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ORIGINAL RESEARCH PAPER

IMPACT OF EDIBLE GRASSHOPPER FLOUR ON THE CHEMICAL AND PHYTOCHEMICAL COMPOSITION OF OGI POWDER AND THE SENSORY ACCEPTABILITY OF GRUEL

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Abstract

Ogi is a traditional staple that is low in protein and high in carbs. It is often produced from cereal grains, including maize, millet, and sorghum. The incorporation of edible grasshopper flour may not only improve the protein quality of Ogi powder but also affect the chemical and phytochemical composition; hence, this research is necessary. The chemical and phytochemical compositions of Ogi powder samples produced from blends of sorghum Ogi powder (SOP) (50–100 g) and grasshopper flour (GF) (10–50 g) generated through Design Expert Software were analyzed via standard methods, with 100 g of SOP used as a control sample. Fifteen untrained panelists performed the sensory evaluation of the gruel. The results revealed that the mean chemical composition of the supplemented sorghum Ogi powder was moisture, 4.62%; fat, 2.16%; ash, 2.43%; protein, 20.56%; crude fibre, 0.92%; total carbohydrates, 69.32%; and energy value, 381.96 kcal/100 g. The mean mineral composition was iron, 2.96 mg/100 g; and zinc, 1.85 mg/100 g. The mean phytochemical composition was oxalate, 0.36 mg/100 g; phytate, 0.94 mg/100 g; and tannin, 0.36 mg/100 g. GF inclusion in the SOP reduced the carbohydrate content and increased the protein, ash, fat, crude fibre, zinc, iron, phytate, and tannin contents. All of the supplemented Ogi gruel samples had statistically identical tastes (except for 75 g SOP:30 g GF and 100 g SOP:10 g GF), appearances (apart from 50 g SOP:10 g GF and 50 g SOP:50 g GF), and overall acceptance (apart from 75 g SOP:30 g GF). Consequently, the risk of macro- and micronutrient deficits linked to the intake of cereal-based foods in developing nations may be reduced by adding GF to SOP.

Keywords: Sorghum Ogi powder, edible grasshopper, supplementation, nutritional composition, phytochemicals, developing countries

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Introduction

In sub-Saharan Africa, weaning foods are often produced from traditional fermented starch staples such as maize, millet, and sorghum. These staples are frequently low in protein and high in carbohydrates, leading to a diet that is not balanced, resulting in an elevated likelihood of protein–energy malnutrition, a major cause of infant morbidity and mortality (Adewale *et al.*, 2013). Many children under the age of five are underweight, thin, and malnourished because of poor nutritional requirements resulting from the consumption of weaning foods such as Ogi.

Ogi is a commonly consumed gruel made from the fermentation of staples such as maize, millet, and sorghum, among others. Its color, taste, and nutritional value are based on the cereal used for its preparation, such as yellow and white maize and red and white sorghum (Adelekan *et al.*, 2021; Akinsola *et al.*, 2021). Ogi is consumed by millions of people in West Africa as a traditional breakfast, complementary, and weaning food (Bolaji *et al.*, 2015). The processing of cereal grain into Ogi not only extends its shelf-life but also leads to a considerable reduction in essential nutrients such as amino acids and minerals, thereby reducing the nutritional value of the food (Ajanaku *et al.*, 2013; Ajala, 2018). Several studies have been conducted to increase the nutritional quality of Ogi (Okafor *et al.*, 2018; Adeyemo and Abimbola, 2019; Ezeocha *et al.*, 2020; Awoyale *et al.*, 2024), but no studies have reported the incorporation of edible insects into sorghum Ogi powder.

Incorporating edible insects into diets has the potential to improve global food security when compared to other protein sources, because they contain high levels of unsaturated fatty acids, proteins with good amino acid quality, and micronutrients like vitamins, minerals, and significant bioactive components (Eggleton, 2000). In general, edible insects are plentiful, rich in nutrients, and profitable. Whether as meals or snacks, they play a significant role in the daily diets of a sizable portion of the global population. Winged adult termites (Macrotermes bellicosus), adult crickets (Brachytrypes spp.), larvae of scarab beetles (Oryctes boas), and larvae of butterflies, moths, and grasshoppers (Zonocerus variegatus) are among the insects that are frequently eaten (Eggleton, 2000; Awoyale and Fadeni, 2023; Awoyale *et al.,* 2024). The grasshopper, scientifically known as Zonocerus variegatus, is a commonly consumed edible insect that constitutes 13% of the total edible insects (Suleiman *et al.*, 2023). In Nigeria, the grasshopper is called 'Fara' in Hausa, 'Tata' in Yoruba, 'Ukpana' in Igbo, and 'Goro' in Nupe (Ademolu *et al.*, 2010). Grasshopper is among over 30 species of edible insects commonly marketed and consumed as food in Western and the Delta region of Nigeria (Ibitoye *et al.,* 2021). It is consumed primarily in the northern part of Nigeria and is seen as a delicacy, usually sold in marketplaces, such as meat (Solomon *et al.*, 2008). It is a source of digestible and highly nutritive proteins, highly essential minerals, and vitamins, and contains relatively low concentrations of antinutrients (Ajai *et al.*, 2013; Sani *et al.*, 2014). According to Haber et al. (2019), the sensory panel rated the 100 g/kg enhanced grasshopper bread and the 100% wheat bread similarly. Haber et al. (2019) added 200 g/kg grasshopper to the bread recipe to enhance the protein level by up to 60%. The inclusion of the Longhorn grasshopper (*Ruspolia differens*) powder into biscuits was also reported by Ronoh *et al.* (2024) to be able to alleviate protein energy malnutrition in developing countries because of its high protein digestibility corrected amino acid score. Similarly, Dewi *et al.* (2020) reported a 14.3% increase in lysine content of wheat biscuits fortified with wood grasshopper powder. However, there is presently no published report on the inclusion of grasshopper flour into sorghum Ogi powder. It is envisaged that incorporating grasshopper flour into Ogi powder from sorghum may influence not only the protein content but also other macro- and micronutrients, as well as the phytochemical composition. This study aims to evaluate the impact of including edible grasshoppers on the chemical and phytochemical composition of sorghum Ogi powder.

Materials and methods

Materials

We bought white sorghum grains from the Oja-Oba market in Ilorin, the capital of Kwara State, Nigeria. The Kurmi market in the Kano municipal local government region of Kano State is where the dried full adult short-horned grasshoppers were bought. Additionally, plastic containers, zip-lock bags, muslin fabric, a sieve, a cabinet dryer, and a locally manufactured milling machine were utilized. These items came from the Food Processing Laboratory at Kwara State University in Malete, Kwara State, which is part of the Department of Food Science and Technology.

Preparation of Ogi powder

The wet-milling method outlined by Awoyale and Fadeni (2023) was used to produce Ogi. The white sorghum grains were cleaned, sorted, and soaked for 48 h in clean water at room temperature (30±2ºC) at a ratio of 1:3 (w/v) sorghum grains to water. The water was decanted, the fermented grains were rinsed in fresh water, and an attrition mill was used for wet milling. The filtrate was left to settle for 24 h to allow sediment. The bran was then removed using a muslin cloth, and the resulting sediment formed a slurry. Using a hydraulic jack, the sediment was dewatered and placed in a jute bag. The dewatered mash was pulverized in a granulating machine, dried in a cabinet dryer (55 ± 5°C), dry milled to pass through a 0.5 mm mesh sieve, cooled, and packed in an airtight Ziplock package before use.

Production of grasshopper flour

Grasshopper flour was prepared using a slightly modified version of the method by Atowa *et al.* (2021). Before being used, the dried adult short-horned grasshoppers were ground in an electric blender, cooled, sieved through a 0.5 mm sieve, and sealed in an airtight plastic container.

Inclusion of grasshopper flour in Ogi powder

Utilizing the ratios obtained from the Response Surface Central Composite Rotatable Design of the Design Expert Software (Version 6.0), sorghum Ogi powder (100 g and 50 g) was supplemented with grasshopper flour (50 g and 10 g). This process produced 13 runs with 5 central points, as shown in Table 1. The mixtures were properly mixed with a laboratory blender, packaged, and sealed in an airtight plastic container before laboratory analysis.

Table 1. Supplementation of sorghum Ogi powder with grasshopper flour

Runs	Sorghum Ogi powder (g)	Grasshopper flour (g)
1	75.0	30.0
2	75.0	1.7
3	75.0	58.3
4	75.0	30.0
5	75.0	30.0
6	110.0	30.0
7	75.0	30.0
8	100.0	50.0
9	50.0	10.0
10	75.0	30.0
11	100.0	10.0
12	39.6	30.0
13	50.0	50.0

Moisture content analysis

The moisture content was assessed using the official standard AOAC (2019) method. A hot air oven (Memmert GmbH+Co. kg, Oven model D-91126 Schwabach FRG, Germany) was used to dry about 1 g (W_1) of the sample at 105±1°C until a constant weight (W_2) was reached. Following the removal from the oven, the samples were weighed after cooling in a desiccator. Equation (1) expresses the moisture content.

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{\text{Weight of sample}} \times 100 \quad (1)$$

Ash content analysis

The ash content was determined using a muffle furnace (Ney Vulvan TM furnace type 3-1750, USA) in accordance with the recognized AOAC (2019) method. After weighing 2 g (W_3) of the sample into an ashing crucible that had previously been weighed (W_2), the sample was placed in the muffle furnace and heated to 700°C for 3 hours, reducing it to ash. The crucible was removed, allowed to cool in a desiccator, and then weighed (W_1). Equation 2 illustrates how the ash content was determined as a percentage of the initial sample's weight.

$$\text{Ash content (\%)} = \frac{W_1 - W_2}{W_3} \times 100 \quad (2)$$

Fat content analysis

The amount of crude fat was calculated using the AOAC (2019) technique and Soxhlet apparatus. To extract the oil from the sample, a round-bottom flask (W_2) that had been preweighed was filled with n-hexane after a thimble containing around 5 g of the ground sample was placed into the Soxhlet extractor. It took about six hours to finish the extraction procedure. The solvent was removed from the oil via distillation. The oil in the flask underwent a second drying phase in a hot-air oven at 90°C for 30 minutes to remove any last traces of organic solvent or moisture. After cooling in a desiccator, this mixture was weighed (W_1). The fat content was expressed as a proportion of the initial sample using Equation 3.

$$\text{Fat content (\%)} = \frac{W_1 - W_2}{\text{Weight of sample}} \times 100 \qquad (3)$$

Protein content analysis

The protein content was ascertained using the Kjeldahl method (AOAC, 2019). A Kjeldahl flask was filled with ground material (0.20 g). Ten milliliters of pure sulphuric acid were added to the flask, followed by the addition of one Kjeldahl tablet. The mixture was broken down on a heating rack to create a transparent solution. After cooling and adding distilled water to bring the digestate to 75 mL, it was moved to a Kjeldahl distillation setup and 50 mL of a 40% sodium hydroxide solution was added. After that, the mixture's ammonia was distilled into 25 mL of a 2% boric acid solution, which contained 0.5 mL of a mixture of 100 mL of bromocresol green solution (made by dissolving 100 mg of bromocresol green in 100 mL of methanol) and 70 mL of methyl red solution (made by dissolving 100 mg of methyl red in 100 mL of methanol). The recovered distillate was then titrated with 0.05 M HCl. A blank determination was carried out following the removal of the samples. The protein content was determined using equation (4).

$$\text{Protein content (\%)} = \frac{1.401 \text{ x M x F x (ml titrant} - \text{ml blank)}}{\text{Weight of sample}} \times 100 \qquad (4)$$

M = Molarity of acid used (mol/dm)

F = Kjeldahl factor = 6.25

Crude fibre content analysis

The crude fibre content was calculated using 2 g (W3) of the sample in accordance with AOAC (2019) guidance. The flask was put on a hot plate, filled with around 200 mL of 1.25% (v/v) sulphuric acid, and brought to a boil for 30 minutes. The content was filtered using filter paper, and any leftover residue was eliminated using 50 to 70 millilitres of distilled water. After removing the washed residue, 200 mL of 1.25% (w/v) NaOH was added, and the mixture was heated for 30 minutes. After filtering the content as previously mentioned, the residue was washed with distilled water and then filtered again using filter paper. The residue was transferred to an ashing dish, dried for two hours at 130°C, cooled in a desiccator, and then weighed (W1). The mixture was cooled and weighed once more (W2) after 30 minutes of ashing at 550°C in a muffle furnace (VULCANTM furnace type 3-1750). The crude fibre content was determined using equation (5).

$$\text{Crude fiber content (\%)} = \frac{W_1 - W_2}{W_3} \times 100 \qquad (5)$$

W_1 = mass of crucible with dried residue (g)

W_2 = Mass of crucible with the ash (g)

W_3 =Weight of sample

Total carbohydrate content determination

The carbohydrate (CH) content was determined as a percentage of the difference between 100% and the inclusion of other proximate compositions, as shown by equation (6).

CH=100 - (protein + fat + ash + crude fibre + moisture) (6)

Energy value determination

Equation (7), a mathematical equation provided by Ijarotimi et al. (2022), was used to compute the energy value.

Energy value=[(%Fat×9) +(%Protein× 4) + (%Carbohydrate ×4)] (7)

Mineral determination

The samples' iron and zinc concentrations were measured using an atomic absorption spectrophotometer (Buck Scientific model 210 VGP) in compliance with AOAC (2019). Two grammes of material were burned for three hours at 600°C in a carbonite muffle furnace. The ash sample was heated for 10 minutes in a water bath after precisely 10 mL of 6 N HCl was applied. After being taken out, the samples were placed in a 100 mL volumetric flask. The filter paper was diluted with deionized water to a volume of 100 mL. The amount of iron and zinc in parts per million (ppm) was measured after the digested sample was split into 10 mL portions, put in a sample container, and aspirated into an atomic absorption spectrophotometer.

Phytochemical composition

Phytate content

The Harland and Oberleas (1986) method was used to test phytate. The phytate was extracted from 5 g of the material using around 2.4% HCl. The extract was mixed with an EDTA/NaOH solution and then placed on an ion exchange column. The phytate was eluted with a 0.7 M HCl solution and wet digested with a solution of concentrated H_2SO_4 (0.5 mL) and HNO_3 (3 mL) to release the phosphate, which was then measured colourimetrically. Hexaphosphate equivalent was used to determine the original sample's phytate concentration.

Tannin content

The amount of tannins was calculated using the AOAC (2019) technique. The sample (5 g) was added to 50 mL of distilled water and agitated. Whatman filter paper No. 3 was used to filter the mixture after it had stood at 28°C for 30 minutes. The extract (2 mL) was put into a 50 mL volumetric flask. Two milliliters of distilled water and two millilitres of standard tannic acid solution (0.1 mg/mL tannic acid) were added to a different volumetric flask. After adding 2.5 mL of saturated sodium carbonate (Na_2CO_3) solution and 1 mL of Folin-C reagent to each flask, the volume was increased to 50 mL and carefully mixed. After 1.5 hours of standing, the sample was filtered through filter paper, and its absorbance at 760 nm was measured in relation to a reagent blank. The tannin content was computed using Equation 8.

$$\text{Tannin content} = \frac{\text{Standard concentration} \times \text{Sample absorbance}}{\text{Standard absorbance} \times \text{Weight ofsample}} \quad (8)$$

Oxalate content

The permanganate titration method outlined by Onwuka (2005) was used to measure the amount of oxalate. After suspending the sample (5 g) in 100 mL of distilled water, 5 mL of 6 M HCl was added. After one hour of digestion at 100°C, the mixture was cooled and filtered. After adding two drops of methyl red indicator, concentrated aqueous ammonia solution (NH_4OH) was added dropwise to adjust the pH until it was between 4 and 4.5, at which point a bright yellow color appeared. The mixture was heated to 90°C, cooled, and filtered (to remove ferrous ion precipitates) in a water bath. After heating the mixture to 90°C once more, the filtrate was added to 10 mL of 5% $CaCl_2$ solution while being constantly stirred. The mixture was centrifuged at 3000 × g for 6 minutes after cooling and being refrigerated for an entire night at 5°C. The supernatant was decanted, and the residue was dissolved in 10 mL of 20% H_2S0_4. The solution was prepared to 100 mL using distilled water, and it was titrated against 0.05 $KMnO_4$ solutions to get a faint pink color that persisted for 30 seconds. The oxalate content was calculated using the formula: 1 mL of 0.05 M $KMnO_4$ solution = 0.00225 g oxalate. Equation 9 was then used to determine the oxalate content.

$$\%\text{Oxalate} = \left(\frac{100 \times \text{titre} \times 0.0025}{W}\right) \times 100 \quad (9)$$

where W = weight of the sample used

Sensory evaluation

A mixture of 70 g of Ogi powder and 125 mL of water was cooked on a heating mantle for 7 minutes in order to turn the Ogi samples into gruel. Following appropriate coding, the samples were assessed for flavor, mouthfeel, aroma, color, appearance, and general acceptability. On a 9-point hedonic scale anchored as follows, fifteen (15) untrained panelists who frequently consume Ogi were asked to score the samples. 1 is "extremely disliked," 2 is "very much disliked," 3 is "moderately disliked," 4 is "slightly disliked," 5 is "neither like nor dislike," 6 is "like slightly," 7 is "like moderately," and 8 is "like very much." 9 stands for "like extremely" (Granato *et al.*, 2010). The sensory analysis of the sorghum Ogi gruel was conducted in accordance with the principles of the 1964 Helsinki Declaration, which was authorized by the ethical review committee at Kwara State University.

Statistical analysis

Except for the sensory evaluation, which involved 15 panellists, all the data were duplicated. Analysis of variance (ANOVA), post-hoc tests, and Pearson correlation were performed on the collected data using the Statistical Package for Social Sciences (SPSS version 21) software. Duncan's multiple range test was used to separate the means at a probability level of $p<0.05$. The free version of XLSTAT software, 2023, was used to do Principal Component Analysis.

Results and discussion

Sorghum Ogi powder's chemical composition with grasshopper flour added

The chemical composition of sorghum Ogi enhanced with grasshopper flour appears in Table 2. The mean values are as follows: moisture content, 4.62%; fat content, 2.16%; ash content, 2.43%; protein content, 20.56%; crude fibre content, 0.92%; total carbohydrate content, 69.32%; and energy value, 381.96 kcal/100 g. The chemical composition of the Ogi blends increased significantly ($p<0.05$) with increasing supplementation level, except for carbohydrates, which showed a significant downward trend. This is expected because the grasshopper flour is low in carbohydrates. Additionally, the protein, crude fibre, and total carbohydrate contents of the 100% sorghum Ogi powder were significantly different from those of the grasshopper flour supplemented with Ogi powder.

Ogi's moisture content varied from 3.30% to 6.33%, with sample 75.0 g SOP: 58.3 g GF having the highest value and sample 100.0 g SOP: 50.0 g GF having the lowest. The moisture content found in this study is less than the 10% mandated by the Codex Alimentarius Commission, indicating the Ogi blends' microbiological resistance and shelf stability (FAO/WHO, 2019). To avoid moisture absorption during the marketing and distribution phases, Ogi blends must be adequately packaged and preserved (Awoyale *et al.,* 2024). The moisture content in this study was lower than the moisture content reported by Adeyemo and Abimbola (2019) for sorghum Ogi fortified with Bambara groundnut flour (8.26–9.13) and Ajala (2018) for Ogi supplemented with oyster mushroom flour. In addition, the moisture content of termite-supplemented Ogi powder (8.62 and 12.05%) reported by Awoyale *et al.* (2024) was higher than that of the present study. The differences in moisture content of the present study compared to other studies may be attributed to variations in raw materials, processing methods, and food formulation (Owheruo *et al.,* 2021).

Fat acts as an energy store in the body and is essential for brain development in children under the age of 2 (Ajanaku *et al.,* 2013). The fat content of the supplemented Ogi ranged between 0.13% and 4.67%, with 50.0 g SOP: 50.0 g GF appearing higher and 75.0 g SOP: 1.7 g GF lower. The range of values reported in this study was within the recommended dietary allowance for fats in food (2 mg/100 g) by the FAO/WHO (2019). Because grasshopper flour has a high fat content, the fat content of the supplemented Ogi powder rose as the amount of grasshopper flour added increased (Siddiqui *et al.,* 2023). Furthermore, the fat content of this study is within the range of values (2.66-5.28%) reported in termite-enriched supplemental food by Adepoju and Ajayi (2016). On the other hand, the fat content values (5.66–12.91%) in termite-supplemented malted maize flour reported by Ezeocha *et al.* (2020) were greater than those obtained in this investigation. Awoyale *et al.* (2024) also reported a higher fat content for termite-supplemented Ogi powder (2.12 and 9.64%). The differences in the raw materials and processing techniques used might have caused the variation in fat content of the samples.

Ash indicates the mineral content of foods and plays a crucial role in contributing to the nutritional value of food, as it helps with the metabolism of organic compounds such as fat and carbohydrates (Awoyale *et al.,* 2024). The ash content of the supplemented Ogi powder ranged between 0.93% and 4.33%, with 50.0 g of SOP:50.0 g of GF and 100.0 g of SOP:10.0 g of GF. The ash content steadily increased as the level of grasshopper flour included increased, which indicates that the supplemented sorghum Ogi powder is high in ash, as it meets the Codex Alimentarius guidelines of having an ash content greater than 1% (FAO/WHO, 2019). The study's findings were in accordance with the ash content values (1.53–2.53%) found in termite-supplemented plantain and breadfruit biscuits (Ani *et al.,* 2021). Awoyale *et al.* (2024) also reported a similar ash content (0.83 and 3.67%)

for the Ogi powder supplemented with termite flour. The ash content in this study, however, was more than the values (0.26–0.91%) in Ogi supplemented with oyster mushroom flour reported by Ajala (2018). The variation in ash content of this study compared to other studies may be attributed to differences in raw materials, processing methods, and food formulation (Owheruo *et al.*, 2021).

The supplemented Ogi powder's protein concentration varied from 9.50 to 35.73%, with the highest value being 50.0 g SOP:50.0 g GF and the lowest being 75.0 g SOP:1.7 g GF. As the amount of grasshopper flour increased, so did the protein content of the supplemented Ogi powder. This is evidenced by the rich protein source in grasshoppers, as they contain a greater protein content than do plants and animal diets such as soybeans, chickens, beef, and fish (Teffo *et al.*, 2007). The protein content (8.90–13.29%) of Ogi supplemented with oyster mushroom flour, reported by Ajala (2018), and Kunu supplemented with African locust bean pulp (8.23–8.81%), reported by Olatoye *et al.* (2023), was lower than that reported in this study. However, Anyiam *et al.* (2022) observed that the protein content (11.09–32.65%) of cassava mahewu fed with termites fell within the range described in this study. Additionally, the protein content of Ogi powder supplemented with termite flour (6.84 and 22.23%) is within the current study's range of values (Awoyale *et al.*, 2024). Differences in raw materials, processing techniques, and food formulation may be the cause of this study's varied protein content as compared to another research (Owheruo *et al.*, 2021).

The supplemented Ogi powder's crude fibre content varied from 0.42% to 1.59%, with 50.0 g SOP:50.0 g GF having the highest content and 75.0 g SOP:1.7 g GF having the lowest. As the amount of grasshopper flour increased, the supplemented Ogi powder's crude fibre content increased significantly ($p < 0.05$). The increased crude fibre content reported in this study may have numerous health benefits, ranging from improving digestion to reducing constipation (Igwe *et al.*, 2011). Ogi powder from specific cereal grains (0.20–0.40%) reported by Ijarotimi *et al.* (2022) had a lower crude fibre content compared to that of this study. On the other hand, Ogi powder added with termite flour had a greater crude fibre content (1.97 and 4.02%), according to Awoyale *et al.* (2024). The use of different raw materials, processing techniques, and dietary supplements may be the cause of the variations in crude fibre content between this study and others (Owheruo *et al.*, 2021). The supplemented Ogi powder's total carbohydrate content varied from 49.62 to 84.51%, with the greatest value being 50.0 g of SOP:50.0 g of GF and the lowest being 75.0 g of SOP:1.7 g of GF. As the supplementation amount rose, the supplemented Ogi powder's carbohydrate content dropped, which was linked to a downward trend and a significant difference ($p < 0.05$) in the samples. The low carbohydrate content of grasshopper flour and the submerged fermentation method used to produce Ogi may be the cause of the observed decline. This is consistent with research by Fadahunsi and Soremekun (2017) and Boyiako *et al.* (2020), who found that fermentation reduces the amount of carbohydrates in starchy foods. This study's findings are in good agreement with those of Awoyale *et al.* (2024), who investigated maize Ogi supplemented with edible termite flour (50.21–77.82%). Except for the 75.0 g

SOP:30.0 g GF Ogi powder (389.83 kcal/100 g), which was significantly higher, the energy value of the 100% sorghum Ogi powder (374.79 kcal/100 g) was not significantly different (p>0.05) from the one of the sorghum-supplemented Ogi powders. The high fat content of the grasshopper flour may be responsible for the high energy value of the 75.0 g SOP:30.0 g GF Ogi powder (Siddiqui *et al.,* 2023). However, the energy value of 75.0 g SOP:30.0 g GF Ogi powder was not significantly different from the one of 100.0 g SOP:10.0 g GF (377.91 kcal/100 g), 50.0 g SOP:50.0 g GF (383.37 kcal/100 g), 39.6 g SOP:30.0 g GF (380.92 kcal/100 g), and 100.0 g SOP:50.0 g GF (382.23 kcal/100 g). Awoyale *et al.* (2024) showed a similar overall energy content (349.63–376.44 kcal/100 g) for termite-supplemented Ogi powder. Yellow maize Ogi powder (428.03 kcal/100 g) and white maize Ogi powder (427.56 kcal/100 g) had higher energy values than the supplemented Ogi powder and 100% sorghum Ogi powder utilized in this investigation (Ijarotimi *et al.*, 2022). This could be explained by various raw materials, processing techniques, and raw material compositions. The energy values (356.99–371.05 kcal/100 g) of Ogi–mango mesocarp flour blends, however, were observed to fall within a similar range (Adepeju *et al.*, 2023).

Mineral content

Table 3 shows the mineral and phytochemical compositions of sorghum Ogi powder supplemented with grasshopper flour. Minerals are essential for both biological activities and the nutritional content of food. According to reports, eating insects can help address micronutrient deficiencies because they are more prone to iron and zinc deficiencies than beef, pigs, and chickens are (Bukkens, 2005; Rumpold and Schluter, 2013). The phytochemical composition of the supplemented Ogi powder increased significantly (p<0.05) with the increase of the grasshopper flour content. These findings confirm that grasshoppers contain phytochemicals such as phytate, tannins, and oxalate and that these phytochemicals may act more as antioxidants than as antinutrients (Lee *et al.*, 2020). The mean iron and zinc contents of the sorghum-supplemented Ogi powder were 2.96 mg/100 g and 1.85 mg/100 g, respectively. The mean phytochemical composition was oxalate 0.36 mg/100 g, phytate 0.94 mg/100 g, and tannin 0.36 mg/100 g. The iron, zinc, phytate, and tannin contents of the 100% sorghum Ogi powder were significantly different (p<0.05) from those of the grasshopper flour-supplemented Ogi powder.

The iron content of Ogi powder supplemented with sorghum varied from 2.14 mg/100 g to 4.40 mg/100 g; the highest iron content was found in 50.0 g SOP:10.0 g GF, while the lowest iron content was found in 50.0 g SOP:50.0 g GF (Table 3). The iron concentration in this study was equivalent to that reported by Adepoju and Ajayi (2016) in supplemental foods enriched with termites (2.81–4.13 mg/100 g) and higher than that reported by Awoyale *et al.* (2024) for maize Ogi supplemented with termite flour (1.68–2.43 mg/100 g). Iron, an essential mineral for brain development and oxygen transfer, is a serious nutritional concern in children because of their fast growth and susceptibility to deficiency (WHO, 2015). The iron concentration found in this study is within the recommended iron intake range for toddlers and babies (4–8 mg per day) (WHO/FAO, 2015).

Table 2. Chemical composition of sorghum *Ogi* powder supplemented with grasshopper flour.

Sample	Moisture Content (%)	Fat Content (%)	Ash Content (%)	Protein Content (%)	Crude Fibre Content (%)	Total carbohydrate content (%)	Energy value (kcal/100 g)
75.0 g SOP:30.0 g GF	3.80±1.53c	3.80±0.58b	2.11±0.29b	26.31±0.04d	1.17±0.00d	62.80±2.08 g	389.83±8.61a
100.0 g SOP:10.0 g GF	5.17±1.04ab	1.00±0.00d	0.93±0.12c	15.15±0.04 h	0.67±0.00 h	77.08±0.93c	377.91±3.83a-c
50.0 g SOP:50.0 g GF	4.07±0.90bc	4.67±0.58a	4.33±1.26a	35.73±0.04a	1.59±0.00a	49.62±1.74j	383.37±9.40ab
50.0 g SOP:10.0 g GF	5.90±0.36a	1.00±0.00d	2.10±0.53b	18.34±0.04f	0.82±0.00f	71.84±0.52e	369.72±2.00c
110.4 g SOP:30.0 g GF	3.50±0.50c	0.83±0.29de	2.83±0.29b	17.34±0.04 g	0.77±0.00 g	74.72±0.62d	375.75±4.29bc
39.6 g SOP:30.0 g GF	6.17±0.76a	4.33±0.58ab	2.83±0.29b	26.49±0.04c	1.18±0.00c	59.00±0.54 h	380.92±6.67a-c
75.0 g SOP:1.7.0 g GF	3.77±1.17c	0.13±0.08e	1.67±0.29bc	9.50±0.04i	0.42±0.00i	84.51±1.36b	377.24±5.58bc
100.0 g SOP:50.0 g GF	3.30±0.30c	2.00±1.00c	2.70±0.35b	21.19±0.04e	0.94±0.00e	69.87±1.13f	382.23±4.43a-c
75.0 g SOP:58.3.0 g GF	6.33±0.29a	3.67±0.58b	2.83±0.58b	29.55±0.04b	1.32±0.00b	56.30±1.08i	376.40±3.78bc
100.0 g SOP	4.20±0.36bc	0.13±0.06e	2.00±1.00bc	5.95±0.04j	0.27±0.00j	87.45±0.63a	374.79±2.92bc
Mean	4.62	2.16	2.43	20.56	0.92	69.32	381.96
p level	**	**	**	***	***	***	**

SOP- Sorghum *Ogi* powder, GF-Grasshopper flour, **p<0.01, ***p<0.001

Means with different letters within the same column are significantly different (p<0.05).

The zinc content of the sorghum-supplemented Ogi powder was greater for 50.0 g of SOP:50.0 g of GF (3.01 mg/100 g) and lower for 75.0 g of SOP:1.7 g of GF (0.92 mg/100 g) (Table 3). The Zinc content increased as the grasshopper flour supplementation level increased in the sorghum Ogi powder. The results of this study indicate that grasshoppers are good sources of zinc. Zinc is important for cellular growth, inhibits growth retardation, and is also a cofactor in the enzyme responsible for converting provitamin A to retinol, which can interfere with micronutrient metabolism when deficient in the diet (Christian and West, 1998). The results of this study are consistent with the findings from the study of Adepoju and Ajayi (2016) for complementary food enriched with termites (2.41–3.92 mg/100 g) and the study of Awoyale *et al.* (2024) on the supplementation of maize Ogi powder with termite flour (2.89–3.21 mg/100 g). On the other hand, Kunu supplemented with African locust bean pulp showed a smaller range of values (0.60–1.85 mg/100 g), according to Olatoye et al. (2023). The types of cereal grains and additives utilized, as well as variations in processing techniques, could be the cause of this variation (Owheruo *et al.,* 2021).

With 100.0 g SOP:50.0 g GF appearing higher and lower in 75.0 g SOP:30.0 g GF, the oxalate content of the sorghum-supplemented Ogi powder varied from 0.29 to 0.42 mg/100 g. The values found in this study were greater than those found in supplementary foods enhanced with termites (0.11–0.13 mg/100 g) by Adepoju and Ajayi (2016) and wheat cakes enriched with termites (0.05–0.09 mg/100 g) by Ojinnaka *et al.* (2013). Furthermore, Awoyale *et al.* (2024) showed a smaller range of results (0.02–0.11 mg/100 g) for maize Ogi powder treated with termite flour than this investigation. However, for the weaning meal made from millet, soybeans, and moringa leaf flour, the values found in this study were marginally lower than the values (0.33–0.95%) published by Gwer *et al.* (2020). The raw materials, supplements, and processing techniques employed may have contributed to the heterogeneity in the outcomes (Owheruo *et al.*, 2021). According to Omueti *et al.* (2016) and Perez-Gregorio and Simal-Gandara (2017), phytate, a common antinutrient, is considered a dietary supplement with some health benefits, including lowering lipid levels and acting as an antioxidant when it is well processed and present in foods at low levels. The supplemented sorghum Ogi powder's phytate level varied from 0.57 mg/100 g to 1.39 mg/100 g, with the highest value being 75.0 g SOP:58.3 g GF and the lowest being 75.0 g SOP:1.7 g GF. In comparison to the values (3.71–69.22 mg/100 g) published by Ijarotimi *et al.* (2022) in Ogi powder from certain cereal grains, the phytate concentration reported in this investigation was lower. On the other hand, the phytate concentration in this study was higher than the range of values (0.04–0.21 mg/100 g) for termite flour-supplemented maize Ogi powder reported by Awoyale *et al.* (2024). The types of cereal grains and supplements utilized, as well as variations in processing techniques, could be the cause of this diversity (Owheruo *et al.*, 2021). Like phytate, tannin is a naturally occurring polyphenol that also inhibits the absorption and availability of proteins when it is unprocessed and present in large quantities (Okafor *et al.,* 2018). The tannin content of the supplemented sorghum Ogi powder ranged between 0.15 mg/100 g and 0.69 mg/100 g, with 50.0 g of SOP:50.0 g of GF and 75.0 g of SOP:1.7

g of GF. The tannin values reported in this study were lower than those reported by Ijarotimi *et al.* (2022) in Ogi made from specific cereal grains (2.08 - 6.08 mg/100 g) and Okafor *et al.* (2018) in maize Ogi co-fermented with pigeon pea (0.39–18.39 mg/100 g). However, a lower range of values (0.01–0.03 mg/100 g) than the one reported in this study was reported by Awoyale *et al.* (2024) for maize Ogi powder supplemented with termite flour. This variation may be attributed to differences in processing methods, the types of cereal grains, and supplements used (Owheruo *et al.*, 2021).

Table 3. Mineral and phytochemical composition of sorghum *Ogi* powder supplemented with grasshopper flour.

Sample	Mineral content (mg/100 g)		Phytochemical composition (mg/100 g)		
	Iron content	Zinc content	Oxalate content	Phytate content	Tannin content
75.0 g SOP:30.0 g GF	3.70±0.77bc	2.01±0.06d	0.29±0.02c	0.84±0.02e	0.49±0.02c
100.0 g SOP:10.0 g GF	3.69±0.10c	1.29±0.06 h	0.33±0.04b	0.59±0.04 h	0.16±0.05f
50.0 g SOP:50.0 g GF	2.14±0.36 h	3.01±0.11a	0.39±0.04ab	1.30±0.02b	0.69±0.02a
50.0 g SOP:10.0 g GF	4.40±0.45a	1.62±0.06 g	0.30±0.02c	0.82±0.01e	0.29±0.02d
110.4.0 g SOP:30.0 g GF	2.44±0.10e	1.80±0.00f	0.40±0.00a	0.72±0.01 g	0.23±0.01e
39.6.0 g SOP:30.0 g GF	3.81±0.52b	2.86±0.06b	0.39±0.01ab	1.13±0.01d	0.60±0.01b
75.0 g SOP:1.7.0 g GF	2.26±0.45f	0.92±0.00i	0.35±0.03b	0.57±0.01 h	0.15±0.01f
100.0 g SOP:50.0 g GF	2.20±0.10 g	1.91±0.00e	0.42±0.02a	1.25±0.02c	0.28±0.02d
75.0 g SOP:58.3.0 g GF	2.92±0.21d	2.24±0.11c	0.36±0.02b	1.39±0.02a	0.60±0.02b
100.0 g SOP	2.02±0.63i	0.88±0.12j	0.32±0.04bc	0.79±0.01f	0.06±0.02 g
Mean	2..96	1.85	0.36	0.94	0.36
p level	**	**	**	***	***

SOP- Sorghum *Ogi* powder, GF-Grasshopper flour, **$p<0.01$

Means with different letters within the same column are significantly different ($p<0.05$).

Sensory attributes

The sensory characteristics of the Ogi gruel made from mixtures of grasshopper flour and sorghum Ogi powder are shown in Table 4. The findings indicated that the gruel's overall acceptability and all its sensory qualities fell within the mean of the likeness range (6.3–7.8). The taste (except for 75 g SOP:30 g GF and 100 g SOP:10 g GF), appearance (except for 50 g SOP:10 g GF and 50 g SOP:50 g GF), and overall acceptability (except for 75 g SOP:30 g GF) of all the supplemented Ogi gruel samples were statistically the same as those of the control sample. The color of the control sample (100 g SOP gruel) was significantly different ($p<0.05$) from that of the supplemented sorghum Ogi gruels. This may be attributed to the brown color formed during the roasting of the grasshopper. However, all the supplemented Ogi gruels were accepted by the panelists. This is because they all fall within a very similar range to that of the control sample. However, the Principal Component Analysis Biplot showed that the 75 g SOP:58.3 g GF, 100 g SOP:50 g GF, and 110.4 g SOP:30 g GF are comparable to the 100 g SOP (control) in terms of taste, aroma, and overall acceptability (Figure 1). This is because all the samples and the attributes fall within the same quadrant. This suggests that the sensory panelists' overall acceptance of the grasshopper-supplemented sorghum Ogi powder gruel from 75 g SOP:58.3 g GF, 100 g SOP:50 g GF, and 110.4 g SOP:30 g GF was caused by its taste and aroma, which were identical to those of the reference sample.

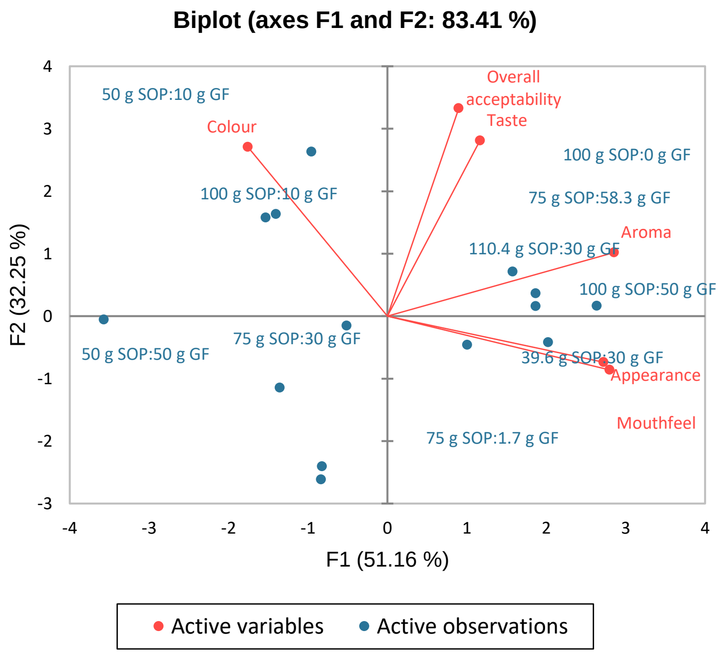

Figure 1. Principal Component Analysis Biplot of the sensory attributes of the grasshopper-supplemented sorghum Ogi powder gruel.

Table 4. Sensory attributes of sorghum *Ogi* powder supplemented with grasshopper flour.

Sample	Taste	Mouthfeel	Aroma	Color	Appearance	Overall acceptability
75.0 g SOP:30.0 g GF	6.41±0.02c	6.04±0.06c	6.13±0.10d	6.43±0.11bc	6.58±0.01bc	7.50±0.75c
100.0 g SOP:10.0 g GF	7.45±0.04a	5.66±0.02d	6.11±0.01d	6.55±0.22b	6.31±0.02c	7.79±0.69b
50.0 g SOP:50.0 g GF	6.01±0.11d	5.67±0.01d	5.22±0.12e	6.78±0.29a	6.12±0.02d	7.64±0.93bc
50.0 g SOP:10.0 g GF	6.98±0.28b	5.98±0.02cd	7.01±0.22c	6.89±0.31a	6.27±0.02c	8.00±0.56a
110.4 g SOP:30.0 g GF	6.88±0.39b	6.43±0.07bc	7.11±0.19bc	6.45±0.33bc	7.11±0.01ab	7.93±0.97ab
39.6 g SOP:30.0 g GF	6.74±0.35bc	6.42±0.09bc	7.08±0.15bc	6.39±0.01c	6.89±0.01b	7.57±0.76bc
75.0 g SOP:1.7 g GF	6.77±0.25bc	6.65±0.05bc	7.14±0.28bc	6.42±0.05bc	7.34±0.03a	7.64±0.75bc
100.0 g SOP:50.0 g GF	6.98±0.33b	6.47±0.04bc	7.34±0.11b	6.39±0.09c	7.11±0.04ab	7.79±0.69b
75.0 g SOP:58.3 g GF	6.79±0.29bc	6.77±0.03a	7.33±0.09b	6.33±0.12cd	6.79±0.04bc	7.86±0.95ab
100.0 g SOP:0.0 g GF	7.01±0.37ab	6.78±0.02a	7.56±0.08a	6.24±0.22d	7.01±0.01b	7.86±0.77ab
Mean	6.80	6.29	6.80	6.49	6.75	7.76
p level	***	***	**	*	*	**

SOP- Sorghum *Ogi* powder, GF-Grasshopper flour, *p<0.05, **p<0.01, ***p<0.001. Means with different letters within the same column are significantly different (p<0.05).

1 = 'Dislike extremely'; 2 = 'Dislikes very much'; 3 = 'Dislikes moderately'; 4 = 'Dislikes slightly'; 5 = 'Neither like nor dislike'; 6 = 'Like slightly', and 7 = 'Like moderately' 8 = "Like very much." 9 represents 'like extremely'

Conclusions

The inclusion of grasshopper flour in sorghum Ogi powder reduced the carbohydrate content and increased the protein, ash, fat, crude fibre, zinc, iron, phytate, and tannin contents. The taste (except for 75 g SOP:30 g GF and 100 g SOP:10 g GF), appearance (except for 50 g SOP:10 g GF and 50 g SOP:50 g GF), and overall acceptability (except for 75 g SOP:30 g GF) of all the supplemented Ogi gruel samples were statistically the same as those of the control sample. The overall acceptability of the grasshopper-supplemented sorghum Ogi powder gruel from 75 g SOP:58.3 g GF, 100 g SOP:50 g GF, and 110.4 g SOP:30 g GF by the sensory panelists was due to the taste and aroma, which were not different from those of the control sample. Therefore, supplementing sorghum Ogi powder with grasshopper flour may limit the risk of macro- and micronutrient deficiencies associated with the consumption of acceptable cereal-based foods in developing countries.

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