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INFLUENCE OF EDIBLE TERMITE FLOUR SUPPLEMENTATION ON THE FUNCTIONAL AND PASTING PROPERTIES OF MAIZE OGI POWDER AND THE SENSORY ACCEPTABILITY OF THE GRUEL

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Abstract

Ogi is a traditional staple food rich in carbohydrates but low in protein. The inclusion of termite flour (TF) apart from increasing the protein content could affect other attributes, thus, the need for this study. The functional and pasting properties of the Ogi samples and the sensory evaluation of the gruel, produced from the blends of Ogi powder (OP) (50-100) with termite flour (TF) (10-50), were evaluated using standard methods. The result showed that adding TF to the OP slightly reduced the water (WAC) and oil absorption capacity (OAC), and increased the bulk density, swelling power, and all the pasting properties (except the peak time and pasting temperature) of the Ogi samples. The overall acceptability of the gruel from the 100g OP (control sample) was not significantly different from that of the 75.0:1.7 and 75.0:30.0 grams of the OP and TF blends. Consequently, the inclusion of the TF in the OP may not only increase the nutritional composition as reported by other researchers but produce an acceptable Ogi gruel of good pasting properties and comparable functionality to that of the control sample, which could be achieved by blending 75.0g of OP with either 1.7 or 30.0 g of TF.

Keywords: fermented maize product, insect supplementation, quality attributes, organoleptic acceptance

Introduction

Ogi is a well-known fermented semisolid food whose color is based on the cereal grain used for its preparation, ranging from white to yellow maize, red to white guinea corn or millet and rice among others (Akinsola *et al.*, 2021). It is generally consumed as a traditional breakfast and complimentary meal in Nigeria (Aworh, 2008; Bolaji *et al.*, 2015).

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Ogi production involves numerous processes, thus reducing its nutritional quality due to a significant loss of the essential nutrients (amino acids and minerals) required by the human body (Osungbaro, 2009; Oluseyi *et al.*, 2013; Ajala, 2018). Subsequently, efforts are being made up to improve the nutritional value of *Ogi*, through supplementation with other food materials of both plant and animal sources such as pigeon pea, millet, cowpea, watermelon seed, African yam bean, egg, milk and edible insects (Oluseyi *et al.*, 2013; Otegbayo, 2016; Oroniran *et al.*, 2017; Okafor *et al.*, 2018; Ukom *et al.*, 2019).

Edible insects are generally abundant, nutrient-dense, and economically valuable. They constitute an important part of the daily diet of a large population worldwide either as a snack or as a meal (DeFoliart, 2002). Research findings have revealed that insects often contain more protein, fat, and carbohydrates than equal amounts of beef or fish, and a higher energy value than soybeans, maize, beef, fish, lentils, or other beans. Also, insects rearing leads to a more favorable conversion factor meant as kg of feed/kg of insect produced. The quantity and quality of proteins, lipids, vitamins, minerals, and calories in edible insect caterpillars are comparable to those of beef, fish, lamb, pork, chicken, milk, and eggs; and they are higher in protein and fat than the plants upon which they feed (Ramos-Elorduy, 2008; FAO, 2013). Commonly consumed insects include adult crickets (Brachytrypes spp and *Acheta domesticus*), adult short-horned grasshoppers (*Cytacanthacrisaeruginosus unicolor*), scarab beetle larvae (*Oryctesboas*), larvae of butterfly and moth (*Anaphe* spp.) and winged adult termites (*Macrotermesbellicosus/Macrotermesnotalensis/ Tenebrio molitor*) (Eggleton, 2000).

Termites (*Isoptera*), classified as social insects with colonies, are widely consumed in many parts of the world, especially in Africa. They are usually classified as Isoptera and are mainly found in tropical areas and subtropical climates in a large and diversified group consisting of over 2,600 species worldwide (Eggleton, 2000). Termite utilization has been recorded in 29 countries across three continents, with Africa being the continent with the highest number of records, followed by the USA and Asia (Afam and Khavhatondwi. 2017). Termites have been used as food in sub-Saharan Africa, Asia, Australia, and Latin America (Cloutier, 2015) and are relished as a delicacy as part of a meal or simply eaten as a snack. Breastfeeding mothers have used dried termites as sprinkles in baby porridge and converted them into other unrecognizable forms in muffins and crackers (Bergeron *et al.*, 1988). Termites can provide food security in many developing and developed countries of the world, as they contain essential nutrients like protein, vitamins, minerals, and calories, which are often lacking in the diets of many people in these countries (FAO, 2013; Münke-Svendsen *et al.*, 2016; Kipkoech, 2017).

The supplementation of the maize Ogi powder with termite flour may not only help to increase its protein content but may affect the functional and pasting properties of maize Ogi powder and the sensory acceptability of gruel. Thus, this research work was aimed at evaluating the influence of termite flour on the functional and pasting properties of Ogi powder and the sensory acceptability of the gruel.

Materials and methods

Materials

The yellow maize grains were purchased from the Oja-Oba market within the Ilorin metropolis of Kwara State, Nigeria. Termite (*Isoptera*) was sourced locally from anthills in the Malete community, Kwara State (8°42'0" North, 4°28'0" East). Other equipment and materials used include, a locally fabricated milling machine, cabinet dryer, muslin cloth, sieve, plastic containers and zip lock bag sourced from the Department of Food Science and Technology Food Processing Laboratory, Kwara State University Malete, Kwara State.

Preparation of Ogi powder

Ogi was prepared using the wet-milling process described by Awoyale *et al.* (2016). The yellow maize grains were sorted, cleaned, and steeped in clean water at room temperature for 48 h. The water was decanted, and the fermented grains were washed with clean water and wet milled using an attrition mill. The bran was removed wet with a muslin cloth and the filtrate was allowed to settle for 24 h to form starchy sediment, which is Ogi slurry. The sediment was dewatered in a jute sack using a hydraulic jack. The dewatered mash was pulverized in a granulating machine, dried in a cabinet dryer (55 ± 5°C), and dry milled to pass a mesh sieve of 0.5 mm, then cooled down and packaged for further use.

Production of termite flour

Fresh termites were picked into a bowl of water to arrest them from flying and to subsequently kill them before processing them into flour using the method described by Akullo *et al.* (2018). Termites were cleaned by removing their wings and legs, then oven-dried at 80ºC for 10 min, roasted (210ºC for 15 min), milled (with attrition mill) cooled and packaged in a plastic container before formulation.

Supplementation of Ogi powder with termite flour

The supplementation of the Ogi powder (100 g and 50 g) with the termite flour (50 g and 10 g) (Table 1) was done using the ratios derived from the Response Surface Central Composite Rotatable Design of the Design Expert software (Version 6.0).

Table 1. Blending ratios for the supplementation of Ogi powder with termite flour.

Runs	Ogi powder (g)	Termite 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	110.4	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

This gave thirteen runs with five central points (That is, 70.0 OP:30.0 TF has five repetitions). The mixture was blended thoroughly with a laboratory blender, packed and sealed in a low-density polyethylene bag before further analyses.

Functional properties

Swelling power

The method described by Leach *et al.* (1959) was used with slight modifications. Each sample (1 g) was weighed and transferred into a clean, dry test tube and weighed (W1). Using a magnetic stirrer, the flour was then dispersed in 50 mL of distilled water. The resulting slurry was heated at 60°C for 30 min in a thermostatically controlled water bath. The mixture was cooled to room temperature and centrifuged at 2,200 rpm for 15 min. An aliquot of the supernatant (5 mL) was dried to a constant weight at 120°C. The residue obtained after drying represented the amount of starch solubilized in water. Solubility was calculated as per 100 g of starch on a dry weight basis. The residue obtained after centrifugation with the water it retained was transferred to the clean, dried test tube and weighed. The swelling power was calculated using equation 1.

$$Swelling\ power = \frac{W_2 - W_1}{Weight\ of\ sample} \quad (1)$$

where, W_1 = Mass of the tube; W_2 = Mass of the tube and sample.

Bulk Density

The procedure of Narayana and Narasinga (1984) was used with slight modification to determine bulk density. A specified amount of the powdered Ogi was placed into an already-weighed 25 mL measuring cylinder, it was gently tapped and the volume was noted. The new level of sample on the measuring cylinder was recorded in mL. The bulk density was computed as shown in equation 2.

$$Bulk\ density = \frac{Mass}{Volume} \quad (2)$$

Water and Oil Absorption Capacity

The water oil absorption capacity (WAC) and oil absorption capacity (OAC) of each sample were determined using the method of Sathe *et al.* (1982). To 1g of each sample, 10 mL of water and oil were added for the WAC and OAC respectively, and the suspension was stirred using a magnetic stirrer for 5 min. and transferred into centrifuge tubes and centrifuged at 3500 rpm for 30 min. The supernatant obtained was measured using a 10 mL measuring cylinder. The density of the water for WAC and oil for OAC was assumed to be 1 g/mL. The water or oil absorbed was calculated as the difference between the initial volume of water or oil used and the volume of the supernatant obtained after centrifugation. The result was then expressed as a percentage of water or oil absorbed by the samples on a percentage g/g basis.

Pasting Properties

Pasting properties were determined with a Rapid Visco Analyzer (RVA) as described by Awoyale *et al.* (2015). Flour suspension was prepared by the addition of an equivalent weight of 3.0 g flour (dry weight basis) to distilled water to make a total of 28 g suspension in the RVA sample canister. This was placed centrally into a paddle coupling and inserted into the RVA. The starting temperature was 50°C for 1 min and later heated from 50°C to 95°C for 6 min. It was held at 90°C for 5 min before the samples were subsequently cooled to 50°C over a 4 min period with continuous stirring, first at 960 rpm for 10 sec and then at 160 rpm throughout the rest of the experiment. This was followed by a period of 1 min where the temperature was kept at a constant of 50 °C. Pasting properties of peak, trough, breakdown, final and setback viscosity, peak time and peak temperature were determined in duplicate.

Sensory Evaluation

The Ogi samples were prepared into gruel by cooking the mixture of 70 g of Ogi powder with 125 mL of water on a heating mantle for 7 min, after which the samples were properly coded and evaluated for color, aroma and taste, and overall acceptability. Fifteen untrained panelists, who are regular consumers of Ogi, were asked to rate the samples based on a 9-point hedonic scale anchored by: 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 = 'Like extremely' (Granato *et al.*, 2010).

Statistical analysis

The data generated were subjected to Analysis of Variance (ANOVA), the Pearson correlation, and the means were separated with Duncan's multiple range test ($p < 0.05$), using the Statistical Package for Social Sciences (SPSS version 21) software. The principal component analysis was carried out using XLSTAT free version 2022.

Results and discussion

Functional properties of Ogi powder supplemented with termite flour

Table 2 shows the values of the functional properties of the Ogi powder (OP) supplemented with termite flour (TF). There was no significant difference ($p > 0.05$) in the water (WAC) and oil (OAC) absorption capacities of the Ogi blends compared to the control sample (100 g OP). However, a significant difference ($p < 0.05$) exists in the bulk density and swelling power of the samples. The mean of the functional properties of the Ogi samples were WAC 115.6%, OAC 116.8%, bulk density 68.0% and swelling power 99.0%.

The samples compositional structure determines important parameters like water absorption and swelling capacities, which ultimately determine sample consistency (Ayo-Omogie and Ogunsakin, 2013). There was a slight decrease though not significant ($p>0.05$) in the level of WAC from 116.6% in the control sample (100g OP) to 115.2% in the following OP:TF Ogi blends (110.4:30.0, 100:10.0, 39.6:30.0 and 50.0:50.0) (Table 2). The high WAC of the control sample may be attributed to free sugars, which are capable of binding a large amount of water through hydrogen bond formation as a result of the partial forces of attraction between hydroxyl (H-) and hydrogen (H+) ions (Elijah *et al.*, 2019). Although, according to Omueti *et al.* (2009), a lower WAC is desirable for making thinner gruels with high caloric density per unit volume. This implied that the inclusion of termite flour in Ogi powder may produce thinner gruels with high caloric density per unit volume. Since there was no statistically significant difference ($p > 0.05$) in the WAC between the control sample and the Ogi samples produced from the OP:TF blends of 75.0:30.0, 75.0:1.7, 75.0:58.3, 100.0: 50.0, 50.0: 10.0 and 39.6:30.0, they may behave the same way as the 100g OP sample in terms of the WAC (Table 2). The WAC of the Ogi supplemented with periwinkle meat flour (82-85%) was lower compared to that of Inyang and Effiong (2016) study.

Because fat retains the flavor and enhances the mouthfeel of foods, OAC is critical. The OAC of the Ogi sample slightly reduced from 118.3% in the control sample to 116.1% in the 100.0:50.0 and 39.6:30.0 OP:TF blends, but not significant ($p > 0.05$) (Table 2). The OAC obtained in this study was higher compared to the value reported by Inyang and Effiong (2016) for Ogi powder supplemented with periwinkle meat flour (77.0-82.0%). This may be attributed to a different source of protein (periwinkle meat flour), processing methods (days of fermentation) and varieties of maize used.

The bulk density of the Ogi samples increased from 67.0% in the control sample to 71.0% in the 100.0:50.0 OP:TF Ogi blend, although the 75.0:1.7 OP:TF Ogi blend showed the lowest value (64.0%) (Table 2). The higher bulk density in the Ogi samples of this study compared to that reported by Inyang and Effiong (2016) for Ogi powder supplemented with periwinkle meat flour (55.0-59.0%) could be due to the difference in protein source and the maize varieties used. In the case of baby foods where a high nutrient density is desired with low bulk, the 75.0 g OP:1.7 g TF Ogi blend would be advantageous because of the lower bulk density (Omogie and Ogunsakin, 2013). This is because the lower the bulk density, the higher the quantity of flour particles that can remain together and consequently expanding the energy content that could be achieved from such an eating routine (Omogie and Ogunsakin, 2013). Packaging and transportation costs could also be reduced by lowered bulk density (Bolaji *et al.*, 2015).

The swelling capacity is a critical parameter which affects the matrix consistency and is subject to the sample composition (Omogie and Ogunsakin, 2013). The swelling capacity of the Ogi samples increased from 102.0% in the control sample to 112.0% in the 39.6:30.0 OP:TF Ogi blend, although the 110.4:30.0 OP:TF Ogi blend showed the lowest value (Table 2). The low value of swelling capacity in the 110.4:30.0 OP:TF Ogi blend could be an advantage because flours with low swelling capacity would provide more nutrients – dense complementary food (Omogie and Ogunsakin, 2013). However, a low swelling capacity could negatively influence the sensory characteristics of the product. The swelling capacity value of the present work was in agreement with earlier findings (Adejuyitan *et al.*, 2012).

Table 2. Functional properties of *Ogi* samples from the blends of *Ogi* powder and termite flour.

Samples g OP:g TF	Water absorption capacity (%)	Oil absorption capacity (%)	Bulk density (%)	Swelling power (%)
75: 30	116.6 ± 0.05[a]	117.3 ± 0.00[ab]	69.0 ± 0.00[abc]	106.0 ± 0.06[a]
75: 1.7	116.3 ± 0.03[ab]	118.1 ± 0.03[ab]	64.0 ± 0.01[d]	83.0 ± 0.03[b]
75.0: 58.3	115.4 ± 0.07[ab]	116.8 ± 0.11[ab]	67.0 ± 0.00[c]	111.0 ± 0.03[a]
110.4: 30	115.2 ± 0.02[ab]	116.3 ± 0.13[ab]	68.0 ± 0.01b[c]	76.0 ± 0.02[b]
100: 50	115.6 ± 0.04[ab]	116.1 ± 0.13[b]	71.0 ± 0.00[a]	101.0 ± 0.04[a]
50: 10	115.5 ± 0.08[ab]	116.3 ± 0.01[ab]	70.0 ± 0.01[ab]	104.0 ± 0.10[a]
100: 10	115.2 ± 0.03[ab]	116.2 ± 0.01[ab]	69.0 ± 0.00[abc]	110.0 ± 0.05[a]
39.6: 30	115.2 ± 0.06[ab]	116.1 ± 0.00[b]	68.0 ± 0.01[bc]	112.0 ± 0.02[a]
50: 50	115.2 ± 0.06[ab]	116.3 ± 0.03[ab]	68.0 ± 0.01[bc]	103.0 ± 0.10[a]
Control sample				
100 g OP	116.6 ± 0.03[a]	118.3 ± 0.06[a]	67.0 ± 0.00[c]	102.0 ± 0.10[a]
100 g TF	115.0 ± 0.11[b]	117.3 ± 0.2[ab]	67.0 ± 0.00[c]	82.0 ± 0.06[b]
Mean	115.6	116.8	68.0	99.0
p-value	NS	NS	**	**

Values with different letters within a column are significantly different at $p < 0.05$, **$p < 0.001$, NS-Not significant. OP-*Ogi* powder and TF-Termite flour.

Table 3 shows the values of the pasting parameters samples of *Ogi* powder supplemented with termite flour. All pasting parameters showed significant differences ($p < 0.05$), showing the control sample (100 g OP) the highest values for all parameters, except for the peak time and pasting temperature. The average values of the pasting properties of the Ogi samples are peak 167.2 RVU, trough 52.3 RVU, breakdown 127.3 RVU, final (169.4 RVU) and setback (162.3 RVU) viscosities, peak time 5.6 min and pasting temperature 82.6^{o}C (Table 3).

Following gelatinization, the dissolution of starch results in the phenomenon known as pasting. Swelling of the granules, the release of molecular components from the starch granules, and eventually complete disruption of the granules are all part of the pasting process (Awoyale *et al.*, 2013). Ogi is typically consumed as a paste after being cooked; so, its pasting properties are crucial in predicting the cooked paste's behavior (Awoyale *et al.*, 2013). The peak viscosity of the Ogi samples decreased from 297.2 RVU in the control sample (100 g OP) to 99.0 RVU in the 50.0 g OP: 50.0 g TF Ogi blend. This is an indication that the TF can`t gelatinize, which could be attributed to a lack of biopolymer such as starch, and high protein content. This trend has also been observed in some earlier studies (Akingbala *et al.*, 2003; Aminigo and Akingbala, 2004; Otunola *et al.*, 2007). The differences observed in the peak viscosities of the Ogi samples could be due to different rates of water absorption and swelling of starch granules during heating (Awoyale *et al.*, 2013).

The breakdown viscosity is viewed as a proportion of the level of breaking down of starch granules during cooking (Awoyale *et al.*, 2013). It is also an index of the stability of starch after cooking (Fernande and Berry, 1989). The breakdown viscosity of the Ogi samples decreased from 142.9 RVU in the control sample to

114.8 RVU in the 50.0 g OP: 50.0 g TF Ogi blend. This finding suggests that the 50.0 g OP: 50.0 g TF Ogi blend with the lowest breakdown value could be more resistant to heat and shear force during heating and could have fewer starch granule ruptures, thus resulting in a more stable cooked paste (Awoyale *et al.*, 2013).

The final viscosity of the Ogi sample decreased from 282.5 RVU in the control sample (100 g OP) to 99.2 RVU in the 50.0 g OP: 50.0 g TF Ogi blend. The final viscosity which is the change in the viscosity after holding cooked starch at 50°C, indicates the ability of the material to form a viscous gel or paste after cooking and cooling, as well as the resistance of the paste to shear force during stirring (Adeyemi and Idowu, 1990). The aggregation of amylose molecules in the paste could be responsible for the higher value of the final viscosity in the control sample. As a result, the low final viscosity value showed by the 50.0 g OP: 50.0 g TF Ogi blend could likely be the result of an apparent enzymatic activity that could have occurred during the stage of the grit soaking process, thus reducing the aggregation of its amylose molecules (Awoyale *et al.*, 2013).

Setback viscosity is an indication of the stability of cooked paste against retrogradation and can be used to predict the storage life of a product prepared from flour (Awoyale *et al.*, 2013). The setback viscosity of the Ogi sample decreased from 171.8 RVU in the control sample (100 g OP) to 154.8 RVU in the 50.0 g OP: 50.0 g TF Ogi blend. A partial dextrinisation of the starch molecules could be responsible for the lowest setback observed in the 50.0 g OP: 50.0 g TF Ogi blend. According to Akingbala *et al.* (1981), the enzymes stimulated in the soaking grains can cause partial hydrolysis of the starch molecules, thereby decreasing the amount of starch that must be gelatinized and the setback viscosity. Because of the lower setback viscosity, this observation suggests that the gruel made from the 50.0 g OP: 50.0 g TF Ogi blend is more likely to have a lower retrogradation tendency and a higher cohesiveness than that of the control sample (100 g OP) (Awoyale *et al.*, 2013).

The peak time of the Ogi samples, which is a measure of the cooking time, ranged between 5 min in the control sample (100 g OP) and 6.1 min in the 50.0 g OP: 50.0 g TF Ogi blend. The pasting temperature of the Ogi samples on the other hand ranged from 75.2 in the control sample to 85.5°C in the 100.0 g OP: 50.0 g TF Ogi blend. This implied that the Ogi gruel can be prepared from the Ogi samples in less than 90.0°C and 6.0 min, thus reducing energy costs (Awoyale *et al*., 2013).

Sensory evaluation of gruel from Ogi powder supplemented with termite flour

Table 4 depicts the sensory attributes of the Ogi gruel prepared from the blends of Ogi powder and termite flour. The result showed that all the sensory attributes and the overall acceptability of the gruel fall within the likeness range averagely (5.8 - 6.5). However, all the sensory attributes of the OP:TF Ogi blends of 75.0:30.0 (except taste); 75.0:1.7; and 50.0:10.0 (except color) were not significantly different ($p > 0.05$) from that of the control sample (100 g OP). On the contrary, the Ogi from the blends of 75.0 g OP:58.3 g TF and 50.0 g OP: 50.0 g TF were significantly different ($p < 0.05$) from the control sample in terms of all the sensory attributes and overall acceptability, which could be ascribed to the high amount of termite flour in the blends.

Table 3. Pasting properties of Ogi samples from the blends of Ogi powder and termite flour.

Samples g OP:g TF	Peak viscosity (RVU)	Trough viscosity (RVU)	Breakdown viscosity (RVU)	Final viscosity (RVU)	Setback viscosity (RVU)	Peak time (min)	Peak temperature (ºC)
75: 30	143.8 ± 1.27d	23.00 ± 3.39h	123.2 ± 2.69e	144.7 ± 0.99f	159.3 ± 0.71f	5.7 ± 0.04d	84.9 ± 0.01d
75: 1.7	279.2 ± 2.83b	134.8 ± 2.12b	139.9 ± 1.41b	265.7 ± 1.41b	170.3 ± 2.83b	5.1 ± 0.06g	75.3 ± 0.04h
75.0: 58.3	113.9 ± 2.83h	10.5 ± 5.66j	118.1 ± 4.24g	113.9 ± 2.12i	157.4 ± 4.95g	5.9 ± 0.00b	85.1 ± 0.04c
110.4: 30	184.3 ± 2.83d	51.5 ± 3.54e	133.4 ± 3.54d	176.6 ± 1.41e	165.8 ± 4.24d	5.5 ± 0.03e	83.4 ± 0.04e
100: 50	135.8 ± 8.49f	14.0 ± 7.07i	122.3 ± 4.24f	134.1 ± 5.66g	160.8 ± 4.95e	5.8 ± 0.04c	85.4 ± 0.04a
50: 10	209.3 ± 7.07c	69.7 ± 1.41d	139.4 ± 2.12b	230.5 ± 3.54c	168.6 ± 4.94c	5.5 ± 0.04e	79.8 ± 0.04f
100: 10	184.5 ± 6.36d	100.7 ± 8.49c	137.0 ± 3.54c	228.7 ± 3.54d	168.9 ± 2.83c	5.2 ± 0.05f	77.5 ± 0.04g
39.6: 30	117.7 ± 4.24g	45.0 ± 2.83f	118.7 ± 2.83g	117.3 ± 2.83h	158.1 ± 2.83g	5.9 ± 0.04b	85.1 ± 0.00c
50: 50	99.0 ± 4.24i	39.3± 9.19g	114.8 ± 4.24h	99.2 ± 2.12j	154.8 ± 5.66h	6.1 ± 0.04a	85.4 ± 0.04b
Control sample							
100 g OP	297.2 ± 56.57a	152.3 ± 10.61a	142.9 ± 6.36a	282.5 ± 6.36a	171.8 ± 4.95a	5.0 ± 0.00h	75.2 ± 0.04h
100 g TF	167.2	52.3	127.3	169.4	162.3	5.6	82.6
Mean	***	***	***	***	***	***	***

Values with different letters within a column are significantly different at $p < 0.05$.
***$p < 0.001$, NS-Not Significant, OP, Ogi powder and TF, Termite flour

Table 4. Sensory attributes of gruel from the blends of Ogi powder and termite flour.

Samples g OP:g TF	Taste	Mouthfeel	Color	Appearance	Aroma	Overall acceptability
75: 30	$6.0{\pm}1.04^{bcd}$	$6.4{\pm}0.93^{abc}$	$6.6{\pm}0.63^{ab}$	$6.7{\pm}0.83^{ab}$	$6.4{\pm}0.76^{ab}$	$6.8{\pm}0.58^{ab}$
75: 1.7	$6.5{\pm}1.22^{abc}$	$7.6{\pm}1.01^{a}$	$7.4{\pm}1.09^{a}$	$7.1{\pm}1.88^{ab}$	$7.2{\pm}1.53^{a}$	7.7±1.07a
75.0: 58.3	$4.7{\pm}1.98^{d}$	$5.4{\pm}2.65^{cd}$	$5.2{\pm}1.31^{cde}$	$5.0{\pm}1.47^{cd}$	$5.3{\pm}2.16^{bcd}$	$5.6{\pm}1.50^{cd}$
110.4: 30	$6.6{\pm}1.65^{abc}$	$6.4{\pm}1.77^{abc}$	$5.9{\pm}1.96^{bcd}$	$5.9{\pm}1.10^{bc}$	$6.4{\pm}1.15^{ab}$	$6.6{\pm}1.55^{bc}$
100: 50	$5.7{\pm}1.72^{bcd}$	$6.0{\pm}2.25^{bc}$	$6.4{\pm}1.95^{abc}$	$6.1{\pm}1.83^{abc}$	$5.3{\pm}2.02^{bcd}$	$6.1{\pm}1.14^{bcd}$
50: 10	$6.9{\pm}1.27^{ab}$	$6.4{\pm}1.65^{abc}$	$6.1{\pm}1.86^{bcd}$	$6.6{\pm}1.82^{ab}$	$6.2{\pm}1.42^{ab}$	$6.9{\pm}1.56^{ab}$
100: 10	$6.1{\pm}1.98^{bc}$	$5.7{\pm}2.20^{cd}$	$6.9{\pm}1.14^{ab}$	$6.9{\pm}1.41^{ab}$	$5.8{\pm}1.63^{bc}$	$6.4{\pm}0.84^{bc}$
39.6: 30	$5.9{\pm}1.27^{bc}$	$6.2{\pm}1.31^{abc}$	$5.0{\pm}1.36^{de}$	$4.5{\pm}2.03^{d}$	$4.9{\pm}1.29^{cd}$	$6.1{\pm}0.61^{bcd}$
50: 50	$5.4{\pm}1.50^{cd}$	$4.4{\pm}1.91^{d}$	$4.5{\pm}2.03^{e}$	$4.2{\pm}1.89^{d}$	$4.2{\pm}1.58^{d}$	$5.2{\pm}1.25^{d}$
100 g OP	$7.7{\pm}1.64^{a}$	$7.4{\pm}1.45^{ab}$	$7.6{\pm}1.60^{a}$	$7.5{\pm}1.83^{a}$	$6.4{\pm}2.03^{ab}$	$7.6{\pm}1.74^{a}$
Mean	6.2	6.2	6.2	6.1	5.8	6.5
p level	***	***	***	***	***	***

Values with different letters within a column are significantly different at $p < 0.05$.
***$p < 0.001$. OP, *Ogi* powder and TF, Termite flour. 9 - like extremely; 8 – like very much; 7 – like moderately; 6 – like slightly; 5 – neither like nor dislike; 4 – dislikes slightly; 3 – dislikes moderately; 2 – dislikes very much; 1 – dislike extremely.

The Pearson correlation (Table 5) showed that the overall acceptability of the gruel was positively correlated with the WAC ($p < 0.01$, r=0.79), OAC ($p < 0.05$, r=0.74), and the peak ($p < 0.01$, r=0.93), trough ($p < 0.01$, r=0.78), breakdown ($p < 0.01$, r=0.86), final ($p < 0.01$, r=0.88), and setback ($p < 0.01$, r=0.85) viscosities of the Ogi blends. In addition, the peak time ($p < 0.01$, r=-0.89) and pasting temperature ($p < 0.01$, r= -0.80) of the Ogi blends were negatively correlated with the overall acceptability of the gruel. This implied that the Ogi powder to be prepared into an acceptable gruel should have high WAC, OAC and high peak, trough, breakdown, final and setback viscosities, as well as low peak time and pasting temperature.

Table 5. Pearson correlation of the sensory attributes of the gruel and the functional and pasting properties of the Ogi blends.

Quality attributes	Taste	Mouthfeel	Color	Appearance	Aroma	Overall acceptance
Water absorption capacity	0.52	0.71*	0.74*	0.69*	0.66*	0.77**
Oil absorption capacity	0.47	0.68*	0.68*	0.60	0.65*	0.74*
Bulk density	-0.11	-0.41	-0.22	-0.09	-0.38	-0.39
Swelling power	-0.36	-0.45	-0.28	-0.27	-0.56	-0.43
Peak viscosity	0.85**	0.84**	0.84**	0 .83**	0.81**	0.93**
Trough viscosity	0.77**	0.66*	0.71*	0.67*	0.59	0.78**
Breakdown viscosity	0.85**	0.74*	0.81**	0.86**	0.80**	0.86**
Final viscosity	0.83**	0.76*	0.85**	0.87**	0.79**	0.88**
Setback viscosity	0.83**	0.75*	0.83**	0.86**	0.78**	0.85**
Peak time	-0.78**	-0.80**	-0.92**	-0.91**	-0.83**	-0.89**
Pasting temperature	-0.72*	-0.67*	-0.79**	-0.78**	-0.68*	-0.80**

$*p < 0.05$; $**p < 0.01$

Relationship between the quality attributes of the control sample and the Ogi powder blends

The principal component analysis (PCA) was applied to study the relationship between the control sample (100 g Ogi powder) and the Ogi power-termite flour blends. The PCA biplot, as shown in Figure 1, allowed us to separate the Ogi blends based on the functional and pasting properties and the sensory attributes of the gruel. The result depicts a data variance of about 81.86%, with the PC1 and PC2 contributing 72% and 9.86% respectively. The PC1 was positively correlated with the WAC (r=0.70), OAC (r=0.73), and peak (r=0.98), trough (r= 0.87), breakdown (r=0.93), final (r=0.96) and setback (r=0.94) viscosities, as well as the overall acceptability (r=0.97) of the Ogi blends (Supplementary Table 1). The PC1 was also negatively correlated with the peak time (r= -0.97) and pasting temperature (r=-0.89) of the Ogi blends. The PC2 had a positive correlation with the BD (r=0.69) and negatively correlated with the WAC (r= -0.58) and OAC (r= -0.63) of the Ogi blends (Table 6).

Table 6. Correlation loading of the functional and pasting properties of the Ogi blends and the sensory attributes of the gruel.

Quality attributes	**F1**	**F2**	**F3**	**F4**	**F5**
Water absorption capacity	0.70	-0.58	0.38	0.06	0.09
Oil absorption capacity	0.73	-0.63	0.10	0.19	0.03
Swelling power	-0.42	0.10	0.51	0.71	0.04
Bulk density	-0.43	0.69	0.53	-0.18	0.09
Peak viscosity	0.98	0.00	-0.14	0.06	0.07
Trough viscosity	0.87	0.10	-0.29	0.35	0.10
Breakdown viscosity	0.93	0.34	-0.09	-0.02	-0.03
Final viscosity	0.96	0.23	-0.09	0.13	-0.03
Setback viscosity	0.94	0.32	-0.03	-0.02	-0.07
Peak time	-0.97	-0.15	0.05	-0.09	0.12
Pasting Temperature	-0.89	-0.19	0.23	-0.33	0.09
Taste	0.84	0.22	0.08	-0.09	0.46
Mouthfeel	0.87	-0.14	0.05	-0.21	0.20
Color	0.89	-0.05	0.34	-0.06	-0.25
Appearance	0.91	0.16	0.30	-0.03	-0.21
Aroma	0.86	-0.16	0.13	-0.36	-0.17
Overall Acceptability	0.96	-0.06	0.13	-0.14	0.14

The 100.0:10.0, 50.0:10.0, and 110.4:30.0 OP:TF Ogi blends were in the same quadrant with the sensory taste, appearance, and setback, breakdown, final, trough and peak viscosities. Similarly, the 75.0:30.0, 75.0:1.7 OP:TF Ogi blends and the control sample were in the same quadrant with water and oil absorption capacity,

color, mouthfeel, aroma and overall acceptability. Also, the 39.6:30.0, 50.0:50.0 and 75.0:58.3 OP:TF Ogi blends were in the same quadrant with the peak time and pasting temperature. Furthermore, the 100.0 g OP:50.0 g TF was in the same quadrant with the bulk density and swelling power (Figure 1). Using the 100 g OP as a control sample, Ogi of similar water and oil absorption capacity, color, mouthfeel, aroma and overall acceptability may be produced from the 75.0 g OP:30.0 g TF and 75.0 g OP:1.7 g TF Ogi blends since they belong to the same quadrants with these attributes. This implies that the sensory acceptability of the 75.0 g OP: 30.0 g TF and 75.0 g OP:1.7 g TF Ogi blends compared to the control sample are the water and oil absorption capacity, color, mouthfeel and aroma.

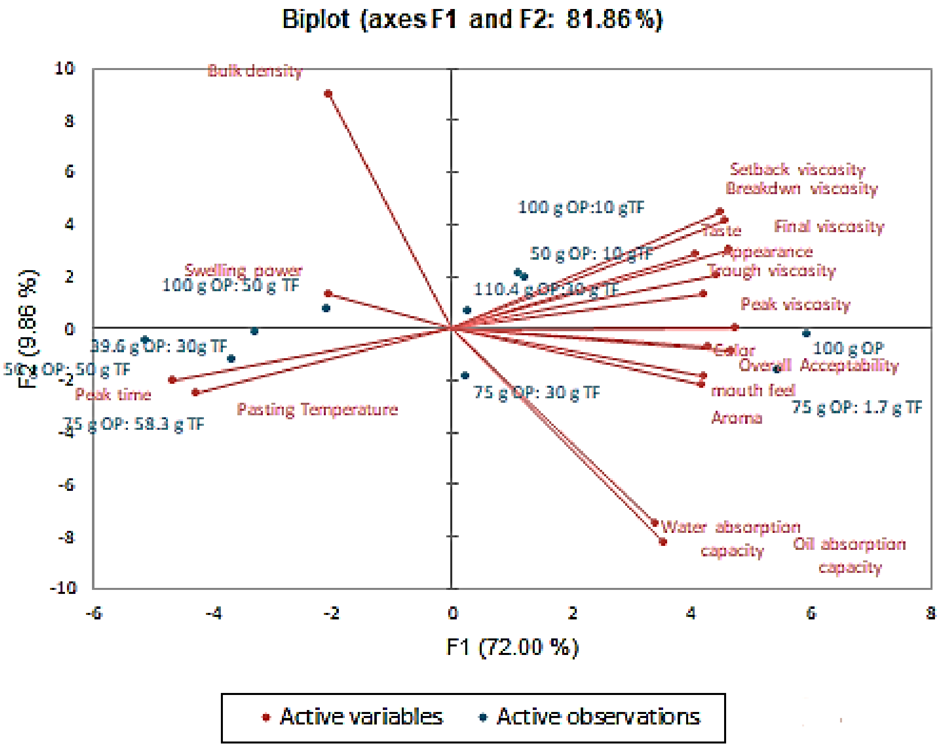

Figure 1. Principal component analysis biplot of the functional and pasting properties of the Ogi blends and the sensory attributes of the gruel.

Conclusions

The inclusion of the termite flour in the Ogi powder may not only increase the nutritional composition as reported by other researchers but produce an acceptable Ogi gruel of good pasting properties and comparable functionality to that of the control sample, which may be achieved by blending 75.0g of Ogi powder with either 1.7 or 30.0 g of termite flour.

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