World Journal of Pharmaceutical and Life Sciences
WJPLS
www.wjpls.org
SJIF Impact Factor: 7.409

NUTRITIONAL COMPOSITION AND SENSORY PROPERTIES OF CHINCHIN PRODUCED FROM WHEAT-SORGHUM COMPOSITE FLOUR

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Article Received on 26/03/2025 **Article Revised on 16/04/2025** **Article Accepted on 06/05/2025**

ABSTRACT

Grains of *Sorghum bicolour* were processed into sorghum modified flour (SMF) and its suitability for chinchin production with or without wheat flour was determined. De-hulled sorghum grains were steeped for 48-hour allowing spontaneous fermentation, drained, dried and milled into fine flour. Microbiological assessment, pH and total titratable acidity (TTA) determination were carried out on the steep water during (0, 24, 48 h) fermentation. Antinutrients (phytate, tannin and oxalate) content of the non-fermented and fermented sorghum grains were also determined. Functional properties of flour samples were determined and used for production of chinchin. Determination of proximate composition and sensory attributes of chinchin samples produced from different flour blends were also carried out. Total heterotrophic plate count of steep water increased from 9.20×10^5 to 9.50×10^6cfu/mL, fungal count from 4.50×10^5 to 7.90×10^6cfu/mL, lactic acid bacteria count from 4.90×10^5 to 8.30×10^6cfu/mL but the enterobacteriaciae count decreased from 1.10×10^5 to 1.11×10^4cfu/mL. Bacteria isolated consist of *Eschericia coli, Staphylococcus aureus, Bacillus subtilis, Klebsiella* spp. *Streptococcus lactis, Lactobacillus plantarum* and *L. acidophilus* while fungi consist of *Saccharomyces cerevisiae, Candida krusei, Fusarium* spp. *Penicillum* spp., *Rhizopus stolonifer, Aspergillus niger, A. flavus* and *Mucor racemoris.* Within 48 h of fermentation, pH of steep water decreased significantly ($\rho<0.05$) from 6.51±0.03 to 5.33±0.01while the tirtratable acidity increased significantly ($\rho<0.05$) from 0.16±0.002% to 0.98±0.004%. The phytate, tannin, and oxalate contents of the fermented grains reduced significantly ($\rho<0.05$) to 8±1.33mg/100g, 4±0.12mg/100g and 3±0.01mg/100g respectively. The functional properties, proximate composition of the 50-50 wheat-sorghum composite flour and the overall acceptability of chinchin produced compares favourably with that of wheat flour and chinchin produced from it. Chinchin from MSF were generally acceptable showing the suitability of MSF for low cost chinchin production as composite flour or when used wholly providing gluten-free chinchin for gluten-intolerant people.

KEYWORDS: Wheat flour, spontaneous fermentation, Modified sorghum flour (MSF), functional properties, Chinchin.

1.0 INTRODUCTION

Production and consumption of wheat (*Triticum aestivum*) based foods and snacks are increasing in both rural and urban areas because of changing lifestyle, convenience and ready availability leading to the increasing importation of wheat (Bongjo et al., 2023). Consequently, the increasing cost of wheat over the years has greatly affected the cost of these wheat based food and snacks necessitating the need for the use of alternative flours or composite flours suitable for the production of these foods and snacks. The use of composite flour in most developing countries has been considered advantageous because it reduces the importation of wheat flour and encourages the use of locally grown crops as flour (Hasmadi et al., 2014). The development of food products using composite flour has increased and is attracting much attention from researchers, especially in the production of bakery products and pastries (Noorfarahzilah, et al., 2014). Composite flours are prepared by substituting a portion of wheat flour by flour obtained from locally grown crops, in bakery products, thereby lowering the cost associated with wheat importation (Olaoye et al., 2006). In other words, composite flours may be considered firstly as blends of wheat and other flours for the production of bakery products (Suresh et al., 2015).

Flours from corn, barley, cassava, chickpea and sorghum are some of the predominantly studied for the production of composite flours used in the production of food and snack that are regularly consumed (Defloor et al., 1993; Ali et al., 2000). Sorghum [*Sorghum bicolor* (L.) Moench] is an important cereal that ranks fifth after rice, wheat, maize, and barley. In sub-Saharan Africa, it has been reported to rank second in importance after maize (Prajapati et al., 2018) and possess easier cultivation process than maize (Kanbar et al., 2019). This has made sorghum to be regarded as a suitable alternative in many places where most cereal crops are not well adapted for cultivation (Nyoni et al., 2020).

Commonly consumed food and snacks produced from composite or alternative flours include bread, cakes, cookies, biscuits and chinchin (Chandra et al., 2014; Adebayo-Oyetoro et al., 2015; Aburime et al., 2020). Chinchin is a popular ready-to-eat, cheap and convenient snack that is consumed among all age groups in many countries. The main ingredient generally used for chinchin production is wheat flour with other ingredients such as margarine, sweeteners (sugar), leavening agents, eggs, milk, salt, vanilla essence and vegetable oil for frying. This study is aimed at processing sorghum grains into sorghum modified flour (SMF) and determining its suitability for chinchin production with or without wheat flour (50% substitution).

2.0 MATERIAL AND METHODS

Materials

The experiments were conducted in the Microbiology Laboratory of the Department of Science Laboratory Technology, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria. The raw materials used such as Sorghum grains, wheat flour (Golden Penny brand), other baking ingredients (eggs, powdered milk, baking powder, nut meg, margarine, granulated sugar, vanilla essence, salt) and vegetable oil were procured from a major market within Ogbomoso, Oyo State Nigeria. All reagents and media were procured from.

Methods

Preparation of modified sorghum flour (MSF)

Modified sorghum flour (MSF) was prepared using the sorghum grains. The sorghum grains were first sorted by removing the shaft and dirt and then de-hulled. The de-hulled grains (1kg) were washed properly in sterile distilled water and steeped in sterile water (3L) for 48 hours to allow for spontaneous fermentation. Steep water was withdrawn aseptically at 0, 24 and 48 hours for microbiological assessment using Nutrient agar (NA), Potato dextrose agar (PDA), De Man Rogosa Sharpe (MRS) and MacConkey agar for microbial isolation and enumeration. Pure isolates were derived by streaking colonies on fresh agar plates and distinct colonies were picked and stored on freshly prepared slants which were maintained at 4ºC until further use. Samples of the steep water were also withdrawn at intervals (0, 24, and 48 h) for determination of pH and total titratable acidity.

The sorghum grains were drained, rinsed in sterile distilled water and oven dried at 60ºC. The dried sorghum grains were milled into fine powder and screened through a 0.25 mm British standard sieve-Model BS 410 (Giami et al., 2004) to obtain smooth sorghum modified flour (SMF) kept in air tight container until further analysis.

Identification of the isolates from steep water

Identification of the bacterial isolates was based on morphological (shape of colonies, colonial outline, colonial evaluation, colour, consistency and size) and biochemical (catalase, endospore stain, and sugar fermentation etc.) characteristics. Motility test was carried out using the method described by Varghese and Joy (2014). Gram staining and biochemical tests were carried out on the bacterial isolates using the procedure described by (Cheesbrough, 2002) and Isu and Onyeagba (2002). Lactophenol cotton blue staining of the fungal isolates were carried out and morphological result observed was recorded using the procedure described by Isu and Onyeagba (2002).

Determination of functional properties of flour samples

The functional properties of the flour samples (100% wheat flour, 50-50 wheat-sorghum composite flour and modified sorghum flour) were all determined using standard procedures. The bulk density, water absorption capacity, oil absorption capacity and swelling capacity were all determined as described by Onwuka (2018).

Production of Chinchin

Chinchin was prepared using wheat flour (100%), wheat-sorghum composite flour (50:50) and MSF (100%) according to the method described by (Owheruo et al., 2023) with modifications. The nut-meg (5g-grated), baking powder (15g) and salt (5g) were all added to the flour (1kg). Margarine (125g) was then rubbed into the flour mixture to become crumb-like before adding well beaten eggs (2). Milk (30g), sugar (200g) and vanilla essence (10mL) were added to 750mL of water stirred properly to homogenize the mixture. The liquid mixture was then added to the flour mixture and kneaded together until the desired texture of dough (smooth and elastic) was obtained. The dough was then rolled on the board to smoothen uniformly and acquire the desired thickness (about 1cm) and sliced evenly into stripes of about 1cm width. The strips were further diced into small pieces (1cm) and deep fried in hot vegetable oil until they turned golden brown in colour. The golden brown chinchin were drained of residual oil on clean absorbent paper, allowed to cool, packaged in clean airtight containers and kept for further analysis.

Proximate analysis of flour and chinchin samples

The flour samples (100% wheat flour, 50-50 wheat-sorghum composite flour and 100% SMF) used and chinchin produced from each of the flour were analyzed for moisture, crude proteins, fat, crude fibre, ash and carbohydrates as described by Association of Official

Analytical Chemists (AOAC, 2019). The moisture content was determined by gravimetric method, while protein content was determined by Kjeldahl method followed by calculation of crude protein content by multiplying the nitrogen content with 6.25. The fat content was determined by the continuous solvent extraction method while the total ash content was determined by using the furnace incineration gravimetric method. The total carbohydrate content was estimated as differences (Raghuramulu et al., 2003) using the formula:

$$Total\ carbohydrate\ (\%) = 100 - [moisture\ (\%) + crude\ protein\ (\%) + crude\ fibre\ (\%) + crude\ fat\ (\%) + ash\ (\%)]$$

The gross energy value was calculated using Attwater factor:

$$(\text{fat x 9}) + \text{carbohydrate x 4 kcal/100g}$$

Sensory evaluation of Chinchin

The sensory attributes of the chinchin samples were determined using hedonic tests of Larmond (1991). Untrained laboratory taste panelists, though regular chinchin consumers, consisting of 40 persons, assessed the chinchin samples on a 9-point hedonic scale (9=like extremely, 8=like very much, 7=like moderately, 6=like slightly, 5=neither like nor dislike, 4=dislike slightly, 3=dislike moderately, 2=dislike very much and 1=dislike extremely) was used to determine overall liking (Lawless and Heymann, 2010). The attributes that were evaluated include appearance, color, aroma, crunchiness, taste, and overall acceptability. Chichin was considered acceptable if the mean value was above 5 (neither like nor dislike).

Statistical analysis

The data obtained from the various analyses were subjected to analysis of variances (ANOVA) using the statistical package for social sciences (SPSS), version 16.0. Results are presented as mean ± standard deviations of triplicate determinations (except where indicated otherwise). One way analysis of variance was used for comparison of the means. Differences between means were considered to be significant at $p<0.05$ using the Duncan multiple range test (DMRT).

3.0 RESULTS

There was a gradual increase the microbial count of the steep water (cfu/mL) with increasing hours of spontaneous fermentation as represented in Table 1. The Total Heterotrophic Plate Count (THPC) increased from 9.20×10^5 cfu/mL at 0 h to 9.50×10^6 cfu/mL at 48 h, Fungal count (FC) increased from 4.50×10^5 cfu/mL at 0h to 7.90×10^6 cfu/mL, while the Lactic acid bacteria count increased from 4.9×10^5 cfu/mL to 8.30×10^6 cfu/mL. On the other hand the Total Enterobacteriaciae Count (TEC) increased from 1.10×10^5 cfu/mL in the first 24 h of spontaneous fermentation before dropping sharply to 1.11×10^4 cfu/mL. The highest microbial count in the steep water of spontaneous fermentation of dehulled sorghum grains was observed in the Total Heterotrophic Plate Count (9.50×10^6 cfu/mL).

A total of 15 microorganisms were identified, seven of which are bacteria while the remaining eight are fungi. The bacteria isolates included *Eschericia coli, Staphylococcus aureus, Bacillus subtilis, Klebsiella* spp., *Streptococcus lactis, Lactobacillus plantarum, L. acidophilus,* while the fungi/mold isolates included *Saccharomyces cerevisiae, Candida krusei, Fusarium* spp., *Penicillum* spp., *Rhizopus stolonifer, Aspergillus niger, A. flavus and Mucor racemoris.* All the bacterial isolates were present at 0 h of spontaneous fermentation of the dehulled sorghum grains while all the fungal isolates except *Aspergillus niger, A. flavus and Mucor racemoris* were present. At 48 h of fermentation, among all the 15 isolates, *E. coli*, *B. subtilis*, *Klebsiella* spp. and *C. krusei* were absent (Table 2).

Table 1: Microbial Count of Steep Water (cfu/mL) During 48 h Spontaneous Fermentation.

Steeping Hour	THPC	FC	TEC	LABC
0	9.20×10^5	4.50×10^5	1.10×10^5	4.90×10^5
24	7.80×10^6	7.20×10^5	2.30×10^5	1.10×10^6
48	9.50×10^6	7.90×10^6	1.11×10^4	8.30×10^6

Key: THPC -Total Heterotrophic Plate Count, FC - Fungal Count, TEC- Total Enterobacteriaciae Count, LABC – Lactic acid bacteria count.

Table 2: Occurrence of microorganisms during 48 h spontaneous fermentation.

Isolates	0 Hour	24 Hour	48 Hour
Eschericia coli	+	+	-
Staphylococcus aureus	+	+	+
Bacillus subtilis	+	-	-
Klebsiella spp.	+	+	-

Streptococcus lactis	+	+	+
Lactobacillus plantarum	+	+	+
L. acidophilus	+	+	+
Saccharomyces cerevisiae	+	+	+
Candida krusei	+	-	-
Fusarium spp.	+	+	+
Penicillum spp.	+	+	+
Rhizopus stolonifer	+	+	+
Aspergillus niger	-	+	+
A. flavus	-	+	+
Mucor racemoris	-	+	+

Key: + = Presence; - = Absence

The result of the pH and TTA is as represented in Table 3. There was significant (ρ<0.05) decrease in the pH value of the fermenting sorghum steep water from 6.51±0.03 at 0 h to 5.33±0.01 at 48 h indicating an increase in the acidity of the steep water within the 48 h of fermentation. Significant (ρ<0.05) increase was observed for the TTA between 0 h and 48 h spontaneous fermentation from 0.16±0.002 to 0.98±0.004%.

The antinutrient content of the sorghum grains (Table 4) shows significant (ρ<0.05) decrease after 48 h of spontaneous fermentation. There was a decrease in the phytate content from 38±3.14 to 8±1.33 mg/100g, a decrease in the tannin content from 42±2.13 to 4±0.12mg/100g while the oxalate content decreased from 25±2.02 to 3±0.01mg/100g.

Table 3: Effect of fermentation on pH value and titratable acidity (TTA) of steep water.

Fermentation Hour	pH	Titratable acidity (%)
0	$6.51±0.03^{b}$	$0.16±0.002^{a}$
24	$5.90±0.01^{ab}$	$0.75±0.001^{b}$
48	$5.33±0.01^{a}$	$0.98±0.004^{b}$

Values represent mean ± standard deviation of triplicate determinations and values with same superscript along the column are not significantly different (p<0.05).

Table 4: Antinutrient composition (mg/100g) of sorghum grains before and after spontaneous fermentation.

Antinutrient	Sorghum grains before fermentation	Sorghum grains after fermentation
Phytate	$38±3.14^{a}$	$8±1.33^{b}$
Tannin	$42±2.13^{a}$	$4±0.12^{b}$
Oxalate	$25±2.02^{a}$	$3±0.01^{b}$

Values represent mean ± standard deviation of triplicate determinations and values with same superscript along the rows are not significantly different (p<0.05).

The result showing the functional properties of flour blends used in this study is as represented in Table 5. The bulk density (an index of the heaviness of flour materials) ranged 0.66±0.02 to 0.87±0.00 g/mL with wheat flour (WF) having the lowest value and modified sorghum flour (MSF) having the highest value. There was no significant difference (ρ>0.05) in the bulk density of wheat flour and the wheat-sorghum composite flour indicating that the bulk density of the flours increased with the increase in the quantity of sorghum flour added The Water absorption capacity of the flour blends ranged from 83.35±3.12 to 93.2±4.17% with the lowest in WF and highest in MSF. Oil absorption capacity (ability of food material to absorb oil which helps to improve the mouth feel and retains flavor) of the flour blends was lowest in WF (17.25±1.47%) and highest in MSF (20.71±2.01%). Swelling capacity was lowest in WF (2.53±0.57g/g) and highest in MSF (3.15±0.48). There was no significant difference in the functional properties of WF and WSF but there was significant difference (ρ<0.05) in the functional properties of WF and MSF.

Table 6 shows the proximate composition (%) and energy value (Kcal/100g) of the flour blends. There was significant differences (ρ<0.05) in the moisture, protein, fibre, ash, carbohydrate and energy content of the flour samples. However, there was no significant difference (ρ>0.05) in the lipid content of all the flour blends. The highest protein, carbohydrate and energy (12.68±0.33, 73.35±0.43 and 357.99±3.49 respectively) were observed in WF while the highest moisture, fibre and ash content (8.64±0.13, 4.25±0.21 and 3.51±0.33 respectively) was highest in MSF.

Table 5: Functional properties of Flour samples.

Functional properties	Flour samples		
	WF	**WSF**	**MSF**
Packed bulk density (g/mL)	0.66±0.02^{a}	0.73±0.02^{a}	0.87±0.00^{b}
Water absorption capacity (%)	1.79±0.12^{a}	2.31±0.33^{a}	2.81±0.17^{b}
Oil absorption capacity (%)	1.54±.33^{a}	1.87±0.00^{a}	2.52±0.02^{b}
Swelling capacity (%)	12.53±1.57^{a}	12.65±2.33^{a}	13.15±1.48^{b}

Values represent mean ± standard deviation of triplicate determinations and values with same superscript along the rows are not significantly different ($p<0.05$).

Key: WF=Wheat flour (100%), WSF=Wheat-Sorghum composite flour (50:50), MSF=Modified sorghum flour (100%)

Table 6: Proximate composition (%) and energy value (Kcal/100g) of the flour blends.

Proximate composition (%)	Flour samples		
	WF	**WSF**	**MSF**
Moisture content	5.90±0.14^{a}	6.53±0.26^{a}	7.64±0.13^{b}
Protein	12.68±0.33^{b}	10.91±0.31^{ab}	9.65±0.23^{a}
Lipid	2.43±0.12^{a}	2.98±0.11^{a}	3.22±0.14^{a}
Fibre	2.40±0.11^{a}	3.81±0.13^{b}	4.25±0.21^{c}
Ash	2.24±0.00^{a}	2.94±0.09^{ab}	3.51±0.33^{b}
Carbohydrate	74.35±0.43^{b}	72.83±0.38^{a}	71.73±0.29^{a}
Energy (Kcal/100g)	319.27±3.49^{b}	317.64±4.11^{a}	315.90±2.91^{a}

Values represent mean ± standard deviation of triplicate determinations and values with same superscript along the rows are not significantly different ($p<0.05$).

Key: WF=Wheat flour (100%), WSF=Wheat-Sorghum composite flour (50:50), MSF=Modified sorghum flour (100%)

The process of the chinchin production in pictures is as represented in Plate 1. The stiff dough obtained as a result of mixing the whole ingredients with adequate water is as shown in (a), rolled dough of uniform thickness (b) and sliced into strips of 1cm width (c). Sliced dough diced into small pieces of about 1cm (d) and fried pieces (chinchin) packaged in airtight jar.

Plate 1: Production process of chinchin - (a) well mixed ingredient into dough; (b) Dough rolled to uniform thickness; (c) Dough sliced into strips of 1cm width; (d) Sliced dough diced into small pieces of about 1cm; (e) Fried pieces (chinchin) packaged in airtight jar.

The proximate composition of chinchin produced from the different blends of flour (Table 7) shows significant differences ($\rho<0.05$) in parameters investigated except in the fibre, ash and carbohydrate content. The highest protein, lipid and energy (14.26±0.20, 11.55±0.24 and 350.19±4.61 respectively) were observed in chinchin produced from wheat flour (WF). There was no significant difference ($\rho>0.05$) in the moisture content of the chinchin produced from WF and chinchin produced from wheat-sorghum composite flour (WSF) but significantly lower than that of the chinchin produced from modified sorghum flour (MSF).

The chinchin prepared from all the flour blends were generally acceptable by the panelists at varying degrees as indicated by their mean scoring (Table 8). The mean scoring from the sensory evaluation of the chinchin produced from different flour blends shows that the chinchin produced from wheat flour was significantly different ($\rho<0.05$) from the others in the sensory attributes investigated except crunchiness. The chinchin produced from WF has higher mean scores in the sensory attributes such as appearance, colour, texture, aroma and taste with mean scores 8.50±0.33, 7.85±0.25, 7.50±0.15, 8.00±0.25 and 8.00±0.10 respectively. The chinchin produced from WSF was significantly different ($\rho<0.05$) from the chinchin produced from MSF in sensory attributes such as appearance, texture, aroma and taste except in colour. The mean scores obtained for the sensory attributes of the chinchin produced from modified sorghum flour were also above 5 implying the chinchin samples were neither liked nor disliked. The overall acceptability of all the chinchin samples was significantly different with chinchin produced from WF having the highest mean score of 8.50±0.12 followed by chinchin produced from WSF with value (7.55±0.22) while chinchin produced from modified sorghum flour has a significantly lower mean score (5.80±0.25) for overall acceptability.

Table 7: Proximate composition (%) and energy value (Kcal/100g) of chinchin produced from different flour blends.

Proximate composition (%)	Chinchin samples		
	WFC	WSFC	MSFC
Moisture content	$6.30±0.19^{b}$	$6.58±0.46^{b}$	$7.72±0.31^{a}$
Protein	$14.26±0.20^{a}$	$12.51±0.38^{b}$	$10.75±0.19^{c}$
Lipid	$11.55±0.24^{a}$	$10.24±0.32^{ab}$	$9.50±0.35^{b}$
Fibre	$2.91±0.28^{b}$	$3.70±0.24^{ab}$	$4.15±0.11^{a}$
Ash	$3.42±0.30^{b}$	$4.12±0.33^{a}$	$4.50±0.33^{a}$
Carbohydrate	$61.56±0.33^{a}$	$62.85±0.42^{a}$	$63.18±0.44^{a}$
Energy (Kcal/100g)	$350.19±4.61^{a}$	$343.56±3.14^{b}$	$338.22±4.75^{c}$

Values represent mean ± standard deviation of triplicate determinations and values with same superscript along the rows are not significantly different ($p<0.05$).

Key: WFC=Chinchin from Wheat flour (100%), WSFC= Chinchin from Wheat-Sorghum composite flour (50:50), MSFC= Chinchin from Modified sorghum flour (100%)

Table 8: Sensory attributes of chinchin produced from the different blends of flour.

Sensory Attribute	Chinchin samples		
	WFC	WSFC	MSFC
Appearance	$8.50±0.33^{a}$	$7.00±0.11^{b}$	$6.00±0.00^{c}$
Colour	$7.85±0.25^{a}$	$6.80±0.20^{b}$	$6.50±0.10^{b}$
Texture	$7.50±0.15^{a}$	$6.30±0.17^{b}$	$5.50±0.21^{c}$
Aroma	$8.00±0.25^{a}$	$7.00±0.15^{b}$	$5.65±0.25^{c}$
Crunchiness	$7.75±0.15^{a}$	$7.50±0.23^{a}$	$6.80±0.11^{a}$
Taste	$8.00±0.10^{a}$	$7.30±0.20^{b}$	$6.55±0.21^{c}$
Overall acceptability	$8.50±0.12^{a}$	$7.55±0.22^{b}$	$5.80±0.25^{c}$

Values represent mean ± standard deviation of 40 determinations and values with same superscript along the rows are not significantly different ($p<0.05$).

Key: WFC=Wheat flour (100%) chinchin, WSFC=Wheat-Sorghum composite flour chinchin (50:50), MSFC=Modified sorghum flour (100%) chinchin.

4.0 DISCUSSION

The increasing microbial count of the steep water from 0 h to 48 h of spontaneous fermentation indicates that the microorganisms were able to metabolize nutrients in the steeped sorghum for growth and proliferation. This is comparable to what has been reported earlier regarding submerged fermentation of cereals (Omemu et al., 2007; Nwokoro and Chukwu, 2012; Adebayo et al., 2013; Obinna-Echem et al., 2014; Obinna-Echem et al., 2015; Amunudu et al., 2018; Itaman and Okenyi, 2022). Studies have shown that many traditional fermentation products rely on spontaneous fermentation by microorganisms that are associated with the raw materials (Pswarayi and Gänzle, 2019). The predominant microorganisms and their successive pattern in spontaneous fermentation observed in this study are similar to the reports obtained from previous studies (Achi and Ukwuru, 2015; Oguntoyinbo and Narbad, 2015). The presence of lactic acid bacteria observed in this study corroborates the finding of previous studies (Omemu et al., 2011; Nwokoro and Chukwu, 2012; Nsofor et al., 2014; Elizaquível et al., 2015), who reported the involvement of the genus *Lactobacillaceace* during most food fermentation as a result of their aciduric property.

The significant decrease in the pH value and increase in the titratable acidity of the steep water during the 48 h spontaneous fermentation of the sorghum grain could be as a result of the production and accumulation of organic acid resulting from the metabolic activity of the proliferating microoganisms. This change in pH and titratable acidity rendered the steep water suitable for the proliferation of Lactic acid bacteria and yeast cell and inhibition of spoilage microoganisms. This finding is in support of earlier finding (Adesokan et al., 2010; Opere et al., 2012; Obinna-Echem et al., 2014; Lawal et al., 2015).

The decrease in the antinutrient (phytate, tannin and oxalate) composition of the sorghum grain within the 48 h of steeping is desirable and beneficial for edibility and corroborates earlier reports (Ejigui et al., 2005; Zhao et al., 2017; Zubair et al., 2023). Reports suggest that lactic acid fermentation also plays important roles in reducing antinutritional factors, increasing nutrient density and antimicrobial activities in the fermented product (Oyarekua, 2011; Handa et al., 2017).

The bulk density properties observed in this study increased as the quantity of modified sorghum flour increased and are different from the pattern reported by Ilelaboye and Jesusina (2019) for different blends of composite flour but within the range reported by Adebayo-Oyetoro et al. (2017), Ndife et al. (2020) and Ihuoma et al. (2021). Bulk density is an index of the heaviness of flour materials and expresses the relative volume of packaging material needed, and is generally affected by the particle size. Report has shown that higher bulk density is advantageous for packaging giving the possibility for larger quantity of flour to be packed within a constant volume (Ihoma et al., 2021). Bulk density is a function of particle size and there occurs an inverse relationship between particle size and bulk density (Ali et al., 2014; Adepeju et al., 2015). Bulk density has been reported to be a determinant factor in the packaging requirement, raw materials handling and application in wet processing in food industry (Ajanaku et al., 2012).

The water absorption capacity (amount of water absorbed per gram depending on particle sizes) indicates that increase in quantity of sorghum modified flour contributed to the increase in water absorption capacity. The oil absorption capacity (ability of food material to absorb oil which helps to improve the mouth feel and retains flavor) also follows the pattern observed for water absorption capacity and falls within the range reported by Ndife et al. (2020) and Aburime et al. (2020). The OAC reported in this study is within the range reported by Adebayo-Oyetoro et al. (2017) for blends of wheat-tigernut composite flour. Cereal-based flour samples with high OAC have been reported to enhance flavor, retain and improve the mouth feel and palatability of bakery products (Iwe et al., 2016; Adegunwa et al. 2017).

The range for swelling capacity observed in this study is higher than the range reported by Okwumodulu et al. (2022) but lower than the range reported by Adebayo-Oyetoro et al. (2017). The higher swelling capacity in the MSF could be as a result of the particle size of the flour since report has shown that the swelling capacity (index) of flours is influenced by the particle size, species variety and method of processing or unit operations (Suresh and Samsher, 2013) and shows the degree of the water absorption of the starch granules in the flour.

The range of moisture content observed for the flour blends in this study was lower than what was reported by Okwunodulu et al. (2022) but falls within the range reported by other authors for different blends of composite flour (Ndife et al., 2020; Kayode et al., 2023; Owheruoe et al., 2023). Likewise the moisture content reported for the chinchin samples produced in this study was observed to be within the range that has been reported (Alagbu, 2022; Bongjio et al., 2023; Owheruo et al., 2023) This range is lower than the 12% recommended moisture content of dried food and flour (Annan et al., 2015). High moisture content is likely to support microbial growth and multiplication leading to microbial spoilage. Reports have shown that relative low moisture content of food is desirable, enhancing storage stability and prolonging the shelf life (Onwuka, 2014). The lower protein content of the WSF and MSF could be due to the low protein content of sorghum grains compared to wheat grain which contains glutein. This was also the trend observed for the chinchin produced and is not surprising because other ingredient used in chinchin production from all the flour blends was similar in quantity. The protein content in this study was different compared to what has been reported (Adebayo-Oyetoro et al., 2017; Abioye et al., 2020; Aburime et al., 2020; Alagbu, 2022). The high carbohydrate and energy content of the flour blends and chichin produced is an indication of the high carbohydrate content of the sorghum grains.

The mean scores for overall acceptability of the chinchin samples shows that chinchin produced from wheat flour was most preferred, followed by that produced from WSF. The scoring for the overall acceptability of the chinchin produced from MSF, on the other hand indicated that it was least preferred probably due to the texture and aroma which developed as a result of the spontaneous fermentation. (Aroma of fermented beverage). Even though the chinchin produced from MSF was least preferred its lack of gluten can make it preferable to people that are gluten intolerant. The deficiency of sorghum in gluten proteins has been reported to make it a desirable substitute for those with celiac disease (Ratnavathi, 2016). This corroborates earlier reports that most cereal flour offer more options in the production of gluten-free baked products which are acceptable (Ndife, 2016). The overall acceptability which is generally regarded as the combination of all the other sensory parameter (Oluwole, 2009) for all the chinchin samples in this study show that none of the scoring falls below 5 i. e. neither like nor dislike.

CONCLUSION

This study shows the possibility of the production of modified sorghum flour from sorghum grain suitable for chinchin production with or without wheat flour thereby decreasing the proportion of wheat hence the production cost of chinchin. Using the modified sorghum flour alone for the production chinchin also reduces dependence on wheat providing an avenue for utilization of locally available cereals for the production of acceptable gluten-free chinchin for gluten-intolerant people. Further studies are still required for continuous improvements on the flour blends and the chinchin production.

ACKNOWLEDGEMENT
None.

Authors' contributions
AAG conceptualized the study, supervised the study and wrote the original draft of the manuscript. AAO determined the functional properties. AJA carried out the microbial aspect and data analysis. AAA provided resources and edited the original draft of the manuscript. AAA determined the antinutrient and proximate composition. AAV produced the flour and chinchin.

Conflict of interest
The authors declare no conflict of interest.

Authors' Declaration
The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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