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In vitro Protein and Starch Digestibility, Nutritional and Bioactive Properties of Elekute (A Maize-Based Snack) Substituted with Catfish (*Clarias gariepinus*)

Folasade A. Taiwo-Olabode[1], Moses T. Ukeyima[2] and Victor N. Enujiugha[1]*

[1]Department of Food Science and Technology, Federal University of Technology, Akure, Nigeria.
[2]Department of Nutrition and Dietetics, Joseph Sarwuan Tarka University, Makurdi, Nigeria.
*Correspondence: vnenujiugha@futa.edu.ng Tel.: +2348034261870

Abstract

One of the popular and most commonly consumed maize-based snacks is elekute, which is made from maize powder mixed with spices and other ingredients depending on individual preferences. In this study, elekute was prepared by substituting maize with catfish powder at graded ratios (100% maize as control; 90:10; 80:20; 70:30; 60:40; 50:50 maize:catfish, respectively). The nutrients, anti-nutrients, antioxidants, as well as in vitro protein and starch digestibility, were all assayed in the respective samples. Results showed higher protein contents with increased substitution (highest was in 60:40). Mineral composition also increased with increased substitution. The phytic acid, oxalate and tannins in the samples reduced with higher substitution level. There was significant difference among the samples in oil absorption capacity, emulsion capacity, swelling capacity, and foaming capacity, but no significant difference in water absorption capacity, bulk density, and least gelation capacity. The antioxidant properties of the Elekute were enhanced with the inclusion of catfish flour. The alpha amylase inhibitory activity was found to increase slightly with the addition of catfish flour up to 20% (80:20). The alpha glucosidase inhibitory activity of the Elekute was also found to be highest at 20% inclusion of the catfish flour (80:20). Enrichment of Elekute snack by adding catfish flour improved the nutritional quality of this maize-based snack with high level of acceptance from the taste panelists.

Keywords: *Maize-based snack elekute; catfish substitution; nutritional quality; bioactive components*

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1. Introduction

In most developing countries of the world, local cuisines and diets are generally loaded with monotonous starchy staples, and this has led to a prevailing incidence of protein malnutrition (Enujiugha, 2020). To mitigate this unsavoury trend, several food science and nutrition researches are geared towards both developing new protein-based foods (Enujiugha, 2000; Olagunju et al., 2018) and enriching the local diets with available high protein substrates (mostly underutilized legumes and oilseeds, via graded substitutions) in order to maintain the original sensory qualities of the meal, while at the same time raising the protein level (Oluwamukomi et al., 2005a; Adeyanju et al., 2019). For example, African oil bean seed (*Pentaclethra macrophylla*) has been successfully applied at different levels, in a completely randomized design, to raise the protein content in ogi (Enujiugha, 2006), elekute (Lawal and Enujiugha, 2016), aadun (Akinola and Enujiugha, 2017) and cookies (Gbadamosi et al., 2011). Other non-conventional and wild forest seeds have also been explored in protein enrichment of our common staple diets (Ojo and Enujiugha, 2016; Enujiugha, 2020); but to our knowledge, no work has been reported on the use of catfish (*Clarias gariepinus*) in protein enrichment of maize-based snack, elekute.

Elekute is produced locally by milling roasted maize into fine powder to which salt or sugar is added (Oluwamukomi et al., 2005b). When oil is added it is known as Aadun (Adeyanju et al., 2016; Akinola and Enujiugha, 2017). Supplementing maize with catfish flour is expected to eliminate the problem of inadequate nutritive quality of the snack. Since Elekute is a widely accepted and consumed snack among all ages in Nigeria, it can serve as means of combating protein-energy malnutrition among children because it is affordable among all the economic classes. Maize is deficient in certain amino acids such as lysine and tryptophan, hence the need to complement maize with catfish which is a better source of these essential amino acids (Pratama et al., 2018). Snacks with high acceptability and nutritional quality are useful in nutritional programs to combat malnutrition and nutrient deficiencies among consumers (Lawal and Enujiugha, 2016; Olagunju et al., 2018). Catfish has been shown to have good amino acid composition such as lysine (Oriowo et al., 2020). The specific objectives of this study were to: (a) determine the effect of catfish on the physicochemical properties and evaluate nutrients (proximate, mineral) composition of the maize based elekute; (b) evaluate in-vitro antioxidant and anti-diabetic properties of the snack; (c) assess the pasting and functional properties of the maize based elekute; and (d) examine the organoleptic acceptability of the maize based elekute using sensory evaluation.

Fish which is an excellent source of protein, omega-3 fatty acids, and key minerals and vitamins (Nwanna et al., 2004) can be included in snack formula to increase protein content and improve nutritional value. Catfish flour is known to be nutrient-dense (Stadlmayr et al., 2010) and has several advantages compared to other sources of protein including a fairly high protein content (±20%) with a patterned amino acid arrangement (Asriani et al., 2018). Hence this study was conducted to investigate the impact of graded substitution of catfish flour in elekute, with a view to exploring alternative means of addressing the prevalent protein-energy malnutrition ravaging populations (especially rural dwellers) in developing countries.

Materials and Methods

Source of Materials

Maize (*Zea mays*) was obtained from the king's market in Ondo, Ondo State, Nigeria. The Catfish was obtained from a local fish farmer in Igba, Ondo. All reagents used in this study were of analytical grade.

Production of Elekute flour

Maize grains were washed, drained, and sun-dried for 24 hours before being roasted over an open fire for 20-25 minutes. After roasting, they were allowed to cool down and then milled into a fine powder using a hammer mill. The resulting flour was sifted using hand sieves. Finally, the flour was stored in a clean, airtight container and kept at 4℃ until it was used for further analysis.

Production of catfish powder

The catfish was cut into pieces, washed, spread on a clean tray and then sun-dried for 72 hours. It was milled into fine powder using hammer mill, and then sieved using 250 µm pore size sieve.

The Elekute flour and the catfish powder were then mixed in the following proportions;

100% Elekute flour (Control)
90:10 (90% Elekute 10% catfish powder)
80:20 (80% Elekute 20% catfish powder)
70:30 (70% Elekute 30% catfish powder)
60:40 (60% Elekute 40% catfish powder)
50:50 (50% Elekute 50% catfish powder)

Determination of proximate chemical composition

The proximate composition was determined on the samples by Standard Analytical methods of AOAC (2012). Moisture content was determined according to method 964.22 using the air oven (AOAC, 2012); the protein content was according to method 955.04 via digestion, distillation and titration (AOAC, 2012); the protein was calculated from the total nitrogen content by multiplying with 6.25. Crude fat was extracted overnight in a Soxhlet extractor with n-hexane and quantified gravimetrically; ash content was carried out in a muffle furnace at 550 ºC according to method 923.03 (AOAC, 2012). Crude fibre was determined after digesting a known weight of fat-free sample in refluxing 1.25% sulphuric acid and 1.25% sodium hydroxide; and carbohydrate was determined by the difference method (subtracting the percent crude protein, crude fibre, crude fat, and ash from 100% dry matter).

Mineral analysis

The sodium (Na) and potassium (K) contents of the samples were determined using digital flame emission photometer (Sherwood Flame Photometer, model 410, Sherwood Scientific Ltd, cambridge, UK) as described by Dauda et al. (2022). The phosphorus was determined colorimetrically using phospho-vanadomolybdate (yellow) method and the absorbance was measured at 470 nm (AOAC, 2012). The other elemental concentrations were determined by using Atomic Absorption Spectrophotometer (AAS, Buck Model 20A, Buck Scientific, East Norwalk, CT06855, USA), after wet digestion of sample ash with a mixture of nitric and perchloric acids (1:1 v/v). All determinations were done in triplicates.

Analysis of Functional Properties

The determination of water and oil absorption capacities followed a modification of the method of Prinyawiwatkul et al. (1997), as described by Enujiugha and Akanbi (2005). Each flour sample (5.0 g) was thoroughly mixed, without pH adjustment with 25 ml of deionized water or oil in 50-ml centrifuge tubes. Suspensions were stirred intermittently over a 30 min period at room temperature (28 ± 2 ºC) and then centrifuged at 12,000 x g for 30 min at 25 ºC. The volume of decanted supernatant was measured, and the water and oil absorption capacities were then calculated.

For the least gelation concentration, triplicate suspensions of 1 - 20% seed flour sample (dry w/v, at 1% increment) were prepared in 10 ml of deionized water and mixed thoroughly without pH adjustment. The slurries were heated in 125 x 20 mm screw- capped test tubes in a water bath with in-built magnetic stirrer (Julabo Model SW22, Julabo Labortechnik GMBH, Seelbach, Germany) at 95 ± 2 ºC. After 1 h of heating, tubes were immediately cooled in tap water for 30 s and then in ice water for 5 min to accelerate gel formation. All tubes were then held at 4 ºC for 3 h. The least gelation concentration (percent) was determined as the concentration above which the sample remained in the bottom of the inverted tube (Enujiugha et al., 2003).

The foaming properties of the samples were determined using the procedure of Coffman and Garcia (1977). Exactly 2.0 g of sample was weighed into 60 ml distilled water in a 100 ml cylinder. Solid material was dispersed with spatula and the suspension was whipped for 5 min using ultra-Turax T25 mixer at a high speed. Volumes before and after whipping were noted and volume increase due to whipping was then calculated. The volume of foam in the standing cylinder was also recorded for foam stability studies at 1, 5, 10, 20, 30, 60, 90, 120 and 180 min after whipping. The results were expressed in percentages.

Emulsifying properties were determined using a modification of the method described by Ige et al. (1984). A known quantity (1.8 g) of sample was dispersed in 25 ml distilled water, and 25 ml vegetable oil (pure groundnut oil) was added. The 50 ml mixture was emulsified at high speed using ultra-Turax T25 mixer for 1 min. Emulsion was filled into centrifuge tubes and centrifuged for 5 min at 1,300 x g.

Pasting properties

Pasting properties of Elekute flour were determined using Rapid Visco Analyzer (Perten German model RVA 4500). About 3 g of sample was weighed into the equipment canister and 25 ml of distilled water was added on the 14.00% moisture basis. The mixture was heated to 50 ºC and stirred at 150 rpm for 20 s for thorough dispersion and held for 1 min at the same temperature before being heated to 95 ºC over 10 min and held at the same temperature for 3 min and finally cooled to 50 ºC.

Determination of antioxidant properties

The total phenol content of the extract was determined by the method of Singleton et al. (1999). An aliquot of the extract (0.2 ml) was mixed with 2.5 ml of 10% Folin Ciocalteau's reagent and 2 ml of 7.5% Sodium carbonate. The reaction mixture was subsequently incubated at 45 ºC for 40 min, and the absorbance was measured at 700 nm using the spectrophotometer. Garlic acid was used as standard phenol.

The total flavonoid content of the extract was determined using a colourimeter assay developed by Bao (2005). Exactly 0.2 ml of the extract was added to 0.3 ml of 5% $NaNO_3$ at zero time. After 5 min, 0.6 ml of 10% $AlCl_3$ was added and after another 6 min, 2 ml of 1 M NaOH was added to the mixture followed by the addition of 2.1 ml of distilled water. Absorbance was read at 510 nm against the reagent blank and flavonoid content was expressed as mg rutin equivalent.

The reducing property of the extract was determined by Pulido et al. (2000) method. A known volume of extract (0.25 ml) was mixed with 0.25 ml of 200 mM of Sodium phosphate buffer pH 6.6 and 0.25 ml of 1% KFC. The mixture was incubated at 50 ºC for 20 min, thereafter 0.25 ml of 10% TCA was also added and centrifuged at 2000 rpm for 10 min; then 1 ml of the supernatant was mixed with 1 ml of distilled water and 0.1% of $FeCl_3$. The absorbance of the mixture was measured at 700 nm.

The free radical scavenging ability of the extract against DPPH (1, 1- diphenyl-2-picryhydrazyl) was carried out using Enujiugha et al. (2012) method. About 1 ml of the extract was mixed with 1 ml of the 0.4 mM methanolic solution of the DPPH. The mixture was left in the dark for 30 min before measuring the absorbance at 516 nm.

The 2, 2'-azino-bis (3-ethylbenthiazoline-6-sulphonic acid) (ABTS) scavenging ability of the extract was determined according to the method described by Re et al. (1999). The ABTS was generated by reacting an 7 mM ABTS aqueous solution with $K_2S_2O_8$ (2.45 mM/l, final conc.) in the dark for 16 hours and adjusting the absorbance at 734 nm to 0.700 with ethanol; and 0.2 ml of the appropriate dilution of the extract was then added to 2.0 ml of ABTS solution and the absorbance was read at 732 nm after 15 min. The TROLOX equivalent antioxidant capacity was subsequently calculated (548.88 g)

Anti-nutrient determination

About 0.2 g of finely ground sample was weighed into a 50 ml sample bottle. Then 10 ml of 70% aqueous acetone was added and properly covered. The bottle was put in an ice bath shaker and shaken for 2 hours at 30 ºC .Each solution was then centrifuged and the supernatant stored in ice. About 0.2 ml of each solution was pipetted into the test tube and 0.8 ml of distilled water was added. Standard tannic acid solutions were prepared from a 0.5 mg/ml of the stock and the solution made up to 1 ml with distilled water. Then 0.5 ml of Folin Ciocalteau reagent was added to both sample and standard followed by 2.5 ml of 20% Na_2Co_3 solution. This was then vortexed and allowed to incubate for 40 minutes at room temperature, its absorbance was read at 725 nm against a reagent blank concentration of the same solution from a prepared standard tannic acid curve (Makkar and Goodchild, 1996).

Phytate was determined according to the method of Wheeler and Ferrel (1971). Four grams (4 g) of sample was soaked in 100 ml of 2% HCl for 3 h and then filtered through a No 1 Whatman filter paper. Twenty-five millilitres (25 ml) was taken out of the filtrate and placed inside a conical flask and 5 ml of 0.3% of ammonium thiocyanate solution was added as indicator. After which 53.5 ml of distilled water was added to give it the proper acidity and this was titrated against 0.00566 g per milliliter of standard iron (iii) chloride solution that contains about 0.00195 g of iron per milliliter until a brownish yellow colouration persisted for 5 min.

The determination of oxalate was performed by soaking 1 g of the sample in 75 ml of 1.5 N H2SO4 for 1 hour, followed by filtration through a No. 1 Whatman filter paper. Subsequently, 25 ml of the filtrate was transferred into a conical flask and titrated at a temperature of about 80-90°C with 0.1 M KMnO4 until a persistent pink coloration was observed for 15 seconds (Day and Underwood, 1986).

Trypsin inhibitor was extracted by mixing 1 g of the sample with 50 ml of 0.01N NaOH at pH of between 8.4-10.00 and allowing the mixture to stand for 3 h, while stirring at intervals. Two millilitres (2 ml) of diluted extract was then dispensed into test tubes to which 2 ml of cold trypsin solution (4 mg in 200 ml of 0.001 M HCl) was added, and the tubes were placed in water bath at 37 ºC, 5 ml of Benzoyl-DL-arginine-P-nitro anilide hydrochloride (BAPNA) (40 mg) was dissolved in 1 ml of dimethyl sulfoxide and diluted to 100 ml with tris buffer 0.05 M, pH 8 and diluted to 100 ml with tris buffer 0.05M, pH 8.2, pre warmed to 37 °C) was added as substrate to each tube. After 10 min the reaction was terminated by adding 30% acetic acid and the content of each tube was thoroughly mixed. Thereafter the content of each tube was centrifuged at 3000 rpm and the absorbance of the filtrate was measured at 410 nm against reagent blank. The reference was prepared using the same procedure as the sample except that 2 ml of distilled water was added in place of extract (Smith *et al*., 1980).

Alpha-Glucosidase Inhibitory Assay

The effect of the plant extracts on α-glucosidase activity was determined according to the method described by Kim et al. (2005) using α -glucosidase from *Saccharomyces cerevisiae*. The substrate solution p-nitrophenylglucopyranoside (pNPG) was prepared in 20 mm phosphate buffer, and pH 6.9. Hundred micolitre (100 μL) of α-glucosidase (0.3 U/mL) was pre-incubated with 50 μL of the sample for 10 min. Then 50 μL of 3.0 mm (pNPG) as a substrate dissolved in 20 mm phosphate buffer (pH 6.9) was then added to start the reaction. The reaction mixture was incubated at 37 ℃ for 20 min and stopped by adding 2 mL of 0.1 M Na_2CO_3. The α-glucosidase activity was determined by measuring the yellow-colored paranitrophenol released from pNPG at 405 nm.

Assay for α –amylase inhibition

The method used involved estimating the amount of reducing sugar produced by the activity of each enzyme on buffered starch. α - amylase was assayed as reported by De Moraes et al. (1999). The substrate for assay was 0.5 ml of 0.5% soluble starch, buffered with 0.2 ml of 0.1 M sodium acetate (pH 5.6). Crude enzyme extract (0.3ml) was added to the mixture, mixed and incubated at 40 ºC for 30 min in a water-bath. DNSA (colorimetric) method was thereafter employed for estimation of reducing sugars produced. One ml of DNSA solution was added to the mixture and boiled for 5 min. Four ml of distilled water was introduced after cooling before absorbance is read at 540 nm in spectrophotometer. Blank that consisted of 0.3 ml distilled water, 0.5 ml of 0.5% soluble starch, 0.2 ml of buffer was subjected to similar treatments.

Angiotensin – Converting Enzyme Assay

Apprropriate dilution of the extracts (0-500 Ml) and solution (50 ml, 4 mU) was incubated at 37 ºC for 15 min. The enzymatic reaction was initiated by adding 150 mL of 8.33 mM of the substrate Bz-Gly-His-Leu in 125 ml MTris-HCLbuffer (pH 8.3) to the mixture. After incubation for 30 minutes at 37^0C, the reaction was arrested by adding 250 mL of 1M HCl. The Bz-Gly produced by the enzymatic reaction was extracted with 1.5 ml ethyl acetate. Thereafter the mixture was centrifuged to separate the ethyl acetate layer, then 1 ml of the ethyl acetate layer was transferred to a clean test tube and evaporated. The residue was re-dissolved in distilled water and its absorbance was measured at 228 nm. The ACE inhibitory activity was expressed as percentage inhibition.

Determination of In-vitro starch digestibility

In-vitro starch digestibility of samples was determined using pancreatic amylase and alpha glucosidase (Singh et al., 1982). 50 mg of the sample was dispersed in 1ml of 0.2 M phosphate buffer pH 6.9. 20 mg of the enzyme was dissolved in 50 ml of the same buffer, and the mixture was heated for 5 min in a boiling water bath. After cooling the absorbance the solution was read at 540 nm against the blank containing buffer and the maltose was used as a standard.

Determination of In-vitro protein digestibility

In-vitro protein digestibility of samples was determined using the modified procedure of Hsu et al (1977). The enzymes used include porcine pancreatic trypsin and pepsin. The activity of the enzymes was initially determined before use by using them to digest casein. 100 mg of the sample were dispersed in 1.0 ml of phosphate buffer pH 7.4. 25 mg of both porcine pancreatic trypsin and pepsin were dissolved in 1.0 ml of distilled water. 200 µl of the sample was dispensed into test tube and 200 µl of the enzymes was added to it and incubated at 37 ºC for 30 min. 2.0 ml of copper alkaline solution was added to it and allowed to stand for 10min, immediately after 10 min, 0.5 ml of folinciocalteau reagent was added and incubated at room temperature for 30 min. The absorbance was measured at 700 nm against reagent blank. The standard calibration curve was prepared using 100 µg/ml of bovine serum albumin (BSA).

Sensory evaluation

This was done using a randomly-selected thirty (30)-member panel of assessors, who were familiar with the sensory properties of the snack (Elekute). Each panelist was asked to score each attribute on a nine point hedonic scale where 1 and 9 represent dislike and like extremely, respectively. The attribute evaluated were colour, taste, aroma, texture, appearance, and overall acceptability. Data obtained were subjected to appropriate statistical analysis using ANOVA to detect differences in the mean scores and Duncan Multiple range test to separate the differences among the means.

Statistical analysis

Statistical analysis was carried out using statistical package for social science (SPSS) version 21.0 for windows. The results were presented as mean (±SEM) and statistical difference between the means was determined using one-way analysis of variance (ANOVA) while means were separated at $p<0.05$ significant difference using New Duncan Multiple Range Test (NDMRT).

Results and Discussion

Proximate Composition of the Maize-Catfish Elekute

The proximate composition of the maize-catfish Elekute is presented in Table 1. The moisture content of the Maize-catfish Elekute ranged from 3.19% in the TP (Elekute produced using 100% maize flour) to 10.20% (Elekute produced with 60% maize flour and 40% catfish). Statistically, significant differences existed in the moisture content of all the blends (at $p \leq 0.05$). The moisture content of the maize-catfish was found to increase with increased substitution of the maize flour with catfish flour. The moisture content of food samples, converted into their flour forms, usually determines their shelf life, and therefore, their storability (Ashun *et al*., 2019). The moisture content obtained in this study are higher than that obtained by Araoye *et al*. (2021) for Elekute formulated from Bambara-nut, maize and ripe-plantain blends. However, the moisture content of all the blends of Elekute in this study, are found in the range of the FAO recommended level (< 10%) for most dried food samples which suggests that the shelf-life of the products will be maintained all things being equal (Adesanmi *et al*., 2020).

The crude fibre content of the elekute ranged from 4.37% in the BT (formulated with 60 % maize, 40% catfish flour) to 7.51% in AA (formulated from 70% Maize, 30% catfish flour). Significant differences existed in the crude content of all the blends (at p ≤ 0.05). Crude fibre decreased with decreased level of maize flour in the blends. Similar results were obtained by Lawal and Enujiugha (2016) for maize-based Elekute enriched with African oil bean seed (*Pentaclethra macrophylla* benth) with crude fibre content ranging from 3.51 to 7.92 %. Crude fibre reduces the rate of the release of glucose into the blood stream and also reduces the intercolonic pressure hence minimizing the risks of colon cancer. Plant fibre consist mainly of cell wall which is comprised of indigestible carbohydrate substances such as cellulose, hemicellulose, lignin and pectin (Godswill, 2019).

The protein content of the elekute varied from 6.86% in the elekute produced from 100% maize flour to 14.43% in BT (the elekute produced with 60 % maize and 40% catfish flours). This shows that the protein content increased with increased addition of catfish flour. There are significant differences (at p<0.05) of all the blends except the control (Elekute produced with 100% maize flour) and XP (the elekute produced with 90% maize flour and 10% catfish flour which showed no significant variation. The protein content of the elekute increased in a similar way as that reported by Idowu (2021) for maize elekute enriched with African Yam Bean flour. The protein enrichment of the maize-elekute with catfish flours suggests that it could be used to mitigate protein-energy malnutrition in children in developing countries.

The ash content of the maize-catfish elekute ranged from 3.03% to 5.52% in a similar way as the protein contents. There were statistical significant differences (at p <0.05) in the ash contents of all the blends except XP (produced from 90% maize and 10% catfish flours) and AA (produced from 80% maize flour and 20% catfish flour). Generally, the ash content increased with increased addition of catfish flours in the elekute. Ash refers to the inorganic (mineral) residue remaining after the combustion or complete acid-facilitated oxidation of organic matter in food (Harris and Marshall, 2017). The ash content of food determines the levels of the inherent minerals present in the food (Victor and Olubukola, 2018). Minerals are essential for the normal function of the cells and immune system and most times work with enzymes and antioxidants in cell protection.

The fat content of the maize-catfish elekute ranged from 2.74% in the TP, control blend (produced with 100% maize flour) to 4.73% in BT (produced with 60% maize and 40% catfish flours). There are significant differences in the fat content of all the samples (at p < 0.05). The fat content of the blends increased with increase in the catfish flour. Dietary fat provide energy, essential fatty acids, transport fat soluble vitamins (A, D, E and K) and aids palatability of food (Gebrezgi, 2019). The low fat content of the elekute suggests that the products will be protected from spoilage due to the effect of lipid oxidation.

The carbohydrate content of the maize-catfish elekute varied from 56.21% in RS (formulated with 50% maize and 50% catfish flours) to 76.38% in TP, control (formulated using 100% maize flour). The result shows that the carbohydrate content of the elekute blends decreased with increasing catfish flour and increased with increasing level of maize flour in the elekute blends. The carbohydrate contents obtained for this study is similar to that obtained by Arise *et al*. (2018) for maize snacks enriched with Bambara groundnut flour and considerably higher than that obtained by Obinna-Echem and Robinson (2019) for Maize-tigernut biscuits. Carbohydrates are sources of dietary energy. However, the decrease in carbohydrate contents of the elekute as the catfish flour increased will reduce weight gain and associated diseases such as cardiovascular diseases, diabetes and obesity when consumed by adults and the elderly.

Table 1: Proximate Composition of the Maize-Catfish Elekute

Sample	MC (%)	C. Fiber (%)	Protein (%)	Ash (%)	Fat (%)	CHO (%)
TP	3.19±0.070^{f}	6.52±0.028^{b}	6.86±0.064^{e}	3.03±0.021^{e}	2.74±0.014^{f}	76.38±0.176^{a}
RS	5.32±0.035^{d}	5.76±0.085^{c}	11.01±0.014^{b}	3.76±0.035^{c}	4.10±0.007^{b}	56.21±0.014^{e}
XP	4.10±0.035^{e}	4.71±0.269^{d}	6.89±0.021^{e}	3.38±0.177^{d}	2.85±0.014^{e}	74.29±0.014^{b}
BT	10.20±0.077^{a}	4.37±0.099^{e}	14.43±0.050^{a}	5.52±0.120^{a}	4.73±0.014^{a}	56.82±0.007^{e}
AA	8.82±0.148^{b}	7.51±0.014^{a}	10.09±0.050^{c}	3.40±0.007^{d}	3.88±0.035^{c}	58.97±0.644^{d}
BB	6.63±0.240^{c}	6.35±0.070^{b}	8.00±0.028^{d}	4.53±0.035^{b}	2.99±0.007^{d}	69.44±0.007^{c}

Means ± SD of duplicate readings
TP- 100% maize flour; RS- 50% Maize, 50% catfish flour; XP- 90 % Maize, 10% catfish flour; BT- 60% Maize, 40% catfish flour; AA: 70% Maize, 30% catfish flour; BB- 80% Maize, 20% catfish flour
Means that do not share a letter (superscript) across a column, are significantly different.

Mineral Composition of the Maize-Catfish Elekute

The mineral composition of the maize-catfish elekute is presented in Table 2 below. Minerals are essential nutrients that are needed to aid proper functioning of certain organs in the body (Inyang *et al*., 2019). Calcium content of the maize-catfish elekute ranged from 22.7 PPM in AA (70:30) to 40.26 PPM in BT (60:40). The Calcium content of all the blends were significantly different from one another (at p <0.05). The calcium content of the maize-catfish elekute was found to increase as the level of catfish increased in the samples. Calcium plays a crucial role in blood clotting, muscle contraction and in certain enzymes in metabolic processes (Inyang *et al*., 2019).

The magnesium content of the Elekute blends on the other hand, varied from 29.60 PPM in AA to 52.34 PPM in BT. There were significant differences (at p <0.05) among the magnesium content of all the elekute blends. The magnesium contents of all the elekute blends increased in a similar way as calcium in the samples; it increased as the level of catfish flour increased in the blends. Magnesium is important for bone health; is needed as a co-factor for numerous reactions in the body and is also essential for nerve and muscle conductivity (Inyang *et al*., 2019).

Iron content was found to be highest in the maize-catfish elekute blends with the highest levels of catfish flour. There was no significant difference in the Fe contents of sample BT (60:40) and RS (50:50) but they were significantly different from others. The result of Fe obtained in this study is higher compared to that obtained by Lawal and Enujiuha (2016) for maize-elekute enriched with African Oil bean seed. The production of blood in the body is associated with the availability of iron which is a key component of red blood cells. The deficiency of iron in the body can lead to anaemia (Adeloye *et al*., 2020).

The sodium content of the maize-catfish elekute blends ranged from 39.12 ppm in AA (70:30) to 69.14 ppm in BT (60:40). Significant differences existed in the Na content of all the elekute blends at $p < 0.05$. The addition of catfish flour was found to increase the Na content of the elekute. This increase can be explained from the findings of Emurotu *et al*. (2014), which reports that dried catfish is rich in sodium.

There were statistical significant differences in the potassium content of all the maize-catfish elekute blends. Potassium was a little lower in the elekute blends compared to Sodium. Catfish contains lower potassium content compared to sodium (Emurotu *et al*., 2014). However, the Potassium content was improved by the addition of catfish flour as seen in sample BT (60:40) and RS (50:50) respectively compared to that of control, TP (elekute produced from 100% Maize flour). High potassium intake is inversely associated with blood pressure in hypertensive populations (Wabo *et al*., 2022).

The phosphorus content of the elekute blends was highest in the blends with highest levels of catfish flour as compared to that produced with 100 % maize flour. There were significant differences in the phosphorus contents of all the blends at $p<0.05$. Phosphorus is an important mineral in the formation of bones and teeth. It is necessary for the body to utilize carbohydrates and fats. It is needed for the body to make proteins required for growth, maintenance and repair of cells and tissues. The increase in phosphorus content of the elekute due to the addition of catfish will be highly beneficial to the health of consumers.

Zinc did not increase significantly in the samples when catfish flour was added. However, the level of zinc in the control, TP (100% maize flour) was not significantly different from that of BT (60:40). Zinc is a cofactor that influences enzymes activities affecting growth and digestion and its deficiency results in growth retardation and impaired immune response (Adeloye *et al*., 2020).

The Cu content of the elekute blends were found to be highest in AA (70:30) and RS (50:50) but lowest in BB (80:20). The results of Cu obtained in this study are higher than that obtained by Araoye *et al*. (2021) for the enrichment of maize-elekute with Bambara groundnut. Cu is a cofactor of antioxidant enzymes necessary for protection of cells from free radicals and it also contributes to the iron absorption and maintenance of healthy bones.

Table 2: Mineral Composition (mg/100g) of the Maize-Catfish Elekut

Sample	Ca	Mg	Fe	Na	K	P	Zn	Cu
TP	28.47±0.049^{d}	36.98±0.028^{d}	1.23±0.007^{c}	48.85±0.014^{d}	43.96±0.014^{d}	23.14±0.014^{d}	1.87±0.014^{a}	1.67±0.014^{b}
XP	27.71±0.021^{e}	35.99±0.014^{e}	1.19±0,014^{c}	47.49±0,021^{e}	42.83±0.021^{e}	22.55±0.021^{e}	1.55±0.014^{b}	1.24±0.070^{d}
BB	32.23±0.028^{c}	41.88±0.014^{c}	1.38±0.014^{b}	55.34±0.021^{c}	49.81±0.014^{c}	26.22±0.014^{c}	1.12±0.014^{e}	1.06±0.014^{e}
AA	22.77±0.014^{f}	29.60±0.021^{f}	0.98±0.014^{d}	39.12±0.028^{f}	35.21±0.036^{f}	18.53±0.014^{f}	1.43±0.014^{c}	1.95±0.014^{a}
BT	40.26±0.028^{a}	52.34±0.028^{a}	1.73±0.021^{a}	69.14±0.014^{a}	62.22±0.014^{a}	32.78±0.035^{a}	1.90±0.028^{a}	1.38±0.014^{c}
RS	39.69±0.021^{b}	51.58±0.014^{b}	1.71±0.021^{a}	68.15±0.014^{b}	61.34±0.014^{b}	32.29±0.014^{b}	1.18±0.021^{d}	1.92±0.028^{a}

Means ± SD of duplicate readings
TP- 100% maize flour; RS- 50% Maize, 50% catfish flour; XP- 90 % Maize, 10% catfish flour; BT- 60% Maize, 40% catfish flour; AA: 70% Maize, 30% catfish flour; BB- 80% Maize, 20% catfish flour
Means that do not share a letter (superscript) across a column, are significantly different.

Functional Properties of Maize-Catfish Elekute

The functional properties of the maize-catfish elekute are presented in Table 3. There was no significant difference in the WAC at $p\leq0.05$. The WAC capacity of the elekute however, increased with increase in maize flour in the blends. It was highest in the control elekute, TP (100:0) and lowest in RS (50:50). This result is similar to that obtained by Adebayo-Oyetoro *et al*. (2021) for complementary food produced from locally fermented maize flour blended with sprouted velvet bean *(Mucuna utilis)* flour. Shad *et al*. (2013) reported a high water absorption capacity for maize flours. Water absorption capacity (WAC) is a property that describes the ability of flour to absorb water during processing. It is also an important property which can be used to determine if the flour can be employed in food formulations (Adebayo-Oyetoro *et al*., 2021).

The Oil Absorption Capacity (OAC) ranged from 0.80g/g in BB (80:20) to 0.94g/g in the control elekute, TP (100:0). Significant differences were found in the OAC of TP and XP but not in TP and XP at $p\leq0.05$. The OAC decreased with increased addition of catfish flour but not significantly. OAC indicates the enhanced hydrophobic character of proteins in the flours. Additionally, it is exhibited by the proteins in the flour which physically bind to fat by capillary attraction. These proteins expose more non-polar amino acids to the fat and enhance hydrophobicity as a result of which flours absorb oil (Shad *et al*., 2013).

The Emulsion Capacity of the Elekute blends ranged from 44.48% in RS (50:50) to 48.61 % in the control, TP (100:0). The Emulsion Capacity (EC) of the samples decreased with increasing addition of catfish flour. Significant differences occurred in the EC of the elekute blends at $p\leq0.05$. EC is the maximum amount of oil emulsified by protein in the given amount of flour (Ishara *et al*., 2018).

The swelling capacity of the maize-catfish elekute blends varied from 336.50% in BT (60:40) to 410.01% in XP (90:10). Significant differences existed among all the blends at $p \leq 0.05$. The SC decreased with decreasing level of maize flour. As more catfish was added, SC decreased in the samples. The swelling capacity (index) of flours are influenced by the particle size, species variety and method of processing or unit operations. High starch content has been noted to increase the swelling capacity of foods and flours, especially in starch with higher amount of the branched amylopectin (Awuchi *et al*., 2019). The decrease in swelling capacity as maize flour decreases may be as a result of reduction in starch content. Maize have been reported to be made up of 60.38 to 66.31% starch (Khan *et al*., 2014).

The foaming capacity of the maize-catfish elekute were highest for the control, TP (100:0) and RS (50:50) but was limited for other samples. Foaming capacity is used to determine the capacity of the flour to foam which is dependent on the presence of the flexible protein molecules which decrease the surface tension of water (Ohizua *et al*., 2017).

The bulk density of the formulated elekute blends ranged from 0.68 to 0.79 g/cm^3. There was no statistical significant difference in the bulk density of the samples at $p \leq 0.05$ though the bulk density was found to slightly decrease with increasing level of catfish flour. The differences in bulk density of foods could be due to the variation in starch content of the foods. The higher the starch content the more likely the increase in bulk density. Also, bulk density depends on factors such as geometry, method of measurement, particle size, surface properties, and solid density of the materials. Bulk density depicts the relative volume or capacity of the required packaging material. The higher the bulk density of the flour, the denser the packaging material required for packaging. It indicates the porosity of a food product which impacts the design of the package and can be used in determining the type of the required packaging material (Awuchi *et al*., 2019). The decrease in the bulk density of the elekute with addition of catfish may be important in minimizing the cost of packaging materials required for the product.

The Least Gelation Concentration (LGC) of all the samples were at a fixed proportion of 3.40% and so no significant differences were observed among all the blends. LGC is the ability of flour to form gel which provide structural matrix for holding water and other water-soluble materials like sugars and flavours. The increasing concentration of proteins facilitates the interaction among the binding forces which in turn increases the gelling ability of flour. The lower the LGC value the better the gelling ability of the flour (Shad *et al*., 2013). The values of LGC obtained in this study is slightly lower than that obtained by Lawal and Enujuigha (2016) for maize Elekute enriched with African Oil bean seed.

Table 3: Functional Properties of the Maize-Catfish Elekute

Sample	WAC(g/g)	OAC (g/g)	Emulsion (%)	Swelling capacity (%)	Foaming capacity (%)	Bulk density (g/cm^3)	Least Gelation Concentration (%)
TP (100:0)	1.79±0.021^a	0.94±0.070^a	48.61±0.057^b	392.50±2.121^b	4.79±0.042^a	0.74±0.021^a	3.40±0.01^a
RS (50:50)	1.65±0.077^a	0.88±0.028^b	44.48±0.057^d	350.00±2.828^d	4.80±0.057^a	0.68±0.014^a	3.40±0.00^a
XP (90:10)	1.73±0.035^a	0.94±0.042^{ab}	51.00±1.414^a	410.01±0.014^a	0.00±0.000^b	0.69±0.021^a	3.40±0.01^a
BT (60:40)	1.71±0.162^a	0.90±0.000^a	47.53±0.665^a	336.50±7.778^e	0.00±0.000^b	0.68±0.007^a	3.40±0.01^a
AA (70:30)	1.76±0.014^a	0.87±0.014^{ab}	45.81±0.134^{cd}	362.00±1.414^c	0.00±0.000^b	0.79±0.162^a	3.40±0.01^a
BB (80:20)	1.65±0.021^a	0.80±0.028^b	47.13±0.099^{bc}	345.00±2.829^e	0.00±0.000^b	0.75±0.084^a	3.38±0.01^a

Means ± SD of duplicate readings TP- 100% maize flour; RS- 50% Maize, 50% catfish flour; XP- 90 % Maize, 10% catfish flour; BT- 60% Maize, 40% catfish flour; AA: 70% Maize, 30% catfish flour; BB- 80% Maize, 20% catfish flour. WAC water absorption capacity; OAC oil absorption capacity
Means that do not share a letter (superscript) across a column, are significantly different

Pasting Properties of Maize-Catfish Elekute

The pasting properties of the maize-catfish elekute blends are shown in Table 4. The peak viscosity varied from 31.00 in RS (60:40) to 118 mPa.s in XP (90:10). The peak viscosity decreased with increasing level of catfish flour in the blends. Significant differences existed among all the peak viscosities of the all the samples. The peak viscosity (PV) is defined as the maximum viscosity reached where starch granules swell to the maximum extent (Liu *et al*., 2021). Increased peak viscosity have been attributed to be a function of higher starch concentration (Waterschoot *et al*., 2014). This explains the decrease in peak viscosity as catfish flour increases in the elekute blends.

The trough viscosity also decreased with increasing levels of catfish flour in the samples. Significant differences occurred in the trough viscosities of all the elekute blends at $p \leq 0.05$. It was highest in XP (90:10) and lowest in BT (60:40). Trough viscosity is the point at which the viscosity reaches its minimum during either heating or cooling processes. It measures the ability of the paste to withstand breakdown during cooling (Sangeeta and Grewal, 2018).

The breakdown viscosity was found to be highest in RS (50:50) and XP (60:40) with the second to the highest and highest levels of catfish flour respectively. The addition of catfish flours up to 50% increased the breakdown viscosity of the control elekute (100% maize flour) by 60%. The breakdown viscosity is the difference between peak viscosity and trough viscosity (Kumar and Khatkar, 2017). The breakdown viscosity is regarded as a measure of the degree of disintegration of starch granules or paste stability during heating (Sangeeta and Grewal, 2018). Thus, the addition of catfish flours up to 40 to 50% improved the paste stability of the elekute during heating.

The final viscosity of the maize-catfish elekute ranged from 40.5 mPa.s in RS (50:50) to 266 mPa.s in XP (90:10). There was statistical significant differences among final viscosities of all the blends at $p \leq 0.05$. The results reveal a negative correlation with the final viscosity and the catfish flour. The final viscosity refers to the viscosity at the end of the pasting cycle (Balet *et al*., 2019).

The setback viscosity was highest in XP (90:10), followed by the control, TP (100:0). It was least in BB (80:20). It is clear that little addition of catfish flour (10% in XP) increased the setback viscosity drastically up to 138% in as compared to that of the control). Significant differences were observed among the setback viscosities of all the blends at p≤0.05. The setback value (SB) signifies the increase in viscosity resulting from the rearrangement of starch molecules leached from swollen starch granules during cooling (Liu et al., 2021). The setback viscosity (difference between peak and final viscosity) is exhibited due to recrystallization of amylose molecules in the gel, which is the measure of the gelling ability or retrogradation ability of starches (Kumar and Khatkar, 2017).

The Peak Time is the time taken by a sample to reach peak viscosity (Balet *et al*., 2019). The peak time of the samples ranged from 5.73 min in RS (50:50) to 7.00 min in XP (90:10). The time taken by a sample to reach peak viscosity is referred to Peak Time (Pt). The peak time decreased significantly (at p≤0.05) as the catfish flour increased in the elekute blends. The peak times obtained in this study are lower than that obtained by Lawal and Enujuigha (2016) for maize Elekute enriched with African Oil bean seed. Thus, RS (50:50) with a considerably low peak viscosity (45.00), lowest final viscosity (40.50), low setback value (12.00) and lowest peak time (5.73 min) may be of higher caloric density per unit volume and a preferred choice when pasting properties are being considered in food processing (Lawal and Enujiugha, 2016).

The temperature at which the viscosity starts to rise is called the pasting temperature (PT) (Liu *et al*., 2019). The pasting temperature varied from 74.00 °C in RS (50:50) to 96.00 °C in the control elekute (100:0). Significant differences were observed among the pasting temperatures of all the blends at p≤0.05. The pasting temperature decreased with increasing level of catfish flour in the blends. The high pasting temperature of starches *indicates a higher resistance to swelling and rupture* (Kumar and Khatkar, 2017). The results of the pasting temperature of the samples therefore reveals that addition of catfish flour decreased its resistant to swelling and rupture during heating compared to the control (100:0).

Table 4: Pasting Properties of the Maize-Catfish Elekute

Sample	Peak Viscosity (mPa.s)	Trough Viscosity (mPa.s)	Breakdown Viscosity (mPa.s)	Final Viscosity (mPa.s)	Setback Viscosity (mPa.s)	Peak Time (min)	Pasting Temp. (°C)
TP	81.05±0.071^{b}	70.50±0.849^{b}	10.00±0.071^{b}	140.50±0.849^{b}	69.00±0.707^{b}	6.93±0.014^{ab}	96.00±0.212^{a}
RS	45.00±0.141^{e}	29.00±0.071^{e}	16.00±0.212^{a}	40.50±0.849^{f}	12.00±0.071^{e}	5.73±0.028^{d}	74.00±0.141^{f}
XP	118.00±0.707^{a}	102.00±0.141^{a}	16.00±0.141^{a}	266.00±0.071^{a}	164.00±0.283^{a}	7.00±0.028^{a}	93.50±0.141^{b}
BT	31.00±0.141^{f}	28.00±0.071^{e}	3.00±0.028^{d}	53.00±0.057^{e}	25.00±0.042^{d}	6.80±0.028^{c}	77.00±0.141^{e}
AA	53.00±0.071^{d}	49.00±0.028^{d}	4.00±0.042^{c}	77.00±0.141^{c}	28.00±0.057^{c}	6.87±0.028^{bc}	89.50±0.283^{c}
BB	58.00±0.283^{c}	54.00±0.707^{c}	4.00±0.071^{c}	60.00±0.141^{d}	6.00±0.071^{f}	6.80±0.042^{c}	84.50±0.424^{d}

Means ± SD of duplicate readings
TP- 100% maize flour; RS- 50% Maize, 50% catfish flour; XP- 90 % Maize, 10% catfish flour; BT- 60% Maize, 40% catfish flour; AA: 70% Maize, 30% catfish flour; BB- 80% Maize, 20% catfish flour
Means that do not share a letter (superscript) across a column, are significantly different

Antinutrient Content of the Maize-Catfish Elekute

The tannin content of the maize-catfish elekute ranged from 1.13 mg/g in BT (60:40) to 1.89 mg/g in XP (90:10). Significant differences occurred among the samples except for RS (50:50) and BB (80:20) which were not significantly different from TP (100:0) at p≤0.05. Tannins have beneficial properties such as antioxidant activities and non-beneficial properties such as chelation of zinc, manganese, and calcium, making them less available (Eleazu *et al*., 2020). The addition of catfish flours up to 40 % as seen in BT (60:40), reduced the tannin content of the samples compared to the control, TP (100:0), which is suggestive that important minerals will be more available in the elekute with the addition of catfish flour. The phytate content of the maize-catfish elekute varied from 9.06 mg/g in BT (60:40) to 15.25 mg/g in XP (90:10). Phytate was found to decrease considerably with the addition of catfish flour. The decrease in phytate content in BT was significant (at p≤0.05) compared to the phytate content of the control, TP and it was found to be 37%. Phytic acid is a chelating agent that reduces the bioavailability of calcium, magnesium, zinc, and iron, through the formation of insoluble complexes with them (Eleazu *et al*., 2020). Generally, cereals are high in phytates (Adejobi et al., 2024). The reduction of phytate with the addition of catfish flour is positive for consumer's health from a nutritional point of view.

The Trypsin Inhibitor Activity (TIA) of the maize catfish elekute blends increased with increasing level of catfish flour. It was 13.95% in the control elekute (TP, 100:0), but drastically increased to 30.77 % in RS (50:50). The increase in the TIA of the elekute as catfish flour increases may be as a result of the high content of TIA in the catfish which was probably fed with fish feeds with a high level of soymeal. Soybean has been reported to contain a TIA of 94.1 U/mg (Avilés-Gaxiola *et al*., 2018). Trypsin inhibitors (TIs) are one of the most relevant Antinutritional Factors (ANFs) because *they reduce digestion and absorption of dietary proteins* (Avilés-Gaxiola *et al*., 2018).

The oxalate content of the maize-catfish elekute ranged from 0.32 mg/g in BT (60:40) to 0.59 mgg in XP (90:10). The results of oxalate showed a significant (at p≤0.05) decrease in oxalate levels as catfish levels in the blends increased. Plants and their products have been reported to be the major sources of dietary oxalate, and studies have shown that frequent consumption of foods with high levels of oxalate could inhibit calcium absorption and increase the risk of kidney stones (Eleazu *et al*., 2020). However, the oxalate levels obtained in this study are lower than that obtained by Lawal and Enujiugha (2016) for maize Elekute enriched with African Oil bean seed.

Table 5: Antinutrient Content of the Maize-Catfish Elekute

Sample	Tannin (mg/g)	Phytate (mg/g)	TIA (%)	Oxalate (mg/g)
TP (100:0)	1.65±0.014[b]	14.42±0.587[a]	13.95±0.148[d]	0.50±0.063[ab]
RS (50:50)	1.59±0.283[b]	11.13±0.587[bc]	30.77±0.382[a]	0.36±0.000[cd]
XP (90:10)	1.89±0.042[a]	15.25±1.747[a]	24.02±0.354[b]	0.59±0.063[a]
BT (60:40)	1.13±0.106[d]	9.06±0.000[c]	24.13±0.064[b]	0.32±0.063[d]
AA (70:30)	1.23±0.190[c]	9.89±0.000[bc]	18.90±0.156[c]	0.36±0.000[cd]
BB (80:20)	1.61±0.021[b]	11.95±0.580[bc]	23.74±0.063[b]	0.45±0.000[bc]

Means ± SD of duplicate readings
TP- 100% maize flour; RS- 50% Maize, 50% catfish flour; XP- 90 % Maize, 10% catfish flour; BT- 60% Maize, 40% catfish flour; AA: 70% Maize, 30% catfish flour; BB- 80% Maize, 20% catfish flour
TIA- Trypsin Inhibitor Activity
Means that do not share a letter (superscript) across a column, are significantly different

Antioxidant Properties of the Maize-Catfish Elekute

The antioxidant properties of the maize-catfish elekute is presented in Table 6. The phenol content of the maize-catfish elekute blend ranged from 8.26 mg/g in BT (60:40) to 14.59 mg/g in BB (80:20). Statistical significance occurred in the phenol content of all the elekute blends except in RS (50:50) and XP (90:10) which were not significantly different at $p\leq0.05$. Diets rich in phenolic have been linked to the prevention of aging-related diseases such as cancer, neurodegenerative diseases, and cardiovascular disease because of their free radical scavenging abilities by which they prevent oxidative stress (Butts-Wilmsmeyer *et al*., 2018). The rich content of phenols in the maize-catfish elekute will contribute greatly to consumer health and wellbeing. The flavonoid content of the maize-catfish elekute blends varied from 0.18 mg/g in BT (60:40) to 0.32 mg/g in BB (80:20). Significant differences existed among the flavonoid content of all the blends except for XP (90:10) and RS (50:50) and XP and AA (70:30) which are not significantly different at $p\leq0.05$. The addition of catfish flours up to 20% as seen in BB increased the flavonoid content by 18.5 % as compared to the control elekute, TP (100:0). Flavonoids possess a number of medicinal benefits, including anticancer, antioxidant, anti-inflammatory, and antiviral properties. They also have neuroprotective and cardio-protective effects (Ullah *et al*., 2020). More specifically, flavonoids in maize flour have been reported to possess antimutagenic properties (Loarca-Piña *et al*., 2019).

The stable DPPH radical, which has maximum absorption at 515 nm, is used widely to evaluate the free radical scavenging activity of hydrogen-donating antioxidants in many plant extracts. The ABTS method is employed extensively to measure the relative radical scavenging activity of hydrogen-donating and chain-breaking antioxidants in many plant extracts (Woo *et al*., 2018). The DPPH radical scavenging capacity of the elekute blends was found to be highest with a value of 77.66% in BB (80:20) and lowest with a value of 57.17% in BT (60:40). However, the addition of catfish flours up to 20% in BT significantly (at $p\leq0.05$) increased the DPPH radical scavenging ability of the flour to 6.2% compared to the control elekute, TP (100:0). The ABTS did not change significantly with the addition of catfish flour in comparison with the control sample, TP (100:0).

The Ferric Reducing Antioxidant Power (FRAP) assay is based on the reducing power of a compound (antioxidant) in a sample. It involves the reduction of the ferric ion (Fe^{3+}) to the ferrous ion (Fe^{2+}) by a potential antioxidant; the latter forms a blue complex (Fe^{2+}/TPTZ), which increases the absorption at 593 nm (Fernandes *et al*., 2016). The FRAP content of the elekute blends ranged from 11.04 mg/g in BT (60:40) to 25.41 mg/g in BB (80:20). Significant differences existed in the FRAP content of all the samples apart from that of TP (100:0) and BB (80:20) which were not significantly different at $p\leq0.05$. The addition of catfish flours up to 20% increased the FRAP content but the increase was not significant. However, adding catfish flours above 20% decreased the FRAP content of the elekute significantly $p\leq0.05$.

Sample BB (80:20) is noted to have a better antioxidant profile in all the antioxidant parameters measured compared to other samples.

Table 6: Antioxidant Properties of the Maize-Catfish Elekute

Sample	Phenol mg/g	Flavonoid mg/g	FRAP mg/g	DPPH %	ABTS Mol/g
TP	13.98±0.127[b]	0.27±0.000[b]	25.17±0.042[a]	73.14±0.566[b]	0.03±0.000[a]
RS	8.87±0.021[d]	0.22±0.000[d]	16.49±0.601[d]	62.17±2.722[c]	0.02±0.000[b]
XP	9.00±0.042[d]	0.23±0.000[cd]	20.03±0.353[c]	70.37±3.104[b]	0.03±0.070[b]
BT	8.26±0.197[e]	0.18±0.000[e]	11.04±0.191[e]	57.17±1.506[d]	0.02±0.000[b]
AA	13.15±0.021[c]	0.25±0.212[c]	23.81±0.198[b]	71.28±0.778[b]	0.02±0.000[b]
BB	14.59±0.39[a]	0.32±0.000[a]	25.41±0.162[a]	77.66±0.389[a]	0.03±0.000[a]

Means ± SD of duplicate readings
TP- 100% maize flour; RS- 50% Maize, 50% catfish flour; XP- 90 % Maize, 10% catfish flour; BT- 60% Maize, 40% catfish flour; AA: 70% Maize, 30% catfish flour; BB- 80% Maize, 20% catfish flour
Means that do not share a letter (superscript) across a column, are significantly different

Alpha-amylase and alpha-glucosidase Inhibitory Activities of The Maize-Catfish Elekute

The alpha-amylase and alpha-glucosidase inhibitory activities of the maize-catfish elekute blends are presented in Figures 1 and 2. The alpha-amylase inhibitory activity was found to increase slightly with the addition of catfish flours up to 20% as seen in BB (80:20). However, it decreased significantly (at $p\leq0.05$) as the levels of catfish flour increased up to 40 and 50% as seen in BT (60:40) and RS (50:50). The results obtained in this study are significant can be justified by the fact that whole cereals are generally recommended for diabetic patients to control their blood glucose level due to the presence of dietary fibre, resistant starch, and polyphenolic compounds (Gong et al., 2020).

The alpha-glucosidase inhibitory activities of the maize-catfish elekute blends (Figure 2) was also found to be highest when catfish was added up to 20% (in BB, 80:20). However, beyond 30 %, the alpha-glucosidase inhibitory activities of the elekute blends decreased significantly but the decrease was not as low as that of the alpha-amylase inhibitory activities.

The dietary starch and other related carbohydrates are digested by α-amylase to large number of maltose, which is further digested by α-glucosidase to glucose to be absorbed in human intestine. Therefore, strict regulation of postprandial blood glucose by inhibiting α-glucosidase and α-amylase is significant for the development of diabetes and the prevention and treatment of diabetic patients (Gong et al., 2020). Therefore, the inhibition of these digestive enzymes especially alpha-glusosidase by the elekute suggests that the elekute will be good for the health of diabetics.

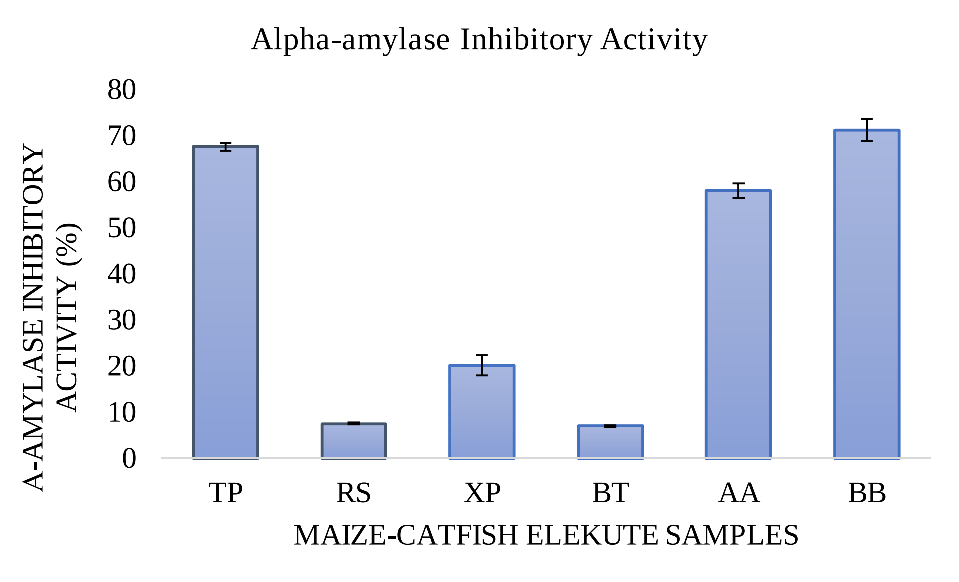

Figure 1: Alpha-Amylase Inhibitory Activity of the maize-catfish elekute blends
TP- 100% maize flour; RS- 50% Maize, 50% catfish flour; XP- 90 % Maize, 10% catfish flour; BT- 60% Maize, 40% catfish flour; AA: 70% Maize, 30% catfish flour; BB- 80% Maize, 20% catfish flour

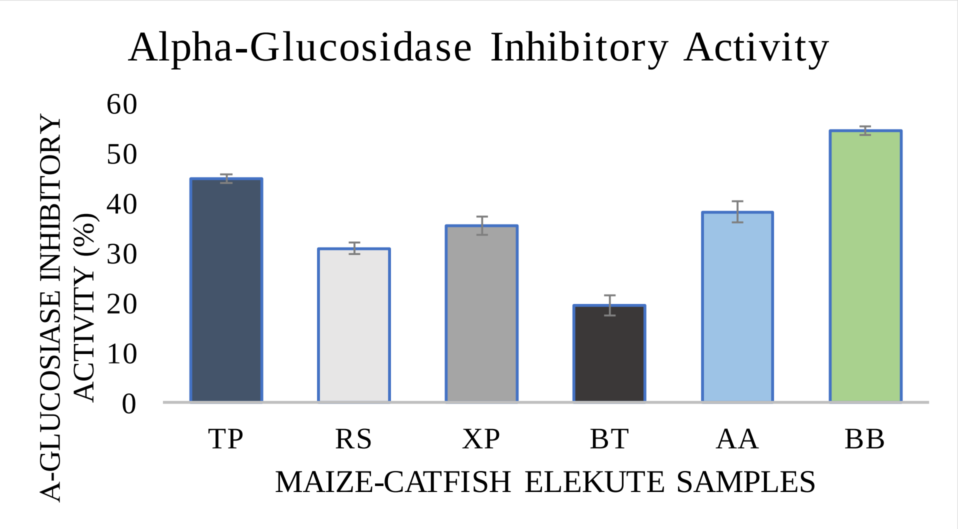

Figure 2: Alpha-Glucosidase Inhibitory Activity of the maize-catfish elekute blends
TP- 100% maize flour; RS- 50% Maize, 50% catfish flour; XP- 90 % Maize, 10% catfish flour; BT- 60% Maize, 40% catfish flour; AA: 70% Maize, 30% catfish flour; BB- 80% Maize, 20% catfish flour

In-vitro Starch and Protein Digestibility Properties of The Elekute

The in-vitro starch and protein digestibility properties of the maize-catfish elekute are presented in Figures 3 and 4 respectively. The in-vitro starch digestibility was highest in the control, TP (100:0) with 217.24 mg/g. However, with addition of catfish flour, the starch digestibility properties decreased significantly (at $p \leq 0.05$). It was lowest in the sample with the highest catfish flour, RS (50:50) with a decrease of 86% when compared to the starch digestibility of the control. Rapidly digestible starch is fast digested and absorbed in the gastrointestinal tract and causes a rapid rise in blood sugar and insulin which may result to several health challenges such as cardiovascular diseases and diabetes after a long period of consumption (Chinma *et al*., 2022). Therefore, the low starch digestibility of the elekute substituted with catfish flour will be good for the management and prevention of diabetes.

The in-vitro protein digestibility (figure 4) was highest for the control sample, TP (100:0) with 4.65 mg/g but decreased significantly (at p≤0.05) with the addition of catfish flours. However, there was no significant difference in the protein digestibility of other samples RS, XP, BT, AA and BB at p≤0.05. The decrease in the protein digestibility of the maize-catfish elekute may be attributed to the fact that plant proteins are more digestible than animal proteins. Many factors may influence the digestibility of proteins in foods including the presence of dietary fiber, antinutritional factors and process variables among others (Chinma *et al*., 2022).

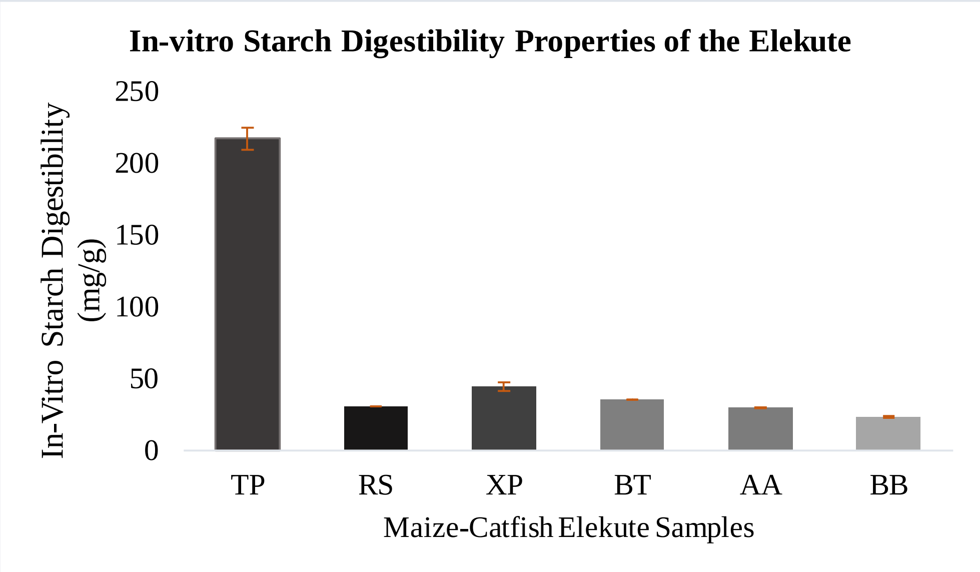

Figure 3: In vitro Starch Digestibility Properties of the maize-catfish elekute blends
TP- 100% maize flour; RS- 50% Maize, 50% catfish flour; XP- 90 % Maize, 10% catfish flour; BT- 60% Maize, 40% catfish flour; AA: 70% Maize, 30% catfish flour; BB- 80% Maize, 20% catfish flour

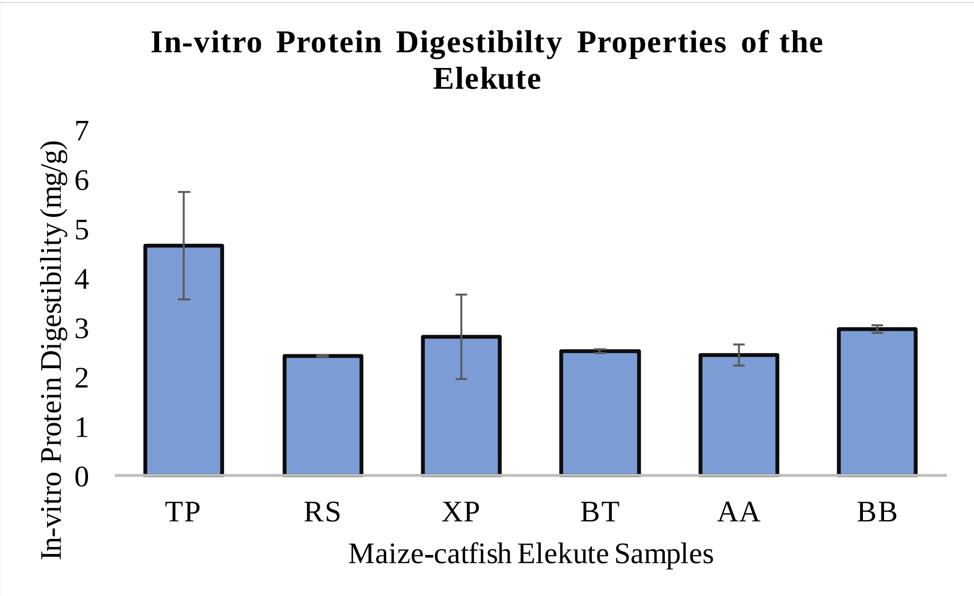

Figure 4: In vitro Protein Digestibility Properties of the maize-catfish elekute blends
TP- 100% maize flour; RS- 50% Maize, 50% catfish flour; XP- 90 % Maize, 10% catfish flour; BT- 60% Maize, 40% catfish flour; AA: 70% Maize, 30% catfish flour; BB- 80% Maize, 20% catfish flour

Sensory Characteristics of the Maize-Catfish Elekute

The sensory characteristics of the maize-catfish are shown in Table 9. The importance of the sensory quality in food acceptability cannot be over-emphasized (Makanjuola and Enujiugha, 2015). The taste of the elekute prepared using 100% maize flour was more preferred, followed by that with 10% catfish flour whereas the least preferred in terms of taste was AA (70:30). The addition of catfish flour did not significantly (at p≤0.05) improve the taste of the elekute. The colour of XP (90:10) was more preferred, followed by that of the control, TP (100:0) and then RS (50:50). In terms of colour, the addition of catfish flour at the level of 50% as seen in RS was not significantly different (at p≤0.05) from the control elekute. However, the colour of the elekute blends with catfish flours of 20, 30 and 40% had a lower colour preference among other samples. Colour is an important sensorial parameter when it comes to consumers making choice of food product. The texture of the elekute was also most preferred for the control, however, the addition of catfish flours up to 10% did not significantly (at p≤0.05) affect the preference of the texture as compared to that of the control (100:0). Texture is important as it affects both the mouthfeel of the product and the ease of chewiness and mastication of the product when being consumed. The aroma of the elekute blends was not significant in the control, TP (100:0), XP (90:10), BB (80:20) and BT (60:40) even though BB (80:20) had the highest preference based on the aroma. Addition of catfish flours at up to 20% improved the aroma but the improvement was not significant at p≤0.05. However, the aroma of AA (70:30) was least preferred among other samples. For the overall acceptability, the control elekute (100:0) had the highest, followed by XP (90:10) and RS (50:50). From the results, to obtain maximum sensorial acceptability, addition of catfish flours should be either at 10% or 50% levels. The results of the sensory acceptability are similar to that obtained by Araoye *et al*. (2021) for maize elekute enriched with Bambara groundnut and ripe plantain.

Table 9: Sensory Characteristics of the Maize-Catfish Elekute

Sample	Taste	Colour	Texture	Aroma	Overall acceptability
TP (100)	6.97±2.175[a]	7.03±1.402[a]	6.93±1.837[a]	7.40±1.404[a]	7.43±1.382[a]
XP (90:10)	6.23±2.192[ab]	7.10±1.269[a]	6.90±1.423[a]	7.27±1.461[a]	7.27±1.230[a]
BB (80:20)	5.30±0.651[c]	5.30±0.702[b]	6.10±0.923[b]	7.57±1.104[a]	6.13±0.629[b]
AA (70:30)	4.30±0.596[d]	5.17±0.592[b]	6.13±0.629[b]	6.33±1.845[b]	5.10±0.759[c]
BT (60:40)	5.43±1.569[bc]	5.53±1.167[b]	6.20±0.610[b]	7.10±1.494[ab]	5.50±0.861[c]
RS (50:50)	5.20±2.203[c]	6.80±1.627[a]	6.00±1.983[b]	7.00±1.509[ab]	6.57±1.251[b]

Means ± SD of duplicate readings
TP- 100% maize flour; RS- 50% Maize, 50% catfish flour; XP- 90 % Maize, 10% catfish flour; BT- 60% Maize, 40% catfish flour; AA: 70% Maize, 30% catfish flour; BB- 80% Maize, 20% catfish flour
Means that do not share a letter (superscript) across a column, are significantly different

Conclusion

The study revealed the possibility of enriching the nutritional (protein, ash, and mineral) contents of maize-based Elekute using catfish flour. The bulk density of the maize-catfish Elekute improved with inclusion of catfish flour as compared to that made with only maize which suggest a heavier packaging material requirement. The peak time and pasting temperature of the Elekute was found to reduce with the addition of catfish flour. The tannin, phytate and oxalate contents of the Elekute reduced with increased level of catfish flour. The antioxidant qualities were also enhanced with the inclusion of the catfish flour. The In- vitro starch digestibility properties of the Elekute decreased significantly with the addition of catfish flour which indicates slow digestion of the starch and this will be good for the management and prevention of diabetes. The sensory analysis showed that enrichment of Elekute with catfish flour is undesirable beyond 9t0:10 level of substitution.

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