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Quality Characteristics of Yellow Maize-Based *Ogi* Incorporated with Treated African Locust Bean Seeds Flour

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The effect of treated (boiled unfermented, fermented, sprouted, and toasted) African locust bean seeds on the quality of yellow maize-based *Ogi* flour was evaluated. Standard methods were used in raw material preparation and analyses. Material balancing was used in the formulation of

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samples: maize flour/boiled unfermented locust bean seeds flour (MULB), maize flour/fermented locust bean seeds flour (MFLB), maize flour/sprouted locust bean seeds flour (MSLB), and maize flour/toasted locust bean seeds (MTLB) based on the 16% protein requirement by the protein advisory group for complementary food. Results for functional properties showed that, the inclusion of locust bean seed flour had a significant ($p<0.05$) effect on all the functional properties analyzed. The bulk density, water absorption capacity, swelling capacity, reconstitution index and gelatinization temperature ranged from 0.63-0.78 g/mL, 0.92-1.29 g/g, 3.93-4.75%, 1.27-1.73% and 85.54-88.44 °C respectively. All the Pasting properties increased with inclusion of treated African locust bean seed flour except pasting temperature which decreased. The pasting temperature ranged from 54.16 to 68.42 °C with the control sample (100% maize flour) having the highest value and the sample with toasted African locust bean seed flour inclusion MTLB (82.05% maize flour+ 17.95% Toasted Locust bean seeds flour) having the lowest pasting temperature respectively. The proximate parameters moisture (6.02-7.04%), protein (9.28-16.42 %), fat (1.83-3.62%), fibre (1.56-3.72%), and ash (4.73-8.82%), respectively, increased while carbohydrate significantly decreased from 61.08- 76.59%. The aroma, taste, and overall acceptability decreased with the inclusion of treated African locust beans flour in yellow maize *ogi*. However, the samples with toasted African locust beans seed flour and boiled unfermented African locust bean seed were within the acceptable range. The study established that acceptable and nutrients dense *ogi* can be produced from blends of yellow maize and treated African locust bean seed flour blends.

Keywords: Ogi; yellow maize; African locust bean seed; functional and pasting properties; proximate; and sensory attributes; treatments.

1. INTRODUCTION

*Og*i is a popular fermented porridge dish produced from basic cereals. It is often taken as a weaning meal by infants, served as common food for convalescents, and breakfast-cooked gruel by adults. Textural quality and colour of porridge differ based on the type of cereal grains, variety, and supplement given to it (Bolaji et al., 2022). *Ogi* is majorly produced from cereals like maize, and considerable nutritional losses, largely `situated in the testa and germ, have been commonly observed during the processing of maize into *ogi* (Bolaji et al., 2018).

Maize, a major cereal grain in the production of *ogi*, is rich in carbohydrates, with considerable levels of other nutrients that contribute to human diets. It contains lipids that are important fatty acids. Particularly the yellow varieties of maize contain beta-carotene, a precursor to vitamin A. Maize contains some vitamins that are necessary for metabolic processes. Maize also contains iron, though relatively low with poor bioavailability due to the presence of phytates (Goyal et al., 2014). However, it also has limitations in some critical nutrients like protein and some micronutrients, resulting in malnutrition cases in areas of high consumption rate. This has informed research into the use of plant protein sources in complementing the deficiency of protein in maize. Chiefly among plant-based protein sources that needed to be explored is African locust bean seeds.

African locust bean seeds (*Parkia biglobosa*) are perennial leguminous plants that are used to make *iru,* a fermented product used as a food condiment. Its nutritional potential includes the possession of relatively higher levels of methionine, lysine, tryptophan, phenylalanine, and valine than other legumes (Komolafe et al., 2024). The African locust bean seeds are valued for their high polyphenol content, highlighting their therapeutic antioxidant and anti-inflammatory, antimicrobial, antidiabetic, and antihypertensive properties (Balogun et al., 2018).

In Nigeria, locust bean is a popular condiment added to soups. Many women across the varied ethnic groups feel their soup is not complete until it is added. It is perceived as a meat substitute (Sackey & Kwaw, 2013). Its utilization in products like *og*i is limited due to taste, smell, and unpleasant sight (Sackey & Kwaw, 2013). The seeds can supply not only an alternative source of protein but also other nutrients necessary for man (Oluwaniyi & Bazambo, 2016; Ogunyinka et al., 2017). Despite its nutritional advantages, African locust beans are reported to be high in anti-nutrients, informing various treatment or processing methods prior to utilization.

Processing methods such as germination, roasting, and fermentation have been employed to improve the functional qualities of cereals and legumes, which significantly improves the digestibility and energy/nutrient densities, as well as the bioavailability of proteins and micronutrients in supplemented foods. These procedures include steeping, dehulling, toasting, fomenting, and germination (Oyerakua, 2013; Mesfin et al., 2021; Anaemene & Fadupin, 2022).

Several studies reported the use of legumes and other protein sources in improving the nutritional quality of *ogi*. For instance, Samuel et al., (2024), incorporated mushroom flour in maize-based ogi; Ameh et al., (2023), reported on the chemical and sensory quality of *og*i supplemented with protein isolates from Bambaranut and soybean. In another study, Ukom et al., (2024), reported on the inclusion of orange-fleshed sweet potato and African yam beans flour in maize-based *ogi*, and Akubor et al., (2024) evaluated the quality of Akamu powder incorporated with fermented sweet orange pulp flour. These studies did not report on the use and effect of treated African locust bean flour inclusion in yellow maize-based ogi. The study therefore aimed to evaluate the quality characteristics of yellow maize-based *ogi* incorporated with treated African locust bean seed flour. `

2. MATERIALS AND METHODS

2.1 Source of Materials

Maize and African locust beans (*Parkia biglobosa*) seeds for the study were purchased from Wurukum, Market Makurdi, Benue State, Nigeria.

2.2 Sample Preparation

The maize flour was processed according to the method of Zubair et al., (2020) with slight modification as presented in Fig. 1 while the African locust beans seed treatments were prepared according to the methods of Makanjuola et al., (2017) with slight modification as presented in Figs. 2-5. While Table 1 shows the blend formulation.

2.3 Blend Formulation of Yellow Maize and African Locust Bean Seeds Composite Flour

The maize flour was blended with African locust bean seed flour in the following ratios MF (100:0), MULB (78.39:21.61%), MFLB (79.41:20.59%), MSLB (78.79:21.21%) and MTLB (82.05:17.95) respectively. The composite flour produced was packaged individually in an airtight plastic container for analysis.

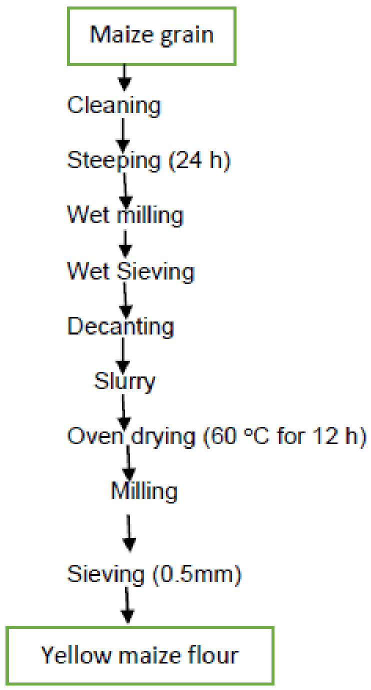

Fig. 1. Flow chart for the production of maize flour
(Zubair et al., 2020) slightly modified

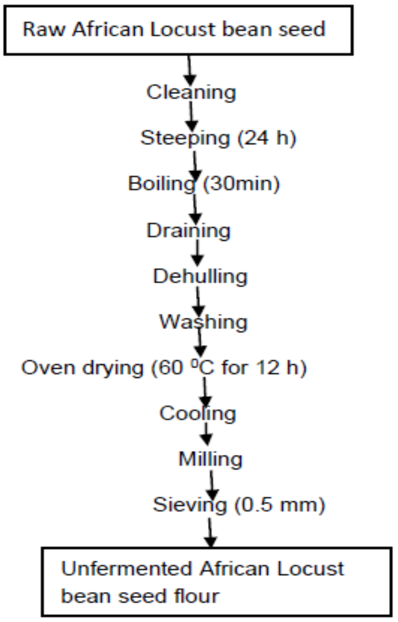

Fig. 2. Flow chart for the production of unfermented locust bean flour
(Makanjuola, et al., 2017) slightly modified

Table 1. Blend formulation for maize and locust beans flour blend %

Sample code	Maize flour	Unfermented Locust bean Seeds	Fermented Locust bean Seeds	Sprouted Locust bean Seeds	Toasted Locust bean Seeds
MF	100.00	-	-	-	-
MULB	78.39	21.61	-	-	-
MFLB	79.41	-	20.59	-	-
MSLB	78.79	-	-	21.21	-
MTLB	82.05	-	-	-	17.95

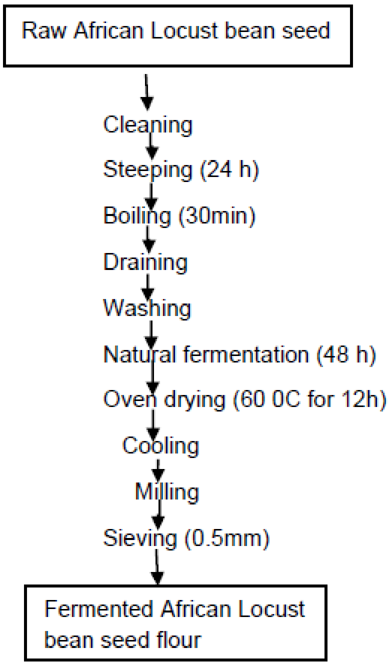

Fig. 3. Flow chart for the production of fermented locust bean flour
(Elizabeth et al., 2016) slightly modified

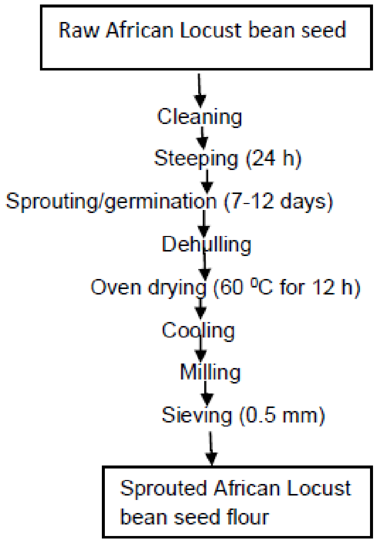

Fig. 4. Flow chart for the production of sprouted locust bean flour
(Adepoju et al., 2017) slightly modified

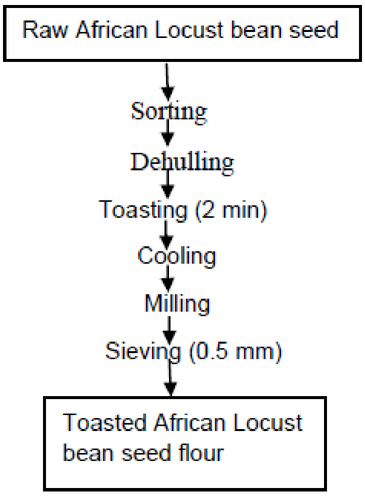

Fig. 5. Flow chart for the production of toasted locust bean flour
(Ogunsina et al., 2015) slightly modified

2.4 Evaluation of Functional Properties of the Flour

The functional properties of the flour blends were analyzed i.e. Swelling capacity (mL), water absorption capacity (WAC, %), gelatinization temperature, Reconstitution index and Bulk density (g/cc).

Bulk density: Bulk density (BD): A 50 g of flour corn starch african locust bean composite flour sample was put into a 100 mL measuring cylinder. The cylinder was tapped continuously until a constant volume was obtained. The bulk density (g/cm3) was calculated as weight of flour (g) divided by flour volume (cm3) according to the method described by Oluwajuyitan & Ijarotimi, (2019).

Swelling capacity: The swelling capacity was determined as previously reported (Ijarotimi et al., 2013). Briefly, 10 mL of distil water was added to 1 g of flour sample in a centrifuge tube and heated up to 90 °C for 30 min. The mixture was shaken periodically to ensure proper dissolution of the suspension. After 30 min, it was centrifuged at 1,000 g for 20 min and the supernatant was decanted while the weight of the paste was recorded. The swelling capacity was calculated using the formula below:

$$Swelling\ capactiy\ = \frac{\text{weight of percentage}}{weight\ of\ dry\ flour}$$

Determination of water absorption capacity (WAC): The water or oil absorption capacity (WAC/OAC) of the flours was determined as previously reported (Aderinola et al., 2020). Briefly, 1 g of the sample was mixed with 10 mL distilled water/oil in a 15 mL centrifuge tube and vortexed for a minute. After standing undisturbed for 30 min at room temperature, the tubes were centrifuged at 5,600 g for 20 min. Supernatant water/oil was decanted and excess free-flowing water/oil was drained by turning the tube upside down on paper towel until the water/oil stopped flowing. The water absorption/oil absorption capacity was calculated using:

$$WAC/\ OAC\ (g\ /g) = \frac{\text{weight after dehydratio}}{weight\ of\ dry\ flour}$$

Gelatinization temperature determination: Gelatinization temperature was determined by the method of Onwuka, (2005). 1-gram flour sample was weighed accurately in triplicate and transferred to 20 mL screw capped tubes. Ten mL of water was added to each sample. The samples were heated slowly in a water bath until they formed a solid gel. At complete gel formation, the respective temperature was measured and taken as gelatinization temperature.

Determination of Reconstitution index (RI): The reconstitution index was determined by the method of Onwuka (2005). From the ground sample, five grams of each sample was dissolved in 50 cm3 of boiling water. The mixture was agitated for 90 seconds and was transferred into a 50 cm3 graduated cylinder and the volume of the sediment was recorded after settling for 30 minutes.

$$RI\ (cm^3/g) = \frac{\text{Volume of sediment}}{Weight\ of\ sediment}$$

2.5 Pasting Properties

The method described by Ojo et al. (2017) was adopted to determine the pasting properties of the composite flours using a Rapid Visco Analyzer (RVA 4500). A flour sample (2.5 g) was weighed into a previously dried canister and 25 ml of distilled water was dispensed into the canister containing the sample. The suspension was thoroughly mixed and the canister was fitted into the Rapid Visco Analyzer (RVA 4500) as recommended. Each suspension was kept at 50 °C for 1 min. and then heated up to 95 °C with a holding time of 2 min. followed by cooling to 50°C for 2 min. holding time. The rate of heating and cooling was at a constant rate of 11.85 °C per min. Peak viscosity (PV), trough viscosity (TV), breakdown viscosity (BDV), final viscosity (FV), and set back viscosity (SBV), was read from the pasting profile with the aid of thermocline for windows software connected to a computer.

2.6 Proximate Composition

The proximate composition of the samples was determined according to AOAC, 2015 method.

Moisture content determination: Moisture content of the composite flour was determined by drying in a Gallenkamp forced hot air oven. The determination was carried out in duplicate. Each sample (5 g) was weighed into pre-weighed moisture content cans. The samples will be dried for 3 h at 105oC and the weight taken. Drying was continuing until their weights were constant. The samples were cooled to room temperature in a desiccator, weighed, and recorded. The final weight of each sample was determined and the moisture content was calculated from the weight loss equation below:

$$\text{Moisture content (\%)} = \frac{W1-W2}{W1} \times 100$$

Where w1 is weight of sample before drying (g) and w2 is weight of sample after drying (g). (AOAC, 2015).

Crude protein determination: Crude protein was evaluated using Kjeldahl nitrogen determination method as described by AOAC, (2015). Sample (1 g) was weighed into digesting tubes and a tablet of Kjeldahl was added. Sulphuric acid (12 mL) was added through a dispenser and mixed thoroughly. Labeled samples in a rack of 8 were then placed on a digester for 1 h to digest the samples. The samples was allowed to cool, and on cooling down, samples was then taken to the automatic distillery (FossTM KJeltecTM 8200 Auto Distillation Machine, FOSS, Hilleroed, Denmark) for 5 min.The distillate was titrated against 0.01 M HCl with an automatic titrator. Percentage nitrogen was then calculated; crude protein content was estimated by multiplying with the factor 6.25.

Crude fat determination: Fat content of the composite flour was determined by a continuous extraction liquid-solid method using Soxhlet extractor with a reflux condenser and a distillation flask (previously dried and weighed). Weighed (2 g) sample into an extraction thimble/filter paper was labeled and recorded (W1) while weighed fat free 500 mL round bottom was recorded as W2. The Soxhlet flask with sample was weighed and placed into the Soxhlet apparatus. The distillation flask was filled to two third capacities with petroleum ether (300 mL) and fitted on the Soxhlet extractor with a reflux condenser. Adjustment of the heat source to ensure that the solvent boils gently was done, and it was left to siphon 6 h. After siphoning the petroleum ether, the condenser was detached and the thimble or filter paper removed. Drying of the flask containing the fat residue was performed in an air oven at 100oC for 5 min, cooled in a desiccator, and then weighed (W3). The difference in the final and initial weight of the distillation flask represented the oil extracted from the sample (AOAC, 2015).

Crude fibre determination: Crude fibre was determined using the weighed (W1) samples. Each sample was transferred into conical flask and 100 mL boiling 1.25% H2SO4 added. Each beaker was heated for 30 min with periodical rotation to prevent adherence of solids to the sides of the beakers. The solution was filtered and rinsed with 50 mL portions boiling water; repeated four times then dried. Boiling 1.25% (w/v) NaOH (Sigma-Aldrich Co., St. Louis, MO, USA) solution (200 mL) will be added and the mixture was boiled for 30 min after which the contents of each beaker was removed and filtered through muslin cloth and washed with 25 mL boiling 1% sulphuric acid, three portions of 50 mL boiling water and 25 mL ethanol. The residue was dried at 100oC to a constant weight followed by cooling in a desiccator to room temperature and weighed (W2). The weighed residue was ignited at 600 ^{0}C in a Gallenkamp muffle furnace for 30 min, cooled in a desiccator and reweighed (W3) The percentage crude fibre in each sample was calculated as:

$$\text{Crude fibre (\%)} = \frac{W1-W2}{W1} \times 100$$

Ash determination: A crucible to be used for the determination was placed in the oven at 105 ^{0}C for about 30 min, cooled in desiccators to room temperature and weighed (W1). The total ash (inorganic residue from the incineration of organic matter) was determined by dry ashing procedure. The samples (2 g) will be weighed into a pre-weighed dry porcelain crucible. The samples was incinerated in a Gallenkamp muffle furnace at 550 ^{0}C for 6 h. After ashing, the remains were removed from the furnace, cooled to room temperature in a desiccator and weighed. The porcelain crucible was weighed and the % total ash weight was obtained by using the equation below:

$$\text{Total ash (\%)} = \frac{weight\ of\ ash\ (g)}{weight\ of\ sample} \times 100$$

(AOAC, 2015).

Determination of total energy: The total energy was determined by the method described by Kanu et al., (2009) the total energy or the caloric values was estimated by calculation using the water quantification factors of 4, 9 and 4kcaV100g respectively for protein, fat and carbohydrate.

2.7 Sensory Quality Attributes

The control sample (yellow maize flour) and the different proportions of composite enriched Ogi were tested for sensory evaluation (Choi et al., 2018). A 25-member panelist was selected to rate the sample on a 9- point hedonic scale where 1 represents lowest and 9 represents the highest for aroma, appearance, taste, texture, and general acceptability. The panelists were made up of people who were familiar with *Ogi.*

2.8 Data Analysis

The data obtained was analyzed using Special Package for Social Science (SPSS, version 20) to detect significant differences ($p < 0.05$) among the sample means. Ducan multiple range test was used in mean separation.

Table 2. Functional Properties of Yellow maize and African locust bean flour blends

Samples	Bulk Density (B D) g/ml	Water Absorption Capacity (B D) g/g	Swelling Capacity (S C) %	Reconstitution Index (R I) %	Gelatinization Temperature (G T) ^{0}C
MF	0.78^a±0.02	1.13^b±0.04	1.73^a±0.01	3.93^e±0.11	85.54^e±0.06
MULB	0.73^a±0.02	1.29^a±0.02	1.52^b±0.01	4.75^a±0.06	85.78^d±0.32
MFLB	0.74^a±0.04	1.03^c±0.04	1.44^c±0.03	4.21^d±0.01	88.44^a±0.08
MSLB	0.63^b±0.03	0.92±^{d}0.03	1.27^d±0.01	4.30^c±0.14	87.89^b±0.54
MTLB	0.64^b±0.02	1.27^a±0.02	1.30^d±0.02	4.36^b±0.06	86.01^c±0.69

Values are Mean ± Standard deviation of duplicate determination
Values with same superscript along the column are not statistically significant P < 0.05 different
MF (100% Maize flour+0% Locust bean seeds flour),
MULB (98.39%Maize flour + 21.61% Unfermented Locust bean seeds flour)
MFLB (79.41%Maize flour + 20.59% Fermented locust bean seeds flour)
MSLB (78.79% maize flour + 21.21% Sprouted locust bean seeds flour)
MTLB (82.05% maize flour+ 17.95% Toasted Locust bean seeds flour)

3. RESULTS AND DISCUSSION

3.1 Effect of Treatments on African Locust Bean Seed Inclusion on the Functional Properties of Yellow Maize Based *Ogi*

The functional properties of yellow maize and African locust bean seeds flour blends *ogi* is presented in Table 2. The inclusion of locust bean seed flour had a significant (p<0.05) effect on all the functional properties analyzed. The bulk density and swelling capacity decreased with the inclusion of treated locust bean seeds ranging from mean values of 0.78-0.63g/mL, 1.73-1.27%. The decrease in bulk density with the inclusion of treated African locust bean seeds flour in the blends implying that the treated African locust bean seed flour had effect on the bulk density of flour blends. Awuchi et al. (2019) stated that the difference or variation in starch content in flours could be responsible for variation in bulk density. Therefore, the decrease in bulk density with the inclusion of African locust beans flour could be due to starch or carbohydrate content which decreased with the inclusion of African locust beans flour in the blends (Prada et al., 2020). The higher the starch content the more likely the increase in bulk density. Among the formulated samples, the sample with sprouted African locust beans flour inclusion had the lowest bulk density and this could be due to low carbohydrate content as well as the structure and composition of the flour as influence by sprouting. The result agreed with the report of Bolarinwa et al., (2015) whose bulk density ranged from (0.60-0.67 g/mL) and decreased with the inclusion of soybeans flour in sorghum-based complementary food. High bulk density of flours indicates that they are suitable for use in food preparation. However, when formulating complimentary foods, low bulk density might be advantageous. (Samsher & Suresh, 2013). The low bulk density reported in this study is therefore advantageous in the preparation of the complementary food. A decrease in bulk density of cereal and legume composite flours provides multiple advantages, particularly in terms of functionality, processing, and application in food formulations: a lower bulk density enhances the nutrient concentration within a given volume of the composite flour, thereby improving its suitability for producing nutrient-dense foods, especially in weaning diets and therapeutic solutions for malnourished individuals. Decreased bulk density enhances digestibility by creating lighter, aerated products that facilitate enzyme penetration during digestion. Foods with a reduced bulk density are easier to compress, using less packaging material and decreasing transportation costs. A diminished bulk density enhances mixing with other components, thus improving homogeneity in food formulations (Ocheme et al., 2018; Olapade & Awofadeju 2021; Akubor et al., 2023).

The inclusion of treated African locust flour in maize-based *ogi* had significant effect on the water absorption capacity of flour blends. Fermented and sprouted African locust beans flours inclusion in the blends significantly decreased the water absorption capacity of maize based *ogi* flour implying that fermentation and sprouting had effect on the hydrophilic and a hydrophobic constituent of proteins since water absorption capacity is dependent on the hydrophilic constituents, such as polysaccharides as well as protein hydrophilic and hydrophobic constituents. Elkhalifa & Bernhardt, (2018) reported that fermentation decreased the water absorption capacity of sorghum flour. The inclusion of unfermented and toasted African locust beans flour decreased the water absorption capacity of maize-based *ogi.* The increase and decrease in water absorption capacity could also be attributed to treatments of African locust bean seed flour, changes in starch structure, and the composition of locust bean seed (Dendegh et al., 2021). The water absorption capacity obtained by this study is similar to that of Abolaji et al., (2019), who reported values ranging from 1.3 to 2.4 g/g for water absorption capacities of flour blends from sorghum, African yam bean, and soybean for use as complementary feeding.

The swelling capacity of flour represent the volume of in milliliters occupied by the swelling of 1 g of flour under specific conditions, is influenced by particle size, composition (such as starch content) and processing methods or unit operations involved in flour production (Zhu, 2017). The addition of locust bean seeds treatments significantly reduced the swelling capacity of the composite flour. This study agrees with the result values (1.36-1.66 ml/g) of Taiwo & Dorcas, (2023), for maize and bean composite flour and values (1.31-2.41 g/ml) for rice and pigeon pea composite flour recorded by Ezeocha et al. (2023).

The result of reconstitution index and gelatinization temperature showed an increase `with the inclusion of treated locust beans seed respectively, with mean value range of 3.93-4.75% and 85.54-88.44 ^{0}C.

The reconstitution index result showed increasing trend with inclusion of treated African locust bean seed flour, compared to the control sample, and this is in agreement with the reconstitution index values (4.20-5.20 ml/g) for malted sorghum and soybean-based food formulations findings of Bello et al. (2020). The significant increase in reconstitution index could be attributed to the inherent functional properties of starch in maize, the water-binding capacity of proteins and polysaccharides in locust beans, and the positive interaction between these components during reconstitution.

The inclusion of treated African locust beans seed flour in the blends significantly ($p<0.05$) increased the gelatinization temperature of the maize flour (Maize-based *Ogi*). This indicates that the preparation of breakfast meals (porridge) made from the blends will consume more energy than that made from 100% maize flour. The gelatinization temperature reported by this study is slightly higher than the 77.60–80.65 °C reported by Ezeocha et al. (2023) for rice and pigeon pea flour blends. The temperature at which food materials form gel or become gelatinous is known as gelatinization temperature. The gelatinization temperature of composite flour can significantly increase as flours are added (Ezeochaet al., 2023). However, the study conducted by Florence et al., (2022) found that flour with higher starch content required the lowest temperature to gelatinize.

Effect of treatments on African locust bean seed inclusion on the Pasting Properties of yellow maize based *Ogi*: The pasting properties of yellow maize-based *Ogi* and treated African locust beans flour are presented in Table 3. The inclusion of treated locust bean seed flour in maize-based *Ogi* had significant effect on the pasting properties of flour blends. The peak viscosity ranged from 162.53 to 189.16 RVU. The control sample (100% maize flour) had the lowest peak viscosity while the sample with sprouted locust beans flour (MSLB) inclusion had the higher peak viscosity. Peak viscosity is the maximum viscosity achieved during heating at 95°C; it indicates the ability of starch-based foods to swell freely before their physical breakdown. A high peak viscosity suggests a high starch content, and vice versa (Inyang & Nwabueze 2020). The peak viscosity increased with inclusion of treated African locust bean seed flour in maze-based *ogi* flour. This could be due to the decrease in starch content with inclusion of treated African locust beans flour in the blends as dependent on the starch content (Inyang Nwabueze 2020). The trend of this result agreed with the report of Yusufu & Alexander, (2022) who reported peak viscosity range of (168.5–181.8 rvu). However, it is lower than peak viscosity values (479.50–816 cP) reported by Atinuke, (2015), the variation of result in result could be due to difference in raw materials used in flour preparation. Peak viscosity is the maximum viscosity attained during or immediately after heating. It is associated with degree of starch damage, and high starch damage results in high peak viscosity (Ohizua et al., 2017). The peak viscosities (PV) of the flours were significantly ($p<0.05$) different and, the relative increase in peak viscosity indicates that the composite flour has the capability of forming a thick paste after gelatinization.

Table 3. Pasting Properties of yellow maize and locust bean seeds flour blends

Samples	Peak Viscosity (RVU)	Final viscosity (RVU)	Setback (RVU)	Breakdown (RVU)	Pasting time, (Min)	Pasting temperature(^{0}C)	Trough (RVU)
MF	$162.53^{e}\pm0.05$	$207.29^{e}\pm0.02$	$54.65^{e}\pm0.02$	$9.85^{e}\pm0.04$	$6.44^{e}\pm0.03$	$68.42^{a}\pm0.03$	$152.69^{d}\pm0.02$
MULB	$178.58^{c}\pm0.04$	$225.72^{d}\pm0.04$	$60.46^{d}\pm0.01$	$11.35^{c}\pm0.01$	$7.15^{d}\pm0.04$	$67.31^{b}\pm0.01$	$165.28^{c}\pm0.06$
MFLB	$187.49^{b}\pm0.24$	$243.29^{b}\pm0.05$	$67.55^{c}\pm0.04$	$11.68^{b}\pm0.08$	$7.26^{c}\pm0.03$	$66.12^{c}\pm0.03$	$175.67^{b}\pm0.07$
MSLB	$189.16^{a}\pm0.05$	$246.49^{a}\pm0.04$	$68.29^{b}\pm0.02$	$10.86^{d}\pm0.01$	$7.67^{b}\pm0.02$	$65.43^{d}\pm0.01$	$178.26^{a}\pm0.033$
MTLB	$168.55^{d}\pm0.01$	$240.56^{c}\pm0.01$	$88.92^{a}\pm0.05$	$16.94^{a}\pm0.03$	$9.86^{a}\pm0.01$	$54.16^{e}\pm0.02$	$151.63^{e}\pm0.01$

Values are Mean ± Standard deviation of duplicate determination
Values with same superscript along the column are not statistically significant P < 0.05 different
MF (100% Maize flour+0% Locust bean seeds flour),
MULB (98.39%Maize flour + 21.61% Unfermented Locust bean seeds flour)
MFLB (79.41%Maize flour + 20.59% Fermented locust bean seeds flour)
MSLB (78.79% maize flour + 21.21% Sprouted locust bean seeds flour)
MTLB (82.05% maize flour+ 17.95% Toasted Locust bean seeds flour)

The final viscosity ranged from 207.29-246.49 RVU. The control sample (100% maize flour) had the lowest final viscosity while the sample with sprouted African locust bean seed flour inclusion had highest final viscosity. The setback ranged was 54.65-88.92 RVU. with inclusion of treated African locust bean seed flour in the blends. Final viscosity is the viscosity used in determining the quality of starch-based flour; it is used in indicating the ability of the flour to form a viscous paste after cooking and cooling. This viscosity is also used to measure the degree to which the paste can resist shear force during stirring (Atinuke, 2015). The final viscosity value, obtained in this study agreed with 230.3-240 range reported by Yusufu & Alexander, (2022) for rice and African yam bean composite flour and lower than the values (302.33–533.08) reported by Ezeocha et al. (2023) for rice and pigeon pea composite flour. This variation in final viscosity can be attributed to the starch content of the samples because a high value of final viscosity indicates aggregation of amylase, and a low final viscosity indicates a paste resistance to shear stress during stirring (Asaam et al., 2018). The final viscosity of the flour samples was significantly ($p<0.05$) different from each other. The results show that the inclusion of treated African locust bean seed flour resulted to higher final viscosity as compared to maize flour indicating that the flour blends have good thickening ability to produce viscous gelling consistency in porridge. Therefore, there is an indication that maize and treated African locust bean seed flour blends porridge have the ability to resist shear stress during stirring and has a better ability to form viscous paste after cooking and cooling.

Setback viscosity is an indicator of the retrogradation tendency of a paste made from starchy food. It indicates the tendency of starch granules to retrograde after gelatinization and cooling and is calculated by subtracting trough viscosity from final viscosity (Shafie et al., 2016). The higher the setback viscosity, the lower the retrogradation of the flour paste during cooling and the lower the stalling rate of the products made from the flour (Iwe et al., 2016). The result of setback viscosity obtained in this study showed a general increase with an inclusion of treated African locust bean seed flour in the blends. The result agreed with

the report of Yusufu & Alexander's (2022) who reported setback viscosity range of 60.1–88.9 rvu in rice and African yam bean composite masa. The low setback viscosity of the control sample (100% maize flour) as compared to the significant increase with inclusion of treated African locust bean seed flour could be due to the effect of heat, enzymatic activity, sprouting, and fermentation of starch (Iwe et al., 2016).

The breakdown viscosity significantly ($p<0.05$) differed among the samples with inclusion of treated African locust bean seed flour and ranged from 9.85 to 16.94 RVU. The control sample (100% maize flour) had the lowest breakthrough viscosity, while sample the sample with toasted African locust bean seed flour inclusion (MTLB) had the highest break down viscosity. The breakdown viscosity of flour is defined as the degree of starch granule disintegration or its paste stability during heating (Asaam et al., 2018). Research carried out by Inyang & Nwabueze, (2020) had earlier reported that high breakdown viscosity indicates a lesser ability of a sample to withstand heating and shear stress during cooking. The breakdown viscosity obtained in this study showed that the flour blends samples had higher breakdown viscosity compared to the 100% maize flour sample. This implies that the gelling stability decreased as the inclusion of treated African locust bean seed flour in the blends. This means that the flour blends sample will be highly resistant to heat and shear stress during cooking. The result of break down viscosity contradicts the report of breakdown viscosity of 11.6-16.9 rvu reported by Yusufu & Alexander, (2022) for rice and African yam bean composite masa. The breakdown viscosity result is also slightly lower than the breakdown viscosity values (14-22) rvu reported by Arise et al., (2018), where maize was incorporated in Bambara groundnut flour. The variation in raw materials used in flour blends preparation could account for the difference in result.

The pasting time increased significantly ($p<0.05$) from 6.44 to 9.86 minutes with the inclusion of treated African locust bean flour in the blends. Pasting time is the total time taken by each sample blend to attain its respective peak viscosity (Asaam et al., 2018). The result of `pasting time obtained by this study is in agreement with the pasting time (6.0–9.8 min) reported by Yusufu & Alexander, (2022) for rice and African yam bean composite masa and the 5.1–5.9 min reported by Iwe et al. (2016). The result showed an increase in pasting time with inclusion of treated African locust beans seed flour in maize flour for *ogi* preparation.

The pasting temperature decreased significantly ($p<0.05$) with inclusion of African locust bean seed flour in the blends. Pasting time is the total time taken by each sample blend to attain its respective peak viscosity (Asaam et al., 2018). The pasting temperature ranged from 54.16 to 68.42 °C with the control sample (100% maize flour) and the sample with toasted African locust bean seed flour inclusion (MTLB) having the lowest pasting temperature respectively. Pasting temperature is a parameter that indicates the minimum temperature required for flour to cook completely and gives an overall idea of the energy cost involved (Asaam et al., 2018). The result obtained in this study showed that there was a decrease in pasting temperatures with inclusion of treated African locust beans seed flour in maize flour. The study showed low pasting temperature as compared to the report of Arise et al., 2018 but consistent with the report of Yusufu and Alexander 2022. There was` a significant difference ($P<0.05$) between the samples; however, the pasting temperature of all the samples is lower than the boiling point of water (100 ºC), which shows that they can form a paste in hot water below the boiling point.

The trough ranged from 151.63 to 178.26 RVU. The sample with toasted African locust bean seed flour inclusion had the least Trough as compared to the control sample. Trough viscosity is defined as the minimum viscosity value in the constant temperature phase of the RVA profile, which measures the ability of a paste to withstand breakdown during cooling (Iwe et al. 2016). The paste viscosity increased with inclusion of treated African locust beans flour in the blends except for the sample with toasted African locust beans flour inclusion. This indicates that both the control sample and the composite blends have a high holding period and can withstand high heat treatment during processing, and it agrees with the trend observed by Yusufu & Alexander, (2022) and slightly lower than the Trough values (158–358 RVU) recorded by Ezeocha et al., (2023) for rice and pigeon pea composite.

Effect of treatments on African locust bean seed inclusion on the proximate content of yellow maize based *Ogi*: The proximate composition of maize and locust bean seed composite flour is presented in Table 4. The inclusion of treated African locust beans flour in maize-based *ogi* had significant ($p<0.05$) effect on the proximate parameters analyzed. The moisture, protein, fat, ash and fibre content significantly ($p<0.05$) increased with inclusion of treated African locust bean seed flour in maize-based Ogi. The moisture, protein, fat, ash and fibre ranged from 6.02-7.04%,9.28-16.42%, 1.83-3.62%,4.73- 8.82% and 1.56 – 3.76 respectively. The carbohydrate decreased significantly ($p<0.05$) with the inclusion of treated locust bean seed flour in maize-based *Ogi.* The carbohydrate content ranged from 61.08 to -76.59%.

The moisture content increased with the inclusion of treated African locust bean seed flour in the blends. The increased in moisture content could be due to the increased in hydrophilic properties of the fibre in treated African locust bean seed. Moisture content is a critical indicator of product shelf-life stability, the lower the moisture content, the better the shelf-life stability (Ayougu et al., 2016). The moisture content is in agreement with the 5.99–7.00 range reported by Bolarinwa et al. (2015) in malted sorghum-soy composite flour and moisture content (4.78–7.84%)) for rice-pigeon pea composite flours (Ezeocha et al., 2023). However, the moisture content reported by this study was lower than the 9.28–12.37% for maize-*ogi* almond flour blends (Ogunjemilusi et al. 2023). The low moisture content of flour blends implies good storage stability since moisture content of ≤ 10% ensures shelf-life stability (Blessing, 2014).

The crude protein result showed a significant ($p<0.05$) increase with the addition of treated African locust beans locust bean seed flour. The result agreed with the protein content (7.84–16.84%) for sorghum and African yam bean flour blends reported by Okoye et al. (2017) and protein content of 6.97–20.09% reported by Ezeocha et al. (2023). The crude protein content of maize flour was the least while the blends with treated locust beans seed flour inclusion had higher protein contents. This showed that the addition of locust treated locust beans seed flour increased protein content of the composite flours. This is probably due to superior protein content of locust beans seed flour as compared to maize flour. Treated locust beans seed flour could be used as an alternative source of protein in the protein diet supplement, especially in a country like Nigeria where the majority of the populace depends on staple foods (Yahaya et al., 2018).

The fat content of the blends increased with the inclusion of treated African locust bean seed. The fat content reported by this study is slightly below the 3.70–5.00% reported by Arise et al. (2018) in maize and Bambara groundnut flour

Table 4. Proximate Composition (%) of yellow maize and locust bean seeds flour blends

Samples	Moisture	Protein	Fat	Fibre	Ash	Carbohydrate
MF	6.02[d]±0.02	9.28[d]±0.01	1.83[e]±0.03	1.56[e]±0.58	4.73[e]±0.03	76.59[a]±0.61
MULB	6.61[b]±0.01	16.02[c]±0.05	2.82[c]±0.03	2.84[c]±0.02	6.97[c]±0.03	64.76[c]±0.13
MFLB	7.04[a]±0.05	16.21[b]±0.12	3.37[b]±0.02	2.94[b]±0.04	7.67[b]±0.02	62.80[d]±0.25
MSLB	6.60[b]±0.01	16.17[b]±0.02	3.62[a]±0.31	3.72[a]±0.03	8.82[a]±0.03	61.08[e]±0.34
MTLB	6.30[c]±0.35	16.42[a]±0.01	2.22[d]±0.02	2.48[d]±0.02	5.67[d]±0.03	66.29[b]±0.12

Values are Mean ± Standard deviation of duplicate determination
Values with same superscript along the column are not statistically significant P < 0.05 different
MF (100% Maize flour+0% Locust bean seeds flour),
MULB (98.39%Maize flour + 21.61% Unfermented Locust bean seeds flour)
MFLB (79.41%Maize flour + 20.59% Fermented locust bean seeds flour)
MSLB (78.79% maize flour + 21.21% Sprouted locust bean seeds flour)
MTLB (82.05% maize flour+ 17.95% Toasted Locust bean seeds flour

blends and the 2.49–9.6 reported for malted sorghum-soy reported by Bolarinwa et al., (2015). The variation in raw materials used in flour blends preparation could account for the difference in result. Fat is a concentrated form of energy. It is very essential in an infant's diet because it supplies essential fatty acids (linoleic acid (LA), alpha-linolenic (ALA), docoxahexanoic acid (DHA), and arachidonic acid (ARA)) and enables absorption of fat-soluble vitamins. Fats provide energy to the liver, muscles, heart, and brain. The recommended intakes of fat for infants aged 0–6 months and 7–12 months are 31 and 30 grams, respectively (Wong, 2016). The low-fat content reported by this study mplies that the flour cannot be vulnerable to oxidative rancidity (Tenagashaw et al., 2015).

Crude fiber, which comprised of indigestible carbohydrates such as cellulose, hemicellulose, pectin, and lignin, reduces the rate of release of glucose into the bloodstream and also reduces inter-colonic pressure, thereby reducing the risk of colon cancer (Awuchi, 2019). The fiber content of the maize and locust bean seed flour blends increased significantly (p<0.05) with inclusion of treated African locust beans flour. The result agreed with the fiber content (3.64–4.50%) in malted sorghum-soy reported by Bolarinwa et al. (2015) but slightly higher than the fiber content of 2.35-2.97% for maize-Bambara flour blends (Arise et al. (2018) and the fiber value (0.85–1.7%) for rice-pigeon-base breakfast cereal (Ezeocha et al., 2023). The increase in the fiber content is an indication that the product from this blend can be good source of fibre which facilitate bowel movement, and hence prevent gastro-intestinal diseases in men and reduce the rate of excess release of glucose into the bloodstream.

It was observed that the inclusion treated African locust beans flour in maize flour significantly (p<0.05) increased the ash content. The ash content reported by this study is lower than the ash content 5.03-9.87 reported by Ezeocha et al. (2023) for Rice-Pigeon-based breakfast cereal. The significant increase in ash content could be attributed to the fact that locust bean seed is a rich source of minerals. The ash content of a product indicates a rough estimate of its mineral content. (Adelekan et al., 2019). Minerals are essential micronutrients that serve a variety of essential functions in metabolism and are among the parts of biomolecules such as hemoglobin, deoxyribonucleic acid (DNA), and adenosine triphosphate (ATP) (Awuchi, 2019).

There was significant (p<0.05) decrease in carbohydrates with the inclusion of treated African locust bean seed flour. This signified that the addition of treated African locust bean seed resulted in a decrease in the carbohydrate content of the blends. The result agreed with the 51.27-73.12% for maize-Bambara flour blends (Arise et al., 2018) and the (51.83-72.73%) for wheat and groundnut protein concentrate flour blends (Ocheme et al., 2018). However, the carbohydrate content reported by this study was slightly lower than the carbohydrate values (68.15–81.22%) reported in rice-pigeon pea composite flour (Ezeocha et al., 2023).

Effect of treatments on African locust bean seed inclusion on the sensory attributes of yellow maize based *Ogi*: The sensory quality attributes of maize and African locust beans seeds flour blends is presented in Table 4. The appearance and taste significantly (p<0.05) decreased with the inclusion of African locust beans seed flour in the formulation. The appearance and taste ranged from 4.19 -8.05 and 2.1-7.14 respectively. Except for the sample with toasted African locust beans seed flour inclusion, the mouthfeel, aroma and general acceptability of the *Ogi* significantly ($p<0.05$) decreased with the inclusion of treated African locust beans seed flour. The mouthfeel, aroma and general acceptability ranged from 2.23 – 7.11, 2.02-8.18 and 2.10-8.25 respectively.

The appearance score of the control (100% maize flour) was better than those of the flour blends. The significant ($p<0.05$) decrease in appearance with inclusion of treated African locust beans flour could be attributed to African locust beans. This result agreed with that reported by Samuel et al. (2024) who reported high appearance rating in maize flour which decreased with inclusion of mushroom flour in maize flour. Factors that can affect the appearance of the composite diets include the chemical composition of the flours, the drying temperature and duration, and the proportions or ratio of ingredients: maize and treated African locust beans four. Low appearance ratings of weaning foods can decrease the acceptability as appearance is an important organoleptic attribute which enhances the product acceptability.

Taste is one of the sensory attributes that involves the use of the taste buds to determine food preferences. The result indicates higher mean scores for the control sample (100% maize flour). Among the samples with treated African locust bean seed flour inclusion, the sample with toasted and unfermented locust bean seed flour was best rated. Low sensory rating of the sample with fermented and sprouted locust bean seed flour inclusion suggests sprouting and fermentation had effects on the taste of the flour blends. Toddlers and pre-school children are likely to prefer flavoured foods therefore, to further improve the taste ratings; flavour or flavour enhancer might need to be incorporated into the formulated samples.

Mouth feel is a characteristic or distinct ogi sensory attribute. The result of mouthfeel indicates higher value for the sample with toasted locust bean seed flour inclusion. This implies that toasted locust bean seed inclusion did not have effect on the mouthfeel of maize flour while the samples with fermented and sprouted African locust beans flour decreased the mouthfeel of Ogi samples. The difference may be due to inclusion of fermented and sprouted African locust beans flour which probably reduced the sour taste in *ogi*. Ajala and (2018) reported similar result in his work on supplementation of Ogi with mushroom flour.

The aroma and general acceptability of the control sample and the sample with toasted, unfermented African locust bean seed flour inclusion had sensory scores ranging from like slightly to like very much while the samples with inclusion of fermented and sprouted locust beans flour had scores rating from dislike very much to dislike moderately. This implies that the fermented and sprouted flour inclusion had effect on the aroma and general acceptability of the blended fours. Aroma is very important in food as it influences the acceptance of food before they are consumed. The factors affecting the general acceptability are the flavour, taste, colour and texture of the diets. The study showed that acceptable maize and African locust bean seed flour blends can be produced from maize, toasted and unfermented African locust beans flour.

Table 5. Sensory Evaluation of *Ogi* from the blends of yellow maize and locust bean seeds flour

Samples	Appearance	Taste	Mouthfel	Aroma	Acceptability
MF	$8.05^{a}\pm0.48$	$7.14^{a}\pm59$	$7.04^{b}\pm0.79$	$7.32^{b}\pm0.41$	$8.21^{a}\pm0.25$
MULB	$6.03^{c}\pm0.57$	$6.15^{b}\pm0.88$	$6.18^{c}\pm0.47$	$6.21^{c}\pm0.66$	$7.09^{b}\pm0.48$
MFLB	$4.19^{e}\pm0.82$	$2.11^{d}\pm0.57$	$2.23^{e}\pm0.47$	$2.00^{e}\pm0.07$	$2.10^{d}\pm0.33$
MSLB	$5.02^{d}\pm0.17$	$3.17^{c}\pm0.00$	$3.05^{d}\pm0.73$	$3.33^{d}\pm0.64$	$3.23^{c}\pm0.72$
MTLB	$7.01^{b}\pm0.75$	$7.05^{a}\pm0.64$	$7.11^{a}\pm0.62$	$8.18^{a}\pm0.68$	$8.25^{a}\pm0.52$

Values are Mean ± Standard deviation of duplicate determination
Values with same superscript along the column are not statistically significant P < 0.05 different
MF (100% Maize flour+0% Locust bean seeds flour),
MULB (98.39%Maize flour + 21.61% Unfermented Locust bean seeds flour)
MFLB (79.41%Maize flour + 20.59% Fermented locust bean seeds flour)
MSLB (78.79% maize flour + 21.21% Sprouted locust bean seeds flour)
MTLB (82.05% maize flour+ 17.95% Toasted Locust bean seeds flour)

4. CONCLUSION

The study showed that the inclusion of treated locust bens flour in maize-based ogi had effect on functional and pasting properties of the flours. The study also showed that treated locust beans seed flour in maize based *ogi* improved the nutritional content of maize based *ogi* meeting the 16% level protein for complementary food, However the general acceptability of fermented and sprouted African locust beans flour was poorly rated suggesting further treatment for improved sensory attributes. The study established that nutritional high-quality product can be produced from blends of Yellow maize and treated African locust beans flour (toasted and unfermented).

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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