Nutritional, Sensory, and Functional Quality of Ogi from Acha and Bambara Groundnut, Spiced with Ginger

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ABSTRACT

Background: *Protein malnutrition remains a major public health challenge in sub-Saharan Africa. To combat this, food-based approaches increasingly promote the development of nutrient-rich cereal foods enriched with affordable legume-based proteins.*

Objective: *This study investigated the sensory, nutrient, and functional quality of a protein-improved Ogi from Acha, and Bambara groundnut, spiced with Ginger.*

Methods: *Five Ogi formulations were developed using fermented acha flour, roasted Bambara groundnut flour, and ginger in specific ratios: FABG1 (100% acha, 0% Bambara, 0% ginger), FABG2 (85% acha, 10% Bambara, 5% ginger), FABG3 (80% acha, 15% Bambara, 5% ginger), FABG4 (75% acha, 20% Bambara, 5% ginger), and FABG5 (70% acha, 25% Bambara, 5% ginger). 30 undergraduate panelists at the University of Ilorin conducted the sensory evaluation. Nutrient and functional properties were determined using standardized methods from the Association of Official Analytical Chemists. One-way ANOVA ($p<0.05$) was used to analyze differences among samples.*

Results: *The findings revealed that sample FABG5 (70:25:5 acha, bambara, ginger) was the most preferred in terms of sensory quality. Similarly, laboratory analysis of nutrient quality showed a significant increase in moisture (5.28% to 8.34%), protein (5.30% to 19.24%), fat (2.01% to 4.62%), crude fiber (2.59% to 3.13%) and ash content (2.05% to 3.15%); while a significant decrease was observed in carbohydrate (82.77% to 61.52%). The functional properties showed significant differences in the swelling index, water absorption capacity, and bulk density.*

Conclusion: *Overall, FABG5 produced the most acceptable blend and is recommended for consumption due to its improved nutritional and sensory qualities.*

Keywords: Ogi, Protein-Energy Malnutrition, Food Insecurity, Nutritional Quality, Functional Analysis

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INTRODUCTION

The constant dependence on cereal-based foods and inadequate intake of protein nutrients in developing countries has led to various forms of malnutrition in both children and adults (1).

Given the need to combat and drastically reduce the observed nutritional problem, food-based interventions are being applied worldwide to reduce nutritional insecurities with major emphasis on the development of adequate cereal foods nutritionally improved with inexpensive protein-rich legumes which would adequately address the nutritional needs of its consumers thus enhancing their health status (2).

Ogi is a fermented cereal gruel typically made from grains such as maize, sorghum, and millet. The cereal gruel is widely consumed as an essential weaning food for infants, a recovery diet for the sick and convalescents as well and a dietary staple for adults in West Africa (3). The indigenous wet-milled gruel has a wide range of acceptability as a result of its good sensory qualities and is either prepared as a thin cereal gruel or thick cereal porridge. Traditionally, developing and underdeveloped countries make use of staple cereals such as sorghum, maize, and millet in producing Ogi and this has led to the vast consumption of Ogi that hardly meets the standard nutritional requirements of its consumers, further corroborating the persistent protein malnutrition problems in developing and undeveloped countries of West Africa since it is consumed as a staple food (4).

Acha (Digitaria exilis) is an annual cereal crop indigenous to Africa where it is cultivated for its straw and edible grains (5). According to the Food and Agriculture Organization (6), it is regarded as the "grain of life" and is considered a rich source of minerals, vitamins, fiber, protein, carbohydrates, and amino acids (7). The amino acids methionine and cysteine present in acha are reportedly lacking in most cereal crops (8). Its health benefits as a dense source of energy, a rich source of iron, and an easily digested meal that improves cardiovascular functions of the body have placed substantive value on acha as a distinct cereal suitable for all individuals including those with poor health status, gluten intolerance and even as baby food (9).

Bambara Groundnut (Vigna subterranea), an indigenous legume crop grown mainly by subsistence farmers in drier parts of sub-Saharan Africa is tagged the third most important grain legume after peanuts (Arachis hypogea) and cowpea (Vigna unguiculata) in semi- arid Africa (10). The nutrient-dense crop plays an important nutritional role in both human and animal diets as a good source of affordable protein, especially in regions where animal protein is comparatively expensive. This has made the pulse a preferred food crop of many local people (11). The crop is richer in essential amino acids than some other legumes and has a higher protein score (80%) than soybean (74%) and cowpea (64%) its protein is more relatively available for human metabolism than other common legumes (12) . Also, comparisons appear favorable with bambara groundnut compositional analysis showing a good

combination of nutrient components and higher sufficiency of limiting amino acids than most legumes (13). It is importantly cultivated for human consumption as it makes a complete food containing sufficient quantities of protein (15%-25%), carbohydrates (49%-63.5%) and fat (4.5%-7.4%), fiber (5.2%-6.4%), ash (3.2%-4.4%), and mineral (2%) (14).

Ginger (Zingiber officinale), one of the oldest spices which grows as an underground rhizome is widely consumed as a delicacy, nutraceutical, and natural spice for functional foods (15,16). The herb plays an important role as a taste enhancer due to the presence of essential oils and bioactive compounds hence possessing health- promoting properties (15). Ginger contains nutrients such as calcium, dietary fiber, iron, magnesium, manganese, potassium, protein, carbohydrate, selenium, sodium, vitamins C, E, and B6 as well as volatile oils- gingerols and shagaols which are beneficial regarding the health of consumers (16).

The world depends on and obtains nutritional sustenance from grain crops including the continent of Africa (17). Cereal gruels are widely utilized in many developing countries as dietary staples for adults and complementary foods for infants. However, this gruel hardly meets or sustains the nutritional requirements of both children and adult consumers due to its low nutritional value. Nutrition-based interventions are applied worldwide to reduce malnutrition and nutrition insecurity with emphasis on enriching, fortifying, and supplementing consumed foods with their inadequate nutrient content. This has encouraged the nutritional improvement of cereal-based gruels with legumes (pulses and oilseeds) to provide a high-protein diet aimed at ensuring the nutritional improvement of consumed foods. Therefore, this study aims at producing a nutritionally improved Ogi from fermented acha, whose crude protein and amino acids content is richer than most cereals (18), and protein-rich bambara groundnut , a plant protein source spiced up with ginger to improve its sensory attributes and product shelf-life stability.

MATERIALS AND METHODS

The study adopted a research and development (R&D) design for the production and evaluation of the formulated Ogi. Hasan (19) defined Research and Development Design as the disciplined investigation conducted in the context of the development of a product for the optimumpurpose of ensuring continuous improvement of the product.

Sources of raw materials

Acha, Bambara Groundnut, and Ginger were purchased from Ipata market in Ilorin West Local Government, Kwara State.

Production process of the products

Production of Acha Flour

Fermented Acha was produced using a local fermentation method. Acha grains were repeatedly washed and de-stoned. The clean grains were steeped in water for 24 hours and then wet-milled using a commercial grinding machine with warm water into a slurry. The slurry was sieved using a muslin cloth, covered, and allowed to ferment for 1 day, resulting in a wet fermented acha starch with a slightly acidic taste. The fermented starch was then decanted, and oven-dried at 60ºC for 6h The dried starch was then milled in a Hammer mill, sieved using 150 µm mesh sieve and packaged in sealed containers (20).

Production of Bambara Groundnut Flour

Bambara groundnut flour was produced following the pre-treatment method recommended by existing literature (21). The combined soaking and roasting method was found suitable for producing gruels. The process began with cleaning the nuts to remove defective seeds and foreign particles. The nuts were soaked in clean water for 48 hours, using three times their weight by volume, to facilitate dehulling. After soaking, the nuts were dehulled using a small iron mortar and pestle and washed to remove the seed coat. The wet nuts were then dried in an oven at 60ºC for 20 minutes and roasted until golden brown. The dried grains were milled into fine flour using a commercial grinding machine and then passed through a sieve of 150 µm mesh screen. The roasted bambara groundnut flour was packaged in a plastic container and stored at room temperature.

Production of Ginger Flour

Ginger flour was produced using an oven-drying method. Fresh gingers were sorted to remove damaged rhizomes, washed to remove dirt, and slightly peeled. The ginger was finely sliced to 3mm thickness to increase surface area for faster drying. The ginger slices were evenly spread on an oven tray and dried at 40°C for 20 minutes. After drying, they were ground into fine flour using a laboratory-grade electric grinder (Hammer Mill, Model ED-5, Thomas Willey, England). The resulting flour was sieved using 150μm mesh size to ensure it was lump-free, packaged in a plastic container, and stored at room temperature (22).

Sample formulation

Five composite flours were formulated to determine acceptable levels of Ogi from fermented acha and roasted bambara nut spiced with ginger. Each formulation was mixed thoroughly in a mixer for 10 minutes to produce the five different formulations and thereafter packaged individually in polyethylene bags until used for analysis. They were formulated as follows FABG1 (100% acha), FABG2 (85% acha, 10% bambara nut flour, 5% ginger), FABG3 (80% acha, 15% bambara nut flour, 5% ginger), FABG4 (75% acha, 20% bambara nut flour, 5% ginger), FABG5 (70% acha, 25% bambara nut flour, 5% ginger). Fermented acha formulation (100% acha) was packaged as the control sample. Each sample weighed 100g.

Proximate analysis

The nutrient composition including protein, fat, crude fibre, moisture, and ash was assessed through the analytical methodology outlined by the Association of Analytical Chemists (AOAC) (23). The determination of each nutrient component involved using the Atomic Absorption Spectrophotometer (AAS). For the specific analysis of carbohydrates, the methodology described by AOAC was utilized, which is based on the principle of calculating difference. Carbohydrate content was estimated by deducting the sum of measured nutrient components (protein, fat, fibre, moisture, and ash) from 100%.

Functional properties of flour blends Water absorption capacity

Water absorption capacity, or water hydration, refers to the moisture retained within a food matrix under specific conditions (24). To determine this, 1g of each sample was weighed into a dry centrifuge tube. Distilled water or oil was added to the starch powder to make a 10 ml dispersion, which was then centrifuged at 3500 rpm for 15 minutes. The supernatant was discarded, and the tube with its contents was reweighed. The gain in mass represents the water or oil absorption capacity of the samples (24).

Bulk density

Bulk density defined as the mass of flour particles divided by the total volume they occupy was determined by weighing 3g of each sample into 10 ml graduated cylinders and tapping ten times against the palm of the hand. The volume of the starch powder after tapping was recorded and bulk density was expressed as g/ml (25).Swelling index The Swelling Index, which evaluates the starch's ability to absorb water and swell, was determined by measuring a 3-gram portion of each sample and placing it into clean, dry, graduated cylinders (24). The powder sample was gently leveled, and the volume was noted before the addition of 30 ml distilled water. The cylinder was swirled and allowed to stand for 60 min while the volume change (swelling) was recorded after 15 min. The swelling index of each sample was calculated as a multiple of the original volume (24).

Dispersibility

To determine dispersibility, 10 grams of each sample was suspended in a 200 ml measuring cylinder and distilled water was added to reach the 100 ml mark. The set- up was stirred vigorously and allowed to settle for 3 hr. The volume of settled particles was recorded and subtracted from 100. The difference was reported as percentage dispersibility (26).

Dispersibility=100−volume of settled particles

Sensory evaluation

The sensory evaluation of Ogi from fermented acha and roasted bambara groundnut spiced with ginger was conducted at the Department of Home Economics and Food Science, University of Ilorin, and evaluated by 30 trained panelists selected from undergraduate students. Panelists were trained for 10 minutes on the rudiments of testing the products. The evaluation of samples was carried out regarding the colour, taste, aroma, mouthfeel, and overall acceptability. The panelists evaluated the samples using a 9-point hedonic scale (27). The order of presented samples was randomized, each panelist rinsed their mouth with water to get rid of residues in between evaluations. The scores for all attributes were recorded on the score sheets earlier given to the panelists.

The formulated Ogi was prepared with a similar method as in oat preparation. Water was brought to a boil on a gas cooker, and whilst boiling, Ogi was made into a slurry by adding water till a paste was formed. The paste was then stirred into boiled water vigorously and consistently till it became viscous and formed porridge.

Data analysis

All analyses were conducted in duplicate determinations. Data were analyzed using descriptive statistics such as percentages, frequencies, mean and standard deviation, and inferential statistics. A one-way analysis of variance (ANOVA) was conducted to evaluate signi·cant differences in the acceptability of the formulated Ogi at varying proportions, with the signi·cance level set at $P < 0.05$.

RESULTS

Nutritional Composition of Acha-Bambara Groundnut Ogi

Table 1 presents the nutritive composition of acha porridge enriched with bambara groundnut and ginger, showing percentages of moisture, ash, protein, fat, ·ber, and carbohydrate contents. The moisture content ranged from 5.28±0.01% to 8.34±0.00%, with sample FABG5 having the highest and FABG1 the lowest. Moisture content

Table 1: Proximate analysis of Ogi from Acha and Bambara Groundnut spiced with Ginger

Sample	Moisture (%)	Crude fat (%)	Crude fibre (%)	Crude protein (%)	Ash (%)	Carbohydrate (%)
FABG1	5.28^{e} ±0.01	2.01^{e} ±0.01	2.59^{e} ±0.00	5.30^{d} ±0.02	2.05^{c} ±0.03	82.77^{a} ±0.01
FABG2	7.23^{d} ±0.00	3.47^{d} ±0.00	2.68^{d} ±0.01	9.88^{c} ±0.00	2.08^{c} ±0.02	74.65^{b} ±0.03
FABG3	7.36^{c} ±0.01	4.34^{c} ±0.02	2.89^{c} ±0.01	10.49^{b} ±0.06	3.02^{b} ±0.01	71.90^{c} ±0.05
FABG4	8.26^{b} ±0.01	4.48^{b} ±0.00	3.02^{b} ±0.01	16.09^{a} ±0.16	3.04^{b} ±0.01	65.12^{d} ±0.18
FABG5	8.34^{a} ±0.00	4.62^{a} ±0.01	3.13^{a} ±0.01	19.24^{a} ±0.03	3.15^{a} ±0.04	61.52^{e} ±0.04

Mean ± Standard deviation. Means with the same superscript along the same column are not signi·cantly different (p< 0.05).

Keys: FABG 1 =100% fermented acha flour+ 0% roasted bambara groundnut flour + 0% ginger, FABG2 = 85% fermented acha flour + 10% roasted bambara groundnut flour + 5% ginger, FABG3 = 80% fermented acha flour + 15% roasted bambara groundnut flour + 5% ginger, FABG4 = 75% fermented acha flour + 20% roasted bambara groundnut flour + 5% ginger, FABG 5 = 70% fermented acha flour + 25% roasted bambara groundnut flour + 5% ginger, FABG: Fermented acha bambara groundnut Ogi.

increased signi·cantly with more roasted bambara groundnut flour. Ash content ranged from 2.05±0.03% to 3.15±0.04%, with FABG5 having the highest and FABG1 the lowest. Ash content also increased signi·cantly with higher Bambara groundnut flour concentration, except in samples FABG3 and FABG4, which were not statistically different. Crude fat content varied from 2.01±0.01% to 4.62±0.01%, with FABG5 having the highest and FABG1 the lowest, showing a signi·cant increase with more Bambara nut flour and constant 5% ginger. Crude ·ber content ranged from 2.59±0.00% to 3.13±0.01%, with FABG5 the highest and FABG1 the lowest, also increasing signi·cantly with more Bambara groundnut flour and 5% ginger. Crude protein content ranged from 5.30±0.02% to 19.24±0.03%, with FABG5 having the highest and FABG1 the lowest. Protein content increased signi·cantly with more bambara groundnut flour and 5% ginger, except in samples FABG4 and FABG5, which were not signi·cantly different. Carbohydrate content ranged from 61.52±0.04% to 82.77±0.01%, with FABG1 having the highest and FABG5 the lowest, showing a signi·cant decrease with more Bambara groundnut flour and 5% ginger.

Sensory Evaluation of Acha-Bambara Groundnut Ogi

Table 2 presents the mean and standard deviation of sensory evaluation for the acceptability of Acha gruel enriched with Bambara groundnut and ginger. For color, sample FABG5 (70% Acha, 25% Bambara groundnut, 5% ginger) was the most preferred $\bar{x}$ = 7.63±0.72), while FABG1 (100% Acha) was the least preferred ($\bar{x}$= 6.20±1.24). For flavor, FABG5 was the most preferred $\bar{x}$ = 7.8±1.0), and FABG1 the least preferred ($\bar{x}$= 5.60±1.19). For texture, FABG5 was the most preferred ($\bar{x}$= 7.80±1.09), and FABG1 the least preferred $\bar{x}$ = 6.37±1.54). For taste, FABG5 was the most preferred ($\bar{x}$ = 8.00±1.39), and FABG1 the least preferred ($\bar{x}$ = 5.83±0.91). For overall acceptability, FABG5 was the most preferred ($\bar{x}$= 8.20±1.06), and FABG1 the least preferred ($\bar{x}$ = 6.00±1.44).

Consumer Acceptability of Acha - Bambara Groundnut Ogi

Figure 1 shows that for overall acceptability, sample FABG5 was the most preferred with a mean score x = 8.20(±1.06), for samples FABG2 and FABG3, there was no signi·cant difference in acceptability of samples, while the least preferred sample FABG1 with mean score x = 6.00(±1.44).

Functional Quality of Acha - Bambara Groundnut Ogi

Table 3 showed the values of bulk density, swelling index, water absorption capacity (WAC), and dispersibility. The Bulk density ranged from (0.53a±0.00) to (0.60b±0.01). Sample FABG 5 had the highest bulk density (0.60g/cm3) while the control sample FABG5 had the least bulk density (0.50g/cm3). The bulk densities of samples FABG1, FABG2, FABG3, FABG4 were not signi·cantly ($p<0.05$) different ranging from values (0.53 g/cm3 to 0.55 g/cm3) with increasing addition of roasted bambara nut flour, and the constant addition of ginger. The bulk density of FABG5 was signi·cantly different from other samples (0.60g/cm3). The swelling index ranged from

Table 2: Mean ($\bar{x}$) and Standard Deviation of Sensory evaluation of Ogi from Acha and Bambara groundnut spiced with Ginger

Sample	Colour	Aroma	Texture	Taste	Overall Acceptability
FABG1	$6.20^{c}\pm1.24$	$5.60^{c}\pm1.19$	$6.37^{c}\pm1.54$	$5.83^{c}\pm0.91$	$6.00^{d}\pm1.44$
FABG2	$6.63^{bc}\pm0.99$	$6.33^{b}\pm1.21$	$6.40^{c}\pm1.16$	$6.30^{bc}\pm1.24$	$6.57^{c}\pm0.97$
FABG3	$6.77^{b}\pm0.77$	$6.50^{b}\pm0.78$	$6.93^{bc}\pm1.08$	$6.63^{b}\pm1.25$	$6.77^{c}\pm0.86$
FABG4	$7.37^{a}\pm0.61$	$7.27^{a}\pm1.01$	$7.40^{ab}\pm0.89$	$7.63^{a}\pm1.04$	$7.60^{b}\pm1.00$
FABG5	$7.63^{a}\pm0.72$	$7.80^{a}\pm1.00$	$7.80^{a}\pm1.09$	$8.00^{a}\pm1.39$	$8.20^{a}\pm1.06$

Mean ± SD. Means with the same superscript within the same column are not signi·cantly different ($p< 0.05$)

(1.34a±0.01) to (0.86e±0.00). Sample FABG1 had the highest swelling index (1.34 g/ml) while sample FABG 5 had the least swelling index (0.86 g/ml). Sample FABG 2 had the highest water absorption capacity (1.38 mg/g) while sample FABG1 had the least water absorption capacity (1.25 mg/g). Dispersibility ranged from (33.34a ±0.01) to (21.66e ±0.01). Sample FABG1 had the highest dispersibility (33.34%) while FABG5 had the lowest dispersibility (21.66%).

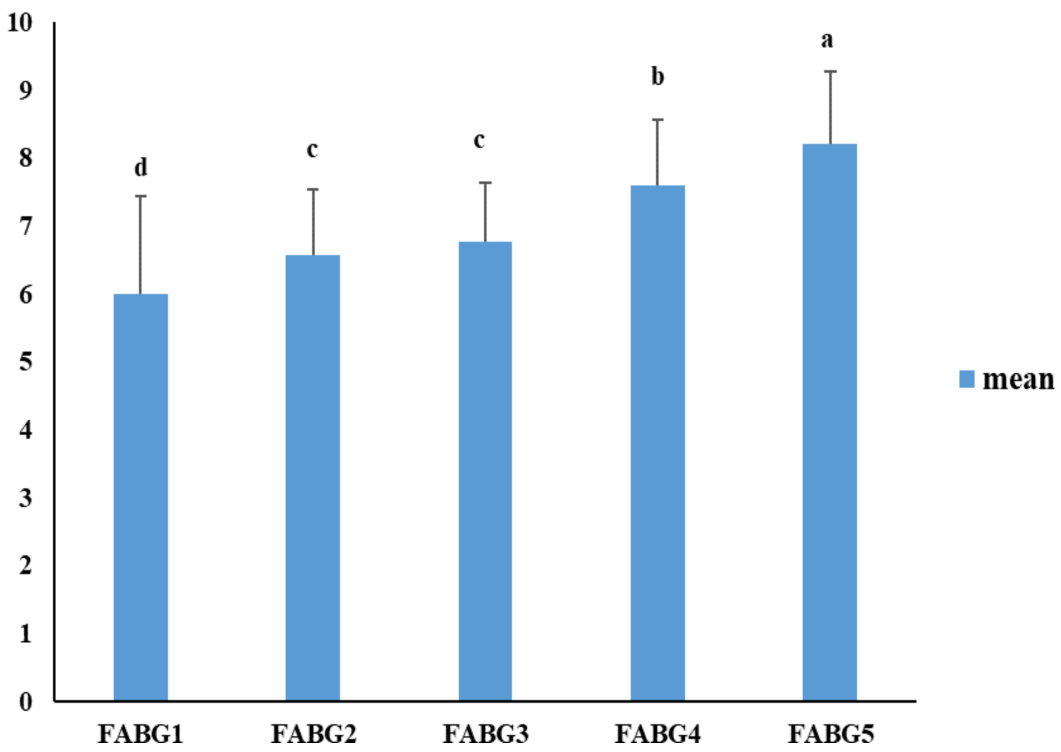


Figure 1: Mean ($\bar{x}$) Sensory acceptability level of FABG *Ogi*

Table 3: Mean ($\bar{x}$) and Standard Deviation of Ogi from Acha and Bambara groundnut spiced with Ginger

Sample	Bulk Density (g/cm^3)	Swelling Index (g/ml)	Water absorption capacity (mg/g)	Dispersibility (%)
FABG1	0.53^{a}±0.00	1.34^{a}±0.01	1.25^{c} ±0.01	33.34^{a} ±0.01
FABG2	0.53^{a}±0.01	1.01^{b} ±0.01	1.38^{a} ±0.01	26.68^{b} ±0.01
FABG3	0.54^{a}±0.01	0.93^{c} ±0.00	1.30^{b} ±0.00	25.34^{c} ±0.01
FABG4	0.55^{a}±0.01	0.91^{d} ±0.01	1.26^{c} ±0.01	25.02^{d} ±0.03
FABG5	0.60^{b}±0.01	0.86^{e}±0.00	1.26^{c} ±0.00	21.66^{e} ±0.01

Values are means ±SD of duplicate determinations. Values in the same column with different superscript are signi·cantly different (P<0.05)

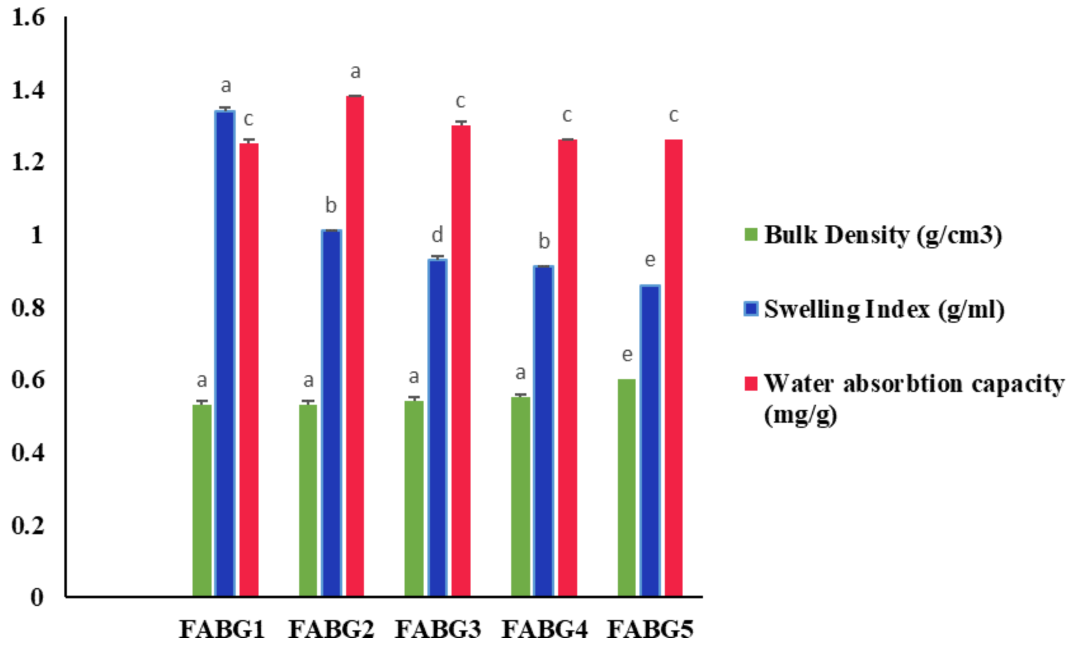
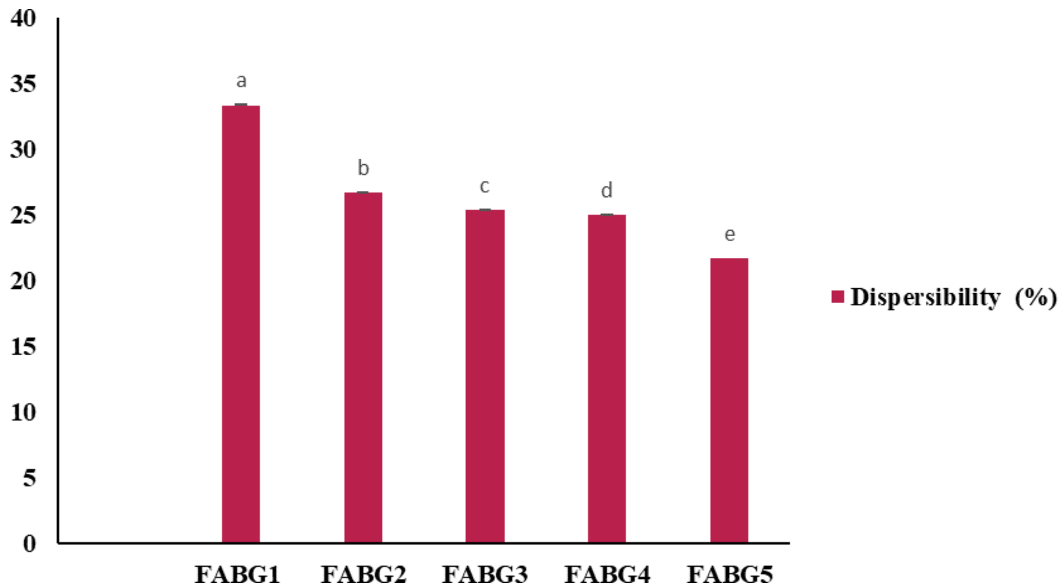


Figure 2: Bulk density, Swelling index, and water absorption capacity of FABG *Ogi*



DISCUSSION

The nutritional composition of the Ogi samples demonstrates the impact of varying levels of roasted bambara groundnut flour on key nutritional parameters. Moisture content, critical for food quality, increased with higher levels of roasted bambara groundnut flour but remained within the recommended range of 5–10% by Achidi et al., (28) and below the critical threshold of 13% for preventing deterioration (29). Ash content, indicative of mineral availability, was higher in samples with increased legume content, consistent with Achidi et al., (28), who reported similar improvements in legume-enriched composite flours. Crude fat content increased due to the oil-rich nature of bambara groundnut. This aligns with FAO/WHO (30) recommendations advocating for the inclusion of vegetable oils in complementary foods to enhance energy density and support the absorption of fat-soluble vitamins. Similarly, crude fiber levels improved across samples, supporting findings by Ukeyima et al., (20), who noted similar enhancements in fiber when legumes were incorporated into composite flours. The dietary fiber levels in all samples met the recommended dietary range of not more than 5g per 100g dry matter (31). Protein content showed significant improvement with the inclusion of bambara groundnut, suggesting its potential ability to enhance protein quality in cereal-based foods. This observation is supported by Temple and Bassa (32), who emphasized the protein- boosting effect of legumes in composite flours. These findings position the enriched Ogi as a viable intervention for addressing protein-energy malnutrition, particularly in regions with limited access to animal protein. Conversely, carbohydrate content decreased in tandem with the higher inclusion of bambara groundnut, consistent with Ayo et al., (33), who observed similar reductions in legume - supplemented blends. This characteristic makes the formulations suitable for nutrient-dense diets tailored to specific dietary needs.

Sensory evaluation revealed that the formulation with the highest bambara groundnut and ginger levels (FABG5) was the most preferred, excelling in flavor, aroma, texture, and overall acceptability. These findings align with Okafor et al., (34), who reported improved sensory attributes in legume-enriched products, and Ukeyima et al., (20), who observed enhanced flavor and texture in similar composite blends.

The functional properties of the Ogi samples further demonstrated the influence of fortification with bambara groundnut. Bulk density increased, consistent with Ayo et al., (33), who noted similar trends in fortified acha products. Increased bulk density supports efficient packaging and storage, while lower bulk densities, as noted in WHO (35), are preferable for infant gruels due to easier consumption and digestion. Swelling index decreased with higher protein levels, likely due to reduced granule expansion, consistent with Ukeyima et al., (20). Water absorption capacity improved due to the hydrophilic properties of legume proteins, as noted by Arise et al., (36), enhancing moisture retention and texture in the blends.

This study highlights the significant benefits of enriching Ogi with roasted bambara groundnut and ginger. These ingredients improved sensory appeal, protein content, and functional properties while ensuring the formulations remained within recommended ranges for moisture, fat, and fiber.

The nutrient density, sensory appeal, affordability and availability of bambara groundnut in regions prone to malnutrition further enhance its value as a nutrition-based intervention for malnutrition and improving diet quality.

CONCLUSION

This study concludes that Ogi from acha and Bambara nut flour spiced with ginger is acceptable and suitable for consumption based on the sensory and nutritive qualities observed. The nutritional value of acha Ogi improved with increasing incorporation of Bambara groundnut, enhancing its protein content and sensory qualities. Fortifying Ogi with Bambara groundnut and ginger provides a promising solution to protein-energy malnutrition, particularly in sub-Saharan Africa, where such deficiencies are prevalent. Future research should focus on amino acid profiling to identify limiting amino acids and optimize the formulation for improved nutritional balance, as well as conducting shelf-life studies to evaluate product stability and support its role in enhancing food and nutrition security.

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