Influence of Tigernut Sprouting on Nutritional, Anti-Nutritional, Functional, and Sensory Properties of Kokoro from Maize–Tigernut Composite Flours

Ogundipe, O. O.[1*], Olaleye, H. T.[1], Sanoussi, F.[2], Ojegbade, R.[1], Abegunde, T. D.[1] and Adeyeye, Samuel A. O.[3]

[1]Department of Food Science and Technology, Yaba College of Technology, Yaba Lagos, Nigeria.
[2]Laboratory of Biotechnology, Genetic Resources and Plant and Animal Breeding (BIORAVE), Faculty of Science and Techniques of Dassa, PO Box 143 Dassa-Zoume, Benin.
[3]Department of Food Technology, Hindustan Institute of Technology and Science, Padur, Chennai - 603103, Tamil Nadu, India.
*Corresponding Author's Email: oladeinde.ogundipe@yabatech.edu.ng ; https://orcid.org/0000-0001-8778-065X

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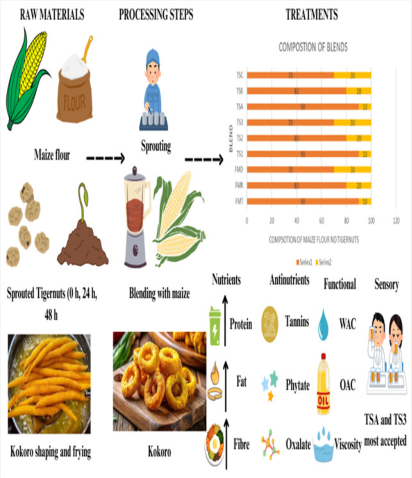
ABSTRACT

In Africa, kokoro is a popular maize-based snack made by extruding and frying a mixture of maize flour, water, and spices. The study evaluated the snack's nutritional, anti-nutritional, functional, and sensory attributes after sprouting tigernut for 0, 24, and 48 hours and incorporating it into maize composite flour. It found that sprouting increases protein, fat, and fibre while decreasing anti-nutritional factors. Kokoro became more nutritious when tigernut flour was germinated. Sprouting for 48 hours raised kokoro's protein content from 13.03% to 21.48%. The main reason is the improved protein quality from sprouting. Kokoro made with sprouted tigernut flour had better energy and functional qualities, making it more attractive to consumers. Significant improvements in water and oil absorption capacity (WAC and OAC) were observed (P < 0.05). The peak water-absorption capacity of the TS1 and TSB samples was 1.03–1.12 g/g. TSA showed the highest oil absorption capacity (0.70-1.03 g/g), while TS1 had the lowest. The enhanced functional qualities improve texture and mouthfeel. The low bulk density makes it suitable for recipes that do not require retrogradation. Sprouting also improved kokoro's flavour. TSA (tigernut grown for 48 hours) was the most popular and was better accepted. This suggests that longer sprouting improved the taste of the kokoro snack. The research shows that sprouting tigernuts during food processing can enhance the nutritional content, functional properties, and flavour of traditional snacks like kokoro, thereby supporting health and food security.

Keywords: *Kokoro, Sprouting, Composite-Flour, Tigernuts, Maize, nutritional enhancement*



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INTRODUCTION

Kokoro, a popular maize-based snack in many African regions, is traditionally produced by cold extrusion and then fried, with a maize-flour paste seasoned with salt, sugar, and spices. The snack is shaped into various forms, including cylindrical rods and rings. The preparation of Kokoro involves mixing maize flour, seasoned with sugar, spices, and salt, with hot water until a thick, consistent dough is obtained. This dough is then kneaded and moulded into ring shapes before being deep-fried in vegetable oil. The colour of Kokoro ranges from cream to light brown and golden yellow, depending on processing conditions. It is a low-moisture snack that is fried at high heat until crisp.

Traditional kokoro often lacks optimal nutritional density, prompting investigations into innovative processing methods to enhance its health benefits and consumer appeal (Okolie et al., 2022). This study specifically examines the impact of incorporating sprouted tigernut flour into maize-based kokoro, aiming to improve its proximate composition, functional properties, physicochemical characteristics, anti-nutritional factors, and sensory attributes (Oluwole et al., 2017). In previous research, nutritional deficiencies in maize-based kokoro have motivated efforts to fortify and supplement it with legumes, such as groundnut, soybean, lima bean, and African yam bean, to boost its nutritional quality (Akinsola et al., 2020). Traditional processing methods, such as fermentation, germination, soaking, and thermal treatments, have been used to enhance nutritional quality and reduce antinutrients in cereals, legumes, and tubers (Atuna et al., 2023). For example, germination can increase protein digestibility and improve mineral accessibility in pulses, even if the microstructure remains unchanged (Chinma et al., 2020; Erba et al., 2018). Enriching maize-based products, such as kokoro, with nutrient-dense ingredients, such as tigernuts, can significantly address common deficiencies in macronutrients and micronutrients among communities reliant on staple crops (Aletor et al., 2013; Azeez et al., 2024). While some research focuses on fortifying kokoro with legumes, this investigation uniquely leverages tigernut sprouting to enhance its nutritional profile and overall quality. Tigernuts, also known as yellow nutsedge or chufa, are an underutilized crop recognized for their high fibre content, natural sugars, proteins, and essential minerals such as phosphorus and potassium, as well as vitamins E and C, offering notable health benefits (Kalahal et al., 2024). They are high in dietary fibre, which has been shown to help prevent and manage various diseases, including colon cancer, coronary heart disease, and gastrointestinal disorders (Awolu, 2017). Moreover, tigernuts are notable for being gluten-free and cholesterol-free, with very low sodium levels, making them particularly suitable for diverse dietary needs, including infant nutrition (Wakil and Ola, 2018). Beyond their intrinsic nutritional value, tigernuts offer functional advantages due to their oil and water absorption capacities, making them a promising gluten-free ingredient for various food formulations (Akeem et al., 2023). Recognized for their high energy content and rich vitamin and mineral profile, including iron, phosphorus, calcium, and sulphur-containing amino acids, tigernuts provide a substantial nutritional foundation, often exceeding the starch content of conventional tubers like potatoes (Uchechi et al., 2020). Therefore, using sprouted tigernut flour offers a novel approach to enhancing the nutritional and functional qualities of kokoro, potentially increasing its overall appeal and health benefits as a traditional snack (Alaka et al., 2020). The natural absence of gluten in tigernuts further positions them as a valuable ingredient for gluten-free food applications, providing an alternative for individuals with dietary restrictions (Gasparre & Rosell, 2019). This study explores the optimization of tigernut sprouting durations (0, 24, and 48 hours) to assess their effects on the nutritional enhancement and sensory acceptance of the resulting Kokoro. This process improves the content of fat, total protein, total sugars, and B vitamins, while concurrently reducing complex colloidal carbohydrate derivatives, dry matter, and antinutrients. Studies (Okoye & Ene, 2018) have shown that germination effectively reduces anti-nutrients, including tannins, oxalates, and phytates. The study aimed to investigate the effect of sprouting time on the proximate composition, functional properties, physicochemical characteristics, anti-nutritional factors, and sensory analysis of Kokoro snacks made from composite flours.

MATERIALS AND METHODS

Materials

Dried, high-quality white maize, tigernuts, sugar, salt, spices, vegetable oil, and sprouting sacks were purchased from Mile 12 Market in Lagos, Nigeria.

Sprouting of Tigernuts

Wholesome tigernut kernels were cleaned, then soaked in potable water for 24 hours in a flat-bottomed, shallow container to allow the seeds to absorb water. The soaked seeds were then washed, drained, and spread on a sterile sprouting jute sack, kept away from light, with additional intermittent wetting to facilitate sprouting at ambient temperature (28 ± 2 °C).

Production of Maize Flour for Kokoro

Wholesome maize kernels were cleaned to remove contaminants, dried at 65˚C for 24 hours, and pulverised into fine flour through attrition. The flour was permitted to cool before being packed in airtight containers for future use (Adegunwa and Adeniyi, 2015).

Production of Tigernut Flour (Sprouted and Unsprouted)

Before sprouting, fresh tigernut kernels were cleaned, steeped in water, and sorted to remove impurities. After sprouting, the seeds were cleaned to remove dead shoots and then winnowed. Both sprouted and unsprouted tigernuts were dried in a hot-air oven at 65˚C for 24 hours and subsequently milled into flour (Ade-Omowaye et al., 2008). The milled tigernut flours (sprouted and unsprouted) were stored in airtight Ziploc® double-zipper, high-density package bags until ready for use.

Preparation of Kokoro from Maize and Tigernuts (Sprouted and Unsprouted)

Maize flour was partially replaced with tigernut flour at ratios ranging from 10% to 30% tigernut (Table 1). The reference sample was prepared using 100% maize flour. Separately, 300 mL of warm water was added to 500 g of the maize and tigernut flour blends according to the respective ratios. The mixture was then mixed with the same proportions of salt and sugar to form a dough. A 20 g portion of the dough was cut into a ring and deep-fried in deodorised cottonseed oil at 180˚C for 9 minutes.

Table 1: Formulation of Composite Blends of Maize and Tigernut Flour Blends (%).

Blend Ratio	Unsprouted	Sprouted (24Hrs)	Sprouted (48Hrs)
100	MZN*	-	-
90:10	FMT	TS1	TSA
80:20	FMR	TS2	TSB
70:30	FMD	TS3	TSC

KEYS

MZN- 100% Maize flour (control)
FMT- 90% Maize flour: 10% unsprouted Tigernuts flour
FMR- 80% Maize flour: 20% unsprouted Tigernuts flour
FMD- 70% Maize flour: 30% unsprouted Tigernuts flour
TS1- 90% Maize flour: 10% sprouted Tigernuts (24hrs) flour
TS2- 80% Maize flour: 20% sprouted Tigernuts (24hrs) flour
TS3- 70% Maize flour: 30% sprouted Tigernuts (24hrs) flour
TSA- 90% Maize flour: 10% sprouted Tigernuts (48hrs) flour
TSB- 80% Maize flour: 20% sprouted Tigernuts (48hrs) flour
TSC- 70% Maize flour: 30% sprouted Tigernuts (48hrs) flour

Proximate analysis of Kokoro

Kokoro from the composite (maize and tigernuts) flours of both sprouted and unsprouted sample treatments were determined according to the AOAC (2005) method: moisture content (Hot air draught oven), crude fibre and ash (in furnace), lipid fat extraction (Soxhlet) method and protein (Kjeldahl) method. The % carbohydrate was obtained by the difference method.

% carbohydrate (Difference method) = 100 % (% moisture + % fat + % crude fiber + % ash)

Evaluation of Kokoro Energy Value

The Atwater factor formula was used to obtain the energy values (4 × % carbohydrate + 4 × % protein + 9 × % fat) in kcal/100g.

Functional Properties of *kokoro* from Composite blends of Maize and Tigernut Flour Loose bulk density and tapped bulk density of the flours

The method employed by Falade and Kolawole (2012) was adopted to obtain the bulk density of starches, while loose and tapped bulk densities were obtained by calculating as the ratios of the bulk and tapped weight, to the volume of the respective container (g/cm^3) used.

Swelling power of Flour blends for Kokoro.

The swelling power of flour blends for kokoro was determined using the method described by Adebowale et al. (2008), with slight modifications.

Oil and Water Absorption Capacity of Different Flour Blends

Oil and Water absorption capacities were determined, respectively, as described by Adebowale *et al.* (2008). They were expressed as millilitres of water or oil bound per gram of dry flour.

Colour Determination of *Kokoro* from Composite Blends of Maize and Tigernut Flour

The colour of Kokoro was obtained using the procedure described in AOAC (2005). a*, b*, and L*and the parameters were determined with a colourimeter (Chroma Meter CR-410, Konica Minolta, Japan).

Determination of Anti-Nutritional Factors in Flour from Composite Blends of Maize and Tigernut Flour

Tannin and oxalate contents were determined by the procedure described by Oke (1966); phytate by the spectrophotometric method at an absorbance (A) wavelength of 640 nm (AOAC, 2005).

Evaluation of Pasting Properties of flour from Composite blends of Maize and Tigernut Flour

A rapid visco analyser (Newport Scientific, RVA Super 5, Germany) was used to determine the pasting characteristics of the flours (Tijani et al., 2016).

Sensory Evaluation of Kokoro Snack

A 20-member panel familiar with the perceptible sensory attributes of Kokoro, rated on a 9-point hedonic perception scale (1 = dislike extremely; 9 = like extremely), according to the method described by Su *et al* (2022), to determine consumer acceptance.

Analysis of Data

Analysis of variance (ANOVA) in the Statistical Package for the Social Sciences (SPSS) version 16.0 was used to analyse the data. The significance ($P \leq 0.05$) of the mean values was assessed for differences.

RESULTS AND DISCUSSION

Proximate Composition of Kokoro

The proximate composition of Kokoro from different treatments, as shown in Table 2, indicates that the moisture content of the food can range from low to high, which helps make reasonable inferences about the product's shelf stability. It helps predict the product's storability. Sample treatment TS3 showed the highest moisture content in this study, while MZN had the lowest. The moisture content was sufficiently low to ensure good shelf stability for all samples, suggesting that the products have stable keeping qualities. Foods with low moisture content are less susceptible to spoilage. Protein content ranged from 13.03% to 21.48%, with the MZN treatment having the lowest protein level. Protein content increased with sprouting time. The protein content of the Kokoro analysed was higher than that reported by Oladele and Aina (2007) for raw tigernuts. This may be due to the sprouting treatment.

The crude fat content ranged from 5. 07% to 14. 05%. Sample treatment TSC had the highest fat content, while FMD had the lowest. This variation may have resulted from longer sprouting times and the amount of maize substituted with tigernuts. The high fat content is likely due to the oil used for frying, the oil-protein bonds in high-protein fried snacks, and the frying duration. However, the fat content is lower than that reported by Adegunwa et al. (2015). Crude fibre content ranged from 24. 96% to 40. 03%, with TSB having the lowest crude fibre content and TS 2 the highest. The values for crude fibre are within the recommended dietary intake of fibre (22–42%) for various age groups, as reported by Akinjayeju (2015). The increase in crude fibre may be due to sprouting, which raises both the quantity and function of crude fibre, a principal component of cell walls, through the breakdown of structural carbohydrates like cellulose and hemicellulose (Shipard, 2005). Fibre is vital for preventing and managing conditions such as diverticulosis, cardiovascular diseases, indigestion, colon irritation, diabetes mellitus, and cancer (Shipard, 2005; Elleuch, 2011). Ash content in the samples ranged from 0.44% to 1.1%. MZN (control) had the lowest ash, while FMR had the highest. The low ash content may be linked to tigernut sprouting duration, with ash decreasing as sprouting duration increases. These findings align with those of Uzor- Peters et al. (2008). The carbohydrate content of Kokoro ranged from 32. 07% in MZN to 47. 51% in FMD. Carbohydrates are a primary macronutrient, accounting for up to 80% of total energy intake in humans, and include monosaccharides, disaccharides, oligosaccharides, and polysaccharides. Their primary role is to provide energy (Vieira et al., 2025). Energy is crucial for all physical activities. The energy value ranged from 270.0 to 358.2 kcal/100g, with treatment TSC having the highest and TS 2 the lowest. The lower energy in TS 2 may be due to the sprouting process. Overall, the Kokoro samples are energy- rich snacks.

Colour Analysis

Colour plays a vital role in assessing a product's quality, freshness, perception, and acceptance. No visible changes were observed in any of the sample blend treatments, except in sample MZN. The L*, a*, and b* values varied with the level of maize substitution by tigernuts (sprouted and unsprouted), as shown in (Table 3). The L* value ranged from 33.49 to 46.18; treatment MZN had the highest value (46.18), while TS2 had the lowest (33.49). L* values decreased in all treatments with sprouted tigernut flour, except in TS1 and TSA, which contained tigernuts sprouted for 24 and 48 hours, respectively. This variation may be due to the amount of maize replaced with tigernut flour. MZN recorded the lowest value (-3.87), and TS2 the highest (0.16) for the degree of redness. The redness (a*) of the Kokoro from maize-tigernut flour was negative, indicating fewer changes in red colour as measured by the Chroma meter. The b* value, which indicates yellowness, decreased with increasing levels of tigernut flour substitution. TS3 (12.10) had the lowest b* value, while MZN (19.10) had the highest. The low b* values in Kokoro samples with tigernuts, whether sprouted or unsprouted, may be associated with browning during drying and deep-frying. The values obtained for L*, a*, and b* were lower than those reported by Falade and Kolawole[12].

Colour intensity and delta Chroma values increased as maize substitution with sprouted tigernuts decreased (at 24 and 48 hours). Besides MZN (control), TSA (12.45 and 15.69, respectively) and TS1 (11.18 and 15.65, respectively) had the highest values, as shown in (Table 3), likely due to sprouting. Colour intensity and delta Chroma ranged from 7.11 to 19.96 and 12.35 to 18.70, respectively. The reduction in L* and delta Chroma values in the treatments could be attributed to the Maillard browning reaction, which relies on the amounts of reducing sugars and amino acids available for amino-carbonyl reactions, as well as frying temperature and time (Krokida, 2001; Moyano, 2002), and also sprouting. The sprouting treatments produced marginally darker samples, reflected by L* values indicating lightness levels. Colour changes may also arise from caramelisation, which occurs in the

Table 2: Proximate Composition of *Kokoro* Produced from Maize and Tigernut Flour Blends (%).

Sample code (MA: TF)	**Moisture Content**	**Crude Protein**	**Crude Fat**	**Crude Fibre**	**Total Ash**	**Carbohydrate Content**	**Energy Value (kcal/100g)**
MZN	1.28 ± 0.05^{a}	13.03 ± 0.10^{a}	9.48 ± 0.11^{d}	30.46 ± 0.06^{e}	0.44 ± 0.06^{a}	45.33 ± 0.25^{f}	318.7 ± 0.36^{f}
FMT	1.69 ± 0.01^{bc}	21.48 ± 0.04^{f}	11.62 ± 0.02^{h}	29.22 ± 0.02^{d}	0.96 ± 0.01^{de}	35.04 ± 0.01^{bc}	330.6 ± 20.08^{g}
FMR	1.45 ± 0.14^{ab}	16.07 ± 0.13^{d}	10.25 ± 0.35^{f}	35.23 ± 0.15^{f}	1.09 ± 0.16^{e}	35.92 ± 0.33^{c}	300.2 ± 2.36^{d}
FMD	1.85 ± 0.11^{cde}	15.08 ± 0.03^{b}	5.07 ± 0.04^{a}	29.95 ± 0.08^{d}	0.56 ± 0.06^{abc}	47.51 ± 0.03^{g}	296.0 ± 0.69^{c}
TS1	2.19 ± 0.13^{f}	14.88 ± 0.13^{b}	9.92 ± 0.11^{e}	39.97 ± 0.06^{g}	0.98 ± 0.06^{de}	32.07 ± 0.27^{a}	277.1 ± 1.58^{b}
TS2	1.63 ± 0.04^{bc}	14.75 ± 0.18^{b}	8.03 ± 0.04^{c}	40.03 ± 0.04^{g}	0.87 ± 0.04^{d}	34.70 ± 0.34^{b}	270.0 ± 0.30^{a}
TS3	2.09 ± 0.04^{ef}	15.53 ± 0.32^{c}	11.05 ± 0.07^{g}	27.43 ± 0.11^{c}	0.67 ± 0.04^{c}	43.24 ± 0.27^{e}	334.5 ± 0.44^{g}
TSA	1.90 ± 0.07^{cdef}	16.64 ± 0.12^{e}	7.08 ± 0.03^{b}	30.13 ± 0.10^{d}	0.50 ± 0.06^{abc}	43.76 ± 0.38^{e}	305.3 ± 0.79^{e}
TSB	1.70 ± 0.78^{bcd}	16.13 ± 0.10^{d}	10.43 ± 0.11^{f}	24.96 ± 0.08^{a}	0.63 ± 0.05^{bc}	46.17 ± 0.17^{g}	343.0 ± 0.70^{h}
TSC	1.99 ± 0.27^{def}	15.76 ± 0.13^{cd}	14.05 ± 0.07^{i}	25.33 ± 0.15^{b}	0.42 ± 0.05^{ab}	42.17 ± 0.06^{d}	358.2 ± 0.10^{i}

All means and deviation values with superscripts on the same column differ (p≤0.05) significantly, and were analyzed using ANOVA.
KEYS: MA- Maize flour, TF- Tigernut flour

Table 3: Colour Attribute of treatments showing *Kokoro* Produced from blends of Maize and Tigernut Flour

Sample code (MA: TF)	L*	a*	b*	ΔC	ΔE	b/a	Tan-1 b/a
MZN	46.18^{j}	-3.87^{a}	19.10^{i}	18.70^{f}	19.96^{j}	-4.94^{f}	-78.56^{a}
FMT	38.89^{h}	-0.67^{g}	15.78^{g}	15.80^{e}	11.35^{f}	-23.39^{g}	-87.54^{a}
FMR	38.7^{g}	-1.17^{e}	16.59^{h}	16.63^{e}	11.67^{h}	-14.12^{h}	-85.95^{bc}
FMD	38.54^{f}	-1.91^{c}	15.50^{e}	15.61^{d}	11.50^{g}	-8.12^{e}	-82.98^{c}
TS1	38.47^{e}	-1.36^{d}	15.58^{f}	15.65^{d}	11.18^{e}	-11.46^{f}	-85.01^{a}
TS2	33.49^{a}	0.16^{i}	$13.46^{c}2$	13.46^{b}	5.75^{a}	89.73^{c}	-89.36^{ab}
TS3	33.98^{b}	-2.43^{b}	12.10^{a}	12.35^{a}	7.73^{c}	$-4.97^{a}1$	-78.62^{b}
TSA	39.41^{i}	-2.43^{b}	15.49^{e}	$15.69^{d}1$	12.44^{i}	-6.38^{e}	-81.82^{ab}
TSB	35.96^{d}	-0.27^{h}	14.49^{d}	14.49^{c}	8.26^{d}	-55.73^{d}	-88.97^{ab}
TSC	34.46^{c}	$-0.96^{f}3$	13.12^{b}	13.16^{b}	7.11^{b}	-13.68^{b}	-85.82^{c}

All means (x) ± SE values with superscripts on the same column differ (p≤0.05) significantly, and were analyzed using ANOVA.
KEYS: MA- Maize flour, TF- Tigernut flour, Lightness, a*- Redness, Yellowness, ΔC- Delta Chroma, ΔE-Colour Intensity, Tan^{-1} b/a–Hue Angles

presence of sugars at temperatures above water's boiling point. A significant difference ($p \leq 0.05$) was observed in hue angles. Hue is the first element in the colour order system, which differentiates red from green and blue from yellow. The hue angle ranged from -78.56 to -89.36, indicating a negative value.

Pasting Properties

The pasting properties of flours influence food quality and acceptance, affecting textural attributes, digestibility, and the intended use of starch matrices in food (Onweluzo, 2009). Peak viscosity measures the ability of starch-based foods to absorb water and swell before breaking down during gelatinization (Sanni, 2006). Pasting properties varied significantly with sprouting treatment and substitution levels. Overall, the pasting properties of all treatments decreased significantly ($p \leq 0.05$), except for pasting temperature, and increased steadily as maize was substituted with tigernut flour. The TSC sample had lower trough, peak, final, breakdown, and setback viscosities, as well as peak time, likely due to the longer sprouting duration.

Peak viscosity reduced as the substitution of maize with tigernuts increased. Sample treatment TSC had the lowest peak viscosity, and MZN had the highest. Peak viscosity indicates the maximum swelling that starch granules can achieve before disintegration. Liu et al. (2007) described it as the latent transition point between the swelling and breakdown of starches. It helps predict the rheological load likely to be encountered during mixing (Maziya-Dixon, 2005; Maziya-Dixon, 2004). The final product quality is often related to peak viscosity. Changes in the starch matrix could lead to decreased pasting characteristics due to starch degradation and debranching into simpler units, as a result of the sprouting treatment. Peak viscosity and trough had a significant ($p \leq 0.05$) correlation.

High trough viscosity indicates the paste's ability to resist breakdown during cooling. A starch with higher trough viscosity is more resistant to breakdown than one with lower trough viscosity. The viscosity values ranged between 1112.0 and 1760.5 cP. Sample treatment MZN had the highest trough viscosity, while sample treatment TSC had the lowest. Breakdown viscosity values ranged from 25.50 to 50.00 cP. TSA and TSB, which sprouted for a longer time (48 hours), had higher breakdown values. Breakdown viscosity measures resistance to heat and shearing force during dough processing.

The final viscosity of the flour treatments ranged from 1834.0 to 3964.0 cp. MZN exhibited the highest final

Table 4: Pasting Properties of Flour from Maize and Tigernut (Sprouted and Unsprouted) Treatments.

Sample code (MA:TF)	Peak (cP)	Trough (cP)	Breakdown (cP)	Final Viscosity (cP)	Setback Value (cP)	Peak Time (min)	Pasting Temperature (°C)
MZN	1786.0^{h}±18.38	1760.5^{h}±14.8	25.50^{a}±3.53	3964.0^{g}±53.7	2203.5^{g}±38.9	6.90^{a} ±0.05	84.78^{a}±0.04
FMT	1564.0^{f}±18.38	1520.5^{f}±14.8	43.50^{cdef}±3.54	3215.5^{f}±17.7	1695.0^{f}±2.82	7.00^{a}±0.00	85.20^{a}±0.64
FMR	1346.5^{cd}±7.78	1296.5^{cd}±9.19	50.00^{g}±1.41	2442.0^{d}±12.7	1145.5^{d}±3.53	7.00^{a}±0.00	86.83^{bc}±0.67
FMD	1201.5^{b}±3.56	1157.0^{b}±1.41	44.50^{defg}±4.95	2097.0^{b}±7.07	940.0^{b}±5.67	7.00^{a}±0.00	87.23^{bc}±1.17
TS1	1605.0^{g}±11.31	1567.5^{g}±9.17	37.50^{bc}±2.12	3209.0^{f}±14.1	1641.5^{f}±4.95	7.00^{a}±0.00	84.75^{a}±0.00
TS2	1364.0^{d}±9.90	1321.5^{d}±10.6	42.50^{cde}±0.71	2464.5^{e}±9.19	1143.0^{d}±19.8	7.00^{a}±0.00	85.95^{ab}±0.57
TS3	1202.0^{b}±18.4	1166.0^{b}±21.2	36.00^{b}±2.83	2054.0^{b}±36.8	888.0^{b}±15.56	6.97^{a}±0.05	87.20^{ba}±0.00
TSA	1437.5^{e}±23.3	1388.5^{e}±21.9	49.00^{fg}±1.41	2666.5^{e}±46.0	1278.0^{e}±24.0	7.00^{a}±0.00	85.98^{ab}±0.53
TSB	1320.0^{c}±12.7	1272.5^{c}±13.4	47.50^{efg}±0.71	2320.0^{c}±97.6	1047.5^{c}±84.1	7.00^{a}±0.00	85.95^{ab}±0.49
TSC	1153.0^{a}±1.41	1112.0^{a}±1.41	41.00^{bcd}±0.00	1834.0^{a}±9.90	722.0^{a}±11.3	7.00^{a}±0.00	87.63^{c}±0.60

All means (x) ± SE values with superscripts on the same column differ (p≤0.05) significantly, and were analyzed using ANOVA.

KEYS: MA- Maize flour, TF- Tigernut flour.

viscosity value, while TSC showed the lowest. Final viscosity indicates the material's ability to form a viscous paste or gel after cooking and cooling, as well as the paste's resistance to shear force during stirring (Adeyemi and Idowu, 1990). Setback viscosity ranged from 722.0 c P to 2203.5 c P. Sample treatment TSC had the lowest value, and MZN had the highest. Setback decreased significantly (p ≤ 0.05) as tigernut substitution increased, as seen in FMT, TS3, and TSC. MZN (control) was more susceptible to retrogradation due to its higher setback viscosity value. MZN, with higher setback viscosity, would exhibit stiffer pastes than TSC, with lower setback viscosity. This is consistent with findings reported by Seog et al. (1987). A high setback is associated with syneresis (weeping) during alternating freeze-thaw cycles. Modified starches are commonly used to avoid this quality defect. Setback viscosity correlated (p ≤ 0.05) with final viscosity.

Peak time, indicative of gelatinization time, was not significantly different (p ≤ 0.05) among sample treatments in (Table 4) and ranged from 6.90 to 7.00 minutes. Pasting temperature increased with the increased substitution of tigernuts in maize flour. Sample treatment TSC had a pasting temperature of 87.63˚C. Pasting temperature indicates the temperature at which a noticeable increase in viscosity occurs (Moorthy, 2002). It helps determine the minimum temperature at which a given sample will cook due to gelatinization. This is important for considering the stability of other components in the flour and determining energy and cost requirements (Newport Scientific, 1995). All treatments generally showed similar trends in terms of their RVA patterns.

Functional Properties of flours used in producing Kokoro snack

Functional properties, as shown in (Table 5), reflect how components of the food matrix behave and interact during processing and cooking, affecting the appearance, taste, and texture of the finished product. The functional properties of composite maize and tigernut (sprouted or unsprouted) flour blend treatments are presented in (Tables 5 and 6). Loose bulk density values ranged from 0.39 g/ml in FMD to 0.48 g/ml in MZN, while the packed bulk density value of the blends ranged from 0.70 g/ml in TSC to 0.82 g/ml in MZN. The low, loose, and packed bulk density values suggest that the samples are predisposed to occupying more space when packed in a container. Karuna et al (1996) reported that bulk density is a function of particle size and flour density, which is important for determining packaging requirements and material handling. The low bulk density suggests that the flour samples can be used in food formulations without concern for retrogradation and are desirable for complementary food formulations (Akpata and Akubor, 1996). Bulk densities obtained in this study were similar to those reported by Ayinde et al (2012), who observed low values for loose and bulk density in composite flour blends of maize and beniseed flour. The water absorption capacity of TS1 and TSB was the highest, ranging from 1.03 g/g to 1.12 g/g. Water absorption capacity indicates how flour-based products interact with water, even in a hydrophobic system (Omueti et al, 2009). A high-water absorption capacity signifies a free arrangement of starch polymers, whereas low values denote a more compact molecular configuration (Oladipo and Nwokocha, 2011). Low water absorption capacity across different flour blend treatments suggests good water-binding ability.

Oil absorption capacity ranged from 0.70 to 1.03 g/g, with TS1 having the lowest and TSA the highest. Oil absorption capacity is key in food formulations, as fat is important for enhancing flavour and mouth-feel (Aremu, 2007). Low oil absorption capacity in these flour treatments may result from the proteins' low hydrophobicity and excellent lipophilic properties (Lawal and Adebowale, 2004). Swelling power at 50ºC, 60ºC, 70ºC, 80ºC, and 90ºC ranged from 1.04 to 1.39, 1.30 to 1.38, 3.85 to 5.04, 4.27 to 5.70, and 4.71 to 5.90 g/g, respectively. Swelling power measures hydration capacity, determined by the weight of swollen starch granules and their water content in the food matrix (Moses, 2012). Retention of water in swollen starch granules is a key attribute that consumers associate with food quality.

The solubility at 50ºC, 60ºC, 70ºC, 80ºC, and 90ºC ranged from 0.02 to 0.70, 0.02 to 0.05, 0.01 to 0.07, 0.02 to 0.05, and 0.02 to 0.04%, respectively. Solubility was higher in TSA, TSB, and TSC. The low solubility values observed in the treatments of maize and tigernut (sprouted or unsprouted) flours may be due to the presence of lipids,

Table 5: Functional Properties of Flour from Maize and Tigernut (Sprouted and Unsprouted) Treatments.

Sample code (MA: TF)	**LBD (g/ml)**	**PBD (g/ml)**	**WAC (g/g)**	**OAC (g/g)**	**SWP 50ºC**	**SWP 60ºC**	**SWP 70ºC**	**SWP 80ºC**	**SWP 90ºC**
MZN	$0.48^{b}\pm0.01$	$0.82^{c}\pm0.01$	$1.04^{a}\pm0.00$	$0.78^{abc}\pm0.02$	$1.04^{bc}\pm0.04$	$1.30^{a}\pm0.03$	$5.04^{e}\pm0.22$	$4.62^{bc}\pm0.03$	$5.88^{f}\pm0.06$
FMT	$0.43^{ab}\pm0.02$	$0.79^{bc}\pm0.04$	$1.03^{a}\pm0.02$	$0.86^{cd}\pm0.01$	$1.39^{d}\pm0.08$	$1.36^{a}\pm0.02$	$4.60^{bcd}\pm0.13$	$5.29^{e}\pm0.03$	$5.90^{f}\pm0.78$
FMR	$0.43^{ab}\pm0.01$	$0.74^{cb}\pm0.00$	$1.05^{a}\pm0.01$	$0.86^{cd}\pm0.01$	$1.39^{d}\pm0.08$	$1.36^{a}\pm0.02$	$4.60^{bcd}\pm0.13$	$4.63^{bc}\pm0.01$	$5.62^{e}\pm0.14$
FMD	$0.39^{a}\pm0.07$	$0.75^{abc}\pm0.03$	$1.08^{a}\pm0.03$	$0.72^{ab}\pm0.04$	$1.32^{cd}\pm0.03$	$1.36^{a}\pm0.02$	$3.85^{a}\pm0.01$	$4.62^{bc}\pm0.13$	$4.98^{bc}\pm0.13$
TS1	$0.40^{a}\pm0.05$	$0.75^{ab}\pm0.00$	$1.12^{a}\pm0.08$	$0.70^{a}\pm0.02$	$1.22^{a}\pm0.07$	$1.33^{a}\pm0.04$	$4.85^{de}\pm0.21$	$4.55^{ab}\pm0.03$	$5.67^{f}\pm0.02$
TS2	$0.42^{ab}\pm0.02$	$0.76^{abc}\pm0.00$	$1.05^{a}\pm0.03$	$0.73^{ab}\pm0.04$	$1.28^{bcd}\pm0.03$	$1.38^{a}\pm0.01$	$4.72^{cd}\pm0.01$	$5.70^{f}\pm0.21$	$5.44^{de}\pm0.04$
TS3	$0.43^{ab}\pm0.01$	$0.73^{ab}\pm0.03$	$1.07^{a}\pm0.00$	$0.73^{ab}\pm0.01$	$1.15^{cb}\pm0.02$	$1.31^{a}\pm0.01$	$4.00^{a}\pm0.20$	$4.92^{cd}\pm0.05$	$5.36^{d}\pm0.11$
TSA	$0.44^{ab}\pm0.03$	$0.76^{abc}\pm0.05$	$1.05^{a}\pm0.05$	$1.03^{e}\pm0.03$	$1.23^{bcd}\pm0.10$	$1.34^{a}\pm0.06$	$4.92^{de}\pm0.02$	$5.00^{de}\pm0.35$	$5.10^{c}\pm0.16$
TSB	$0.42^{ab}\pm0.02$	$0.77^{abc}\pm0.01$	$1.12^{a}\pm0.01$	$0.86^{d}\pm0.01$	$1.25^{bcd}\pm0.06$	$1.32^{a}\pm0.00$	$4.41^{bc}\pm0.06$	$4.81^{bcd}\pm0.05$	$4.77^{ab}\pm0.18$
TSC	$0.43^{ab}\pm0.01$	$0.70^{a}\pm0.04$	$1.10^{a}\pm0.08$	$0.80^{bcd}\pm0.07$	$1.33^{cd}\pm0.02$	$1.33^{a}\pm0.00$	$4.34^{b}\pm0.14$	$4.27^{a}\pm0.07$	$4.71^{a}\pm0.05$

All means (x) ± SE values with superscripts on the same column differ ($p \leq 0.05$) significantly, and were analyzed using ANOVA. **KEYS:** MA- Maize flour, TF- Tigernut flour, LBD- Loose bulk density, PBD- Packed bulk density, WAC-Water absorption capacity, OAC- Oil absorption capacity, SWP-Swelling power

Table 6: Anti-nutritional Content of Maize and Tigernut (Sprouted and Unsprouted) Flour Blends.

Sample code (MA: TF)	Oxalate	Tannin	Phytate
MZN	$0.08^{c}\pm0.00$	$0.15^{d}\pm0.00$	$0.72^{cd}\pm0.10$
FMT	$0.08^{ab}\pm0.14$	$0.12^{c}\pm0.01$	$0.85^{de}\pm0.14$
FMR	$0.07^{a}\pm0.00$	$0.09^{ab}\pm0.00$	$0.73^{cd}\pm0.14$
FMD	$0.09^{g}\pm0.00$	$0.13^{cd}\pm0.0$	$0.46^{a}\pm0.07$
TS1	$0.08^{f}\pm0.00$	$0.12^{c}\pm0.00$	$0.52^{ab}\pm0.00$
TS2	$0.08^{e}\pm0.00$	$0.12^{c}\pm0.00$	$0.63^{bc}\pm0.00$
TS3	$0.07^{b}\pm0.00$	$0.11^{bc}\pm0.01$	$1.13^{f}\pm0.02$
TSA	$0.14^{i}\pm0.00$	$0.09^{a}\pm0.00$	$0.88^{e}\pm0.04$
TSB	$0.11^{h}\pm0.00$	$0.08^{a}\pm0.03$	$0.84^{de}\pm0.01$
TSC	$0.08^{c}\pm0.00$	$0.08^{a}\pm0.00$	$0.82^{de}\pm0.00$

All means (x) ± SE values with superscripts on the same column differ ($p \leq 0.05$) significantly, and were analysed using ANOVA., **KEYS:** MA-Maize flour, TF- Tigernut flour

which reduce water absorption capacity, thus decreasing swelling power and solubility. The low solubility of the composite flour treatments suggests their potential use as ingredients in infant food formulations.

Anti-Nutritional Content of Kokoro Snack

The anti-nutritional content of Kokoro produced from maize-tigernut flour blend composites is presented in (Table 6). Oxalate content decreased with increasing levels of maize in sprouted tigernut flour. The values obtained for oxalate were lower than those reported by Ewulo et al (2017). Tannin content ranged from 0.08% to 0.15%. TSA, TSB, and TSC had the lowest tannin content, which is attributed to the effect of the sprouting process, as reported by Okoye and Ene (2018). Tannins form complexes with proteins in some food products, preventing their utilisation in the digestive system (Osuntogun, 1987). The low tannin content observed in this study for Kokoro, produced from blends of maize and tigernut flour, is similar to the findings reported by Bello et al. (2021). Phytate content ranged from 0.46% to 1.13%. TS1 (0.52%) had the lowest phytate level among the sprouted samples. Phytates are found in the non-starch components of seeds and block intestinal absorption, preventing the utilisation of essential minerals such as calcium, magnesium, iron, and, especially, zinc. Phytates are organic acids that can chelate divalent cations. The levels of oxalate, tannin, and phytate analysed were lower than those reported by Chukwuma et al. (2010) for raw tigernuts, likely due to the sprouting effect, which reduces anti-nutritional factors such as phytic acid in the seed coats and germ tissues.

Sensory Analysis of Kokoro Snack

Sensory scores for Kokoro produced from maize-tigernut flour blends, as shown in (Table 7), indicate that TSA was the most preferred among the sprouted samples, whereas FMD had the highest likability on the 9-point Hedonic scale. TSA and FMD were moderately preferred among the samples. TSA had the highest rating for Kokoro crispness. Only FMD and TS3 showed significant ($p \leq 0.05$) differences regarding flavour, indicating that both sprouted and unsprouted samples were accepted. The overall acceptability of the samples reflects consumers' disposition toward the product as a whole, with TS3 having the lowest value. Sensory parameters became less acceptable as the inclusion of sprouted tigernut flour

Table 7: Sensory Score of *Kokoro* Produced from Treatments of Maize and Tigernut Flour Blends.

Sample code (MA: TF)	Appearance	Taste	Crispness	Aroma	Crunchiness	Overall acceptability
MZN	$7.56^{a}\pm0.89$	$7.10^{abc}\pm0.91$	$7.00^{bc}\pm1.26$	$6.85^{ab}\pm1.09$	$6.90^{ab}\pm1.25$	$7.20^{ab}\pm0.89$
FMT	$7.60^{ab}\pm1.14$	$7.40^{bc}\pm0.75$	$6.60^{bc}\pm1.90$	$7.15^{ab}\pm1.09$	$6.50^{ab}\pm1.64$	$7.00^{ab}\pm1.92$
FMR	$7.45^{a}\pm0.10$	$7.40^{bc}\pm1.10$	$6.75^{bc}\pm1.58$	$7.25^{ab}\pm1.29$	$7.15^{bc}\pm1.42$	$7.65^{b}\pm1.09$
FMD	$7.80^{c}\pm0.89$	$7.80^{c}\pm1.44$	$7.25^{bc}\pm1.21$	$7.40^{b}\pm1.23$	$7.30^{c}\pm1.45$	$7.70^{b}\pm1.22$
TS1	$7.35^{bcd}\pm1.04$	$7.05^{abc}\pm1.28$	$7.10^{bc}\pm1.02$	$7.20^{ab}\pm1.23$	$6.95^{ab}\pm1.05$	$7.25^{ab}\pm1.21$
TS2	$6.65^{ab}\pm1.42$	$7.10^{abc}\pm1.07$	$7.00^{bc}\pm1.21$	$6.95^{ab}\pm1.23$	$7.05^{ab}\pm0.94$	$7.00^{ab}\pm1.21$
TS3	$6.35^{a}\pm1.60$	$6.55^{ab}\pm1.57$	$5.60^{a}\pm1.73$	$6.45^{a}\pm1.27$	$6.10^{a}\pm1.71$	$6.45^{a}\pm1.64$
TSA	$7.65^{bc}\pm0.99$	$7.65^{c}\pm0.01$	$7.45^{bc}\pm1.10$	$7.25^{ab}\pm1.19$	$7.00^{ab}\pm1.17$	$7.65^{b}\pm0.88$
TSB	$6.90^{abc}\pm1.37$	$7.05^{abc}\pm1.54$	$7.10^{bc}\pm1.07$	$7.10^{ab}\pm1.48$	$7.00^{ab}\pm1.17$	$7.50^{b}\pm1.05$
TSC	$6.30^{a}\pm1.26$	$6.35^{a}\pm1.53$	$6.35^{ab}\pm1.75$	$6.65^{ab}\pm1.31$	$6.20^{ab}\pm1.47$	$6.80^{ab}\pm1.15$

All means $(x)\pm$ SE values with superscripts on the same column differ ($p\leq0.05$) significantly, and were analysed using ANOVA.,**KEYS:** MA- Maize flour, TF- Tigernut flour

increased. However, Kokoro samples from different maize and tigernut flour treatments were all accepted by the panellists.

Conclusion

In conclusion, the study demonstrates novelty as sprouting tigernuts and incorporating them into maize flour for kokoro production can significantly enhance nutritional quality by increasing protein, fat, and fibre while reducing anti-nutrients. While some physical and pasting properties were altered, and sensory acceptability varied with substitution levels (10-30%), based on findings from preliminary studies. The overall findings suggest that this processing method holds promise for improving the nutritional value of traditional snacks and contributing to food security.

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Author Contributions

Ogundipe, O.O: Conceptualization; writing-review and editing; writing-original draft; formal analysis; validation. **Olaleye, H.T.**: writing-review and editing; **Sanoussi, F**: Writing-review and editing; writing-original draft; validation. **Ojegbade, R**: Conceptualisation; writing-review and editing; writing-original draft; formal analysis; validation. **Abegunde, T.D**: Conceptualisation; writing-review and editing; writing-original draft; formal analysis; validation. **Adeyeye Samuel A. O.**: Writing-review and editing; writing-original draft; validation.

Conflict of Interest Statement

The authors declare no conflicts of interest.

Ethical guidelines

Our institution does not require ethics committee approval. However, the Head of the Department and the departmental committee reviewed and approved the sensory study, and informed consent was obtained from each panellist before they participated.

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