Open Access

Recent Progress in Nutrition

Original Research

Functional and Nutritional Properties of Doughmeals Developed from Garden Egg and Sorghum Byproducts

Taiwo Ayodele Aderinola [1,*], Uche Capulet Anyaiwe [2], Sinmiloluwa Esther Ogunbowale [1]

1. Department of Food Science and Technology, Federal University of Technology, PMB 704, Akure, Nigeria; E-Mails: taaderinola@futa.edu.ng; ogunbowaleesthersinmikings@gmail.com
2. Department of Microbiology, Faculty of Science, Dennis Osadebay University, Anwai, Asaba, Delta State, Nigeria; E-Mail: anyaiwecyriano@yahoo.com

* **Correspondence:** Taiwo Ayodele Aderinola; E-Mail: taaderinola@futa.edu.ng

Academic Editor: Jose Pinela

Recent Progress in Nutrition
2026, volume 6, issue 3
doi:10.21926/rpn.2603023

Received: April 14, 2026
Accepted: September 09, 2026
Published: September 23, 2026

Abstract

This study evaluates the potential of composite flours made from cassava, sorghum residue, and garden egg (both ripe and unripe) to create a nutritionally enhanced doughmeal. Seven flour blends were formulated: A (100% cassava), B (95% cassava, 2.5% sorghum residue, 2.5% ripened garden egg), C (95% cassava, 2.5% sorghum residue, 2.5% unripened garden egg), D (90% cassava, 5% sorghum residue, 5% ripened garden egg), E (90% cassava, 5% sorghum residue, 5% unripened garden egg), F (85% cassava, 7.5% sorghum residue, 7.5% ripened garden egg), and G (85% cassava, 7.5% sorghum residue, 7.5% unripened garden egg). Results showed that supplementation with sorghum residue and garden egg increased moisture (64.20-69.12%), protein (0.47-13.77%), fibre (0.95-2.03%), and ash (0.95-2.09%) contents, while reducing carbohydrate content (11.98-32.77%) compared to the control (A). Sample E had the highest moisture content (69.12%), while B and D, with ripened garden egg, showed higher protein content. Mineral analysis revealed that supplementation increased essential minerals, with D showing the highest values for calcium (15.09-77.25 mg/100 g), magnesium (35.27-92.01 mg/100 g), and potassium (42.02-62.49 mg/100 g). Phytochemical analysis showed higher total phenol (0.603-6.19 mg GAE/g) and flavonoid (0.026-0.027 mg RE/g) contents in samples with ripened garden egg. Samples with higher sorghum residue and ripened garden egg showed significant inhibition of α-amylase (10.77-54.87%) and α-glucosidase (7.05-67.95%), which may help manage postprandial glucose levels. Sensory evaluation revealed that while the control sample was preferred, samples with ripened garden egg were more acceptable than those with unripened garden egg, indicating their potential for developing nutritionally improved cassava-based doughmeals.

Keywords

Valorisation; garden eggs/sorghum residue; doughmeal; composite flour; proximate composition

1. Introduction

In recent years, the need to ensure food security, especially in developing countries such as Nigeria has become more pronounced in the face of various challenges (postharvest losses, disease and pests, climate change and poor/lack of infrastructure) affecting food production and preservation in the region [1, 2]. In addition to drought or flooding from climate change, inadequate facilities for food processing and preservation have also adversely affected optimum utilisation of available produce, thereby resulting in wastage of scarce commodities. Cassava (*Manihot esculenta*), although often considered a food for people experiencing poverty due to its poor nutritional profile, is one of the crops produced in large quantities in Nigeria [3]. Globally, Nigeria ranks first among the top ten cassava producers with approximately 61 Mmt for 2022 [4]. Garden egg (*Solanum melongena*) and sorghum (*Sorghum bicolor*) are also common crops in Nigeria, contributing significantly to the dietary diversity of the populace. However, while cassava is widely used in various forms, opportunities for value addition for garden egg and sorghum residue are currently very minimal. In the production of local beverages such as *"Ogi" and "kunu",* where sorghum is commonly used, a lot of residues are usually generated as waste. In the quest for sustainable and resource-efficient food systems, there is a pressing need to explore innovative ways to valorize these by-products and increase their opportunities for value addition [5]. Garden egg contains appreciable amounts of dietary fibre, minerals (including potassium, calcium, and iron), phenolic compounds, flavonoids, and other bioactive constituents. These components may vary with maturity, with ripening influencing the distribution and availability of phenolic compounds, soluble carbohydrates, and other phytochemicals [6]. Unripe and ripened garden eggs therefore represent potentially different sources of nutritional and bioactive compounds that may influence their suitability for food product development. Similarly, sorghum residue generated during processing retains valuable nutrients, including dietary fibre, minerals, protein fractions, and phenolic compounds, making it a potential ingredient for food product enrichment and waste valorisation [5, 6]. Therefore, incorporating them into cassava-based doughmeals may improve nutritional quality while promoting the use of underused food resources. The emphasis on produce valorisation, or the strategic enhancement of agricultural by-products, is integral to sustainable and circular food systems [7]. Creating an avenue for the utilisation of these by-products or low-value produce by transforming them into valuable food products will not only reduce waste but also increase their value-addition avenues [5, 7, 8].

The valorisation of garden egg and sorghum residue is particularly important as they are often overlooked and discarded, although they possess essential nutritional and bioactive components that can be exploited through further product development. This is particularly relevant for ripened garden egg, which often has reduced consumer acceptance because of changes in appearance and texture despite retaining valuable nutritional components. Utilising both ripe and unripened garden egg in food formulations may therefore provide an opportunity to explore the potential of different maturity stages while reducing avoidable postharvest losses. One viable way to further exploit these low-value crops and byproducts is to develop composite flours for producing commonly consumed foods such as doughmeal [9-11]. Doughmeal is a popular mealhighly cherished in Nigeria, especially in the southern part. One of the commonest flours is *"lafun"*. Dough meals are usually prepared by mixing the flour with an adequate amount of boiling water, and the mixture is stirred until it solidifies [10, 11]. These foods are mainly cassava-based, although doughmeal similar to that obtained from *"lafun" flour* (*"amala"*) could also be obtained from yam and plantain flours. Because cassava has a poor nutritional profile and may promote diabetes due to its high glycemic index [6], studies have explored various composite flours suitable for doughmeal production, with or without cassava flour. These studies aimed to improve the flour's nutritional profile or reduce its glycemic index by supplementing it with high-protein or high-fibre crops, respectively [6, 11, 12]. Unlike most previous studies that investigated cassava-based composite flours with single plant fortificants, this study evaluates the combined incorporation of sorghum processing residue and ripening-stage variation (ripe vs unripe) of garden egg in doughmeal formulation, enabling a comparative assessment of nutritional and biofunctional outcomes. Although previous studies have investigated cassava, garden egg, and sorghum residue composite flours [6], these studies were limited to flour characterisation. They did not evaluate their application in doughmeal production or the influence of garden egg maturity stage on the nutritional and functional attributes of the final product. Therefore, this study aimed to evaluate the nutritional and health-promoting properties of composite flours from cassava, garden egg and sorghum residue.

2. Materials and Method

2.1 Source of Materials

Cassava (*Manihot esculenta*), garden egg and sorghum used for this study were purchased from Oja-Oba market, Akure, Ondo State, Nigeria.

2.1.1 Production of Cassava Flour

Cassava tubers were peeled, washed, cut into small chunks and allowed to ferment in excess water for five days. After fermentation, the softened mash was compressed using a hydraulic jack to remove excess water. The lumps resulting from pressing were sun-dried on racks for 5 to 7 h before milling in a hammer mill. After milling, the flour was sieved to pass through a 0.5 mm sieve, packaged and stored at room temperature in a Ziplock bag until needed for further analysis.

2.1.2 Production of Sorghum Residue Flour

Sorghum residue was obtained from sorghum grain following a previous [13] method for *"Ogi"* production. About 500 g of sorghum grains were weighed, cleaned and soaked in excess water at room temperature for 72 h. Thereafter, the water was drained and the soaked grains were milled in an attrition mill to produce a slurry, which was sieved through muslin cloth. The residue collected by the cloth was oven-dried at 60°C for about 8 h, milled, sieved and packaged as described above for cassava flour.

2.1.3 Production of Garden Egg Flour

Garden eggs at two maturity stages were used: unripened (mature, green stage) and fully ripened (characterised by complete colour change). The garden eggs were washed, then sliced into small pieces and sun-dried on racks for 7-9 h daily until a sufficiently dry condition suitable for milling was attained. Temperature and relative humidity during sun-drying were not monitored, as drying conditions were not investigated as an experimental factor in this study. The dried samples were thereafter milled, sieved and packaged as described above for cassava flour.

2.1.4 Production of Doughmeal

Doughmeal was prepared by mixing each composite flour (Table 1) with boiling water. The mixture was stirred until a smooth paste was obtained. Then, an appropriate amount of water was added based on the flour quantity to achieve the desired dough consistency, and the doughmeal was cooked for about 5 min. It was removed from the hot plate and allowed to cool before samples were taken for analysis.

Table 1 Blending ratio (%) for the formulation of cassava, sorghum residue and garden egg composite flour.

Samples	**Cassava**	**Sorghum Residue**	**Ripened Garden Egg**	**Unripened Garden Egg**
A	100	-	-	-
B	95	2.5	2.5	-
C	95	2.5	-	2.5
D	90	5	5	-
E	90	5	-	5
F	85	7.5	7.5	-
G	85	7.5	-	7.5

2.2 Sample Extraction

The samples used for biochemical analyses were derived from dry doughmeal flours. A 10 mg/mL extract was prepared by weighing the required amount of flour into 2 mL microcentrifuge tubes. After the addition of distilled water, the mixture was vortexed for approximately one minute and left to hydrate for 10 minutes. Subsequently, the solute was briefly mixed for about 15 seconds and then centrifuged at 10,000 g for 10 minutes using a KX3400C model centrifuge from KENXIN Intl. Co. The resulting supernatant was utilized for further analysis.

2.2.1 Determination of Proximate Composition

The proximate compositions of the doughmeal were determined following the AOAC [14] method. Carbohydrate content was calculated by difference.

2.2.2 Determination of Mineral Composition

Mineral composition was analyzed using the standard method [14]. One gram of each sample was digested with a mixture of nitric, perchloric, and sulfuric acids in the ratio 9:2:1, respectively. After filtration, the filtrate was adjusted to volume in a 5-mL volumetric flask. The resulting solution was then introduced into an atomic absorption spectrophotometer (model 703; Perkin Elmes, Norwalk, CT). Standard curves for minerals such as calcium, magnesium, iron, zinc, and manganese were established using known standards, and the mineral concentrations in the samples were determined by comparing them against these standard curves. Sodium and potassium values were measured using a Flame Photometer (Sherwood Flame Photometer 410; Sherwood Scientific Ltd., Cambridge, U.K.) with NaCl and KCl as standards [14]. Phosphorus was quantified using the Vanadomolybdate method.

2.2.3 Determination of Total Phenolic Contents

The total phenol content of the sample was determined with an established method [15]. In this process, 0.2 mL of the extract was combined with 0.5 mL of 10% Folin Ciocalteau's reagent and 2 mL of 7.5% Sodium carbonate. After incubating the mixture for 40 minutes at 45°C, the absorbance was measured at 700 nm using a spectrophotometer (Healicom 721S, China). Gallic acid served as the standard phenol, and the total phenolic content of the sample was expressed in mg gallic acid equivalent per gram of the sample (mg GAE/g).

2.2.4 Determination of Total Flavonoid Contents

The total flavonoid content was determined using a previously reported method [16]. Approximately 200 µL of the extract was added to 300 µL of 5% sodium nitrate, followed by the sequential addition of 600 µL of 10% aluminum chloride, 2 mL of 1 M sodium hydroxide after 6 minutes, and 2.1 mL of distilled water. The absorbance was read at 415 nm with a Healicom 721S (China) UV spectrophotometer against the reagent blank. The flavonoid content was expressed as mg rutin equivalent per gram of the sample (mg RE/g).

2.2.5 Determination of Tannin Contents

Tannin contents were determined as earlier described [17]. Approximately 200 mg of the dry doughmeal flour was carefully weighed into a 50 mL sample bottle, followed by the addition of 10 mL of 70% aqueous acetone. The bottle was then placed in an ice bath shaker and agitated for 2 hours at 30°C. After centrifugation, the resulting supernatant was stored on ice. Subsequently, 0.2 mL of the solution was pipetted into a test tube, and 0.8 mL of distilled water was introduced. A standard solution was prepared using 0.5 mg/mL of the stock (tannic acid), and the solution was made up to 1 mL with distilled water. To both the sample and standard, 0.5 mL of Folin-Ciocalteu reagent was added, followed by the addition of 2.5 mL of 20% sodium carbonate. The solution was vortexed and then incubated at room temperature for 40 minutes. The absorbance was measured at 725 nm against a reagent blank using a UV spectrophotometer (Healicom 721S, China). The tannin content was calculated using the standard tannic acid curve.

2.2.6 Determination of Alkaloid Contents

The determination of alkaloid contents was carried out using a previously described method [18]. Approximately 5 g of the sample was placed in a 250 mL beaker, and 200 mL of 10% acetic acid in ethanol was added, allowing it to stand for 4 hours. Following filtration, the extract was evaporated in a water bath until it reached one-quarter of the original volume. Concentrated ammonium hydroxide was gradually introduced into the extract until no further precipitation occurred. After allowing the solution to settle, the precipitate was gathered, rinsed with dilute ammonium hydroxide, and subsequently filtered. The alkaloid content was determined based on the weight of the dried residue.

2.2.7 Determination of Saponin Contents

Saponin content was determined following a previously described method [19]. A 20 g sample was measured and combined with 200 mL of 20% ethanol. The mixture was heated for 4 h in a hot water bath (55°C) with continuous stirring. After filtration, the residue was re-extracted with 200 mL of diethyl ether through vigorous shaking. The aqueous layer was separated, discarding the diethyl ether layer. This purification process was repeated, and the 60 mL of n-butanol was added. The resulting extract was washed several times with 10 mL of 5% aqueous sodium chloride. The remaining solution was evaporated by heating in a water bath, and the sample was dried in the oven until a constant weight was achieved. Saponin content was determined using the formula provided below:

$$Saponin\ content(\%) = \frac{weight\ of\ residue}{weight\ of\ sample} \times 100$$

2.2.8 Determination of Alpha Amylase Inhibitory Ability

The α-amylase inhibition capacity was assessed following a recently reported method [10] with slight modifications. Equal volumes (100 µL) of sample's extract and the enzyme (dissolved in 0.02 M phosphate buffer, pH 6.9, and containing 0.006 M sodium chloride) were combined and incubated at 28°C for 10 minutes. Subsequently, 200 µL of 1% starch (dissolved in the same buffer) was added, and the reaction mixture was incubated at room temperature for 10 minutes. To terminate the reaction, 1 mL of dinitrosalicylic acid was added, and the mixture was heated in a boiling water bath for 5 minutes. Following cooling to room temperature, the mixture was diluted with distilled water at a ratio of 1:5 (sample/distilled water, v/v), and the absorbance was measured at 540 nm using a Healicom 721S (China) spectrophotometer. The percentage of α-amylase inhibition for the sample was computed using the provided formula below:

$$Alpha\ amylase\ inhibition(\%) = \frac{A_{control} - A_{sample}}{A_{control}} \times 100$$

2.2.9 Determination of Alpha-Glucosidase Inhibitory Ability of the Composite Flour

The impact of flour extracts on α-glucosidase activity was assessed following a recently reported method [10] utilizing α-glucosidase sourced from Saccharomyces cerevisiae. A substrate solution, p-nitrophenyl glucopyranoside (pNPG), was prepared in 20 mM phosphate buffer at pH 6.9. To initiate the reaction, 100 µL of α-glucosidase (0.3 U/mL) was pre-incubated with 50 µL of the extract for 10 minutes. Subsequently, 50 µL of 3.0 mM pNPG, dissolved in 20 mM phosphate buffer (pH 6.9), was added. The reaction mixture was then incubated at 37°C for 20 minutes and halted by the addition of 2 mL of 0.1 M Na_2CO_3. The α-glucosidase activity was determined by measuring the release of p-nitrophenol from pNPG at 405 nm.

$$Alpha\ glucosidase\ inhibition(\%) = \frac{A_{control} - A_{sample}}{A_{control}} \times 100$$

2.2.10 Sensory Evaluation

For the sensory evaluation, 30 semi-trained panelists, who were students (aged 16-25) of the Department of Food Science and Technology, Federal University of Technology, Akure, were used. The panelists comprised both males and females familiar with the product. Each doughmeal was uniquely coded and presented to panelists in a random order. The samples were assessed for appearance, texture, aroma and overall acceptability on a 9-Point Hedonic Scale (1 being the most disliked and 9 being the most liked).

2.3 Statistical Analysis

Data were expressed as means ± standard deviation (SD) of triplicate technical replicates. One batch of each doughmeal formulation was prepared, and all analytical determinations were performed in triplicate on samples obtained from the same batch. Statistical analysis was performed using the one-way analysis of variance (ANOVA) with SPSS version 22.0, and the means were separated with Duncan's Multiple Range (DMR) test at $p < 0.05$.

2.4 Ethical Statement/Informed Consent

This study adhered to the principles of the Declaration of Helsinki. Although ethics committee approval was not required for questionnaire studies on food-related consumer preferences, no personal information (name, age, sex etc.) was collected. This study used anonymous questionnaires only, ensuring that no participant data can be identified or linked to individual participants. Informed consent was obtained from the participants after they were properly informed about the study, including the approximate time required to complete the exercise. They were also told they could withdraw from the study at any point without providing reasons and without facing any consequences.

3. Results and Discussion

3.1 Proximate Composition of the Doughmeal

The proximate composition of the doughmeal from cassava flour substituted with garden egg and sorghum residue flours is shown in Table 2. Moisture content is an important factor in food quality, preservation, and resistance to deterioration [20]. The moisture content of the doughmeal ranged from 64.20-69.12%. The control sample (A, 100% Cassava flour) had the lowest value, while sample E had the highest moisture content among the composite flours. This type of doughmeal is generally not kept for long. In most cases, they are consumed within 6 h of preparation. Therefore, the obtained moisture content, although considerably high, is acceptable considering that the product is consumed shortly after preparation. While supplementation slightly increased the moisture content of the doughmeal, the impact of ripening was not pronounced. However, for the crude protein content, both supplementation and ripening significantly affected the result. For instance, while the control sample had 0.47% crude protein content, the sample supplemented with unripened garden egg ranged between 6.60 and 9.99%, but supplementation with ripened garden egg ranged between 8.79 and 13.77%. Higher crude protein in composite doughmeals, particularly those containing ripened garden egg, may be attributed to ripening-associated biochemical changes that influence protein composition and extractability. During fruit maturation, metabolic transformations involving structural carbohydrate degradation and cellular disintegration may enhance the accessibility of intracellular proteins during flour preparation and extraction. In addition, the contribution of sorghum residue, which contains residual protein fractions after processing, may have further increased the protein content of the composite formulations. Similar ripening-associated modifications in macronutrient availability have been reported in plant-based foods [21, 22]. Given the high post-harvest losses of garden egg, especially when ripened, its potential to significantly improve the crude protein content of doughmeal compared to the control sample may promote value addition and further utilisation.

Table 2 Proximate composition of the doughmeal (%).

	Moisture content	Crude protein	Crude fibre	Total ash	Crude fat	Carbohydrates
A	64.20 ± 0.71^{c}	0.47 ± 0.06^{f}	0.95 ± 0.28^{d}	1.18 ± 0.14^{f}	0.44 ± 0.17^{d}	32.77 ± 0.12^{a}
B	67.56 ± 1.27^{ab}	8.79 ± 0.31^{d}	1.24 ± 0.11^{c}	1.54 ± 0.53^{e}	1.53 ± 0.36^{c}	19.35 ± 0.68^{c}
C	67.12 ± 0.75^{ab}	6.60 ± 0.54^{e}	1.32 ± 0.26^{bc}	1.61 ± 0.10^{de}	1.74 ± 0.04^{c}	21.63 ± 1.17^{b}
D	67.49 ± 0.52^{ab}	10.87 ± 0.19^{b}	1.40 ± 0.54^{bc}	1.64 ± 0.29^{cd}	2.27 ± 0.21^{a}	16.33 ± 1.17^{d}
E	69.12 ± 0.42^{a}	9.14 ± 0.21^{d}	1.45 ± 0.47^{b}	1.70 ± 0.40^{c}	1.98 ± 0.30^{b}	16.63 ± 0.06^{d}
F	68.11 ± 0.33^{ab}	13.77 ± 0.30^{a}	1.90 ± 0.34^{a}	2.16 ± 0.16^{b}	2.08 ± 0.05^{ab}	11.98 ± 0.48^{e}
G	68.43 ± 0.49^{ab}	9.99 ± 0.17^{c}	2.03 ± 0.17^{a}	2.45 ± 0.04^{a}	2.06 ± 0.01^{ab}	15.04 ± 0.88^{d}

Results are mean of triplicate determinations. Values (mean ± SD) with the same superscript within the same column are not significantly ($p < 0.05$) different. A: 100% cassava flour; B: 95% cassava, 2.5% sorghum residue and 2.5% ripened garden egg flour; C: 95% cassava, 2.5% sorghum residue, 2.5% unripened garden egg flour; D: 90% cassava, 5% sorghum residue and 5% ripened garden egg flour; E: 90% cassava, 5% sorghum residue and 5% unripened garden egg flour; F: 85% cassava, 7.5% sorghum residue and 7.5% ripened garden egg flour; G: 85% cassava, 7.5% sorghum residue and 7.5% unripened garden egg flour.

Adequate fibre intake is associated with various health benefits, including improved digestion and reduced risk of chronic diseases. The addition of sorghum residue and garden egg flours, as may be expected, increased the crude fibre content of the samples, which ranged between 0.95 (A) and 2.03% (G). Higher fibre content in the composite flours may offer an additional health benefit, including improved digestion and reduced risk of cardiovascular diseases. The total ash reflects the content of available mineral elements. Similar to crude fibre, supplementation with unripened garden egg increased total ash, with slightly higher values. The reduced crude fibre and total ash contents of the sample with ripened garden egg compared to the sample supplemented with unripened garden egg may be due to the activity of enzymes such as cellulase, which is involved in the breakdown of the complex structural components of fruit and the major components of dietary fibre (cellulose and hemicellulose). As these complex structures are broken down, fibre becomes more soluble and digestible. Depending on fruit type and the method of determination, other authors also reported reduced fibre content during ripening [23, 24]. Crude fat content is generally low, ranging from 0.44 to 2.08%. These values are expected since all the raw materials are low-fat content samples. No statistically significant differences was observed between samples with ripened and unripened garden egg at the same concentration level except at 5%. The obtained result may be beneficial for the safekeeping or shelf stability of the flour. Carbohydrates are a primary energy source in diets. The carbohydrate content of the flour ranged from 11.98 to 32.77. The obtained low values may be due to the already high moisture content. Again, the lower carbohydrate content in composite samples compared to the control sample may suggest a reduced glycemic load, which may help manage blood sugar levels.

3.2 Mineral Composition of the Doughmeal

The mineral composition of the composite flour is shown in Table 3. Calcium, magnesium, potassium, phosphorus, sodium and manganese were the main macro elements determined, while iron and zinc were determined as trace elements. Although the addition of sorghum residue and garden egg generally led to an increase in mineral element content, sample D showed significantly higher contents of most of the mineral elements determined compared to other composite flours, except for manganese and iron contents. The increase in mineral content of the composite flours is particularly evident in Ca, Mg, K, and Zn contents. Sorghum residue, being a by-product of sorghum processing, is rich in essential minerals; thus, its incorporation into the flour blends may have contributed to the observed trend. Calcium is crucial for bone health and metabolic functions [25]. The highest Ca content is observed in sample D (90% cassava, 5% sorghum residue, 5% ripened garden egg) at 77.25 mg/100 g, while the lowest is in sample A (100% cassava) at 15.09 mg/100 g. Magnesium is a crucial nutrient that regulates muscle and nerve function; it also supports heart and bone health and aids in energy production, blood sugar regulation, and immune function. The Mg content of the sample ranged between 35.27 and 92.01 mg/100 g. Potassium is an essential nutrient that is required for numerous bodily functions. Also, potassium is required to maintain the osmotic balance of the body fluids and the pH of the body, to control muscle and nerve irritability, control glucose absorption, and improve normal retention of protein during growth [26]. The K content obtained in this study ranged between 42.02 and 62.49 mg/100 g. These values are relatively low and provide less than 2% of the daily recommended allowance (RDA, 4,700 mg per day). Phosphorus is a vital nutrient essential for DNA, RNA, and ATP production, bone and tooth formation, and other functions in the body like nerve transmission, muscle contraction, and heart regulation. Adequate intake is crucial for overall health, and deficiencies can lead to weakened bones, fatigue, and impaired cognitive function. The RDA for phosphorus for adults is 700 mg/day. The obtained result, 31.98-54.43 mg/100 g, provides 5 and 8% of the RDA for P.

Table 3 Mineral composition of the doughmeal.

	A	B	C	D	E	F	G
Ca (mg/100 g)	15.09 ± 0.23^{f}	65.95 ± 0.32^{d}	18.52 ± 0.71^{e}	77.25 ± 0.20^{a}	68.62 ± 0.11^{c}	70.05 ± 0.32^{b}	17.92 ± 0.36^{e}
Mg (mg/100 g)	35.27 ± 0.18^{g}	74.35 ± 0.14^{d}	43.55 ± 0.38^{e}	92.01 ± 0.30^{a}	79.43 ± 0.01^{c}	88.93 ± 0.34^{b}	39.52 ± 0.02^{f}
K (mg/100 g)	43.21 ± 0.02^{e}	49.78 ± 0.01^{d}	42.02 ± 0.01^{g}	62.94 ± 0.01^{a}	56.60 ± 0.04^{c}	62.04 ± 0.01^{b}	42.63 ± 0.02^{f}
P (mg/100 g)	31.98 ± 0.00^{g}	51.98 ± 0.02^{d}	33.48 ± 0.00^{e}	54.43 ± 0.01^{a}	53.21 ± 0.01^{b}	53.58 ± 0.01^{c}	32.58 ± 0.01^{f}
Na (mg/100 g)	36.85 ± 0.06^{e}	97.55 ± 0.01^{d}	33.86 ± 0.01^{g}	104.84 ± 0.1^{a}	99.83 ± 0.21^{c}	103.91 ± 0.11^{b}	35.81 ± 0.02^{f}
Mn (mg/kg)	23.24 ± 0.02^{e}	21.78 ± 0.01^{g}	28.14 ± 0.02^{a}	26.09 ± 0.01^{b}	22.46 ± 0.01^{f}	23.36 ± 0.02^{d}	26.35 ± 0.01^{c}
Fe (mg/kg)	0.71 ± 0.01^{d}	0.26 ± 0.03^{g}	1.55 ± 0.02^{a}	0.78 ± 0.01^{c}	0.44 ± 0.01^{f}	0.55 ± 0.00^{e}	1.24 ± 0.01^{b}
Zn (mg/kg)	0.12 ± 0.00^{g}	2.62 ± 0.01^{d}	0.78 ± 0.01^{e}	3.53 ± 0.00^{a}	2.74 ± 0.00^{c}	2.82 ± 0.00^{b}	0.67 ± 0.00^{f}

Results are mean of triplicate determinations. Values (mean ± SD) with the same superscript within the same column are not significantly ($p < 0.05$) different. A: 100% cassava flour; B: 95% cassava, 2.5% sorghum residue and 2.5% ripened garden egg flour; C: 95% cassava, 2.5% sorghum residue, 2.5% unripened garden egg flour; D: 90% cassava, 5% sorghum residue and 5% ripened garden egg flour; E: 90% cassava, 5% sorghum residue and 5% unripened garden egg flour; F: 85% cassava, 7.5% sorghum residue and 7.5% ripened garden egg flour; G: 85% cassava, 7.5% sorghum residue and 7.5% unripened garden egg flour.

Sodium is involved in the regulation of fluid balance and blood pressure, nerve and muscle function. A balanced sodium intake is important because excessive intake can lead to hypertension and cardiovascular issues, while inadequate intake can cause dehydration and muscle cramps. Although supplementation increased the sodium content of the samples compared to the control, the values obtained are relatively low in contrast to the 2,300 mg recommended daily limit for sodium. Manganese is essential for enzyme function, bone health, wound healing, and metabolism. It also supports immune function, brain health, and antioxidant defenses. Manganese deficiency can impair growth, weakness, and poor wound healing. The manganese contents ranged between 21.78 and 28.14 mg/kg. While the manganese content is relatively low compared to other mineral elements, the values obtained in this study are significantly higher than the 2.3 mg/day RDA for manganese. The impact of supplementation was also less pronounced than for other mineral elements. Inadequate intake of zinc and iron has been associated with severe malnutrition, increased disease conditions, and mental impairment [27, 28]. Generally, samples with ripened garden egg (B, D, F) show higher mineral contents compared to those with unripened garden egg (C, E, G). The observed differences may reflect compositional changes associated with fruit ripening and their contribution to the composite flour formulations.

3.3 Phytochemical Contents of the Doughmeal

Phytochemicals have been reported to possess various beneficial properties, including antioxidative, antidiabetic and other therapeutic properties. Phenols are compounds that can scavenge free radicals because they contain hydroxyl groups. They give up hydrogen atoms from their hydroxyl groups to radicals and form stable phenoxyl radicals; hence, they play an important role in antioxidant activity [29, 30]. Figure 1A shows the total phenol values for the samples. The values range from 0.603- 6.19 mg GAE/g. The total phenolic content increased with the addition of sorghum residue and garden egg flour. Ripened garden egg, however, significantly increased the phenolic content compared to the unripened garden egg. The higher phenolic content observed in ripened garden egg-supplemented samples may be associated with metabolic changes occurring during fruit maturation. Ripening involves extensive biochemical transformations, including modification of phenolic profiles, degradation of cellular structures, and changes in the distribution of free and bound phenolic compounds. These changes may increase the extractability of phenolic compounds during analysis. Similarly, increased flavonoid levels in ripened samples may reflect alterations in secondary metabolism during maturation, although the magnitude and direction of these changes can vary depending on plant species and cultivar. This suggests that using ripened garden egg in flour formulations for doughmeal production may increase the phenolic content of the resulting doughmeal compared with formulations containing unripened garden egg. Flavonoids are among the most diverse groups of natural compound shown to possess a broad spectrum of chemical and biological activities, including radical scavenging properties, anti-allergenic, antiviral and anti-inflammatory effects [30]. They are secondary metabolites with antioxidant activity, the potency of which depends on the number and position of free OH groups. The total flavonoid content of the samples is presented in Figure 1B. The values ranged from 0.026-0.027 mg RE/g. Sample C had the highest flavonoid content, while the control sample (A) had the lowest flavonoid content. As with total phenolic content, adding sorghum residue and ripened garden egg flour increased the total flavonoid content of the doughmeal samples.

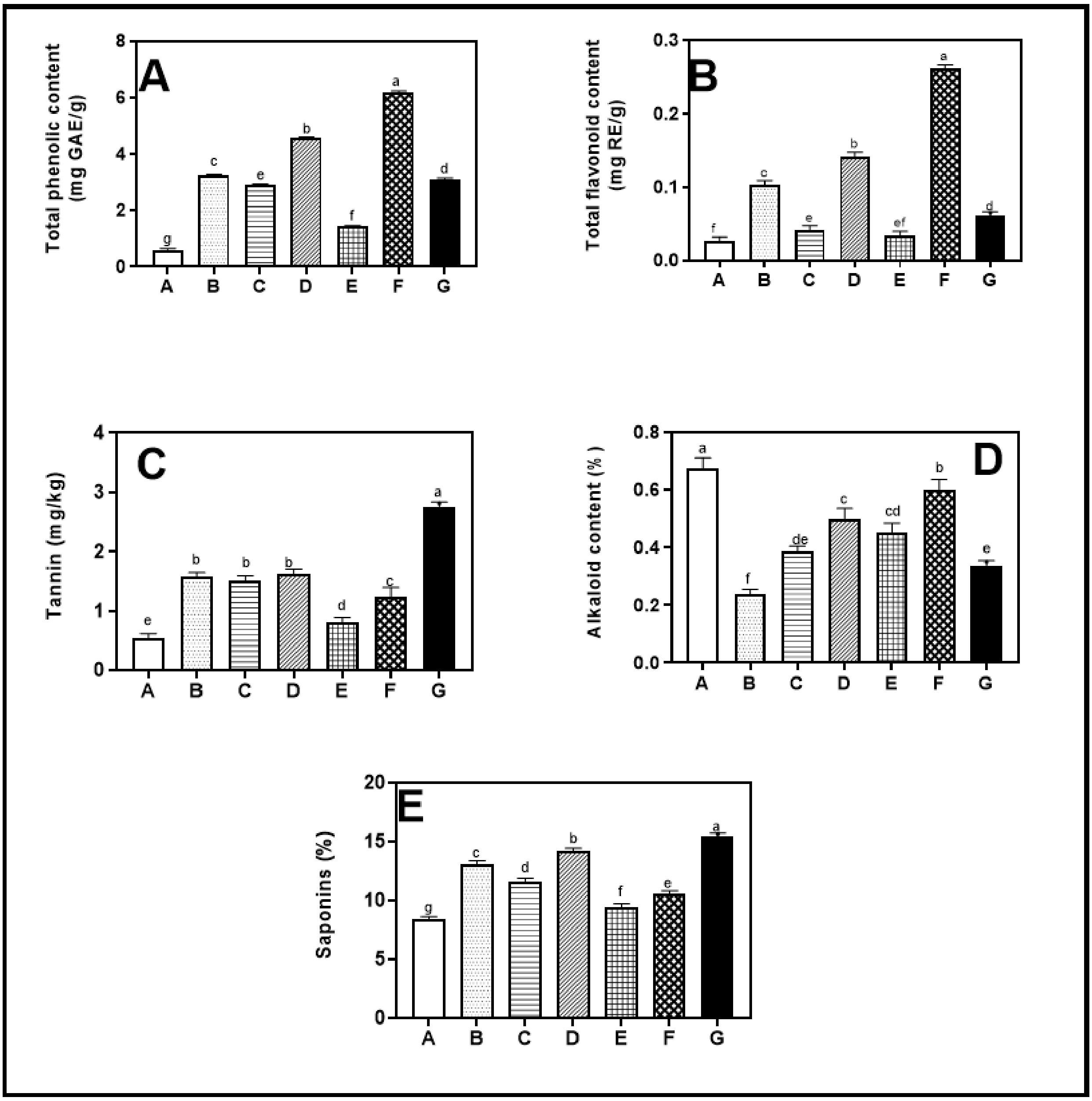

Figure 1 Phytochemical contents of the doughmeal. Results are the mean of triplicate determinations. Bars with the same letters are not significantly ($p < 0.05$) different. A: 100% cassava flour; B: 95% cassava, 2.5% sorghum residue and 2.5% ripened garden egg flour; C: 95% cassava, 2.5% sorghum residue, 2.5% unripened garden egg flour; D: 90% cassava, 5% sorghum residue and 5% ripened garden egg flour; E: 90% cassava, 5% sorghum residue and 5% unripened garden egg flour; F: 85% cassava, 7.5% sorghum residue and 7.5% ripened garden egg flour; G: 85% cassava, 7.5% sorghum residue and 7.5% unripened garden egg flour.

The total tannin content of the samples is presented in Figure 1C. The values ranged from 0.54 to 2.76 mg/kg. The total alkaloid and saponin contents of the samples are presented in Figure 1D. Alkaloids and saponins (Figure 1E) can have diverse physiological effects and are associated with medicinal properties, including anti-inflammatory and immune-modulating effects. They may also contribute to the preservation of the meal by acting as natural preservatives [31, 32]. Alkaloid content differed across samples, with the highest values in sample A (0.68%) and the lowest in sample F (0.2%). The differences may be attributed to the varying proportions of cassava, sorghum residue, and garden egg in the samples. The total saponin content of the samples ranged from 8.36 to 15.45%.

3.4 α-Amylase and α-Glucosidase Inhibition Potential of the Doughmeal

Inhibition of α-amylase and α-glucosidase is essential for managing postprandial blood glucose levels and is therefore an important target for developing foods with potential for glycaemic control. The inhibitory potential of the doughmeal against α-amylase is presented in Figure 2A. The value ranged from 10.77%-54.87%. There was a progressive increase in inhibition of α-amylase with an increase in the concentration of sorghum residue and garden egg. Ripening had a very significant impact compared with the unripe sample. The α-glucosidase inhibition potential of the samples (Figure 2B) ranged from 7.05%-67.95%. The trend for α-glucosidase is also similar to that obtained for α-amylase, with doughmeal containing ripened garden egg showing significantly higher inhibition against α-glucosidase. The differences in α-amylase and α-glucosidase inhibition may be associated with the combined influence of dietary fibre and bioactive compounds contributed by sorghum residue and garden egg. Dietary fibre can limit enzymatic access to starch by increasing matrix viscosity, reducing starch swelling, and restricting the diffusion of digestive enzymes towards starch granules [6, 33, 34]. In addition, phenolic compounds and flavonoids may interact with carbohydrate-digesting enzymes through hydrogen bonding and hydrophobic interactions, potentially reducing enzyme activity [29, 30]. The presence of these compounds within a starch-rich cassava matrix may therefore influence starch hydrolysis behaviour. Furthermore, ripening-related changes in garden egg composition, including increased phenolic extractability, may partly explain the higher inhibitory activity observed in ripened garden egg-containing samples [35-37]. However, these findings represent in vitro enzyme inhibition responses. They should not be interpreted as direct evidence of antidiabetic effects in humans without further validation through digestion models, glycaemic response studies, or clinical investigations.

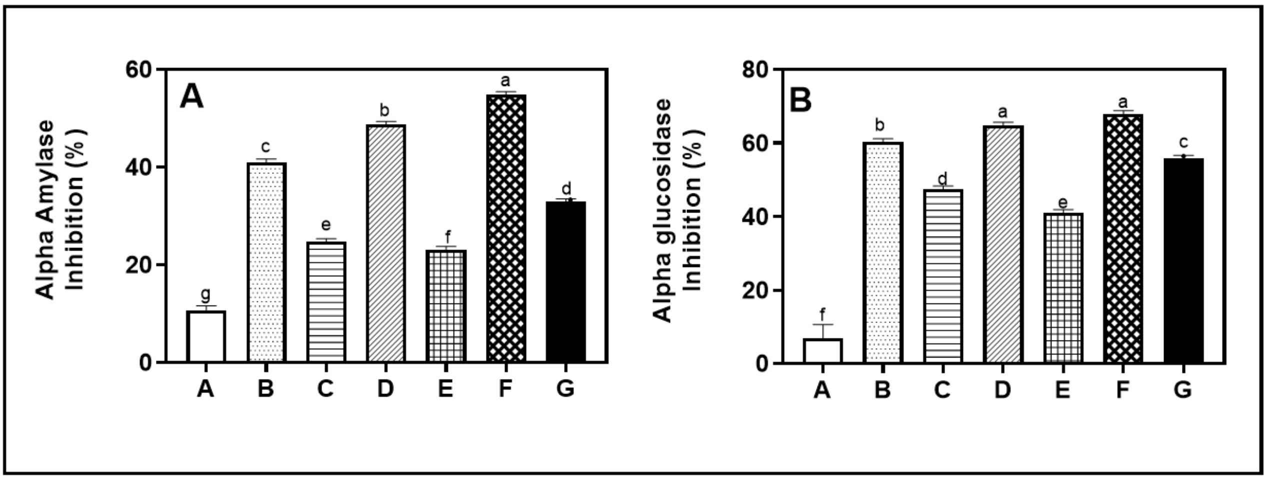

Figure 2 Inhibition potential of the doughmeal against α-amylase (A) and α-glucosidase (B). Results are the mean of triplicate determinations. Bars with the same alphabets are not significantly ($p < 0.05$) different. A: 100% cassava flour; B: 95% cassava, 2.5% sorghum residue and 2.5% ripened garden egg flour; C: 95% cassava, 2.5% sorghum

residue, 2.5% unripened garden egg flour; D: 90% cassava, 5% sorghum residue and 5% ripened garden egg flour; E: 90% cassava, 5% sorghum residue and 5% unripened garden egg flour; F: 85% cassava, 7.5% sorghum residue and 7.5% ripened garden egg flour; G: 85% cassava, 7.5% sorghum residue and 7.5% unripened garden egg flour.

3.5 Sensory Evaluation of the Doughmeal

Table 4 summarised the mean hedonic sensory evaluation scores for appearance, texture, aroma and overall acceptability of the doughmeal samples as observed by the panelists. Substitution of cassava flour with sorghum residue and garden egg significantly affected panelists' ratings of the doughmeal. Sorghum residue and garden egg, while nutritionally beneficial, seem to negatively affect sensory attributes when used in higher proportions. This could be due to their different flavour, texture, and appearance properties compared to cassava flour. However, even small amounts (2.5% to 7.5%) of garden egg flour still resulted in lower scores than the pure cassava sample. The result showed that panelists preferred the control sample compared to doughmeal from the composite flours. However, samples with ripened garden egg (B, D, F) were better scored in all sensory attributes compared to those with unripened garden egg (C, E, G). Garden egg ripeness may have affected taste and aroma. This may be attributed to the sweeter, milder flavor profile of ripened garden egg compared to the bitter taste of unripened garden egg.

Table 4 Quality acceptability of the doughmeal.

	Appearance	Texture	Aroma	Overall acceptability
A	8.25 ± 0.54^{a}	8.36 ± 0.01^{a}	8.16 ± 0.01^{a}	8.13 ± 0.17^{a}
B	6.69 ± 0.21$_{b}$	7.46 ± 0.02^{b}	6.01 ± 0.01^{b}	6.58 ± 0.07^{b}
C	6.64 ± 0.13^{b}	6.89 ± 0.16^{c}	6.04 ± 0.01^{b}	6.27 ± 0.11^{c}
D	6.83 ± 0.01^{b}	5.64 ± 0.28^{de}	6.19 ± 0.02^{b}	6.15 ± 0.08^{c}
E	5.81 ± 0.05^{c}	5.38 ± 0.21^{ef}	5.54 ± 0.13^{c}	5.43 ± 0.10^{d}
F	6.99 ± 0.01^{b}	5.93 ± 0.12^{d}	5.92 ± 0.04^{b}	6.07 ± 0.05^{c}
G	5.94 ± 0.37^{c}	5.14 ± 0.04^{f}	5.64 ± 0.01^{c}	5.39 ± 0.13^{d}

Results are the mean of triplicate determinations. Values (mean ± SD) with the same superscript within the same column are not significantly different ($p < 0.05$). A: 100% cassava flour; B: 95% cassava, 2.5% sorghum residue and 2.5% ripened garden egg flour; C: 95% cassava, 2.5% sorghum residue, 2.5% unripened garden egg flour; D: 90% cassava, 5% sorghum residue and 5% ripened garden egg flour; E: 90% cassava, 5% sorghum residue and 5% unripened garden egg flour; F: 85% cassava, 7.5% sorghum residue and 7.5% ripened garden egg flour; G: 85% cassava, 7.5% sorghum residue and 7.5% unripened garden egg flour.

4. Conclusion

This study explores the potential of incorporating sorghum residue and garden egg into composite flours to enhance the nutritional and bioactive properties of cassava-based doughmeals. The findings show that these additions significantly improve the nutritional profile in terms of crude protein, fibre, and essential minerals. The increased levels of bioactive compounds (phenols and flavonoids), especially in samples containing ripened garden egg, as well as higher inhibition of α-amylase and α-glucosidase, may suggest enhanced potential functional benefits compared with the control sample. Although the composite flour showed improved nutritional properties, doughmeal from the control sample was the most preferred. This study, however, shows that producing doughmeal from sorghum and ripened garden egg may offer greater potential to improve the nutritional and bioactive properties of cassava-based doughmeals compared with doughmeals containing unripened garden egg.

Acknowledgments

The corresponding author affirms that Sinmiloluwa Esther Ogunbolwale (SEO) made a substantive contribution to this work and meets the criteria for authorship. Despite reasonable efforts, SEO could not be reached to confirm authorship; this statement is made on her behalf by the corresponding author, who takes full responsibility for this affirmation.

Author Contributions

Conceptualisation: TAA; Formal analysis: SEO; Methodology: TAA, UCA, SEO; Project administration; Supervision: TAA; Writing-original draft: SEO; and Writing-review & editing: TAA, UCA. All authors reviewed the results and approved the final version of the manuscript.

Funding

No funding was received for this study.

Competing Interests

The authors have declared that no competing interests exist.

Data Availability Statement

Data is available from corresponding author on request.

AI-Assisted Technologies Statement

ChatGPT was used to improve grammar, readability, and clarity. All scientific content, analyses, and interpretations were developed independently by the authors, who reviewed the text and take full responsibility for the manuscript.

References

1. Mirón IJ, Linares C, Díaz J. The influence of climate change on food production and food safety. Environ Res. 2023; 216: 114674.
2. Aderinola TA, Allikura OJ. Quality evaluation of cookies from wheat and breadfruit composite flour. Ann Food Sci Technol. 2015; 16: 354.
3. Ikuemonisan ES, Mafimisebi TE, Ajibefun I, Adenegan K. Cassava production in Nigeria: Trends, instability and decomposition analysis (1970-2018). Heliyon. 2020; 6: e05089.

4. FAOSTAT. Food and agriculture data [Internet]. Rome, Italy: FAOSTAT; 2025. Available from: https://www.fao.org/faostat/en/#data/QCL/visualize.
5. Tchonkouang RD, Onyeaka H, Miri T. From waste to plate: Exploring the impact of food waste valorisation on achieving zero hunger. Sustainability. 2023; 15: 10571.
6. Aderinola TA, Makinwa OJ, Aderehinwo OM. Proximate composition, functional and bioactive properties of cassava, garden egg and sorghum residue composite flours. Food Humanity. 2023; 1: 1576-1583.
7. Sarangi PK, Mishra S, Mohanty P, Singh PK, Srivastava RK, Pattnaik R, et al. Food and fruit waste valorisation for pectin recovery: Recent process technologies and future prospects. Int J Biol Macromol. 2023; 235: 123929.
8. Aderinola TA. Effects of processing techniques on the functional properties of wheatbreadfruit composite flour. Int Food Res J. 2016; 23: 2759.
9. Aderinola TA, Mayomi PT. Functional, nutritional and in-vitro antidiabetic properties of plantain-African walnut composite flour. Food Nutr. 2025; 1: 100001.
10. Mayomi PT, Aderinola TA. Proximate, mineral, amino acid composition, and bioactive properties of dough meals supplemented with African walnut flour. Food Sci Eng. 2024; 5: 404-417.
11. Akinyede AI, Ayibiowu EO, Fakologbon T, Awolu OO, Fagbemi TN. Nutritional assessment, glycemic indices and anti-diabetic potentials of dough meal generated from optimized blends of matured plantain, soya cake and wheat bran flours. J Future Foods. 2023; 3: 374-382.
12. Anyaiwe U, Oluwamukomi M, Aderinola T, Fagbemi T. Effects of enrichment on amino acid profile, mineral composition and anti-nutritional factors of Lafun powder. Turk J Agric Food Sci Technol. 2022; 10: 1515-1523.
13. Adebowale OJ, Adeyanju AA. Evaluation of sorghum-ogi gruel complemented with ginger and garlic powders. J Culin Sci Technol. 2023; 21: 922-931.
14. AOAC International. Official Methods of Analysis of AOAC International. 19th ed. Gaithersburg, MD: AOAC International; 2012.
15. Singleton VL, Orthofer R, Lamuela-Raventós RM. Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. In: Methods in enzymology. Cambridge, MA: Academic Press; 1999. pp. 152-178.
16. Adeyemi AP, Aderinola TA, Ademilua IE. Production of Kokoro with enhanced antioxidant and in-vitro antidiabetic properties from maize-beans composite flours. Appl Trop Agric. 2023; 28: 357-367.
17. Makkar HP, Goodchild AV, El-Moneim AM, Becker K. Cell-constituents, tannin levels by chemical and biological assays and nutritional value of some legume foliage and straws. J Sci Food Agric. 1996; 71: 129-136.
18. Harborne JB. Methods of plant analysis. In: Phytochemical methods: A guide to modern techniques of plant analysis. Dordrecht, Netherlands: Springer Dordrecht; 1984. pp. 1-36.
19. Ayo J. Physicochemical, phytochemical and sensory evaluation of acha-carrot flours blend biscuit. Curr J Appl Sci Technol. 2017; 25: 1-15.
20. Amit SK, Uddin MM, Rahman R, Islam SR, Khan MS. A review on mechanisms and commercial aspects of food preservation and processing. Agric Food Secur. 2017; 6: 51.

21. Antala PA, Chakote A, Varshney N, Suthar K, Singh D, Narwade A, et al. Phytochemical and metabolic changes associated with ripening of *Lycopersicon esculentum*. Sci Rep. 2025; 15: 10692.
22. Rashidinejad A, Ahmmed MK. The influence of ripening on the nutrient composition and antioxidant properties of New Zealand damson plums. Food Sci Nutr. 2024; 12: 4311-4320.
23. Phillips KM, McGinty RC, Couture G, Pehrsson PR, McKillop K, Fukagawa NK. Dietary fiber, starch, and sugars in bananas at different stages of ripeness in the retail market. PLoS One. 2021; 16: e0253366.
24. Adewole MB, Duruji RW. Quality assessment of plantain (*Musa paradisiaca* L.) as affected by different ripening methods. Afr J Biotechnol. 2010; 9: 6290-6293.
25. Aggarwal R, Bains K. Protein, lysine and vitamin D: Critical role in muscle and bone health. Crit Rev Food Sci Nutr. 2022; 62: 2548-2559.
26. Niyi OH, Jonathan AA, Ibukun AO. Comparative assessment of the proximate, mineral composition and mineral safety index of peel, pulp and seeds of cucumber (*Cucumis sativus*). Open J Appl Sci. 2019; 9: 691-701.
27. Allai FM, Gul K, Zahoor I, Ganaie TA, Nasir G, Azad ZA. Malnutrition: Impact of zinc on child development. In: Microbial biofertilizers and micronutrient availability: The role of zinc in agriculture and human health. Cham, Switzerland: Springer; 2022. pp. 83-100.
28. Ishfaq M, Wakeel A, Shahzad MN, Kiran A, Li X. Severity of zinc and iron malnutrition linked to low intake through a staple crop: A case study in east-central Pakistan. Environ Geochem Health. 2021; 43: 4219-4233.
29. Xue Y, Teng Y, Chen M, Li Z, Wang G. Antioxidant activity and mechanism of avenanthramides: Double H^+/e^- processes and role of the catechol, guaiacyl, and carboxyl groups. J Agric Food Chem. 2021; 69: 7178-7189.
30. Anitha S, Krishnan S, Senthilkumar K, Sasirekha V. Theoretical investigation on the structure and antioxidant activity of (+) catechin and (-) epicatechin-a comparative study. Mol Phys. 2020; 11: e1745917.
31. Agrawal RS, Ranveer RC, Rathod NB, Nirmal NP. Phytochemicals as bioactive ingredients for functional foods. In: Recent frontiers of phytochemicals. Amsterdam, Netherlands: Elsevier; 2023. pp. 95-108.
32. Olvera-Aguirre G, Piñeiro-Vázquez ÁT, Sanginés-García JR, Zárate AS, Ochoa-Flores AA, Segura-Campos MR, et al. Using plant-based compounds as preservatives for meat products: A review. Heliyon. 2023; 9: e17071.
33. Zhang H, Sun S, Ai L. Physical barrier effects of dietary fibers on lowering starch digestibility. Curr Opin Food Sci. 2022; 48: 100940.
34. Jayawardana SA, Samarasekera JK, Hettiarachchi GH, Gooneratne J, Mazumdar SD, Banerjee R. Dietary fibers, starch fractions and nutritional composition of finger millet varieties cultivated in Sri Lanka. J Food Compos Anal. 2019; 82: 103249.
35. Aniqa, Rizvi ZF. Ripening associated antioxidant and phytochemical changes in mango (*Mangifera indica*) cultivar Dusehri. Sci Rep. 2025; 15: 410.
36. Ionică ME. Evolution of some physico-chemical characteristics of the eggplant (*Solanum melongena* L.) fruits during their growth and ripening. South West J Hortic Biol Environ. 2020; 11: 27-35.

37. Badejo AA, Adebowale AP, Enujiugha VN. Changes in nutrient composition, antioxidant properties, and enzymes activities of snake tomato (*Trichosanthes cucumerina*) during ripening. Prev Nutr Food Sci. 2016; 21: 90-96.