Nixtamalization and fermentation enhance the Nutritional and Sensory Attributes of Maize and Cassava-based *fufu*

Abstract

This study evaluated the effects of nixtamalization and fermentation on the functional, nutritional, and sensory properties of maize and cassava-based *fufu* flours. Nixtamalized maize and fermented cassava were processed into flours and formulated in various ratios (2:1) to produce four samples: nixtamalized maize + fermented cassava (NXF), nixtamalized maize + non-fermented cassava (NXNF), non-nixtamalized maize + fermented cassava (NNF), and non-nixtamalized maize + non-fermented cassava (NNNF). All analyses were carried out using standard methods. Functional property analysis revealed significant differences ($p<0.05$) among samples, with NXF exhibiting the highest water absorption capacity (2.21 g/g) and swelling index (2.77 mL/g), while NXNF showed the highest bulk density (0.68 g/mL). Proximate composition indicated significant enhancement in protein (21.67% in NXNF) and ash content (3.88% in NXNF) due to the treatments. The mineral analysis demonstrated higher calcium (284.86 mg/100 g) and potassium (384.81 mg/100 g) in NXNF, while NXF displayed lower antinutrient levels, including tannins (0.58 mg/100 g) and phytates (1.47 mg/100 g), signifying improved nutritional value. Vitamin analysis revealed a significant increase in thiamine (0.55 mg/100 g) and niacin (0.65 mg/100 g) in NXF. Sensory evaluation ranked NXNF as the most preferred sample with an overall acceptability score of 8.15. The results indicate that nixtamalization and fermentation significantly improve the functional, nutritional, and sensory properties of maize and cassava-based *fufu* flours. It is recommended that these treatments be adopted to enhance the quality of *fufu* products to address nutritional deficiencies in staple diets and promote consumer acceptance. Further studies should explore scaling these processing techniques for industrial applications and evaluating their economic feasibility.

Keywords: Nixtamalization, Fermentation, *Fufu*, Nutritional Enhancement, Consumer acceptance

1.0 INTRODUCTION

Fufu is a thick, starchy paste commonly consumed in West Africa, where it serves as a dietary staple. It is prepared by adding flour to boiling water and vigorously stirring until a smooth, gelatinous consistency is achieved. The choice of ingredients, which include cassava, yam, cocoyam, potatoes, and cereals, determines its composition and nutritional profile (Akubor, 2019). It's generally known to be a fermented food product produced and consumed widely in West African countries, particularly Nigeria, Ghana, and Cameroon (Odoh et al., 2022). Although the term *fufu* is considered primarily a cassava-based product, *fufu* is known in other parts of Nigeria and Cameroon to be made from other sources. Some of these sources include yam, plantain, banana, and a host of cereal crops including maize or corn. Corn *fufu* is one of the so many Cameroon staple foods eaten almost daily by the most vulnerable rural dwellers. It is typically prepared using maize flour, and the preparation method involves boiling water and then adding maize flour, which is then stirred to form a uniform mix. The resulting gelatinous mass is then cooled and served with various soups, such as huckleberry, bitter leaf, okra, or *egusi* soup (Akubor, 2019; Odoh et al., 2022). Corn *fufu* analogs have been reported in some parts of Nigeria and other African countries for example "Ojeakpa" (known and indigenous to the Igala people of Kogi state). In such preparations, they incorporate cassava flour in small amounts maintaining corn *fufu* to be in high amounts. This is because the flour's starch concentration is responsible for the texture of *fufu* dough (Akubor, 2019; Bello et al., 2020; Tahseen et al., 2024).

Maize is a globally significant cereal grain, ranking third after wheat and rice. It is nutritionally important, providing carbohydrates for energy and fatty acids from its germ. In Nigeria, maize is used in diverse cuisines like *gwate*, popcorn, *corn fufu*, *pap*, and several other traditional dishes. Beyond food, maize has applications in medicine and various processing industries (Shiriki et al., 2015). Maize, both common and quality protein varieties, contains approximately 9.72% protein, 4.85% fat, 1.50% ash, and 73.98% carbohydrates. Key amino acids include lysine (2.64 g/100g), isoleucine (2.74 g/100g), and phenylalanine (4.20 g/100g). In Africa, various processing techniques are used to transform maize into diverse traditional foods (Sefa-Dedeh, 1991). The high dependence on corn as a staple food in tropical Africa, coupled with its relatively low nutritive value has often led to the employment of simple traditional methods aimed at improving the nutritional quality of maize-based foods (Sefa-Dedeh et al., 2003).

Nixtamalization is the process of soaking and cooking maize grains in alkaline solutions prior to dehulling. It generally also refers to the removal of the pericarp from any grain using an alkaline process (Ocheme et al., 2010). Although native to Mesoamerica, nixtamalization has been employed as a primary processing step in the production of maize-based products in several other countries of the world (Ocheme et al., 2010; Offiah et al., 2016). It has been reported to increase the bioavailability of niacin, improve protein quality, increase calcium, and reduction of aflatoxin concentrations while improving the functional properties of the flours (Sefa-Dedeh et al., 2004; Matendo et al., 2023). While most food processors in Africa do not often use the nixtamalization process, the unit operations employed are not entirely novel. Thus, nixtamalization can be used to increase the nutritional value of maize while also introducing and fostering variation in the processing and application of maize in West Africa.

Cassava (*Manihot esculenta* Crantz), is a crop that is widely grown in Nigeria and other West African nations for its starchy and high-energy tuber roots (Awolu et al., 2022). It is processed into a variety of fermented staple foods, such as *fufu*, gari, *pupuru*, and *lafun*, among others (Awolu et al., 2022; Fayemi & Ojokoh, 2014). The sweet cultivar cassava (employed for this study) has been reported to have higher moisture, ash, lipid, calcium, and iron values but lower levels of fiber, protein, carbohydrate, phosphorus, and antinutrients (Akubor, 2019) than the bitter cassava. However, several studies have also reported on low nutritional qualities of cassava products; hence, the need to enrich the product with desirable functional ingredients. The reliance on cassava as a food source and the resulting exposure to the goitrogenic effects of thiocyanate has been responsible for several endemic diseases (like goitre) across the world. It is a problem, particularly in the region where cassava is the major source of calories (Awolu et al., 2022; Fayemi & Ojokoh, 2014). There is therefore every need to employ various treatments like fermentation that can reduce this cyanide content and improve the nutritional and sensory attributes of cassava-based foods.

Fermentation is an adaptable household technology for improving the nutritive value of plant foods. Cereals such as maize, sorghum, millet, and rice can be fermented to increase the nutrient content, carbohydrate digestibility, and energy densities of gruels, increase the bio-availability of amino acids and also improve their shelf life under controlled environments (Oladeji et al., 2018). Similar studies have also reported the same results indicating that fermentation could reduce the level of contamination by microorganisms thereby extending the shelf life of the food product (Afoakwa & Aidoo, 2006; Sefa-Dedeh et al., 2003).

This study is therefore aimed at formulating and evaluating the quality of "*fufu*" from maize and cassava flours as influenced by nixtamalization and fermentation.

2.0 MATERIALS AND METHOD

2.1. Sourcing of Raw Material and Sample Preparation

White maize variety and sweet cassava cultivar were used in this study and obtained from Wurukum and Wannune Markets respectively (all in Makurdi, Nigeria).

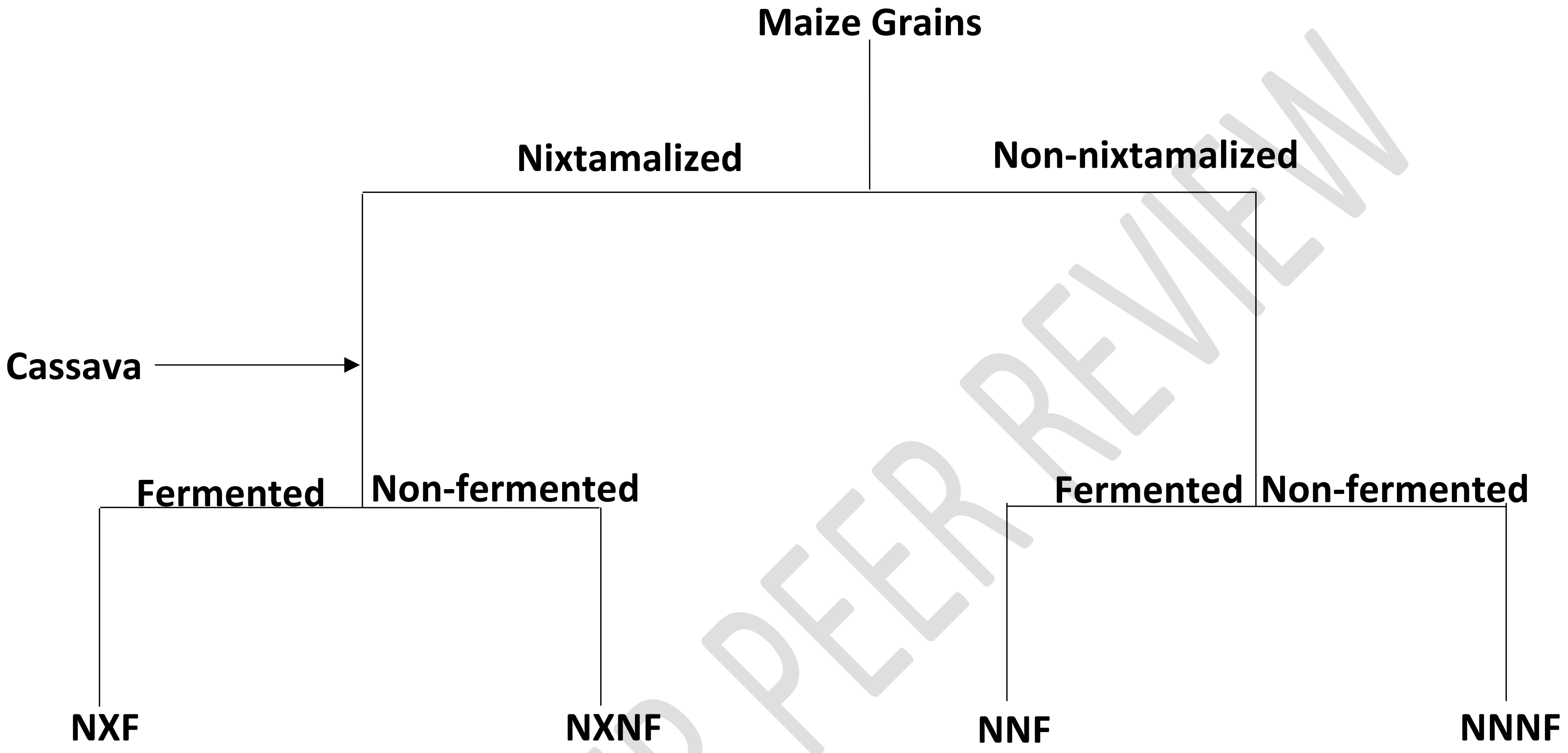
Maize grains were sorted and cleaned from extraneous materials. These were further milled using a hammer mill and passed through a 40 mm mesh sieve. This (non-nixtamalized maize flour) was then packaged in low-density polyethylene bags and stored for further analysis (Akubor, 2019).

Nixtamalized maize flour was prepared by the modified method of Offiah et al. (2016). The maize grains were cooked for 40 min in 1 % lime solution using a ratio of 1:3 (w/v grains: lime solution). After cooking, the maize grains were allowed to steep in the lime water for 18 h and the liquor (nejayote) was drained. The nixtamal (alkaline cooked maize) was then washed three times with clean tap water to remove the pericarp and excess residual lime, followed by drying in a laboratory dehydrator (BONNETT, Model: ST-02, China) at 65 ^{o}C for 24 h. The dried nixtamal was then milled using a hammer mill to pass through a 40 mm mesh to obtain nixtamalized maize flour. The nixtamalized maize flour was packaged in low-density polyethylene bags, sealed and stored for further analysis.

Non-fermented cassava flour was produced by the method described by Awolu et al. (2022). Cassava tubers were sorted, peeled, washed, and cut into small pieces. The pieces were then oven-dried at 65°C for 48 hours. Cassava flour was fermented using the back-slopping method at room temperature. Fifty grams of flour was mixed with 150 mL of distilled water and fermented for 24 hours. Half of the fermented mixture was used as a starter for subsequent fermentation cycles. Titratable Acidity and pH were monitored throughout the process. Fermentation continued until the pH stabilized. The fermented broths were then dried at 50°C for 24 hours and ground through a 40 mm mesh sieve.

2.2. Flour blend formulation for *fufu* Preparation

Four samples were formulated by blending the different flours in a ratio of 2:1 (w/w Maize: Cassava) using a laboratory mixer (FOOD MIXER, Model, B5, China). The four samples include; Non-nixtamalized maize + Non-fermented cassava (NNNF), Non-nixtamalized maize + Fermented cassava (NNF), Nixtamalized maize + Non-fermented cassava (NXNF) and Nixtamalized maize + Fermented cassava (NXF). These flours were packaged in low-density polyethene bags and stored in plastic containers with airtight lids until used. The experimental layout is shown in Figure 1. The chosen samples were then subjected to quality analyses



KEY

NXF-Nixtamalized Maize+Fermented cassava
NXNF-Nixtamalized maize+Non-fermented cassava
NNF-Non-Nixtamalized maize+Fermented cassava
NNNF-Non-nixtamalized maize+Non-fermented cassava

Figure 1: Experimental Lay-out

2.3. Determination of pH and total titratable acidity during cassava fermentation

This was carried out as described by Ariahu et al. (1999). The Total Titratable Acidity (TTA) was evaluated by dissolving 2 g of the sample in distilled water and making up to 25 mL with the water followed by titration of 10 mL aliquots with 0.1 M NaOH in the presence of phenolphthalein indicator. TTA was expressed quantitatively in terms of Lactic acid as follows:

$$Lactic\ acid(g\ /\ 100g) = (ml\ NaOH)/(ml\ of\ sample) \times 0.9 \qquad (1)$$

About 2 g of each sample was homogenized with 40 mL of distilled water in a warring blender for 2 minutes. The mixture was allowed to equilibrate for 3 minutes prior to pH determination using a previously referenced electrode of a pocket-sized pH meter (PHEP, HANNA instruments).

2.4. Physicochemical analyses of the samples

2.4.1 Determination of the functional properties

Water absorption capacity (WAC): The method described by Onwuka, (2018) was used. One gram of the flour sample was weighed into a 15 mL centrifuge tube and suspended in 10 mL of water. It was shaken on a platform tube rocker for 1 min at room temperature. The sample was allowed to stand for 30 min and centrifuged at 1200 x g for 30 min. WAC was then calculated as follows:

$$WAC = \frac{Amount\ of\ water-free\ water}{Weight\ of\ sample} \times density\ of water \times 100 \qquad (2)$$

Oil absorption capacity (OAC): One gram of the flour sample was weighed into a 15 mL centrifuge tube and suspended in 10 mL of vegetable oil. It was shaken on a platform tube rocker for 1 min at room temperature. The sample was allowed to stand for 30 min and centrifuged at 1200 x g for 30 min (Onwuka, 2018).

$$OAC = \frac{Amount\ of\ oil-free\ oil}{Weight\ of\ sample} \times density\ of oil \times 100 \qquad (3)$$

Bulk density (BD): Fifty grams of the flour sample was poured into 100 mL measuring cylinder. The cylinder was tapped continuously until a constant volume was obtained. The bulk density (g/mL) was calculated as the weight of flour (g) divided by flour volume (mL) (Awolu et al., 2022).

$$BD = \frac{Weight\ of\ sample}{Volume\ of\ sample\ after\ tapping} \times 100 \qquad (4)$$

Swelling index (SI): One gram (1.0 g) of the flour sample was mixed with 10 mL distilled water in a centrifuge tube and heated at 80 °C for 30 min. This was continuously shaken during the heating period. After the heating, the suspension was centrifuged at 1000 x g for 15 min. The supernatant was decanted and the weight of the paste was taken (Awolu et al., 2022). The swelling power was calculated as follows:

$$SI(\%) = \frac{Weight\ of\ sample\ paste}{Weight\ of\ dry\ flour} \times 100 \qquad (5)$$

2.4.2. Determination of the proximate composition of flours/formulations

The proximate parameters namely; moisture, ash, crude protein crude fat, and crude fibre) were determined by standard methods of the Association of Official Analytical Chemists (AOAC, 2012). Carbohydrate was calculated by difference as follows;

$$\%\ \mathrm{Carbohydrate} = 100 - [\mathrm{Protein}(\%) + \mathrm{Fat}(\%) + \mathrm{Ash}(\%) + \mathrm{Fibre}(\%) + \mathrm{moisture}\ (\%)] \qquad (6)$$

2.4.3. Determination of the mineral content of the flours

The Magnesium, Calcium, Potassium, Sodium and Phosphorous contents of samples were determined by the atomic absorption spectrophotometer method (AOAC, 2012). Two grams of the dried samples were ignited in a muffle furnace at a temperature of 600 °C. The ash was dissolved in 10 mL of 5 M HCl. Acid digestion of the ash was then be carried out on a steam plate and the digested sample carefully washed with distilled water and filtered using Whatman's filter paper into a 50 mL volumetric flask and diluted to volume. The samples and blanks were then analyzed for the different minerals using the Atomic Absorption Spectrophotometer (Perkin-Elmer Analyst 700 spectrophotometer (Norwalk, CT, USA).

2.4.4. Anti-nutritional analysis of samples

Determination of Tannin contents

The tannin content was determined using the Burn method (Krishnaiah et al., 2009). Five (5) g of sample was treated with 50 mL methanol and kept for 24 hours before filtration. Five (5 mL) of freshly prepared vanalin hydrochloric acid was added and the solution was allowed to stand for 20 min for color development. The absorbance was measured at 550 nm using spectronic 20 and the machine value was used in calculating the tannin content as follows:

$$C_1 = \frac{C_1 C_2}{V_1}$$

$$\%\ \text{Tannic acid content} = \frac{\text{C1 X 100}}{\text{Weight of sample}} \qquad (7)$$

Where;

C_1= Conc. of tannic acid, C_2=Conc. of base, V_1=Volume of tannic acid, V_2= Volume of base

Determination of phytates content

The method of Young and Greaves with slight modification was used (Disseka et al., 2018). Exactly 2 g of samples was soaked with 100 mL of 20% concentrated HCl for 3 hours in a 250 conical flask. Thereafter the samples were filtered with a filter paper, 50 mL of the filtrate placed in a 250 beaker and 100 mL of distilled water added. Then 10 mL of 0.3 % ammonium thiocyanate solution was added as an indicator and titration was carried out with standard Iron (III) Chloride (0.00915 g/mL). After titrations, the phytate content was calculated as follows;

$$\text{Phytates Acid} = \frac{titre\ value \times 0.00195 \times 1.19 \times 100}{sample\ mass\ (g)} \qquad (8)$$

Determination of cyanide

Alkaline picrate reagent was prepared by a modification of the method described by Wasiams and Edwards (1980) as follows: Test tubes with 2 mL of 2 % KOH and 1 mL of picric acid: Na_2CO_3: H_2O (1:5:200 v/w/v) was prepared (Nwokoro et al., 2010). Standard absorbance curves were made with 3 Whatman No. 1 papers each with a dimension of 8×1 cm. The papers were dipped into the alkaline picrate solution for 15 minutes. The picrate-impregnated papers were removed from the solution and used immediately for cyanide determination. Cyanide solutions containing (50-200 μgKCN/mL) were each be prepared in glass bottles. The cyanide was acidified with 20 % HCl solution heated to 80 ^{o}C and immediately sealed with 3 picrate-impregnated papers. The system was incubated at room temperature (28 ± 2 ^{o}C) for 24 h. The red-coloured complex formed was eluted with 50 % ethanol solution for 30 min. The eluate absorbance was measured at 510 nm using a spectrophotometer. Cyanide levels of the samples were extrapolated from the standard curve.

Determination of oxalate content

This was determined by the standard method of AOAC (2012). One gram **(**1 g) of the sample was placed in a 250 mL volumetric flask, 190 mL of distilled water and 10 mL of 6 M HCl was added. The mixture was warmed in a water bath at 90 ^{o}C for 4 h and the digested sample was centrifuged at a speed of 2000 rpm for 5 min. The supernatant was diluted to 250 mL. Three (3) 50 mL aliquots of the supernatant were evaporated to 25 mL, and then the brown precipitate was filtered off and washed. The combined solution and washings were titrated with concentrated ammonia solution in drops until Salmon pink color of methyl orange changed to faint yellow. The solution was heated in a water bath to 90 ^{o}C and the oxalate was precipitated with 10 mL of 5 % $CaCl_2$ solution. The solution was allowed to stand overnight and then centrifuged. Each precipitate was washed into a beaker with hot 25 % H_2SO_4, diluted to 125 mL with distilled water and after warming to 90 ^{o}C it was titrated against 0.05 M KMnO4 until a faint pink color persisted for at least 30 s. The oxalate content was calculated by taking;

1 mL of 0.05 M $KMnO_4$ = 2.2 mg oxalate (9)

2.5. Determination of Color Attributes of the flour samples for *fufu*

The color differences was analyzed according to the method described by Capule & Trinidad, (2016) with a chromameter (CR-300; Minolta, Tokyo, Japan) using the Hunterlab system, which identifies color using three attributes: L (white = 100, black = 0), a (red = positive, green = negative) and b (yellow = positive, blue = negative).

2.6. Evaluation of the sensory attributes of the *fufu* samples

Twenty (20) habitual panelists consisting of adult males and females were used for sensory evaluation according to the method described by (Awolu et al., 2022). *Fufu* samples were evaluated on a 9-point Hedonic scale of 9 (like extremely) to 1 (dislike extremely) for appearance, taste, aroma, texture, mouldability, and overall acceptability. The samples were prepared by stirring flour in boiling water 1:4 (v/v) of flour to water dispersion at 100 °C for 30 min. The reconstituted food samples were coded with three digits (using the random number table) and presented to panelists.

2.7. Statistical analysis

Data was collected in triplicates and analyzed using SPSS (Statistical Package for Social Sciences) Version 27. The Analysis of Variance (ANOVA) was performed to determine significant differences between the means while the Duncan Multiple Range Test was used to compare and separate means. Significance was accepted at $p<0.05$

3. RESULTS AND DISCUSSION

3.1 Effect of nixtamalization and fermentation on the functional properties of blends of nixtamalized maize and fermented cassava

The effect of nixtamalization and fermentation on the functional properties of *fufu* flours produced from blends of nixtamalized maize and fermented cassava are presented in Table 1.

The water absorption capacity ranged from 2.08 (NNNF) to 2.21 g/g (NXF). The treatments were observed to significantly affect the water absorption capacity of the flours, wherein the treated samples had higher values than the treated samples. Ocheme et al. (2010) obtained higher (2.29 to 5.91 g/g) water absorption capacity values when investigating the effect of lime cooking on the quality of sorghum flours. Lower values (0.18-0.34 g/g) were obtained for unfermented *fufu* composite flour made from cassava sievate, guinea corn and unripe plantain flours blends (Odoh et al., 2022). Reports have also noted that the water absorption capacity of nixtamalized maize flour increased with fermentation hours, demonstrating the importance of the interplay between the two treatments:-nixtamalization and fermentation (Afoakwa & Aidoo, 2006).

Table 1: Functional properties of Blends of Maize and Cassava Flours

Parameters	**Sample**			
	NXF	NXNF	NNF	NNNF
WAC (g/g)	$2.21^{a}\pm0.03$	$2.18^{a}\pm0.02$	$2.16^{ab}\pm0.01$	$2.08^{b}\pm0.08$
OAC (g/g)	$1.69^{b}\pm0.01$	$1.72^{a}\pm0.00$	$1.65^{c}\pm0.01$	$1.63^{d}\pm0.01$
BD (g/ml)	$0.65^{b}\pm0.00$	$0.68^{a}\pm0.00$	$0.62^{d}\pm0.00$	$0.65^{c}\pm0.00$
SI (mL/g)	$2.77^{c}\pm0.03$	$3.08^{a}\pm0.00$	$2.71^{d}\pm0.03$	$2.87^{b}\pm0.04$

Values are means±standard deviation of triplicate determinations. Means across a row with different superscripts are significantly different at p<0.05

***NXF**-Nixtamalized maize + Fermented cassava, **NXNF**-Nixtamalized maize + Non-Fermented cassava,*
***NNF**-Non-Nixtamalized maize + Fermented cassava, **NNNF**-Non-Nixtamalized maze + Non-Fermented cassava*
***WAC**-Water Absorption Capacity, **OAC**-Oil Absorption Capacity, **BD**-Bulk Density, **SI**-Swelling index*

The oil absorption capacity of the flour blends ranged from 1.63 g/g (NNNF) to 1.69 (NXF) with significant differences (p<0.05) among the samples. Just like the water absorption capacity, the treated samples had significantly higher oil absorption capacities than the non-treated samples. This could be due to the exposure of more hydrophobic ends which favours oil absorption (and this is brought about by the treatments). Hassan et al. (2023) observed oil absorption capacity ranging from 88.82 to 88.89 % for maize tortillas. The oil absorption capacity of African yam bean flour was observed to be enhanced by fermentation as reported by Chinma et al. (2020) to increase from 1.14 to 1.80 g/g. Oil absorption capacity ranging from 1.21 to 1.58 g/g was observed by Ocheme et al. (2010) for lime-cooked sorghum flours.

The bulk density ranged from 0.62 g/mL (NNF) to 0.68 g/mL (NXNF) with significant differences among the samples. The treated sample (NXF) was seen to have the lowest bulk density implying the treatments significantly reduced the bulk density and therefore made packaging of the product much easier. Bulk density ranging from 0.44 to 0.62 g/mL was reported by Oladeji et al. (2018) for fermented maize flours. Similar results were observed by Ocheme et al. (2010), just like Odoh et al. (2022) who observed bulk density values ranging from 0.54 to 0.72 g/mL for unfermented *fufu* composite flour made from cassava sievate, guinea corn and unripe plantain flours blend.

The swelling capacity of the flour blends ranged from 2.71 mL/g (NNF) to 3.08 mL/g (NXNF). Significant differences were observed among the samples owing to the treatments employed. These results are higher than those reported for African yam bean flour as influenced by fermentation (Chinma et al., 2020). Authors have also observed a swelling power of 2.70 to 4.83 mL/g for *soy-poundo* yam flour (Maloma et al., 2013). A comparative study of *fufu* flours from 3 cassava varieties observed a swelling capacity ranging from 15.35 to 17.36 ml/g (Adesola et al., 2022).

3.2. Effect of nixtamalization and fermentation on the proximate composition of blends of maize and cassava-based flours

The moisture content of the blends are presented in Table 2. The moisture content of the blends varied significantly ($p<0.05$) from 11.44 % db (NXNF) solids to 13.03 % db (NNF). The moisture was generally lower in samples involving nixtamalization or a combination of nixtamalization and fermentation. This complements the report that due to the concentration of the lime, nixtamalization modifies starch structure, reducing its ability to retain water and in turn lowering the moisture content (Santiago-Ramos et al., 2018). The moisture content of foods is a very critical factor in the handling and storage of food products. The Standard Organization of Nigeria (SON) recommends a moisture content of <14% for the safe storage of flour (Bongjo et al., 2022). The observed results are higher than those reported for *fufu* produced from sweet cassava and guinea corn flour (7.02-9.89 %) as reported by Awolu et al. (2022). In another study by Matendo et al. (2023), the authors recorded a moisture content (dry basis) ranging from 4.0 % to 5.6 % which is lower than those reported in this study. This difference could be due to differences in processing methods as well as geographical location.

Table 2: Proximate composition of Blends of Maize and Cassava Flours

Nutrient (g/100 g solids)	Sample			
	NXNF	NXF	NNF	NNNF
Moisture	11.44^{c}±0.02	11.52^{bc}±0.01	13.03^{a}±0.10	11.59^{b}±0.03
Ash	3.88^{a}±0.00	3.63^{b}±0.01	3.29^{d}±0.03	3.55^{c}±0.03
Crude protein	21.67^{a}±0.00	13.30^{c}±0.01	17.87^{b}±0.12	8.76^{d}±0.03
Crude fibre	3.83^{a}±0.02	3.65^{b}±0.01	3.33^{c}±0.01	3.12^{d}±0.03
Crude fat	7.60^{a}±0.09	6.08^{b}±0.03	6.35^{c}±0.02	3.87^{d}±0.02
Carbohydrate	63.02^{d}±0.10	73.34^{b}±0.01	69.16^{c}±0.12	81.82^{a}±0.01
Energy (kcal)	407.18^{a}±0.38	401.28^{c}±0.23	405.24^{b}±0.18	397.18^{d}±0.08

Values are means±standard deviation of triplicate determinations. Means across a row with different superscripts are significantly different at p<0.05

***NXF**-Nixtamalized maize + Fermented cassava, **NXNF**-Nixtamalized maize + Non-Fermented cassava,*
***NNF**-Non-Nixtamalized maize + Fermented cassava, **NNNF**-Non-Nixtamalized maze + Non-Fermented cassava*

The Ash content of a food sample depicts the inorganic residue that remains after the removal of water and organic matter. In other words, provides a measure of the amount of minerals in a food. The ash content of the samples was greatly enhanced by the treatments; of nixtamalization and fermentation, with samples treated with both nixtamalization and/or fermentation having higher ash content. Authors have reported enhancement in the ash content (1.29 to 2.8 %) of a maize-soybean-based composite flour (Matendo et al., 2023) which were however lower than those reported in this study varying between 3.29 to 3.88 %. (Awolu et al., 2022) also reported ash content lower for cassava-sorghum-based *fufu* ranging from 1.50 to 2.20 %. Results in this study are also consistent with those of Fayemi & Ojokoh (2014) emphasizing the role of fermentation in the enhancement of the nutritional content of food products. Akubor (2019) reported the ash content for instant *fufu* flours to range from 2 to 4.4 %.

Proteins are very essential in the functioning of the body by serving as structural support, biochemical catalysts, hormones, enzymes, building blocks, etc. It was observed that both nixtamalization and fermentation greatly enhanced the protein content of the samples with values ranging significantly ($p<0.05$) from 8.76 % (untreated sample NNNF) to 21.67 % (treated sample, NXNF). A protein content ranging from 2.40 % to 11.16 % was reported for unfermented *fufu* from cassava sievate, guinea corn and unripe plantain flour blend (Odoh et al., 2022), which are lower than those reported in this study, could be because the flours were not treated (unfermented as mentioned). Other reports have also presented protein content ranging from 6.50 to 7.99 % for *fufu* from maize, millet and sorghum (Okwulehie et al., 2021). Chinma et al. (2020) on the other hand reported a protein content of up to 25.02 % in bread produced from fermented African yam bean. Ocheme et al. (2010) while investigating the effect of lime cooking on the physicochemical properties of sorghum and millet flour observed an enhancement in the protein content ranging from 11.57 % in untreated samples to 14.57 % in lime-cooked flours.

Consumption of foods appreciably high in fibre contributes to an increase in faecal bulk thus increased the rate of intestinal transit. Dietary fibre intake has also been linked with lower risk of coronary heart disease, stroke, hypertension, diabetes, lowering blood pressure as well as cholesterol levels in the serum (Anderson et al., 2009). It was observed in this study that samples treated by nixtamalization and/or fermentation had appreciably higher fibre content compared to the untreated samples. This is consistent with reports that the combination of heat and alkali during traditional nixtamalization acts aggressively on the pericarp's outer layers, promoting partial removal of hemicelluloses and partial lignin from the pericarp's fibre matrix (Bello-Pérez et al., 2015). Other researchers highlighted a similar report in a study evaluating the effect of nixtamalization of maize and heat treatment of soybean on the nutrient, antinutrient, and mycotoxin levels of maize-soybean-based composite flour (Matendo et al., 2023). In another study on the effect of solid-state fermentation on proximate composition, anti-nutritional factor, microbiological and functional properties of lupin flour (Olukomaiya et al., 2020), the fibre content was reported to range from 12.4 to 14.9 %, which is higher than that reported in this study. This could be due to the difference in the fermentation technique used.

The fat content ranged from 3.87 to 7.60 %. The trend observed in this study contradicts reports that nixtamalization led to a reduction in the fat content of flours (Bello-Pérez et al., 2015), just like fermentation (Chinma et al., 2020). Matendo et al. (2023) however, complement this study as they observed an increase in the fat content with nixtamalization. There have been reports of lower fat content in *fufu* prepared by employing different fermentation techniques (Fayemi & Ojokoh, 2014). Results in this study are similar to those reported by Ocheme et al. (2010) for lime-cooked millet and sorghum flours. While evaluating the quality of *fufu* produced from sweet cassava and guinea corn flour, Awolu et al. (2022) observed similar fat content of 4.99 to 5.34 %. This low fat content is desirable in *fufu* as a product because higher content would adversely affect the product by acting as a shortening.

The carbohydrate content of the samples were significantly different from each other with treated samples (NXNF) having the least carbohydrate compared to the untreated samples (NNNF, 81.82 %). This low carbohydrate content in treated samples could be due to its higher protein, ash and fibre content since carbohydrate was obtained by difference. Several studies have reported different values for carbohydrate contents ranging from 85.95 to 86.86 % (Ramírez-Jiménez et al., 2019), 68.4 to 75.4 % (Hassan et al., 2023) as well as 74.43 to 78.86 % (Matendo et al., 2023). These differences could be due to differences in varieties and/or processing methods. This was also echoed by another study (Ocheme et al., 2010).

The energy value of the samples ranged from 397.18 kcal (NNNF) to 407.18 kcal (NXNF). However, these values were higher when compared with the FAO/WHO recommended energy value (344 kcal/day) (Awolu et al., 2022). The codex standards also recommend energy values in the range of 400–425 kcal. Results in this study also fall within this range. This is evident that the flour samples could be much more suitable for providing the daily energy requirement for both adults and children. The observed high energy value of these experimental flour samples may be attributed to the high fat and protein content of guinea corn and this is in agreement with the findings of Awolu et al. (2022) and Hassan et al. (2023)

3.3. Effect of nixtamalization and fermentation on the mineral composition of maize and cassava-based flours

Calcium, Magnesium, Potassium, Sodium and Phosphorus were analyzed in the formulated samples as seen in Table 3. It was generally observed that except for Phosphorus, samples NXF and NXNF had higher mineral content compared to the other samples. NXNF had the highest mineral contents compared with NXF. This could be explained by the fact that during fermentation some minerals are leached into the broth medium, implying that a combination of nixtamalized maize and fermented cassava (NXF) would normally have a lower mineral content compared with NXNF (nixtamalized maize and non-fermented cassava).

Calcium is necessary for bone and tooth structural integrity and mineralization. It is essential for a variety of metabolic and regulatory functions. It cofactors several enzymes required for nerve and muscle function, participates in the blood clotting cascade and regulates numerous intracellular activities. Enhanced calcium contents have been reported ranging from 1383.0 to 1449.4 mg/100 g in maize-soybean composite flour (Matendo et al., 2023), with nixtamalized samples having the highest value. This is in agreement with results in this study observing calcium contents in the range 198.56 to 284.86 mg/100 g, though lower. Awolu et al. (2022) reported even higher calcium values than reported in this study ranging from 124.00 to 885.00 mg/100 g. These results are however higher than those reported for bread made from African yam bean flour measuring 43.14 to 48.10 mg/100 g (Chinma et al., 2020). While evaluating the acceptability of *fufu* produced using residue from maize, millet and sorghum as a strategy for sustainable food security (Okwulehie et al., 2021), calcium content was observed to range from 2.46 to 3.73 mg/100 g which is lower than reported in this study. This could be because no treatment such as nixtamalization and/or fermentation was applied to the raw materials.

Table 3 Mineral Composition (mg per 100g) of Blends of Maize and Cassava Flours

Parameter	**Sample**			
	NXF	NXNF	NNF	NNNF
Calcium	245.83^{b}±0.05	284.86^{a}±0.04	214.33^{c}±0.01	198.56^{c}±0.06
Magnesium	165.36^{c}±0.02	178.63^{a}±0.03	172.84^{b}±0.04	165.37^{c}±0.00
Potassium	260.84^{c}±0.04	384.81^{a}±0.05	282.21^{b}±0.01	237.32^{d}±0.08
Sodium	45.84^{c}±0.04	56.33^{a}±0.01	49.64^{b}±0.02	45.78^{d}±0.01
Phosphorus	148.10^{d}±2.56	179.31^{b}±0.55	166.97^{c}±1.57	193.46^{a}±0.01

Values are means±standard deviation of triplicate determinations. Means across a row with different superscripts are significantly different at p<0.05

NXF*-Nixtamalized maize + Fermented cassava,* ***NXNF****-Nixtamalized maize + Non-Fermented cassava,* ***NNF****-Non-Nixtamalized maize + Fermented cassava,* ***NNNF****-Non-Nixtamalized maze + Non-Fermented cassava*

Magnesium is known for its control of a variety of biochemical processes in the body including protein synthesis and the operation of muscles and nerves. Values recorded for magnesium (165.36 to 178.63 mg/100 g) are higher than those reported by Fayemi & Ojokoh (2014) for *fufu* flours produced by different fermentation techniques. Nixtamalization was also shown to significantly enhance the magnesium content of maize-soybean composite flour with values ranging from 100.6 to 142.9 mg/100 g (Matendo et al., 2023). Chinma et al. (2020) also reported lower magnesium content than those reported in this study. This could be because nixtamalization and fermentation were employed in this study, which better enhanced the mineral content.

Because potassium serves as a crucial electrolyte in the neurological system and has been demonstrated to have a potent, dose-dependent inhibitory effect on sodium sensitivity, the body requires relatively significant amounts of this mineral. The potassium content observed (237.32 to 384.81 mg/100 g) is higher than the 267.58-286.35 mg/100 g reported for sprouted soybean-supplemented nixtamalized maize flour (Inyang et al., 2019). Also, *fufu* produced from maize, sorghum and millet flours had potassium contents ranging from 265.92 to 380.66 mg/100 g (Okwulehie et al., 2021). In another study, the potassium content of spontaneously fermented finger millet flour was found to range from 416.20 to 444.09 mg/100 g. A study evaluating the physicochemical properties and anti-nutrient contents of unripe banana and African yam bean flour blends observed a potassium content of 345.96-382.41 mg/100 g which is higher than those reported in this study (Inyang & Ekop, 2015). This study could be due to differences in varieties as well as differences in processing methods.

Sodium is required to maintain the correct concentration of body fluids as well as aid in nerve impulse transmission. The sodium content reported in this study (45.78 to 56.33 mg/100 g) are higher than those put forth by Inyang & Ekop (2015). Fayemi & Ojokoh (2014) observed sodium contents in the range of 0.097 to 0.555 mg/100 g, which is lower than those reported in this study. Awolu et al. (2022) also reported similar but lower sodium content ranging from 31.00 to 39.50 mg/100 g for *fufu* flours produced from cassava and sorghum flours.

Phosphorus is a necessary element for animal growth and development since it strengthens bones and promotes overall health and well-being. It was observed that nixtamalization and fermentation significantly enhanced the phosphorus content of the samples. The phosphorus content ranged from 148.10 to 193.46 mg/100 g. The phosphorus content of *fufu* flours from maize and sorghum ranged from 234.93 to 1864.0 mg/100 g as reported by Awolu et al. (2022). Also, (Fayemi & Ojokoh, 2014) reported phosphorus content in the range of 0.057 to 0.152 mg/100 g. While evaluating the acceptability of *fufu* produced using residue from maize, millet and sorghum calcium content was observed in the range of 258.29 to 298.09 mg/100 g (Okwulehie et al., 2021).

3.4. Effect of nixtamalization and fermentation on the antinutritional composition of maize and cassava-based flours

Four antinutrients were analysed in this work namely tannins, phytates, alkaloids and hydrogen cyanide and are presented in Table 4. It was generally observed that the samples treated with nixtamalization and/or fermentation had antinutrient content lower than the samples not treated at all. Anti-nutritional factors are known to be toxic and can cause impairments in protein digestibility and mineral availability, which can negatively affect the nutrient value of foods.

The tannin content observed in this study (0.58 to 0.89 mg/100 g) is lower than reported for *fufu* from cassava and sorghum flours who reported 2.86 to 3.95 mg/100 g (Awolu et al., 2022). Ocheme et al. (2010)also reported higher values than reported in this study (5.31 to 13.4 g/kg). (Ngozi & Nkiru, 2014), claim that tannin-protein complexes are responsible for low protein digestibility, growth depression, and decreased availability of amino acids.

Table 4 Antinutrient Composition of Blends of Maize and Cassava Flours

Parameters	Sample			
	NXF	NXNF	NNF	NNNF
Tannin	$0.58^{d}\pm0.00$	$0.75^{b}\pm0.00$	$0.65^{c}\pm0.01$	$0.89^{a}\pm0.00$
Phytate	$1.47^{c}\pm0.01$	$1.45^{c}\pm0.00$	$1.96^{b}\pm0.01$	$2.43^{a}\pm0.49$
Oxalate	$0.65^{c}\pm0.00$	$0.96^{b}\pm0.00$	$0.63^{d}\pm0.00$	$1.03^{a}\pm0.01$
Hydrogen cyanide	$0.89^{d}\pm0.00$	$1.44^{a}\pm0.01$	$0.95^{c}\pm0.01$	$1.28^{b}\pm0.00$

Values are means±standard deviation of triplicate determinations. Means across a row with different superscripts are significantly different at $p<0.05$

***NXF**-Nixtamalized maize + Fermented cassava, **NXNF**-Nixtamalized maize + Non-Fermented cassava, **NNF**-Non-Nixtamalized maize + Fermented cassava, **NNNF**-Non-Nixtamalized maze + Non-Fermented cassava*

According to Ngozi & Nkiru (2014), phytic acid forms insoluble salts. It affects digestibility by chelating with calcium or proteolytic enzymes, which prevents the body from absorbing certain metals like iron and zinc. In this study, the phytic acid content observed were in the range 1.45 to 2.43 mg/100g These are lower than those reported in previous studies (Awolu et al., 2022; Ocheme et al., 2010). However, the results are higher than those advanced by Ojokoh et al. (2013).

Oxalates chelate minerals such as calcium, zinc and iron, preventing their absorption and utilization in the human body. The oxalate content observed in this study ranged from 0.63 to 1.03 mg/100 g. This is lower than results gotten by Awolu et al. (2022) ranging from 0.86 to 1.03 mg/g. Hassan et al. (2023) also got oxalate content higher (1.0 - 4.71 mg/100 g) than those reported in this study. This could be due to processing efficiency as well as the variety of the raw materials.

Hydrogen cyanide is a respiratory poison which interferes with the processes of the electron transport chain, disrupting the respiratory chain. The cyanide content obtained is comparatively lower than the value (0.84 to 1.69 mg/100 g) and 7.8 to 16.05 mg/100 g reported by Awolu et al. (2022) and Ocheme et al. (2010) respectively. The recommended safe limit for hydrogen cyanide content in cassava according to scientific standards 10 mg/kg. Values obtained herein are therefore within the recommended safe limit**.**

3.5. Effect of nixtamalization and fermentation on the vitamin composition of maize and cassava-based flours

The vitamin content of the samples was greatly enhanced by the treatments; nixtamalization and fermentation as seen in Table 5. The vitamins analysed (B1, B2, B3 and C) are water-soluble and are known to be heat-labile. The thiamin content reported in this study (0.35 to 0.55 mg/100 g) is lower than the recommended value set by the International Organization for Migration which is 1.1-1.2 mg/day (for adult men and women) also processing has been known to significantly reduce the thiamine content of processed products. It is also known that processed maize products contain less than whole grains; however, the bioavailability of thiamin increases with processing (Suri & Tanumihardjo, 2016). Fermentation has been reported to increase the bioavailability of vitamin content by way of precipitating and reducing the levels of antinutrients (Bamidele et al., 2015). Shrivastava & Ananthanarayan (2015) also observed thiamin content in *idli* with fermentation time. Thiamin is implicated in several metabolic reactions in carbohydrate metabolism. It is very essential in the growth of children and health improvement as well as aids in the functioning transmission of nerve impulses. Thiamin deficiency leads to growth retardation in children with chronic deficiency leading to a disease known as *beri beri* (Mrowicka et al., 2023).

Table 5 Vitamin Composition (mg/100g) of Blends of Maize and Cassava Flours

Vitamin (mg/100 g)	Sample			
	NXF	NXNF	NNF	NNNF
Thiamine (B1)	0.55^{a}±0.01	0.48^{b}±0.00	0.40^{c}±0.01	0.35^{d}±0.00
Riboflavin (B2)	0.28^{a}±0.00	0.24^{c}±0.01	0.26^{b}±0.00	0.21^{d}±0.00
Niacin (B3)	0.65^{a}±0.00	0.57^{c}±0.01	0.60^{b}±0.00	0.54^{d}±0.00
Ascorbic acid (C)	2.17^{a}±0.01	1.91^{c}±0.02	1.96^{b}±0.01	1.62^{d}±0.00

Values are means±standard deviation of triplicate determinations. Means across a row with different superscripts are significantly different at $p<0.05$

NXF*-Nixtamalized maize + Fermented cassava,* ***NXNF****-Nixtamalized maize + Non-Fermented cassava,* ***NNF****-Non-Nixtamalized maize + Fermented cassava,* ***NNNF****-Non-Nixtamalized maze + Non-Fermented cassava*

Riboflavin content (vitamin B2) reported in this study (0.21 to 0.28 mg/100 g) is higher than reported by (Suri & Tanumihardjo, 2016) in the order of 0.2 mg/100 g. This is however lower than the recommended value of 1.1 to 1.3 mg/day. It plays a significant role in energy production by aiding in the conversion of carbohydrates into glucose and is involved in the body's metabolic processes. A daily supply of riboflavin is required for all age groups. Riboflavin deficiency can fail to grow, skin lesions and mouth soreness (Suwannasom et al., 2020).

Niacin (Vitamin B3) is an important factor in the release of energy from food, especially carbohydrates, by oxidation. Daily consumption is required. Deficiency in niacin content results in the disease pellagra, with the following symptoms; dermatitis, dementia and diarrhoea (Meyer-Ficca & Kirkland, 2016). The niacin content in this study (0.54 to 0.65 mg/100 g) is lower than those reported for Philippine salt bread (0.6 to 1.6 mg/100 g) (Sunico et al., 2021). The recommended daily value for niacin is 14 mg/day. In a report by Lay & Fields (1981) and cited by (Suri & Tanumihardjo, 2016) it was observed that maize fermented after germination had significantly higher levels of niacin.

The nutritional importance of vitamin C as an essential water-soluble vitamin is well established. Vitamin C is a cofactor in numerous physiological reactions, including collagen gene expression, peptide hormone activation, and carnitine synthesis. It is also an effective antioxidant. Therefore, adequate intake of vitamin C from food is vital for normal functioning of the human body (Gupta et al., 2022). The vitamin C content observed in this study (1.62 to 2.17 mg/100 g) is lower than the RDA for vitamin C which is 75 and 90 mg/day for women and men, respectively (Suri & Tanumihardjo, 2016)

3.6. Effect of nixtamalization and fermentation on the Color attributes of maize and cassava-based flours

The results are presented in Table 6. Colour is a vital sensory attribute that determines consumers' acceptability of food products (Awolu et al., 2022; Chinma et al., 2020). Significant differences were observed in colour among the *fufu* flour samples using the Hunter lab system. The Hunter L*, a*, b*, colour space is organized in a cube form. The L axis runs from the top to the bottom with a maximum L* value of 100 (for a perfect reflecting diffuser) and a minimum L* value of zero (black). The axes a* and b* have no specific numerical limit; +a* is red, -a* is green, +b* is yellow, -b* is blue (Hunter lab 2008). Nixtamalization and fermentation were seen to significantly ($p<0.05$) affect the colour attributes of the flours. NNNF (75.40) was the lightest while NNF (65.38) was comparatively the darkest. Interestingly samples with lower *L* values had higher a* values (meaning that they were redder than the non-treated samples). Sample NXF (12.54) was yellower than the other samples with sample NNF being the bluest.

Table 6 Color attributes of blends from Maize and Cassava Flours

Parameter	**Sample**			
	NXF	NXNF	NNF	NNNF
L*	68.42^{c}±0.02	72.63^{b}±0.03	65.38^{d}±0.00	75.40^{a}±0.00
a*	5.31^{a}±0.01	4.61^{b}+±0.01	2.40^{d}±0.00	4.25^{c}±0.00
b*	9.45^{d}±0.00	10.75^{c}±0.03	12.54^{a}±0.06	11.27^{b}±0.02

Values are means±standard deviation of triplicate determinations. Means across a row with different superscripts are significantly different at $p<0.05$

***NXF**-Nixtamalized maize + Fermented cassava, **NXNF**-Nixtamalized maize + Non-Fermented cassava, **NNF**-Non-Nixtamalized maize + Fermented cassava, **NNNF**-Non-Nixtamalized maze + Non-Fermented cassava*
L*-Lightness, **a***-Red/green, **b***-Yellow/Blue*

This observation could be because the nixtamalization resulted in gelatinization of the maize starch, allowing the cooked grains to imbibe the lime solution more readily than the non-nixtamalized grains, thereby changing the colour of the nixtamalized samples (Canelo-Álvarez et al., 2023; Sefa-Dedeh et al., 2004). It was also observed that fermentation made the samples less light (darker) than non-fermented samples as can be seen in NXF and NNNF. This is consistent with reports by (Chinma et al., 2020) for bread produced from African yam bean flour. Another study by other researchers (Amador-Rodríguez et al., 2019) showed that the colour of dry nixtamalized maize flours ranged from white to dark yellow, depending on the alkali concentration, processing conditions and corn type. This yellowing could be due to the concentration of lime imbibed.

3.7 Effect of nixtamalization and fermentation on the mean sensory scores of *fufu* produced from blends of maize and cassava flour

The mean sensory scores of the *fufu* produced showed that nixtamalization and fermentation enhanced the product's sensory characteristics as presented in Table 7. The nixtamalized samples recorded higher scores for all the sensory parameters than the other samples. This was further correlated with the overall acceptability score wherein sample NXNF having the highest score (8.15). Therefore panelists preferred nixtamalized samples to fermented samples like NNF. Results in this study complement those reported by Nurdjanah et al. (2014) for nixtamalized corn-based biscuits. This study also reported higher sensory scores compared to those advanced for gluten-free cornbread (Canelo-Álvarez et al., 2023). Other researchers who worked on *fufu* reported acceptable scores as affected by fermentation and other treatments (Akubor, 2019; Awolu et al., 2022). The observed sensory attributes indicate that nixtamalization and fermentation could be conveniently employed for the production of *fufu* flour.

Table 7 Mean Sensory Scores of *fufu* produced from blends of Maize and cassava flour

Attributes	Mean Score			
	NXF	NXNF	NNF	NNNF
Appearance	7.75^{ab}±0.79	8.25^{a}±0.97	7.30^{b}±0.98	7.60^{b}±0.68
Aroma	7.45^{ab}±1.28	7.90^{a}±0.97	6.80^{b}±1.15	7.85^{a}±0.81
Taste	7.50^{a}±1.00	8.15^{a}±0.93	6.55^{b}±1.15	7.50^{a}±1.05
Texture	7.80^{a}±0.95	8.05^{a}±0.83	6.80^{b}±1.28	7.35^{ab}±1.31
Moldability	7.75^{ab}±0.97	8.10^{a}±0.72	6.95^{c}±1.23	7.30^{bc}±1.45
Overall acceptability	7.90^{ab}±0.97	8.15^{a}±0.67	7.00^{c}±0.97	7.40^{bc}±1.05

Values are means±standard deviation of triplicate determinations. Means across a row with different superscripts are significantly different at p<0.05

***NXF**-Nixtamalized maize + Fermented cassava, **NXNF**-Nixtamalized maize + Non-Fermented cassava, **NNF**-Non-Nixtamalized maize + Fermented cassava, **NNNF**-Non-Nixtamalized maze + Non-Fermented cassava*

CONCLUSION

This study demonstrates the transformative potential of nixtamalization and fermentation in enhancing the quality of maize and cassava-based *fufu*. The dual treatments significantly improved functional properties such as water absorption and swelling index, increased protein and mineral content, and reduced antinutrient levels, while also boosting sensory attributes like texture, moldability, and overall acceptability. These results underscore the nutritional and sensory advantages of integrating nixtamalization and fermentation into traditional food processing practices, offering a sustainable pathway to address dietary deficiencies and improve food security. By leveraging these simple yet effective treatments, the production of *fufu* and similar staple foods can be optimized to meet the rising demand for nutritious, functional, and consumer-friendly food products. The findings provide a strong basis for adopting these methods at both household and industrial levels, with potential to scale production and diversify applications in West Africa and beyond. Future research should focus on refining these techniques for commercial viability and exploring their impact on a broader spectrum of traditional foods. This innovation represents a significant stride toward enhancing the value and acceptability of staple diets, contributing to public health and nutritional well-being.

REFERENCES

Abiose, S. H., & Ikujenlola, A. V. (2014). Comparison of chemical composition, functional properties and amino acids composition of quality protein maize and common maize (Zea may L). *African Journal of Food Science and Technology*, *05*(03), 81–89. https://doi.org/10.14303/ajfst.2014.024

Adesola, D. I., Esther, O. O., Aishat, O. S., Odunayo, A. W., & Adeola, A. O. (2022). Comparison of Functional Properties of *Fufu* Powder and Sensory Evaluation of the Dough Produced from TME 419, TME 693 and IBAO 11371 Cassava Varieties. *Journal of Food and Nutrition Sciences*, *10*(6), 178–184. https://doi.org/10.11648/j.jfns.20221006.12

Afoakwa, E. O., & Aidoo, P. R. (2006). Effect of solid-state fermentation on the physico-chemical, functional and textural properties of nixtamalized maize. *International Journal of Food Engineering*, *2*(1). https://doi.org/10.2202/1556-3758.1061

Akubor, P. I. (2019). Evaluation of the quality of instant *fufu* flours prepared from corn, cassava and soybean flour blends. *South Asian Journal of Food Technology and Environment*, *05*(01), 785–790. https://doi.org/10.46370/sajfte.2019.v05i01.05

Amador-Rodríguez, K. Y., Pérez-Cabrera, L. E., Guevara-Lara, F., Chávez-Vela, N. A., Posadas-Del Río, F. A., Silos-Espino, H., & Martínez-Bustos, F. (2019). Physicochemical, thermal, and rheological properties of nixtamalized blue-corn flours and masas added with huitlacoche (Ustilago maydis) paste. *Food Chemistry*, *278*(November 2018), 601–608. https://doi.org/10.1016/j.foodchem.2018.11.008

Anderson, J. W., Baird, P., Davis, R. H., Ferreri, S., Knudtson, M., Koraym, A., Waters, V., & Williams, C. L. (2009). Health benefits of dietary fiber. *Nutrition Reviews*, *67*(4), 188–205. https://doi.org/10.1111/j.1753-4887.2009.00189.x

AOAC. (2012). Association of official analytical chemist. In *Official methods of analysis of the analytical chemist international* (18th editi).

Ariahu, C. C., Ukpabi, C., & Mbajunwa, K. O. (1999). Production of African breadfruit (Treculia africana) and soybean (Glycine max) seed based food formulations, 1: Effects of germination and fermentation on nutritional and organoleptic quality. *Plant Foods for Human Nutrition*, *54*(3), 196–206.

Awolu, O., Iwambe, V., Oluwajuyitan, T., Bukola Adeloye, J., & Ifesan, B. (2022). Quality Evaluation of '*Fufu*' Produced from Sweet Cassava (Manihot Esculenta) and Guinea Corn (Sorghum Bicolor) Flour. *Journal of Culinary Science and Technology*, *20*(2), 134–164. https://doi.org/10.1080/15428052.2020.1821858

Bamidele, O. P., Fasogbon, M. B., Oladiran, D. A., & Akande, E. O. (2015). Nutritional composition of *fufu* analog flour produced from cassava root (*Manihot esculenta*) and cocoyam (*Colocasia esculenta*) tuber. *Food Science and Nutrition*, *3*(6), 597–603. https://doi.org/10.1002/fsn3.250

Bello-Pérez, L. A., Flores-Silva, P. C., Camelo-Méndez, G. A., Paredes-López, O., & De Figueroa-Cárdenas, J. D. (2015). Effect of the nixtamalization process on the dietary fiber content, starch digestibility, and antioxidant capacity of blue maize tortilla. *Cereal Chemistry*, *92*(3), 265–270. https://doi.org/10.1094/CCHEM-06-14-0139-R

Bongjo, N. B., Aondoaver, A. S., Gbertyo, J. A., Fulai, A. M. A., & Nchung, L. (2022). Nutritional and Functional Properties of Wheat-Defatted Peanut-Orange Peel Composite Flour. *European Journal of Nutrition & Food Safety*, *14*(12), 74–86. https://doi.org/10.9734/ejnfs/2022/v14i121283

Canelo-Álvarez, F., Figueroa-Cárdenas, J. de D., Martínez-Cruz, E., Pérez-Robles, J. F., Arámbula Villa, G., Mariscal-Moreno, R. M., & Véles Medina, J. J. (2023). Effect of nixtamalization on gluten-free whole corn, dough viscoelasticity, and the bread-making quality of leavened corn bread. *International Journal of Gastronomy and Food Science*, *31*(August 2022). https://doi.org/10.1016/j.ijgfs.2022.100648

Capule, A. B., & Trinidad, T. P. (2016). Isolation and characterization of native and modified starch from adlay (Coix lacryma jobi-L.). *International Food Research Journal*, *23*(3), 1199–1206.

Chinma, C. E., Azeez, S. O., Sulayman, H. T., Alhassan, K., Alozie, S. N., Gbadamosi, H. D., Danbaba, N., Oboh, H. A., Anuonye, J. C., & Adebo, O. A. (2020). Evaluation of fermented African yam bean flour composition and influence of substitution levels on properties of wheat bread. *Journal of Food Science*, *85*(12), 4281–4289. https://doi.org/10.1111/1750-3841.15527

Disseka, W., Faulet, M., Koné, F., Gnanwa, M., & Kouamé, L. (2018). Phytochemical Composition and Functional Properties of Millet (Pennisetum glaucum) Flours Fortified with Sesame (Sesamum indicum) and Moringa (Moringa oleifera) as a Weaning Food. *Advances in Research*, *15*(6), 1–11. https://doi.org/10.9734/air/2018/42811

Fayemi, O. E., & Ojokoh, A. O. (2014). The effect of different fermentation techniques on the nutritional quality of the cassava product (*Fufu*). *Journal of Food Processing and Preservation*, *38*(1), 183–192. https://doi.org/10.1111/j.1745-4549.2012.00763.x

Gupta, R. K., Kumar, S., Trivedi, A., Verma, R., & Yogesh. (2022). Vitamin C and Its Role in Body. *International Journal of Pharmacy and Pharmaceutical Sciences*, *14*(2), 1–5. https://doi.org/10.22159/ijpps.2022v14i2.43394

Hassan, S. M., Forsido, S. F., Tola, Y. B., Bikila, A. M., & Ahmed, Z. (2023). Effect of Nixtamalization on the Nutritional, Anti-nutritional, Functional, Physicochemical and Mineral Properties of Maize (Zea mays) Tortillas. *Journal of Food Chemistry & Nanotechnology*, *9*(3), 132–140. https://doi.org/10.17756/jfcn.2023-159

Inyang, U. E., Akindolu, B. E., & Elijah, A. I. (2019). Nutrient Composition, Amino Acid Profile and Anti-nutritional Factors of Nixtamalized Maize Flour Supplemented with Sprouted Soybean Flour. *European Journal of Nutrition & Food Safety*, *9*(1), 41–51. https://doi.org/10.9734/ejnfs/2019/46150

Inyang, U. E., & Ekop, V. O. (2015). Physico-Chemical Properties and Anti-nutrient Contents of Unripe Banana and African Yam Bean Flour Blends. *International Journal of Nutrition and Food Sciences*, *4*(5), 549. https://doi.org/10.11648/j.ijnfs.20150405.16

Krishnaiah, D., Devi, T., Bono, A., & Sarbatly, R. (2009). Studies on phytochemical constituents of six Malaysian medicinal plants. *Journal of Medicinal Plants Research*, *3*(2), 067–072.

Maloma, O., Ogunmoyela, O. A. B., Adekoyeni, O. O., Jimoh, O., Oluwajoba, S. O., & Sobanwa, M. O. (2013). Rheological and Functional Properties of Soy-Poundo Yam Flour. *International Journal of Food Science and Nutrition Engineering*, *2*(6), 101–107. https://doi.org/10.5923/j.food.20120206.01

Matendo, R. E., Imathiu, S., Udomkun, P., & Owino, W. O. (2023). Effect of nixtamalization of maize and heat treatment of soybean on the nutrient, antinutrient, and mycotoxin levels of maize-soybean-based composite flour. *Frontiers in Sustainable Food Systems*, *7*(October), 1–12. https://doi.org/10.3389/fsufs.2023.1057123

Meyer-Ficca, M., & Kirkland, J. B. (2016). Meyer-Ficca M, Kirkland JB. Niacin. Adv Nutr. 2016 May 16;7(3):556-8. *Advances in Nutrition*, *7*(3), 556–558. https://doi.org/10.3945/an.115.011239.TABLE

Mrowicka, M., Mrowicki, J., Dragan, G., & Majsterek, I. (2023). The importance of thiamine (vitamin B1) in humans. *Bioscience Reports*, *43*(10), 1–18. https://doi.org/10.1042/BSR20230374

Ngozi, O.-O. P., & Nkiru, O.-A. (2014). Evaluation of Tannin, Phytate and Mineral Composition of Different Indigenous Dishes Based on Pumpkin (Cucurbita Pepo). *International Journal of Nutrition and Food Sciences*, *3*(6), 493. https://doi.org/10.11648/j.ijnfs.20140306.11

Nurdjanah, S., Astuti, S., Musita, N., & Febriyaningsih, T. (2014). The Sensory Properties of Nixtamalized Corn-Based Biscuit. *Jurnal Teknologi Industri Dan Hasil Pertanian*, *19*(2), 127–136.

Nwokoro, O., Ogbonna, J. ., & Okpala, G. . (2010). Simple picrate method for the determination of cyanide in cassava flour. *Bio-Research*, *7*(2), 502–504. https://doi.org/10.4314/br.v7i2.56582

Ocheme, O. B., Oludamilola, O. O., & Mikailu, E. G. (2010). Effect of Lime Soaking and Cooking (Nixtamalization) on the Proximate, Functional and Some Anti-nutritional

Properties of Millet Flour. *Au J.T*, *14*(2), 131–138.

Odoh, E. N., Okafor, R. O., & Ikegwu, T. M. (2022). Physicochemical and Sensory Properties of Unfermented *Fufu* Composite Flour Made from Cassava Sievate , Guinea Corn and Unripe Plantain Flours Blend. *American Journal of Food Science and Technology*, *10*(1), 27–34. https://doi.org/10.12691/ajfst-10-1-4

Offiah, L. O., Ariahu, C. C., & Igyor, M. A. (2016). Effect of malting and fermentation on the proximate composition and sensory properties of maize (Zea mays) and African yam bean (Sphenostylis stenocarpa) based Tortilla. *The International Journal of Engineering And Science*, *5*(8), 1–6.

Ojokoh, A. O., Daramola, M. K., & Oluoti, O. J. (2013). Effect of fermentation on nutrient and anti-nutrient composition of breadfruit (Treculia africana) and cowpea (Vigna unguiculata) blend flours. *African Journal of Agricultural Research*, *8*(27), 3566–3570. https://doi.org/10.5897/ajar12.1944

Okwulehie, F. C., Anyanwu, H. O., Ukozor, A. U. C., Ukwujieagu, C. U., & Okafor, A. C. (2021). Acceptability of *Fufu* Produced Using Residue from Maize, Millet and Sorghum: Strategy for Sustainable Food Security. *International Journal of Advanced Research in Public Policy, Administration and Development Strategies*, *33*(July 2017), 129–138. https://doi.org/10.48028/iiprds/

Oladeji, B. S., Irinkoyenikan, O. A., Akanbi, C. T., & Gbadamosi, S. O. (2018). Effect of fermentation on the physicochemical properties, pasting profile and sensory scores of normal endosperm maize and quality protein maize flours. *International Food Research Journal*, *25*(3), 1100–1108.

Olukomaiya, O. O., Adiamo, O. Q., Fernando, W. C., Mereddy, R., Li, X., & Sultanbawa, Y. (2020). Effect of solid-state fermentation on proximate composition, anti-nutritional factor, microbiological and functional properties of lupin flour. *Food Chemistry*, *315*. https://doi.org/10.1016/j.foodchem.2020.126238

Onwuka, G. I. (2018). *Food Analysis and Instrumentation Theory and Practice*. Naphthadi prints. A division of Hug Support Nig. Ltd.

Ramírez-Jiménez, A. K., Rangel-Hernández, J., Morales-Sánchez, E., Loarca-Piña, G., & Gaytán-Martínez, M. (2019). Changes on the phytochemicals profile of instant corn flours obtained by traditional nixtamalization and ohmic heating process. *Food Chemistry*, *276*(September 2018), 57–62. https://doi.org/10.1016/j.foodchem.2018.09.166

Santiago-Ramos, D., Figueroa-Cárdenas, J. de D., Véles-Medina, J. J., & Salazar, R. (2018). Physicochemical properties of nixtamalized black bean (Phaseolus vulgaris L.) flours. *Food Chemistry*, *240*(February 2017), 456–462. https://doi.org/10.1016/j.foodchem.2017.07.156

Sefa-Dedeh, S., Cornelius, B., & Afoakwa, E. O. (2003). Effect of fermentation on the quality characteristics of nixtamalized corn. *Food Research International*, *36*(1), 57–64. https://doi.org/10.1016/S0963-9969(02)00108-4

Sefa-Dedeh, S., Cornelius, B., Sakyi-Dawson, E., & Afoakwa, E. O. (2004). Effect of nixtamalization on the chemical and functional properties of maize. *Food Chemistry*, *86*(3), 317–324. https://doi.org/10.1016/j.foodchem.2003.08.033

Shiriki, D., Igyor, M. A., & Gernah, D. I. (2015). Nutritional Evaluation of Complementary Food Formulations from Maize, Soybean and Peanut Fortified with Moringa oleifera Leaf Powder. *Food and Nutrition Sciences*, *06*(05), 494–500. https://doi.org/10.4236/fns.2015.65051

Shrivastava, N., & Ananthanarayan, L. (2015). Use of the backslopping method for accelerated and nutritionally enriched idli fermentation. *Journal of the Science of Food and Agriculture*, *95*(10), 2081–2087. https://doi.org/10.1002/jsfa.6923

Sunico, D. J. A., Rodriguez, F. M., Tuaño, A. P. P., Mopera, L. E., Atienza, L. M., & Juanico, C. B. (2021). Physicochemical and Nutritional Properties of Nixtamalized Quality Protein Maize Flour and its Potential as Substitute in Philippine Salt Bread. *Chiang Mai University Journal of Natural Sciences*, *20*(2), 1–15. https://doi.org/10.12982/CMUJNS.2021.035

Suri, D. J., & Tanumihardjo, S. A. (2016). Effects of Different Processing Methods on the Micronutrient and Phytochemical Contents of Maize: From A to Z. *Comprehensive Reviews in Food Science and Food Safety*, *15*(5), 912–926. https://doi.org/10.1111/1541-4337.12216

Suwannasom, N., Kao, I., Pruß, A., Georgieva, R., & Bäumler, H. (2020). Riboflavin: The health benefits of a forgotten natural vitamin. *International Journal of Molecular Sciences*, *21*(3). https://doi.org/10.3390/ijms21030950

Bello, Florence A., Nkpoikana A. Akpaoko, and Victor E. Ntukidem. 2020. "Formulation and Assessment of Nutritional Functional and Sensory Attributes of Complementary Foods from Maize-Carrot-Pigeon Pea Flour Blends". Journal of Scientific Research and Reports 26 (2):90-99. https://doi.org/10.9734/jsrr/2020/v26i230228.

Tahseen, Aaliya, Sathu. T, Muthukumar Muthupalani, Vasudevan. V. N., Irshad. A, Preethy John, K. Raji, and MHS Abrar Basha. 2024. "Comparative Evaluation of Nutritional Composition, Fatty Acid Profile and Sensory Attributes of Commercial Plant-Based Meat Analogues and Chicken Nuggets". Archives of Current Research International 24 (12):197-206. https://doi.org/10.9734/acri/2024/v24i121010.