Sensory and Physicochemical Properties of Unfermented Fufu Powder from Multi-Grain Pap-Tigernut Residues and Cassava Starch Blends

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ABSTRACT

The physicochemical and sensory properties of unfermented fufu powder from multi-grain pap-tigernut residues and cassava starch blends were studied. Using a mixture design, 11 formulations (40:20:40, 29:50:21, 75:20:5, 36.5:30:13.5, 56.5:30:13.5, 20:60:20; 35:60:5, 38:40:22, 29:40:31, 40:20:40, 39:30:31; and a 100-control sample) were developed into fufu powder and produced fufu meal subjected to sensory properties evaluation. The selected best five samples (40:20:40, 20:60:20, 39:30:31, 36.5:50:13, and 20:40:40 with a control sample included from sensory evaluation) were subjected to proximate composition, vitamins, and anti-nutrients analysis using standard methods. Results ranged: ash (0.4–3.5%), moisture (1.32–5.10%), fat (1.53–6.6%), crude fiber (10.67–18.7%), protein (4.5–9.7%), and carbohydrate (61.8–79.89%). Anti-nutrients were very minimal: cyanide (0.20–0.97 mg/100g), trypsin inhibitors (0.05–0.66 mg/100g), tannins (0.15–1.23 mg/100g), and phytate (0.15–0.52 mg/100g). Vitamins were present in measurable quantities, and sensory attributes were rated positively. The 20:40:40 (pap residue: tigernut residue: cassava starch) formulation had the highest overall acceptability score (7.0), with appreciable protein level (9.7%) and fiber (8%) content, making it nutritionally superior to traditional starch-based fufu. These findings highlight the potential for commercialization of this product as a sustainable and health-promoting alternative, contributing to waste reduction and addressing nutrition-related challenges.

Keyword: Unfermented fufu, multi-grain pap residue, tigernut milk drink residue, cassava starch

INTRODUCTION

Fufu is a fermented or unfermented staple food in Nigeria, especially in the southeastern regions, and across Africa. It is traditionally made from fermented cassava and ranks second to garri among indigenous Nigerian foods (IITA, 2005). Even though its odour is objectionable to some, fufu remains widely consumed. Fufu is traditionally sold as a wet pastry, its quality varies across batches and processors (Iwuoha and Eke, 1996). Mechanized fufu production has introduced fufu powder, a dried, odourless, slightly sour version with low particle size, zero cyanide content, and improved shelf-life. The fufu powder is a response to addressing the high perishability challenge of semi-wet fufu. Unfermented fufu can also be made from yam, cocoyam, cereals, or other starchy sources (Akubor and Ukwuru, 2013).

Food security and sustainability are major global priorities, prompting increased interest in maximizing the utility of agro-industrial residues and local food resources. Food waste contributes to global warming and environmental menace while people are hungry. One such promising approach is the development of

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composite flour products that leverage underutilized resources while maintaining consumer acceptability. Fufu is an ideal candidate for such innovation due to its cultural significance and widespread consumption. However, fufu's conventional production is resource-intensive and fermentation can sometimes alter desirable sensory attributes, posing a challenge to diversification and scalability.

Recent trends in food science have explored blending cassava starch with residues or by-products from other cereal or tuber crops to create functional and nutrient-enriched fufu. Multi-grain pap and tigernut milk drink residues are food wastes generated from the production of pap (akamu) and tigernut milk drink, respectively. They are valuable due to their significant fiber, protein, and other nutrients such as vitamins and minerals (Eke *et al.,* 2020; Ayo *et al.,* 2018). They are fibrous materials with sustainable food security potentials due to their availability. This is because of the increasing consumption rate of pap and tigernut milk drinks in Nigeria due to their great health benefits as traditional functional foods. When these food residues are incorporated into food formulations, these residues offer the potential for both nutritional enhancement and waste minimization, aligning with sustainable food processing goals (Okeke *et al.,* 2021).

Pap (akamu) is a complementary food from the fermented cereal porridge popular in West Africa as a weaning diet. It is usually made from maize, millet, or sorghum as a single-grain pap or combined to form multi-grain pap. Pap is widely recognized as a nutritious traditional food in Nigeria (Odunfe and Oyewole, 1998). Its variations, such as multi-grain pap, enhance its nutritional profile, blending cereals like maize, millet, and guinea corn (Adebolu *et al.,* 2007).

Tigernut milk drink is a plant-based beverage made by blending soaked tigernuts (*Cyperus esculentus*) with water and straining the mixture. It is naturally sweet, nutty, and free of lactose, gluten, and nuts, making it suitable for individuals with food allergies. It is rich in dietary fiber, healthy fats, vitamins notably E and C; and minerals like magnesium and potassium. Its antioxidant properties along with benefits for heart health, digestion, and blood sugar regulation, make it a functional beverage (Adekanmi *et al.,* 2009; Sanchez-zapata *et al.,* 2012). It is traditionally enjoyed as a refreshing drink and it is also gaining popularity as a dairy alternative in various recipes, appealing to health-conscious consumers and those on plant-based diets (Belewu and Belewu, 2007)

Cassava starch is a potential binder that can modify the residue's fibrous nature. Cassava starch is widely used as a natural binder due to its high amylopectin content, providing excellent adhesive and gel-forming properties. It enhances cohesion in food find industrial applications, offering biodegradable and cost-effective solutions (Akinniyi *et al.,* 2020; Oluwasina *et al.,* 2018). Its versatility makes it a preferred binding agent. The use of food residues in the production of fufu flour usually faces challenges such as reduced cohesion (due to lack of structural integrity (Awoyale *et al.,* 2010)), poor reconstitution properties (failure to rehydrate adequately or hold its shape when stirred in boiling water affecting its traditional preparation (Oladiran *et al.,* 2022)), inconsistent quality (variation in composition (Adeola and Aworh, 2010)) and decreased consumer acceptability (less smooth and elastic qualities (Eke-Ejiofor and Beleya, 2016. The use of the cassava starch enables the multi-grain pap and tigernut milk residues to bind together thoroughly to form fufu flour with smooth and elastic qualities as desired and compared to the existing traditional fufu.

This research contributes to the growing body of knowledge on sustainable food production and functional food development, offering a pathway to reduce food waste while creating nutritionally balanced, consumer-friendly products. Thus, the study of the physicochemical and sensory properties of unfermented fufu powder from blends of multi0grain pap-tigernut milk drink residues and cassava starch.

MATERIALS AND METHODS

Raw samples procurement and research design

The Maize, Guinea corn, Millet, Cassava root, and Tiger nuts (*Cyperus esculentus*) were obtained from the Eke-Awka market in Awka South Local Government of Anambra State.

The mixture research design using mini tab software was used to generate a total number of 11 samples

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(20:40:40, 29:50:21, 75:20:5, 36.5:30:13.5, 56.5:30:13.5, 20:60:20, 35:60:5, 38:40:22, 29:40:31, 40:20:40 and 39:30:31 for P: T: C (pap residue: tigernut residue: cassava starch)) plus the control sample (100% whole wheat meal) making it all 12 samples.

Production of multi-grain pap residue

Pap residue powder was prepared according to the method described by Odunfa and Oyewole (1998) with slight modifications. Maize, guinea corn, and millet grains were sorted to remove contaminants, steeped in water for 72 hours, and the water changed daily for three days at room temperature. After steeping, the grains were drained and thoroughly washed with clean water. The cleaned grains were milled using an attrition mill, and the resulting slurry was mixed with clean water. This slurry was placed in a muslin cloth and sieved, with the residue collected after each sieving. The collected residue was oven-dried at 70°C for 10 hours, then milled using a hammer mill. The milled residue was passed through a 0.8 mm mesh sieve to obtain fine pap residue powder. The resulting powder was packaged in polyethylene bags and stored for further use.

Production of tigernut milk drink residue

Tigernut residue flour was prepared according to the method described by Rita (2009). Tigernuts and date palm fruits were sorted to remove defective nuts, stones, and dirt. Ginger was washed and peeled, while coconut was deshelled and cut into smaller pieces. All ingredients, including tigernuts, deshelled coconut, date palm fruits, and peeled ginger, were thoroughly washed with clean water to remove sand and adhered dirt. The cleaned ingredients were blended with water in a 1:1 ratio. The residue obtained after extracting the milk was collected and oven-dried in batches at 70°C for three hours. The dried residue was milled into flour using a dry milling machine and sieved through a 5 mm laboratory sieve to obtain tigernut residue flour with uniform particle size. The resulting flour was packaged in polyethylene bags and stored at room temperature (37°C) for further use.

Production of cassava starch

Cassava starch was prepared following the method of Kamaljit *et al.* (2016). Fresh cassava tubers were peeled, washed, and ground using a hammer mill. The resulting pulp was suspended in ten times its volume of water, stirred for 5 minutes, and then filtered through double-folded cheesecloth. The filtrate was allowed to stand for 2 hours to allow the starch to settle, after which the top liquid was decanted and discarded. Water was added to the sediment, and the mixture was stirred again for 5 minutes. Filtration was repeated, and the starch from the filtrate was allowed to settle. After decanting the top liquid, the starch sediment was dried at 55°C for one hour.

Production of unfermented fufu from the multi-grain and tigernut milk drink residues

The multi-grain pap residue, tigernut residue, and cassava starch were blended in different ratios as shown in the design. Each blended ratio was separately mixed thoroughly and packaged using a zip lock polyethylene bag for further use.

Sensory Evaluation of the

The sensory evaluation was conducted by 20 panelists, all of whom were familiar with the quality attributes of fufu powder. The samples were assessed using a 9-point Hedonic Scale, where 1 indicated "extremely disliked," 5 represented "neither liked nor disliked," and 9 signified "extremely liked." Panelists were asked to rate the samples based on attributes such as color, flavor, hand-feel, moldability, and overall acceptability (Odoh *et al.*, 2022).

Proximate composition

The moisture, crude fiber, protein, fat, and ash were determined according to the described conventional standard method of AOAC (2010) while the carbohydrate content was obtained by difference.

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Tannins content determination

The quantitative determination of tannins was performed using the method of Amadi *et al.* (2004) and Ejikeme *et al.* (2014). To prepare the Folin-Denis reagent, 50 g of sodium tungstate (Na_2WO_4) was dissolved in 37 cm^3 of distilled water. Then, 10 g of phosphomolybdic acid ($H_3PMo_{12}O_{40}$) and 25 cm^3 of orthophosphoric acid (H_3PO_4) were added to the solution. The mixture was refluxed for two hours, cooled, and diluted to 500 cm^3 with distilled water. One (1) gram of the plant material was placed in a conical flask and mixed with 100 cm^3 of distilled water. This was gently boiled for 1 hour on an electric hot plate, then filtered through Whatman No. 42 (125 mm) filter paper into a 100 cm^3 volumetric flask. To develop color, 5.0 cm^3 of Folin-Denis reagent and 10 cm^3 of saturated Na_2CO_3 solution were added to 50 cm^3 of distilled water, followed by 10 cm^3 of the diluted plant extract. The mixture was thoroughly agitated and allowed to stand for 30 minutes in a water bath at 25°C. The optical density was measured at 700 nm using a Spectrum Lab 23A spectrophotometer and compared to a standard tannic acid curve. The standard curve was obtained by dissolving 0.20 g of tannic acid in distilled water and diluting it to a final volume of 200 cm^3 (1 mg/cm^3). Standard solutions with concentrations ranging from 0.2–1.0 mg/cm^3 were prepared and analyzed in the same manner. The optical density (absorbance) of these solutions was plotted against tannic acid concentration. % Tannins = $\frac{AN \times C \times 100 \times Vf}{As \times W \times VA}$

An= absorbance of the test sample

As= Absorbance of standard solution

C= Concentration of standard solution

W= weight of sample used

Vf= Total volume of extract

VA= Volume of extract analyzed

Trypsin inhibitor determination

To determine the trypsin inhibitor, a 30 g/L azocasein stock solution was prepared according to AOAC (2000) by dissolving the protein in 100 mM Tris-buffer (pH 8.5), containing 5 mM $CaCl_2$, and heating to 50°C before cooling to 37°C. Trypsin was accurately weighed to achieve a concentration of 0.3–0.4 mg/mL and dissolved in 1 mM HCl, prepared immediately before analysis. Sample material was dispersed in a pH 3.3 acetic acid solution, and material that was hard to disperse was homogenized for 10 seconds. A series of sample dilutions were prepared to cause approximately 50% signal loss upon incubation, using the highest concentration. Each dilution (125 µL) was mixed with either 25 µL of trypsin stock solution or 25 µL of demineralized water (control). For the positive and negative controls, 125 µL of demineralized water was used instead of sample material. Then, 225 µL of warm azocasein was added to each mixture, which was incubated for 30 minutes at 37°C. The reaction was terminated by adding 150 µL of 15% (w/v) TCA solution. To ensure equal incubation times, azocasein was added in the same order as the TCA. Non-hydrolyzed azocasein and other insolubles were removed by centrifugation at 15,000 g at 4°C for 10 minutes using a Heraeus Multifuge 1S-R centrifuge with a Thermo Scientific rotor. Following centrifugation, 100 µL of the supernatant was transferred to a microtiter plate and mixed with 100 µL of 1.5 M NaOH. The absorbance was measured at 450 nm using a BioRad Model 680 microplate reader. Absorbance values were plotted against the sample material amount. The slope of the resulting line was determined via linear regression using the least squares method, reflecting the absorbance lost per quantity of sample. The positive control, which lacked the sample material, represented the maximum absorbance caused by the known trypsin amount. By dividing the sample's slope by the positive control absorbance, trypsin inhibitory activity was expressed as the amount of trypsin inhibited per sample material, reported in mg/g.

Phytate content determination

Phytate content was determined using the method described by AOAC (2005). Approximately 1 g of the flour sample was weighed, and phytate was extracted by mixing with 10 mL of 0.2 N HCl. The mixture was stirred

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for 30 minutes using a magnetic stirrer. Next, 1 mL of ammonium iron (III) sulfate solution (prepared by dissolving 0.2 g of ammonium iron (III) sulfate, $12H_2O$, in 100 mL of 2 N HCl, then diluting to 1 L with water) was added to a test tube. The solution was then boiled for 30 minutes in a water bath, followed by cooling to room temperature in ice water. The mixture was thoroughly mixed and centrifuged for 30 minutes at 3000 rpm. Then, 1 mL of the supernatant was transferred to another tube, to which 1.5 mL of a 2,2′-bipyridine solution (10 g of 2,2′-bipyridine and 10 mL of thioglycolic acid in 1000 mL of distilled water) was added. The absorbance of the solution was measured at 519 nm against distilled water. A standard curve was prepared using phytate-phosphorus concentrations ranging from 3 to 30 µg/mL, treated the same way but without the sample. All measurements were conducted in triplicate. The total percentage of phylate was calculated.

Total phytates was calculated as follows:

$$\frac{titre\ value \times 0.00195 \times 1.9 \times 100}{2}$$

Hydrogen Cyanide content determination

Hydrogen cyanide content was determined using the method described by Simon (2015). A 15 g sample was weighed and placed into an 800 mL Kjeldahl flask containing 200 mL of distilled water. The mixture was allowed to stand for 3 hours at 25 ± 5°C. Autolysis was then performed with the apparatus connected to a distiller. A 150 mL distillate was collected into 20 mL of a 25% NaOH solution, and further diluted to 250 mL with distilled water. From this, 100 mL of the diluted distillate was mixed with 8.0 mL of 6.0 N NH_4OH and 2.0 mL of 5% KI indicator solution. This mixture was titrated against 0.02 N $AgNO_3$. The endpoint was reached when a faint, permanent turbidity appeared in the solution.

% of total hydrogen cyanide was calculated as follows: $\frac{Average\ titre \times 100}{weight\ of\ sample}$

Vitamin A content determination

Vitamin A content was determined using the method outlined by AOAC (2010). One gram of the sample was mixed with 30 mL of absolute alcohol, and 3 mL of 5% potassium hydroxide (KOH) solution was added. The mixture was boiled under reflux for 30 minutes. After cooling, it was washed with distilled water, and vitamin A was extracted using 150 mL of diethyl ether. The extract was evaporated to dryness at low temperature, then dissolved in 10 mL of isopropyl alcohol. A 1 mL aliquot of standard vitamin A solution was prepared, and both the dissolved extract and standard solution were transferred to separate cuvettes. The absorbance of each was measured at 325 nm in a spectrophotometer, with the reagent blank set to zero. The percentage of vitamin A in the sample was calculated based on the absorbance values.

$$\frac{Absorbance\ of\ sample\ \times\ Concentration\ of\ standard\ solution\ \times\ Dilution\ factor}{Absorbance\ of\ standard\ solution\ \times\ Sample\ volume}$$

Vitamin B_1 and B_2 content determination

Thiamin (vitamin B_1) content was determined using the method outlined by AOAC (1995). A standard thiamin solution and a reagent solution, prepared by mixing 1% potassium ferricyanide and 10% sodium hydroxide in a 1:9 ratio, were used to determine thiamin concentration in serial dilutions at 367 nm. A graph was plotted to extrapolate the concentration of thiamin in the test sample based on its absorbance. Approximately 2 mL of the tigernut product sample solution was pipetted into a 100 mL separating funnel, and 2 mL of the reagent solution was added. After 1 minute, 15 mL of isobutyl alcohol was added, and the mixture was gently shaken for 2 minutes to separate the isobutyl alcohol layer. The resulting layer was then passed through anhydrous sodium sulfate. The absorbance of the sample was measured at 367 nm, using isobutyl alcohol as the blank. The thiamin content was calculated using the appropriate formula, and the percentage of vitamin B_1 was determined.

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$$\frac{Absorbance\ of\ sample\ \times\ Concentration\ of\ standard\ solution\ \times\ Dilution\ factor}{Absorbance\ of\ standard\ solution\ \times\ Sample\ volume}$$

Riboflavin (vitamin B_2) content was determined using the method outlined by AOAC (1995). A standard riboflavin solution and Denigees reagent, prepared by dissolving 5 g of yellow mercuric oxide in 80 mL of water and 20 mL of sulfuric acid, were used to determine riboflavin concentration in serial dilutions at 525 nm. A graph was plotted to extrapolate the riboflavin concentration in the test sample. Approximately 1.5 mL of the multi-grain and cassava starch flour product sample was taken and diluted with 8.5 mL of distilled water. Then, 5 mL of the diluted sample was mixed with 5 mL of Denigees reagent and allowed to stand for 2 minutes. The mixture was filtered, and the absorbance was measured at 525 nm. The riboflavin concentration in the sample was calculated using the appropriate formula. The percentage (%) of Vitamin B_2 was calculated as follows:

$$\frac{Absorbance\ of\ sample\ \times\ Concentration\ of\ standard\ solution\ \times\ Dilution\ factor}{Absorbance\ of\ standard\ solution\ \times\ Sample\ volume}$$

Vitamin E content determination

Vitamin E content was determined using the Futter-Mayer calorimetric method, as described by Kirk and Sawyer (1991). The absorbance of both the standard vitamin E solution and the sample extract was measured at 410 nm using a spectrophotometer, with the blank reagent set to zero. One gram of the sample was mixed with 10 mL of ethanolic sulfuric acid and gently boiled under reflux for 30 minutes. The mixture was then transferred to a separating funnel and extracted with three 30 mL portions of diethyl ether, recovering the ether layer each time. The ether extract was transferred to a desiccator to dry for 30 minutes, then evaporated to dryness at room temperature. The dried extract was dissolved in 19 mL of pure ethanol. One mL of the dissolved extract, as well as 1 mL of standard vitamin E solution, were placed in separate tubes. To each tube, 5 mL of absolute alcohol and 1 mL of concentrated nitric acid solution were added. The mixtures were allowed to stand for 5 minutes. Afterward, the absorbance of each solution was measured at 410 nm using a spectrophotometer, with the blank reagent set to zero.

Conc. of vitamin E in the sample (mg/100 g) = AS x CS

ASt

Where;

AS = Absorbance of sample

CS = Concentration of standard

ASt = Absorbance of standard.

Vitamin B_6 content determination

The extraction method followed Kall (2003) with slight modifications. Ten grams of each sample were first homogenized and placed in a 100 mL Erlenmeyer flask. To this, 60 mL of 0.1 N hydrochloric acid solution was added. The mixture was then transferred to an autoclave and heated at 121°C for 30 minutes. After cooling, the pH was adjusted to 4.5 using a 2.5 mM sodium acetate solution. Subsequently, 100 mg of takadiastase, 10 mg of acid phosphatase, and 10 mg of ß-glucosidase enzymes were added to the samples, which were then incubated for 18 hours at 37°C in a shaking water bath. After incubation, the samples were allowed to cool to room temperature, and the volume was adjusted to 100 mL. A 0.4 µm filter was used to filter the samples before transferring them to the spectrophotometer.

Absorbance was measured at 220 nm. % of Vitamin B_6 = $\frac{Absorbance \times 100}{Weight\ of\ sample}$

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Statistical analysis

The data were analyzed using ANOVA with SPSS software (version 20). Means were separated using Duncan's Multiple Range Test to determine if there were significant differences among the various parameters in the multi-grain pap-tigernut fufu powder samples with whole wheat meal.

RESULTS AND DISCUSSION

Sensory evaluation of the unfermented fufu powder samples from multi-grain pap-tigernut residues and cassava starch blends

The Sensory evaluation of the unfermented fufu powder from multi-grain pap-tigernut residues and cassava starch blends is shown in Table 1. There was no significant ($p>0.05$) difference between the colour and the flavor of all the fufu samples produced compared with the control sample (whole wheat meal). Most sample scores for hand feel and moldability were close to the same value scored for the commercial sample. Interestingly, the fufu sample ratio 20:40:40 scored the same value as the overall acceptability of the control sample, showing the commercial potential of this fufu sample.

Table 1: Sensory evaluation of the unfermented fufu powder from multi-grain pap-tigernut residues and cassava starch blends

Samples P:T:C	Colour	Hand feel	Moldability	Flavour	Overall Acceptability
20:40:40	$6.90^{a}\pm1.21$	$6.40^{a}\pm1.82$	$6.15^{ab}\pm1.53$	$6.35^{a}\pm1.76$	$7.00^{a}\pm1.35$
29:50:21	$5.95^{a}\pm1.47$	$6.00^{abc}\pm1.92$	$6.00^{abc}\pm1.65$	$5.60^{a}\pm2.01$	$5.95^{ab}\pm1.99$
75:20:5	$5.95^{a}\pm2.11$	$4.65^{c}\pm1.79$	$4.55^{d}\pm2.14$	$5.00^{a}\pm2.64$	$5.10^{b}\pm2.02$
36.5:50:13.5	$6.45^{a}\pm1.76$	$5.85^{abc}\pm1.76$	$5.65^{abcd}\pm1.90$	$5.60^{a}\pm2.04$	$6.10^{ab}\pm2.13$
56.5:30:13.5	$6.10^{a}\pm1.51$	$5.50^{abc}\pm2.24$	$4.90^{bcd}\pm1.77$	$5.20^{a}\pm2.38$	$5.40^{ab}\pm1.96$
20:60:20	$6.40^{a}\pm1.82$	$6.40^{a}\pm2.50$	$6.40^{a}\pm1.76$	$6.15^{a}\pm2.01$	$6.10^{ab}\pm2.05$
35:60:5	$6.30^{a}\pm1.98$	$5.45^{abc}\pm2.28$	$5.60^{abcd}\pm2.01$	$5.10^{a}\pm2.43$	$5.75^{ab}\pm2.31$
38:40:22	$6.30^{a}\pm1.78$	$6.15^{abc}\pm2.03$	$6.30^{a}\pm1.87$	$5.25^{a}\pm1.97$	$5.75^{ab}\pm2.12$
29:40:31	$5.95^{a}\pm1.47$	$4.75^{bc}\pm2.22$	$5.30^{abcd}\pm2.05$	$5.35^{a}\pm2.39$	$5.05^{b}\pm2.31$
40:20:40	$6.70^{a}\pm1.17$	$5.80^{abc}\pm1.99$	$6.50^{a}\pm1.36$	$5.95^{a}\pm1.88$	$6.25^{ab}\pm1.48$
39:30:31	$6.25^{a}\pm1.37$	$5.10^{abc}\pm2.02$	$4.80^{cd}\pm2.33$	$5.90^{a}\pm2.17$	$5.50^{ab}\pm2.31$
100:0	$6.50^{a}\pm2.01$	$6.25^{ab}\pm1.89$	$6.60^{a}\pm1.85$	$6.45^{a}\pm1.50$	$7.00^{a}\pm1.77$

Values are mean scores ± standard deviation of triplicate determination. Samples in the same column bearing different superscripts differ significantly ($p<0.05$).

P = pap residue, T = tiger nut residue, C = cassava starch. 100=control (whole wheat meal)

Proximate composition of the five best-selected fufu powder samples from blends of multi-grain pap-tiger residues binded with cassava starch.

The Proximate composition of best-selected samples of fufu powder from blends of multi-grain pap-tiger residues binded with cassava starch is seen in Table 2.

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Unfermented fufu powder samples with ratios 40:20:40, 20:60:20, and 39:30:31 for pap-tigernut residue-cassava starch, respectively were not significantly ($p>0.05$) different in ash content from each other but were significantly ($p<0/05$) different when compared with other samples and control sample (commercial sample). The fufu powder sample with a ratio of 20:40:40 had the highest ash value of 3.5% and was observed to be higher than that of the commercial sample (1.93%). It was observed that the ash content increased with an increase in the tigernut residues and cassava starch. The values obtained in this study are above the range of 1.15 to 2.05 % and 0.5 to 2.53% reported by Obinna *et al*. (2020) and Odoh *et al.* (2022) for tigernut-cowpea flour pancakes and unfermented fufu composite flour from cassava sievate, Guinea corn, and unripe plantain flour blends. Ash is the inorganic residue after the incineration of organic matter and an indication of the mineral content of the samples. Since ash is an index of the mineral value in the food, it could be said that the produced fufu powder has a superior mineral content compared to whole wheat meal (the control sample).

There was a significant ($p<0.05$) difference among the fufu sample's moisture content when compare with the control sample. The moisture content of the produced fufu powder ranged from 3.2 to 5.1%. The moisture content of the developed fufu obtained in this study is within the range of 3.23 to 7.81 % reported by Bristone *et al*. (2018) for a Nigerian Indigenous-based food (Upursah) from tiger nut composite flour blends with sweet potato and below the value of 6.6 to 10.99% reported by Odoh *et al.* (2022) for unfermented fufu composite flour from cassava sievate, Guinea corn, and unripe plantain flour blends. This low moisture of the developed fufu powder ensures that the meals are generally free from microbiological spoilage and have a long shelf life if they are protected from absorbing moisture from damp surroundings or the atmosphere (Sanni *et al*., 2001).

There was a significant ($p<0.05$) difference in the fat content of the fufu powder samples when compared with the control sample. The fufu powder with a ratio of 20:40:40 had the highest fat value of 6.6%. the fat content of the produced fufu powder is below the values of 9.16 to 20.12% reported by Brimstone (2018) for "Upursah" from tigernut, sorghum, sweet potato and soybean and above the value of 0.96 to 3% reported by Odoh *et al.* (2022) for unfermented fufu composite flour from cassava sievate, Guinea corn, and unripe plantain flour blends.

A significant ($p<0.05$) difference occurred in the crude fiber value of all the fufu powder samples when compared with the control sample. The crude fiber of the produced fufu powder was all higher than the control sample showing a better source of fiber with a fufu powder sample ratio of 40:20:40 having the highest value of 18.7%. The values of crude fiber obtained from this research ranged from 13.3 to 18.7% and are higher than the value of 0,33 to 2.54 reported by Odoh *et al.* (2022) for unfermented fufu composite flour from cassava sievate, Guinea corn, and unripe plantain flour blends.

The protein content of the fufu powder showed a significant ($p<0.05$) difference except sample ratio of 40:20:40 when compared with the control sample. The fufu powder sample with the ratio of 39:30:31 had the highest protein value of 9.7% which is a notable achievement in fufu production considering that fufu is known to be a very poor source of protein but majorly carbohydrate. The value of protein of the produced fufu powder is within a close range of 4.68 to 10.55 % and 2.4 to 12.5% reported by Obinna *et al.* (2020) and Odoh *et al.* (2022) for tiger nut-composite flour for pancakes and unfermented fufu composite flour from cassava sievate, Guinea corn, and unripe plantain flour blends, respectively.

The carbohydrate value of the fufu samples differed significantly ($p<0.05$) when compared with the control. It was observed that the fufu produced, all had lower carbohydrate content ranging from 61.8 to 70.1% when compared to the control sample (79.89). The values obtained are below the reported value of 78.18 % and 72.41 to 87.96% by Bristone *et al.* (2018) and Odoh *et al.* (2022) for "Upursah" from tigernut, sorghum, sweet potato, and soybean composite flour blends and unfermented fufu composite flour from cassava sievate, Guinea corn, and unripe plantain flour blends, respectively.

Table 2: Proximate composition of best-selected samples of fufu powder from blends of multi-grain pap-tiger residues binded with cassava starch (%)

Sample (P: T: C)	Ash	Moisture	Fat	C. Fibre	C. Protein	CHO
40:20:40	2.60^{ab}±0.1	4.10^{c}±0.1	5.50^{b}±0.1	18.70^{a} ± 0.1	4.50^{e}±0.1	64.60^{c} ± 0.1

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20:60:20	2.70^{ab}±0.1	3.20^{d}±0.0	6.10^{ab}±0.1	14.50^{c} ± 0.2	7.70^{c}±0.1	65.90^{c} ± 0.1
39:30:31	1.90^{b}±0.1	4.10^{c} ±0.1	4.00^{c} ± 1.00	16.80^{b} ± 0.2	9.70^{a}± 0.1	63.50^{cd}±0.1
36.5:50:13.5	0.40^{c}±0.1	4.70^{b}±0.1	3.20^{d}± 0.10	13.30^{d} ± 0.2	8.30^{b} ± 0.1	70.10^{b} ± 0.1
20:40:40	3.50^{a}±0.1	5.10^{a}±0.1	6.60^{a}± 0.10	17.70^{ab}± 0.1	5.30^{d} ± 0.1	61.80^{d} ± 0.1
100:0	1.93^{b}±0.1	1.32^{e}±0.0	1.53^{e} ± 0.15	10.67^{e} ± 1.5	4.63^{e} ± 0.1	79.89^{a} ± 0.1

Values are mean scores ± standard deviation of triplicate determination. Samples in the same column bearing different superscripts differ significantly ($p<0.05$).

P:T:C = pap residue: tiger nut residue: cassava starch; C= crude; CHO= Carbohydrate, 100=control (whole wheat meal)

Anti-nutrients of best selected 5 (five) samples of fufu powder from blends of multi-grain pap-tiger residues binded with cassava starch

Table 2 shows the anti-nutrients of five best-selected samples of fufu powder from blends of multi-grain pap-tiger residues binded with cassava starch. Generally, it is observed that the cyanide, trypsin, tannins, and phytate content of the produced fufu powder samples were lower when compared with the control sample. This showed that the produced fufu samples had antinutrients at a level of no concern and were safe for consumption.

The cyanide content of the best selected fufu powder samples ranged from 0.2 to 0.49mg/100g while the control sample was 0.97mg/100g. The cyanide content of the fufu meal agreed with the cyanide content (0.43 to 0.78 mg/100g) of cassava recipes as reported by Nicodemus *et al.* (2018) in the anti-nutritional composition of cassava recipe and values were considered safe based on 10mg/kg permissible limit approved by World health organization as reported by Odoh *et al.* (2022).

The trypsin inhibitors were significantly different ranging from 0.05 to 0.38mg/100g. This value is below the tolerable level of 5 trypsin inhibitor units per milligram of protein for foods (FAO/WHO, 2016). The values reported in this study were lower compared to the reported values of 0.97 to 1.20 mg/g by Mazib *et al.* (2013) in cassava and groundnut fufu meal. Trypsin is an enzyme that helps to digest protein and break it down into amino acids needed by the body. Trypsin inhibitor thereby prevents the activation and breakdown of active trypsin (Secti, 2018). These low values of trypsin inhibitor indicate a greater action of trypsin and increased absorption of amino acid. The low values obtained could be due to the soaking and fermentation (Sarkayayi and Agar, 2010).

The tannin contents of the produced fufu powder is significantly different when compared to the control sample. It ranged from 0.15 to 0.53mg/100g when compared with control (1.23mg/100g). This value is below the acceptable limit of below 4% of the dry weight of the sample. Higher levels of tannins may reduce protein digestibility and impact palatability (Makkar, 2003). These values were below the value of 2.86 to 4.67 mg/g in fufu produced from sweet cassava and guinea corn flour blends as reported by Awololu *et al.* (2020). Tannins are astringent, bitter-tasting polyphenols that bind and precipitate proteins (Archana and Kadam, 2010). Tannins have been reported to exert physiological effects such as accelerating blood clotting, reducing blood pressure, decreasing the serum lipid level, producing liver necrosis, and modulating immune responses (Sharma *et al.*, 2019).

The values of the phytate content of the fufu powder sample ranged from 0.18 to 0.3mg/100g when compared with the control (0.52mg/100g). the phytate content value of the produced fufu meal is lower than that found in the control sample (whole wheat meal, a commercial sample) which is commendable and more safety in its consumption. the values obtained in this study are lower than the reported values of 14.83 to 25.96 mg/g and 78.73 to 712.18 mg/g by Awolu *et al.* (2020) and Nicodemas *et al.* (2018) in fufu produced from sweet cassava and guinea corn flour blends; and cassava recipe formulation, respectively thereby indicating a much better

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quality. This is also a desired positive recommended result, the lower the phytate in food the better that food considering its negative effect. The presence of phytate in human food mainly affects the uptake of mineral ions and also their absorption in the body (Afinah *et al.*, 2010). As a result, undigested phytate complex formed at physiological pH and it is the major reason for poor mineral bioavailability (Cheryan, 1980). Phytates can impair the bioavailability of iron, calcium, magnesium, and zinc in the diets of people. The values obtained are below the recommended safe level in food of below 1% (10mg/g) to avoid significant mineral binding effects, particularly iron absorption (WHO, 2004).

Table 3: Anti-nutrients of best-selected samples of fufu powder from blends of multi-grain pap-tiger residues binded with cassava starch in mg/100g.

Sample (P: T: C)	Cyanide	Trypsin Inhibitor	Tannins	Phytate
40:20:40	0.46^{bc}±0.02	0.16^{c}±0.00	0.44^{c}±0.00	0.18^{b}±0.00
20:60:20	0.48^{bc}±0.42	0.05^{f}±0.00	0.30^{d}±0.00	0.30^{b}±0.00
39:30:31	0.20^{c}±0.02	0.09^{d}±0.00	0.53^{b}±0.00	0.15^{b}±0.00
36.5:50:13.5	0.34^{bc}±0.00	0.07^{e}±0.00	0.15^{f}±0.00	0.30^{ab}±0.39
20:40:40	0.49^{b}±0.00	0.38^{b}±0.00	0.27^{e}±0.00	0.20^{b}±0.00
100	0.97^{a}±0.02	0.66^{a}±0.01	1.23^{a}±0.00	0.52^{a}±0.02

Values are mean scores ± standard deviation of triplicate determination. Samples in the same column bearing different superscripts differ significantly ($p<0.05$).

P:T:C = pap residue: tiger nut residue: cassava starch; 100=control (whole wheat meal)

Vitamin composition of best-selected samples of unfermented fufu powder from blends of multi-grain pap-tiger residues binded with cassava starch

Table 4 shows the Vitamin composition of best-selected samples of fufu powder from blends of multi-grain pap-tiger residues binded with cassava starch

The vitamin A content of the produced fufu powder ranged from 1.6 to 2.1mg/100g and was significantly ($p<0.05$) higher than the control sample (0.34mg/100g). the value of vitamin A obtained is within a close range even though some of the fufu meal samples were above the vitamin A for tigernut residues (0.51-1.75mg/L) as reported by Wayah and Shehu (2013). This high amount of Vitamin A indicated that fufu made with processed (multi-grains) can help improve the vision of patients suffering from cataracts, glaucoma, and other eye-related diseases (Smith, 2005).

The vitamin B_1 of the produced fufu samples ranged from 0.18 to 1.7mg/100g. all the produced fufu samples were significantly ($p<0.05$) different in their vitamin B_1 except the sample with a ratio of 20:40:40 when compared with the control sample (whole wheat meal). The result of B_1 is within the range values of 0.34-2.38 mg/100g reported by Ani *et al.* (2021) for tigernut flour. The recommended daily intake of 1.0-1.5mg/day of vitamin B1 is required for normal adults to avoid its deficiency resulting in beriberi (Aleksandrova, 2016). This indicates that the produced fufu meal has good vitamin B_1 content.

The vitamin B_2 content of the produced fufu samples ranged from 0.05 to 0.6mg/100g and were significantly ($p<0.05$) different from the control sample (0.02mg/100g). the value obtained in the produced fufu is higher than the value of 0.089mg for 240g of cooked fufu meal reported by USDA (2025).

The vitamin B_6 of all the fufu powder samples was not significantly ($p>0.05$) different from each other but was

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significantly different when compared with the control sample except for sample ratio 20:40:40. Their vitamin B_6 ranged from 0.23 to 1.8mg/100g, which is within the range value of 0.458mg for 240g of cooked fufu meal by USDA (2025).

The vitamin E content of the produced fufu powder was not significantly ($p>0.05$) different from that of the control sample except for the sample with a ratio of 36.5:50:13.5, which ranged from 0.13 to 0.77mg/100g. The value obtained in the produced fufu meal is higher than the USDA's reported value of 52.80 mcg (0.0528mg) for 240g of cooked fufu (2025).

Table 4: Vitamin composition of best-selected samples of fufu powder from blends of multi-grain pap-tiger residues binded with cassava starch in mg/100g

Sample (P: T: C)	Vitamin A	Vitamin B_1	Vitamin B_2	Vitamin B_6	Vitamin E
40:20:40	1.80^{b}±0.21	1.54^{c}±0.02	0.32^{c}±0.02	1.20^{a}±0.21	0.13^{b}±0.00
20:60:20	1.98^{a}±0.00	1.60^{a}±0.21	0.60^{a}±0.21	1.80^{a}±0.21	0.23^{b}±0.00
39:30:31	2.00^{a}±0.08	1.70^{a}±0.21	0.53^{ab}±0.02	1.40^{a}±0.21	0.27^{b}±0.00
36.5:50:13.5	2.10^{a}±0.08	1.22^{b}±0.02	0.42^{bc}±0.02	1.50^{a}±0.21	0.77^{a}±0.02
20:40:40	1.60^{c}±0.08	0.18^{d}±0.37	0.05^{d}±0.11	0.23^{b}±0.46	0.16^{b}±0.32
100	0.34^{d}±0.02	0.20^{d}±0.01	0.02^{e}±0.01	0.05^{b}±0.07	0.12^{b}±0.01

Values are mean scores ± standard deviation of triplicate determination. Samples in the same column bearing different superscripts differ significantly ($p<0.05$).

P:T:C = pap residue: tiger nut residue: cassava starch; 100=control (whole wheat meal)

CONCLUSION

The samples were generally rated positively, with the 20:40:40 sample ratio receiving the highest overall acceptability score of 7 (liked moderately) as same with the control sample of whole wheat meal, an already existing commercial fufu powder sample. The 39:30:31 sample ratio demonstrated promising nutritional qualities, with a protein content of 9.7%. These values make it a nutrient-dense alternative compared to traditional fufu. The proximate and vitamin contents were present in measurable amounts. Anti-nutrient levels were generally low across all samples, indicating that they are safe for consumption, even better than the control sample. The 20:40:40 formulation shows great potential for commercialization due to its balanced nutrient profile, acceptable sensory qualities, and reduced anti-nutrient content compared to traditional fufu. The incorporation of multi-grain pap and tigernut milk drink residues with cassava starch offers a more nutritious and commercially viable fufu powder option. This formulation could also serve as a viable alternative to help reduce food waste (thus minimizing environmental pollution) while enhancing the nutritional value of fufu products. Additionally, it offers functional benefits to support a healthy diet and could contribute to the management of common nutrition-related health challenges such as weight management, improved digestive health, blood sugar regulation, reduced chronic diseases, and overall enhanced nutrition. Thus, in addition to the list of nutrient-dense fufu meals.

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Plates

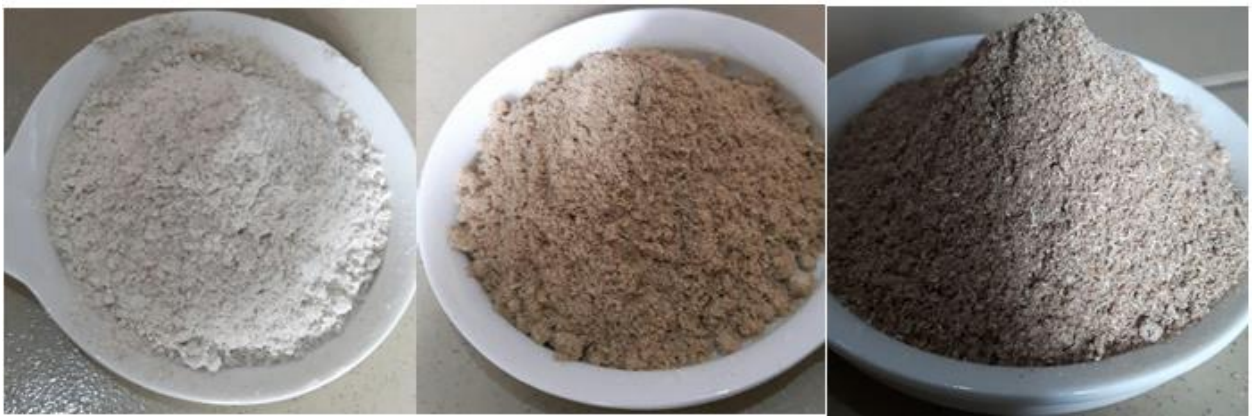

Plate 1: Whole Wheat Powder Plate 2:Tigernut Residue Powder Plate 3: multi-grain Pap Residue Powder

Plate 4: Cassava Starch Plate 5: multi-grain pap and tigernut milk drink residue with cassava starch Fufu Powder meal