IPS Journal of Nutrition and Food Science
IPS J Nutr Food Sci, 4(2): 444-455 (2025)
DOI: https://doi.org/10.54117/ijnfs.v4i2.103

Enhancing the Techno-Functional Properties of Sorghum Ogi via Starter Culture Fermentation and Mixed-Spice Incorporation

Sekinat O. Alabi[1], Mercy A. Okeji[2], Daniel S. Ajewole[1], Oluwapelumi E. Foluso[1] and Victor N. Enujiugha[1]*

[1]Department of Food Science and Technology, Federal University of Technology, Akure, Nigeria.
[2]Department of Food Science and Technology, Federal University, Oye-Ekiti, Nigeria.

*Corresponding Author's Email: vnenujiugha@futa.edu.ng; Tel.: +234(0)8034261870

Abstract

Sorghum *ogi* is a traditional fermented cereal-based porridge that holds significant nutritional value and cultural importance. It is usually consumed as a breakfast gruel for adults and weaning food for infants. This study was carried out to determine the effect of ginger and garlic incorporation into sorghum mash for *Lactobacillus fermentum* starter culture controlled fermentation into *ogi*. The *ogi* composited blends were produced by adding ginger (5, 15 and 25%) and garlic (5%) in proportional gradients into sorghum *ogi* (70, 80 and 90%), while 100% sorghum *ogi* served as control. The proximate nutrient composition, microbial analysis, mineral concentrations (calcium, iron, potassium, phosphorus, and sodium), colour measurements and sensory (organoleptic) profile analysis of the resulting samples were carried out. The moisture content ranged from 0.67% to 3.05%, ash from 0.25% to 0.78%, crude fibre and crude fat 0.46% to 3.08% and 0.52% to 3.08%, respectively, and carbohydrate content 74.87% to 94.13%. The sodium contents ranged from 46.77 to 55.05 mg/ 100 g, potassium, zinc, calcium, iron and phosphorus contents ranged from 82.15 to 95.05 mg/100 g, 1.29 to 1.51 mg/100 g, 35.60 mg/100g to 39.15 mg/100g, 0.74 to 1.19 mg/100 g and 9.69 mg/100g to 13.21 mg/100g, respectively, with the overall acceptability of the samples having mean scores ranging from 5.53 to 7.40 where sample S100 was adjudged to be the most acceptable, while sample SGG90 with combined spices (5% garlic+5% ginger) was the second acceptable one during sensory evaluation that was carried out with 50 untrained panelists. Hence, *Ogi* with combined spices could be useful as food for the aged and sick people with little or no appetite. The study also revealed that fortification with ginger and garlic led to notable changes in the nutritional content and bioactivity of sorghum *ogi* as the increasing proportions of ginger were associated with enhanced levels of bioactive compounds, such as antioxidants, polyphenols, and essential minerals. The study established that the inclusion of ginger and garlic enhanced the properties of the enriched sorghum *ogi* samples.

Keywords: *Garlic, ginger, health-promoting, sensory attributes, sorghum-Ogi*

Article History
Received: 28 Feb 2025
Accepted: 04 Mar 2025
Published: 31 May 2025

Scan QR code to view♦

License: CC BY 4.0♦
Open Access article.

How to cite this paper: Alabi, S. O., Okeji, M. A., Ajewole, D. S., Foluso, O. E., & Enujiugha, V. N. (2025). Enhancing the Techno-Functional Properties of Sorghum Ogi via Starter Culture Fermentation and Mixed-Spice Incorporation. *IPS Journal of Nutrition and Food Science*, *4*(2), 444–455. https://doi.org/10.54117/ijnfs.v4i2.103.

1. Introduction

Staple foods in Sub-Saharan Africa, particularly Nigeria, are primarily composed of cereals, which play a crucial role in addressing global nutritional challenges for rapidly growing populations (Adisa and Enujiugha, 2020; Vila-Real *et al*., 2017). Sorghum stands out as a climate-friendly cereal with high yields and minimal cultivation requirements, serving as a staple for over 500 million people in the region (ICRSAT, 2018). One popular product derived from sorghum is "*Ogi*," a fermented porridge and breakfast gruel known by various names across different African countries (Oluwamukomi *et al*., 2003).

Ogi, also recognized as akamu, uji, Tuwo, or Bogobe in different cultures, undergoes diverse processing techniques, including fermentation (Enujiugha, 2006). This traditional food holds cultural significance and is widely consumed by various demographic populations, including sick patients, the elderly, and infants during weaning period owing to its easy digestibility. The preparation involves cleaning, steeping, wet-milling, and a two-phase fermentation process (Oluwamukomi *et al*., 2005; Ladunni *et al*., 2013).

To enhance *Ogi*'s nutritional profile, researchers have explored incorporating complementary ingredients such as enriched groundnut seed, garlic, and ginger (Ajanaku *et al*., 2012; Olaniran *et al*., 2019; Adejobi *et al*., 2024a). These additions not only contribute vital minerals and polyphenols but also improve the overall characteristics of the enriched sorghum *ogi*. However, despite its popularity, sorghum *ogi* is

♦This work is published open access under the Creative Commons Attribution License 4.0, which permits free reuse, remix, redistribution and transformation provided due credit is given.

nutritionally deficient in certain elements, particularly protein and minerals (Afolayan *et al*., 2010).

Ginger and garlic, known for their health-promoting properties (Makanjuola and Enujiugha, 2018; Adejobi *et al*., 2024a), have been identified as beneficial additions to sorghum *ogi*. These ingredients bring antioxidant benefits and essential vitamins and minerals, contributing to overall health of the consumers (Gunathilake *et al*., 2013; Ryu and Kang, 2017). *Lactobacillus fermentum*, a key lactic acid bacteria species, plays a crucial role in the fermentation process, enriching the product with flavors, aromas, and essential nutrients (Babatuyi *et al*., 2023; Tulumoğlu *et al*., 2014; Tamene *et al.*, 2019).

2. Materials and Methods

2.1. Source of Raw Materials

Sorghum, ginger, and garlic were among the raw materials that were purchased from Oja Oba in Akure, Ondo State. A starting culture called *Lactobacillus fermentum* was obtained from the International Institute of Tropical Agriculture (IITA) located in Ibadan, Oyo State. Every chemical or reagent used was of analytical quality, and was purchased from a reliable chemical supplier.

2.2. Procedure for Preparing Samples

The method of making sorghum ogi powder involved carefully selecting and screening the grains of sorghum to remove any impurities. Afterwards, 5 litres of water were used to soak 2 kg of sorghum grains for 48 hours at room temperature after they had been cleaned. The water was decanted after steeping, and sorghum grains were then wet milled in an attrition mill. The starch solution was kept after the milled slurry was filtered through a muslin cloth to remove pomace from the filtrate (Adelakan *et al*., 2021).

2.3. Preparation of Garlic and Ginger Powder

Freshly harvested ginger rhizomes and garlic bulbs (250 g each) were washed, peeled, and then dried for 12 hours at 65 °C. After being dried and processed in a lab mill, the mixture was sieved over a 50 µm screen to get rid of any leftover material. In preparation for later usage, the resultant powder samples were kept at -20°C and individually wrapped in Ziplock bags (Adejobi *et al*., 2024a).

2.4. Preparation of Sorghum-*Ogi* with Garlic and Ginger Powder

To sterilize sorghum *ogi*, it was parboiled for ten minutes at 121 °C. As a control, the starter culture, *Lactobacillus fermentum*, was inoculated into the sterilized slurry, serving as the control (Adisa and Enujiugha, 2020). Four formulations were created by adding varying weights of ginger and garlic powder to the sieved *ogi* slurry: 90% *ogi* + 5% ginger + 5% garlic, 80% *ogi* + 5% garlic + 15% ginger, and 70% *ogi* + 25% ginger + 5% garlic. The mixtures were allowed to ferment for 48 hours before being decanted and dried for 12 hours at 65 °C in a lab oven.

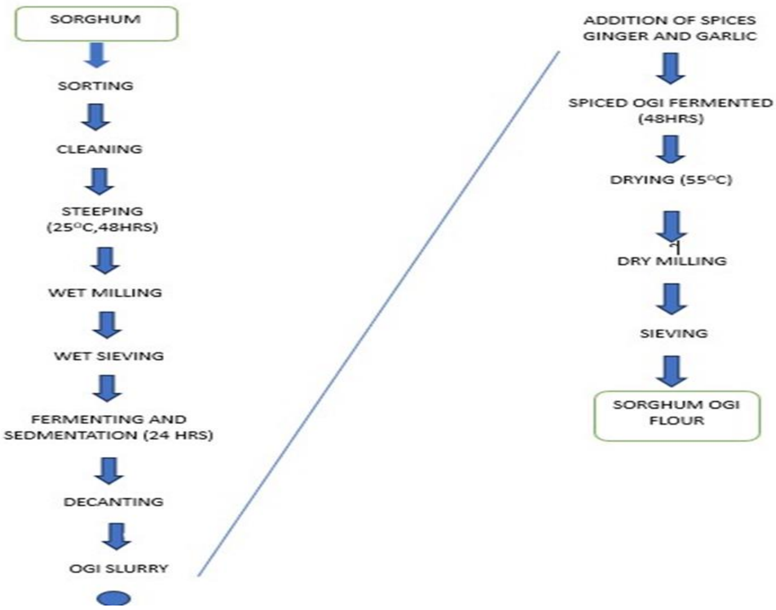

Figure 1: Flowchart for the production of spiced Sorghum *ogi* (Adelekan *et al*., 2021)

Table 1: Ratio of Formulated Sorghum *Ogi* Fortified with Ginger and Garlic

Code	Sorghum *OGI* (G)	Ginger (G)	Garlic (G)
S100	100	0	0
SGG90	90	5	5
SGG80	80	15	5
SGGS70	70	25	5

Keys: S100:(100% Sorghum *Ogi*)
SGG90: (90% Sorghum+ 5% Ginger+ 5% Garlic)
SGG80: (80% SO:(90% Sorghum+ 5% Ginger+ 5% Garlic)
SGG70: (70% Sorghum+ 25% Ginger+ 5% Garlic)

2.5. Proximate Analyses

Using the guidelines provided in AOAC (2012) methods, the proximate composition of the sorghum *ogi* samples was evaluated. Samples were dried in a hot air oven at 105 ℃ until a consistent weight was reached in order to determine the moisture content**.**

The moisture content was calculated using the following formula:

Moisture Content (%) $= \frac{(Initial\ Weight - Final\ weight)}{Initial\ Weigth} \times 100$

Using a Soxhlet extraction device, a determined sample weight was extracted with hexane in order to estimate the amount of crude fat. By burning the material for three hours at 550 ℃ in a muffle furnace (Carbolite AAF, UK) until a white ash was produced, the total ash content was calculated gravimetrically.

The ash content was calculated using the formula:

Ash content (%) $= \frac{w3 - w2}{w2 - w1} \times 100$

W1= Weight of dried crucibles

W2= Weight of sample and crucible

W3= Weight of content and crucible after ashing.

Protein content was determined using the Kjeldahl method, with the nitrogen values' efficiency calculated and multiplied by a factor of 6.25 to obtain the protein value.

Following the incineration of the ash-less filter paper containing insoluble elements from the hydrolysis and the washing of the moisture-free defatted sample, crude fiber was extracted by difference. Carbohydrate content was determined by the formula: 100% - (% Moisture Content + % Ash + % Crude Protein + % Fat + % Crude Fiber). The energy content (E) was calculated using the Atwater factor method, as described by Enujiugha and Ayodele-Oni, (2003).

2.6. Mineral Composition

The mineral composition including iron, calcium, magnesium, zinc, copper, and potassium, was analyzed using atomic absorption spectroscopy. The procedure involved dry-ashing the samples in a muffle furnace at 550 ℃ for 6 hours. The minerals were then extracted from the ash using 20 mL of 2.50% HCl. This mixture was heated in a steam bath until the volume was reduced to 8.0 mL. The resulting solution was quantitatively transferred to a 50 mL volumetric flask and diluted to volume using deionized water. The extracts were stored in dry, clean plastic sample bottles. Subsequently, the mineral concentrations were determined using an atomic absorption spectrophotometer. For sodium and potassium, the flame photometric method, as outlined in AOAC (2012), was employed, utilizing a low-temperature direct-reading single-channel emission flame photometer.

2.7. Determination of Antioxidant properties

The total phenolic content was calculated using gallic acid (Sigma, St. Louis, USA) as the standard, following the methodology outlined by Enujiugha (2010) using Folin–Ciocalteu reagent. The amount of flavonoids in the extracts was quantified as quercetin equivalents (QE) using the method described by Enujiugha *et al*. (2014). The maize *ogi* samples' 2,2-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) free radical scavenging activity was ascertained in accordance with Chen *et al*. (2017).

Olaniran and Abiose (2019) description of the maize *ogi* samples' free radical scavenging activity on 2, 2-Diphenyl-1-picryhydrazyl (DPPH) was followed. Using Pulido *et al*. (2010)'s approach, the ferric-reducing antioxidant power (FRAP) activity of the maize *ogi* samples was ascertained.

2.8 Determination of pasting properties

The pasting characteristics were assessed using the Rapid Visco Analyzer (RVA) method, as outlined by Adejobi *et al*. (2024a), with slight modifications. The obtained values were conveniently analyzed utilizing the software integrated into the instrument. A 50-g sample of each ogi flour was slurred in 450 ml of distilled water to give 12% solids (w/v dry basis). The mixture was heated to 50 ºC and stirred at 150 rpm for 20 s for thorough dispersion and held for 1 min at the same temperature before being heated to 95 ºC over 10 min and held at the same temperature for 3 min and finally cooled to 50 ºC.. The parameters measured included peak viscosity (measured in Rapid Visco Units, RVU), trough viscosity (RVU), breakdown viscosity (RVU), final viscosity (RVU), setback (RVU), peak time (minutes), and peak temperature (°C).

2.9 Determination of Functional Properties

2.9.1. Water absorption capacity

Water absorption capacities (WAC) of the flour were determined as described by (Omowaye-Taiwo *et al*, 2015). For WAC, about 1g of the flour sample was suspended in 10 mL in a 15 mL centrifuge tube, mixed for 1 min at room temperature. The mixture was centrifuged after 30 min, at 1200 x g for 30 min. The volume of free water was read directly from the graduated tube and water absorption capacity was calculated thus:

$$WAC\ \% = \frac{Amount\ of\ water\ added - free\ water\ (ml)}{Weight\ of\ sample\ (g)} \times density\ of\ water \times 100$$

2.9.2. Oil Holding Capacity

The oil absorption of sorghum *ogi* sample was determined using the centrifuge method as described by Ogori *et al*. (2022). One gram (1 g) of the sample was dissolved in a 10 ml pure canola oil in a 15 ml pre weighed centrifuge tube. It was vortexed for 1 min and allowed to stand for a period of 30 min, it was then centrifuged at 7000 x g for 25 min at room temperature. The supernatant was decanted, and excess oil at the upper phase was drained for 15 min and the tube containing the residue was weighed again to determine the amount of oil retained per gram of sample.

The formular to calculate oil absorption capacity is

$$OAC\ \% = \frac{Amount\ of\ oil\ added - free\ oil\ (ml)}{Weight\ of\ sample\ (g)} \times density\ of\ \mathrm{oil} \times 100$$

2.9.3. Bulk density

The bulk density of the sorghum *ogi* flour was determined as described (Ferrari *et al*., 2013). Ten grams (10 g) of each powder sample was filled into a graduated measuring cylinder and their weights were noted. The cylinder was tapped continuously until there is no further change in the volume. The weight and final volume of the powder in the cylinder were noted and the difference in weight and volume was determined. The bulk density was calculated in gram per millilitre (g/mL) of the sample.

2.9.4. Swelling capacity

The swelling capacity of sorghum *ogi* flour was determined using the procedure carried out by Ahaotu *et al*. (2021). Three grams (3 g) of the sample were measured and transferred into a clean, dry test tube, with the combined weight of both the sample and test tube recorded. The sample was dispersed in 50 ml of water and stirred, and the resulting suspension was heated at 60°C for 15 minutes in a thermostat water bath, with gentle stirring to prevent clumping. After cooling to room temperature, the slurry was centrifuged at 2500 rpm for 15 minutes, the supernatant was poured off, and the residue was weighed. The swelling capacity was calculated as the ratio of the difference in the weight of the flour multiplied by 100.

2.9.5. Emulsion capacity

The method outlined by Enujiugha and Akanbi (2005) was used to measure the emulsion capacity of sorghum *ogi* samples. Two grams (2 g) of the sample were blended for 30 seconds at 1600 rpm with 25 mL of distilled water in a blender. Refined oil from a burette was added after full dispersion, and the mixture was mixed until the water and fat layers separated. The amount of oil emulsified by one gram of flour was expressed as the emulsion capacity in millilitres.

$$Emulsion\ capacity = \frac{Volume\ of\ oil\ used(ml) - Volume\ of\ olil\ separated(ml)}{Volume\ of\ oil\ used\ (ml)} \times 100$$

2.9.6. Foaming properties

The procedure outlined by Ogori *et al*. (2022) was utilized to assess the foaming capability. Protein weight basis slurries were generated as sample dispersions in 50 ml graduated centrifuge tubes containing 0.1M phosphate buffer. Using a blender, sample slurries were homogenized at 20000 x g for one minute. It was established how much air could be continuously included (foaming capacity).

2.10. Determination of Color

The method outlined by Akintayo *et al*. (2020) was used to determine the CIE L* a* b* colour determination, and a colorimeter was used to assess the colour of the *ogi* flour samples in an objective manner. It uses three sets of numbers: L*, a*, and b* from the International Commission on Illumination (CIE), where L* stands for "lightness" (axis: 0 is black, 100 is white), a* for "red-green" (axis: positive values are red, negative values are green, and 0 is neutral), and b* for "yellow-blue" (axis: positive values are yellow, negative values are blue, and 0 is neutral). The standardization of the instrument preceded the analyses. This is how the total colour difference (ΔE) was computed (Makanjuola *et al*., 2015):

$\Delta E = \sqrt{\Delta a2 + \Delta b2 + \Delta L2}$

Where $\Delta a = a1 - a0$

$\Delta b = b1 – b0$

$\Delta L = L1 - L0$

ao, b0, L0 are corresponding values for the control sample.

2.11. Determination of pH and Total Titratable Acidity

Adejobi *et al*. (2024a) provided a protocol for determining the pH of the sorghum *ogi* samples. Using a digital pH metre, the hydrogen ion concentration (pH) variations of the fermenting sorghum *ogi* were determined. The pH probe electrode was sanitized with 90% ethanol prior to the pH metre being submerged in the sample. The pH metre was calibrated using Buffer 4.0 and 7.0.

Using the method outlined by Malomo and Abiose (2020), the total titratable acidity of the *ogi* was ascertained. Using phenolphthalein as the indicator, 0.1M NaOH was titrated against 25 ml of the fermenting sorghum *ogi* samples to quantify it.

2.12. Microbial analysis

2.12.1. Serial Dilution

Normal saline used as diluent was prepared by dissolving 0.85 g of sodium chloride and making it up to 100 mL distilled water and poured into clean McCartney bottles which where corked and sterilized autoclaving at 121℃ and 0.15 MPa for 15 min. The petri dishes used were sterile disposable petri dishes. One gram (1 g) of sample was aseptically weighed and added into 9 mL sterile saline solution and homogenized to permit even distribution of the microorganisms. The samples were serially diluted up to 10^ (-2) using sterile syringes and the process was repeated for all the three samples. Which was carried out in an aseptic condition according to the Adejobi *et al*. (2024b) protocol.

2.12.2. Total plate count

The total plate count of the sorghum *ogi* was determined. Bacteria were examined using nutrient agar (NA) while fungi were examined using potato dextrose agar (PDA), malt extract agar (MEA) was used for yeast counts and de Mann-Rogosa-Sharpe agar (MRS) was used for the lactic acid bacteria. 2.8 g of NA and 3.5 g of PDA, MEA and MRS were weighed separately into 250 mL conical flasks and mixed with 100 mL of distilled water. The conical flasks were corked and sterilized by autoclaving at 121℃ and 0.15 MPa for 15 min. 1 mL of each sample from 10^{-3} dilution was aseptically taken with the aid of a sterile syringe and transferred into the sterile petri-dishes and the molten agar cooled to 42-45 ℃ were added respectively. The plates were inverted and incubated at 35 ℃ for 24 hours and 27 ℃ for 48 hours, for bacteria and fungi respectively. During the incubation period, growth and multiplication of cell occurred and after the incubation period, the viable colonies were counted. The number of colonies was multiplied by the dilution factor and recorded as the number of microorganisms per gram of food (Adejobi *et al*., 2024b; Ekwen and Okolo, 2017).

2.13. Sensory analysis

The sensory analysis was determined using the procedure described by Adejobi *et al*. (2024a). The objective of sensory evaluation was for each panelist to objectively and subjectively evaluate the sorghum *ogi* samples. Sensory Analysis was carried out using the multiple comparison test method for the sample. The sorghum *ogi* samples was evaluated based on appearance, colour, aroma, mouth-feel taste for objective analysis while overall acceptability was subjectively determined by 30 untrained panelists using a 9 – Point hedonic scale rating (1= dislike extremely; while 9 = like extremely) (Taiwo-Olabode *et al*., 2024). The panelists were briefly addressed on the objectives of the analysis to familiarize them with the sensory parameters as well as the hedonic scales to be used based on appearance, colour, odor, aroma/flavour, mouthfeel and taste.

2.14. Statistical analysis

All data collected were subjected to Analysis of Variance (ANOVA) using Statistical Package for Social Sciences

(SPSS) version 22. Duncan's new multiple range test (DNMRT) was used to compare the differences in mean score at 5% significant difference.

3. Results and Discussion

3.1. Proximate composition of sorghum *ogi* samples with the inclusion of ginger and garlic

Table 2 shows the proximate composition of the spiced sorghum-*ogi*. The moisture content of the fortified sorghum *ogi* samples are significantly different (p>0.05). The moisture content of the sorghum *ogi* samples was observed to increase with sample SGG70 having the highest moisture content value (3.05%) when compared to the control sample S100 having the least of (0.67%). The moisture content of the breakfast meal was observed to be within the recommended value of (<10.00 g/100g) for food products. Comparatively, the values observed in this study are a little lower to (6.74-7.49g/100g) as reported by Babarinde *et al*. (2020) for breakfast cereal developed from fonio millet and pigeon pea flour. Hence, the formulated *ogi* may have longer shelf life as low moisture reduce water activity thereby inhibiting microbial growth. Ash is use to indicate the mineral content in food samples. Sample SGG70 shows the highest ash content (0.78 ± 0.20), followed by SGG80, SGG90, and S100 having the lowest ash content of (0.25 ± 0.08). There is an increase in the ash contents of the sample with increase in the ginger and garlic supplementation this might be due to the high mineral content in garlic and ginger. The level of ash in food is an important nutritional indicator of minerals density and also a quality parameter for contamination (Lee *et al*., 2007). The fat content of the developed complementary food is significantly higher than the 100% sorghum *ogi*, however, all the diets met the minimum requirement of 10-25% recommended for infant and illness adult food by (Muszalik, 2009). Sample SGG70 exhibits the highest fat content (3.89 ± 0.61), followed by SGG80 (1.35 ± 0.17), SGG90 (1.19 ± 0.00), and S100 (0.52 ± 0.11). This may be due to the presence of garlic and ginger in the formulation which is a good source of fat. All experimental crude fat values are higher than the values 4.8 and 9.42% reported by Ikujenlola and Fashakin (2005). Fiber content represents the dietary fiber present in the samples, with SGG70 exhibiting the highest fiber concentration. SGG70 demonstrates the highest fiber content (3.09 ± 0.21), followed by SGG80 (1.35 ± 0.17), SGG90 (0.52 ± 0.00), and S100 (0.46 ± 0.03).
The protein content of sample SGG70 which is (22.29±0.19) is relatively higher than 100% sorghum *ogi* which is (5.45±0.07). However, the protein content of all the samples falls between the range of 15% recommended for complementary by (Muszalik, 2009).

The protein content is comparable similar to 16.00-20.00% reported by Lalude and Fashakin (2006) that produced weaning foods from sorghum and oil seeds and 9.45-19.70% reported by Osundahunsi and Aworh (2002) for various tempeh-fortified maize-based complementary diets. The crude carbohydrate of the samples shows that S100 has the highest carbohydrate content (89.67 ± 0.12), followed by SGG90, SGG80 and SGG70 which have the least sample of (68.52 ± 0.30). The carbohydrate content of the developed samples is in agreement with the values reported in germinated weaning formulations using millet (60.2-69.6%). Carbohydrate contributes to the bulk of energy of the sample which makes it high energy food and ideal for the growth of growing infants (Agu and Aluyah. 2004).

The calories in an infant diet are provided by the protein, fat and carbohydrate which are major components of complementary foods that help to meet the energy requirement of growing infants and lack of any of these may lead to malnutrition (Asma *et al*., 2006). The calorie value of formulated diets was in the range of 372 -397 kcal/100g reported for complementary diets based on cereal and legumes combination. S100 exhibits the highest energy content (385.10 ± 0.71), followed by SGG90 (384.21 ± 0.11), SGG80 (374.54 ± 0.89), and SGG70 (371.02 ± 0.67). Tizazu *et al*. (2010) also reported energy values of weaning blends prepared from sorghum, legumes and oilseeds as 405.8 to 413.2 Kcal/100g which is higher than the values obtained in this study.

Table 2: Proximate composition of sorghum *ogi* samples with the inclusion of ginger and garlic

Samples	Moisture Content %	Ash Content %	Crude Fibre %	Crude Fat %	Protein %	Carbohydrate %	Energy Kcal
S100	3.670±0.318^{c}	0.254±0.008^{c}	0.459±0.028^{c}	0.523±0.106^{d}	5.454±0.073^{d}	89.671±0.123^{a}	385.207±0.707^{d}
SGG80	4.437±0.126^{bc}	0.328±0.058^{c}	0.519±0.001^{c}	1.192±0.004^{c}	11.293±0.129^{c}	82.231±0.117^{b}	384.824±1.334c
SGG80	5.319±0. 344^{ab}	0.646±0.063^{b}	1.339±0.169^{b}	1.348±0.169^{b}	17.137±0.134^{b}	73.479±0.640^{d}	374.545± 0.886^{b}
SGG70	6.051±0.566^{d}	0.783±0.020^{a}	3.086±0.214^{a}	3.89 ± 0.61^{a}	22.290±0.189^{a}	68.522±0.302^{c}	371.022± 0.666^{a}

Values are means ± standard deviations of replicate determinations (n=3). Mean values with same letter(s) in the column are not significantly (p<0.05) different.

Keys: S100: control (100% Sorghum *ogi*) SGG90: (90% sorghum, 5% ginger and 5% garlic) SGG80: (80% sorghum, 15% ginger and 5% garlic) SGG70: (70% Sorghum, 25% Ginger, 5%Garlic)

3.2. Mineral composition of maize *ogi* samples with inclusion of ginger and garlic

Table 3 shows the minerals composition of the fortified sorghum *ogi* samples. According to Ejigbo *et al*. (2018), minerals are crucial for supporting development, growth, and general health. It is a crucial component of several compounds, including DNA, adenosine triphosphate (ATP), and haemoglobin (Bukuni *et al*., 2022).

The sodium contents ranged from 46.770 to 55.045 mg/ 100 g, potassium, zinc, calcium, iron and phosphorus contents ranged from 82.150 to 95.050 g/100 g, 1.292 to 1.508 g/100 g, 35.600 g/100g to 39.150 g/100g, 0.743 to 1.195 g/100 g and 9.690 g/100g to 13.205 g/100g respectively. This aligns with findings by Olaniran *et al*. (2015), which highlight that garlic and ginger are rich sources of phosphorus, potassium, and calcium. Interestingly, iron and zinc levels remained consistently low throughout the fermentation process of the spiced sorghum *ogi*. The results demonstrated fluctuations in mineral increase during fermentation. Notably, sample S100 displayed the highest potassium and sample SGG80 has highest content of calcium while sample SGG70 exhibited significantly high levels of potassium, sodium, and calcium. Comparatively, when contrasted with the control (S100), the addition of ginger and garlic during fermentation notably affected the mineral content of the spiced sorghum *ogi*.

Table 3: Mineral composition of maize *ogi* samples with inclusion of ginger and garlic

SAMPLE	Na (ppm)	K (ppm)	Ca (ppm)	Fe(ppm)	Zn (ppm)	P (ppm)
S100	50.185±0.120^c	95.050±0.070^a	37.050±0.070^b	1.195±0.035^a	1.506±0.042^a	9.690±0.085^c
SGG90	46.770±0.042^d	82.150±0.070^d	35.600±0.141^d	0.912±0.064^b	1.389±0.075^{ab}	13.205±0.106^a
SGG80	50.435±0.091^b	87.450±0.070^c	39.150±0.070^a	0.743±0.079^b	1.504±0. 044^a	13.050±0.071^a
SGG70	55.045±0.063^a	90.200±0.141^b	35.950±0.070^c	1.191±0.093^a	1.292±0.011^b	10.605±0.049^b

Values are Mean ± standard deviation. Mean values with the same superscript along the same column are not significantly different at p<0.05
Key: S100: 100% Sorghum *Ogi*; SGG90: 90% Sorghum *Ogi*: 5% Ginger: 5% Garlic; SGG80: 80% Sorghum *Ogi*: 15% Ginger: 5% Garlic; SGG70: 70% Sorghum *Ogi*: 25% Ginger: 5% Garlic

3.3: Microbial loads of sorghum *ogi* samples fortified with ginger and garlic

The Table 4 shows the microbiol*ogi*cal changes occurring in the spiced sorghum *ogi* samples that was under seek at 48 hours mark of the secondary fermentation stage. The microbiol*ogi*cal analysis was carried out to ascertain the safety of the product for consumption (Adisa *et al*., 2024). The colony forming units of the bacteria as well as fungi was investigated in the fortification of the sorghum *ogi* samples. *Lactobacillus* count of the sorghum *ogi* samples showed a higher inhibition of lactic acid bacterial growth with sample SGG70 having the least growth of 1.150 × 10^5 CFU which indicates it is fit for consumption while sample SGG80 had the highest growth of 4.75 × 10^5 CFU. This could be probably due to antioxidant effect of ginger which indicate that ginger and garlic did not affect lactic acid bacteria negatively (Adejobi *et al*., 2024a). Total bacteria count of the sorghum *ogi* samples ranged from 4.8 × 10^5 cfu/ml in sample SGG90 to 8.0 5 × 10^5 cfu/ml with sample S100 having the highest bacteria growth making it susceptible to spoilage while sample SGG80 and SGG70 having a low bacterial growth of 4.5 × 10^5 cfu/ml. Total fungal count in the sorghum *ogi* samples also ranged from 1.4 ×10^5 CFU in sample S100 to 5 × 10^5 cfu/ml with sample SGG80 having the highest colony forming unit of 5 ×105 cfu/ml which indicates a high proportion of bacteria growth which might not be safe for consumption. Fungi predominantly yeasts, play a crucial role in introducing the distinctive flavour and aroma during the fermentation process of *ogi* (Adelekan *et al*., 2021).

The introduction of garlic and ginger in combination with sorghum *ogi* paste, enhanced the lactic acid bacteria flora and decreased microbial loads during fermentation. Encouraging the inclusion of ginger and garlic during fermentation can be beneficial in eliminating undesirable microorganisms in sorghum *ogi* (Olaniran *et al*. 2020).

Table 4: Microbial Load (CFU/ ml) of sorghum *ogi* fortified with ginger and garlic

Sample	*Lactobacillus* count	Total bacteria count	Total fungal count
S100	2.5 × 10^5	8.0 × 10^5	1.4 × 10^5
SGG90	1.8 × 10^5	4.8 × 10^5	3.0 × 10^5
SGG80	4.7 × 10^5	4.5 × 10^5	5.0 × 10^5
SGG70	1.150 × 10^5	4.5 × 10^5	1.6 × 10^5

Values are Mean ± standard deviation. Mean values with the same superscript along the same column are not significantly different at p<0.05
Key: S100: 100% Sorghum *Ogi*; SGG90: 90% Sorghum *Ogi*: 5% Ginger: 5% Garlic; SGG80: 80% Sorghum *Ogi*: 15% Ginger: 5% Garlic; SGG70: 70% Sorghum *Ogi*: 25% Ginger: 5% Garlic

3.4. pH and total titratable acidity of the sorghum *ogi* slurry with inclusion of ginger and garlic

Figure 2 shows the changes in pH and TTA during fermentation of spiced sorghum *ogi*. There was a general steady reduction in pH and simultaneous significant increase in TTA during the 48h fermentation period.

The decreased pH values in the sorghum *ogi* samples can primarily be linked to acid production by microorganisms during the fermentation process. This outcome aligns with the observations made by Singh *et al*. (2012) regarding the impact of fermentation on cereals. The quality of fermented products is also dependent on the population of fermenting microorganisms, a factor associated with the rise in lactic acid concentration resulting from the activity of lactic acid bacteria (Adebowale and Adeyanju, 2022). Based on all indications, incorporating garlic and ginger possesses the potential to inhibit the growth and spread of spoilage and pathogenic bacteria in sorghum in *ogi* samples which is in agreement with the studies carried out by Olaniran *et al*. (2019).

The pH content after 0 hours of fermentation was observed to decrease with an increase in the ginger content of the sorghum *ogi* samples with values ranging from 3.355 % and 3.885 % in which sample S100 had the lowest value and sample SGG80 had the highest value. pH after 24 hours and 48 hours was also observed to increase with values ranging from 2.515% in sample AS100 to 3.275 % in sample SGG70 and 1.905 % also in sample S100 and 2.470 % in sample SGG70 respectively. TTA content however 0 hours was observed to reduce as the ginger content increased in the sorghum *ogi* samples with values ranging from 3.710 % to 2.42 % in the control sample S100 and sample SGG70 respectively. TTA contents after both 48 hours was also observed to reduce in the sorghum *ogi* samples where the values obtained ranged from 6.390 % to 20.290% and 2.690 % and 2.100 % respectively.

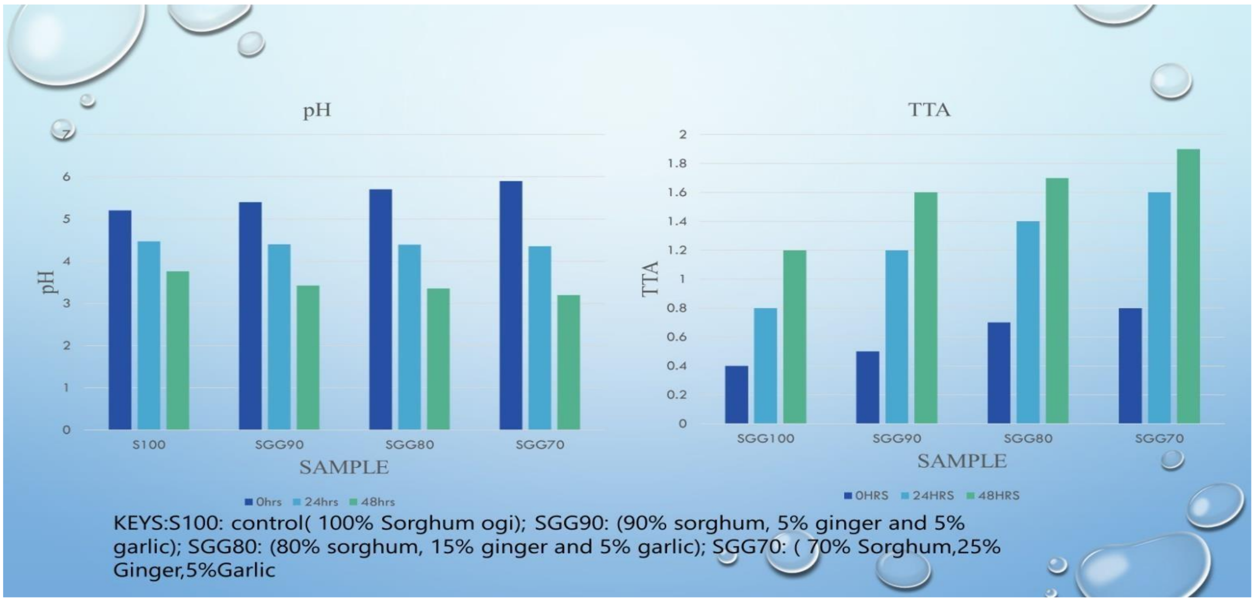

Figure 2: Shows pH and TTA of sorghum *ogi* samples with inclusion of ginger and garlic.
Keys: S100: control (100% Sorghum *ogi*), SGG90: (90% sorghum *ogi*, 5% ginger and 5% garlic)
SGG80: (80% sorghum *ogi*, 15% ginger and 5% garlic), SGG70: (70% Sorghum *ogi*, 25% Ginger,5%Garlic

3.5. Antioxidant properties of sorghum *ogi* samples with inclusion of ginger and garlic

Anti-oxidant values of all the sorghum *ogi* samples are presented in Table 5. Phenol content of the sorghum *ogi* samples increased with an increase with garlic and ginger inclusion with the control sample S100 (100% sorghum *ogi*) having a value of 1.549 (mg GAE/g) and sample SGG70 (70% sorghum, 25% ginger and 5% garlic) having a value of 10.658 (mg GAE/g). This result is similar to a study by Odunlade *et al*. (2016) where cocoa powder was added in different ratios to sorghum *ogi* samples. This depicts that the addition of ginger (25%) and garlic (5%) increased the polyphenols of the samples thereby having the highest TPC and it was also reported by Hejazi and Orsat, (2016) that higher intake of phenolic compounds from plant sources has been linked to a decreased risk of cardiovascular diseases and certain cancers. Sorghum *ogi* sample enriched with 70% sorghum *ogi*, 25% ginger and 5% garlic had the highest DPPH (78.3553%) while the control sample has the lowest DPPH (11.54392 %).

The same trend was reported in a study by Olaniran *et al*. (2019) where *ogi* supplemented with 4% garlic+2% ginger showed the highest radical scavenging activity (0.75∼0.97IC50 mg/mL). Garlic and ginger are rich in antioxidants and possess good free radical scavenging abilities that can used as radical inhibitors (Ryu and Kang, 2017). Garlic showed stronger radical scavenging activity than ginger, hence antioxidant activity of garlic has been previously reported by (Asimi *et al*., 2013).

The Flavonoid contents of the sorghum *ogi* samples ranged from 0.0038 (mg/g) to 1.92 (mg/g). Garlic and ginger are both good sources of flavonoids in food (Adejobi *et al*., 2024a). As presented in Table 5, the FRAP of the samples ranged between 1.34 and 22.405 mg AAE/g. This depicted an increase of 20-fold for 25% ginger and 5% garlic enriched sorghum *ogi*. The control sample (S100) had the lowest ferric reducing antioxidant activity (1.34 mg AAE/g). This indicates that ginger and garlic contributed significantly to the ferric reducing antioxidant power of the enriched samples. The ABTS value of the sorghum *ogi* samples ranged from 0.003 to 0.025 Mmol/g with the control sample having the lowest value.

Table 5: Antioxidant properties of sorghum *ogi* samples with inclusion of ginger and garlic

Sample	Phenol mg/g	Flavonoid mg/g	FRAP mg/g	ABTS Mmol/g	DPPH %
S100	1.549±0.043^{d}	0.038±0.005^{c}	1.343±0.021^{d}	0.003±0.000^{d}	11.534±11.200^{c}
SGG90	4.770±0.043^{b}	0.088±0.005^{b}	18.797±0.021^{b}	0.014±0.000^{c}	34.910±34.833^{b}
SGG80	4.197±0.043^{c}	0.188±0.005^{a}	10.448±0.021^{c}	0.004±0.000^{a}	78.274±78.200^{a}
SGG70	11.835±0.042^{a}	0.207±0.005^{a}	23.67±0.021^{a}	0.026±0.001^{a}	79.984±0.109^{a}

Values are Mean ± standard deviation. Mean values with the same superscript along the same column are not significantly different at $p<0.05$
Key: S100: 100% Sorghum *Ogi*; SGG90: 90% Sorghum *Ogi*: 5% Ginger: 5% Garlic; SGG80: 80% Sorghum *Ogi*: 15% Ginger: 5% Garlic; SGG70: 70% Sorghum *Ogi*: 25% Ginger: 5% Garlic

3.6. Functional properties of sorghum *ogi* samples with inclusion of ginger and garlic

According to Adeleke and Odedeji (2010), a food material's functional qualities are what define its final application and use. In most cases, it indicates that they will quickly reconstitute into a fine, consistent gruel or pudding when mixed (Adebowale *et al*., 2018). Table 6 shows the outcomes of the functional qualities. There was a significant difference ($P < 0.05$) in all six functional parameters of the samples: bulk density (BkD), water absorption capacity (WAC) indexes, emulsion capacity (EmC), foaming capacity (FoC), foaming stability (FoS) and oil absorption capacity (OAC). The result of bulk density (BD) is used to evaluate the *ogi* flour heaviness, handling requirement and the type of packaging materials suitable for storage and transportation of food materials (Oppong *et al*., 2015). Food ingredients such as thickening agents and confections require starch with a high-water absorption capacity, while goods like mayonnaise and frying batters require starch with an appropriate oil absorption capacity (Alimi *et al*., 2016). The bulk density varies considerably, ranging from 0.59 for S100 to 0.77 for SGG70 g/ml. These values are comparable to those reported by Ayo and Okoye (2020) and lower than those found by Ramachia *et al*. (2018), who examined the functional properties of finger millet and found values ranging from 0.89 to 0.93g/ml. The range of values for the water absorption capacity is 1.278 for SGG70 to 2.159 g/g for S100, which is relatively close to the value reported by Ramachia *et al*. (2018), who examined the functional qualities of finger millet and found values between 0.93 ± 0.06 and 1.23 ± 0.06 mL/g. When evaluating whether flour or isolate can be successfully incorporated into water-based food formulations—especially when dough is being worked with the water absorption capacity (WAC) of the flour or isolate is a useful metric to consider (Ramachia *et al*., 2018). The samples for the oil absorption capacity value of sorghum *ogi* ranges from 1.278 g/g in S100 to 2.159 g/g in SGG70, were considerably ($p<0.05$) different. The highest amount of oil emulsified by protein in a specific amount of flour is measured via emulsion. As the amount of ginger and garlic was added, the EC decreased, ranging from 62.287g/ml for S100 to 54.246g/ml for SGG70. According to Sathe and Diphase (2009), the main protein's globular structure may be the cause of its high emulsification capacity. Emulsions are produced through the dispersion of one immiscible liquid into another in the form of tiny droplets, typically with a size between 0.1 and 10 µm (Yan *et al*., 2020). Studies show that proteins' ability to create emulsions is directly related to their quick adsorption, unfolding, and repositioning at the oil-water interface (Cansu *et al*., 2017). The swelling capacity varies from 300.611 in SGG90 to 325.611% in S100, indicating a significant difference ($P<0.05$). According to Awuchi *et al*. (2019), swelling capacity is the volume in milliliters that one gram (1g) of food material can absorb when it swells under particular circumstances. Foods and flours with a high starch content have a higher swelling capacity (index), particularly when the starch has a larger quantity of branched amylopectin (Awuchi *et al*., 2019). It is possible that the high starch content in the sorghum-*ogi* combination is the cause of the high swelling capability. Measuring the amount of interfacial area formed by whipping a food or flour yields its foaming capacity (Mauer, 2003). According to Canat *et al*. (2013), foams are created when pockets of gas are trapped in liquid or solid food. Maybe the low protein content in the sorghum-*ogi* mixture is the cause of the low foaming capacity (Enujiugha *et al*., 2003).

Table 6: Functional properties of sorghum *ogi* samples with inclusion of ginger and garlic

Sample	Bulky density(g/ml)	Foaming capacity (%)	Swelling capacity (%)	Oil Absorption(g/g)	Emulsion (%) Capacity	Water Absorption(g/g)
S100	0.59± 0.051^{b}	0.786±0.007^{b}	325.611±0.864^{a}	1.1661±0.235^{a}	62.287±0.540^{a}	2.159±0.097^{a}
SGG90	0.67± 0.003^{a}	0.396±0.004^{c}	300.611±0.864^{a}	1.257±0.009^{a}	53.608±0.465^{b}	1.706±0.174b
SGG80	0.75±0.031^{c}	1.597±0.014^{a}	266.269±6.690^{b}	1.218±0.051^{a}	53.172±0.461^{b}	1.545±0.009^{bc}
SGG70	0.77±0.034^{c}	0.768±0.007^{b}	240.222±0.315^{c}	1.188±0.063^{a}	54.246±0.470^{b}	1.278±0.015^{c}

Values are Mean ± standard deviation. Mean values with the same superscript along the same column are not significantly different at $p<0.05$
Key: S100: 100% Sorghum *Ogi*; SGG90: 90% Sorghum *Ogi*: 5% Ginger: 5% Garlic; SGG80: 80% Sorghum *Ogi*: 15% Ginger: 5% Garlic; SGG70: 70% Sorghum *Ogi*: 25% Ginger: 5% Garlic

3.7. Pasting properties of sorghum *ogi* samples with inclusion of ginger and garlic

Table 7 shows the pasting properties of sorghum *ogi* mix with ginger and garlic. Peak viscosity, which is the ability of flour or starch-based foods to swell freely before physical decomposition Poutanen *et al*. (2008), ranged from 183 RVU for SGG70 to 5983 RVU for S100 in samples, representing different maximum viscosity levels. Trough is a measure of a paste's resistance to breaking down during cooling; a higher trough suggests a paste that will be more stable because of the influence of the ginger and garlic in the sorghum flour blend. While sample SGG70 had the lowest peak and trough viscosities, sample S100 had the best overall peak and trough viscosities, closely followed by SGG90, SGG800. Nonetheless, sample SGG70, which has the lowest breakdown viscosity, would be more stable during cooking (Zhang *et al*., 2017). It would also have the least retrogradation in addition. It is reasonable to assume that the preparation's superior heat treatment contributed to its increased stability and less retrogradation. The degree to which the swollen granules can be disrupted is represented by the breakdown viscosity, which is a measure of starch stability (Kaur *et al*., 2007). Adebowale *et al*. (2005) state that the lower the breakdown viscosity, the greater the flour's resistance to heat and shear stress. Because of its low breakdown viscosity, which has a value range of 105-338 RVU, the formed sorghum *ogi* may be able to tolerate heat and shear stress. The final viscosity indicates the possibility of starchy foods solidifying into a paste after cooking and cooling. This attribute is important since it is a quality criterion that helps predict the final texture of starchy foods (Arinola *et al*. 2016). Sample S100 has the greatest value, indicating that it may be a stable food product after cooking. The final viscosity value ranged from 2582–3669 RVU, which is quite similar to the report of Oluwajuyitan *et al*. (2022) and Babatuyi *et al*. (2023). Setback, peak time, and pasting temperature fall between 299 and 102 RVU, 4:18 and 5:14 min, and 77.53 and 71.89 0C, respectively. The results are quite similar to those of Babatuyi *et al*. (2023) and Oluwajuyitan *et al*. (2022). The temperature and pasting time show how long or how hot cooking must be for minimum results.

Table 7: Pasting properties of sorghum *ogi* samples with inclusion of ginger and garlic

Sample	Peak Viscosity	Trough Viscosity	Breakdown	Final Viscosity	Setback	Peak Time	Pasting Temperature
S100	5983.050±1.345^{a}	1676.000±1.414^{a}	338.000±1.414^{a}	3669.000±1.414^{a}	299.000±1.414^{a}	4.679±0.013^{c}	77.527±0.179^{a}
SGG90	383.000±1.414^{a}	857.000±1.414^{a}	982.000±1.414^{d}	3529.000±1.414^{b}	267.000±1.414^{b}	5.525±0.177^{a}	80.806±0.008^{a}
SGG80	358.000±1.414^{a}	681.500±1.414^{a}	184.000±1.414^{b}	3194.000±1.414^{d}	2040.000±1.414^{d}	5.509±0.055^{a}	80.788±0.124^{a}
SGG70	183.500±1.414^{a}	155.000±1.414^{b}	105.000±1.414^{c}	2582.000±1.414^{c}	102.000±1.414^{c}	5.140±0.014^{b}	77.899±2.829^{a}

Values are Mean ± standard deviation. Mean values with the same superscript along the same column are not significantly different at $p<0.05$

Key: S100: 100% Sorghum *Ogi*; SGG90: 90% Sorghum *Ogi*: 5% Ginger: 5% Garlic; SGG80: 80% Sorghum *Ogi*: 15% Ginger: 5% Garlic; SGG70: 70% Sorghum *Ogi*: 25% Ginger: 5% Garlic

3.8. Colour determination of sorghum *ogi* samples with inclusion of ginger and garlic

The degree of lightness from black to white (Hunter *L*, *a*, and *b* value) of the control sample S100 (100% sorghum grain) and fortified samples is shown in Table 8. The *L** values of the samples which indicate lightness ranged from 86.87 (SGG70) to 99.98 (S100). Addition of ginger and garlic reduced slightly the *L** of the samples. The *a** value of the samples decreased with increase in the percentage of ginger and garlic added to the sorghum *ogi*. The *a** which signifies the redness or greenness of the sample decreased in the fermented samples due to the color of the garlic used in this study ranging from 12.53 (S100) to 23.61 (SGG70). The *b** values of the formulated samples ranged between 1.64 for sample S100 and 6.90 for sample SGG80 which had the highest and lowest values. The color intensity (*C**) of the samples slightly decreased with increase in ginger and garlic added, and this was also observed in a recent study (Adejobi *et al.*, 2024a). The *C** value ranged from 12.71 for sample AS70 to 23.66 for sample S100

Table 8: Colour determination of sorghum *ogi* samples with inclusion of ginger and garlic

Sample	L*	a*	b*	c*	h*	ΔE
S100	99.980±0.000^{a}	23.610±1.021^{a}	1.640±0.026^{d}	23.667±1.015^{a}	3.803±0.461^{d}	0.000^{d}
SGG90	99.980±0. .000^{a}	13.46667±0.43^{c}	5.137±0.042^{b}	14.600±0.395^{c}	20.620±0.74^{b}	10.730±0.439^{c}
SGG80	88.860±0.1082^{b}	15.333±0.08^{b}	6.907±0.015^{a}	16.793±0.031^{b}	24.290±0.101^{a}	14.844±0.487^{b}
SGG70	86.877±1.1288^{c}	12.530±0.010^{c}	2.130±0.010	12.710±0.010^{d}	9.640±0.046^{c}	1.259±1.259^{a}

Values are Mean ± standard deviation. Mean values with the same superscript along the same column are not significantly different at $p<0.05$

Key: S100: 100% Sorghum *Ogi*; SGG90: 90% Sorghum *Ogi*: 5% Ginger: 5% Garlic; SGG80: 80% Sorghum *Ogi*: 15% Ginger: 5% Garlic; SGG70: 70% Sorghum *Ogi*: 25% Ginger: 5% Garlic

3.9. Sensory evaluation of sorghum *ogi* samples with inclusion of ginger and garlic

Mean scores (n=2) of sensory attributes of sorghum *ogi* fortified with garlic and ginger are as shown in Table 9. Generally, *Ogi* pastes prepared from sorghum with added garlic and/or ginger were significantly (p<0.05) different and favourably comparable tto the control sample (without added garlic or ginger), in terms of all the sensory attributes. Ratings for colour, appearance, aroma, taste, and texture (mouthfeel) for the samples showed significant differences for all the samples. The overall acceptability of sorghum *Ogi* fortified with ginger and garlic were comparable with the control (without garlic or ginger). The results of the sensory evaluation test showed that, the preferred sorghum *Ogi* was that prepared from 5% garlic, 5% ginger and 90% sorghum *ogi* addition. In a previous study, it was observed that the addition of ginger and garlic powder was able to mask and improve the sensory attributes of sorghum-*Ogi* resulting from the presence of volatile compounds including terpenes, allyl sulfide, diallyl trisulfide, diallyl disulfide, and 2-propen-1-ol (Li *et al*, 2016). Garlic and ginger are good sources of antioxidants and mineral elements (Ryu and Kang, 2017). Therefore, the addition of garlic and/or ginger to *Ogi* has the potential to improve the sensory qualities of *Ogi*, which has also been documented elsewhere (Adejobi *et al*., 2024a; Olaniran *et al*., 2019). The least preference observed among all the sorghum-*Ogi* samples was that containing 5% garlic, 25% ginger and 70% sorghum.

Table 9: Sensory evaluation of sorghum *ogi* samples with inclusion of ginger and garlic

Sample	Appearance	Taste	Flavour	Consistency	Overall Acceptability
S100	7.602±0.932[a]	6.671±1.446[a]	6.272±1.552[a]	6.677±1.322[a]	7.404±1.070[a]
SGG90	7.004±1.174[ab]	6.603±1.354[a]	6.334±1.124[a]	6.805±1.375[a]	7.236±0.898[a]
SGG80	6.531±1.852[b]	5.602±1.714[b]	5.670±1.900[a]	6.403±2.207[a]	6.001±1.438[b]
SGG70	6.632±1.752[b]	5.473±1.697[b]	5.673±1.647[a]	6.331±1.688[a]	5.532±1.756[b]

Values are Mean ± standard deviation. Mean values with the same superscript along the same column are not significantly different at p<0.05
Key: S100: 100% Sorghum *Ogi*; SGG90: 90% Sorghum *Ogi*: 5% Ginger: 5% Garlic; SGG80: 80% Sorghum *Ogi*: 15% Ginger: 5% Garlic; SGG70: 70% Sorghum *Ogi*: 25% Ginger: 5% Garlic

4. Conclusion

In the present study, a novel functional breakfast gruel was developed by incorporating ginger and garlic into starter culture-fermented fortified sorghum *ogi*. The bioactive components increased with the increasing concentration of ginger in the sorghum *ogi*, indicating a higher potential to act as a functional food for infants during weaning period and for nursing mothers and malnourished populations. The results of the sensory analysis indicated that the inclusion of ginger and garlic in sorghum *ogi* formulations did not have a negative impact on the product acceptability. The sample S100, which contains 100% sorghum *ogi* with no added spices, was found to be the most acceptable among the formulations tested, followed by Sample SGG90 which was prepared with 90% sorghum *ogi*, 5 % ginger and 5 % garlic.

Competing Interest: Authors declare no conflict of interest.

References

Adelakan, A. O. and Oyewole, O. B. (2021). Production of *Ogi* from germinated sorghum supplemented with soybean. *African Journal of Biotechnology*, 9(42), 7114-7121.

Adelekan, A. O., Alamu, E. A. and Daramola, B. E. (2021). Effect of enrichment with turmeric and ginger on some quality characteristics of fermented maize ogi, *Croatian Journal of Food Science and Technology*, 13(2), 210-220.

Adeleke, R. O. and Odedeji, J. O. (2010). Functional properties of wheat and sweet potato flour blends. *Pakistan Journal Nutrition*, 9, 535–538.

Adebowale, A. A., Sanni, L. O. and Ladapo, F. O. (2018). Chemical, functional and sensory properties of instant yam-breadfruit. *Nigeria Food Journal*, 26, 2–12.

Adebowale, J. O. and Adeyanju, A. (2022) Evaluation of Sorghum-*Ogi* Gruel Complemented with Ginger and Garlic Powders. *Journal of Culinary Science and Technology*, 21(2), 1-10.

Adebo, O.A. (2020). African sorghum-based fermented foods: past, current and future

Prospects-Review. *Nutrients*, 12, 1111.

Adejobi, T. H., Olorunnusi, J. O., Adegbanke, O. R., Oguntoyinbo, O. O., and Enujiugha, V. N. (2024a). Effect of Ginger and Garlic Inclusion on the Performance of *Lactobacillus plantarum* in Maize (*Zea mays* L.) Fermentation into Ogi. *IPS Journal of Applied Microbiology and Biotechnology*, **3**(1), 46–56. https://doi.org/10.54117/ijamb.v3i1.18

Adejobi, T. H., Fagbemi, S. A., Olorunnusi, J. O., Enujiugha, V. N., Oguntoyinbo, O. O., and Isaac-Bamgboye, F. J. (2024b). Recent Advances in the Identification and Characterization of Fermentative Microorganisms: An Exploratory Review. *IPS Journal of Applied Microbiology and Biotechnology*, **3**(1), 71–83. https://doi.org/10.54117/ijamb.v3i1.26.

Adisa, A. M., and Enujiugha, V. N. (2020). Microbiology and safety of ogi fermentation: a review. European Journal of Nutrition and Food Safety, 12(5), 90-100. [DOI: 10.9734/ejnfs/2020/v12i530231]

Adisa, A. M., Badejo, A. A., Ifesan, B. O. T., and Enujiugha, V. N. (2024). Phenotypic and molecular differentiation of lactic acid bacteria in fonio millet ogi fermentation and their potential as starter cultures. Food and Humanity, 2, 100230.

Afolayan, M. O., Afolayan, M. and Abuah, J. N. (2010). An investigation into sorghum based ogi (ogi baba) storage characteristics. *Advance Journal of Food Science and Technology*, 2, 72-78.

Agu, H.O., Aluyah, E. (2004). Production and chemical analysis of weaning food from maize, soybean and luted pumpkin seed flour. *Nigeria Food Journal*, 22(1), 171-177.

Ajanaku K.O., Ajanaku, C.O., Edobor-Osoh, A., and Nwinyi, O.C. (2012). Nutritive value of sorghum-Ogi fortified with groundnut seed (Arachis hypogeal L.*) American Journal of Food Science and Technology*, 7(2), 82-88.

Ahaotu, I., Eni C.V. and Maduka N. (2021). Quality Assessment of Powdered Maize Ogi Fortified with African Walnut (*Tetracarpidium conophorum*) Flour. *Microbiology Research Journal International*, 31(4): 28-51.

Akinwande BA, Babarinde GO, Ajeigbe OP. (2014) Production and evaluation of ready to-eat breakfast cereals from blends of whole maize and African yam bean (*Sphenostylis stenocarpa*). *Elixir Food Science*, 72, 25625-25628.

Akintayo, O. A., Hashim, Y. O., Adereti, A. G., Balogun, M.A., Bolarinwa, I. F., Abiodun, O. A., Dauda, A.O., Solaja, A.A. and Alabi, O.F. (2020). Potentials of rice as a suitable alternative for the production of ogi (a cereal-based starchy fermented gruel). *Journal of Food Science*.

Asimi, O.A., Sahu, N.P., Pal, A.K. (2013). Antioxidant activity and antimicrobial property of some Indian spices. *International Journal of Science and Research*, 3, 1–8.

Asma, M.A., Fadil, E.B.E., and Tinay, A.H.E. (2006). Development of weaning food from sorghum supplemented with legumes and oil seeds. *Food Nutrition Bull*, 27(1), 26-34.

AOAC (2012). 'Official methods of Analysis'. Association of official analytical chemist. 19th edition. Gathersburg, *Maryland*, U.S.A; 2012.

Ayo, J.A. and Okoye, E. (2020). Nutrient Composition and Functional Properties of Fonio (*Digitaria exilis*) and Amaranth (*Amaranthus cruentus*) Flour Blends. *Asian Food Science Journal*, 2581-7752.

Awuchi, C. G.; Owuamanam, I., Chika, C. Ogueke, V., Igwe, S. (2019). Evaluation of Patulin Levels and impacts on the Physical Characteristics of Grains. *International Journal of Advanced Academic Research*, 5 (4), 10 – 25.

Babatuyi, C.Y., Israel, C.T., Adisa, A.M. and Enujiugha, V.N. (2023). The variations in chemical composition, antioxidant capacity, and pasting properties of Fonio sourdoughs. *DYSONA-Applied Science*, 4(2), 51-61.

Bukuni, S.J., Julius Kwagh-al Ikya, J., Dinnah, A. and Bongjo, N.B. (2022). Chemical and Functional properties of Composite Flours Made from Fermented Yellow Maize, Bambara Groundnut, and Mango fruit for ogi production. *Asian food science journal*, 21(2): 22-33.

Cansu, E.G., Eric, A.D., and David, J.M. (2017). Impact of legume protein type and location on lipid oxidation in fish oil-in-water emulsions: Lentil, pea, and fava bean proteins. *Food Research International*, 100(2), 175-185.

Emelike, N. J. T., Ujong, A. E. and Achinewhu S. C. (2020). Effect of Ginger and Cinnamon on the Proximate Composition and Sensory Properties of Corn Ogi. EJNFS, 12(7): 78-85.

Ekwen, O.H. and Okolo, B.N. (2017). Microorganism Isolated during Fermentation of Sorghum for Production of Akamu (A Nigerian Fermented Gruel). *Microbiology Research Journal International*, 21(4), 1-5.

Ejigbo, E. A., Omenna, E. C. and Olanipekun O. T (2018). Microbiological, Physicochemical and Sensory Properties of Spiced Quality Protein Maize (QPM) Products. *Moor Journal of Agricultural Research*, 19, 113 - 128.

Enujiugha, V.N. (2006). Supplementation of ogi, a maize-based infant weaning food, with African oil bean seed (*Pentaclethra macrophylla* Benth). *International Journal of Postharvest Technology and Innovation*, **1**(2), 202-211.

Enujiugha, V.N. (2010). The antioxidant and free radical-scavenging capacity of phenolics from African locust bean seeds (*Parkia biglobosa*). *Advances in Food Sciences* **32**(2), 88-93.

Enujiugha, V.N., and Ayodele-Oni, O. (2003). Evaluation of nutrients and some anti-nutrients in lesser-known underutilized oilseeds. *International Journal of Food Science and Technology*, **38**(5), 525-528.

Enujiugha, V.N., Badejo, A.A., Iyiola, S.O., and Oluwamukomi, M.O. (2003). Effect of germination on the nutritional and functional properties of African oil bean (*Pentaclethra macrophylla* Benth) seed flour. *Journal of Food, Agriculture and Environment*, **1**(3/4), 72-75.

Enujiugha, V.N., Oluwole, T.F., Talabi, J.Y., and Okunlola, A.I. (2014). Selected bioactive components in fluted pumpkin (*Telfairia occidentalis*) and amaranth (*Amaranthus caudatus*) leaves. *American Journal of Experimental Agriculture*, **4**(9), 996-1006.

Ferrari, C. C., Marconi Germer, S. P., Alvim, I. D., and de Aguirre, J. M. (2013). Storage Stability of Spray-Dried Blackberry Powder Produced with Maltodextrin or Gum Arabic. *Drying Technology*, 31(4), 470–478.

Gunathilake, K.P., Wang, Y. and Rupasinghe, H.V. (2013). Hypocholesterolemia and hypotensive effects of a fruit-based functional beverage in spontaneously hypertensive rats fed with cholesterol richdiet. Journal of Functional Foods, 5(3), 1392–1401.

Hejazi, S. N., and Orsat. V. (2016). Malting process optimization for protein digestibility enhancement in finger millet grain. *Journal of Food Science Technology*, 53 (4):1929–1938.

ICRISAT. (2018). Millets and sorghum: Forgotten foods for the future. ICRISAT Happenings Newsletter.

Kaur, M. and Singh, N. (2017). Studies on functional, thermal and pasting properties of flours from different chickpea (Cicer arietinum L.) cultivars. *Food Chemistry*, 91 (3), 403-411.

Lalude, L.O., Fashakin, J.B. (2006). Development and Nutritional Assessment of a Weaning Food From Sorghum and Oil–Seeds. *Pakistan Journal of Nutrition*, 5(3), 257-260.

Ladunni, E., Aworh, O.C., Oyeyinka, S.A., and Oyeyinka, A.T. (2013). Effects of drying Method on selected properties of Ogi (Gruel) prepared from sorghum (Sorghum vulgare), millet (Pennisetum glaucum) and maize (Zea mays*). Journal of Food Processing and Technology*, 4, 248.

Lee, Y.R., Kim, J.Y., Woo, K.S., Hwang, I.G., Kim, K.H. (2007). Changes in the chemical and functional components of Korean rough rice before and after germination. *Food Science Biotechnology*, 16(6), 1006-1010.

Li, J.L., Tu, Z.C., Zhang, L., Sha, X.M., Wang, H., Pang, J.J. (2016). The effect of ginger and garlic addition during cooking on the volatile profile of grass carp (Ctenopharyngodon idella) soup. *Journal of Food Science and Technology*, 53, 3253–3270.

Makanjuola, S.A., and Enujiugha, V.N. (2018). Modelling and prediction of selected antioxidant properties of ethanolic ginger extract. *Journal of Food Measurement and Characterization*, **12**(2), 1413-1419.

Makanjuola, S.A., Enujiugha, V.N., Omoba, O.S., and Sanni, D.M. (2015). Combination of antioxidants from different sources could offer synergistic benefits: A case study of tea and ginger blend. *Natural Product Communications*, **10**(11), 1829-1832.

Mauer, L. (2003). Encyclopedia of Food Sciences and Nutrition (Second Edition), *Science Direct*.

Malomo A. A. and Abiose S.H. (2019). Effect of ginger extract on the viability of lactic acid bacteria and sensory characteristics of dairy yoghurt and soy yoghurt. *Bacterial Empire*, 3, 41-45.

Muszalik, M., Kedziora-Kornatowska, K., Kornatowski, T. (2009). Functional assessment and health related quality of life (HRQOL) of elderly patients on the basis of the illness therapy (FACIT), *Archive of Gerontology and Geriatrics*, 49(3), 404-408.

Odunlade, T.V., Taiwo, K.A. and Adeniran, H.A. (2016). Functional and antioxidant properties of sorghum *ogi* flour enriched with cocoa. *Annals. Food science and Technology*.

Ogori, A. F., Eke, M. O., Girgih, T. A. and Abu, J. O. (2022). Influence of Aduwa (Balanites aegyptiaca. del) Meal Protein Enrichment on the Proximate, Phytochemical, Functional and Sensory Properties of Ogi. Acta Botanica Plantae, 22–35.

Olanira n, A. F., Abiose, S. H., and Gbadamosi, S. O. (2019). Nutritional quality and acceptability evaluation of *Ogi* flour bio fortified with garlic and ginger. *Journal of Health Science*, 7, 101-109.

Olaniran, A.F. and Abiose, S.H. (2019). Nutritional evaluation of enhanced unsieved *Ogi* paste with garlic and ginger. *Preventive Nutrition and Food Science*, 24(3), 348-356.

Olaniran, A.F., Abiose, S.H., Adeniran, H.A., Gbadamosi, S.O., and Iranloye, Y.M. (2020). Production of a cereal based product (*Ogi*). Influence of co-fermentation with powdered garlic and ginger on the micro-biome. *Agrosearch*, 20(1), 81-93.

Olayiwola, J.O., Inyang, V., and Bello, M.A. (2017). Bacteriological and proximate evaluation of ginger-fortified fermented maize (Ogi). *American Journal of Food Technology*, 12(6), 374-378.

Oluwajuyitan, T.D., Ijarotimi, O.S. and Fagbemi, T.N. (2022). Plantain-based dough meal. Nutritional property, antioxidant activity and dyslipidemia ameliorating potential in high fat induced rats. *Food Frontiers*, 3(3), 489-504.

Oluwamukomi, M.O., Eleyinmi, A.F., Enujiugha, V.N., and Atofarati, S.O. (2003). Nutritional, physico-chemical and sensory evaluation of sorghum and cowpea–based weaning formulation. *Nigerian Food Journal*, **21**, 11-17.

Oluwamukomi, M.O., Eleyinmi, A.F., and Enujiugha, V.N. (2005). Effect of soy supplementation and its stage of inclusion on the quality of ogi – a fermented maize meal. *Food Chemistry*, **91**, 651-657.

Omowaye-Taiwo, O.A., Fagbemi, T.N., Ogunbusola, E.M., and Badejo, A.A. (2015). Effect of germination and fermentation on the proximate composition and functional properties of full-fat and defatted cucumeropsis mannii seed flours. *Journal of food science and technology*, 52, 5257-5263.

Oppong, D., Arthur, E., Kwadwo, S. O., Badu, E. and Sakyi, P. (2015). Proximate composition and some functional properties of soft wheat flour. *International Journal Innovative Research Science and Engineering Technology*, 4, 753–758.

Osundahunsi, O. and Aworh, O.C. (2002). A preliminary study on the use of tempe-based formula as weaning diets in Nigeria. *Plant Foods for Human Nutrition*, 57(3-4), 365-37.

Ryu, *J.* H. and Kang, D. (2017). Physicochemical properties, biol*ogi*cal activity, health benefits, and general limitations of aged black Garlic, *A Review. Molecules*, 22(6), 919.

Singh, A., Yadav, N., and Sharma, S. (2012). Effect of fermentation on the physicochemical properties and in-vitro starch and protein digestibility of selected cereals. International Journal of Agriculture and Food Science, 2(3), 66–70.

Taiwo-Olabode, F. A., Ukeyima, M. T. and Enujiugha, V. N. (2024). In vitro Protein and Starch Digestibility, Nutritional and Bioactive Properties of Elekute (A Maize-Based Snack) Substituted with Catfish (*Clarias gariepinus*). *IPS Journal of Nutrition and Food Science*, **3**(3), 192–206. https://doi.org/10.54117/ijnfs.v3i3.59

Tamene, A., Baye, K., Kariluoto, S., Edelmann, M., Bationo, F., Leconte, N. and Humblot, C. (2019). *Lactobacillus plantarum* P2R3FA isolated from traditional cereal-based fermented food increase folate status in deficient rats. *Nutrients*, 11, 2819.

Tizazu, S.K., Urga, C., Abuye, P., Retta, N. (2010). Improvement of energy and nutrient density of sorghum based complementary foods using germination. *African Journal of Food Agriculture and Nutrition Development*, 10(8), 1684-5358.

Tulumoğlu, Ş., Kaya, H.İ. and Şimşek, Ö. (2014). Probiotic characteristics of Lactobacillus fermentum strains isolated from Tulum cheese. Anaerobe, 30(6), 120–5.

Vila-Real, C., Pimenta-Martins, A., Maina, N., Gomes, A., and Pinto, E. (2017). Nutritional value of African indigenous whole grain cereals millet and sorghum. *Nutrition of Food Science International Journal.*

Zhang, Y., Wei, C., Yan, B. (2017). Emission characteristics and associated health risk assessment of volatile organic compounds from a typical coking wastewater treatment plant. *Science Total Environmental*, 693, 133-417.

.

•*Thank you for publishing with us.*