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Research Article

Nutrient, Physical and Organoleptic Characteristics of Wheat-Unpeeled Plantain Composite Flour Bread Fortified with Prawn Powder

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Abstract

This was aimed to produce and evaluate the nutrient, physical and organoleptic properties of wheat-unpeeled plantain composite flour bread fortified with prawn powder. The raw materials were procured at Relief Market, Owerri, Imo State, Nigeria and unpeeled plantain and prawn were processed to flour/powder. The proximate composition of the bread samples had moisture content ranged from 38.77-41.27%, dry matter: 58.73-61.23%, ash: 2.19-2.61%, crude protein: 9.49-10.79%, crude fibre: 1.62-1.87%, fat: 9.27-15.27%, carbohydrate: 29.95-36.74% and energy value: 267.47-304.99 (kcal/100g). The mineral compositions had sodium: 168.41-184.78 mg/100 g, phosphorus: 123.63-136.77 mg/100 g, iron: 1.44-1.81 mg/100 g and magnesium: 75.38-89.66 mg/100 g. The physical properties had specific volume: 1.026-2.156 cm^3/g, loaf volume: 300-600 cm^3, loaf weight: 2726.92-3170.28 N, bread thickness: 39.37-55.69 mm, loaf length: 151.73-174.68, width: 80.79-87.60 mm, bread density: 0.46-0.97 g/cm^3, bread mass: 278.07-323.28 g, crust colour: 1606-1783 pcu, spread ratio: 1.46-2.09, absorbance: 1.568-2.429, oven spring: 3.26-3.02 cm and baking loss: 8.00-11.04 g. The sensory result showed taste scores from 4.70-5.90, colour: 4.50-7.00, aroma: 5.10-5.90, texture: 5.60-6.80 and general acceptability: 5.10-6.30. The results collectively suggested that bread produced from 75% wheat flour, 20% unpeeled plantain flour, and 5% prawn powder provided the best balance between improved nutritional quality, retained minerals, desirable physical properties, and acceptable sensory attributes.

Keywords

Bread, Wheat (Triticum Aestivum L.), Plantain (Musa Paradisiaca), Prawn Powder

1. Introduction

Bread, a staple food globally, with significant production industry whereas in Nigeria, bread has gained widespread acceptance and most popular wheat-based product, consumed across all socio-economic classes and age groups. The versatility of bread production allows for the use of various flours,

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including wheat, plantain, and other composite flours. Consuming bread made from composite flours can have potential health benefits, including improved digestive health and reduced risk of chronic diseases. Similarly, the use of composite flours made from wheat, plantain, and other ingredients can improve the nutrient, physical and organoleptic properties of bread [23]. Wheat (*Triticum aestivum L.*) remains one of the most widely consumed grains in the world and a staple food in many cultures. It is a versatile crop that can be grown in a variety of environments and can be used to produce range of products, including bread, pasta, cakes, pastries etc., hence, good source of nutrients, including carbohydrates, fiber, and protein [16]. Additionally, wheat is also a major source of gluten, a protein that can cause adverse reactions in some individuals. Gluten is a major concern for individuals with celiac disease, a condition in which the immune system reacts to gluten and to address this concern, researchers have been exploring the use of composite flours made from wheat and other ingredients [24].

Plantain (*Musa paradisiaca*), a starchy fruit that is widely consumed in many parts of the world, particularly in tropical regions. Plantain is rich in carbohydrates, fiber, and other essential nutrients. Unpeeled plantain, in particular, has been shown to have several benefits, where its flour contains higher amounts of fiber and nutrients compared to peeled plantain flour [8]. Additionally, unpeeled plantain has been shown to have antioxidant and anti-inflammatory properties [2]. Despite its nutritional benefits, plantain is commonly peeled before processing and consumption, resulting in the loss of valuable nutrients. Studies have shown that plantain peel is rich in dietary fibre, phenolic compounds, antioxidants, and essential minerals, suggesting that the utilization of unpeeled plantain can enhance the nutritional quality of food products [29]. Prawn powder, produced from dried and milled prawns, is a nutrient-rich ingredient that provides high-quality protein, omega-3 fatty acids, essential amino acids, vitamins, and minerals such as calcium, phosphorus, iron, and zinc, making it an excellent fortifying ingredient for composite food formulations [9]. It has antioxidant and anti-inflammatory properties, which can help protect against chronic diseases such as heart disease, diabetes, and cancer and a versatile ingredient that can be used in a variety of food products. In Nigeria, prawn powder is not commonly used as an ingredient in food production [1]. The production of bread in Nigeria has been largely dependent on wheat flour, which is imported and expensive and has resulted in bread being a luxury food item for many Nigerians, particularly those in rural areas. Furthermore, wheat flour alone is low in essential nutrients, including fiber, protein, and micronutrients, which are essential for maintaining good health. In addition, the high glycemic index of wheat flour can lead to a rapid increase in blood sugar levels, which can be detrimental to health, particularly for individuals with diabetes. However, this study aimed to ascertain the nutrient, physical and organoleptic properties of bread made from wheat-unpeeled plantain composite flour fortified with prawn powder.

2. Source of Materials

The raw materials including Wheat (*Triticum aestivum*) flour, plantain (*Musa paradisiaca*) and prawn were procured at Relief Market, Owerri, Imo State, Nigeria.

2.1. Preparation of Unpeeled Plantain (Musa Paradisiaca) Flour

The production of unpeeled plantain flour was done according to the modified method described by [5]. Plantain fruits (unripe) was removed from bunches, sorted, cleaned, washed, and sliced (2 mm thickness) with a stainless-steel kitchen slicer without peeling, blanched at 80 ℃ for 5 min, and dried in a hot air oven at 65 ℃ for 48 h. The dried slices were milled, sieved through a <0.25 mm mesh, sealed, and stored in a low-density polyethylene bag for later use.



Figure 1. *Flowchart for the production of unpeeled plantain flour [5].*

2.2. Preparation of Prawn Powder

The production of prawn powder was done according to the modified method described by [31]. The prawn was sorted, cleaned, washed, drained and oven dried at 60 ℃ for 4 h (Gallenkemp, 300 Plus, England). The dried prawn was further milled using hammer mill (model ED-5 Thomas Wiley, England) and sieved through 0.2 mm mesh size to obtain fine powder, after which it was packaged in an air tight container subsequent to further usage.



Figure 2. *Preparation of prawn powder [31].*

2.3. Recipe for the Production Bread

An overall flour weight of 500 g was adopted for the production of bread (made of composite flour) using the following formulation of the flours into ratios of 100: 0: 0; 85: 10: 5; 75: 20: 5 and 65: 30: 5.

Table 1. *Sample Formulation for Bread Samples.*

Samples	Wheat Flour (%)	Unpeeled Plantain Flour (%)	Prawn Powder (%)
AOA	100	0	0
AOB	85	10	5
AOC	75	20	5
AOD	65	30	5

Key: AOA: 100% Wheat Flour, AOB: 85% Wheat Flour, 10% Unpeeled Plantain Flour and 5% Prawn Powder, AOC: 75% Wheat Flour, 20% Unpeeled Plantain Flour and 5% Prawn Powder, AOD: 65% Wheat Flour, 30% Unpeeled Plantain Flour and 5% Prawn Powder

2.4. Method of Production of Bread

Four batches of bread loaves were made, comprising of 100% whole wheat bread and composite breads produced from unpeeled unripe plantain flour and prawn powder at substitution levels. The straight dough method of bread making as described by [36] was used to produce the bread samples. The proportions of ingredients used for making the bread were flour (500 g), sugar (16.67 g), salt (8.33 g), fat (15.00 g), yeast (18.00 g), and water (250 ml). All the ingredients were mixed in a kenwood mixer at speed 3 for 4 min. The dough was fermented at room temperature (26±2 ℃) for 60 min and then punched back, scaled, rolled, shaped, proofed for 60 min in light greased bread pans at room temperature (26±2 ℃) and baked in a preheated oven operating at 200 ℃ for 20 min. The baked breads were allowed to cool, packaged in low density polyethylene bags and stored at 4 ℃ for analysis.

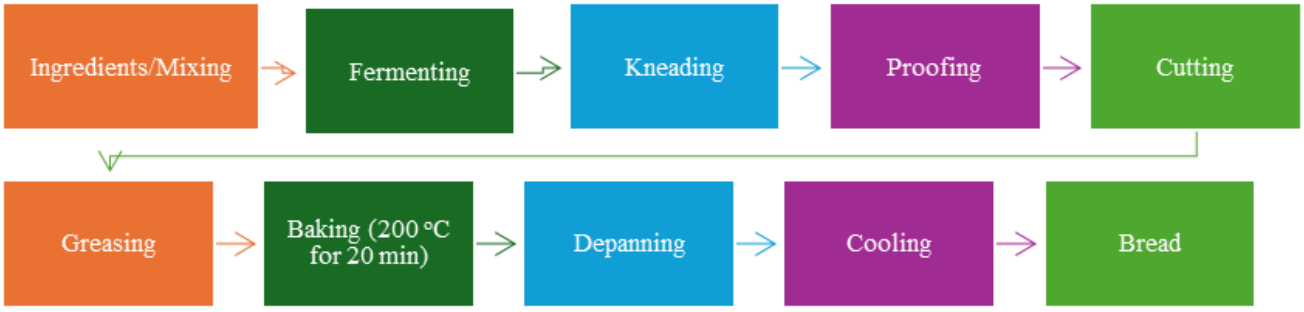


Figure 3. *Flow Chart for the Production of Bread [36].*

3. Methodology

3.1. Proximate Analysis

This analysis was carried out according to the method described by [6].

Moisture Content Determination: The [6] method was adopted. Three (3) grams of sample were weighed into clean, dried and pre-weighed Petri dish. The Petri dish and its content were dried in the moisture extraction oven at 110 ℃ for 4 h. The sample was removed from the oven, cooled in a desiccator and re-weighed. The sample was put back into the oven, dried, cooled and re-weighed. The process was repeated until a constant weight was obtained. This analysis was carried out in triplicate and the average value recorded as moisture content.

$$\% \text{ Moisture content} = \frac{Initial\ wt\ of\ sample - wt\ of\ oven\ dried\ sample}{Initial\ wt\ of\ sample} x \frac{100}{1} \quad (1)$$

Ash Content Determination: The [6] method was used. Clean dried crucibles were weighed on an electronic balance and 5 g of the samples were weighed into the crucibles. The sample was incinerated/charred in a fume cupboard and then transferred into the muffle furnace with a pair of tongs and ashed at 550 ℃ for 4 h to obtain a white or grey ash. The sample was removed from the furnace, cooled in a desiccator and weighed. The experiment was carried out in triplicate. The percentage ash was calculated as follows:

$$\% \text{ Ash content} = \frac{Weight\ of\ ash}{Weight\ of\ sample} x \frac{100}{1} \quad (2)$$

Crude Protein Determination: The AOAC [6] method called the Kjeldahl method was used. The crude protein analysis was carried out in three parts namely: digestion, distillation and titration.

Digestion: Approximately 0.1 g of the samples were weighed into clean dried Kjeldahl flask and 0.1 g $CuSO_4$ crystals, 0.5 g Na_2SO_4 crystals and 25 ml of concentrated H_2SO_4 acid was added into the flask. Some glass beads were also added into the flask to act as anti-bumping agents. The Kjeldahl flask and its content was transferred to the digesting chamber kept in a fume cupboard (to ensure proper exhausting of the smoke) and digested at 420 ℃. Digestion continued for 30 mins with constant rotation of the digestion flask until the sample changed colour (from black to light blue). The digestion flask was then removed from the digestion chamber and allowed to cool. The digest was made up to 100 ml using distilled water and shaken vigorously to a homogenous solution.

Distillation: Out of the homogenous solution of the digest, 20 ml was transferred into a distillation flask using a pipette. Then, 20 ml of 40% NaOH solution was added carefully down the side of the flask through a funnel. Then 50 ml of 2% boric acid solution was pipette into a receiving flask and two drops of methyl red indicator added. The distillation unit was fitted such that the condenser was connected to the receiving flask with a glass tube, and the condenser cooled with constant supply of cold water from the tap. Also, the tip of the glass tube was immersed in the boric acid. The distillation unit was heated on a heating mantle for 35 minutes until the pink solution of the boric acid turned blue and the volume increased to about 100 ml by the distillate.

Titration: 0.1N HCl was titrated against ten (10) milliliters of the distillate (and blank) to a colourless end point. The titre values were recorded. The experiment was carried out in triplicates. The percentage crude protein was calculated as follows: % Nitrogen

$$= \frac{28}{100} x \frac{Vt - Vb}{Wo} \quad (3)$$

$$\% \text{ Crude Protein} = \% \ Nitrogen \ x \ 6.25 \quad (4)$$

Where; Vt = Titre value of sample, Vb = Titre value of blank, Wo = Weight of sample.

Crude Fat Determination: The [6] method was used. Five (5) grams of the samples were weighed into a light filter paper, wrapped and put in extraction thimble of the soxhlet extraction apparatus. A clean dried and weighed soxhlet extraction flask was half-filled with petroleum ether and the whole apparatus assembled together, with the flask placed on the heating mantle and heated at 60 - 80 ℃. The condenser was cooled with constant running water and the fat extracted for three (3) hours. At the end of extraction, the extractor was disconnected and the thimble containing the sample removed. The equipment was reassembled, the flask heated at 60 ℃ and the solvent evaporated, leaving the oil in the flask. The oil was dried in a moisture extraction oven at 110 ℃ for 1 h in order to remove the solvent residues in the oil. The dried oil in the flask was cooled in a desiccator and weighed. The drying, cooling and re-weighing of the oil sample was repeated until a constant weight was obtained. The percentage fat content was calculated thus:

$$\% \text{ Crude fat} = \frac{Weight\ of\ flask + oil - weight\ of\ empty\ flask}{Initial\ wt\ of\ sample} x \frac{100}{1} \quad (5)$$

Crude Fibre Determination: The [6] method was used. Two (2) grams of defatted sample were weighed into a 250 ml beaker containing 200 ml of 0.125M H_2SO_4. The mixture was heated in a steam bath at 70 - 90 ℃ for 2 h, and then allowed to cool. The cooled mixture was filtered using a muslin cloth over a Buckner funnel. The residue was washed three times with hot water to remove the acid and then put in a beaker containing 200 ml of potassium hydroxide (KOH). The mixture was heated as before over a steam bath for 2 h. The solution was filtered and the residue washed three times with hot water, then with alcohol and water. The final residue obtained was put in clean pre-weighed crucible and dried at 120 ℃ to a constant weight. The crucible with the oven-dried sample was put in a muffle furnace and ashed at 550 ℃ for 30 min such

that the sample became ash-white. The crucible and its contents were removed from the furnace, cooled in a desiccator and weighed. The percentage crude fibre was calculated thus:

$$\% \text{ Crude fibre} = \frac{Weight\ of\ oven\ dried\ sample - Weight\ of\ ash}{Initial\ weight\ of\ sample} x \frac{100}{1} \quad (6)$$

Carbohydrate Content Determination: The carbohydrate content of the sample was obtained by difference, that is, as the difference between 100 and the total summations of percentage moisture, ash, fat, protein and fibre.

$$\% \text{ Carbohydrate content} = 100 - (\% \ Moisture + \% \ Ash + \% \ Fat + \% \ Protein + \% \ Crude \ fibre) \quad (7)$$

Energy Value and Dry Matter Determination: The total calorific energy value or metabolizable energy was calculated using the equation as described by [21].

$$\text{Total calorific value} = (Carbohydrate + Protein)4 + (Lipid)\ 9 \quad (8)$$

This is based on the fact that one (1 g) of *carbohydrate* and protein has calorific value of 4 Kcal/g and 9 Kcal/g respectively, while the dry matter content (DM%) was deduced according to the following relationship:

$$\text{Dry matter content (\%)} = 100 - (Moisture\ \ Content) \quad (9)$$

3.2. Mineral Analysis

The mineral content of the samples was determined by dry ash extraction method followed with specific mineral element. Two grammes (2 g) of the sample were burnt to ashes in a muffle furnace, the resulting ash was dissolved in 100 ml of dilute hydrochloric acid and then diluted to 100 ml in a volumetric flask using distilled water.

Sodium (Na) Content Determination: The method of [7] was adopted to determine Sodium for the sample extract. The Flame Photometer instrument was set up according to the manufacturer. It was switched on and allowed to stay for about 10 minutes before use. The gas and air inlet was opened as the start knob was turned on. Standard solution was prepared separately and each dilute to a concentration of 2, 4, 6, 8 and 10 ppm when analyzing for a specific element. The appropriate fibre was selected and the instrument flushed with distilled water, the highest concentrated standard solution was put in place and reading adjusted 100 ppm, there after starting with least concentration 2 ppm, all the standard solution was sucked to the instrument, to spray over the non-luminous flame. The reading was recorded and later plotted into a standard curve used to extrapolate the Na level in the sample. After that into a standard the sample digest was siphoned in turns into the instrument and their reading recorded. The values were calculated with reference to the graph and obtained as follows;

$$\text{Na (mg/100g)} = \frac{(100 \text{ x } Vt \text{ x } 1 \text{ x } D)}{W \text{ x } 1 \text{ x } 10^3} \quad (10)$$

Where, W = Weight of Sample used, Vt = Total extract volume, D = Dilute factor for where applicable.

Phosphorous (P) Content Determination: Phosphorous in the test sample was determinate by the Vendomobydate spectrophotometeric method [20]. A measured volume of the dry ash of 2 mg digest of the sample was dispersed into 50 ml volume flask. At the same time, the same volume of distilled water and standard P solution was measured into different flask to serve as reagent blank and standard respectively. 2 ml of the phosphorus colour reagent (Venadomeby dates solution) was added to each of the flasks and allowed to stand at room temperature for 15 minutes. The content of each flask was diluted to the 50 ml mark with distilled water and its absorbance was measured in a spectrophotometer at a wavelength of 540 nm with the reagent blank at zero.

$$\text{P (mg/100g)} = \frac{(100 \text{ x } Au \text{ x } C \text{ x } Va)}{W \text{ x } As \text{ x } Va} \quad (11)$$

Where; W = Weight of sample ash, Au = Absorbance of test sample, As = Absorbance of standard phosphorous solution, C = Concentration of standard phosphorous solution, Vt = Total extract volume, Va = Volume of extract analyzer

Iron (Fe) Content Determination

The method of [34] was adopted and used for iron content determination. The standard Iron solution contains 0.25 g/l of pure Iron pipe 25 ml of standard Iron solution into a 500 ml volumetric flask and dilute up to the mark with distilled water. The calibrated solutions were prepared by pipetting the indicated amount of the above Iron solution (Step1) into labeled 50 ml volumetric flasks. Pipette 10 ml of an unknown sample solution into a 250 ml volumetric flask and dilute to the mark with distilled water. Invert and shake flask severally to mix the solution. Pipette two 25 ml aliquots of this solution into 50 ml volumetric flask labeled unknown. Using a 100 ml graduated cylinder, add 4 ml of 10% hydroxylamine hydrochloride solution and 4 ml of 0.3%; O phenanthroline solution to each volumetric flask. Dilute each flask to the mark with distilled water and mix well by inverting and shaking the capped volumetric flasks several times using the spectronic 30 spectrophotometer, carefully measure the percent transmittance of the various solutions in the 50 ml volumetric flask, including the two unknown solutions.

$$\text{Fe (mg/100g)} = \frac{0.10\ \text{mg Fe X 50 (dilution) X 1000 ml X 100 mg Fe}}{50\ \text{ml x Factor x L x L}} \quad (12)$$

Magnesium (Mg) Content Determination: The method of [33] was used in determining Mg content. 5 g of each sample was washed on a muffle furnace at 550 ℃ for 12 h, the resulting Ash was cooled in desiccators. The Ash was dissolved in 2 ml of concentrated HCl and few drops of concentrated HNO_3 was added, the resulting solution was evaporated almost to dryness in a water bath. Further dilution of the original solution was done using 0.5 ml and enough distilled water was added to it to make the volume 100 ml. The Atomic Absorption Spectrophotometer was used to determine the Magnesium content and its concentration recorded in terms of "ppm" was converted to milligram (mg) by multiplying the ppm with Dilution factor and dry weight and dividing by 1000 as follows;

$$\text{Mg (mg/100g)} = \frac{\text{Absorbance (ppm) x dry weight x DF}}{\text{Weight of sample x 100}} \quad (13)$$

Where; ppm = Percentage per mole, DF = Dilution Factor, Wt = Weight

3.3. Physical Properties

Determination of Appearance and Color: The modified method of [35] was adopted. The overall appearance of the bread was documented by photographing the entire loaf using a digital camera (WG-30W, Ricoh, Tokyo, Japan). To examine the internal structure, the bread was sliced into 2 cm thick pieces, and the center of each slice was photographed using both the digital camera and a stereomicroscope (DS-L3, Nikon Corp., Tokyo, Japan). The color of the bread cross-sections was measured using a color reader (CR-13, Konica Minolta, Inc., Osaka, Japan), which provided L*, a*, and b* values. The L* value represents lightness, the a* value indicates the red-green axis, and the b* value corresponds to the blue-yellow axis. The color of each sample was measured 10 times to ensure accuracy.

Determination of Volume: Bread loaf volume was determined by the rapeseed displacement method described by [11]. Briefly, a container was filled with rapeseed and the volume of the rapeseed was measured using a measuring cylinder (V_1). Then, the bread sample was placed into the container and the volume of the rapeseed with the bread sample was measured and noted as V_2. The analysis was performed with triplicate samples. The volume of each loaf was calculated using the equation:

$$\text{Loaf volume} = V_1 - V_2 \ \text{(mL)} \quad (14)$$

Determination of Weight: Loaf weight was determined using the method described by [11]. The weight of bread loaves was measured in gram units using normal weighing methods. Each loaf was weighed one hour after the cooling process.

Determination of Oven Spring: Oven spring (cm) was calculated using the differences between loaf heights before and after baking.

Determination of Specific Volume: Specific volume was determined using the modified method described by [28]. Bread loaf volume was measured by rapeseed displacement method as described. Rapeseeds were poured into the container of known volume until the bottom was covered. The loaf was placed inside the container which was then filled to the top with more seeds. The extra rapeseeds, which are equal to the loaf volume, were measured in a graduated cylinder. The loaf volume was determined from the difference between the initial volume of the rapeseeds and the final volume after placing of the loaf in it. Loaf weight was simply measured by placing the loaf on an electronic weighing balance (Soehnle Professional 9230). The specific volume was determined by using the ratio of the two parameters above, loaf volume to loaf weight:

$$\text{Specific volume (cm}^3\text{/g)} = \frac{Loaf\ Volume}{Loaf\ Weight} \quad (15)$$

Determination of Loaf Height: The height of the bread was measured using a ruler. The distance from the base of the sliced bread to its highest point was recorded. This measurement was repeated three times for each sample to ensure accuracy.

Determination of Baking Loss: Baking loss was done using the method described by [17]. Baking losses were analyzed in terms of moisture loss. Loss was also calculated by the baking yield. Dough baking yield was determined by comparing the fresh dough weight (W_1) before placing in the oven and with the final bread weight (W_2). The loaves were weighed 1 h after removal from the oven (W_2). This baking loss was a measure of loss of moisture of the bread during baking and expressed in terms of percentage.

3.4. Sensory Analysis

The sensory test conducted was based on the consumers' preference of the taste, aroma, mouthfeel, appearance and general acceptability of the bread. The scale used for preference testing was the 9-point hedonic scale described by [27]. The attributes were assessed by ten (10) semi-trained panelists selected among students of Federal Polytechnic Nekede, Owerri. The panelists were made to do an assessment under carefully controlled conditions to avoid biased judgment. The samples were presented in coded serving plates with a glass of water to mask the effect of the previous determination and the panelists were made to understand that coding had nothing to do with the quality of the products. The 9-point hedonic scale was used for the evaluation. It stipulates thus: 9 - Like extremely, 8 - Like very much, 7 - Like moderately, 6 - Like slightly, 5 - Neither like nor dislike, 4 - Dislike slightly, 3 - Dislike moderately, 2 - Dislike very much and 1 - Dislike extremely. The result obtained from the panel was used to determine if any significance

existed in the sensory attributes of the pap samples.

3.5. Statistical Analysis

The experimental data generated from the various assessments were statistically analyzed with the aid of SPSS 20.00 and MS Excel package at a confidence level of 95%. Analysis of Variance (ANOVA) was deployed for the replicate measurements for identifying significant differences amongst the sample results. The mean and standard deviation for each parameter of the experiment was calculated. The Duncan's New Multiple Range test was applied to isolate the mean values at a level of significance amounting to 5%. Where appropriate, the experimental outcomes were presented as mean ± standard deviation.

4. Results and Discussion

4.1. Nutrient Composition of Wheat-unpeeled Plantain Flour Breads Fortified with Prawn Powder

Table 2 showed the results of the nutrient compositions of bread produced from wheat-unpeeled plantain composite flours fortified with prawn powder. The data provides a detailed scientific foundation for understanding the shifts in nutritional attributes resulting from composite flour substitution. Moisture content of the bread samples ranged from 38.77% in AOA to 41.27% in AOC, and this showed that moisture generally increased with increasing levels of unpeeled plantain flour up to 20% substitution before decreasing at 30% substitution. This explained the fact that plantain flour contains high fibre and resistant starch fractions which promote water absorption, but at higher substitution levels, the dough structure becomes more compact during baking, resulting in increased moisture loss [38]. High moisture values such as those seen in AOB and AOC may predispose the bread to faster spoilage, but they also enhance consumer acceptability due to improved softness, although marketers must consider shorter shelf-life and the need for faster product turnover. Dry matter content ranged from 58.73% in AOC to 61.23% in AOA, essentially the inverse of moisture content because its increase, reduces dry matter. This occurs because it represents all the solid components of the bread including protein, fat, carbohydrate, fibre, and ash, and as more plantain flour was added, the retained moisture increased and reduced the proportion of solids until the structural limitations at higher substitutions cause moisture loss. Dry matter determines the concentration of nutrients in a food product and affects texture, density, and mouthfeel. Its variation affects consumer perception of heaviness or lightness in bread, and products with higher values such as AOA and AOD may appeal to consumers seeking denser bread, while breads with lower values may be perceived as softer but may have reduced storage stability [23]. Ash content, which is an indication of total mineral content, ranged from 2.19% in AOD to 2.61% in AOA, showing a decrease as the level of unpeeled plantain flour increased. This is explained by the dilution effect resulting from reducing the proportion of wheat flour, which naturally contains higher mineral levels compared with plantain flour, although prawn powder contributed some minerals but not sufficiently to counteract the dilution. Lower ash values in samples with higher plantain substitution may reduce the mineral contribution of the bread to consumers, and samples with slightly higher values such as AOA may be promoted as more mineral-rich, while those with lower values may appeal to consumers seeking lighter formulations. Crude protein values ranged from 9.49% in AOD to 10.79% in AOA, and showed overall decline in protein as wheat flour decreased. This can be explained by the fact that wheat flour contains gluten proteins that significantly contribute to the protein content of bread, while plantain flour contains much lower protein levels, and the inclusion of 5% prawn powder does not sufficiently offset this reduction. Lower protein levels in high-substitution samples may reduce bread volume and elasticity, affecting texture [32] and consumer acceptance, but samples fortified with prawn powder may still be positioned as protein-enhanced despite lower overall protein compared to 100% wheat bread.

Crude fibre content ranged from 1.62% in AOB to 1.87% in AOA, and this showed a slight rise in fibre with increasing unpeeled plantain flour, especially at higher substitution levels. This behaviour is expected because unpeeled plantain flour contains substantial dietary fibre such as lignin, cellulose, and hemicellulose, which contribute to increased fibre levels in the bread. Higher fibre levels in AOC and AOD made these samples more attractive to consumers seeking functional foods with digestive benefits, and marketers can promote them as high-fibre or healthier alternatives compared to conventional wheat bread [38]. Fat content ranged from 9.27% in AOB to 15.27% in AOD, while fluctuating and explained the interaction between wheat lipids, plantain flour lipids, and prawn powder lipids, and the sharp reduction in AOB may be due to the combined effect of lower endogenous wheat lipid and moderate plantain lipid content, but higher values in AOC and AOD indicated that prawn powder contributed more significantly as substitution increased. Higher fat values in AOC and AOD increased flavour richness and palatability, which may enhance consumer appeal, while marketers can position these products as premium bread varieties with richer taste profiles [13]. Carbohydrate content ranged from 29.95% in AOC to 36.74% in AOB, with a non-linear trend influenced by fluctuations in moisture, fat, and protein, since carbohydrate is calculated by difference. This trend is explained by the fact that samples with lower fat and protein such as AOB had higher calculated carbohydrate, while samples with higher moisture such as AOC showed lower carbohydrate values. Higher carbohydrate values in AOB made it more energy-dense, which may appeal to consumers seeking high-energy foods, while lower carbohydrate samples such as AOC may be marketed to individuals seeking reduced-carbohydrate options [14]. The metabolizable energy values of the bread samples

ranged from 267.47 kcal/100 g to 304.99 kcal/100 g. The energy values were calculated using the General Atwater conversion factors, whereby protein and carbohydrate each contribute 4 kcal/g, while fat contributes 9 kcal/g. The Atwater system remains the internationally accepted method for estimating the metabolizable energy of foods and is widely applied in food composition studies and nutritional labelling [21]. Among the bread samples, AOD recorded the highest energy value (304.99 kcal/100 g), whereas AOB had the lowest value (267.47 kcal/100 g). The higher caloric value of AOD can be attributed primarily to its highest crude fat content (15.27%). Fat is the most energy-dense macronutrient, supplying approximately 9 kcal/g, which is more than twice the energy provided by either protein or carbohydrate (4 kcal/g) [21]. Consequently, even slight increases in fat concentration substantially increase the metabolizable energy of bakery products. Sample AOA produced the second highest energy value (298.14 kcal/100 g). This may be attributed to its relatively high fat content (14.22%) together with the highest crude protein content (10.79%). In addition, AOA possessed the lowest moisture content (38.77%) and the highest dry matter content (61.23%). Since water does not contribute metabolizable energy, foods with lower moisture and higher dry matter generally contain a greater concentration of energy-yielding nutrients. The relatively high nutrient density of AOA therefore explains its higher caloric value compared with AOB and AOC. Sample AOC recorded an intermediate energy value of 290.95 kcal/100 g. Although its fat content (14.27%) was comparable to that of AOA, its higher moisture content (41.27%) and lower carbohydrate content (29.95%) contributed to a slight reduction in energy value. Moisture dilutes the concentration of macronutrients within foods, thereby lowering the amount of metabolizable energy available per unit weight. Interestingly, AOB contained the highest carbohydrate content (36.74%) but exhibited the lowest energy value because of its comparatively low fat content (9.27%). This finding demonstrated that the caloric value of bread depends on the combined contribution of protein, fat, and carbohydrate rather than on carbohydrate concentration alone. Since lipids possess a much higher caloric coefficient than carbohydrates and proteins, reductions in fat content produce a more pronounced decrease in metabolizable energy than equivalent changes in the other macronutrients [21]. Similar observations were reported [25] where bread formulated from wheat, mature green plantain, and amaranth flour exhibited improved protein, fibre, and energy values compared with conventional wheat bread.

Table 2. *Proximate Composition of Bread Produced from Wheat-Unpeeled Plantain Composite Flours Fortified with Prawn Powder.*

Properties/Samples (%)	AOA	AOB	AOC	AOD
Moisture	38.77±0.04	40.35±0.01	41.27±0.04	39.03±0.40
Dry Matter	61.23±0.04	59.65±0.01	58.73±0.04	60.98±0.40
Ash	2.61±0.01	2.41±0.01	2.46±0.01	2.19±0.01
Crude Protein	10.79±0.01	9.61±0.01	10.28±0.03	9.49±0.01
Crude Fibre	1.87±0.02	1.62±0.00	1.78±0.00	1.84±0.05
Fat	14.22±0.03	9.27±0.04	14.27±0.04	15.27±0.04
Carbohydrate	31.75±0.04	36.74±0.09	29.95±0.10	32.19±0.30
Energy (kcal/100 g)	298.14±0.44	267.47±0.73	290.95±0.76	304.99±0.40

Properties/Samples (mg/100g)

Table 3. *Mineral Contents of Bread Produced from Wheat-Unpeeled Plantain Composite Flours Fortified with Prawn Powder.*

Sodium, Na	184.78±0.03	168.41±0.20	175.90±0.70	173.64±0.20
Phosphorus, P	136.77±0.04	124.87±0.04	134.37±0.50	123.63±0.04
Iron, Fe	1.81±0.01	1.62±0.02	1.44±0.02	1.74±0.02
Magnesium, Mg	89.66±0.09	78.36±0.09	85.31±0.01	75.38±0.10

KEY: AOA = Bread Produced from 100% Wheat Flour, AOB = Bread Produced from 85% Wheat Flour, 10% Unpeeled Plantain Flour and 5% Prawn Powder, AOC = Bread Produced from 75% Wheat Flour, 20% Unpeeled Plantain Flour and 5% Prawn Powder, AOD = Bread Produced from 65% Wheat Flour, 30% Unpeeled Plantain Flour and 5% Prawn Powder

Table 3 shows the results of the mineral contents of bread produced from wheat-unpeeled plantain composite flours fortified with prawn powder. The sodium content of the bread samples ranged from 168.41 mg/100 g in AOB to 184.78 mg/100 g in AOA, which indicated that sodium content generally decreased when wheat was partially replaced with unpeeled plantain flour and prawn powder, with a slight increase observed in AOC compared to AOB. The decreasing trend can be explained by the natural low sodium content of plantain flour, which diluted the higher sodium levels inherent in wheat flour, while the prawn powder contributed modest sodium, resulting in the observed variations. Sodium is a vital electrolyte that regulates fluid balance, nerve conduction, and muscle contraction, and it is critical for maintaining proper physiological functions [37]. From a consumer and marketing perspective, the reduced sodium levels in composite breads make these products more suitable for individuals with hypertension or those seeking heart-healthy alternatives. Therefore, AOB and AOD can be promoted as reduced-sodium functional breads to attract health-conscious consumers [3]. Phosphorus content ranged from 123.63 mg/100 g in AOD to 136.77 mg/100 g in AOA, where the trend showed a decrease in phosphorus levels with moderate substitution, a slight recovery in AOC, and a subsequent decrease in AOD. This trend may be attributed to the phosphorus contributions of both unpeeled plantain flour and prawn powder. While plantain flour contains moderate phosphorus levels, prawn powder is rich in phosphorus due to its protein content and exoskeleton minerals [19], explaining the slight increase in AOC. Phosphorus is essential for bone and teeth formation, energy metabolism through ATP production, and nucleic acid synthesis [12]. For consumers, adequate phosphorus intake supports skeletal health, energy provision, and overall metabolic efficiency, and breads like AOC may be marketed as bone-supportive functional foods suitable for adolescents, athletes, and the elderly. Iron content ranged from 1.44 mg/100 g in AOC to 1.81 mg/100 g in AOA, showing a decrease from AOA to AOC, followed by a slight increase in AOD. The reduction in iron in AOB and AOC can be explained by the lower iron content of unpeeled plantain flour compared to wheat flour, while the increase in AOD suggested the contribution of prawn powder and the iron retained in the plantain peel. Iron is a critical component of hemoglobin and myoglobin, facilitating oxygen transport, supporting immune function, and enhancing cognitive performance [10]. From a consumer standpoint, composite breads with higher iron, such as AOD, can help mitigate dietary iron deficiencies, making them attractive to women of reproductive age, children, and populations prone to anemia. Consequently, these breads can be marketed as iron-fortified functional breads targeting health-conscious and nutritionally aware consumers. Magnesium content ranged from 75.38 mg/100 g in AOD to 89.66 mg/100 g in AOA, showing a general decrease in magnesium with increasing substitution of wheat flour with plantain flour, with a slight improvement in AOC relative to AOB. This trend occurs because wheat flour naturally contains higher magnesium concentrations than plantain flour, while prawn powder adds a small magnesium contribution, causing minor fluctuations. Magnesium is essential for enzymatic reactions, nerve and muscle function, blood pressure regulation, and energy metabolism [30]. For consumers, breads with substantial magnesium levels support cardiovascular health, stress management, and overall metabolic function. Although composite breads have slightly lower magnesium than 100% wheat bread, they remain nutritionally beneficial and can be promoted as functional bakery products with balanced mineral profiles. The mineral composition results indicated that partial substitution of wheat flour with unpeeled plantain flour and fortification with prawn powder can modulate sodium, phosphorus, iron, and magnesium levels in bread. Composite breads like AOC and AOD provided improved mineral balance, offering health benefits such as reduced sodium intake, iron supplementation, and moderate phosphorus and magnesium supply. From a product marketing perspective, these breads can be positioned as functional and nutrient-enhanced bakery products catering to health-conscious consumers, populations requiring iron supplementation, and those seeking reduced-sodium options.

4.2. Physical Properties of Wheat-unpeeled Plantain Flour Fortified Prawn Powder Bread

Table 4 presented the physical properties of bread produced from wheat-unpeeled plantain composite flours fortified with prawn powder. The incorporation of unpeeled plantain flour, which is high in starch, fiber, and bioactive compounds, along with prawn powder rich in proteins and minerals, is expected to alter the physical characteristics of bread. Understanding these changes provides insights into processing modifications required for industrial-scale production and potential consumer acceptance of nutrient-enriched, composite breads. The specific volume of bread samples ranged from 1.026 cm^3/g in AOA to 2.156 cm^3/g in AOD, with increasing substitution of plantain flour, hence the trend indicated that composite breads have higher specific volume compared to the control. Specific volume is defined as the ratio of loaf volume to loaf mass and is a direct measure of loaf lightness, airiness, and gas-holding capacity of the dough [4]. The increase in specific volume may be attributed to the high water absorption capacity of plantain flour, which enhanced dough expansion during fermentation and baking. The starch in plantain flour gelatinizes during baking, retaining gas bubbles and promoting an open crumb structure whereas prawn powder may also contribute proteins that interact with starch to stabilize gas cells. For consumers, higher specific volume translates into bread that is lighter, softer, and more palatable, enhancing market appeal while from a marketing perspective, such breads can be positioned as premium or specialty breads targeting health-conscious and

convenience-oriented consumers who prefer soft, airy textures. The loaf volume ranged from 300 cm^3 in AOA to 600 cm^3 in both AOC and AOD, indicating that inclusion of unpeeled plantain flour and prawn powder enhanced dough expansion during baking. Loaf volume represents the total space occupied by a baked loaf and reflects the interplay of dough fermentation, gluten network strength, gas cell formation, and retention. The starch-rich plantain flour contributes to water absorption and swelling, which supports gas expansion and partially compensates for the dilution of gluten in composite doughs. Additionally, the proteins in prawn powder may form a weak network that interacts with starch and gluten, aiding in gas cell stabilization and supporting loaf structure. Increased loaf volume improves the visual appeal of bread, conveys freshness, and signals good aeration qualities that are highly valued by consumers. From a marketing perspective, larger loaf size can be highlighted as a value-for-money and visually attractive product, potentially enhancing consumer purchase intent. Studies have shown that moderate substitution of wheat flour with plantain flour can improve loaf volume, provided water content and baking conditions are optimized [32]. However, excessive substitution may eventually reduce volume due to weakened gluten networks and insufficient structural support for gas cells. Loaf weight varied slightly among the samples, ranging from 2726.92 N in AOB to 3170.28 N in AOC. Loaf weight reflects the total mass of the baked product and is influenced by moisture content, ingredient composition, water retention, and baking loss. Slight reductions in loaf weight at certain substitution levels, such as AOB and AOD, may result from increased baking loss due to higher water evaporation or from a less cohesive gluten network that is less capable of retaining moisture. Conversely, the higher weight observed in AOC likely arose from enhanced water absorption and retention associated with plantain starch and the interaction with prawn protein, which helped maintain dough cohesion during baking. For consumers, loaf weight affects perceived value, portion size, and satiety, while for industrial producers, maintaining consistent loaf weight is critical for regulatory compliance, quality assurance, and customer satisfaction. Studies have demonstrated that composite flours may produce slight variations in loaf weight depending on substitution level, water content, and baking conditions, highlighting the importance of process control to achieve uniform products [15].

Bread thickness decreased from 55.69 mm in AOA to 39.37 mm in AOD, while loaf length decreased from 174.68 mm in AOA to 151.73-155.35 mm in the composite breads, and width fluctuated between 80.79 mm and 87.60 mm. These trends indicated that partial substitution of wheat flour with plantain flour and prawn powder altered dough expansion and spread during baking. Bread dimensions are influenced by gluten network integrity, dough elasticity, water absorption, and starch gelatinization, all of which govern vertical rise and lateral expansion. The reduced thickness is likely due to weakened gluten networks in the composite dough, which limited vertical lift but allow some lateral spreading, whereas minor fluctuations in width suggested that lateral flow is partially restrained by the structural effects of fiber and starch from plantain flour. Uniform thickness, length, and width are critical for visual appeal, consumer perception of quality, and ease of slicing. From a commercial perspective, predictable loaf dimensions are essential for automated slicing and packaging operations, ensuring consistent product presentation, shelf appeal, and portion standardization. These findings align with [22] where composite breads exhibited altered heights and variable dimensions, which can be mitigated through careful process optimization, dough conditioning, use of emulsifiers and gluten supplements. Bread density decreased significantly from 0.97 g/cm^3 in AOA to 0.46 g/cm^3 in AOD, showing a clear inverse relationship with loaf volume and specific volume. Density, which is the ratio of mass to volume, provides a direct measure of loaf aeration, compactness, and crumb openness. The decrease in density is likely due to the higher water absorption and swelling capacity of starch in unpeeled plantain flour, which promotes gas retention during baking and results in a lighter, more porous crumb structure. Additionally, the fiber content of plantain flour contributes to matrix expansion, creating larger pores, while the small proportion of prawn powder may stabilize gas cells through its protein content, further supporting lower-density loaves. As the loaf volume increased faster than mass, density naturally decreased, indicating enhanced aeration and softer crumb texture. Studies have shown that composite breads with plantain flour substitutions often exhibit lower densities due to improved gas-holding capacity and starch gelatinization [4]. However, excessive substitution of non-wheat flours may increase density in some cases due to gluten network weakening and poor gas retention [15]. Lower-density breads are generally preferred by consumers for their soft texture, palatability, and ease of chewing, and they can be marketed as light, airy, and nutritious options targeting health-conscious individuals, children, and the elderly. It is important to note that very low density could compromise crumb strength, sliceability, and handling stability, which requires attention during processing and packaging.

Table 4. *Physical Properties of Bread Produced from Wheat-Unpeeled Plantain Composite Flours Fortified with Prawn Powder.*

Properties/Samples (%)	AOA	AOB	AOC	AOD
Specific Vol. (cm^3/g)	1.026±0.002	1.798±0.001	1.856±0.004	2.156±0.001

Properties/Samples (%)	AOA	AOB	AOC	AOD
Loaf Vol. (cm^3)	300.00±0.00	500.00±0.00	600.00±0.00	600.00±0.00
Loaf Weight (N)	2866.96±0.01	2726.92±0.02	3170.28±0.01	2728.89±0.02
Thickness (mm)	55.69±0.09	41.99±0.08	49.01±0.04	39.37±0.01
Length (mm)	174.68±0.01	155.33±0.06	151.73±0.06	155.35±0.01
Width (mm)	81.23±0.04	87.60±0.01	80.79±0.01	81.20±0.02
Density (g/cm^3)	0.97±0.01	0.56±0.04	0.54±0.01	0.46±0.01
Mass (g)	293.35±0.01	278.07±0.05	323.28±0.02	278.29±0.20
Colour (pcu)	1763.000	1676.00	1783.00	1606.00
Spread Ratio	1.46±0.20	2.09±0.05	1.65±0.10	2.06±0.09
Absorbance (abs)	2.277	1.568	2.201	2.429
Oven Spring (cm)	3.26±0.10	3.02±0.09	3.00±0.10	3.00±0.20
Baking Loss (g)	8.00±0.00	11.04±0.05	9.40±0.06	10.01±0.06

KEY: AOA = Bread Produced from 100% Wheat Flour, AOB = Bread Produced from 85% Wheat Flour, 10% Unpeeled Plantain Flour and 5% Prawn Powder, AOC = Bread Produced from 75% Wheat Flour, 20% Unpeeled Plantain Flour and 5% Prawn Powder, AOD = Bread Produced from 65% Wheat Flour, 30% Unpeeled Plantain Flour and 5% Prawn Powder

Bread mass ranged from 278.07 g in AOB to 323.28 g in AOC, showing modest variations across the treatments, and it reflected the combined effects of water retention, baking loss, and ingredient composition. The higher mass observed in AOC may be due to the optimal water-binding capacity of plantain starch, which allows the loaf to retain more moisture during baking, while the lower mass in AOB and AOD may result from incomplete structural network formation or higher water evaporation. The interplay between starch, fiber, gluten, and prawn protein determines the loaf's ability to retain water and solids, influencing the final mass. Studies on wheat-plantain composite breads have reported that moderate substitution levels, around 20%, often produce heavier loaves due to better moisture retention, whereas very low or very high substitutions may yield inconsistent masses [15]. Mass is not always directly proportional to loaf volume because composite flours affect water retention, gas retention, and structural stability in complex ways. Consistent loaf mass is important for consumers as it ensures predictable portion sizes, satiety, and perceived value. For industrial producers, standard mass is critical for product uniformity, regulatory compliance, and accurate labeling, as variation can affect packaging, pricing, and quality assurance. Controlling hydration, mixing, proofing, and baking parameters is necessary to maintain loaf mass across batches, and monitoring moisture content is essential to prevent over- or under-moist loaves that may compromise shelf-life or consumer acceptance. The colour of the bread crust ranged from 1606 pcu in AOD to 1783 pcu in AOC, showing slight fluctuations with increasing substitution of wheat flour by unpeeled plantain flour and the addition of prawn powder. The trend suggested that breads containing 20-30% plantain flour exhibit noticeable variations in crust intensity, with AOC showing the highest value. Colour in bread is primarily determined by Maillard reactions between reducing sugars and amino acids, caramelization of sugars during baking, and the presence of pigments in the raw ingredients [13]. Plantain flour contributed natural sugars and carotenoid pigments that promote browning, while prawn powder provided proteins that interacted with sugars to enhance Maillard reaction, giving the crust a darker and more appealing appearance. Colour is an important sensory attribute for consumers, as it is often associated with flavor, freshness, and baking quality. Breads with attractive golden-brown crusts can be positioned as premium, wholesome, or artisanal products, appealing to consumers seeking both visual and gustatory satisfaction. The spread ratio, which measures the horizontal expansion relative to vertical height, ranged from 1.46 in AOA to 2.09 in AOB. This irregular trend indicated that lateral expansion is influenced by the complex interplay of gluten content, starch gelatinization, and water absorption in composite flours. Spread ratio is an indicator of dough elasticity and dimensional stability; a higher spread ratio suggested that the dough expanded more laterally than vertically, often due to weaker gluten networks or higher starch content [26]. In this study, substitution with unpeeled plantain flour partially diluted wheat gluten, allowing the dough to spread more during proofing and baking, while water absorbed by starch helped maintain loaf structure. A proper spread ratio ensures consistent loaf shape, which is critical for slicing, packaging, and consumer convenience. Uniform spread contributes to aesthetic appeal and perceived quality, while marketers can highlight the professional, even, and high-quality loaf shape as a selling point.

Absorbance values, an objective measure of crust and crumb colour intensity, ranged from 1.568 in AOB to 2.429 in AOD, reflecting the degree of Maillard browning and caramelization during baking. The trend showed that breads with higher plantain flour substitution tend to exhibit increased absorbance, indicating darker crust formation. Absorbance is influenced by the concentration of reducing sugars, amino acids, and proteins in the flour, as well as baking temperature and time [13]. The increased absorbance in higher substitution breads is likely due to the combined effect of naturally occurring sugars in plantain flour and prawn powder proteins, which enhanced Maillard reactions. Darker crusts are often perceived as more flavorful and well-baked by consumers, contributing positively to sensory evaluation and acceptability. For product marketing, breads with consistent and attractive absorbance can be promoted as high-quality, artisanal, or nutrient-enriched, leveraging both visual and perceived taste appeal. Oven spring, the vertical rise of the bread during the initial stages of baking, decreased slightly from 3.26 cm in AOA to 3.00 cm in AOC and AOD. The slight reduction in oven spring indicated that partial substitution of wheat flour with plantain flour and prawn powder has a moderate impact on vertical expansion. Oven spring is a critical parameter, the increase in loaf height during the first few minutes of baking, resulting from the rapid expansion of trapped gases as the dough heats [32]. In composite breads, the gluten network is partially diluted by plantain starch, reducing its ability to fully retain CO_2. However, high water absorption and starch gelatinization compensate to some extent, preventing dramatic collapse. Oven spring influences crumb openness, texture, and consumer perception of freshness; breads with adequate oven spring are considered soft, airy, and desirable. Emphasizing breads with consistent oven spring assures quality, uniformity, and baking expertise, enhancing brand reliability. Baking loss ranged from 8.00 g in AOA to 11.04 g in AOB, with intermediates, reflecting differences in moisture retention, water evaporation, and volatile loss during baking. Baking loss represents the weight reduction of the dough due to water and other volatile compounds lost during baking [18]. Higher losses in composite breads may result from increased water absorption by plantain starch, which leads to more water being expelled during baking. Controlling baking loss is important to ensure proper crust formation, desirable texture, and yield. Moderate baking loss contributes to crumb softness, improved mouthfeel, and enhanced eating quality, hence, understanding and managing baking loss is essential for standardizing product weight, reducing variability, and ensuring economic efficiency.

4.3. Organoleptic Profile of Wheat-unpeeled Plantain Flour Bread Fortified with Prawn Powder

Table 5 presents the results of organoleptic profile of breads produced from composite flours of wheat-unpeeled plantain flour and prawn powder. This evaluation provides a consumer-oriented assessment of how substitution of wheat with plantain flour (and fortification with prawn powder) influenced the organoleptic qualities of bread. The taste scores ranged from 5.90 in AOA to 4.70 in AOD, showing a gradual decline as the level of unpeeled plantain flour substitution increased. The control bread (AOA) had the highest taste score, which is consistent with the familiar flavor and sweetness associated with pure wheat bread. The slight decrease in taste with the addition of plantain flour and prawn powder may be attributed to changes in carbohydrate composition, starch-sugar interactions, and the presence of prawn proteins that introduce subtle umami or marine notes, which may be less preferred by some panelists. This aligns with prior studies showing that moderate plantain flour substitution slightly reduces sweetness and alters flavor profiles but maintains overall acceptability [25]. The colour scores decreased from 7.00 in AOA to 4.50 in AOD, with AOB and AOC showing intermediate scores of 6.20 and 4.90, respectively, indicating a perceptible darkening of the bread as substitution increased. Colour is influenced by Maillard browning, caramelization of sugars, and the natural pigments in plantain flour, while prawn powder may also affect crust hue due to its protein content and browning reactions. The darker appearance at higher substitution levels may be less preferred by panelists accustomed to light-colored wheat bread, although some consumers may perceive it as “wholegrain” or “traditional” bread. Consistent colour is important for consumer expectation, product recognition, and retail presentation, as first impressions often determine acceptability. This result is consistent with reports that substitution with unripe plantain flour typically darkens crumb and crust color due to higher sugar and fiber content that accelerate browning reactions during baking [32]. Aroma scores ranged from 5.90 in AOA and AOB to 5.10 in AOD, showing minimal decline despite increasing plantain flour content. This suggests that the composite flour, including prawn powder, did not drastically alter the bread’s characteristic baked aroma. Aroma in bread is primarily driven by fermentation products, Maillard reactions, and volatile compounds from flour and other ingredients. The retention of aroma indicated that yeast activity and thermal reactions during baking were sufficient to produce acceptable sensory characteristics across substitution levels. Aroma contributes significantly to perceived freshness and quality, influencing both consumer preference and perceived flavor. The slight decrease at higher substitution levels may reflect minor interactions of plantain starch and prawn protein with aromatic compounds, slightly modifying volatile release [15].

Texture scores varied from 6.80 in AOA to 5.60 in AOD, indicating that the bread crumb became slightly less soft and cohesive with higher levels of plantain flour substitution. Bread texture is influenced by gluten network integrity, starch gelatinization, water retention, and crumb structure. The reduction in texture scores may be due to gluten dilution caused by plantain flour, which limits elasticity and resilience, while prawn protein may only partially compensate for structural support. A softer, more cohesive crumb in AOA was preferred

by panelists, whereas composite breads exhibited a slightly firmer or more open crumb, consistent with lower density and higher specific volume observed in physical analyses. Previous research indicated that partial wheat replacement with plantain flour may slightly affect chewiness and crumb softness but does not render the product unacceptable [4]. General acceptability remained high for AOA, AOB, and AOC (all scoring 6.30), but dropped to 5.10 in AOD, reflecting that moderate substitution (up to 20%) did not negatively impact overall consumer perception. The lower score in AOD indicated that excessive substitution (30%) may start to compromise sensory harmony, particularly in taste and colour, even though physical properties such as loaf volume and density were favorable. This finding emphasizes the importance of balancing nutritional enhancement with sensory quality when formulating composite breads. Similar patterns where composite breads with plantain flour maintained high general acceptability, while higher levels may reduce consumer preference due to changes in flavor, colour, or texture [32].

Table 5. *Sensory Properties of Bread Produced from Wheat-Unpeeled Plantain Composite Flours Fortified with Prawn Powder.*

Properties/Samples	AOA	AOB	AOC	AOD	LSD
Taste	5.90[a]	5.60[a]	5.40[a]	4.70[a]	1.540
Colour	7.00[a]	6.20[ab]	4.90[b]	4.5[b]	1.650
Aroma	5.90[a]	5.90[a]	5.40[a]	5.10[a]	1.198
Texture	6.80[a]	5.90[a]	6.00[a]	5.60[a]	1.256
General Acceptability	6.30[a]	6.30[a]	6.30[a]	5.10[a]	1.655

KEY: AOA = Bread Produced from 100% Wheat Flour, AOB = Bread Produced from 85% Wheat Flour, 10% Unpeeled Plantain Flour and 5% Prawn Powder, AOC = Bread Produced from 75% Wheat Flour, 20% Unpeeled Plantain Flour and 5% Prawn Powder, AOD = Bread Produced from 65% Wheat Flour, 30% Unpeeled Plantain Flour and 5% Prawn Powder

5. Conclusion and Recommendation

The findings demonstrated that partial substitution of wheat flour with unpeeled plantain flour and prawn powder improved the nutritional quality of bread by increasing fibre, ash, and overall mineral retention while maintaining acceptable physical and sensory characteristics. Although protein content decreased slightly due to gluten dilution, the inclusion of prawn powder helped enhance the protein quality. Among the formulations, bread containing 75% wheat flour, 20% unpeeled plantain flour, and 5% prawn powder exhibited the best overall performance, providing an optimal balance of nutritional enhancement, desirable loaf quality, and consumer acceptability. This formulation therefore represents a promising alternative for producing nutrient-enriched composite bread with good market potential. Additionally, food manufacturers can consider developing other functional breads using local flours and protein sources, promoting value addition, dietary diversification, and utilization of underused ingredients.

Abbreviations

NaOH	Sodium Hydroxide
H_2SO_4	Sulfuric Acid
$CuSO_4$	Copper (II) Sulfate
Na_2SO_4	Sodium Sulfate
HCl	Hydrochloric Acid
KOH	Potassium Hydroxide
HNO_3	Nitric Acid
TCV	Total Calorific Value
AOAC	Association of Official Analytical Chemists

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Conflicts of Interest

The authors declare no conflicts of interest.

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