



Effect of Cassava (*Manihot esculenta* Crantz) and Sesame Seed (*Sesamum indicum*) Blend Flour Incorporation on the Nutritional, Anti-nutritional, and Sensory Properties of Wheat-Based Biscuits

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ABSTRACT

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The study evaluated the nutritional, anti-nutritional, and sensory properties of biscuits produced from wheat, cassava, and sesame seed composite flours. Three formulations were prepared: XXA (80% wheat, 5% cassava, 15% sesame), XXB (70% wheat, 20% cassava, 10% sesame), and XXC (100% wheat, control). Standard methods were used to determine proximate composition, minerals, vitamins, anti-nutritional factors, and sensory attributes. The results showed that composite flour incorporation significantly influenced the nutritional composition of the biscuits ($p < 0.05$). Ash and fat contents were higher in formulations containing sesame seed flour, whereas carbohydrate content increased with higher levels of cassava flour. Mineral composition varied significantly among samples, with XXA exhibiting higher iron, magnesium, zinc, and calcium contents. Vitamin E and vitamin B₁ contents were significantly enhanced in composite biscuits, particularly in XXA, whereas vitamin A was highest in XXB. The levels of anti-nutritional factors, including tannins, oxalates, phenols, and hydrogen cyanide, differed significantly among formulations but remained within acceptable safety limits. Sensory evaluation indicated that the composite biscuits were acceptable and comparable to the control. The study showed that cassava and sesame seed flours can be successfully used in biscuit production to improve nutritional quality.

1. INTRODUCTION

Biscuits are widely consumed bakery products for their long shelf life, convenience, and affordability, and they are an important snack for both children and adults in many developing countries, including Nigeria. However, conventional biscuits produced solely from refined wheat flour are generally limited in essential micronutrients and dietary fibre, and their dependence on imported wheat also places a substantial economic burden on wheat-importing countries (FAO, 2021; Oyeyinka & Oyeyinka, 2022). Consequently, the use of locally available crops as partial substitutes for wheat flour has received increasing attention as a sustainable strategy for improving the nutritional quality of bakery products while reducing reliance on imported raw materials.

Cassava (*Manihot esculenta* Crantz) is one of the most important staple crops in sub-Saharan Africa and plays a major role in Nigeria's food security. It is predominantly a source of carbohydrates and energy, but its protein and micronutrient contents are generally low (FAO, 2021). In recent years, biofortified vitamin A cassava has been promoted as a practical intervention for addressing vitamin A deficiency, which remains a public health concern in many low- and middle-income countries (Saltzman et al., 2017; Birol et al., 2020). The incorporation of vitamin A–fortified cassava flour into commonly consumed foods such as biscuits, therefore, offers a promising approach for enhancing the micronutrient intake of vulnerable populations.

Sesame seed (*Sesamum indicum*) is an underutilised oilseed crop with high nutritional and functional potential. It is rich in high-quality plant protein, unsaturated fatty acids, and important minerals such as calcium, iron, and zinc, as well as bioactive compounds including tocopherols and lignans with recognised antioxidant properties (Pathak et al., 2022; Wei et al., 2022). Several studies have reported that incorporation of sesame seed or sesame flour into cereal-based products improves protein quality, mineral density, and antioxidant capacity (Bakare et al., 2020; Mostashari & Mousavi, 2024). However, sesame seeds also contain certain anti-nutritional factors, including tannins and phytochemicals that may influence nutrient bioavailability, making it important to evaluate both nutritional benefits and possible limitations when they are used in composite food formulations.

The development of composite flours from cereals, roots, and oilseeds has been widely proposed as a viable strategy for producing nutritionally improved bakery products that are affordable and locally sourced (Adeola et al., 2021; Dada et al., 2023). In biscuit production, partial substitution of wheat flour with non-wheat flours can significantly affect dough handling properties, baking performance, nutrient composition, and consumer acceptability (Agu et al., 2023; Oyewole et al., 2024). While several studies have examined the use of cassava or sesame individually in baked products, limited information is available on the combined use of vitamin A–fortified cassava flour and sesame seed flour in wheat-based biscuits, particularly with respect to their effects on micronutrient composition, anti-nutritional factors, and sensory quality. Moreover, the presence of naturally occurring anti-nutritional compounds such as hydrogen cyanide in cassava-based products and polyphenolic compounds in oilseeds necessitates careful assessment to ensure product safety and nutritional adequacy (FAO/WHO, 2021; Lambebo et al., 2025). Evaluating the balance between nutrient enhancement and potential anti-nutritional effects is therefore essential for the development of functional composite biscuits suitable for regular consumption.

Against this background, the present study was designed to evaluate the effect of partial substitution of wheat flour with vitamin A fortified cassava flour and sesame seed flour on the proximate composition, mineral and vitamin contents, anti-nutritional factors, and sensory attributes of biscuits. The study seeks to provide scientific evidence on the nutritional and sensory suitability of wheat, cassava, and sesame composite biscuits and to support the utilisation of locally available raw materials as a means of improving dietary quality and promoting sustainable food systems in Nigeria.

2. MATERIALS AND METHODS

2.1. Description of Testing Sites

All raw materials used for this study, including dried white sesame seeds (*Sesamum indicum*), wheat flour, granulated sugar, margarine, eggs, baking powder, salt, nutmeg, and flavouring agents, were purchased from a retail outlet in Abakaliki, Ebonyi State, Nigeria. Vitamin A fortified cassava roots (*Manihot esculenta* Crantz) were also obtained from a retail outlet in Abakaliki, Ebonyi State. All chemicals and reagents used for laboratory analyses were of analytical grade, and standard laboratory equipment was employed.

2.2. Preparation of Sesame Seed Flour

White sesame seeds (*Sesamum indicum*) were manually sorted to remove stones, broken seeds, and other extraneous materials. The seeds were washed thoroughly with potable tap water and drained. Thereafter, the cleaned seeds were spread in a single layer on stainless steel trays and sun-dried for approximately 7 h, following the method described by Ogundele et al. (2022). The dried seeds were allowed to cool to ambient temperature (25–27 °C), milled into flour using an attrition milling machine, and subsequently sieved through a 0.5 mm aperture sieve to obtain a fine and uniform particle size.

2.3. Preparation of Cassava Flour

Cassava flour was prepared from vitamin A-fortified cassava roots using the method of Nilusha et al. (2021) with slight modification. Fresh, mature cassava roots were thoroughly washed with potable tap water to remove adhering soil and debris, and were manually peeled. The peeled roots were rewashed and cut into cubes of approximately 2–3 cm to facilitate uniform drying. The cassava pieces were spread on clean trays and sun-dried for two days until a sufficiently low moisture content was attained. The dried cassava chips were milled using a heavy-duty cutting mill (SM2000/695 upm, Germany), and the resulting flour was passed through a 0.5 mm aperture sieve to obtain a fine, homogeneous cassava flour. The formulation of the blend from wheat, cassava, and sesame flours is shown in Table 1

Table 1. Formulation of wheat, sesame, and cassava flour blends

Sample	Wheat flour (%)	Cassava flour (%)	Sesame Flour (%)
XXA	80	5	15
XXB	70	20	10
XXC	100	0	0

2.4. Production of Biscuit

Biscuits were produced according to the method described by Peter et al. (2017) with slight modifications. Composite flour blends of wheat, cassava, and sesame seed flour (500 g) were weighed into a mixing bowl. Margarine (200 g) and granulated sugar (100 g) were added and creamed using a whisk until a light and fluffy consistency was obtained (approximately 30 min).

In a separate bowl, whole eggs (2 units) were mixed with potable water (100 mL). The egg and water mixture was then added to the creamed fat and sugar mixture and beaten for approximately 1 min to obtain a uniform batter. The composite flour blend was subsequently incorporated gradually, together with powdered milk (50 g), baking powder (1 g), salt (1 g), nutmeg (1 g), and vanilla flavour (5 g), under continuous mixing until a slightly firm and homogeneous dough was formed. The dough was transferred onto a clean, flat working surface and gently kneaded for 4 min to ensure uniform distribution of ingredients while avoiding excessive gluten development. The dough was manually rolled into sheets and flattened to a uniform thickness of approximately 1.0 mm, after which it was cut into desired shapes using a biscuit cutter. The cut dough pieces were arranged on greased baking trays

and baked in a preheated oven at 180 °C for 30 min. After baking, the biscuits were removed from the oven, allowed to cool to room temperature, and subsequently packaged in airtight containers prior to further analyses.

2.5. Proximate Determination

The determination of the proximate composition of the biscuit was done following the procedure described by (AOAC, 2010).

2.5.1. Moisture Content Determination

Moisture content was determined using the drying oven method. A clean Petri dish was dried, cooled in a desiccator, and weighed. About 2 g of the sample was placed in the dish and weighed again. The sample was dried in an oven at 105°C until a constant weight was obtained. After drying, the sample was cooled in a desiccator and reweighed. The loss in weight was used to determine the moisture content. The moisture content was calculated as follows:

$$\text{Moisture content (\%)} = \frac{W_2 - W_3}{W_2 - W_1} \times \frac{100}{1} \quad \text{Eq. 1}$$

Where: W_1 = weight of empty petri-dish, W_2 = weight of petri-dish + sample before drying, W_3 = weight of petri-dish + Sample after drying

2.5.2. Crude Protein Determination

Crude protein was determined using the Kjeldahl method. About 0.5 g of the sample was weighed into a Kjeldahl flask, and 10 g Na_2SO_4 , 1 g CuSO_4 , and 20 ml concentrated H_2SO_4 were added. The mixture was digested on a heating mantle in a fume cupboard for about 2 hours until a clear blue-green solution was obtained, indicating complete digestion. The digest was cooled, diluted with distilled water, and 40% NaOH was added. The mixture was distilled, and the liberated ammonia was collected in 4% boric acid containing methyl red indicator. The distillate was then titrated with 0.1 N HCl until the endpoint colour change was observed. The protein content was calculated thus:

$$\text{Protein (\%)} = \frac{T_v \times N \times 6.25 \times 0.014 \times 100}{\text{weight of Sample}} \quad \text{Eq. 2}$$

Where: T_v = Titre value, N = Normality of the HCl (0.1N), 6.25 = Conversion Factor for Nitrogen, 0.014 = Liberation factor for Nitrogen.

2.5.3. Ash Determination

An empty crucible was washed, oven-dried (Model 2836; 240 V and 50/60 Hz), and cooled in desiccators for about 15 minutes, and the weight was taken as W_1 . Two grammes (2 g) of each sample were weighed into the crucible of known weight, the weight was taken as W_2 . The sample was heated in a heating mantle for carbonization. It was transferred into a muffle furnace at a temperature of 600 °C and the sample was allowed to cool until the colour turned grey. It was taken into the desiccator to cool for 15 minutes, and the weight was taken as W_3 . The percentage ash was calculated as follows:

$$\text{Ash (\%)} = \frac{W_3 - W_1}{\text{weight of the sample}} \times \frac{100}{1} \quad \text{Eq. 3}$$

Where: W_1 = Weight of empty crucible, W_2 = Weight of crucible + sample before ashing, W_3 = Weight of crucible + sample after ashing.

2.5.4. Fat Content Determination

Five grammes (5 g) of the sample was weighed into a conical flask; 50 ml of n-hexane was added. A beaker was washed, oven-dried (Model 2836; 240 V and 50/60 Hz), cooled in a desiccator for about 15 minutes, and weighed as W_1 . It was filtered into the beaker with a funnel and No.1 Whatman filter paper (110 mm), and then taken into the oven until the n-hexane evaporated. It was cooled in the desiccator and weighed as W_2 . The percentage crude fat was calculated using the formula:

$$\text{Fat (\%)} = \frac{W_2 - W_1}{\text{Weight of sample}} \times \frac{100}{1} \quad \text{Eq. 4}$$

Where: W_1 = Weight of the empty beaker, W_2 = Weight of the beaker and oil extracted.

2.5.5. Fiber Content Determination

Crude fibre was determined by acid and alkaline digestion method. About 2 g of defatted sample was boiled with 1.25% H_2SO_4 for 30 minutes and filtered using Whatman No. 1 filter paper. The residue was washed with hot water and boiled again with 1.25% NaOH for another 30 minutes. After filtration and washing, the residue was dried in an oven, weighed, and then transferred into a crucible. The sample was ashed in a muffle furnace at 550°C for 3 hours, cooled in a desiccator, and reweighed. The loss in weight after ashing was used to determine the crude fibre content. The crude fibre content was calculated thus:

$$\text{Crude Fibre (\%)} = \frac{W_5 - W_3}{\text{Weight of sample}} \times \frac{100}{1} \quad \text{Eq. 5}$$

Where: W_1 = Weight of filter paper, W_2 = Weight of filter paper + the residue, W_3 = Weight of the empty crucible, W_4 = Weight of the crucible + residue + filter paper, W_5 = Weight after ashing.

2.5.6. Carbohydrate Determination

The carbohydrate content of the test smoke was determined by estimation using the arithmetic difference method. The carbohydrate was calculated and expressed as nitrogen-free extract, as shown below;

$$\% \text{ Carbohydrate} = (A + B + C + D + E) \quad \text{Eq. 6}$$

Where: A = % Protein, B = % Fat, C = % Ash, D = % Fiber, E = % Moisture.

2.6. Minerals Analysis

2.6.1. Sample Digestion

The determination of the mineral element of the sample was done using the wet digestion extraction methods as described by AOAC (2010). The sample was digested using 5 ml of 6-molar solution of trioxonitrate (v) acid (6MHNO_3) and 2 ml of pechloric acid ($6(\text{HClO}_4)$). The solution was filtered using No.1 Whatman filter paper after adding 15 ml of distilled water to a 50 ml volumetric flask, and the volume was made up to the mark with more water. The digested samples were analyzed using a Spectronic 21D spectrophotometer, which was calibrated with appropriate standard solutions for each mineral before analysis.

2.6.2. Determination of Magnesium

The method described by AOAC (2010) was used. A ten (10 ml) measuring cylinder was used to measure 10 ml of the sample solution into a 250 ml conical flask, a pinch was pipetted into a 150 ml conical flask, a pinch of hydrochloride was added, 20 ml of ammonium buffer, and a pinch of

solochrome black was added, and then titrated with 0.02 M ethylene diamine tetraacetic acid (EDTA). This was replicated, and the data obtained was used for calculating the level of magnesium in the sample. Magnesium was calculated as:

$$Mg \left(\frac{mg}{100g} \right) = \frac{Tv \times 0.2432 \times 1.661 \times 1000}{weight\ of\ sample} \quad Eq. 7$$

Where: TV = Titre value, 0.2432 = Liberated factors for EDTA, 1.661 = Cofactor constant value

2.6.3. Determination of Zinc

The method described by AOAC (2010) was used. Exactly 10 ml of digested extract was pipette into a 150 ml conical flask, sodium chloride, hydroxylamine, and hydrochloride was added, and then 20 ml of ammonium buffer (NH₄ buffer) with a pinch of solochrome black indicator was added to the mixture. The solution was then shaken for a minute to homogenize. Subsequently, the solution was titrated with 0.02 M EDTA (Ethylenediamine tetra-acetic acid) until the colour changed from wine red to blue. These were replicated, and the data obtained were used to calculate the level of zinc in the sample.

$$Zn \left(\frac{mg}{100g} \right) = \frac{Tv \times vf \times 0.6538 \times 0.02}{weight\ of\ sample \times volume\ used} \quad Eq. 8$$

Where: Tv = Titre value, Vf = Total volume of the digested sample

2.6.4. Determination of Iron (Fe)

The recommended methods of the Association of Official Analytical Chemists (AOAC, 2010) was used to determine the iron content. Five (5 ml) of the digested sample was pipetted into a beaker, and 5 ml of sodium acetate buffer (buffer 4.5) was added to it. Additionally, 5 ml of 10 % hydroxylamine hydrochloride was added together with 0.5 ml of 0.25 % n-phenol tritoline. The absorbance will be taken at 510nm using a 721 (D) spectrophotometer. The iron content of the sample was calculated as given

$$Fe \left(\frac{m}{100g} \right) = \frac{100 \times C \times Vf}{weight\ of\ sample \times Va} \quad Eq. 9$$

Where: C = Concentration, Vf = Total volume of digested sample, Va = Volume of sample analyzed

2.6.5. Determination of Calcium

Ten (10) ml of the digest was pipetted into a 150 ml conical flask. A pinch of potassium cyanide and potassium hydroxide was added, followed by 20 ml of ammonium buffer and a pinch of Patton and Reeder indicator. The mixture was titrated with 0.01M ethylenediamine tetraacetic acid (EDTA)solution until a distinct endpoint was observed. The procedure was repeated, and the data obtained were used to calculate the calcium content of the sample.

$$Calcium \left(\frac{mg}{100g} \right) = \frac{Tv \times 0.4008 \times Vf \times 100}{Wt \times Va} \quad Eq. 10$$

Where: Tv = Titre value, Vf = Total volume of digested sample, Wt = Weight of sample used, Va = Volume of sample used.

2.7. Vitamins Analysis

2.7.1. Determination of Vitamin A (Retinol)

The method of Kirk and Sawyer (1991) was used. One gram (1 g) of the sample was weighed and steeped with 20 ml of n-hexane in a test tube for 10 minutes and filtered using No.1 Whatman filter paper. The filtrate was evaporated to dryness. Thereafter, 0.2 ml of acetic anhydride chloroform reagent was added, and 2 ml of 50 % trichloroacetic acid (TCA) in chloroform was also added. The absorbance was taken at 350 nm in 15 seconds using 721 (D) spectrophotometer. Vitamin A content was calculated using the formula:

$$\text{Vitamin A} = \frac{C \times V_f}{W_t \times V_a} \quad \text{Eq. 11}$$

Where: C = Concentration, Vf = Total volume of the sample, Va = Analyzed volume of the sample, Wt = weight of the sample

2.7.2. Vitamin E Content Determination

The titration method, as described by AOAC (2010), was used. Five (5 ml) of acetone was measured and added to 0.2 g of the sample. The mixture was allowed to stand with occasional shaking for 10 minutes to extract the content. Then, 2 ml of distilled water was added, followed by the addition of 3 of petroleum ether. The oily layer was transferred into a cuvette, and the absorbance was measured using the wavelength of 292 nm using a 721 (D) spectrophotometer. Vitamin E content was calculated using the formula;

$$\text{Vitamin E} = \frac{C \times V_f}{W_t \times V_a} \quad \text{Eq. 12}$$

Where: C = Concentration, Vf = Total volume of sample, Wt = Weight of sample, Va = Volume analyzed from the sample.

2.7.3. Determination of Vitamin B1 (Thiamine) Content

The method described by Pearson (1976) was used. Five (5) g of the test sample was filtered into a 100 ml flask using whatman N0.1 filter paper. Ten (10) ml of the filtrate was pipetted into a separate flask, and the colour was developed by adding ten (10) ml of potassium dichromate. The absorbance of the solution was measured at a wavelength of 360 nm using a Spectronic 21D spectrophotometer. The data obtained were used to calculate the thiamine content of the sample in mg/100g. Calculation:

$$\text{Vitamine B1} \left(\frac{\text{mg}}{\text{ml}} \right) = \frac{\text{Concentration} \times \text{total volume of the sample}}{\text{Weight of sample} \times \text{volume of sample}} \quad \text{Eq. 13}$$

2.8. Anti-nutrient Analysis

2.8.1. Determination of Tannin

Tannin content was determined using the AOAC (2010) method. Five grams of the sample was extracted with diethyl ether containing 1% acetic acid to remove pigments, followed by extraction with 70% acetone for 2 hours using an electric shaker. The mixture was filtered, and 5 mL of the filtrate was diluted with distilled water. Folin–Denis reagent was added, and the mixture was allowed to stand at room temperature for 40 minutes. Absorbance was measured at 765 nm using a spectrophotometer, and tannin concentration was determined from a tannic acid standard curve. The tannin was calculated below:

$$Tannin \left(\frac{mg}{ml} \right) = \frac{Extract-Blank}{standard-Blank} \quad \text{Eq. 14}$$

Where: C = Concentration of the standard, Vf = Total volume of the filtrate, Va = Volume analyzed

2.8.2. Determination of Oxalate

The oxalate content was determined using the method described by AOAC (2010). Exactly 0.1 gram of the sample was weighed on glazed weighing paper using an Analytical Balance. The sample was transferred into a 125 mL Erlenmeyer flask. Exactly 30 ml of deionized water and 5 ml of 6 M H₂SO₄ was added. The glazed weighing paper was rinsed with a small portion of deionized water from the bottle into the flask. It was swirled to dissolve the sample. The sample was heated to about 60 °C. The sample was titrated to a pink endpoint with 0.01 M KMnO₄. The Oxalate content was calculated using the formula:

$$Oxalate \left(\frac{mg}{100g} \right) = \frac{5mole\ C_2O_4^{2-}}{2\ mole\ MnO_4} \times V_{std} \times M_{std} \quad \text{Eq. 15}$$

Where: Vstd = Titre Value, Mstd = Molarity (0.01 M KMnO₄)

2.8.3. Determination of Phenol

The phenol content was determined according to the method described by (AOAC,2010). Two grams (2 g) of the sample were soaked in 50mlof petroleum ether and allowed to stand for 2 hours. After filtration, the residue was resoaked with diethyl ether, covered, and heated in a water bath for 15 minutes. A 5 mL aliquot of the resulting extract was pipetted into a 50 mL volumetric flask. To this, 10 ml of ammonium hydroxide (NH₄OH) and 5 ml of concentrated amyl alcohol were added. The mixture was made up to the 10 ml mark of the volumetric flask using distilled water and left to stand for 30 minutes to allow complete colour development. The absorbance was then measured at 505 nm using a 712 (D) spectrophotometer. The phenol content was calculated using the formula:

$$Phenol \left(\frac{mg}{100g} \right) = \frac{100 \times Au \times C \times Vf}{W \times As \times Va} \quad \text{Eq. 16}$$

Where: C = Concentration of standard, Au = absorption of standard, Vf = Total volume of filtrate, Va = Volume analyzed

2.8.4. Determination of Hydrogen Cyanide

The method described by AOAC (2010) was adopted. One gram of the biscuit sample was added to a small plastic bottle; a buffer/enzyme paper was added. The bottles were allowed to stand overnight at 30 °C, the picrate papers were removed from the plastic support, and 5.0 ml of water was added to elute the colour. The absorbance was measured in a 721 (D) spectrophotometer at 510 nm, and total cyanide content in mg HCN equivalents/100g fresh was evaluated, and values were reported in triplicate. The HCN was calculated as follows:

$$HCN \left(\frac{mg}{100g} \right) = \frac{\frac{g}{ml} \text{ of cyanide} \times \text{final volume}}{\text{Weight of the sample}} \quad \text{Eq. 17}$$

2.9. Sensory Evaluation

The sensory evaluation of biscuits from wheat, sesame, and cassava flour was conducted to assess the organoleptic attributes, including appearance, aroma, taste, crispiness, texture, and general acceptability. Twenty (20) semi-trained panelists from the Department of Food Science and Technology, Ebonyi State University, Abakaliki, participated in the evaluation using a 9-point hedonic scale. The panelists were familiar with sensory evaluation procedures and were selected

based on their willingness and availability to participate. The panelists were asked to rate the different formulated biscuits presented to them under controlled conditions to prevent biased results. In the questionnaire, the panelists were instructed to observe and test each coded sample and rank them using a preference ranking test. Portable water was provided for the panelists to rinse their mouths between evaluations. The panelists ranked the products based on their level of preference in hedonic order, following the grading system outlined by Okaka (2010). 1 = Dislike extremely, 2 = Dislike very much, 3 = Dislike Moderately, 4 = Dislike slightly, 5 = Neither like nor dislike, 6 = Like slightly, 7 = Like Moderately, 8 = Like very much, 9 = Like extremely.

2.10. Experimental Design and Statistical Analysis

The study adopts a Completely Randomized Design (CRD). Data obtained were analyzed with the Statistical Package for the Social Sciences (SPSS) version 26. Summary statistics (Mean and standard deviation) was estimated for each treatment group (processing method). One-way Analysis of Variance (ANOVA) was adopted to test the difference in mean among several treatment groups (processing methods). Tukey HSD multiple test was deployed as a post-hoc test for the determination of treatment groups that differ significantly from each other. All tests were conducted at 5% level of significance, that is, $p < 0.05$ is considered significant.

3. RESULT AND DISCUSSION

3.1. Proximate Composition of Biscuits Made from Flour Blend

The result of the proximate composition of biscuits made from wheat (*Triticum aestivum*), Cassava (*Manihot esculenta* Crantz), and Sesame seed (*Sesamum indicum*) Flour Blends is presented in Table 2. The proximate composition of biscuits produced from wheat, cassava, and sesame seed flour blends (XXA, XXB, and XXC), as represented in Table 2, revealed significant variations in nutritional quality attributable to differences in flour composition. Moisture content ranged from 3.50–4.40% with no significant difference ($p > 0.05$) among samples, indicating good shelf stability across all formulations. Moisture values below 5% are desirable in biscuits, as they limit microbial growth and extend storage life (Asadi *et al.*, 2022).

Protein content increased significantly ($p < 0.05$) from XXA (10.65%) to XXC (15.80%), suggesting that inclusion of sesame seed flour markedly reduced protein levels. Sesame seeds are known to be rich in high-quality plant protein, and their incorporation has been widely reported to improve the protein content of baked products (Msugh *et al.*, 2024; Bakare *et al.*, 2020). However, the reduction recorded in this study agrees with the report of Naqvi *et al.* (2024), the probable explanation is that in fine (refined) wheat flour, which is relatively higher in gluten proteins per unit dry weight compared to its other fractions, the addition of whole sesame seeds (which contribute fat, fibre, and other components alongside protein) effectively dilutes the proportional protein in the final baked product on a dry weight basis. Fat content showed a decreasing trend from XXA (14.50%) to XXC (5.10%), reflecting the relative proportions of wheat and sesame flour used in the blends.

Lower fat content can be advantageous in producing biscuits with reduced caloric density and improved oxidative stability (Obasi and Askepnde, 2023). Ash content, an indicator of mineral composition, was highest in XXA (1.25%) and lowest in XXC (0.51%), with significant differences observed ($p < 0.05$). This suggests a reduction in mineral concentration as wheat flour proportion decreased. Similar trends have been reported in composite biscuits where root and oilseed flours partially replaced wheat (Dada *et al.*, 2023). Crude fibre content showed no significant difference ($p > 0.05$) among samples, though XXA had a numerically higher value. This may be attributed to the fibre contribution of whole wheat flour. Dietary fibre, even at modest levels, is beneficial for digestive health and glycaemic control (Forester *et al.*, 2025). Carbohydrate content increased significantly in XXC (74.60%), reflecting the high starch content of cassava flour.

Cassava is predominantly carbohydrate-based, and its increased inclusion predictably elevated total carbohydrate levels (FAO, 2021). This makes XXC a potential energy-dense snack suitable for populations with high caloric requirements. Overall, the results demonstrate that strategic blending of wheat, cassava, and sesame seed flours can be used to tailor the nutritional profile of biscuits. In particular, sesame seed inclusion significantly improved protein content, while cassava flour increased carbohydrate levels, highlighting the potential of composite flours in developing nutritionally enhanced, locally sourced bakery products.

3.2. Mineral Composition of Biscuits Made from Flour Blend

The result of the mineral composition of biscuits made from wheat (*Triticum aestivum*), Cassava (*Manihot esculenta* Crantz), and Sesame seed (*Sesamum indicum*) Flour Blends is presented in Table 3.

The mineral composition of biscuits produced from wheat–cassava–sesame flour blends presented in Table 3 differed significantly ($p < 0.05$) among the formulations. Iron content decreased significantly from XXA (134.35 mg/100 g) to XXC (50.74 mg/100 g). Magnesium content ranged from 6.07 to 7.67 mg/100 g, with XXA having the highest value. Zinc content was significantly highest in XXA (23.18 mg/100 g), calcium content was also highest in XXA (15.05 mg/100 g), and lowest in XXB (11.01 mg/100 g). Overall, XXA was characterized by superior zinc content, higher iron, magnesium, and calcium levels. The observed significant differences in mineral composition among the biscuit samples indicate that the incorporation of cassava and sesame seed flour altered the mineral profile of the products. The relatively high iron content in XXA compared with XXB and XXC suggests that the mineral contribution from wheat flour and possibly processing conditions played a greater role in this formulation. Although sesame seeds are recognized as good sources of iron, the dilution effect caused by increasing cassava flour, which is intrinsically low in minerals, may have contributed to the progressive reduction in iron content observed from XXA to XXC. Similar reductions in iron concentration with increasing cassava substitution in baked products have been reported in recent studies (Oyewole et al., 2024; Abu et al., 2021). Magnesium levels were generally low but differed significantly among samples, with XXA having the highest value.

Cassava roots contain very small amounts of magnesium compared with cereals and oilseeds, and their inclusion has been reported to lower the overall magnesium density of composite baked products (Adeola et al., 2021). The present results are therefore consistent with earlier reports on cassava-based composite flours. In contrast, the significantly higher zinc content observed in XXA is most likely attributable to the higher proportion of sesame seed flour in this formulation. Sesame seed is a recognized source of zinc and has been widely reported to improve the micronutrient quality of composite foods when incorporated into cereal-based products (Wei et al., 2022; Hafza et al., 2025). The marked increase in zinc concentration in XXA highlights the potential of sesame seed fortification as a practical strategy for improving the zinc content of commonly consumed snack foods.

Calcium content was significantly higher in XXA than in XXB and XXC. This pattern suggests that the reduction in calcium content may also be linked to increased substitution with cassava flour, which contains relatively low calcium compared with wheat and oilseeds. Similar trends have been reported in biscuits and bread formulated with increasing levels of cassava or other root crops, where mineral density declined as the level of substitution increased (Adeola et al., 2021; Abu et al., 2021). From a nutritional perspective, the results indicate that formulation XXA offers a clear advantage in terms of zinc enrichment, an essential micronutrient required for immune function and growth, particularly in vulnerable populations. However, the relatively higher iron and calcium contents of XXA suggest that optimisation of the blending ratios of wheat, cassava, and sesame seed flours would be necessary to achieve a more balanced mineral profile in the final biscuit product.

Table 2. Proximate composition of biscuits made from wheat (*Triticum atestivum*), Cassava (*Manihot esculenta Crantz*), and sesame seed (*Sesamum indicum*) Flour Blends.

Proximate (%)	Base Flour			Biscuit from Blend			F-value (p-value)
	Wheat Flour (mean±SD)	Sesame Flour (mean±SD)	Casava Flour (mean±SD)	XXA (mean±SD)	XXB (mean±SD)	XXC (mean±SD)	
Moisture	11.83 ±0.15	7.00 ±0.26	9.47 ±0.49	4.30 ^a ± 0.14	4.40 ^a ± 0.28	3.50 ^a ± 0.42	1.89(0.24)
Protein	10.40 ±0.26	41.83 ±0.90	1.63 ±0.21	10.65 ^c ± 0.21	14.45 ^b ± 0.07	15.80 ^a ± 0.14	8.45(0.003)
Fat	1.07 ±0.06	46.87 ±0.25	0.54 ±0.08	14.50 ^a ± 0.71	9.50 ^b ± 0.71	5.10 ^c ± 0.14	12.67(<0.001)
Ash	0.49 ±0.05	5.60 ±0.10	1.37 ±0.12	1.25 ^a ± 0.35	1.13 ^{ab} ± 0.18	0.51 ^b ± 0.01	3.99(0.038)
Fibre	2.63 ±0.12	9.95 ±0.27	2.68 ±0.28	2.50 ^a ± 0.71	1.13 ^a ± 0.88	0.75 ^a ± 0.35	1.36(0.652)
Carbohydrate	73.78 ±0.19	82.72 ±0.38	84.72 ±0.78	67.25 ^b ± 2.76	68.65 ^b ± 1.06	74.60 ^a ± 0.14	8.97(0.003)

Note: Values are triplicate mean ± standard deviation. Comparison was made only for the biscuit from the blend. Means along the row with different alphabetical superscripts indicate a significant difference($p<0.05$). XXA = 80 % Wheat flour: 5 % Cassava flour: 15 % Sesame seed, XXB = 70% wheat flour: 20 % Cassava: 10 % Sesame seed flour, XXC = 100 % wheat flour

Table 3. Mineral Composition of Biscuits Made from Wheat (*Triticum atestivum*), Cassava (*Manihot esculenta Crantz*), and Sesame Seed (*Sesamum indicum*) Flour Blends.

Minerals (mg/100g)	Base Flour			Biscuit from Blend			F-value (p-value)
	Wheat Flour (mean±SD)	Sesame Flour (mean±SD)	Cassava Flour (mean±SD)	XXA (mean±SD)	XXB (mean±SD)	XXC (mean±SD)	
Iron	0.81±0.03	11.56±3.12	0.39±0.01	134.35 ^a ± 0.01	84.46 ^b ± 0.01	50.74 ^c ± 0.01	134.67 (<0.001)
Magnesium	21.05±6.72	389.6±23.3	27.65±5.64	7.67 ^a ± 0.01	6.07 ^c ± 0.01	6.24 ^b ± 0.01	23.32 (0.009)
Zinc	0.89±0.01	8.78±1.32	0.37±0.02	23.18 ^b ± 0.01	10.52 ^c ± 0.01	9.18 ^a ± 0.01	32.54 (0.001)
Calcium	15.89±2.13	896.56±16.70	38.76±5.67	15.05 ^a ± 0.07	11.01 ^c ± 0.01	13.01 ^b ± 0.01	19.68 (0.035)

Note: Values are triplicate mean ± standard deviation. Comparison was made only for the biscuit from the blend. Means along the row with different alphabetical superscripts indicate a significant difference($p<0.05$). XXA = 80 % Wheat flour: 5 % Cassava flour: 15 % Sesame seed, XXB = 70% wheat flour: 20 % Cassava: 10 % Sesame seed flour, XXC = 100 % wheat flour

3.3. Anti-nutrient Composition of Biscuits Made from Flour Blend

The result of the anti-nutrient composition of biscuits made from wheat (*Triticum aestivum*), Cassava (*Manihot esculenta* Crantz), and Sesame seed (*Sesamum indicum*) Flour Blends is presented in Table 4. The anti-nutrient composition of the composite biscuits presented in Table 4 showed significant differences ($p < 0.05$) among samples XXA, XXB, and XXC for all the anti-nutrients evaluated. Tannin content ranged from 0.27 to 0.20 mg/100 g, with sample XXA having the highest value, while XXC recorded no value for tannin; this may be a result of 100% wheat that was used for this sample. Hydrogen cyanide (HCN) varied markedly among samples, with XXB having the highest level (0.79 mg/100 g) and XXC having no record of hydrogen cyanide it maybe as a result of the absence of hydrogen cyanide in wheat flour. Phenolic anti-nutrient levels were generally low, ranging from 0.04 to 0.55 mg/100 g, whereas oxalate content ranged between 0.53 and 1.33 mg/100 g, with XXB recording the highest value. The higher tannin concentration observed in XXA may be associated with the relatively higher contribution of plant materials such as sesame seed and composite flour components, which are known to contain appreciable levels of polyphenolic compounds, including tannins.

Tannins are capable of forming complexes with proteins and minerals, thereby reducing protein digestibility and mineral bioavailability when consumed in large quantities. However, moderate levels of tannins have also been associated with antioxidant and antimicrobial benefits, particularly in cereal–legume–based foods (Okaiyeto et al., 2025; Ehis-Eriakha et al., 2025). The presence of hydrogen cyanide in the biscuits, particularly in sample XXB, is most likely attributable to the inclusion of cassava flour, since cassava roots naturally contain cyanogenic glycosides that release HCN during processing. Similar trends have been reported in baked and extruded products formulated with cassava flour, where residual cyanide remains after processing, depending on the degree of fermentation, drying, and heat treatment applied (Lambebo et al., 2025; Scaria et al., 2024). Importantly, the HCN values obtained in this study (0.66-0.79 mg/100 g) remain below the maximum tolerable limit of 10 mg/kg recommended for cassava products, suggesting that the biscuits are within acceptable safety margins (FAO/WHO, 2021). Phenolic anti-nutrients were generally low in all samples, with XXA showing a slightly higher value. This may reflect a greater contribution of sesame seed and wheat fractions, which are known to contain phenolic compounds that can act both as anti-nutrients and as bioactive antioxidants.

Recent studies have highlighted that although some phenolic compounds may reduce mineral availability, they also contribute positively to the functional quality and oxidative stability of baked products (Irine et al., 2022; Ehis-Eriakha et al., 2025). Oxalate levels were highest in XXB and lowest in XXA. Oxalates are known to chelate divalent minerals such as calcium and iron, thereby limiting their bioavailability. The relatively higher oxalate content in XXB may be attributed to the botanical composition of the blend, particularly the inclusion of cassava and other plant-based ingredients known to contribute to oxalate levels in composite flours (Samuel et al., 2025). Nevertheless, the oxalate values observed in this study are considerably lower than levels reported to pose serious nutritional concerns in cereal-based snack products (Irine et al., 2022).

Overall, the results indicate that although the composite biscuits contain measurable amounts of tannins, hydrogen cyanide, phenols, and oxalates, the levels are generally low and within acceptable limits for safe consumption. The observed variations among samples further confirm that the proportion of wheat, cassava, and sesame seed flours significantly influences the anti-nutritional profile of the products. Adequate processing steps such as drying, roasting, and baking appear to be effective in reducing anti-nutrient concentrations, particularly hydrogen cyanide, in cassava-based composite biscuits.

Table 4. Anti-nutrient composition of biscuits made from wheat (*Triticum atestivum*), Cassava (*Manihot esculenta Crantz*), and sesame seed (*Sesamum indicum*) Flour Blends.

Anti-nutrient (mg/100g)	Base Flour			Biscuit from Blend			F-value (p-value)
	Wheat Flour (mean±SD)	Sesame Flour (mean±SD)	Cassava Flour (mean±SD)	XXA (mean±SD)	XXB (mean±SD)	XXC (mean±SD)	
Tannin	-	-	1.27±0.01	0.27 ^a ±0.01	0.20 ^a ±0.01	-	1.89 (0.84)
Hydrogen Cyanide	-	-	2.39±0.12	0.66 ^a ± 0.01	0.79 ^a ± 0.01	-	0.98(0.871)
Phenol	83.64±9.25	159.68±21.67	17.85±2.57	0.55 ^a ± 0.01	0.04 ^b ± 0.01	0.06 ^b ± 0.01	3.89(0.040)
Oxalate	5.56±0.68	268.58±13.67	67.89±32	0.53 ^c ± 0.01	1.33 ^a ± 0.01	0.83 ^b ± 0.01	4.99(0.035)

Note: Values are triplicate mean ± standard deviation. Comparison was made only for the biscuit from the blend. Means along the row with different alphabetical superscripts indicate a significant difference($p<0.05$). XXA = 80 % Wheat flour: 5 % Cassava flour: 15 % Sesame seed, XXB = 70% wheat flour: 20 % Cassava: 10 % Sesame seed flour, XXC = 100 % wheat flour

Table 5. Vitamin composition of biscuits made from wheat (*Triticum atestivum*), Cassava (*Manihot esculenta Crantz*), and sesame seed (*Sesamum indicum*) Flour Blends.

Vitamins (mg/100g)	Base Flour			Biscuit from Blend			F-value (p-value)
	Wheat Flour (mean±SD)	Sesame Flour (mean±SD)	Cassava Flour (mean±SD)	XXA (mean±SD)	XXB (mean±SD)	XXC (mean±SD)	
Vitamin E	2.57±0.13	0.47±0.02	0.18±0.00	27.89 ^a ± 0.01	20.75 ^b ± 0.01	16.74 ^c ± 0.01	67.89(<0.001)
Vitamin B1	0.48±0.02	1.85±0.10	0.08±0.00	36.37 ^a ± 0.01	32.42 ^b ± 0.01	24.83 ^c ± 0.01	68.95(<0.001)
Vitamin A	-	-	5.86±1.02	12.51 ^b ± 0.01	16.18 ^a ± 0.01	11.61 ^c ± 0.01	9.69 (0.008)

Note: Values are triplicate mean ± standard deviation. Comparison was made only for the biscuit from the blend. Means along the row with different alphabetical superscripts indicate a significant difference($p<0.05$). XXA = 80 % Wheat flour: 5 % Cassava flour: 15 % Sesame seed, XXB = 70% wheat flour: 20 % Cassava: 10 % Sesame seed flour, XXC = 100 % wheat flour

3.4. Vitamin Composition of Biscuits Made from Flour Blend

The result of the vitamin composition of biscuits made from wheat (*Triticum aestivum*), Cassava (*Manihot esculenta* Crantz), and sesame seed (*Sesamum indicum*) Flour Blends is presented in Table 5. The vitamin composition of the biscuits formulated from wheat, cassava, and sesame seed flour blends presented in Table 5 showed statistically significant differences ($p < 0.05$) among the samples (XXA, XXB, and XXC) for all the vitamins evaluated. Sample XXA recorded the highest contents of vitamin E (27.89 mg/100 g) and vitamin B₁ (36.37 mg/100 g), while sample XXB had the highest vitamin A content (16.18 mg/100 g). The lowest values of vitamin E, vitamin A, and vitamin B₁ were observed in XXC. The significantly higher vitamin E content observed in sample XXA can be attributed to the relatively higher contribution of sesame seed flour in this formulation, since sesame seeds are well recognized as rich sources of vitamin E, particularly γ - and α -tocopherol, which exhibit strong antioxidant activity. Similar increases in vitamin E content of bakery products enriched with oil-rich seeds and legumes have been reported in recent studies (Mostashari and Mousavi, 2024; Ayoub and Wani, 2026).

The enhanced vitamin E level in XXA therefore suggests an improved antioxidant potential of the product, which may contribute to better oxidative stability and added functional value. Vitamin B₁ (thiamine) was also significantly higher in sample XXA, followed by XXB. Thiamine is predominantly present in cereal grains and seeds, and its level is influenced by both the type of raw materials and processing conditions. The observed increase in vitamin B₁ with increasing inclusion of sesame seed and composite flours agrees with the findings of Mumukom et al. (2025) and Garg et al. (2021), who reported improved B-vitamin contents in composite baked products formulated with seeds and non-wheat flours. Although thermal processing such as baking is known to reduce thiamine content, the appreciable levels recorded in this study indicate that a substantial proportion of the vitamin was retained after baking, supporting the suitability of composite flour formulation for micronutrient enhancement.

In contrast, vitamin A content was highest in sample XXB and lowest in XXC. This variation may be related to differences in the proportion of cassava flour and other ingredients in the blends, as cassava and some cereal-based ingredients can contribute provitamin A carotenoids, while oil-rich seeds such as sesame contribute relatively less vitamin A. Furthermore, carotenoids and retinol equivalents are sensitive to heat, light, and oxidation during baking, which could partly explain the lower vitamin A level observed in some formulations (Annapurna et al., 2025). Similar trends of variable vitamin A retention in composite biscuits have been reported by Agu et al. (2023) and Ukpong et al. (2021). Overall, the results demonstrate that incorporation of cassava and sesame seed flours into wheat-based biscuits significantly improves the vitamin profile of the products, particularly vitamin E and vitamin B₁. This indicates that such composite biscuits could serve as convenient functional snacks capable of contributing to daily micronutrient intake, especially in populations where vitamin deficiencies remain a public health concern.

3.5. Sensory Quality of Biscuits Made from Flour Blend

The result of Sensory Quality of biscuits made from wheat (*Triticum aestivum*), Cassava (*Manihot esculenta* Crantz), and Sesame seed (*Sesamum indicum*) Flour Blends is presented in Table 6. The sensory evaluation of biscuits produced from wheat, cassava, and sesame seed composite flours presented in Table 6 showed significant differences ($p < 0.05$) among the samples for all assessed attributes. Samples XXA and XXB were consistently rated higher and were not significantly different from each other ($p > 0.05$) in taste, crispness, appearance, aroma, texture, and overall acceptability, whereas sample XXC recorded significantly lower scores across all attributes. Taste scores ranged from 7.50 to 8.40, with XXA and XXB being more preferred by the panelists. The relatively lower taste score of XXC may be associated with the higher inclusion level of sesame seed and/or cassava flour in the formulation, which can impart a slightly bitter or nutty after-taste when used at higher proportions. Similar observations have been reported for composite biscuits enriched with oilseeds

and non-wheat flours, where increased substitution levels reduced consumer preference for taste (Agu et al., 2023; Abu et al., 2021).

Table 6. Sensory quality of biscuits made from wheat (*Triticum aestivum*), Cassava (*Manihot esculenta* Crantz), and sesame seed (*Sesamum indicum*) Flour Blends.

Sensory attributes	XXA (mean±SD)	XXB (mean±SD)	XXC (mean±SD)	F-value (p-value)
Taste	8.40 ^a ± 0.75	8.25 ^a ± 0.85	7.50 ^b ± 1.00	6.78(0.041)
Crispness	7.80 ^a ± 1.15	7.80 ^a ± 0.83	6.05 ^b ± 1.31	5.89(0.039)
Appearance	8.45 ^a ± 0.69	8.25 ^a ± 0.72	6.50 ^b ± 1.05	6.35(0.043)
Aroma	8.35 ^a ± 0.59	8.05 ^a ± 1.05	6.50 ^b ± 1.05	6.69(0.040)
Texture	8.20 ^a ± 0.89	8.30 ^a ± 0.80	6.10 ^b ± 0.97	9.63(0.031)
General Acceptability	8.35 ^a ± 0.67	8.30 ^a ± 0.73	6.40 ^b ± 0.88	7.98(0.029)

Note: Values are triplicate mean ± standard deviation. Comparison was made only for the biscuit from the blend. Means along the row with different alphabetical superscripts indicate a significant difference (p<0.05). XXA = 80 % Wheat flour: 5 % Cassava flour: 15 % Sesame seed, XXB = 70% wheat flour: 20 % Cassava: 10 % Sesame seed flour, XXC = 100 % wheat flour.

Crispness and texture followed the same trend, with XXA and XXB showing significantly higher scores (7.80–8.30) than XXC. This may be linked to the dilution of gluten and the higher fibre and lipid contents associated with cassava and sesame seed flours, which are known to modify dough structure and weaken the continuous protein–starch matrix required for the development of a typical crispy biscuit texture. Earlier studies have demonstrated that increasing non-wheat and oil-rich ingredients in biscuit formulations often leads to softer and less crispy products (Oyewole et al., 2024; Bakare et al., 2020). Appearance and aroma were also significantly better in XXA and XXB. The reduced appearance score of XXC could be due to darker colour development and surface irregularities arising from higher fat and protein contents, which intensify Maillard reactions during baking. Although moderate browning is desirable, excessive browning has been associated with lower visual acceptability in composite biscuits (Koukoumaki et al., 2022). Likewise, the lower aroma score observed in XXC may reflect the stronger characteristic odour of sesame seed, which can become dominant at higher substitution levels and may not be preferred by all consumers.

General acceptability was highest in XXA (8.35) and XXB (8.30), with no significant difference between them, indicating that moderate substitution of wheat flour with cassava and sesame seed flour produced biscuits that were more preferred in sensory quality to the control-like formulation. However, the significantly lower overall acceptability of XXC (6.40) suggests that higher levels of composite flour incorporation, although nutritionally advantageous, may compromise consumer appeal. This agrees with recent findings that optimal substitution levels are necessary to balance nutritional enhancement and sensory quality in composite bakery products (Gbeminiyi and Shonisani, 2024). Overall, the results indicate that formulations represented by XXA and XXB are more suitable for product development, as they achieved high sensory ratings while accommodating cassava and sesame seed flours, whereas excessive substitution, as observed in XXC, adversely affected key sensory attributes and overall acceptability.

4. LIMITATION OF THE STUDY

Despite the valuable findings obtained in this study, certain limitations should be acknowledged. The study evaluated only three flour formulations, which may not fully represent the broad range of possible wheat–cassava–sesame flour combinations suitable for biscuit production. In addition, the analytical determinations were conducted using conventional laboratory procedures without advanced instrumental validation techniques such as High-Performance Liquid Chromatography (HPLC) or Atomic Absorption Spectrophotometry (AAS), which could provide more precise quantification of vitamins, minerals, and anti-nutritional factors. The study also relied primarily on proximate composition and selected micronutrient analyses; therefore, other important quality attributes such as

amino acid profile, fatty acid composition, antioxidant activity, glycaemic index, and storage stability were not investigated. Furthermore, the sensory evaluation involved a relatively small panel of semi-trained assessors from a single institution, which may limit the generalizability of consumer acceptability findings to larger and more diverse populations.

Although anti-nutritional factors were found to be within acceptable safety limits, the study did not assess nutrient bioavailability or the long-term physiological effects of regular consumption of the composite biscuits. In addition, variations associated with cassava cultivar, sesame seed variety, processing conditions, and environmental factors were not extensively examined. Future studies should therefore include a wider range of flour substitution levels, employ advanced analytical and validation techniques, evaluate storage and shelf-life stability, and investigate nutrient bioavailability and consumer acceptance across broader demographic groups. Such investigations would provide deeper insight into the nutritional functionality, safety and commercial potential of wheat–cassava–sesame composite biscuits.

5. CONCLUSION

This study demonstrated that partial substitution of wheat flour with cassava and sesame seed flours significantly influenced the proximate composition, micronutrient profile, anti-nutritional factors, and sensory quality of the biscuits. Incorporation of sesame seed flour markedly improved the protein, iron, calcium, magnesium, vitamin E, and vitamin B₁ contents of the products, while cassava flour contributed mainly to higher carbohydrate levels. Although measurable amounts of tannins, hydrogen cyanide, phenols, and oxalates were detected in the composite biscuits, their concentrations were generally low and within acceptable safety limits, indicating that the applied processing methods were effective in reducing potential anti-nutritional risks. From a nutritional standpoint, formulation XXA was superior in all minerals and selected vitamins. However, sensory evaluation revealed that biscuits produced with moderate levels of cassava and sesame seed flours (XXA and XXB) were significantly more acceptable to consumers than the formulation with higher substitution. Overall, the results confirm that optimal blending of wheat, cassava, and sesame seed flours can be used to develop nutritionally enhanced and sensorially acceptable biscuits, thereby offering a practical approach for improving the nutritional quality of locally produced snack foods.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors upon reasonable request.

Conflict of interest statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

- Abu, M. S., Aso, R. E., Onuche, J. I., Yohanna, R. E., Mashi, R. L., & Ahmad, S. (2021). Proximate composition, mineral content and functional properties of composite flours and microbiological/sensory analysis of composite flour bread. *Journal of Research in Agriculture and Animal Science*, 8(8), 1–8.
- Adeola, A., & Olayioye, D. (2021). Quality characteristics of biscuits prepared from composite flour of yellow-fleshed cassava and quality protein maize. *Food and Environment Safety*, 19(4), 297–306.

- Agu, H. O., Ihionu, J. C., & Mba, J. C. (2023). Sensory and physicochemical properties of biscuit produced from blends of whole wheat, soy okara and tigernut residue flours. *Heliyon*, 9(4), e15318. <https://doi.org/10.1016/j.heliyon.2023.e15318>
- Amani, W., & Wansapala, M. A. J. (2024). Compatibility of whole wheat-based composite flour in the development of functional foods. *Food Technology and Biotechnology*, 62(4), 425–448. <https://doi.org/10.17113/ftb.62.04.24.8588>
- Annapurna Reddy, A., Vimala, Y., Sreenivasa Rao, J., Goudar, G., & Munikumar, M. (2025). Effect of thermal processing on carotenoids compared among organic and conventional vegetables. *Research Journal of Chemistry and Environment*, 29(5), 27–35. <https://doi.org/10.25303/295rjce027035>
- AOAC. (2010). Official methods of analysis (18th ed.). Association of Official Analytical Chemists.
- Asadi, S. Z., Khan, M. A., & Zaidi, S. (2022). A study on the shelf life of cookies incorporated with sapota and beetroot leaf powders. *Journal of Food Science and Technology*, 59, 3848–3856. <https://doi.org/10.1007/s13197-022-05408-1>
- Ayoub, M., & Wani, I. A. (2026). A comprehensive review on nutritional profile, health advantages, advanced methods for sesame seed processing and their applications. *Discovery Food*, 6(6). <https://doi.org/10.1007/s44187-025-00729-4>
- Bakare, A. H., Adeola, A. A., Otesile, I., Obadina, A. O., Afolabi, W. A., Adegunwa, M. O., Akerele, R. A., Bamgbose, O. O., & Alamu, E. O. (2020). Nutritional, texture, and sensory properties of composite biscuits produced from breadfruit and wheat flours enriched with edible fish meal. *Food Science & Nutrition*, 8(11), 6226–6246. <https://doi.org/10.1002/fsn3.1919>
- Dada, M. A., Bello, F. A., Omobulejo, F. O., & Olukunle, F. E. (2023). Nutritional quality and physicochemical properties of biscuit from composite flour of wheat, African yam bean and tigernut. *Heliyon*, 9(11), e22477. <https://doi.org/10.1016/j.heliyon.2023.e22477>
- Ehis-Eriakha, C. B., Oleghe, P. O., & Akharaiyi, F. C. (2025). Enhancing food security and nutrition through indigenous agro-product-based functional foods: A case study on composite flour development. *Proceedings*, 118(1), 4. <https://doi.org/10.3390/proceedings2025118004>
- FAO. (2021a). Roots, tubers, plantains and bananas in human nutrition. Food and Agriculture Organization of the United Nations.
- FAO. (2021b). The state of food and agriculture 2021: Making agrifood systems more resilient to shocks and stresses. Food and Agriculture Organization of the United Nations.
- FAO/WHO. (2021). Joint FAO/WHO food standards programme—Codex Alimentarius: Standard for edible cassava products. Food and Agriculture Organization of the United Nations.
- Forester, S. M., Reyes, E. M., Slavin, J. L., Fahey, G. C., Jr., McCleary, B. V., King, G. J., Andrés-Hernández, L., Dooley, D., & Fukagawa, N. K. (2025). Addressing dietary fiber terminology consistency: Insights from a multidisciplinary roundtable and establishment of the dietary fiber ontology working group. *Nutrition Today*, 60(3), 97–103. <https://doi.org/10.1097/NT.0000000000000719>
- Forkum, A. T., Wung, A. E., Kelese, M. T., Ndum, C. M., Lontum, A., Kamga, E. B., Nsaikila, M. N., & Okwen, P. M. (2025). Safety of cassava and cassava-based products: A systematic review. *Frontiers in Sustainable Food Systems*, 9, 1497609. <https://doi.org/10.3389/fsufs.2025.1497609>
- Garg, M., Sharma, A., Vats, S., Tiwari, V., Kumari, A., Mishra, V., & Krishania, M. (2021). Vitamins in cereals: A critical review of content, health effects, processing losses, bioaccessibility, fortification, and biofortification strategies for their improvement. *Frontiers in Nutrition*, 8, 586815.
- Gbeminiyi, O., & Ramashia, S. E. (2024). Impact of composite flour on nutritional, bioactive and sensory characteristics of pastry foods: A review. *Current Research in Nutrition and Food Science*, 12(3), 1018–1034. <https://doi.org/10.12944/CRNFSJ.12.3.4>
- Hafza, M. J., Akhtar, I., Saleem, M. Z., Malik, T., & Ayub, A. (2025). A comprehensive review of the health benefits, nutritional composition, and agricultural aspects of sesame seeds. *Journal of Food Biochemistry*. <https://doi.org/10.1155/jfbc/8713698>
- Irine, M., & Ariahu, C. C. (2022). Production and quality evaluation of biscuits from blends of wheat, millet and sesame seeds composites: Functional and nutrients characteristics. *International*

- Journal of Nutrition and Food Sciences, 11(2), 20–29. <https://doi.org/10.11648/j.ijnfs.20221102.12>
- Kirk, R. S., & Sawyer, R. (1991). *Pearson's composition and analysis of foods* (9th ed.). Longman Scientific and Technical.
- Koukoumaki, D. I., Giannoutsos, K., Devanthi, P. V. P., Karmiris, P., Bourni, S., Monemvasioti, A., Psimouli, V., Sarris, D., & Gkatzionis, K. (2022). Effect of wheat replacement by pulse flours on the texture, color, and sensorial characteristics of crackers: Flash profile analysis. *International Journal of Food Science*, Article 2354045. <https://doi.org/10.1155/2022/2354045>
- Lambebo, T., Deme, T., & Geleta, M. (2025). Nutritional enhancement of cassava through processing: Implications for sustainable food systems. *Frontiers in Sustainable Food Systems*, 9, 1660792. <https://doi.org/10.3389/fsufs.2025.1660792>
- Manisha, P., & Navjot, K. (2020). Development and organoleptic evaluation of bakery products and extruded snacks prepared from composite flour. *International Journal of Current Microbiology and Applied Sciences*, 9(2), 1680–1690. <https://doi.org/10.20546/ijcmas.2020.902.194>
- Mostashari, P., & Mousavi Khaneghah, A. (2024). Sesame seeds: A nutrient-rich superfood. *Foods*, 13(8), 1153. <https://doi.org/10.3390/foods13081153>
- Msugh, C. T., Adah, C. A., & Asemave, K. (2024). Quality evaluation of composite flour from wheat, soybean and sunflower seeds for bread making. *African Journal of Agriculture and Food Science*, 7(3), 265–283. <https://doi.org/10.52589/AJAFS-C84BU7GC>
- Mumukom, M. A., Gabriel, I. O., & Philip, J. K. (2025). Fortified cereal innovation: Vitamin retention, anti-nutritional factors, physiochemical properties, and storage stability. *Journal of Food Processing and Preservation*, Article 7738527. <https://doi.org/10.1155/jfpp/7738527>
- Naqvi, S. N., Liaquat, M., Kazmi, A., Sammi, S., Ali, A., Luna-Arias, J. P., & Sherzad, I. U. (2024). Sesame-enriched delights: A comparative exploration of physicochemical and sensory attributes in fine and whole wheat flour cookies. *Food Science & Nutrition*, 12, 7751–7765. <https://doi.org/10.1002/fsn3.4343>
- Nilusha, R. A. T., Jayasinghe, J. M. J. K., Perera, P. I. P., & Jayasinghe, C. V. L. (2021). Proximate composition, physicochemical, functional, and antioxidant properties of flours from selected cassava (*Manihot esculenta* Crantz) varieties. *International Journal of Food Science*, Article 6064545. <https://doi.org/10.1155/2021/6064545>
- Nweke, C. B., & Odo, M. O. (2025). Effect of pre-processing operations on antioxidant properties and activities of *Prosopis africana* seed. *African Journal of Agriculture and Food Science*, 8(3), 28–42. <https://doi.org/10.52589/AJAFS-VPMFZRHT>
- Obasi, B. C., & Askepnde, P. (2023). Phytochemical, physical and functional properties of flour blends produced from wheat, unripe plantain and pigeon pea. *International Journal of Science and Research Archive*, 10(1), 516–526. <https://doi.org/10.30574/ijrsra.2023.10.1.0754>
- Ogundele, O. M., Ojedokun, F. O., Fasogbon, B. M., & Bamidele, O. P. (2022). Effects of roasted defatted sesame seed (*Sesamum indicum*) flour addition on the nutritional quality, dietary fibre, and glycemic index of malted amaranth grain (*Amaranthus hybridus*) flour. *Food Research*, 6(6), 78–87.
- Okaiyeto, S. A., Liu, D., Zhang, C., Bai, J.-W., Chen, C., Sharma, P., Venugopal, A. P., Asiamah, E., Ketemepi, H. K., Imadegbor, F. A., Gabriel, O. T., Lv, W., & Xiao, H.-W. (2025). Anti-nutrients of plant-based food: Physicochemical properties, effects on health, and degradation techniques—A comprehensive review. <https://doi.org/10.1016/j.jfutfo.2025.06.022>
- Oyewole, S. N., Ajao, T. O., Oyewole, O. S., Ogundare, A. O., Adeniyi, B. M., Ogungbemi, K., Ibitoye, O., Famakinwa, J. O., Ajala, O. V., & Solomon-Ibunwuwa, O. M. (2024). Functional properties and sensory attributes of products produced from high-quality cassava-wheat composite flours. In *Nigerian Women in Agricultural Research for Development (NiWARD)* (pp. 231–244).
- Pearson, D. (1976). *The chemical analysis of foods* (7th ed.). Churchill Livingstone.
- Scaria, S. S., Balasubramanian, B., Meyyazhagan, A., Gangwar, J., Jaison, J. P., Kurian, J. T., Pushparaj, K., Pappuswamy, M., Park, S., & Joseph, K. S. (2024). Cassava (*Manihot*

- esculenta Crantz)—A potential source of phytochemicals, food, and nutrition: An updated review. *eFoods*, 5(1), e127.
- 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.2021.17.1.0303>
- Wei, P., Zhao, F., Wang, Z., Wang, Q., Chai, X., Hou, G., & Meng, Q. (2022). Sesame (*Sesamum indicum* L.): A comprehensive review of nutritional value, phytochemical composition, health benefits, development of food, and industrial applications. *Nutrients*, 14(19), 4079. <https://doi.org/10.3390/nu14194079>