72^{c}	0.53 ± 0.01^{b}	3.43 ± 0.04^{e}
F	45.70 ± 0.14^{b}	102.40 ± 2.40^{b}	186.14 ± 0.87^{b}	0.65 ± 0.01^{a}	2.94 ± 0.01^{f}
G	49.98 ± 2.09^{a}	120.65 ± 1.49^{a}	212.08 ± 2.94^{a}	0.67 ± 0.04^{a}	2.27 ± 0.10^{g}

Notes: Sample: A: 100% plantain flour, B: 70% plantain flour and 30% Tiger nut flour, C: 60% plantain flour and 40% Tiger nut flour, D: 50% plantain flour and 50% Tiger nut flour, E: 40% plantain flour and 60% Tiger nut flour, F: 30% plantain flour and 70% Tiger nut flour, G:100% Tiger nut flour. Results are expressed as mean ± standard deviation.
*Values followed by different letters in each column are significantly different at $p < 0.05$.

the initial change due to the swelling of the starch (*39, 44*). It can have implications for the stability of other components in a formula and indicate energy costs (*66*). The pasting temperature of the flour samples ranges between 82.38 ± 0.04 to 83.33 ± 0.04°C and the plantain flour sample had the lowest pasting temperature of 82.38 ± 0.04°C, while the tiger nut flour had the highest pasting temperature of 83.33 ± 0.04°C. The results of the peak time and pasting temperature obtained in this study agreed with Awolu (*67*), who reported the peak time (5.47 min) and pasting temperature (89.60°C) for composite flour comprising pearl millet, kidney beans and tiger nut with xanthan gum.

The mineral composition of the plantain–tiger nut composite flour is shown on Table 5. The results showed that there is significant difference ($p < 0.05$) in the mineral composition of the composite flour samples. The magnesium content of the flour samples ranges between 30.65 ± 1.49 and 49.98 ± 2.09. There is increase in magnesium content of the flour as the level of tiger nut flour substitution increases. The phosphorus content of the flour samples ranged between 32.65 ± 0.50 and 120.65 ± 1.49 mg/100 g. The100% tiger nut flour has the highest phosphorus content, while 100% plantain flour has the lowest mean value. The result of magnesium and phosphorus obtained for 100% tiger nut flour in this study was comparable to the value (51.2 and 121 mg/100 g), respectively, reported by Oladele and Aina (*25*). The result of phosphorus for 100% plantain flour obtained in this study was comparable to result (33.43 mg/100 g) reported by Adeoye et al. (*46*).

The potassium content of the flour samples ranges between 71.62 ± 1.97 and 212.08 ± 2.94 mg/100 g. The 100% tiger nut flour has the highest mean value of potassium content, while plantain flour has the lowest mean value. The result of potassium content obtained for 100% tiger nut flour was comparable to the value (216 mg/100 g) reported by Oladele and Aina (*25*). The iron content of the flour samples ranges between 0.25 ± 0.01 and 0.67 ± 0.04 mg/100 g. The iron content of the flour increases as the level of tiger nut flour substitution increases. The result of the iron content for 100% plantain flour obtained in this study was comparable to the value (0.24 mg/100 g) reported by Adeoye et al. (*46*).

The calcium content of the flour samples ranges between 2.27 ± 0.10 and 6.92 ± 0.04 mg/100 g. 100% plantain flour has the highest mean value for calcium, while 100% tiger nut flour has the lowest value. The result of calcium content obtained for 100% tiger nut flour in this study is low

Table 6. Vitamin composition of plantain–tiger nut composite flour

Sample/	Vitamin C (mg/100 g)	Vitamin B1 (mg/100 g)	Vitamin A (μg/100 g)	Vitamin E Component (mg/100 g)
A	3.18 ± 0.21[e*]	0.034 ± 0.00[a]	14.71 ± 0.95[c]	0.10 ± 0.01[g]
B	3.49 ± 0.22[de]	0.031 ± 0.00[b]	17.23 ± 2.62[c]	0.24 ± 0.01[f]
C	3.79 ± 0.21[cd]	0.027 ± 0.00[c]	32.77 ± 1.90[b]	1.41±0.02[e]
D	4.24 ± 0.00[bc]	0.026 ± 0.00[c]	34.26 ± 6.29[b]	2.02 ± 0.03[d]
E	4.40 ± 0.22[b]	0.024 ± 0.00[d]	35.37 ± 1.82[b]	2.58 ± 0.01[c]
F	4.70 ± 0.21[b]	0.022 ± 0.00[e]	37.75 ± 0.93[b]	3.75±0.01[b]
G	5.30 ± 0.21[a]	0.018 ± 0.00[f]	51.31 ± 1.91[a]	3.95 ± 0.50[a]

Notes: Sample: A: 100% plantain flour, B: 70% plantain flour and 30% Tiger nut flour, C: 60% plantain flour and 40% Tiger nut flour, D: 50% plantain flour and 50% Tiger nut flour, E: 40% plantain flour and 60% Tiger nut flour, F: 30% plantain flour and 70% Tiger nut flour, G:100% Tiger nut flour.

Results are expressed as mean ± standard deviation.

*Values followed by different letters in each column are significantly different at $p < 0.05$.

compared to the value (155 mg/100 g) reported by Oladele and Aina (*25*). However, the result of calcium obtained for 100% plantain flour in this study is comparable to the value (6.55 mg/100 g) reported by Abioye et al. (*46*). Generally, the results obtained in this study have shown tiger nut flour to be richer in mineral elements than plantain flour.

The results of the vitamin composition of the flour samples are shown on Table 6. The results showed that there is a significant difference ($p < 0.05$) in the vitamin composition of the composite flour samples. The vitamin C content of the flour samples ranges between 3.18 ± 0.21 and 5.30 ± 0.21 mg/100 g. Increase in the level of tiger nut flour substitution increases the vitamin C content of the flour samples and chinchin. The result of the vitamin C content obtained in this study is comparable to the value (3.0 ± 0.98 mg/100 g) reported by Oladeji et al. (*42*). The mean value of vitamin B1 content of the flour samples ranges between 0.018 ± 0.00 and 0.034 ± 0.00 mg/100 g. The 100% plantain flour has the highest value in vitamin B1, while 100% tiger nut flour has the lowest value.

The vitamin A content of the flour samples ranges between 14.71 ± 0.95 and 51.31 ± 1.91 μg/100 g. There is an increase in the vitamin A content of the flour samples as the level of tiger nut flour substitution increases. This shows that tiger nut is richer in vitamin A than plantain. The results of the vitamin E content ranged between 0.10 ± 0.01 and 3.95 ± 0.50 mg/100 g for the composite flour. There is an increase in vitamin E content of the flour samples as the level of tiger nut flour substitution increases.

5. Conclusion

In conclusion, increased substitution of plantain flour with tiger nut flour considerably enhanced the protein, fat, ash and the dietary fibre contents of the composite flour, which could be nutritionally advantageous to Nigerians, especially the low-income earners who can hardly afford high proteinous food because of the costs. The inclusion of tiger nut flour is a good protein, minerals and vitamins supplement for plantain flour and a naturally gluten-free alternative to wheat flour. This composite flour could therefore have good potentials in food formulation. Further research should be carried out on the application of the composite flours in deep fat frying products which do not require the leavening action of gluten.

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References

(1) Ciclitira, P.J.; Ellis, H.J. Investigation of Cereal Toxicity in Coeloac Disease. *Postgrad. Med.* 1987, *63*, 767–775.

(2) Davidson, A.G.F.; Bridges, M. Coeliac Disease: A Critical Review of Aetiology and Pathogenesis. *Clin. Chim. Acta* 1987, *163*, 1–40. https://doi.org/10.1016/0009-8981(87)90031-3

(3) Shahzadi, N.; Butt, M.S.; Rehman, S.U.; Sharif, K. Chemical Characteristics of Various Composite Flours. *Inter. J. Agric. Biol.* 2005, *7*, 105–108.

(4) Olaoye, O.A.; Onilude, A.A.; Idowu, O.A. Quality Characteristics of Bread Produced from Composite Flours of Wheat, Plantain and Soybeans. *Afr. J. Biotechnol.* 2006, *5*, 1102–1106.

(5) Oladunmoye, O.O.; Akinoso, R.; Olapade, A.A. Evaluation of some Physical-Chemical Properties of Wheat, Cassava, Maize and Cowpea Flours for Bread Making. *J. Food Qual.* 2010, *33*, 693–708. doi:10.1111/j.1746-4557.2010.00351.x

(6) Alvarenga, N.B.; Lidon, F.C.; Belga, E.; Motrena, P.; Guerreiro, S.; Carvalho, M.J.; Canada, J. Characterization of Gluten-Free Bread Prepared from Maize, Rice and Tapioca Flours Using Hydrocolloid Seaweed Agar-Agar. *Recent Res. Sci. Technol.* 2011, *3*, 64–68.

(7) Idolo, I. Sensory and Nutritional Quality of Madiga Produced from Composite Flour of Wheat and Sweet Potato. *Pak. J. Nutr.* 2011, *10*, 1004–1007.

(8) Oluwamukomi, M.O.; Oluwana, I.B.; Akinbowale, O.F. Physicochemical and Sensory Properties of Wheat-Cassava Composite Biscuit Enriched with Soy Flour. *Afr. J. Food Sci.* 2011, *5*, 50–56.

(9) FAO. *Food and Agriculture Organisation of the United Nations. The State of Food Insecurity in the World. Eradicating World Hunger—Taking Stock Ten Years after the World Food Summit*, 2006.

(10) FAO. *Food and Agriculture Organisation of the United Nations*. Joint Meeting of the Fourth Session of the Sub-group on Bananas and the Fifth Session of the Sub-Group on Tropical Fruits held in Rome, 9–11th December 2009, 2009.

(11) Akubor, P.I.; Adamolekun, F.O.; Oba, C.O.; Obari, H.; Abudu, I.O. Chemical Composition and Functional Properties of Cowpea and Plantain Flour Blends for Cookie Production. *Plant Foods Hum. Nutr.* 2003, *58* (3), 1–9.

(12) Swennen, R. *Plantain Cultivation under West African Condition. A Reference Manual*; Institute of Tropical Agriculture (IITA), Ibadan, 1990; pp 1–24.

(13) IITA. *Plantain/Banana*; Youth Agripreneurs, International Institute of Tropical Agriculture: Ibadan, 2014.

(14) Mepba, D.H.; Eboh, L.; Nwaojigwa, S.U. Chemical Composition, Functional and Baking Properties of Wheat-Plantain Composite Flours. *Afr. J. Food Agric. Nutr. Develop.* 2007, *7* (1), 1–22.

(15) Simmond, N.W. *Food Uses of Banana*; Macmillan Publishers, Ibadan, 1976.

(16) Akubor, P.I. *Functional Properties of Cowpea-Plantain Flour Blends*. Proceedings: 22nd Annual NIFST Conference, University of Agriculture, Abeokuta, 1998.

(17) Abiodun-Solanke, A.O.; Falade, K.O. A Review of the Uses and Methods of Processing Banana and Plantain (*Musa Spp.*) into Storable Food Products. *J. Agric. Res. Develop*. 2010, *9*, 85–96.

(18) Ogazi, P.O.; Oyewusi, F.A.; Ozumba, A.U., Ogundipe, H.O., Osifo, B.O.A.; Lukambi, F.A.. *Development and Sensory Evaluation of Soyamusa: A Soybean-Plantain Baby Food*. International Conference on Banana and Plantain for Africa, ISHS Acta Hortic., 1996; p. 540.

(19) Belewu, M.A.; Belewu, K.Y. Comparative Physio-Chemical Evaluation of Tigernut, Soybean and Coconut Milk Sources. *Inter. J. Agric. Biol.* 2007, *9*, 785–787.

(20) Adejuyitan, J.A. Tigernut Processing: Its Food Uses and Health Benefits. *Am. J. Food Technol.* 2011, *6*, 197–201.

(21) Temple, V.J.; Ojobe, T.O.; Kapu, M.M. Chemical Analysis of Tiger Nut (*Cyperus esculentus*). *J. Sci. Agric.* 1990, *50*, 261–263.

(22) de Vries, Femke T.; Chufa, F.T. (*Cyperus esculentus*, *Cyperaceae*): A Weedy Cultivar or a Cultivated Weed? *Econ. Bot.* 1991, *45*, 27–37. https://doi.org/10.1007/BF02860047

(23) Oderinde, R.A.; Tairu, O.A. Evaluation of the Properties of Yellow Nutsedge (*Cyperus esculentus*) Tuber Oil. *J. Agric. Food Chem.* 1988, *28*, 233–237. https://doi.org/10.1016/0308-8146(88)90055-6

(24) Facciola, S. Cornucopia In: *A Source Book of Edible Plants*, 2nd ed.; Kampong Publications: Vista, CA, 1990. ISBN-10: 0962808725 1990.

(25) Oladele, A.K.; Aina, J.O. Chemical Composition and Functional Properties of Flour Produced from Two Varieties of Tigernut (*Cyperus esculentus*). *Afr. J. Biotechnol.* 2007, *6*, 2473–2476. https://doi.org/10.5897/AJB

(26) Rita, E.S. The Use of Tiger-Nut (*Cyperus esculentus*), Cow Milk and Their Composite as Substrates for Yoghurt Production. *Pak. J. Nutr.* 2009, *6*, 755–758.

(27) FAO, WHO. *Expert Consultation. Energy and Protein Requirements*; World Health Organization, Geneva, 1985.

(28) Bosch, L.; Alegría, A.; Farré, R. RP-HPLC Determination of Tigernut and Orgeat Amino Acid Contents. *Food Sci. Technol. Inter.* 2005, *11*, 33–40. https://doi.org/10.1177/1082013205051266

(29) Sowonola, O.A.; Akintunde, T.Y.; Adedeji, F. Nutritional and Sensory Qualities of Soymilk- Kunnu Blends. *Afr. J. Food Nutr. Sci.* 2005, *5*, 1–12.

(30) Anderson, J.W.; Smith, B.M.; Gustafson, N.J. Health Benefits and Practical Aspects of High Fibre Diets. *American J. Clin. Nutr.* 1994, *59*, 1242S–1247S.

(31) Chevallier, A. *The Encyclopedia of Medicinal Plants*; Dorling Kindersley Publishers, London, 1996.

(32) Belewu, M.A.; Abodunrin, O.A. Preparation of Kunnu from Unexploited Rich Food Source: Tiger Nut (*Cyperus esculentus*). *World J. Dairy Food Sci.* 2006, *1*, 19–21.

(33) Bamigbola, Y.A.; Awolu, O.O.; Oluwalana, I.B. The Effect of Plantain and Tigernut Flours Substitution on the Antioxidant, Physicochemical and Pasting Properties of Wheat-Based Composite Flours. *Cogent Food Agric.* 2016, *2* (1), 1245060. doi:10.1080/23311932.2016.1245060

(34) Yasumatsu, K.; Sawada, K.; Maritaka, S.; Toda, J.; Wada, T.; Ishi, K. Whipping and Emulsifying Properties of Soy Bean Products. *Agric. Biol. Chem.* 1992, *36*, 719–727.

(35) Narayana, K.; Narasinga Rao, M.S. Functional Properties of Raw and Heat Processed Winged Bean (*Psophocarpus tetragonolobus*) Flour. *J. Food Sci.* 1982, *47*, 1534–1538. https://doi.org/10.1111/jfds.1982.47.issue-5

(36) Okaka, J.C.; Potter, N.N. Physiochemical and Functional Properties of Cowpea Flours. *J. Food Sci.* 1979, *44*, 1237–1242.

(37) Sosulski, F.W. The Centrifuge Methods for Determining Flour Absorption in Hard Red Spring Wheat. *Cereal Chem.* 1962, *39*, 344–349.

(38) Walker, C.E.; Ross, A.S.; Wrigley, C.W.; McMaster, G.J. Accelerated Starch Paste Characterization with the Rapid Visco Analyzer. *Cereals Food World* 1998, *33*, 491–494.

(39) Alamu, E.O.; Maziya-Dixon, B.; Dixon, A.G. Evaluation of Proximate Composition and Pasting Properties of High Quality Cassava flour (HQCF) from Cassava Genotypes (Manihot Esculenta Crantz) of β-Carotene-Enriched Roots. *LWT—Food Sci.Technol.* 2017, *86* (2017), 501–506. doi:10.1016/j.lwt.2017.08.040.

(40) A.O.A.C. *Official Methods of Analysis of the Association of Analytical Chemists International*, 18th ed.; (Official methods). AOAC International: Gathersburg, MD, 2005.

(41) A.O.A.C. *Official Methods of Analysis*16th ed.; Association of Official Analytical Chemists: Arlington, VA, 1995.

(42) Oladeji, Oladeji; Akanbi, C.T.; Gbadamosi, S.O. Comparative Studies of Physico-Chemical Properties of Yam (*Discorea Rotundata)*, Cocoyam (*Collocasia Taro*), Breadfruit (*Artocapus Artilis*) and Plantain (*Musa Parasidiaca*) Instant Flours. *Afr. J. Food Sci.* 2013, *7*, 210–215. https://doi.org/10.5897/AJFS

(43) Sanni, L.O.; Adebowale, A.A.; Maziya-Dixon, B.; Dixon, A.G.O. Chemical Composition and Pasting Properties of CMD Resistant Cassava Clones Planted at Different Locations. *J. Food Agric. Environ.* 2008, *6*, 97–104.

(44) Adegunwa, M.O.; Adebowale, A.A.; Bakare, H.A.; Ovie, S.G. Compositional Characteristics and Functional Properties of Instant Plantain-Breadfruit Flour. *Inter. J. Food Res. (IJFR)* 2014, *1*, 1–7.

(45) Ashworth, A.; Draper, A. *The Potential of Traditional Technologies for Increasing the Energy Density of Weaning Foods. a Critical Review of Existing Knowledge with Particular Reference to Malting and Fermentation*. WHO/CBDEDP/92.4. Geneva: WHO, 1992.

(46) Abioye, V.F.; Ade-Omowaye, B.I.O.; Babarinde, G.O.; Adesigbin, M.K. Chemical, Physico-Chemical and Sensory Properties of Soy-Plantain Flour. *Afr. J. Food Sci.* 2011, *5*, 176–180.

(47) Coşkuner, Y.; Ercan, R.; Karababa, E.; Nazlıcan, A.N. Physical and Chemical Properties of Chufa (*Cyperus esculentus L.*) Tubers Grown in the Cuijkurova Region of Turkey. *J. Sci. Food Agric.* 2002, *82*, 625–631. https://doi.org/10.1002/jsfa.1091

(48) Adegunwa, M.O.; Alamu, E.O.; Fasanya, O.O. Effects of Processing on the Physicochemical Properties and Carotenoid Contents of Plantain Flour. *J. Food Process. Preserv.* 2012, *36*(4), 339–347.

(49) Sánchez-Zapata, E.; Fernández-López, J.; Angel Pérez-Alvarez, J. Tiger Nut (*Cyperus esculentus*) Commercialization: Health Aspects, Composition, Properties, and Food Applications. *Comp. Rev. Food Sci. Food Saf.* 2012, *11*, 366–377. https://doi.org/10.1111/j.1541-4337.2012.00190.x

(50) Okladnikov, I.; Vorkel, L.; Trubachev, I.; Vlasova, N.; Kalacheva, G. Inclusion of Chufa in the Human Diet as a Source of Polyunsaturated Fatty Acids. *Vopr. Pitan.* 1977, *3*, 45–48.

(51) Ezebor, F.; Igwe, C.C.; Owolabi, F.A.T.; Okoh, S.O. Comparison of the Physico-Chemical Characteristics, Oxidative and Hydrolytic Stabilities of Oil and Fat of *Cyperus Esculentus L.* and *Butyrospermum Parkii* (Shea Nut) from Middle-Belt States of Nigeria. *Niger. Food J.* 2005, *23*, 33–39.

(52) Zhang, H.Y.; Hanna, M.A.; Ali, Yusuf; Nan, L. Yellow Nut-Sedge (*Cyperus Esculentus* L) Tuber Oil as a Fuel. *Ind. Crops Prod.* 1996, *5*, 177–181. https://doi.org/10.1016/0926-6690(96)89446-5

(53) Official Journal of European Commission. COMMISSION REGULATION (EU) No 1047/2012 of 8 November 2012; Amending Regulation (EC) No 1924/2006 with Regard to the List of Nutrition Claims, 2012.

(54) Kaur, M.; Singh, N. Relationships between Selected Properties of Seeds, Flours, and Starches from Different Chickpea Cultivars. *Inter. J. Food Prop.* 2006, *9*, 597–608. https://doi.org/10.1080/10942910600853774

(55) Siddiq, M.; Nasir, M.; Ravi, R.; Dolan, K.D.; Butt, M.S. Effect of Defatted Maize Germ Addition on the Functional and Textural Properties of Wheat Flour. *Inter. J. Food Prop.* 2009, *12*, 860–870. https://doi.org/10.1080/10942910802103028

(56) Adebowale, A.A.; Sanni, S.A.; Oladapo, F.O. Chemical, Functional and Sensory Properties of Instant Yam Breadfruit Flour. *Niger. Food J.* 2008, *26*, 2–12.

(57) Padmashrre, T.S.; Vijayalashmi, L.; Puttaraj, S. Effect of Traditional Processing on the Functional Properties of Cowpea (*Vigna Catjang*) Flour. *J. Food Sci. Technology* 1987, *24*, 221–225.

(58) Akpata, M.I.; Akubor, P.I. Chemical Composition and Selected Functional Properties of Sweet Orange (Citrus Sinensis) Seed Flour. *Plant Food Hum. Nutr.* 1999, *54*, 353–362. https://doi.org/10.1023/A:1008153228280

(59) Adeyeye, E.I.; Aye, P.A. The Effect of Sample Preparation on Proximate Composition and the Functional Properties of African Yam Bean Flours. Note 1. *Riv Ital Sostanze Gr.* 1998, *LXXV-Maggio*, 253–261.

(60) Kaushal, P.; Kumar, V.; Sharma, H.K. Comparative Study of Physico-Chemical, Functional, Anti-Nutritional and Pasting Properties of Taro (*Colocasia esculenta*), Rice (*Oryza sativa*), Pegion Pea (*Cajanus cajan*) Flour and Their Blends. *LWT-Food Sci. Technol.* 2012, *48*, 59–68. https://doi.org/10.1016/j.lwt.2012.02.028

(61) Adebowale, Y.A.; Adeyemi, I.A.; Oshodi, A.A. Functional and Physicochemical Properties of Flour of Six Mucuna Species. *Afr. J. Biotechnol.* 2005, *4*, 1461–1468.

(62) Iwe, M.O. *Handbook of Sensory Methods and Analysis*. Rojoint Communications Services Ltd, Uwani—Enugu, 2002.

(63) Sanni, L.; Onitilo, M.; Oyewole, O.B.; Keiths, T.; Westby, A. *Studies into Production and Qualities of Cassava Grits (Tapioca) in Nigeria*. Paper presented at the sixth International Scientific Meeting of the Cassava Biotechnology Network, 8–14 March 2004, CIAT, Cali Columbia, 2004.

(64) Maziya-Dixon, B.; Dixon, A.G.O.; Adebowale, A.A. *Targeting Different End Uses of Cassava: Genotypic Variations for Cyanogenic Potentials and Pasting Properties*. A paper presented at ISTRC-AB Symposium, 31 October – 5 November 2004, Whitesands Hotel, Mombassa, Kenya, 2004.

(65) Shittu, T.A.; Lasekan, O.O.; Sanni, L.O.; Oladosu, M.O. The Effect of Drying Methods on the Functional and Sensory Characteristics of Pukuru-a Fermented Cassava Product. *ASSET-An Inter. J.* 2001, *1*, 9–16.

(66) Newport Scientific. *Applications Manual for the Rapid Visco Analyzer Using Thermocline for Windows*. Newport Scientific Pty Ltd.: Warriewood, 1998; pp. 2–26.

(67) Awolu, O.O. Optimization of the Functional Characteristics, Pasting and Rheological Properties of Pearl Millet-Based Composite Flour. *Heliyon* 2017, *3*, e00240. https://doi.org/10.1016/j.heliyon.2017.e00240