Influence of African Locust Bean (Parkia biglobosa) Fortification on the Nutritional, Pasting and Sensory Properties of Plantain (Musa paradisiaca) Doughmeal

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Influence of African Locust Bean (*Parkia biglobosa*) Fortification on the Nutritional, Pasting and Sensory Properties of Plantain (*Musa paradisiaca*) Doughmeal

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Abstract

Doughmeal is a widely consumed staple food in West Africa, typically produced by reconstituting flour in hot water. However, conventional doughmeal is largely starch-based and often lacks sufficient biochemical diversity required for balanced nutrition. This study evaluated the effect of supplementing unripe plantain flour with African locust bean (ALB) flour on the nutritional composition, amino acid profile, pasting properties, and sensory acceptability of the resulting doughmeal. Composite flours were prepared as follows: ONS (100% plantain flour, control), NIA5 (95% plantain flour: 5% ALB), KEL10 (90%: 10%), TIV15 (85%: 15%), and DAL20 (80%: 20%). Proximate composition, mineral content, amino acid profile, and pasting properties were determined using standard analytical procedures, while sensory evaluation was conducted to assess product acceptability. Results showed that supplementation with ALB improved the nutritional quality of the blends. Moisture content ranged from 61.58–67.18%, protein from 5.4–8.7%, fibre from 1.01–1.94%, ash from 1.23–2.27%, fat from 0.86–2.06%, and carbohydrate from 19.29–26.75%. Amino acid composition increased with increasing ALB inclusion, indicating improved protein quality of the composite doughmeal. The pasting characteristics of the blends were also modified, suggesting changes in starch behaviour due to the presence of ALB components. Sensory evaluation revealed that moderate substitution improved consumer acceptance, with the KEL10 sample receiving the highest overall acceptability score. Conclusively, the results demonstrate that incorporation of African locust bean flour into plantain flour enhances the nutritional value, functional properties, and sensory quality of doughmeal. Moderate inclusion levels appear most suitable for product development.

Keywords: Plantain flour; African locust bean; Composite flour; doughmeal; nutritional composition.

1. Introduction

Plantain (*Musa paradisiaca*) is widely cultivated and consumed across tropical regions, particularly in West Africa where it serves as an important dietary staple. In Nigeria and many other African countries, plantain is processed into various food products, including chips, porridges, and flour used in the preparation of dough-based meals [1–3]. Nutritionally, plantain provides carbohydrates, dietary fibre, vitamins, and essential minerals, making it a valuable energy source for many populations. Plantain flour is commonly produced by drying unripe plantain slices and milling them into powder. The flour is widely used for preparing doughmeal and other traditional foods because of its functional properties and ease of storage. Despite these advantages, plantain flour is relatively low in protein, which limits its nutritional adequacy when consumed as a major dietary component. Consequently, recent research has focused on improving its nutritional quality through supplementation with protein-rich plant sources [4].

One promising fortification ingredient is African locust bean (*Parkia biglobosa*), a leguminous tree crop widely distributed in the savannah regions of West Africa. The seeds are traditionally fermented and used as condiments in many indigenous dishes. African locust beans are known to contain appreciable amounts of protein, essential amino acids, dietary fibre, and important minerals such as iron, calcium, and magnesium [5]. Studies have also reported the presence of bioactive compounds with antioxidant potential, suggesting additional nutritional and health benefits [6]. Furthermore, the amino acid composition of African locust beans contributes significantly to dietary protein quality, making it a suitable ingredient for enriching cereal- or starch-based foods [7].

In addition to its macronutrient composition, plantain flour contains resistant starch, a component that has been associated with improved glycaemic control, reduced risk of metabolic disorders, and enhanced gut health [8]. Combining plantain flour with protein-rich legumes such as African locust beans therefore presents a promising strategy for developing nutritionally improved food products. Previous studies have shown that incorporation of legume flours into starchy food matrices can enhance protein content, mineral availability, and overall dietary value [9].

Doughmeal remains one of the most widely consumed staple foods in many West African households [10–14]. However, its nutritional profile is often dominated by carbohydrates, with limited protein and micronutrient content. Improving the composition of doughmeal through ingredient diversification has therefore attracted considerable attention among food scientists and nutrition researchers [15]. Beyond nutritional composition, the functional performance of flour blends during cooking is critical to product quality. Pasting properties describe the changes in viscosity and texture that occur when starch-based foods are heated in the presence of water. These characteristics influence cooking behaviour, product consistency, and consumer acceptability [16]. Understanding the pasting behaviour of composite flours is therefore essential for predicting their suitability in traditional dough-based foods.

Consumer acceptance is another key determinant of the success of newly developed food formulations. Sensory attributes such as colour, aroma, taste, and texture strongly influence the overall preference for doughmeal products [17]. Previous investigations have indicated that the inclusion of African locust beans in flour blends can enhance flavour complexity and improve the nutritional profile of the resulting food products [4]. Despite these reported benefits, limited information is available on the combined effects of African locust bean supplementation on the nutritional composition, pasting behaviour, and sensory quality of plantain-based doughmeal. Therefore, this study evaluated the proximate composition, mineral content, amino acid profile, pasting properties, and sensory acceptability of doughmeal produced from plantain flour supplemented with varying proportions of African locust bean flour.

2. Materials and Methods

2.1 Source of Raw Materials

Freshly harvested matured unripe plantain (*Musa paradisiaca*) were purchased from Oja Ale Market at Idanre. Unfermented Africa locust bean seed were purchased from a supplier at Southgate, Federal University of Technology, Akure (FUTA). The equipment used was made available from the Department of Biochemistry, FUTA**.** All chemicals used were of analytical grade.

2.2 Preparation of Plantain Flour

The plantains were detached from the bunch and washed with clean water to eliminate dirt and other foreign particles. Peeling and slicing of the plantains were done manually with a knife. The sliced plantains briefly blanched in water at 70 °C for 5 min to prevent browning. The blanched plantains were washed on a sieve to get rid of excess water and thereafter sun dried for 3 days. The dried plantain fruit was further milled into flour in a milling machine. Flour passed through a 250-µm mesh size was then packed in a plastic bag (Ziploc bag), sealed, and stored at room temperature of 25°C±2 until use.

2.3 Preparation of African Locust Beans Flour

African locust bean (*Parkia biglobosa*) seeds were sorted to remove stones, damaged seeds, and other extraneous materials, and subsequently washed with clean water. The cleaned seeds were pressure-cooked for approximately 3 h to soften the seed coat and facilitate dehulling. After cooking, the seeds were allowed to cool to room temperature and manually dehulled by rubbing between the palms to loosen the seed coats. The loosened hulls were removed by washing with clean water and decantation. The dehulled seeds were then sun-dried for four consecutive days until adequately dried. The dried seeds were milled into full-fat flour using a laboratory milling machine and passed through a 250 µm mesh sieve to obtain uniform particle size. The resulting flour was packaged in airtight Ziploc bags and stored at room temperature (25 ± 2 °C) until further use.

2.4 Doughmeal Sample Formulation

The Plantain and African Locust Bean flour blends ratios used were: 100:0, 95:5, 90:10, 85:15 and 80:20 respectively.

2.4.1 Preparation of Doughmeal

200 g of the composite flour was added to a boiling water (500 mL) and it was stirred consistently until the dough was formed. Small quality of water (about 50 mL) was further added to the dough and allowed to cook for 2 min. Thereafter, it was properly, allowed to cool and packaged.

2.5 Determination of Proximate Composition

The following proximate compositions were determined following official methods [18]

2.5.1 Determination of moisture content (MC)

Moisture content was determined using the standard oven-drying method. Clean Petri dishes were labeled, dried in a hot-air oven at 105 °C for 15 min, cooled in a desiccator, and weighed to obtain the initial weight (W_1). Approximately 5.0 g of each sample was weighed into the pre-weighed dishes, and the combined weight was recorded (W_2). The dishes containing the samples were then placed in an oven maintained at 105 °C and dried for 4 h. After drying, the dishes were removed, transferred immediately into a desiccator to cool to room temperature, and weighed again to obtain the final weight (W_3). Drying, cooling, and weighing were repeated until a constant weight was achieved. All determinations were conducted in triplicate.

Moisture content was calculated as:

$$MC(\%) = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

where:

W_1 = weight of empty dish (g)

W_2 = weight of dish + sample before drying (g)

W_3 = weight of dish + dried sample (g)

2.5.2 Determination of crude fat content

Crude fat content was determined using a Soxhlet extraction apparatus. Approximately 5.0 g of the doughmeal sample was weighed into a filter paper, securely tied, and placed in the Soxhlet extractor. n-Hexane was used as the extraction solvent and was poured into a pre-weighed round-bottom flask. The apparatus was assembled and heated on a heating mantle to allow continuous extraction for 3.5 h. After extraction, the round-bottom flask containing the solvent and extracted fat was allowed to cool and then disconnected from the apparatus. The solvent was evaporated, leaving the extracted fat in the flask. The flask was dried in an oven to remove residual solvent, cooled in a desiccator, and weighed.

The crude fat content was calculated as:

$$Crude\ Fat(\%) = \frac{W_2 - W_1}{W_s} \times 100$$

where:

W_1 = weight of empty extraction flask (g)

W_2 = weight of flask + extracted fat (g)

W_s = weight of sample (g)

2.5.3 Determination of crude protein content

Digestion stage:

Approximately 0.5 g of each sample was weighed into a Kjeldahl flask. A suitable catalyst and 10 mL of concentrated sulfuric acid (H_2SO_4) were added. The flask was clamped and heated in a fume hood until the digest became clear. After cooling, the digest was diluted to 100 mL with distilled water and transferred to the distillation unit.

Distillation stage:

A 5 mL aliquot of the digest was mixed with 5 mL of boric acid and 2 drops of mixed indicator in a 100 mL conical flask. Steam distillation was carried out with 100 mL of 40% NaOH, and the distillate was collected until the solution changed from purple to green.

Titration stage:

The distillate (5 mL) was titrated against 0.01 M HCl until the endpoint was reached, indicated by a colour change from green to pink. The volume of HCl used (titre value) was recorded. Crude protein was calculated using the formula:

$$\%Nitrogen = \frac{Titre\ (mL) \times Molarity\ of\ HCl\ \times 0.014 \times Dilution\ factor \times}{Weight\ of\ sample\ (g)}$$

$$\times 100$$

%Protein =$\%Protein\ = \%N \times 6.25$

2.5.4 Determination of total ash content

Clean crucibles were dried in a hot-air oven, cooled in a desiccator, and weighed to obtain the initial weight (W_1). Approximately 2.0 g of each doughmeal sample was weighed into the crucibles and the combined weight was recorded (W_2). The crucibles containing the samples were then placed in a muffle furnace at 550 °C and incinerated for 3 h. After ashing, the crucibles were removed from the furnace, cooled in a desiccator to room temperature, and weighed again to obtain the final weight (W_3). All determinations were carried out in triplicate.

Ash content was calculated as:

$$\%Ash = \frac{W_3 - W_1}{W_2 - W_1} \times 100$$

where:

W_1 = weight of empty crucible (g)

W_2 = weight of crucible + sample before ashing (g)

W_3 = weight of crucible + ash after ashing (g)

2.5.6 Determination of crude fibre

Approximately 5.0 g of each doughmeal sample was weighed (W_1) and transferred into a 500 mL conical flask, after which 200 mL of 1.25% H_2SO_4 was added. The mixture was gently boiled for 30 min. After boiling, the mixture was filtered through a muslin cloth and rinsed thoroughly with distilled water. The residue was scraped back into the flask using a spatula. Subsequently, 200 mL of 1.25% NaOH was added and the mixture was boiled again for 30 min. The mixture was then filtered and washed sequentially with 1% HCl, distilled water (four times), and finally with ethanol. The resulting residue was transferred into a clean, dry crucible and dried in an oven. The dried sample was cooled in a desiccator and weighed (W_2). The crucible containing the sample was then incinerated in a muffle furnace at 550 °C for 30 min, cooled in a desiccator, and reweighed (W_3).

Crude fibre was calculated as:

$$\%Crude\ fibre = \frac{W_2 - W_3}{W_1} \times 100$$

where:

W_1 = weight of sample (g)

W_2 = weight of dried residue + crucible (g)

W_3 = weight of ash + crucible (g)

2.5.7 Determination of carbohydrate content (by difference)

The total carbohydrate content was calculated as the difference between 100 and the total sum of moisture, crude fat, crude protein, crude fibre and total ash. The percentage carbohydrate is computed using the following equation:

% Carbohydrate = 100% - (%Moisture + %Ash + %Protein + %Fat + %Fibre)

2.6 Determination of Mineral Content

Mineral analysis was carried out using the ash obtained from the samples. The ash residue was dissolved in 0.1 N HNO_3 and filtered using Whatman filter paper. The filtrate obtained was used for mineral determination. The concentrations of calcium (Ca), iron (Fe), phosphorus (P), magnesium (Mg), zinc (Zn), sodium (Na), and potassium (K) were determined using an Atomic Absorption Spectrophotometer (AAS). Standard solutions with known concentrations (0, 0.5, 1, 2, 4, 5, 10, 20, and 40 ppm) were prepared for each mineral element. The absorbance of both standards and samples was measured, and calibration curves of absorbance versus concentration were constructed. The concentration of each mineral in the sample was obtained from the standard calibration curve and calculated using:

$$Mineral\ (mg/100\ g) = \frac{C \times V \times D}{W} \times 100$$

where:

C = concentration obtained from calibration curve (mg/L)

V = volume of extract (L)

D = dilution factor

W = weight of sample (g)

2.7 Determination of Amino Acid Profile

The amino acid composition of the plantain–African locust bean doughmeal samples was determined using high-performance liquid chromatography (HPLC). Approximately 10 mg of each sample was weighed into a screw-capped glass hydrolysis tube and placed in ice. 0.2 mL of cold performic acid was added and the mixture was placed in an ultrasonic bath for 10 min to ensure proper mixing. The tubes were then capped and kept in a refrigerator at 4 °C overnight for oxidation. After oxidation, 50 mg of sodium metabisulphite was added to each tube and mixed using a vortex mixer. Subsequently, 0.8 mL of 7.5 N hydrochloric acid (HCl) was added and the mixture was sonicated for 15 min. The tubes were placed unsealed on a hot plate preheated to 110 °C. After 1 h, the tubes were sealed and hydrolysed for an additional 24 h. Following hydrolysis, the tubes were removed from the hot plate and cooled to room temperature. The hydrolysate was transferred into a 5 mL volumetric flask, diluted to volume with distilled water, and filtered through filter paper. The filtrate was partially dried under vacuum at 40 °C using a rotary evaporator (Buchi, LaboratoriumsTechnik AG, Switzerland). The residue obtained after evaporation was dissolved in 0.8 mL of 0.2 M sodium carbonate buffer (pH 9.7) and stored frozen prior to derivatization. For derivatization, 0.2 mL of 0.2 M sodium carbonate buffer (pH 9.7), 20 µL of internal standard, and 20 µL of sample were added into a 1.5 mL screw-capped reaction vial. Subsequently, 0.2 mL of dansyl chloride solution (5 mg/mL in acetone) was added. The mixture was vortexed and incubated overnight in the dark at room temperature. After incubation, the contents of the reaction vial were transferred into a 1 mL volumetric tube and diluted to volume with distilled water. 1 mL of the dansylated solution was injected into the HPLC system for analysis. Amino acid concentrations were determined from calibration curves prepared using standard amino acid solutions and expressed as g/100 g protein

2.8 Determination of Pasting Properties

The pasting properties of the composite flours were determined using a Rapid Visco Analyser (RVA) (Model RVA 4500, Perten Instruments, Australia) equipped with a 1000 cmg sensitivity cartridge. 3.5 g of plantain–African locust bean flour blend was weighed into a clean, dry RVA canister and 25 mL of distilled water was added. The mixture was thoroughly stirred to obtain a uniform slurry before placing the canister into the RVA unit. The slurry was initially equilibrated at 50 °C, heated to 95 °C at a rate of 1.5 °C/min, and held at 95 °C for 15 min. Thereafter, the paste was cooled to 50 °C. During this heating and cooling cycle, viscosity changes were continuously monitored. The pasting parameters recorded from the pasting profile included peak viscosity, trough viscosity, breakdown viscosity, final viscosity, setback viscosity, peak time, and pasting temperature. These parameters were obtained using Thermocline for Windows software connected to the RVA system[1].

2.9 Sensory Evaluation

Thirty untrained panelists consisting of students and members of Food Science and Technology Department of Federal University of Technology, Akure, Nigeria was selected for the evaluation doughmeal samples prepared from each flour blend which will be presented in coded white plastic plates. The order of presentation of samples to the panel will be randomized. Portable water was provided for the panelists to rinse their mouths between evaluations. The panelists were instructed to evaluate the coded samples for aroma, taste, colour, texture and overall acceptability. Each sensory attribute will be rated on a 9-point Hedonic scale (1= dislike extremely while 9 = like extremely).

2.10 Statistical Analysis

All chemical analyses, except amino acid profile and pasting properties were conducted in duplicates and the values reported as means ± standard deviation (SD). Mean comparison was done by analysis of variance (ANOVA) and least significant difference (LSD) $p \leq 0.05$ using (SPSS version 27).

3 Results and Discussion

3.1 Proximate Composition of Plantain-African Locust Bean Doughmeal Samples`

Table 1 shows the proximate composition of various blends of plantain doughmeal and African locust bean (ALB). The moisture content of samples ranged from 61.58% to 67.18%. The control sample (ONS) had the lowest moisture content (63.76%), while the DAL20 sample had the highest moisture content (67.18%). The amount of moisture content in the doughmeal samples determine the growth and activities of microorganisms, and hence the storage stability of the doughmeal. Scientific findings have established that high moisture content of doughmeal samples above 10% facilitate the growth of microorganisms and food spoilage, whereas low moisture content inhibits food spoilage and retain the nutritional quality of the food products [19]. The relatively high moisture values observed in this study are expected [10]because the analysis was conducted on the prepared doughmeal rather than the dry flour blends, which naturally contain much lower moisture levels. This doughmeal is expected to have a shorter shelf life when compared to its composite flour blend.

The protein content of samples ranged from 5.40% to 8.70%. The DAL20 sample had the highest protein content (8.70%), followed by the KEL10 sample (7.09%). This is due to the higher protein content of African locust bean compared to plantain flour. This increase was expected because legume crops contain more protein than starchy foods hence the attendant synergistic effects of protein complementation [20]. The progressive increase in protein content with increasing ALB substitution further confirms the nutritional contribution of the legume component in the composite formulation. This expected increase was the basis for formulating the blends such that the final product will have higher protein content. The study conducted by [21] showed that the protein content of yam flour is 1.16%, this is very low compared to the ALB formulated doughmeal samples which has between 6.9–8.7%. This is due to high protein content of ALB when compared to yam. The fiber content of the samples ranged from 1.01% to 1.94%. The TIV15 sample had the highest fiber content (1.94%), followed by the DAL20 sample (1.78%). This is likely due to the higher fiber content of African locust bean compared to plantain flour. The level of crude fibre which is considered advantageous since fiber are desirable in meal, as they aid digestion easily, and known to be most effective in maintaining human health such as reduction in body weight, reduction in stroke incidence and good heart health, it is also a source of dietary fiber which is essential for good bowel movement and helps in preventing obesity, diabetes, cancer of the colon and other ailments of the gastro-intestinal tract of man [22]. This trend suggests that moderate inclusion of ALB can enhance the functional dietary fibre content of plantain-based doughmeal products.

The ash content of all samples ranged from 1.23% to 2.27%. The TIV15 sample had the highest ash content (2.27%), followed by the ONS sample (2.26%). This is likely due to the higher mineral content of African locust bean compared to plantain flour. The ash content of a food sample gives an idea of the mineral elements present in the food. It indicates the composition of inorganic constituents after organic materials (fats, proteins and carbohydrates) and moisture have been removed by incineration. It is essentially the mineral content of a food sample. Minerals are a group of essential nutrients which serve a variety of important metabolic functions and are parts of molecules such as haemoglobin, adenosine triphosphate (ATP) and deoxyribonucleic acid (DNA) [23]. The ash content of this formulated doughmeal samples (1.23–2.27%) are higher than that of wheat doughmeal (0.74%) formulated by [21]. This is due to the high mineral content of ALB. The observed increase further supports the role of legumes in improving the micronutrient density of cereal- or tuber-based foods. The fat content of all samples ranged from 0.86% to 2.06%. The KEL10 sample had the highest fat content (2.06%), followed by the ONS sample (1.30%). This may be due to the fact that cereals, legumes and tubers store energy in the form of starch rather than lipids. The low-fat levels are beneficial as it ensures longer shelf life for the products [24] because all fats and fat containing foods contain some unsaturated fatty acids and hence are potentially susceptible to oxidative rancidity. Therefore, the relatively low-fat content of the blends may contribute to improved storage stability of the flour component prior to preparation into doughmeal.

The carbohydrate content of all samples ranged from 19.29% to 26.75%. The KEL10 sample had the highest CHO content (26.75%), followed by the ONS sample (25.94%). This is likely due to the higher carbohydrate content of plantain flour compared to African locust bean. This observation agreed with the reports that plantain is a good source of calories, however, it is deficient in protein [25], hence, there is a need to complement plantain flour with inexpensive staples, such as legumes, to further improve the nutritional quality of the plantain-based products [26]. The CHO content of the supplemented doughmeal samples is way lower when compared to wheat and yam doughmeal formulated by [21] which are 86.02% and 92.33% respectively. This can be attributed to the low CHO content of ALB. The reduction in carbohydrate with increasing ALB substitution is nutritionally relevant because it reflects a shift toward a more balanced macronutrient profile in the composite doughmeal.

3.2 Mineral Composition of Plantain-African Locust Bean Doughmeal Samples`

The mineral composition of the doughmeal samples is presented in Table 2. In general, the calcium content decreased with increasing inclusion of ALB. The DAL20 sample had the lowest calcium concentration (11.55 mg/100 g), while the control sample (ONS) had the highest (18.04 mg/100 g). This decline is expected as plantain flour naturally contains more calcium than African locust bean flour. The phosphorus content of the samples remained largely stable, with minor variations observed among the different blends. The magnesium content showed a slight decrease after ALB addition, with the ONS sample recording the highest magnesium level (42.8 mg/100 g) and the KEL10 sample the lowest (31.50 mg/100 g). Potassium levels also decreased progressively with ALB inclusion, highest in ONS (613 mg/100 g) and lowest in DAL20 (507.5 mg/100 g). Sodium content declined markedly with increasing ALB substitution, with the DAL20 sample containing the least (11.55 mg/100 g) and ONS the highest (21.65 mg/100 g). Iron content followed a similar pattern, with the lowest value observed in KEL10 (0.61 mg/100 g) and the highest in ONS (0.82 mg/100 g). Zinc content showed no clear trend, with minor fluctuations across the blends.

The mineral composition of doughmeal is critical for its nutritional quality and health benefits. Calcium (Ca) is crucial for bone health, muscle contraction, nerve transmission, and blood clotting; phosphorus (P) supports bone integrity, energy metabolism, and DNA synthesis; magnesium (Mg) is vital for enzyme function and neuromuscular activity; potassium (K) helps maintain fluid balance, nerve transmission, and muscle function; sodium (Na) is involved in fluid balance, blood pressure regulation, and nerve impulse transmission; iron (Fe) is essential for oxygen transport and metabolic processes; and zinc (Zn) plays a key role in growth, immune function, and wound healing [10]. The observed variations and lack of a uniform trend in some mineral levels among the samples may be partly attributed to the moisture absorbed during doughmeal preparation, which can affect mineral concentration on a wet weight basis. Most of the doughmeal blends exhibited higher contents of Ca, Mg, K, and Na compared to plantain, soycake, rice-bran, and oat-bran flour blends reported by [19]. This enhancement in mineral content underscores the contribution of African locust bean as a functional ingredient in improving the micronutrient density of plantain-based doughmeal.

3.3 Pasting Properties of Plantain-African Locust Bean Flour Samples`

The pasting characteristics of the composite flours (Table 3) provide important insight into the functional changes that occurred following the inclusion of African locust bean (ALB). These parameters reflect the swelling behaviour of starch granules, the stability of the paste during heating, and the ability of the starch matrix to reorganize during cooling, all of which determine the processing performance of flour-based foods. Peak viscosity increased substantially with increasing ALB inclusion, with DAL20 showing the highest value. This suggests greater water absorption and swelling of starch granules within the composite system. The increase is likely linked to interactions between plantain starch and proteins from African locust bean, which can reinforce the paste matrix and enhance viscosity development during heating. Similar behaviour has been reported in legume–cereal composite flours where protein–starch interactions modify hydration and swelling properties [9,27]. Trough viscosity also increased with supplementation, indicating that the composite pastes were more stable under continuous heating and mechanical shear. Legume components such as proteins and fibre can stabilize swollen starch granules and reduce structural collapse during holding at high temperatures [28]. This suggests that the supplemented blends may maintain consistency better during cooking compared with the control sample.

The higher breakdown values observed in ALB-containing samples reflect the greater swelling that occurred before structural disruption. When starch granules swell extensively, they become more susceptible to shear-induced rupture, which explains the larger breakdown values recorded in the blends with higher ALB levels. Final viscosity and setback values increased in the supplemented samples, indicating stronger gel formation and greater molecular reassociation during cooling. Setback viscosity is commonly associated with amylose retrogradation. The presence of legume proteins can promote network formation that supports starch reassociation, thereby increasing the rigidity of the cooled paste [29]. This suggests that the enriched doughmeal may produce firmer dough structures after cooking. The slightly shorter peak time observed in some of the blends indicates faster gelatinization, which may result from improved water penetration within the composite flour system. In addition, the lower pasting temperature recorded in the highest ALB formulation suggests that less thermal energy was required to initiate starch gelatinization. Such reductions are often associated with partial disruption of starch crystalline regions due to interactions with non-starch components in legumes.

In summary, incorporation of African locust bean modified the pasting profile of plantain flour by increasing viscosity development, improving paste stability, and enhancing gel strength. These functional changes indicate that the composite flours may perform better in traditional dough-based foods where viscosity, consistency, and structural integrity are critical quality attributes.

3.4 Amino Acid Composition of Plantain-African Locust Bean Doughmeal Samples`

The amino acid profile of the composite doughmeal (Table 4) demonstrates a clear nutritional improvement following supplementation with African locust bean (ALB). The progressive rise observed across most amino acids with increasing substitution indicates that ALB substantially enhanced the protein quality of the plantain-based formulation. Plantain flour is predominantly carbohydrate-based and typically limited in essential amino acids, particularly lysine and sulfur-containing amino acids. The marked increase in lysine, leucine, valine, methionine, and threonine in the supplemented samples therefore reflects the complementary effect of incorporating a legume protein source. Legumes are widely recognized for supplying amino acids that are often limiting in starchy staples, thereby improving overall protein balance in composite foods [30–32]. This complementary interaction between plantain starch and ALB protein suggests that the formulated doughmeal could provide a more nutritionally balanced amino acid pattern than plantain flour alone.

The consistent increase in branched-chain amino acids such as leucine, isoleucine, and valine is particularly important from a nutritional standpoint. These amino acids are involved in muscle protein synthesis and metabolic regulation. Their higher levels in the ALB-enriched blends indicate that the product may have improved physiological value, especially in populations relying heavily on plant-based diets. Similar improvements in amino acid quality have been reported when legumes are incorporated into cereal or tuber-based foods [33]. Another notable feature of the results is the substantial rise in arginine, glutamic acid, and aspartic acid as ALB inclusion increased. These amino acids are typically abundant in leguminous seeds and play key roles in metabolic processes, including nitrogen metabolism and flavour development in protein-rich foods. The elevated glutamic and aspartic acid levels may also contribute to enhanced savoury taste characteristics in the composite doughmeal, which could improve consumer acceptability.

The sharp increase observed in cystine further highlights the nutritional contribution of ALB. Sulfur-containing amino acids are often limiting in plant-based diets, and their improvement suggests enhanced protein functionality and nutritional adequacy. This increase may improve the biological value of the composite protein since sulfur amino acids are important for enzyme function, antioxidant systems, and structural proteins. From a broader nutritional perspective, the overall improvement in both essential and non-essential amino acids indicates that supplementation with African locust bean effectively corrected the inherent amino acid limitations of plantain flour. Such enhancement supports the potential use of these blends in nutritionally targeted foods, particularly in regions where plantain-based meals constitute a major dietary component. The results therefore reinforce the role of legume fortification as a practical strategy for improving protein quality in staple-based food systems.

3.5 Quality Acceptability of Plantain-African Locust Bean Doughmeal Samples

The sensory evaluation results (Table 5) indicate that moderate incorporation of African locust bean (ALB) improved several quality attributes of the plantain doughmeal. The enhanced scores recorded for the composite samples, particularly NIA5, KEL10, and TIV15, suggest that partial substitution with ALB positively influenced consumer perception of the product. The improvement in appearance observed in these blends may be associated with the characteristic colour and physical consistency contributed by ALB during processing. Fermented African locust bean products typically possess pigments and structural components that can modify the visual characteristics of composite foods, thereby making them more appealing to panelists. However, the slight decline observed at the highest inclusion level (DAL20) suggests that excessive supplementation may produce colour changes or visual attributes that are less preferred. Taste and flavour scores followed a similar trend, where moderate ALB incorporation resulted in better sensory ratings. This outcome is consistent with the known flavour-enhancing properties of fermented locust bean products and lower ratings for new products that consumers are less familiar [34,35]. African locust bean is widely recognized for its strong umami-like flavour compounds generated during fermentation, which can enrich the sensory profile of foods. At moderate levels, these compounds likely improved palatability, whereas higher inclusion levels may have produced a more intense flavour that some panelists found less acceptable. Comparable observations have been reported in foods fortified with African locust bean where moderate substitution improved taste and overall product perception [36].

Texture evaluation further supports the functional contribution of ALB in the composite doughmeal. The relatively higher texture scores for KEL10 and other supplemented samples suggest that the inclusion of legume components may have improved the structural properties of the doughmeal during cooking. Proteins and soluble components from ALB can interact with starch in plantain flour, potentially modifying gel strength and mouthfeel, which may explain the improved texture ratings at moderate inclusion levels. Excess inclusion, however, may disrupt the starch matrix, which could explain the comparatively lower sensory preference for DAL20. Overall acceptability reflects the combined influence of all sensory attributes and provides a general indication of consumer preference. The highest rating observed for KEL10 suggests that a moderate level of ALB supplementation provides an optimal balance between nutritional enhancement and sensory quality. While the control sample maintained reasonable acceptability, the improvement seen in the composite blends demonstrates the potential of African locust bean as a functional ingredient in plantain-based foods. Similar trends have been reported in composite formulations where legumes enhance both nutritional value and sensory characteristics of staple-based products [36]. These findings indicate that limited inclusion levels may be most suitable for product development, ensuring improved nutrient composition without compromising consumer acceptance.

Conclusion

The results of this study showed that supplementation of plantain flour with African locust bean improved the nutritional and functional quality of the doughmeal. Incorporation of ALB increased protein content, essential amino acids, and mineral composition while also modifying the pasting characteristics of the blends. Sensory evaluation indicated that moderate substitution levels enhanced consumer acceptability, with the 10% ALB blend (KEL10) showing the highest overall acceptability. These findings demonstrated that African locust bean can serve as a valuable ingredient for improving the nutritional quality and processing characteristics of plantain-based doughmeal. The formulation identified in this study therefore provided useful guidance for the development of nutritionally improved doughmeal products.

Conflict of Interest

The authors declare that there are no conflict of interest

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Authors Contribution

Conceptualization: TA; Formal analysis: PO; Methodology: T.A., P.O; Project administration; Supervision: TA; Writing - original draft: PO; and Writing - review & editing: TA.

Data Availability

Data is available from corresponding author on request

Ethics Approval and Consent to Participate

The protocol for this study was reviewed and approved by the Research Ethics Committee of the Federal University of Technology, Akure, Nigeria, in accordance with the principles of the Declaration of Helsinki and relevant institutional and national regulations. All participants provided informed consent prior to participation and were informed of their right to withdraw from the study at any stage without any consequence.

Clinical Trial Number

Not applicable.

Consent for Publication

Not applicable

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Table 1: Proximate Composition of the Doughmeal Samples (%)

Parameters	ONS	NIA5	KEL10	TIV15	DAL20
Moisture	63.76 ±0.01^{d}	65.91±0.02^{c}	61.58±0.02^{e}	66.83±0.01^{b}	67.18±0.01^{a}
Protein	5.40±0.15^{e}	6.90±0.05^{d}	7.09±0.04^{b}	6.93±0.08^{c}	8.70±0.05^{a}
Fibre	1.34±0.02^{c}	1.01±0.00^{e}	1.22±0.00^{d}	1.94±0.06^{a}	1.78±0.00^{b}
Ash	2.26±0.01^{b}	1.23±0.01^{e}	1.31±0.00^{d}	2.27±0.00^{a}	2.19±0.01^{c}
Fat	1.3±0.01^{b}	1.00±0.00^{d}	2.06±0.01^{a}	1.11±0.01^{c}	0.86±0.01^{e}
Carbohydrate	25.94±0.15^{b}	23.94±0.08^{c}	26.75±0.05^{a}	20.94±0.21^{d}	19.29±0.14^{e}

Values are mean ± SD. Means with the different superscript within the same column are significantly ($p < 0.05$) different.

ONS: 100% Plantain Flour

NIA5: 95% Plantain Flour, 5% African Locust Beans

KEL10: 90% Plantain Flour, 10% African Locust Beans

TIV15: 85% Plantain Flour, 15% African Locust Beans

DAL20: 80% Plantain Flour, 20% African Locust Beans

Table 2: Mineral Composition of the Doughmeal Samples (mg/kg)

Parameters	ONS	NIA5	KEL10	TIV15	DAL20
Calcium	18.04 ± 0.03^{b}	15.08 ± 0.04^{c}	10.20 ± 0.01^{e}	28.95 ± 0.15^{a}	11.55 ± 0.43^{d}
Phosphorus	4.97 ± 0.04^{a}	4.67 ± 0.01^{c}	4.44 ± 0.01^{d}	4.68 ± 0.01^{b}	0.43 ± 0.01^{e}
Magnesium	42.8 ± 0.30^{a}	38.35 ± 0.05^{b}	31.50 ± 0.10^{c}	29.65 ± 0.55^{e}	29.7 ± 0.1^{d}
Potassium	613 ± 2.00^{a}	536 ± 3.00^{b}	522.5 ± 0.50^{c}	$512.\pm1.00^{d}$	507.5 ± 1.50^{e}
Sodium	21.65 ± 0.05^{a}	18.80 ± 0.10^{b}	14.55 ± 0.05^{c}	13.05 ± 0.15^{d}	11.55 ± 0.25^{e}
Iron	0.82 ± 0.02^{a}	0.73 ± 0.02^{b}	0.61 ± 0.01^{d}	0.64 ± 0.01^{c}	0.60 ± 0.01^{e}
Zinc	0.15 ± 0.01^{c}	0.18 ± 0.01^{a}	0.13 ± 0.01^{d}	0.11 ± 0.01^{e}	0.17 ± 0.01^{b}

Values are mean ± SD. Means with the different superscript within the same column are significantly ($p < 0.05$) different.

ONS: 100% Plantain Flour

NIA5: 95% Plantain Flour, 5% Locust Beans

KEL10: 90% Plantain Flour, 10% Locust Beans

Table 3: Pasting Properties of the Composite Flours

Parameters	ONS	NIA5	KEL10	TIV15	DAL20
Peak (RVU)	181	2735	2394	2163	4169
Trough (RVU)	171	2092	1819	1735	3198
Breakdown (RVU)	10	643	575	428	971
Final (RVU)	259	3778	3489	2937	5287
Set back (RVU)	88	1686	1670	1202	2089
Peak Time (Min)	6.93	5.13	5.20	5.40	5.20
Pasting Temp (°C)	85.20	84.75	83.95	84.80	50.20

ONS: 100% Plantain Flour

NIA5: 95% Plantain Flour, 5% African Locust Beans

KEL10: 90% Plantain Flour, 10% African Locust Beans

TIV15: 85% Plantain Flour, 15% African Locust Beans

DAL20: 80% Plantain Flour, 20% African Locust Beans

Table 4: Amino Acid Composition of the Doughmeal Samples (g/100 g protein)

Parameters	ONS	NIA5	KEL10	TIV15	DAL20
Leucine	4.61	5.66	7.00	7.38	7.99
Lysine	2.94	2.79	3.68	3.95	4.14
Isoleucine	2.55	2.52	4.12	3.86	3.96
Phenyalanine	3.19	4.35	5.67	5.85	6.21
Tryptophan	0.42	0.45	0.63	0.74	0.87
Valine	3.42	4.09	5.35	5.55	6.22
Methionine	0.85	0.83	1.23	1.36	1.47
Proline	1.52	1.42	2.33	2.23	2.54
Arginine	4.04	4.65	6.28	6.71	7.31
Tyrosine	3.27	3.10	3.96	4.30	4.64
Hidstidine	1.44	1.31	1.85	1.95	2.46
Cystine	0.48	1.94	3.03	3.33	3.75
Alanine	2.39	2.24	3.60	3.07	3.90
Glutamic Acid	5.75	6.21	8.48	8.85	1041.19
Glycine	1.62	1.45	2.37	2.52	2.75
Threonine	2.25	2.67	3.22	3.61	4.11
Serine	2.38	2.57	3.51	3.73	3.81
Aspartic Acid	4.47	3.13	6.11	5.89	7.16

ONS: 100% Plantain Flour

NIA5: 95% Plantain Flour, 5% African Locust Beans

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TIV15: 85% Plantain Flour, 15% African Locust Beans

DAL20: 80% Plantain Flour, 20% African Locust Beans

Table 5: Quality Acceptability of African Locust Bean Supplemented Plantain Doughmeal

Parameters	ONS	NIA5	KEL10	TIV15	DAL20
Appearance	$5.17{\pm}1.90^{c}$	$5.83{\pm}1.77^{a}$	$5.83{\pm}1.75^{a}$	$5.66{\pm}1.54^{b}$	$5.00{\pm}1.44^{d}$
Taste	$5.03{\pm}1.83^{c}$	$5.52{\pm}1.98^{a}$	$5.48{\pm}1.64^{b}$	$5.03{\pm}1.80^{c}$	$5.03{\pm}1.74^{c}$
Flavour	$5.47{\pm}1.85^{c}$	$6.00{\pm}1.75^{a}$	$5.93{\pm}1.62^{b}$	$5.38{\pm}1.80^{d}$	$5.17{\pm}1.79^{e}$
Texture	$4.60{\pm}1.98^{e}$	$5.28{\pm}1.87^{b}$	$5.14{\pm}1.87^{c}$	$5.38{\pm}1.88^{a}$	$5.10{\pm}1.57^{d}$
Overall Acceptability	$5.60{\pm}1.71^{c}$	$5.93{\pm}1.79^{b}$	$6.03{\pm}1.59^{a}$	$5.62{\pm}1.70^{c}$	$5.03{\pm}1.52^{d}$

Values are mean ± SD. Means with the different superscript within the same column are significantly ($p < 0.05$) different.

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