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Quality Evaluation of Model Biscuits Produced from Sweet Potato and African Almond Seed Flour Blends

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Abstract Biscuits are widely consumed bakery products traditionally made from wheat flour; however, increasing demand for nutrient-dense and gluten-reduced or free alternatives has encouraged the use of composite flours from sweet potato and almond. This study evaluated the functional properties of flours, proximate, physical, and sensory properties of biscuits produced from sweet potato flour and its blends with raw, blanched, and toasted almond flours, using wheat and sweet potato biscuits as controls. Flours were analyzed for functional properties, while proximate composition was determined using AOAC methods. Biscuits were produced and evaluated for physical characteristics. Sensory evaluation was conducted using a 9-point hedonic scale with semi-trained panelists. Data were subjected to ANOVA at $p < 0.05$, and means were separated using LSD. Functional properties differed significantly ($p < 0.05$), with water absorption capacity (172.00–183.50%), oil absorption capacity (105.50–172.66%), bulk density (0.62–0.g/mL), swelling capacity (35.50–65.00%), gelation temperature (47.00–59.00 °C), and least gelation concentration (4.00–14.00%). Proximate composition varied significantly, with almond incorporation increasing protein (5.47–16.43%), fat (8.23–33.47%), ash (1.05–1.52%), and fibre (0.85–1.21%), while reducing carbohydrate (42.16–74.59%).Sensory scores (6.20–7.90) indicated good acceptability across samples. Biscuits containing toasted almond flour recorded the highest flavour (8.20), texture (7.30), and overall acceptability (7.40), attributed to enhanced nutty flavour and improved crispness from roasting. Wheat biscuits showed superior appearance (8.40), while raw almond biscuits had lower texture (5.30) and acceptability (6.20). No significant differences ($p > 0.05$) were observed among most sensory attributes, indicating comparable consumer acceptance. The incorporation of almond flour, particularly toasted almond, significantly enhances the nutritional quality and sensory appeal of sweet potato biscuits without compromising acceptability, making it suitable for development of nutrient-enriched and acceptable sweet potato-almond composite biscuits.

Keywords: *Sweet potato flour, Almond flour, Composite flour, Biscuit quality, Proximate composition, Sensory evaluation*

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1. Introduction

Biscuits are among the most widely consumed bakery products globally due to their convenience, long shelf-life, affordability, and wide consumer acceptance. Conventionally, biscuits are produced mainly from wheat flour because of its gluten-forming ability, which provides desirable structure and texture. However, the heavy reliance on wheat flour presents both nutritional and economic concerns, particularly in developing countries where wheat is largely imported. This dependence increases production costs and undermines food security, thereby necessitating the exploration of alternative, locally available raw materials for biscuit production [1,2].

Sweet potato (Ipomoea batatas) is an under-utilized root crop with high carbohydrate content and appreciable levels of dietary fibre, β-carotene, vitamins, and antioxidant compounds. Several studies have reported that partial substitution of wheat flour with sweet potato flour in biscuit formulations improves nutritional quality, particularly fibre and antioxidant content, while producing products with acceptable physical and sensory attributes when used at appropriate substitution levels [1,2]. The use of sweet potato flour in baked products has also been promoted as a means of value addition and post-harvest loss reduction for the crop.

Almond (Prunus dulcis) flour is another nutritionally valuable ingredient, rich in high-quality protein, unsaturated fats, dietary fibre, and essential minerals. Research on the incorporation of almond flour into bakery products, particularly cookies and biscuits, has shown improvements in nutritional composition and sensory appeal. Importantly, processing treatments such as raw, toasted, and blanched almond flours significantly influence functional properties, flavour development, colour, and consumer acceptability. Toasted almond flour has been associated with enhanced nutty flavour and aroma, while blanched almond flour produces lighter-coloured products with smoother texture due to the removal of the seed coat [3].

Despite the documented benefits of sweet potato flour and processed almond flours when used independently in biscuit or cookie production, there is a paucity of research that evaluates their combined use, particularly the comparative effects of raw, toasted, and blanched almond flours in sweet potato-based biscuit formulations. Existing studies have largely focused on sweet potato–wheat composites or almond–wheat composites, with no attention given to dual fortification systems involving sweet potato and differently processed (raw, toasted and blanched) almond flours. Consequently, this lack of information limits the understanding of how these ingredients interact to influence the nutritional composition, physical characteristics, and sensory quality of biscuits. Addressing this gap offers an opportunity to develop novel, nutrient-dense biscuits while promoting the utilization of locally available crops and reducing reliance on imported wheat flour.

The increasing consumer demand for healthier and functional snack foods has intensified research into alternative flour sources for biscuit production. Although sweet potato flour has been widely studied as a partial wheat flour substitute and shown to enhance fibre and antioxidant content of biscuits, and almond flour has been evaluated in raw, toasted, and blanched forms for its nutritional and sensory contributions, there is no documented study that integrates sweet potato flour with raw, toasted, and blanched almond flours in biscuit production. This research gap limits understanding of the combined effects of these flours and the influence of almond processing methods on biscuit quality. Therefore, this study aimed to evaluate the functional properties of sweet potato -almond composite and quality characteristics of biscuits produced from the sweet potato fortified with differently processed almond flours.

2. Materials and Methods

2.1. Source of Materials

The almond fruits (*Prunus amygdalus*), werepicked from the polytechnic environment while the sweet potato tuber and other ingredients were purchased from Egah market in Idah Kogi State Nigeria.

2.2. Processing of Almond Flours

Almond nuts used in this study were cleaned to remove debris and defective kernels. The nuts were divided into three portions for the preparation of raw, toasted, and blanched almond flours, following modified procedures described by [3].

2.2.1. Raw Almond Flour

The cleaned almonds were air-dried at room temperature 28°C for 24 h to remove surface moisture. The dried almonds were then milled using a laboratory hammer mill to a fine flour consistency The resulting flour was sieved through a 60-mesh sieve to obtain uniform particle size. The raw almond flour was stored in airtight containers at 4°C until use.

2.2.2. Toasted Almond Flour

Cleaned almonds were spread in a single layer on a baking tray and toasted in a preheated oven at 150°C for 15 minutes, cooled to room temperature and milled into flour using a hammer mill. The flour was sieved through a 60-mesh sieve to ensure uniform particle size and was stored in airtight containers at 4°C until use.

2.2.3. Blanched Almond Flour

Cleaned almonds were immersed in boiling water for 3 minutes. The blanched almonds were immediately cooled in cold water and oven-dried at 50°C for 6 hours until moisture content was reduced to below 8%. The dried almonds were milled using a hammer mill and sieved through a 60-mesh sieve to obtain fine blanched almond flour. The flour was stored in airtight containers at 4°C until use.

2.3. Preparation of Sweet Potato Flour

Fresh sweet potato (Ipomoea batatas) tubers were sorted, washed, peeled, and sliced (2 mm). The slices were blanched (65 °C, 5 min) to reduce enzymatic browning, drained, and oven-dried at 60 ± 2 °C for 24 h to constant weight. The dried chips were milled, sieved (60-mesh sieve), and the flour obtained was packaged in airtight containers and stored at ambient temperature until use.

2.4. Formulation of Flour Blends

Protein content determination of raw almond seed flour, toasted almond seed flour and blanched almond seed flour was carried out respectively. A material balance *was* used to obtain product of 16% protein content in each blend respectively.

Table 1. Blending of Flour Samples

SAMPLES	Wheat flour	Sweet potato flour (g)	Raw almond flour (g)	Blanched almond flour (g)	Toasted almond flour (g)
A	100	-	-	-	-
B		23.37	76.63	-	-
C		21.69	-	78.31	-
D		27.14	-	-	72.86
E		100 -	-	-	-

2.5. Procedure for Biscuit Production

Biscuits were prepared using a standard creaming method with modifications. Sweet potato and almond flour blends (raw, toasted, and blanched) were used as composite flours. Biscuits were also prepared from sweet potato and wheat flours separately. The dry ingredients, including flour, sugar, baking powder, and salt, were thoroughly mixed in a bowl. In a separate container, fat margarine was creamed with sugar until a light, fluffy consistency was achieved. The dry mixture was gradually incorporated into the creamed fat, followed by the addition of liquid milk, egg and water to form a uniform dough. The recipe consisted of flour 1000 g, sugar (sucrose) 300g, margarine 250g, salt 5g, baking powder 10g, liquid milk 100 g, water 50 g and whole egg 100g. The dough was rested for 20 minutes at room temperature to improve handling. It was then rolled to a thickness of approximately 5 mm and cut into desired shapes using cookie cutters. The biscuits were baked in a preheated oven at 180 °C for 15 minutes. After baking, the biscuits were cooled to room temperature on wire racks before packaging.

2.6. Determination of Functional Properties of Flours

Functional properties including water absorption capacity (WAC), oil absorption capacity (OAC), bulk density, and swelling capacity were determined following standard procedures. WAC and OAC were determined using the method [4], where 1 g of flour was mixed with 10 mL of distilled water or oil, centrifuged at 3000 rpm for 25 min, and the supernatant measured. Bulk density was determined by tapping a known weight of flour into a graduated cylinder and recording the settled volume [4].

The swelling capacity of the flour was determined according to the method described by [4]. One gram(1g) of the sample was prepared into a slurring using 5 ml of water in a calibrated cylinder. Then immersed in a boiling water bath at 90°C for 30 minutes. The height (volume) of the sample slurry was recorded before and after boiling in the water bath.

$$\text{Swelling capacity \%} = \frac{\text{V2-V1x100}}{\text{V1}}$$

Where, V1 = Volume of flour before soaking

V2 = Volume of the soaked flour sample

The gelatinization temperature was determined as follows: Ten grams (10g) of the sample was weighed into a beaker with 27ml of water and heated until gelling points. The temperature at which it gelled was measured using a thermometer.

The least gelation concentration was determined by the method described by [5]. The test tubes containing suspension of 2%, 4%, 6%, 8%, 10%, 12%, 14%,16%, 18% and 20%(W/V) of flour in 5ml distilled water and were heated for 30minuntes in boiling water bath. This *was* followed by rapid cooling under cold running tap water, the least gelation concentration (LGC) was taken as that concentration at which the sample in the inverted test tube did not fall down or slip.

2.7. Determination of Physical Properties of Biscuits

The physical properties of the biscuits were determined using the method described [6], with slight modifications. The parameters evaluated included thickness, diameter, weight, spread ratio, and breaking strength.

Biscuit thickness was determined by stacking three biscuits edge to edge and measuring them with a manual vernier caliper. The measurement was repeated five times for each sample, and the average value was recorded in cm (cm).

Biscuit diameter was measured by aligning three biscuits edge to edge and determining the distance across them with a manual vernier caliper. The measurements were repeated five times and the average value was recorded in centimeters {cm}.

The weight of the biscuits was determined by weighing four individual biscuits using an analytical balance. The average weight was calculated and reported in grams (g).The spread ratio was calculated as the ratio of biscuit diameter to thickness.

Breaking strength was determined using the method [7]. A biscuit of known thickness was placed centrally between two parallel metal bars set 3 cm apart. Weights were gradually added to the biscuit until it fractured. The minimum weight required to break the biscuit was recorded as the breaking strength, expressed in grams (g).

2.8. Proximate Analysis of Biscuits

Moisture, crude protein, crude fat, ash, and crude fiber contents were determined according to AOAC methods [8]. Carbohydrate content was calculated by difference. Moisture was determined by drying at 105 °C to constant weight, protein by Kjeldahl method, fat by Soxhlet extraction, ash by incineration at 550 °C, and fiber by enzymatic-gravimetric method.

2.9. Sensory Evaluation

This evaluation involved 50 semi trained human participants for sensory evaluation and was performed in accordance with the institutional guidelines of the Federal Polytechnic, Idah. Formal ethical approval was not required for this type of study. Informed consent was obtained from all participants (senior members of staff and traders within the Polytechnic), and participation was voluntary and anonymous.

Sensory attributes of biscuits (appearance, texture, taste, aroma, and overall acceptability) were evaluated using a 9-point hedonic scale (1 = dislike extremely, 9 = like extremely) . Samples were coded with random three-digit numbers and served at room temperature under controlled conditions. Evaluation was carried out in individual booths under adequate lightning and portable water was provided for palate cleansing between samples.

2.10. Statistical Analysis

All experiments were conducted in triplicate, and results were expressed as mean ± standard deviation. Data obtained from functional, proximate, physical, and sensory analyses were subjected to one-way analysis of variance (ANOVA) using (Spss version 23.0). The significance of differences among sample means was determined at a 95% confidence level ($p < 0.05$). Where significant differences existed, mean separation was performed using Duncan’s Multiple Range Test (DMRT). Sensory evaluation data obtained from the 9-point hedonic scale were similarly analyzed using ANOVA to determine differences in panelists’ preferences among the biscuit samples. Results were presented in tables with appropriate superscripts to indicate significant differences between means.

3. Results and Discussion

3.1. Functional Properties of Flour Samples

Table 2 presents the water absorption capacity (WAC), oil absorption capacity (OAC), bulk density, swelling capacity, gelation temperature, and least gelation concentration (LGC) of sweet potato flour, sweet potato–almond composite flours, and wheat flour.

Water absorption capacity ranged from **172.00–183.50%**, with Sample B (sweet potato–raw almond blend) showing the highest WAC, while Sample C recorded the lowest. The generally high WAC of sweet potato–almond composites compared to wheat flour (Sample E) may be attributed to the hydrophilic nature of starch and the presence of proteins with polar side chains capable of binding water. The inclusion of almond flour, particularly raw almond, likely increased protein–water interactions, enhancing hydration capacity. High WAC is desirable in bakery products as it improves dough handling and moisture retention in finished products [10,11].

Oil absorption capacity differed significantly ($p < 0.05$), ranging from **105.50–172.66%**. Sample B exhibited the highest OAC, while Sample D (toasted almond blend) had the lowest. High OAC is often associated with non-polar amino acid side chains and porous starch structures that physically entrap oil. The reduction in OAC observed in toasted almond blends may be due to protein denaturation and structural collapse during heat treatment, which reduces oil-binding sites. Flours with high OAC are beneficial for flavour retention and mouthfeel in baked and fried products [12,13].

Bulk density values ranged from **0.62–0.76 g/mL**, with wheat flour showing the lowest value. Lower bulk density is advantageous for product formulation as it improves dispersibility and reduces packaging cost. The relatively higher bulk density of sweet potato flour (Sample A) may be attributed to its finer particle size and compact starch granules. Similar trends have been reported for root-crop-based composite flours [14,15].

Swelling capacity varied significantly among samples, with values between **35.50–65.00%**. Sample A (100% sweet potato flour) showed the highest swelling capacity, reflecting the strong water-binding ability and granule expansion of sweet potato starch. Almond incorporation significantly reduced swelling capacity, likely due to starch dilution by lipids and proteins, which restrict granule swelling. Reduced swelling capacity is advantageous in baked products where excessive expansion may negatively affect texture [16].

Gelation temperature ranged from **47.00–59.00°C**, indicating moderate heat requirements for gel formation. Composite flours containing toasted almond showed higher gelation temperatures, suggesting that heat treatment increased starch–protein–lipid interactions, requiring more thermal energy for gelatinization. Higher gelation temperatures can be beneficial in improving thermal stability during baking and extrusion processes [17,18].

The least gelation concentration varied from **4.00–14.00%**, with wheat flour showing the lowest LGC and toasted almond composites the highest. Lower LGC values indicate better gel-forming ability. The increased LGC observed in almond-rich samples may be due to reduced starch content and the interference of lipids with starch network formation. These findings agree with previous reports on legume- and nut-enriched composite flours [13,19].

Table 2. Functional properties of sweet potato, wheat and blends of sweet potato with raw, blanched and toasted almond flours

Samples	Water absorption Capacity (%)	Oil absorption Capacity (%)	Bulk Density (g/mL)	Swelling Capacity (%)	Gelation Temperature (°C)	Least Gelation Concentrate
A	175.00^{b} ±3.00	126.50^{c} ±0.50	0.76^{a}± 0.00	65.00^{a}± 0.00	51.00^{b}± 1.00	6.00^{b}± 1.00
B	183.50^{a} ±0.50	172.66a ±0.57	0.66b± 0.00	44.50^{b} ±0.50	56.50a± 0.50	8.00^{b}± 1.00
C	172.00^{b} ±0.00	120.50^{d} ±0.50	0.73^{b}± 0.00	35.50^{d} ±0.50	53.50a± 0.50	12.00^{a} ±1.00
D	178.00^{a} ±1.00	105.50^{e} ±0.28	0.71^{c}± 0.00	41.00^{c}± 1.00	59.00a± 0.00	14.00^{a} ±1.00
E	177.50^{b} ±0.00	152.43^{b} ±0.51	0.62^{d}± 0.00	37.00^{d} ±1.00	47.00c± 1.00	4.00^{b}± 1.00
LSD	5.60	2.96	0.004	3.33	3.33	3.988

The values are expressed as mean ± standard deviation. Means with the same superscripts in the same column are not significantly different 5% significant level.
Sample A: 100% sweet potato flour
Sample B: Sweet potato (23.37): Raw almond (76.63)
Sample C: Sweet potato (21.69): Blanched Almond (78.31)
Sample D: Sweet Potato (27.14): Toasted Almond (72.86)
Sample E: 100% Wheat flour

3.2. Proximate Composition of the Biscuit Samples

Proximate composition of biscuits produced from sweet potato, wheat and sweet potato–almond flour blends is presented in Table 3.

The proximate composition of the biscuit samples—A (sweet potato biscuits), B (sweet potato–raw almond biscuits), C (sweet potato–blanched almond biscuits), D (sweet potato–toasted almond biscuits), and E (wheat biscuits)—showed significant differences ($p < 0.05$), confirming that almond incorporation and processing methods influenced the nutritional quality of the products.

Moisture content ranged from 3.40 to 6.21%, with sample C (sweet potato–blanched almond) recording the lowest value (3.40%) and sample E (wheat biscuits) the highest (6.21%). The relatively low moisture contents observed across all samples are desirable for baked products, as they enhance shelf stability and reduce susceptibility to microbial spoilage[20]. The reduction in moisture in almond-enriched samples may be attributed to the lower water-binding capacity of lipid-rich almond flour compared to wheat flour.

Ash content, an indicator of mineral composition, increased from 1.05% in sample E (wheat biscuits) to 1.52% in sample D (sweet potato–toasted almond biscuits). The progressive increase from sample A (1.17%) through samples B and C to D suggests that almond flour significantly contributed to mineral enrichment. This aligns with findings that nut-based fortification improves ash content due to their higher mineral density [21].

Crude fibre content also increased with almond incorporation, ranging from 0.85% in sample E (wheat biscuits) to 1.21% in sample D (sweet potato–toasted almond biscuits). Although the increase was moderate, it reflects nutritional enhancement, as dietary fibre plays an important role in digestive health. The higher fibre content in samples B, C and D compared to sample A (sweet potato biscuits) and sample E is consistent with reports on composite flour biscuits enriched with plant-based ingredients [22].

Fat content showed a marked increase across the samples, rising from 12.12% in sample A (sweet potato biscuits) and 8.23% in sample E (wheat biscuits) to 33.47% in sample D (sweet potato–toasted almond biscuits). Samples B and C also exhibited high fat contents (23.30% and 31.12%, respectively). This trend is attributable to the high lipid content of almond flour. The highest value observed in sample D may be due to the effect of toasting, which reduces moisture and concentrates fat content, as reported [23].

Protein content followed a similar trend, increasing significantly from 5.47% in sample A (sweet potato biscuits) to 16.11%, 16.42% and 16.43% in samples B, C and D, respectively. The wheat control (sample E) contained 13.47% protein. This indicates that almond flour substantially enhanced the protein content of the biscuits. Sweet potato flour is inherently low in protein, whereas almond flour is protein-rich, thereby improving the overall nutritional quality of the composite biscuits [24].

Conversely, carbohydrate content decreased with increasing almond substitution. The highest value was observed in sample A (sweet potato biscuits, 74.59%), followed by sample E (wheat biscuits, 70.19%), while the lowest was recorded in sample D (sweet potato–toasted almond biscuits, 42.16%). This inverse relationship is expected because carbohydrate is calculated by difference, and the increase in protein, fat and fibre in almond-enriched samples results in a proportional decrease in carbohydrate content [25,26].

Table 3. Proximate composition of sweet potato, wheat and blends of sweet potato with raw, blanched and toasted almond flours

Samples	Moisture%	Ash%	Crude Fibre %	Fat%	Protein %	Carbohydrate%
A	5.78^{a}±0.01	1.17^{d}±0.00	0.96^{c}±0.32	12.12^{d}±0.45	5.47^{e}±0.45	74.50^{a}±0.29
B	4.54^{c}±0.00	1.29^{c}±0.00	1.08^{b}±0.01	28.30^{c}±0.01	16.11^{c}±0.05	48.68^{c}±0.20
C	3.40^{d}±0.00	1.37^{b}±0.20	1.18^{a}±0.01	31.12^{b}±0.02	16.42^{a}±0.03	46.51^{d}±0.01
D	5.21^{b}±0.28	1.52^{a}±0.02	1.21^{a}±0.06	33.47^{a}±0.01	16.43^{b}±0.03	42.16^{e}±0.04
E	6.21^{e}±0.01	1.05^{e}±0.00	0.85^{d}±0.01	8.23^{e}±0.01	13.47^{d}±0.07	70.19^{b}±0.09
LSD	0.54	0.06	0.03	0.07	0.18	0.56

The values are expressed as mean ± standard deviation. Means with the same superscripts in the same column are not significantly different 5% significant level.
Sample A: 100% sweet potato flour biscuits
Sample B: Sweet potato (23.37): Raw almond (76.63) biscuits
Sample C: Sweet potato (21.69): Blanched Almond (78.31) biscuits
Sample D: Sweet Potato (27.14): Toasted Almond (72.86) biscuits
Sample E: 100% Wheat flour biscuits

3.3. Physical Properties of Biscuit Samples

Table 4 presents the weight, thickness, diameter, spread ratio, and break strength of biscuits produced from sweet potato flour, sweet potato–almond composite flours, and wheat flour.

Biscuit weight ranged from **12.21–15.78 g**, with the highest value observed in biscuits produced from 100% sweet potato flour (Sample A) and the lowest in wheat flour biscuits (Sample E). The higher weight of sweet potato-based biscuits may be attributed to their greater water absorption capacity, which enhances dough hydration and mass retention during baking. Conversely, the reduced weight of wheat flour biscuits could be linked to moisture loss and gluten network formation, which promotes structural expansion and mass reduction during baking. Similar trends have been reported for biscuits produced from root crop–based composite flours [10,15].

Thickness values varied significantly ($p < 0.05$) from **1.35–1.76 cm**, with biscuits from blanched almond composite flour (Sample C) showing the highest thickness. Increased thickness in almond-enriched biscuits may result from higher fat content, which limits dough spread and promotes vertical rise during baking. Fat acts as a shortening agent, weakening the gluten/starch matrix and trapping air, which can increase biscuit thickness. This observation agrees with previous studies on nut-enriched biscuits [13,27].

The diameter of biscuits ranged between **5.15–5.75 cm**, with composite flour biscuits generally exhibiting larger diameters than 100% sweet potato biscuits. Almond incorporation likely reduced dough viscosity due to lipid interference with starch gelatinization, allowing greater lateral expansion during baking. The observed diameter values fall within acceptable limits reported for commercial biscuits and related baked products [11,12].

The spread ratio of the biscuit samples ranged from 3.15-3.85, indicating moderate expansion during baking. Statistically, the differences among the samples were not significant($p > 0.05$), suggesting that variations in flour composition and treatments did not markedly influence spread ratio. The uniformity implies that the dough flow properties, fat distribution and moisture content across the formulations were relatively similar, leading to comparable flow and expansion during baking. The observed range also falls within values reported in related studies on composite biscuits, where spread ratios typically lie between 3.0 and 4.0, indicating acceptable baking performance [28]. Biscuits with moderate to high spread ratios are usually preferred by consumers due to their improved texture and appearance [16,28].

Break strength values varied significantly from **1019.66–1937.43 g**, indicating differences in biscuit hardness. Wheat flour biscuits (Sample E) exhibited the highest break strength, reflecting the presence of gluten, which forms a continuous and elastic protein network that enhances structural rigidity. In contrast, biscuits from 100% sweet potato flour showed the lowest break strength, indicating a more fragile texture. Almond incorporation significantly improved biscuit strength, particularly in the toasted almond blend (Sample D), likely due to enhanced starch–protein–lipid interactions and moisture redistribution during baking. These findings are consistent with previous reports on gluten-free and composite biscuits [18,29].

Table 4. Physical properties of biscuit from sweet potato, wheat and blends of sweet potato with raw, blanched and toasted almond flours

Samples	Weight (g)	Thickness (cm)	Diameter (cm)	Spread ratio	Break strength (g)
A	15.78^{a}±0.01	1.35^{e}±0.01	5.15^{c}±0.01	3.80^{a}±0.50	1019.66^{e}±0.50
B	14.44^{b}±0.01	1.66^{b}±0.01	5.75^{a}±0.01	3.45^{a}±0.01	1631.52^{c}±0.00
C	14.27^{b}±0.01	1.76^{a}±0.01	5.55^{b}±0.01	3.15^{a}±0.01	1427.58^{d}±0.00
D	14.41^{b}±0.01	1.46^{d}±0.01	5.65^{a}±0.05	3.85^{a}±0.05	1733.49^{b}±0.00
E	12.21^{c}±0.01	1.53^{c}±0.01	5.43^{b}±0.01	3.54^{a}±0.01	1937.43^{a}±0.00
LSD	1.08	0.02	0.13	1.31	0.10

The values are expressed as mean ± standard deviation. Means with the same superscripts in the same row column not significantly different 5% significant level.
Sample A: 100% sweet potato flour biscuits
Sample B: Sweet potato (23.37): Raw almond (76.63) biscuits
Sample C: Sweet potato (21.69): Blanched Almond (78.31) biscuits
Sample D: Sweet Potato (27.14): Toasted Almond (72.86) biscuits
Sample E: 100% Wheat flour biscuits

Table 5. Sensory properties of biscuit from sweet potato, wheat and blends of sweet potato with raw, blanched and toasted almond flours

Samples	Colour	Flavor	Taste	Texture	Appearance	Acceptability
A	8.40^{a}±0.69	6.60^{b}±1.64	7.40^{a}±1.34	6.40^{a}±0.87	7.90^{a}±1.19	7.10^{ab}±0.73
B	7.20^{b}±0.81	7.20^{ab}±1.50	6.70^{a}±2.18	5.30^{b}±1.79	6.90^{ab}±1.28	6.20^{b}±1.05
C	7.80^{a}±0.78	6.70b±0.94	7.10^{a}±0.99	6.80^{a}±1.13	6.20^{b}±0.78	6.80^{ab}±0.87
D	7.30^{ab}±1.63	8.20^{a}±1.56	7.20^{a}±1.39	7.30^{a}±1.49	7.80^{a}±0.81	7.40^{a}±0.51
E	7.60^{a}±0.51	7.40^{ab}±1.34	7.40^{a}±0.69	7.20^{a}±0.69	8.40^{a}±0.84	7.90^{a}±0.84
LSD	1.16	1.18	1.17	1.08	1.05	1.11

The values are expressed as mean ± standard deviation. Means with the same superscripts in the same column are not significantly different 5% significant level.
Sample A: 100% sweet potato flour biscuits
Sample B: Sweet potato (23.37): Raw almond (76.63) biscuits
Sample C: Sweet potato (21.69): Blanched Almond (78.31) biscuits
Sample D: Sweet Potato (27.14): Toasted Almond (72.86) biscuits
Sample E: 100% Wheat flour biscuits

3.4. Sensory Evaluation of Biscuit Samples

The sensory attributes of the biscuit samples (A–E), including colour, flavour, taste, texture, appearance, and overall acceptability, are presented in Table 5. Sensory evaluation remains a key indicator of consumer acceptance as it integrates multiple quality attributes [30,31].

Colour scores ranged from 7.20 to 8.40, with sample A (100% sweet potato flour) recording the highest value (8.40), while sample B (raw almond blend) had the lowest (7.20). The generally high scores indicate good visual acceptability across all formulations. The slight reduction observed in almond-enriched samples may be attributed to intensified Maillard browning reactions during baking, which can influence consumer perception [32]. However, the absence of significant differences ($p > 0.05$) suggests that substitution with almond flour did not adversely affect colour quality.

Flavour scores varied from 6.60 to 8.20, with sample D (toasted almond- sweet potato blend) having the highest score (8.20), while sample A recorded the lowest (6.60). The improved flavour in toasted almond biscuits may be linked to the formation of desirable volatile compounds during roasting, which enhance nutty and aromatic characteristics [33]. Similar findings have been reported [34], who observed enhanced flavour acceptability in composite biscuits due to ingredient processing.

Taste scores ranged from 6.70 to 7.40, with samples A and E showing higher values (7.40), while sample B had the lowest (6.70). The relatively lower taste score in raw almond blends may be associated with the presence of inherent bitter compounds, which are reduced during processing such as blanching and toasting. This agrees with findings [35], who reported that processing methods improve taste perception in fortified biscuits.

Texture scores ranged from 5.30 to 7.30, with sample D (7.30) being the most preferred and sample B (5.30) the least. The superior texture of toasted almond biscuits may be attributed to improved fat distribution and structural modification during roasting, resulting in enhanced crispness. Texture is a critical determinant of product acceptability in baked goods due to its influence on mouthfeel and eating quality [32]. The lower score observed in sample B suggests poor structural integration of raw almond flour in the dough matrix.

Appearance scores ranged from 6.20 to 8.40, with sample E (100% wheat flour) recording the highest score (8.40), followed by samples A and D. Wheat-based biscuits are generally preferred in terms of appearance due to their uniform structure and familiar characteristics. Nevertheless, the high scores across all samples indicate that incorporation of sweet potato and almond flours did not significantly compromise visual quality.

Overall acceptability scores ranged from 6.20 to 7.90, with sample E (7.90) being the most preferred, closely followed by sample D (7.40). Sample B recorded the lowest acceptability (6.20), consistent with its lower ratings in texture and taste. The high acceptability of sample D highlights the positive impact of almond toasting on sensory quality. This agrees with [34], who reported improved consumer preference for processed composite flour biscuits.

The statistical grouping based on LSD ($p \leq 0.05$) indicates that most samples were not significantly different across several attributes, suggesting that substitution with sweet potato and processed almond flours can yield products with sensory properties comparable to conventional wheat biscuits.

4. Conclusion

The research indicates that incorporation of sweet potato–almond composite flours, particularly toasted almond, into biscuit formulations significantly enhance functional, nutritional, physical, and sensory qualities compared with 100% sweet potato flour, while approaching the performance of wheat-based biscuits. Functional improvements such as higher water and oil absorption, along with enhanced protein, fat, fibre, and ash which is an indication of mineral contents, suggest that these composite flours can produce nutritionally superior biscuits. Physically, almond-enriched biscuits exhibited better spread, acceptable thickness, and increased structural strength. The biscuits samples generally showed no significant differences ($p > 0.05$) across attributes, indicating consistent and comparable quality with the controls. Collectively, these findings imply that sweet potato–almond composite flours are promising alternatives to wheat flour for developing nutritionally enhanced and acceptable biscuits, supporting diversification of bakery products and utilization of underutilized crops.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this research. The study was funded by TETFund, which provided financial support for materials and laboratory analyses; however, the funding body had no role in the study design, data collection, analysis, interpretation, or preparation of the manuscript.

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