React Engineering, Environmental, and Applied Sciences
https://research.federalpolyede.edu.ng/react-eeas
1(1), 1-15, (2025)
RESEARCH ARTICLE

Development and Evaluation of Nutrient-Enriched Cookies from Malted Quality Protein Maize, Soybean, and Ginger-Based Composite Flours

Enwerem Deborah Ekpenyobhiele[1]*, Oyinloye Olaitan Daniel[1], Babalola Abibat Oluwakemi[2], Oladapo Mojisola Aderonke[2], Adebimpe Tolulope Olubunmi[2], Akinyele Adijat Adeola[1]

[1] Nutrition and Dietetics Department, Federal Polytechnic of Ede, Ede, Osun State. Nigeria

[2] Department of Food Science and Technology, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria

Received: 26 September 2025 | *Accepted:* 10 October 2025 | *Published:* 12 October 2025
Corresponding author: debbyfavours@gmail.com | D.E. Enwerem

Abstract

Cookies are commonly consumed as snacks, but are often made solely with wheat flour, which offers limited nutrition. This study investigated the effects of partially replacing wheat flour with malted Quality Protein Maize (QPM), defatted soy flour (16%), and ginger powder (4%) on the nutritional, functional, and sensory properties of cookies. Wheat flour was substituted with QPM at levels of 10–40%. The blends showed protein (9.06% to 16.38%), ash (0.82% to 1.14%), and fiber (0.71% to 2.94%) content, indicating enhanced protein, dietary fiber, and mineral availability with slight reductions in fat and carbohydrates. Mineral levels, especially iron (3.12–6.28 mg/100 g) and calcium (21.6–39.2 mg/100 g), also improved. Functional properties such as water absorption (1.71 to 2.14 g/g), swelling power (2.36 to 2.85), oil absorption (1.48 to 1.76), and foaming capacity (0.77 to 1.13) were enhanced with higher QPM levels, suggesting better dough handling and stability. Sensory evaluation showed that cookies with 10% QPM were the most acceptable (score: 8.45/9), with no significant difference ($p > 0.05$) from the control, while higher QPM levels slightly reduced acceptability. Overall, the inclusion of malted QPM, soy, and ginger improved the nutritional value and functionality of cookies without compromising taste, offering a promising way to produce baked products using local ingredients to improve dietary quality.

Keywords: Cookies, maize, soyabean, ginger, composites

1. Introduction

Protein-energy malnutrition and micronutrient deficiencies continue to pose major public health concerns in Nigeria and other developing regions, particularly among vulnerable groups such as children and low-income families (Aigbedion et al., 2025). Although cookies are widely enjoyed for their taste, affordability, and ease of access, they are typically made from refined wheat flour, a nutrient-poor, largely imported ingredient (Mamat et al., 2020). Incorporating locally available, nutrient-rich alternatives into cookie formulations could offer a practical strategy to improve dietary quality while supporting local agriculture.

Quality Protein Maize (QPM), a bio-fortified maize variety enriched with lysine and tryptophan, two essential amino acids lacking in conventional maize, has shown promise in enhancing protein quality in cereal-based products (Maqbool et al., 2021). Malting further improves its digestibility and functional performance. Likewise, defatted soybean flour contributes high-quality protein, fiber, and minerals (Murtaza et al., 2024). Ginger (Zingiber officinale) adds not only flavor but also antioxidant and antimicrobial benefits that may enhance product stability and shelf life (Shaukat et al., 2023).

Despite the nutritional potential of these ingredients, few studies have examined their combined use in cookie production. Existing research largely focuses on binary blends or alternative flours like tubers and legumes (Adeola & Ohizua, 2018; Ervina, 2023). This study, therefore, investigates a composite flour blend of wheat, malted QPM, defatted soybean, and ginger, evaluating their nutritional value, functional properties, and the sensory appeal of cookies produced from the blends as a potential strategy to support better nutrition through locally made snack foods.

2. Materials and Methods

2.1 Sourcing of raw materials

Commercial wheat flour (Mama Gold brand) was purchased from Oje Market in Ede, Osun State, Nigeria. Quality Protein Maize (QPM) grains, labelled Batch No: QPM/IAR&T-2025, were obtained from the Institute of Agricultural Research and Training (IAR&T), located in Ibadan, Oyo State. Defatted soybean flour was procured from Spectra Industries Limited, Oko-Oba, Lagos. Fresh ginger rhizomes, Zingiber officinale, yellow-fleshed variety, were sourced from the Osogbo Central Market, Osun State. Other baking ingredients, including butter, sugar, baking powder, eggs, vanilla essence, and salt, were sourced locally from Ede, Osun State, Nigeria.

2.2 Sample preparation

2.2.1 Preparation of Malted QPM flour

Malted QPM flour was prepared using the method described by Ikujenlola and Adurotoye (2014) with modifications as illustrated in Figure 1. The maize grains were first cleaned and sorted to remove impurities, then soaked in clean water at ambient temperature for 8 hours. Germination was carried out in the dark for 72 hours under controlled conditions, with periodic watering to facilitate sprouting. After germination, the grains were dried in a cabinet dryer (Memmert UN110, Memmert GmbH, Germany) at 60 °C for 48 hours. The dried malted grains were milled using an attrition mill (Thomas Wiley Mill, Model 4, Thomas Scientific, USA), sieved for uniform particle size, and stored in airtight containers for analysis.

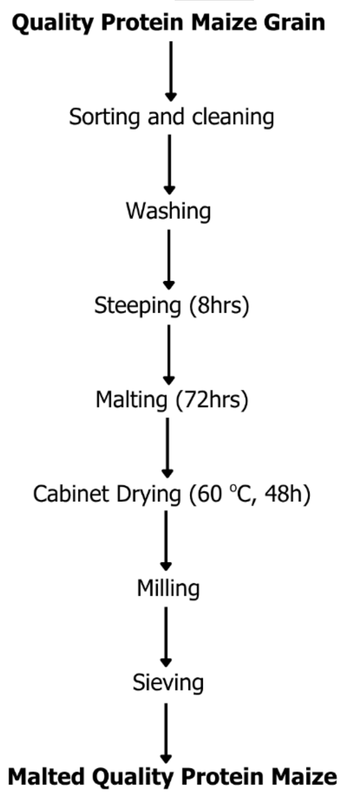


Figure 1: Production flowchart of Malted Quality Protein Maize Powder

Source: Ikujenlola and Adurotoye (2014)

2.2.2 Ginger powder and preparation of ginger flour

The process for producing ginger flour was based on the method described by Rashid (2021), with slight modifications as shown in Figure 2. Fresh ginger rhizomes were first blanched by briefly immersing them in boiling water for about 10 seconds. This was followed by soaking the blanched ginger in a 0.2% potassium metabisulphite solution for 5 minutes at room temperature to help preserve the ginger and maintain its natural colour. After soaking, the ginger was rinsed thoroughly under running water and then sliced into thin pieces, approximately 2 to 5 mm thick. The slices were dried in a hot air oven (Memmert UN110, Memmert GmbH, Germany) at a steady temperature of 50 °C for 8 hours. Once fully dried, the ginger was milled using an attrition mill (Thomas Wiley Mill, Model 4, Thomas Scientific, USA), sieved to achieve uniform particle size, and stored in airtight containers until needed for further processing.

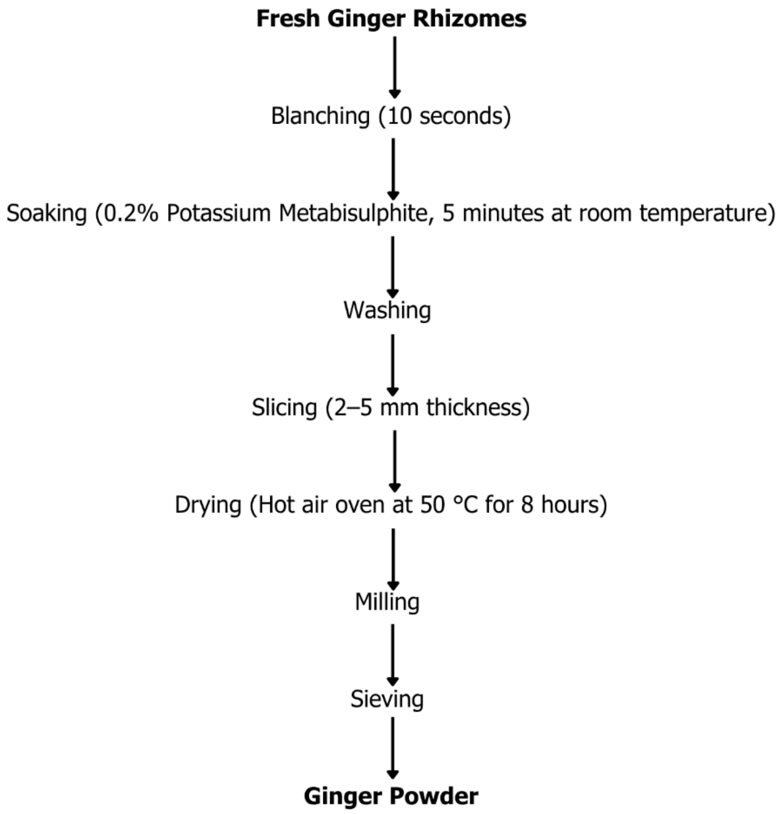


Figure 2: Flow Chart for the Production of Ginger Flour (*Rashid, 2021)*

2.2.3 Composite flour formulation

Composite flours were developed by combining wheat flour, malted QPM flour, defatted soybean flour, and ginger powder in specific proportions. The base blends of wheat and malted QPM were prepared in the following ratios: 100:0, 90:10, 80:20, 70:30, and 60:40, as detailed in Table 1. To enhance the nutritional profile, particularly protein content, mineral levels, and antioxidant potential, each blend was supplemented with 16% defatted soybean flour and 4% ginger powder. These fortification levels were determined based on findings from preliminary experiments with a guide from previous works done (Rana & Ahmed, 2021; Ajibola & Oyinlola, 2020; Akinola & Ogundele, 2023) and were kept constant across all samples to specifically assess the effect of varying QPM content on the final product.

Table 1. Composite Flour Formulations from (Wheat and Malted QPM), Defatted Soybean, Ginger

Sample	Wheat + QPM (%)	Defatted Soybean (%)	Ginger (%)
DA	100	0	0
DB	80 (60:40)	16	4
DC	80 (70:30)	16	4
DD	80 (80:20)	16	4
DE	80 (90:10)	16	4

Key: DA – 100% Wheat (Control); DB – 60:40 Wheat: QPM, 16% Defatted Soybean, 4% Ginger; DC – 70:30 Wheat: QPM, 16% Defatted Soybean, 4% Ginger; DD – 80:20 Wheat: QPM, 16% Defatted Soybean, 4% Ginger; DE – 90:10 Wheat: QPM, 16% Defatted Soybean, 4% Ginger; QPM- Quality Protein Maize

2.2.4 Cookie production and preparation

Cookies were produced using the rubbing-in technique as illustrated in Figure 3. The composite flour blends (coded DA to DE) were combined with standard baking ingredients such as sugar, butter, salt, baking powder, vanilla essence, and egg. Mixing was carried out using a planetary dough mixer (Kenwood Chef XL, Model KVL4100S, UK) fitted with a paddle attachment. The mixture was blended at a medium speed (150 rpm) for approximately 10 minutes, or until a smooth, uniform dough was formed. The dough was then rolled out to a consistent thickness of 3.5 mm and cut into circular shapes using a cookie cutter to maintain uniformity in size. Shaped dough pieces were arranged on baking trays and baked in a preheated oven at 150 °C for 30 minutes. After baking, the cookies were left to cool naturally at room temperature. Once completely cooled, they were packed in low-density polyethylene (LDPE) bags for storage.

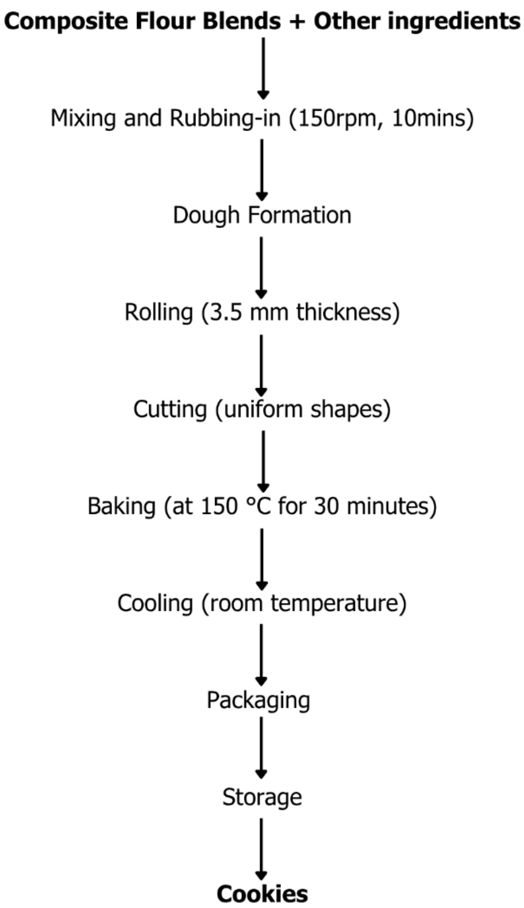


Figure 3: Flow Chart for the Production of Cookies.

2.3 Analysis

2.3.1 Determination of chemical composition

The chemical composition of both the composite flour blends and the resulting cookie samples was assessed using standard procedures outlined by the Association of Official Analytical Chemists (AOAC, 2005). Specific AOAC method numbers were applied for each component measured. Protein content was analyzed using the semi-micro Kjeldahl method (AOAC 2005.992.23), which involves digestion, distillation, and titration steps. Fat content was determined through Soxhlet extraction (AOAC 2005.963.15), using petroleum ether (boiling point 40–60 °C) as the solvent. Moisture was measured by drying samples in a hot-air oven at 105 °C to a constant weight, following AOAC 2005.925.10. Ash content was obtained by incinerating the samples in a muffle furnace at 550 °C until only a light grey residue remained (AOAC 2005.923.03). Crude fiber was estimated using sequential digestion with acid and alkali solutions in accordance with AOAC 2005.978.10. Carbohydrate content was calculated by difference using the following formula:

$$Carbohydrate\ (\%) = 100 - (\%\ Moisture + \%\ Protein + \%\ Fat + \%\ Ash + \%\ Fiber) \quad (1)$$

Mineral analysis included calcium (Ca), iron (Fe), zinc (Zn), and magnesium (Mg), determined using an Atomic Absorption Spectrophotometer (PerkinElmer Analyst 400) in line with AOAC 1998.985.35. Sodium (Na) and potassium (K) levels were assessed using a flame photometer (Corning 400), based on AOAC 1998.984.27.

2.3.2 Functional Properties of the Composite Flours

Standard laboratory methods were employed to evaluate the functional properties of the composite flour samples. Bulk density was measured following the procedure by Nwosu (2013). Two grams of flour were gently poured into a 10 mL graduated cylinder, tapped ten times against a firm surface to settle the contents, and the final volume was recorded. Bulk density was calculated using the equation:

$$Bulk\ Density\ (g/mL) = Weight\ of\ sample\ (g)\ /\ Final\ volume\ (mL) \quad (2)$$

Water Absorption Capacity (WAC) and Oil Absorption Capacity (OAC) were determined using the method of Falade and Akeem (2020). For each, 1 g of flour was mixed with 10 mL of distilled water or oil in a centrifuge tube, vortexed for 30 seconds, and left to stand for 30 minutes. The mixture was then centrifuged at 3000 rpm for 20 minutes using a Remi R-8C centrifuge. The absorbed liquid was quantified by calculating the difference in weight before and after centrifugation.

Least Gelation Concentration (LGC) was assessed using the method by Coffman and Garcia (1977). Various concentrations (2%–20%) of flour suspensions were prepared in 5 mL of distilled water and heated in a boiling water bath at 100 °C for 1 hour. Samples were then cooled under running water and refrigerated at 4 °C for 2 hours. The LGC was identified as the lowest concentration that formed a firm, stable gel.

Foam Capacity (FC) and Foam Stability (FS) were tested using the protocol by Narayana and Narasinga Rao (1982). Two grams of flour were whipped in 100 mL of distilled water at 1600 rpm for five minutes using a Kenwood HM220 electric mixer. Foam volume was recorded immediately (for FC) and again after 30 minutes (for FS) to assess stability over time.

Swelling capacity was evaluated using the method of Ojinaka and Nnorom (2015). One gram of flour was dispersed in 10 mL of distilled water and heated at 90 °C for 30 minutes. After cooling, the mixture was centrifuged at 3000 rpm for 15 minutes, and the weight of the sediment was recorded to determine the swelling capacity.

2.3.3 Sensory evaluation

Sensory testing was carried out using a panel of ten semi-trained individuals, consisting of six females and four males, aged between 22 and 35 years. Panelists were chosen based on their prior experience with bakery products and familiarity with sensory evaluation methods. The cookies were assessed on taste, color, texture, mouthfeel, and overall acceptability using a 9-point Hedonic scale, where 1 indicated "dislike extremely" and 9 represented "like extremely." Samples were coded with random three-digit numbers and presented in a randomized order to minimize bias. Evaluations took place in individual sensory booths under controlled conditions to maintain consistency and reduce external distractions. The relatively small panel size was due to the limited availability of trained participants and is acknowledged as a limitation of this study.

2.4 Statistical analysis

All measurements were performed in triplicate to ensure data reliability. Statistical differences among sample means were evaluated using one-way Analysis of Variance (ANOVA). When significant differences were found, Duncan's Multiple Range Test was applied to identify specific differences between means at a significance level of $p < 0.05$. Data analysis was conducted using IBM SPSS Statistics version 25, with a confidence level set at 95%.

3. Results and Discussions

3.1 Proximate composition of composite flours

Table 2 presents the proximate analysis results for the composite flour blends. Moisture content ranged from 7.71% in sample DE to 8.96% in sample DD, with the control sample (DA, 100% wheat flour) recording 7.81%. The increase in moisture observed in samples with higher proportions of Quality Protein Maize (QPM) and defatted soybean flour, especially in DD and DB, may be due to the hydrophilic nature of dietary proteins and fibers, which are known to retain more water (Karim et al., 2023). These findings are in agreement with earlier work on rice–soybean blends by Eke-Ejiofor and Williams (2016). The lowest moisture value in DE suggests better shelf stability, as reduced moisture helps inhibit microbial activity (Sowmya & Ramalingappa, 2023). Importantly, all samples remained well below the 13% moisture limit recommended for flour-based products (Alam et al., 2019).

Fat content showed minimal variation across the samples, ranging from 1.33% to 1.45%, with no statistically significant differences ($p > 0.05$). These low-fat levels reflect the use of ingredients with inherently low lipid content, particularly defatted soybean flour. The slightly higher fat level in DE is likely due to its greater proportion of wheat flour, which typically contains around 2.4% to 3.8% fat on a dry basis (Akram et al., 2023). Compared to higher fat levels found in maize–pigeon pea blends (4.79–6.19%) as reported by Ezegbe et al. (2025), these results suggest the effectiveness of the defatting process.

Crude fiber content ranged from 2.38% (DC) to 2.56% (DD), while the control sample (DA) recorded 2.54%. The higher fiber levels in DD are likely influenced by the combined presence of QPM and soybean flour, both recognized for their high fiber contributions (Mankad et al., 2024; Aanchal, 2023). Interestingly, the control sample also exhibited relatively high fiber content, which may be due to residual bran in the commercial wheat flour used (Skrivan et al., 2024). All fiber values complied with the Codex limit of under 5% and were consistent with findings from Iwanegbe et al. (2019), though higher values (0.51%–0.87%) were reported by Aderinola and Adeoye (2022) for maize–bean flour combinations.

Ash content varied from 0.72% in DE to 0.94% in DD. The higher ash values in DD and DB may be attributed to the inclusion of mineral-rich ingredients like defatted soybean flour and ginger (Robinson et al., 2025). Conversely, the lower ash value in DE aligns with its higher wheat content and lower substitution rate. These results are somewhat lower than those reported for blends such as maize–cassava–soybean and lafun–pigeon pea (Igbua et al., 2018; Bolaji et al., 2021), but they are similar to ash values observed in QPM–soursop flour blends (Adebayo, 2025) and lower than the 1.32%–2.12% range reported by Noah and Banjo (2020) for wheat–kidney bean–moringa formulations.

Protein content showed significant variation ($p < 0.05$), increasing from 10.36% in DE to 13.31% in DD, compared to 11.06% in the control (DA). This increase corresponds with the inclusion of protein-rich defatted soybean flour (Kang et al., 2017) and QPM, which is high in lysine and tryptophan. The protein levels in this study exceed those reported for maize–soy–jack bean blends (7.3%–9.8%) by Meka et al. (2019) and are consistent with the values (10.03%–15.97%) observed by Asouzu and Umerah (2022) in wheat–pigeon pea flour blends.

Carbohydrate content ranged from 72.10% in DD to 77.50% in DE, with the control sample at 76.44%. The lower carbohydrate levels in DD and DB reflect a proportional decrease due to the higher presence of protein, ash, and fiber; an inverse relationship was also observed by Adejumo et al. (2020) and Deedam et al. (2020). Conversely, the higher carbohydrate level in DE is consistent with its lower inclusion of QPM and soybean flour, retaining more of the energy-dense wheat flour component (Sogo-Temi et al., 2023). These values are generally higher than the 59.38% to 66.99% range reported by Ewunonu and Umerah (2024) for wheat–kidney bean flour mixtures.

Table 2. Proximate composition of the flour blends

Samples	Moisture (%)	Fat (%)	Fiber (%)	Ash (%)	Protein (%)	Carbohydrate (%)
DA	7.81± 0.02c	1.33 ± 0.01a	2.54 ± 0.01a	0.81 ± 0.01b	11.06 ± 0.02b	76.44 ±0.04a
DB	8.71± 0.03b	1.34 ± 0.02a	2.43 ± 0.01ab	0.84 ± 0.02b	13.12 ± 0.02a	73.46 ± 0.04a
DC	7.84± 0.01c	1.34 ± 0.01a	2.38 ± 0.01b	0.73 ± 0.01c	10.73 ± 0.12c	73.53 ± 0.17a
DD	8.96± 0.02a	1.38 ± 0.19a	2.56 ± 0.09 a	0.94 ± 0.01a	13.31 ± 0.12a	72.10 ± 4.50a
DE	7.71± 0.03d	1.45 ± 0.02a	2.39 ± 0.02 b	0.72 ± 0.01c	10.36 ± 0.05d	77.50 ± 0.05a

Mean values with the same superscript in a column are not significant (p<0.05)
DA - 100% Wheat Flour; DB- 80% (W60%, QPM 40%), 16% Defatted Soy Flour, 4% Ginger; DC-80% (W70%, QPM 30%), 16% Defatted Soy Flour, 4% Ginger; DD-80% (W80%, QPM 20%), 16% Defatted Soy Flour, 4% Ginger; DE-80% (W90%, QPM 10%), 16% Defatted Soy Flour, 4% Ginger

3.2 *Percentage change in composition relative to wheat flour*

The percentage variations between each composite flour blend and the control sample (DA) are summarized in Table 3. Notably, protein content increased significantly in samples DB (+18.63%) and DD (+20.34%), a result of the protein-enriching effect of QPM and defatted soybean flour. Moisture content also rose, particularly in sample DD (+14.72%), reinforcing earlier observations about the strong water-holding capacity of fiber- and protein-rich ingredients. While fat content showed only slight increases across all samples, the highest was observed in DE (+9.02%), likely due to its higher wheat flour proportion. Ash content saw a marked increase in DD (+16.05%) and a smaller rise in DB (+3.70%), reflecting the mineral-rich nature of the added components such as ginger and soybean flour. A slight increase in fiber content was recorded in DD (+0.79%), whereas minor reductions were noted in other samples, potentially the result of ingredient interactions or variations in fiber solubility. Carbohydrate levels declined across all blends except DE, which showed a modest increase of +1.39%. This trend supports the inverse relationship between carbohydrate content and the enrichment of protein and fiber in composite flours. Overall, these results suggest that incorporating QPM, soybean, and ginger into wheat flour can significantly enhance its nutritional value particularly in protein and minerals without greatly affecting its caloric contribution.

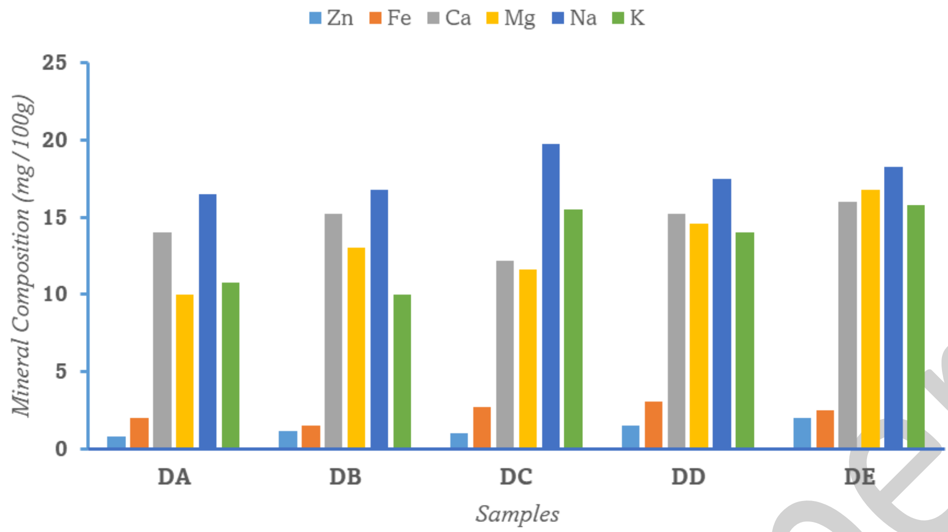
Table 3. Percentage Differences in Proximate Composition of Composite Flours

Samples	Moisture (%)	Fat (%)	Fiber (%)	Ash (%)	Protein (%)	Carbohydrate (%)
DB	+11.52	+0.75	-4.33	+3.70	+18.63	-3.90
DC	+0.38	+0.75	-6.30	-9.88	-2.98	-3.81
DD	+14.72	+3.76	+0.79	+16.05	+20.34	-5.68
DE	-1.28	+9.02	-5.91	-11.11	-6.33	+1.39

Mean values with the same superscript in a column are not significant (p<0.05)
DA - 100% Wheat Flour; DB- 80% (W60%, QPM 40%), 16% Defatted Soy Flour, 4% Ginger ; DC-80% (W70%, QPM 30%), 16% Defatted Soy Flour, 4% Ginger ; DD-80% (W80%, QPM 20%), 16% Defatted Soy Flour, 4% Ginger ; DE-80% (W90%, QPM 10%), 16% Defatted Soy Flour, 4% Ginger

3.3 *Mineral Composition of Composite Flours*

Figure 4 illustrates the mineral content of the various flour blends (DA–DE), showing statistically significant differences ($p < 0.05$) in levels of zinc (Zn), iron (Fe), calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K). These differences reflect the influence of ingredient composition across the samples. The inclusion of Quality Protein Maize, defatted soybean flour, and ginger each known for their mineral richness contributed to the improved micronutrient profile in the composite blends when compared to the control. The extent of enhancement varied depending on the proportion of these functional ingredients in each formulation.



DA - 100% Wheat Flour; DB- 80% (W60%, QPM 40%), 16% Defatted Soy Flour, 4% Ginger ; DC-80% (W70%, QPM 30%), 16% Defatted Soy Flour, 4% Ginger ; DD-80% (W80%, QPM 20%), 16% Defatted Soy Flour, 4% Ginger ; DE-80% (W90%, QPM 10%), 16% Defatted Soy Flour, 4% Ginger

Figure 4: Mineral Composition of the Blends

Zinc content increased markedly from 0.75 mg/100 g in the control sample (DA) to 1.95 mg/100 g in sample DE. This improvement reflects the zinc-dense nature of both QPM and soybean flour. These results are consistent with prior findings by Okpalanma et al. (2022), who observed elevated zinc levels in soy- and vegetable-based flour blends. However, despite these gains, the zinc levels remain below the FAO/WHO (2002) recommended daily intake of 4–5 mg for infants and young children, suggesting a need for additional zinc sources in the diet.

Iron levels varied significantly, with the highest concentrations found in DD (3.05 mg/100 g) and DE (2.50 mg/100 g), while DB recorded the lowest (1.50 mg/100 g). The increased iron in DD and DE is attributed to the presence of soybean and QPM, both recognized for their iron content. Although the iron levels were lower than 7.67–15.78 mg/100 g reported in QPM–soursop blends (Adebayo, 2025), the observed increase still contributes meaningfully to addressing iron deficiency, particularly in vulnerable populations.

Calcium content ranged between 12.20 mg/100 g (DC) and 16.00 mg/100 g (DE). The rise in calcium in most composite samples is likely due to the inclusion of soy and ginger, which are known sources of this mineral (Okereke et al., 2022). Nonetheless, these conform with the findings of Adnan et al. (2025) who observed increase in calcium content of wheat-yellow/white maze composite blends indicating only dietary contribution even as defatted soyabeans was added.

Magnesium levels, essential for neuromuscular and metabolic function, were lowest in the control (DA: 10.00 mg/100 g) and peaked in DE (16.80 mg/100 g). The improved magnesium content correlates with the inclusion of QPM and soy. While still lower than the concentrations reported 50.63–56.50 mg/100 g in sweet potato–peanut–wheat blends (Chiedu et al., 2023), the improvement demonstrates the mineral-enhancing potential of the composite flour.

Sodium content showed modest increases, ranging from 16.50 mg/100 g (DA) to 19.75 mg/100 g (DC). These variations align with findings from Abiona et al. (2023), where sodium content was influenced by functional protein ingredients. All values remain well within safe consumption limits, far below the FAO/WHO (2002) recommended adult maximum of 2000 mg/day.

Potassium concentrations ranged from 10.00 mg/100 g (DB) to 15.75 mg/100 g (DE), likely boosted by QPM and soybean content. Potassium plays a key role in regulating muscle function and blood pressure. Although the values fall short of the FAO/WHO's recommended daily intake of 3500 mg, the blends still offer meaningful contributions in potassium-deficient populations. Notably, the higher potassium-to-sodium ratios observed may benefit cardiovascular health.

3.4 Percentage increase in mineral content

Table 4 outlines the percentage increase in mineral content of composite blends (DB–DE) relative to the control (DA). Zinc showed the most substantial rise, with sample DE increasing by 160% and DD by 100%, reinforcing the mineral-enhancing impact of QPM and soybean flour. Iron content also improved considerably, with increases of 52.5% in DD and 35% in DC. However, a 25% reduction in DB suggests that the higher QPM ratio may have diluted the iron contribution from the soybean.

Calcium levels increased by 14.3% in DE and 8.57% in both DB and DD. A slight decrease was observed in DC (–12.86%), likely due to lower ginger content in that blend. Magnesium rose by 68% in DE, underscoring its improved nutritional potential. Sodium showed smaller but consistent increases across samples, peaking at 19.7% in DC. Potassium content saw notable increases as well, especially in DE (+46.51%) and DC (+44.19%).

These improvements highlight the nutritional advantage of fortifying wheat flour with QPM, defatted soybean flour, and ginger. In particular, the substantial increases in zinc, magnesium, and potassium suggest enhanced functionality in supporting immune health, metabolic activity, and cardiovascular function.

Table 4. Percentage Differences in Mineral Composition of Composite Flours

Sample	Zn (%)	Fe (%)	Ca (%)	Mg (%)	Na (%)	K (%)
DB	+53.33	-25.00	+8.57	+30.00	+1.52	-6.98
DC	+33.33	+35.00	-12.86	+16.00	+19.70	+44.19
DD	+100.00	+52.50	+8.57	+46.00	+6.06	+30.23
DE	+160.00	+25.00	+14.29	+68.00	+10.61	+46.51

DA - 100% Wheat Flour; DB- 80% (W60%, QPM 40%), 16% Defatted Soy Flour, 4% Ginger ; DC-80% (W70%, QPM 30%), 16% Defatted Soy Flour, 4% Ginger ; DD-80% (W80%, QPM 20%), 16% Defatted Soy Flour, 4% Ginger ; DE-80% (W90%, QPM 10%), 16% Defatted Soy Flour, 4% Ginger

3.5 Functional properties of composite flours

Table 5 summarizes the functional properties measured for the composite flour samples (DA–DE). Statistically significant differences ($p < 0.05$) were found in water absorption capacity (WAC), oil absorption capacity (OAC), swelling power, foam capacity and stability, bulk density, and least gelation concentration (LGC).

The WAC ranged from 1.71 g/g (in DE) to 2.14 g/g (in DD), with DD showing the greatest capacity. This elevated WAC may be linked to hydrophilic amino acid residues in defatted soy flour, which attract and bind water (Mamat et al., 2020). Forwoukeh et al. (2023) similarly observed that high-protein flours tend to retain more water. High WAC is advantageous in baking, as it aids dough handling and moisture retention, potentially enhancing shelf life. Nevertheless, our WAC values are lower than the 158–183% reported by Adeyanju et al. (2018) for wheat–acha–pigeon pea blends.

OAC values ranged from 1.48 g/g (DE) to 1.76 g/g (DD). The higher OAC in DD likely arises from the non-polar side chains of soy proteins interacting with lipids, which aids in flavor and fat retention (Eke-Ejiofor, 2018). These findings echo those by Forwoukeh et al. (2023), who showed that protein-rich flours tend to absorb more oil. Although improved by soy addition, our OAC values are lower than 191.20–206.80% for millet–sesame–moringa blends (Disseka et al., 2018).

Swelling power varied significantly: DD recorded the highest value (2.85 g/g), while DC had the lowest (2.34 g/g). The greater swelling in DD may reflect enhanced starch gelatinization and interactions between wheat starch, QPM, and soy proteins (Jia et al., 2023). Ahemen et al. (2018) observed similar behavior in wheat–tigernut–sesame blends. Our swelling values also align with Ukpong et al. (2021) for African yam bean–wheat composite flours.

Foaming capacity ranged from 0.77% (DE) to 1.13% (DD), and foaming stability ranged from 0.51% (DE) to 0.76% (DD). The improvements in DD are probably due to soy proteins lowering surface tension at the air–water interface, thus supporting better foam formation and maintenance (Xiao & Konemann, 2015). Eke-Ejiofor (2018) reported similar enhancements in legume-enriched flour systems.

Bulk density values varied between 0.59 g/mL (DE) and 0.65 g/mL (DD). The higher bulk density in DD suggests tighter packing of particles, which may have implications for storage and packaging. These numbers fall within ranges observed in other cereal–legume composites (e.g. 0.63–0.79 g/mL for wheat–sweet potato–African yam bean blends).

Overall, sample DD consistently exhibited superior functional performance, delivering the highest WAC, OAC, swelling power, foaming properties, and bulk density. That suggests that the formulation W80:QPM20 + soy + ginger is especially apt for applications requiring water retention, oil binding, and foaming behavior in baked goods. These findings concur with earlier work highlighting the benefits of enriching composite flours with legumes, bio-fortified maize, and spices to boost both functionality and nutrition (Lawrence, 2022; Okereke et al., 2022).

Table 5. Functional properties of flour blends

Samples	Water absorption capacity (%)	Oil Absorption Capacity (%)	Swelling power (%)	Foaming capacity (%)	Foaming stability (%)	Bulk Density (g/ml)
DA	1.93 ± 0.01^{c}	1.65 ± 0.01^{b}	2.38 ± 0.01^{c}	0.95 ± 0.02^{c}	0.52 ± 0.01^{bc}	0.60 ± 0.01^{b}
DB	2.03 ± 0.01^{b}	1.71 ± 0.01^{a}	2.54 ± 0.02^{b}	1.05 ± 0.02^{b}	0.56 ± 0.01^{b}	0.63 ± 0.01^{ab}
DC	1.75 ± 0.01^{d}	1.61 ± 0.01^{b}	2.34 ± 0.01^{c}	0.79 ± 0.04^{d}	0.53 ± 0.01^{bc}	0.60 ± 0.01^{b}
DD	2.14 ± 0.02^{a}	1.76 ± 0.01^{a}	2.85 ± 0.02^{a}	1.13 ± 0.01^{a}	0.76 ± 0.01^{a}	0.65 ± 0.01^{a}
DE	1.71 ± 0.01^{d}	1.48 ± 0.02^{c}	2.36 ± 0.01^{c}	0.77 ± 0.01^{d}	0.51± 0.00^{c}	0.59 ± 0.01^{b}

Mean values with the same superscript in a column are not significant (p<0.05)
DA - 100% Wheat Flour; DB- 80% (W60%, QPM 40%), 16% Defatted Soy Flour, 4% Ginger ; DC-80% (W70%, QPM 30%), 16% Defatted Soy Flour, 4% Ginger ; DD-80% (W80%, QPM 20%), 16% Defatted Soy Flour, 4% Ginger ; DE-80% (W90%, QPM 10%), 16% Defatted Soy Flour, 4% Ginger;

3.6 Percentage deviations in functional properties of composite flours

Table 6 illustrates the percentage differences in functional properties of the composite flours (DB–DE) when compared to the control sample (DA). These differences emphasize how ingredient substitutions influence functional behavior. Water Absorption Capacity (WAC) increased in DB (+5.18%) and showed the most improvement in DD (+10.88%), suggesting stronger water-binding ability, particularly with moderate QPM inclusion. In contrast, WAC decreased in DC (–9.33%) and DE (–11.40%), potentially due to lower protein or fiber content. A similar pattern was observed in Oil Absorption Capacity (OAC), which increased in DD (+6.67%) and DB (+3.64%), but declined in DC (–2.42%) and more significantly in DE (–10.30%). This reflects the role of soy protein in enhancing lipid interactions. Swelling power also showed a notable increase in DD (+19.75%), likely due to improved starch–protein interaction, while DB rose slightly (+6.72%). Slight reductions were observed in DC (–1.68%) and DE (–0.84%). Foaming capacity and stability improved considerably in DD (+18.95% and +46.15%, respectively), with DB also showing gains (+10.53% and +7.69%). In contrast, DC and DE showed declines, likely linked to lower protein content which plays a key role in foam formation and stability. Bulk density increased modestly in DD (+8.33%) and DB (+5.00%), reflecting tighter particle packing. A minor decline was observed in DE (–1.67%). These findings reinforce the functional advantages of DD (W80:QPM20 + soy + ginger), which consistently outperformed other blends in most functional attributes.

Table 6. Percentage Differences in Functional Properties of Composite Flours

Sample	Water absorption	Oil absorption	Swelling power	Foaming capacity	Foaming stability	Bulk density
DB	+5.18	+3.64	+6.72	+10.53	+7.69	+5.00
DC	-9.33	-2.42	-1.68	-16.84	+1.92	+0.00
DD	+10.88	+6.67	+19.75	+18.95	+46.15	+8.33
DE	-11.40	-10.30	-0.84	-18.95	-1.92	-1.67

Mean values with the same superscript in a column are not significant (p<0.05)
DA - 100% Wheat Flour DB- 80% (W60%, QPM 40%), 16% Defatted Soy Flour, 4% Ginger, DC-80% (W70%, QPM 30%), 16% Defatted Soy Flour, 4% Ginger , DD-80% (W80%, QPM 20%), 16% Defatted Soy Flour, 4% Ginger , DE-80% (W90%, QPM 10%), 16% Defatted Soy Flour, 4% Ginger

3.7 Sensory Properties of Cookies Produced from Flour Blends

The sensory attributes of cookies produced from the various composite flour blends are presented in Table 7. Attributes assessed include taste, flavor, color, texture, crispiness, and overall acceptability.

Taste scores differed significantly ($p < 0.05$) among the samples, ranging from 7.40 (DC) to 8.65 (DA). The control sample (DA) was most preferred for taste and was significantly higher than DC, while DE (8.35) did not differ from the control. This suggests that cookies formulated with 10% QPM (DE) retained a taste profile comparable to 100% wheat cookies, whereas higher substitutions (30–40% QPM) reduced taste acceptability.

Flavour evaluation showed significant variation, with DE (8.30) receiving the highest score, statistically similar to DA (8.55) but significantly higher than DB (7.50), DC (7.45), and DD (7.65). This indicates that moderate QPM substitution (10%) enhanced flavour perception, while higher levels (≥20%) negatively influenced it.

For colour, no significant differences ($p > 0.05$) were observed, as all samples scored between 7.70 and 8.25. This demonstrates that substitution with QPM, soybean, and ginger did not adversely affect visual quality.

Texture scores ranged from 7.35 (DB) to 8.30 (DE), with no significant differences among treatments ($p > 0.05$). Similarly, crispiness ratings (7.35–8.25) were statistically comparable across samples, indicating that QPM and soybean inclusion did not impair cookie structure.

Overall acceptability was highest in DE (8.45), statistically similar to DA (8.40) and DD (8.10), but significantly higher than DC (7.10). These findings reinforce that 10% QPM incorporation (with constant 16% soybean and 4% ginger) produced cookies with overall sensory appeal equivalent to wheat-based cookies, while higher substitution levels diminished consumer acceptance.

Statistical evidence shows that moderate substitution with QPM (10%) produced cookies with taste, flavour, and overall acceptability comparable to the control. In contrast, higher substitution levels (30–40% QPM) significantly lowered taste, flavour, and acceptability scores, even though colour, texture, and crispiness remained unaffected. The result suggest a well-balance formulation, with defatted soy and ginger likely enhancing the flavour depth and contributing to a pleasant mouthfeel (Johnson et al., 2022).

Table 7. Sensory Properties of Cookies Produced from Flour Blends

Sample	Taste	Flavour	Colour	Texture	Crispiness	Acceptability
DA	8.65 ± 0.12[a]	8.55 ± 0.13[b]	8.25 ± 0.14[a]	7.95 ± 0.12[a]	8.25 ± 0.18[a]	8.40 ± 0.13[a]
DB	7.80 ± 0.35[bc]	7.50 ± 0.47[b]	7.90 ± 0.24[a]	7.35 ± 0.40[a]	7.40 ± 0.45[a]	7.55 ± 0.35[bc]
DC	7.40 ± 0.33[c]	7.45 ± 0.26[b]	7.70 ± 0.27[a]	7.55 ± 0.27[a]	7.35 ± 0.41[a]	7.10 ± 0.34[c]
DD	7.95 ± 0.27[abc]	7.65 ± 0.27[b]	8.25 ± 0.25[a]	8.15 ± 0.22[a]	7.50 ± 0.28[a]	8.10 ± 0.24[ab]
DE	8.35 ± 0.20[ab]	8.30 ± 0.19[ab]	8.20 ± 0.19[a]	8.30 ± 0.22[a]	8.25 ± 0.23[a]	8.45 ± 0.14[a]

Mean values with the same superscript in a column are not significant ($p<0.05$)
DA - 100% Wheat Flour; DB- 80% (W60%, QPM 40%), 16% Defatted Soy Flour, 4% Ginger ; DC-80% (W70%, QPM 30%), 16% Defatted Soy Flour, 4% Ginger ; DD-80% (W80%, QPM 20%), 16% Defatted Soy Flour, 4% Ginger ; DE-80% (W90%, QPM 10%), 16% Defatted Soy Flour, 4% Ginger

Figure 5 (Radar Chart) visually highlights the sensory performance, showing that both DA and DE occupy the largest area, reflecting superior overall acceptability. Although DA slightly outperformed DE in taste and crispiness, DE maintained consistently high scores across all parameters. Its lower moisture content (see Section 4.4) may also contribute to longer shelf life, making it a promising candidate for commercial snack production (Harris, 2020).

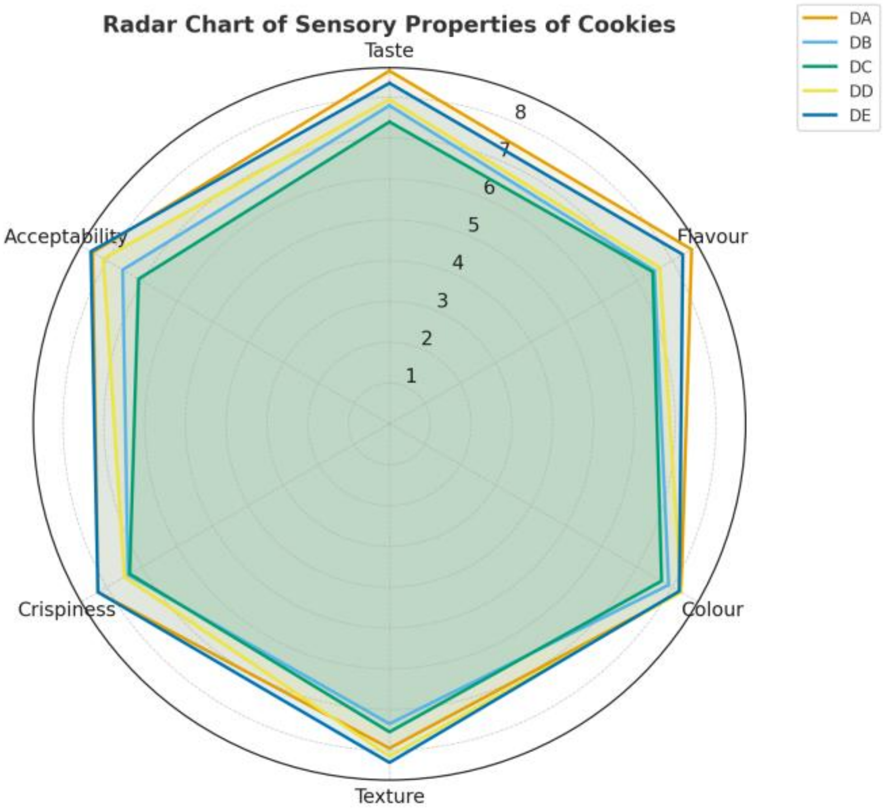


Figure 5. Radar chart showing the sensory properties of cookies

4. Conclusion and Recommendations

The study demonstrated that fortifying wheat flour with malted quality protein maize (QPM), defatted soybean flour, and ginger powder significantly improved the nutritional and functional properties of the composite flour blends compared to 100% wheat flour. Defatted soybean flour notably enhanced protein content, QPM contributed to increased energy density, and ginger improved fiber content and flavor profile. Cookies prepared from these blends, particularly sample DE (90% wheat and 10% QPM), exhibited favorable sensory properties, achieving good overall acceptability. This study is among the first studies to combine malted QPM, soy, and ginger for cookies. However, the study had limitations: nutritional and functional analyses were only performed on the flour blends, while sensory evaluation was limited to the cookies. Additionally, the sensory panel size was small due to the limited availability of trained assessors, and no microbial or cost analyses were conducted. Future research should broaden consumer testing, investigate shelf life, and assess economic viability to determine the product's commercial potential.

Declarations

Data availability: Data will be made available upon reasonable request.

Funding: This study received no funding.

Competing interests: Authors declare no known competing or financial interests.

References

Abiona S.O, Ogunlade A.O, Idowu-Mogaji G.O. (2023). Proximate, Mineral and Sensory Analysis of Maize-Soybeans Composite Flour Biscuit Enriched With Edible Insect "Kanni". Food Sci Nutr Res. 6(2): 1-4

Adebayo, T. K. (2025). Evaluation of flour blends made from high quality protein maize and soursop seed flours. Research Journal of Food Science and Nutrition, 10(1), 9–22. https://doi.org/10.31248/RJFSN2024.194

Adejumo, P. O., Adejumo, A. O., Edebiri, O. E., & Olukoya, F. O. (2020). Effect of unripe banana and pigeon pea flour on the chemical, anti-nutritional and sensory properties of whole wheat-based cookies. GSC Advanced Research and Reviews, 4(1), 17–23. https://doi.org/10.30574/gscarr.2020.4.1.0050

Adeola, A. A., & Ohizua, E. R. (2018). Physical, chemical, and sensory properties of biscuits prepared from flour blends of unripe cooking banana, pigeon pea, and sweet potato. Food Science and Nutrition, 6(3), 532–540. https://doi.org/10.1002/fsn3.590

Aderinola, T., & Adeoye, A. D. (2022). Proximate, amino acid compositions and functional properties of maize-beans composite flours. Food Science and Engineering, 4(1), 9–19. https://ojs.wiserpub.com/index.php/FSE/article/view/1874

Adeyanju, J. A., Babarinde, G. O., Adekunle, A. A., Olajire, A. S., & Adegboye, A. A. (2018). Quality characteristics of cookies produced from wheat, acha and pigeon pea flour blends. Annals Food Science and Technology, 19(4), 691–698.

Adnan, M., Butt, M. S., Pasha, I., & Shahid, M. (2025). Development of cookies from wheat-yellow/white maize composite blends and their physical and sensory evaluation. PLoS ONE, 20(6), e0326532. https://doi.org/10.1371/journal.pone.0326532

Ahemen, T., Pius, O., & Addass, P. A. (2018). Effect of concentrate to fresh Gmelina arborea leaf combinations on haematological and serum biochemical parameters of rabbit bucks. Asian Journal of Research in Animal and Veterinary Sciences, 1(4), 244–252. https://doi.org/10.9734/AJRAVS/2018/44095

Aigbedion, G., Tseng, P.-C., & Puthussery, S. (2025). Micronutrient deficiencies and determinants among pregnant women and children in Nigeria: Systematic review and meta-analysis. Nutrients, 17(14), 2338. https://doi.org/10.3390/nu17142338

Ajibola, F. O., & Oyinlola, A. (2020). Nutritional evaluation and sensory acceptability of trifoliate yam and soybean flour blends in cookies. Agrosearch, 20(1), 50–61. https://doi.org/10.4314/agrosh.v20i1.5

Akinola, O. S., & Ogundele, J. O. (2023). Utilisation of cassava/soybean composite flour in biscuit making. International Journal of Health, Environment, and Allied Research, 12(2), 145–154. https://www.ajol.info/index.php/ijhehar/article/view/261967

Akram, M. U., Yılmaz, R., Salantur, A., & Uygun, U. (2023). Bioactive compounds in lipids of selected wheat genotypes. International Journal of Food Science & Technology, 58(11), 6049–6058. https://doi.org/10.1111/ijfs.16713

Alam, M. R., Scampicchio, M., Angeli, S., & Ferrentino, G. (2019). Effect of hot melt extrusion on physical and functional properties of insect based extruded products. Journal of Food Engineering, 259, 44–51. https://doi.org/10.1016/j.jfoodeng.2019.04.021

AOAC. (2005). Official Methods of Analysis of AOAC International (18th ed.). AOAC International.

Asouzu, A. I., & Umerah, N. N. (2022). Evaluation of cookies produced from malted pigeon pea (Cajanus cajan). Asian Journal of Biotechnology and Bioresources Technology, 8(4), 1–9. https://doi.org/10.9734/AJB2T/2022/v8i4177

Bolaji, T., Kamoru, M. A., & Adeyeye, S. A. O. (2021). Quality evaluation and physico-chemical properties of blends of fermented cassava flour (lafun) and pigeon pea flour. Scientific African, 12, 1–9. https://doi.org/10.1016/j.sciaf.2021.e00833

Chiedu, U. C., Abiodun, M. S., Steve, I. O., Eguno, E. E. & Joy, A. T. (2023) 'Physicochemical, nutritional and functional properties of composite flour blends from whole wheat, sweet potato, defatted peanut and rice bran', European Journal of Nutrition & Food Safety, 15(12), pp. 41–55. https://doi.org/10.9734/ejnfs/2023/v15i121366

Coffman, C. V., & Garcia, V. V. (1977). Functional properties and amino acid content of a protein isolate from mung bean flour. Journal of Food Technology, 12, 473–480. https://doi.org/10.1111/j.1365-2621.1977.tb00132.x

Deedam, N. J., China, M. A., & Wachukwu, H. I. (2020). Utilization of soursop (Annona muricata) flour for the production of Chin-Chin. Agriculture and Food Sciences Research, 7(1), 97–104. https://doi.org/10.20448/journal.512.2020.71.97.104

Disseka, W. K., Faulet, M. B., Kone, F. M. T., Gnanwa, M. J., & Kouame, L. P. (2018). Phytochemical composition and functional properties of millet (Pennisetum glaucum) flours fortified with sesame (Sesamum indicum) and moringa (Moringa oleifera) as a weaning food. Advances in Research, 15(6), 1–11. https://doi.org/10.9734/air/2018/42811

Eke-Ejiofor, J., & Williams, I. (2016). Evaluation of defatted soybean flour inclusion on the properties of rice-based biscuits. International Journal of Biotechnology and Food Science, 4(4), 63–71.

Eke-Ejiofor, J., Wordu, G. O., & Bivan, S. K. (2018). Functional and pasting properties of Acha, defatted soybean and groundnut flour blends. American Journal of Food Science and Technology, 6(5), 215–218. https://doi.org/10.12691/ajfst-6-5-4

Ervina, E. (2023). The sensory profiles and preferences of gluten-free cookies made from alternative flours sourced from Indonesia. International Journal of Gastronomy and Food Science, 33, 100796. https://doi.org/10.1016/J.IJGFS.2023.100796

Ewunonu, O. C., & Umerah, N. N. (2024). Comparative evaluation of biscuits from wheat (Triticum aestivum) and red kidney bean (Phaseolus vulgaris) flour blends. ASRIC Journal on Natural Sciences, 4(1), 10–18.

Ezegbe, C. C., Nkhata, S. G., Ukpong, E. S., Ezeh, M. C., Okocha, K. S., & Pedro, B. F. (2025). Physicochemical and sensory quality of breakfast cereals produced from flour blends of maize and pigeon pea. Heliyon, 11(4), e42612. https://doi.org/10.1016/j.heliyon.2025.e42612

Falade K. O., and Akeem S. A. (2020). Physicochemical Properties, protein digestibility and thermal stability of processed African mesquite bean (Prosopis africana) flours and protein isolates. Journal of Food Measurement characteristics. 14(3): 1481-1496. https://doi.org/10.1007/s11694-020-00398-0

FAO/WHO (2002) Joint Expert Consultation. Vitamin and mineral requirements in human nutrition. Geneva: World Health Organization.

Forwoukeh, V. H., Amove, J., & Yusufu, M. I. (2023). Characteristics of whole wheat, red kidney bean and defatted coconut flour blends and its application in bread production. Asian Food Science Journal, 22(9), 23–39. https://doi.org/10.9734/afsj/2023/afs95440

Harris, L. (2020). Moisture content and its impact on cookie shelf life. Baking Science Journal, 12(1), 45–52.

Igbua, F. Z., Adejo, S. O., Igoli, N. P., & Daagema, A. A. (2018). Production and quality evaluation of maize, cassava and soybeans composite flour. International Journal of Science and Research, 8(10), 798–803. https://doi.org/10.21275/ART20201767

Iwanegbe, I., Jimah, A., & Suleiman, M. (2019). Evaluation of the nutritional, phytochemicals and functional properties of flour blends produced from unripe plantain, soybean and ginger. Asian Food Science Journal, 8(1), 1–8.

Jia, R., Cui, C., Gao, L., Qin, Y., Ji, N., Dai, L., Wang, Y., Xiong, L., Shi, R., & Sun, Q. (2023). A review of starch swelling behavior: Its mechanism, determination methods, influencing factors, and influence on food quality. Carbohydrate Polymers, 321, Article 121260. https://doi.org/10.1016/j.carbpol.2023.121260

Johnson, R., Smith, J., & Lee, T. (2020). Aeration properties of flour blends in cookie production. International Journal of Culinary Science, 17(3), 76–85.

Kang, S. W., Rahman, M. S., Kim, A. N., Lee, K. Y., Park, C. Y., Kerr, W. L., & Choi, S. G. (2017). Comparative study of the quality characteristics of defatted soy flour treated by supercritical carbon dioxide and organic solvent. Journal of Food Science and Technology, 54(8), 2485–2493. https://doi.org/10.1007/s13197-017-2691-8

Karim, A., Raji, Z., Habibi, Y., & Khalloufi, S. (2023). A review on the hydration properties of dietary fibers derived from food waste and their interactions with other ingredients: opportunities and challenges for their application in the food industry. Critical Reviews in Food Science and Nutrition, 64(32), 11722–11756. https://doi.org/10.1080/10408398.2023.2243510

Lawrence, I. G. (2022). Production and quality evaluation of masa made from maize, rice and millet fortified with soybean and tigernut. International Journal of Scientific Research and Management, 10(8), 132–142.

Mamat, H., Masri, N., Noraidah, H., & Jahurul, M. H. (2020). Functional properties of composite flour: A review. Food Research, 4(6), 1820–1831. https://doi.org/10.26656/fr.2017.4(6).419

Mankad, P. M., Hubert, Y. G. J., Mankad, M. C., Patel, N., & Talati, J. (2024). Nutritional and phytonutrient analysis of QPM and normal maize inbred lines. Indian Journal of Pure and Applied Biosciences, 12(1), 7–14. http://dx.doi.org/10.18782/2582-2845.9040

Maqbool, M. A., Issa, A. B., & Khokhar, E. S. (2021). Quality protein maize (QPM): Importance, genetics, timeline of different events, breeding strategies and varietal adoption. Plant Breeding, 140(3), 375–399. https://doi.org/10.1111/pbr.12921

Meka, E., Igbabul, B. D., & Ikya, J. (2019). Chemical and functional properties of composite flours made from yellow maize, soybeans, and jackfruit seed. International Journal of Research and Innovation in Applied Science, 4(11), 57–63.

Murtaza, G., Habib, M. M., & Abdullah, M. (2024). Nutritional fortification of pasta with defatted soy flour: improving protein content and enhancing functional properties. Biological Times, 3(7), 33–34.

Narayana, K., & Narsinga, R. M. S. (1982). Functional properties of raw and heat processed winged bean (Psophocarpus tetragonolobus) flour. Journal of Food Science, 42, 534–538. https://doi.org/10.1111/j.1365-2621.1982.tb04976.x

Noah, A. A., & Bango, O. A. (2020). Microbial, nutrient composition and sensory qualities of cookies fortified with red kidney beans (Phaseolus vulgaris L) and moringa seeds (Moringa oleifera). International Journal of Microbiology and Biotechnology, 5(3), 152–158.

Nwosu, J. N. (2013). Production and evaluation of biscuits from blends of bambara groundnut and wheat flour. International Journal of Food and Nutrition, 2, 12–20.

Ojinaka, M. C., & Nnorom, C. (2015). Quality evaluation of wheat-cocoyam-soybean cookies. Nigerian Journal of Agricultural, Food and Environment, 11, 123–129.

Okereke, G. O., Igbabul, B. D., & Ikya, J. K. (2022). Evaluation of breads made from wheat flour, modified white yam/trifoliate yam/sweet potato starches and Moringa oleifera seed flour blends. International Journal of Food Science and Nutrition, 6(20), 107–119.

Okpalanma, E. F., Ukpong, E. S., Chude, O. C. & Abah, C. R. (2022) 'Production of maize-soybean complementary foods fortified with crayfish, bonga fish and carrot flours rich in essential nutrients', African Journal of Food Science, 16(12), pp. 319–325. https://doi.org/10.5897/AJFS2021.2165

Ikujenlola A. V., Adurotoye E. A. (2014). Evaluation of Quality characteristics of high nutrient dense complementary food from mixtures of malted Quality Protein Maize (Zea mays L.) and Steamed Cowpea (Vigna unguiculata). J. Food Process Technology 5:291. Doi:10.4172/2157-7110.1000291

Rana, S., & Ahmed, T. (2021). Effect of ginger powder incorporation on physicochemical and organoleptic characteristics of biscuits. Pure and Applied Biology, 10(1), 143–150. https://doi.org/10.19045/bspab.2021.100016

Rashid, M. (2021). Ginger (Zingiber officinale) powder from low temperature drying technique. Bangladesh Journal of Scientific and Industrial Research, 56(1). https://doi.org/10.3329/bjsir.v56i1.54320

Robinson, J., Yang, G., Lashley, W. IV, & Minor, R. C. (2025). Mineral nutrient analysis of ginger (Zingiber officinale Rosc.) cultivars grown under different conditions. Journal of Biotech Research, 20, 130–142.

Shaukat, M. N., Nazir, A., & Fallico, B. (2023). Ginger bioactives: A comprehensive review of health benefits and potential food applications. Antioxidants (Basel), 12(11), 2015. https://doi.org/10.3390/antiox12112015

Skrivan, P., Sluková, M., Stýblová, B., Trusová, Š., Sinica, A., Bleha, R., Švec, I., & Kotrcová, V. (2024). Utilization of the nutritional potential of wheat bran using different fractionation techniques. Applied Sciences, 14(16), 7222. https://doi.org/10.3390/app14167222

Sogo-Temi, C. M., Idowu, O. A., & Lateef, A. M. (2023). Nutritional quality assessment of complementary food from plantain, velvet bean and crayfish. International Journal of Scientific Research and Management, 11(10), 143–148. https://doi.org/10.18535/ijsrm/v11i10.fe02

Sowmya, L., & Ramalingappa, B. (2023). Distribution of mycoflora and assessment of moisture content measurement methods of Indian bakery food products. Journal of Food and Nutrition Sciences. https://doi.org/10.11648/j.jfns.20231104.13

Ukpong, S. E., Njoku, H. O., & Ire, F. S. (2021). Quality evaluation of flour and biscuits produced from wheat and African yam bean tempeh flours. GSC Biological and Pharmaceutical Sciences, 17(1), 124–132. https://doi.org/10.30574/gscbps.2021.17.1.0172

Xiao, Y., & Konermann, L. (2015). Protein structural dynamics at the gas/water interface examined by hydrogen exchange mass spectrometry. Protein Science, 24(8), 1247–1256. https://doi.org/10.1002/pro.2680