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Quality Characteristics of Biscuits Produced with Wheat-Sweet Potatoes Composite Flour

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ABSTRACT

This study investigated the functional, nutritional, mineral, physical, and sensory properties of biscuits produced from wheat flour fortified with sweet potato (Ipomoea batatas) flour at 10, 20, 30, and 40% substitution levels, with 100% wheat flour as control. Increasing sweet potato inclusion significantly enhanced flour bulk density (0.56–0.73 g/cm³), swelling capacity (10.07–11.57%), water absorption (3.60–5.06%), oil absorption (1.07–1.67%), and gelatinization temperature (69.67–78.00 °C), while foaming capacity decreased (7.23–8.85%). Proximate analysis of the biscuits revealed reduced moisture (6.74–8.85%), protein (13.93–18.70%), lipid (7.39–8.65%), and energy (380.89–390.04 kcal), but increased ash (1.47–3.23%), dietary fiber (2.83–4.21%), and carbohydrate (59.49–64.51%). Mineral content showed elevated phosphorus (250.13–320.85 mg/100 g) and calcium (39.75–52.52 mg/100 g), alongside reduced iron (2.99–4.90 mg/100 g) and zinc (1.83–3.10 mg/100 g). Physically, biscuit weight remained similar (9.08–9.50 g), whereas height (0.58–1.00 cm) and spread ratio (0.77–1.07) declined and length (3.35–3.50 cm) slightly increased with higher sweet potato levels. Sensory evaluation indicated that biscuits with 10–20% sweet potato flour maintained desirable taste, texture, and overall acceptability. Overall, moderate fortification of wheat flour with 10–20% sweet potato flour improved the nutritional and functional quality of biscuits while preserving consumer acceptability, offering a viable strategy for developing nutritionally enriched bakery products.

Keywords

Sweet potato flour, Wheat flour, Biscuit fortification, Composite flour, Functional properties.

Introduction

Biscuits are among the most widely consumed bakery products worldwide, valued for their convenience, ready-to-eat nature, affordability, and extended shelf life. They are traditionally produced from wheat flour, which provides desirable visco elastic properties due to gluten formation, contributing to the characteristic texture, structure, and mouth feel of the final product. However, in many developing countries, including Nigeria, wheat is not cultivated on a large scale, resulting in heavy dependence on importation. This dependence not only increases production costs but also places pressure on foreign exchange reserves and threatens long-term food security [1]. Furthermore, conventional wheat-based biscuits are typically high in refined carbohydrates and possess a high glycaemic index, which has been associated with increased risks of obesity, diabetes, and other non-communicable diseases. These challenges have necessitated the exploration of alternative, locally available raw materials to partially replace wheat flour in bakery products.

In recent years, the use of composite flours has emerged as a sustainable and nutritionally advantageous approach in food product development. Composite flour technology involves the blending of wheat flour with flours derived from indigenous crops such as tubers, legumes, and cereals to enhance nutritional quality, diversify product functionality, and reduce reliance on imported wheat [2]. Among these, sweet potato (*Ipomoea batatas*) has gained considerable attention due to its abundance in tropical regions, ease of cultivation, and rich nutritional profile. Sweet potato is an excellent source of complex carbohydrates, dietary fiber, β-carotene (a precursor of vitamin A), vitamins (particularly vitamins C and B-complex), and essential minerals such as potassium and iron. Additionally, it contains bioactive compounds with antioxidant properties that contribute to health promotion and disease prevention. The inclusion of sweet potato flour in biscuit formulation has been reported to improve the nutritional profile, particularly by increasing dietary fiber and pro-vitamin A content, which is critical in addressing micronutrient deficiencies such as vitamin A deficiency prevalent in many developing regions.

Several studies have demonstrated the feasibility of incorporating sweet potato flour into wheat-based biscuit formulations. For instance, Tortoe et al. and Oladunmoye et al. reported that partial substitution of wheat flour with sweet potato flour resulted in biscuits with improved nutritional quality while maintaining acceptable sensory attributes. Similarly, Ponka et al. [3] observed that the incorporation of complementary protein sources such as soybean flour into sweet potato–wheat composite flour significantly enhanced the protein and fiber content of the resulting biscuits. Despite these advantages, increasing the proportion of sweet potato flour beyond optimal levels may adversely affect the functional and sensory properties of biscuits, including texture, spread ratio, color, and overall acceptability, due to the absence of gluten and differences in starch composition. Therefore, determining the appropriate substitution level is critical to achieving a balance between improved nutritional quality and desirable product characteristics.

The incorporation of sweet potato flour into biscuit production offers significant nutritional, economic, and environmental benefits. Nutritionally, it enhances dietary fiber intake and provides pro-vitamin A, thereby contributing to improved public health outcomes. Economically, it reduces dependence on imported wheat and lowers production costs, while environmentally, it promotes the utilization of locally available and underutilized crops, supporting sustainable agricultural practices and rural livelihoods. In view of these potentials, this study aimed to develop biscuits using composite blends of wheat and sweet potato flours and to evaluate their quality characteristics. Specifically, the study assessed the functional properties of the flour blends, determined the proximate and mineral composition of the produced biscuits, evaluated their physical properties, and analyzed their sensory attributes to establish the suitability of sweet potato flour as a partial substitute for wheat flour in biscuit production.

Materials and Methods

Materials Procurement

Wheat flour and white fleshed sweet potatoes were purchased from Akpan Andem Market, Uyo, Akwa Ibom State. Other ingredients used for making the biscuits were purchased from Akpanandem Market in Uyo, Akwa Ibom State. Reagents used were of analytical grade and equipment used was from the Food Science and Technology Processing Laboratory, University of Uyo, Nigeria.

Production of sweet potato flour

The sweet potato flour was produced following the method described by Bello et al. [4]. The sweet potato roots were trimmed and peeled manually using a kitchen knife, then washed and sliced to about 2–3 mm thickness. Two methods of pretreatments (blanching and soaking in NaCl) were applied on the sliced tubers. Blanching was done at 70°C for 20 minutes, followed by soaking of the sliced tubers in 1% NaCl solution for 20 minutes. The pretreated sliced sweet potatoes were dried in an oven (model NAAFCO BS Oven: OVH–102) at 60–65ºC for 24 hours. The dried sweet potatoes chips were ground with a hammer mill (model Corona: 9FC–260). The ground sweet potato was sieved through a mesh of 500 µm pore screen to obtain a fine flour. The flour was packaged in air tight plastic bags and labeled for subsequent use.

Formulation of composite flour blends

The composite blend of wheat and sweet potato flours used in this study are 90:10, 80:20, 70:30 and 60:40. 100% wheat flour served as the control sample. Each blend was thoroughly mixed in a warring blender to have a homogeneous mixture, packaged in air tight plastic bags, labeled and stored at 4°C until used. The blending ratios are presented in Table 1.

Table 1: Formulation of Composite Flour Blends (%).

Samples	A	B	C	D	E
Wheat flour	100.00	90.00	80.00	70.00	60.00
Sweet potato flour	0.00	10.00	20.00	30.00	40.00

Preparation of Biscuits

Biscuits were prepared following the method of Adeyanju et al. [5] with slight modifications. Fat and sugar were first creamed together until a light and fluffy consistency was achieved. The composite flour blends, baking powder, whole egg, and salt were subsequently added and thoroughly mixed to form homogeneous dough. The dough was then rolled to a uniform thickness, cut into desired shapes, and baked in a preheated oven at 170 °C for 20 minutes. After baking, the biscuits were removed from the oven and allowed to cool at ambient temperature on a wire rack. The cooled samples were then packaged in low-density polyethylene (LDPE) bags and stored in airtight plastic containers prior to further analyses.

Methods of Analysis

Determination of Functional Properties of the flour blend from Wheat Flour Fortified with Sweet-potato Flour

Bulk density, Swelling Capacity, Water and Oil Absorption and Foaming Capacity according to the standard methods described by [6].

Determination of physical properties of biscuit samples

The method described by Bala et al. [7] was used. The thickness and height of the biscuits were determined by measuring the thickness of the biscuit samples placed edge to edge with a digital vernier caliper. The diameter of biscuit was determined by measuring the average values of individual biscuits using a ruler. The weight of the biscuits was measured as average values of the individual biscuits using an analytical weighing balance. The spread ratio was calculated by dividing the diameter by thickness.

Determination of the proximate composition of the biscuit samples

Proximate composition (moisture content, protein, lipid, ash, fiber) of the cookie was determined using standard methods [6]. Carbohydrate content was determined by difference.

Determination of Mineral Content of the biscuit samples

The minerals (Mg, Ca, K and P) were determined using Atomic Absorption Spectrophotometer (UNICAM model 939) described by Fraga et al.

Sensory Evaluation of cookies made from the composite flour of biscuit samples

Statistical Analysis

All the analyses were conducted in triplicate and the mean data ± SD (standard deviation) were reported. Data were subjected to one-way Analysis of Variance (ANOVA) for repeated measurements. Each of the parameter was analyzed using statistical package for the social sciences (SPSS) version 20.0 software the treatment means separated using Fisher's Less Significant difference (LSD) test. Significance was accepted at $p<0.05$.

Results and Discussion

Functional Properties of the Composite Flour Blend from Wheat Flour Fortified with Sweet-potato Flour

The functional properties of wheat flour fortified with sweet potato flour are presented in Table 2. The results indicated that bulk density, swelling capacity, gelatinization temperature, water absorption capacity (WAC), and oil absorption capacity (OAC) increased significantly ($p <0.05$) with increasing levels of sweet potato substitution, whereas foaming capacity decreased. The control sample (100% wheat flour) recorded the lowest values for bulk density (0.56 g/cm³), swelling capacity (10.07%), gelatinization temperature (69.33 °C), WAC (3.60%), and OAC (1.07%), while the 60:40 wheat–sweet potato blend exhibited the highest values (0.73 g/cm³, 11.57%, 78 °C, 5.06%, and 1.67%, respectively).

The progressive increase in bulk density with sweet potato inclusion suggests improved flour compactness and packing characteristics, likely due to reduced particle size and enhanced particle arrangement, consistent with previous findings [8,9]. Similarly, the increase in swelling capacity reflects enhanced water uptake and starch granule expansion, which may be attributed to variations in starch composition and amylose content of sweet potato flour [10,11]. The observed rise in gelatinization temperature (69.33–78 °C) indicates increased thermal stability of the starch matrix, suggesting improved resistance to heat during processing and suitability for baked products requiring higher temperatures [12,13].

Furthermore, the significant increase in WAC and OAC with higher sweet potato substitution demonstrates enhanced water- and oil-binding capacities, which are important for dough handling, texture development, and flavor retention in baked products [3,14]. These improvements may be attributed to the higher fiber content and hydrophilic components present in sweet potato flour. In contrast, the reduction in foaming capacity with increasing substitution levels is likely due to the dilution of gluten and reduced protein functionality, which are essential for foam formation and stability [11]. This suggests that while the composite flour is suitable for dense baked products such as biscuits, its application in aerated products may be limited.

Physical Properties of the Biscuits Made from Wheat Flour Fortified with Sweet-potato Flour

The physical characteristics of biscuits produced from wheat–sweet potato composite flours are presented in Table 3. The results showed that biscuit weight ranged from 9.08 to 9.50 g, with no significant differences ($p > 0.05$) observed among the samples. This indicates that substitution of wheat flour with sweet potato flour had minimal influence on the overall mass of the biscuits, suggesting uniformity in dough formulation and portioning across treatments. In contrast, biscuit height decreased significantly ($p < 0.05$) from 1.00 cm in the control sample (100% wheat flour) to 0.58 cm at higher substitution levels (30–40%). This reduction in height may be attributed to the dilution of gluten proteins, which are responsible for gas retention and structural development during baking. The lower gluten content in sweet potato flour likely resulted in reduced dough elasticity and weaker structural integrity, leading to a denser and more compact crumb structure.

Conversely, biscuit length increased slightly from 3.35 to 3.70 cm with increasing levels of sweet potato substitution, indicating a tendency for lateral expansion during baking. This may be

Table 2: Functional Properties of the Composite Flour Blend from Wheat Flour Fortified with Sweet-potato Flour.

Samples	Bulk Density (g/cm³)	Swelling Capacity (%)	Gelation Temperature (°C)	Water Absorption Capacity (%)	Oil Absorption Capacity (%)	Foaming Capacity (%)
A	$0.56^c \pm 0.02$	$10.07^d \pm 0.03$	$69.33^d \pm 3.51$	$3.60^e \pm 0.04$	$1.07^d \pm 0.12$	$8.85^a \pm 0.10$
B	$0.60^b \pm 0.01$	$10.46^c \pm 0.05$	$69.67^d \pm 2.65$	$4.07^d \pm 0.10$	$1.27^c \pm 0.06$	$8.37^b \pm 0.16$
C	$0.63^b \pm 0.02$	$10.78^b \pm 0.08$	$73.00^c \pm 0.58$	$4.32^c \pm 0.09$	$1.28^c \pm 0.03$	$7.82^c \pm 0.08$
D	$0.67^b \pm 0.02$	$11.23^a \pm 0.06$	$77.67^b \pm 0.82$	$4.60^b \pm 0.06$	$1.43^b \pm 0.06$	$7.27^d \pm 0.25$
E	$0.73^a \pm 0.06$	$11.57^a \pm 0.06$	$78.00^a \pm 1.53$	$5.06^a \pm 0.10$	$1.67^a \pm 0.12$	$7.23^d \pm 0.15$

Values are mean of the triplicate determination ± standard deviation. Means with different superscript on the same column are significantly ($p<0.05$) different. Keys for the wheat + sweet potato flour blends:A = 100% wheat flour (control sample), B = 90% wheat + 10% sweet potato flour, C =80% wheat + 20% sweet potato flour, D = 70% wheat + 30% sweet potato flour, E = 60% wheat + 40% sweet potato flour.

associated with changes in dough rheology and reduced resistance to flow, allowing the dough to spread more horizontally under heat. However, despite this slight increase in length, the spread ratio decreased significantly ($p < 0.05$) from 1.07 in the control to 0.77 in biscuits containing 40% sweet potato flour. The spread ratio, which is an important indicator of dough viscosity and baking performance, reflects the balance between dough expansion and structural setting during baking. The observed decrease suggests increased dough viscosity and reduced extensibility, likely due to the higher fiber content and absence of gluten in sweet potato flour [15]. These findings imply that while sweet potato flour incorporation influences the dimensional characteristics of biscuits, moderate substitution levels can still yield products with acceptable physical quality, whereas higher inclusion levels may result in denser and less spreadable biscuits.

Table 3: Physical Properties of the Biscuits Made from Wheat Flour Fortified with Sweet-potato Flour.

Sample	Weight (g)	Height (cm)	Length (cm)	Spread ratio
A	$9.37^a \pm 1.02$	$1.00^a \pm 0.33$	$3.35^b \pm 0.61$	$1.07^a \pm 0.34$
B	$9.50^a \pm 1.03$	$0.80^b \pm 0.29$	$3.50^b \pm 0.62$	$0.90^b \pm 0.31$
C	$9.27^a \pm 1.01$	$0.85^b \pm 0.31$	$3.50^b \pm 0.62$	$0.92^b \pm 0.32$
D	$9.43^a \pm 1.02$	$0.58^c \pm 0.31$	$3.70^a \pm 0.64$	$0.90^b \pm 0.31$
E	$9.08^a \pm 1.04$	$0.75^b \pm 0.29$	$3.50^b \pm 0.62$	$0.77^c \pm 0.29$

Values are mean of the triplicate determination ± standard deviation. Means with different superscript on the same column are significantly ($p<0.05$) different. Keys for the wheat + sweet potato flour blends: A = 100% wheat flour (control sample), B = 90% wheat + 10% sweet potato flour, C = 80% wheat + 20% sweet potato flour, D = 70% wheat + 30% sweet potato flour, E = 60% wheat + 40% sweet potato flour.

Proximate Composition (%) and Energy Value (Kcal/100g) of the Biscuits Made from Wheat Flour Fortified with Sweet-potato Flour

The proximate composition and energy values of biscuits produced from wheat–sweet potato composite flours are presented in Table 4. The results revealed that moisture content decreased significantly ($p < 0.05$) with increasing levels of sweet potato substitution, ranging from 8.85% in the control sample (100% wheat flour) to 6.74% in biscuits containing 40% sweet potato flour. This reduction can be attributed to the relatively lower moisture content of sweet potato flour compared to wheat flour, as well as differences in water-binding capacity. Lower moisture content is desirable in baked products, as it is associated with reduced microbial growth, improved shelf stability, and extended storage life [11,14,16,17].

A significant decrease ($p < 0.05$) was also observed in protein and lipid contents, which declined from 18.70% to 13.93% and from 8.65% to 7.39%, respectively, with increasing levels of sweet potato flour incorporation. This trend is expected, as sweet potato flour generally contains lower protein and fat levels compared to wheat flour [3,18]. The reduction in protein content may influence dough functionality, particularly gluten development, which is critical for elasticity, gas retention, and structural integrity during baking. In contrast, ash, crude fiber, and carbohydrate contents increased significantly ($p < 0.05$) with higher substitution levels, rising from 1.47%, 2.83%, and 59.49% in the control sample to 3.23%, 4.21%, and 64.51%, respectively, in biscuits containing 40% sweet potato flour. The increase in ash content suggests a higher mineral composition, while the elevated fiber content reflects the dietary fiber richness of sweet potato flour, which is beneficial for digestive health and glycemic regulation [3,14].

The increase in carbohydrate content contributed to the overall energy density of the biscuits; however, a slight reduction in total caloric value was observed, decreasing from 390.04 to 380.89 kcal with increasing substitution levels. This decrease is primarily due to the reduction in fat and protein contents, which contribute more significantly to total caloric value compared to carbohydrates. Overall, the incorporation of sweet potato flour into wheat-based biscuits enhanced the nutritional profile by increasing dietary fiber and mineral content, while also improving shelf stability through reduced moisture content, although with a moderate reduction in protein and energy value.

Mineral Composition of the Biscuits Made from Wheat Flour Fortified with Sweet-potato Flour

The mineral composition of biscuits produced from wheat–sweet potato composite flours is presented in Table 5. The results showed that phosphorus and calcium contents increased significantly ($p < 0.05$) with increasing levels of sweet potato substitution, rising from 250.13 to 320.85 mg/100 g and from 39.75 to 52.52 mg/100 g, respectively. This trend can be attributed to the relatively higher mineral content of sweet potato flour compared to refined wheat flour, which typically undergoes milling processes that remove the nutrient-rich bran and germ fractions [18]. The observed increase in phosphorus is nutritionally important, as phosphorus plays a critical role in bone and teeth formation, cellular energy metabolism (ATP production), and overall physiological function [1,19]. Similarly, the increase in calcium content enhances the nutritional value of the biscuits, as calcium is essential for bone development, muscle function, and nerve transmission. The

Table 4: Proximate Composition (%) and Energy Values (kcal/100g) of the Biscuits Made from Wheat Flour Fortified with Sweet-potato Flour.

Samples	Moisture	Protein	Lipid	Ash	Fiber	Carbohydrate	Energy
A	$8.85^a \pm 0.10$	$18.70^a \pm 0.35$	$8.65^a \pm 0.05$	$1.47^d \pm 0.09$	$2.83^d \pm 0.16$	$59.49^d \pm 0.41$	$390.04^a \pm 1.11$
B	$8.13^b \pm 0.11$	$17.07^b \pm 0.39$	$8.46^b \pm 0.05$	$1.87^c \pm 0.09$	$3.15^c \pm 0.12$	$61.32^c \pm 0.30$	$389.37^a \pm 1.22$
C	$7.79^c \pm 0.18$	$16.33^c \pm 0.52$	$8.13^c \pm 0.11$	$2.09^b \pm 0.05$	$3.61^b \pm 0.16$	$62.35^b \pm 1.09$	$387.24^b \pm 2.22$
D	$7.69^c \pm 0.29$	$15.44^d \pm 0.44$	$7.56^d \pm 0.44$	$2.26^b \pm 0.13$	$3.85^b \pm 0.07$	$62.86^b \pm 0.43$	$381.25^c \pm 5.09$
E	$6.74^d \pm 0.26$	$13.93^e \pm 0.00$	$7.39^d \pm 0.13$	$3.23^a \pm 0.24$	$4.21^a \pm 0.11$	$64.51^a \pm 0.07$	$380.89^c \pm 0.15$

Values are mean of the triplicate determination ± standard deviation. Means with different superscript on the same column are significantly ($p<0.05$) different. Keys for the wheat + sweet potato flour blends: A = 100% wheat flour (control sample), B = 90% wheat + 10% sweet potato flour, C = 80% wheat + 20% sweet potato flour, D = 70% wheat + 30% sweet potato flour, E = 60% wheat + 40% sweet potato flour.

elevated calcium levels observed in this study are consistent with previous reports highlighting sweet potato as a moderate source of calcium [3,12,14].

In contrast, iron and zinc contents decreased significantly ($p < 0.05$) with increasing substitution levels, declining from 4.90 to 2.99 mg/100 g and from 3.10 to 1.83 mg/100 g, respectively. This reduction may be attributed to the comparatively higher concentrations of these trace minerals in wheat flour relative to sweet potato flour, as well as possible dilution effects during blending [3,18]. Iron and zinc are essential micronutrients involved in critical biological processes, including oxygen transport, immune function, and enzymatic activities. Therefore, their reduction may limit the contribution of the composite biscuits to addressing micronutrient deficiencies, particularly in populations at risk of iron-deficiency anemia and zinc deficiency. Overall, while incorporation of sweet potato flour enhances the phosphorus and calcium content of biscuits, it may require complementary fortification strategies to maintain adequate levels of iron and zinc, thereby achieving a more balanced mineral profile [9].

Table 5: Mineral Composition of the Biscuits Made from Wheat Flour Fortified with Sweet-potato Flour (mg/100g).

Samples	Phosphorus	Calcium	Iron	Zinc
A	$250.13^{c} \pm 0.11$	$39.75^{d} \pm 1.27$	$4.90^{a} \pm 0.14$	$3.10^{a} \pm 0.08$
B	$268.86^{c} \pm 0.11$	$42.34^{c} \pm 0.83$	$4.27^{b} \pm 0.07$	$2.83^{b} \pm 0.06$
C	$284.55^{b} \pm 0.77$	$45.84^{b} \pm 0.12$	$4.04^{c} \pm 0.04$	$2.67^{c} \pm 0.05$
D	$309.78^{a} \pm 9.33$	$50.58^{a} \pm 0.42$	$3.77^{d} \pm 0.11$	$2.10^{d} \pm 0.02$
E	$320.85^{a} \pm 1.62$	$52.52^{a} \pm 0.38$	$2.99^{e} \pm 0.11$	$1.83^{e} \pm 0.03$

Values are mean of the triplicate determination ± standard deviation. Means with different superscript on the same column are significantly ($p<0.05$) different. Keys for the wheat + sweet potato flour blends: A = 100% wheat flour (control sample), B = 90% wheat + 10% sweet potato flour, C = 80% wheat + 20% sweet potato flour, D = 70% wheat + 30% sweet potato flour, E = 60% wheat + 40% sweet potato flour.

Sensory Scores of Biscuits made from Wheat Flour Fortified with Sweet-potato Flour

The sensory attributes of biscuits produced from wheat–sweet potato composite flours are presented in Table 6. The evaluated parameters included taste, appearance, crispiness, mouthfeel, and overall acceptability, with mean scores ranging from 5.40 to 7.20 for taste, 5.80 to 6.20 for appearance, 5.80 to 7.60 for crispiness, 5.80 to 7.00 for mouthfeel, and 5.80 to 7.60 for overall acceptability. The control sample (100% wheat flour) consistently recorded the highest scores across all sensory attributes, while biscuits containing 40% sweet potato flour had the lowest ratings. A significant ($p < 0.05$) decline in sensory scores was observed with increasing levels of sweet potato substitution, indicating that higher inclusion levels adversely affected overall product quality and consumer perception.

The reduction in taste and mouthfeel at higher substitution levels may be attributed to the characteristic earthy flavor and increased dietary fiber content of sweet potato flour, which can influence both flavor profile and textural properties [12]. Interestingly, appearance scores were highest at moderate substitution levels (10–20%), suggesting that partial incorporation of sweet potato flour may enhance the visual appeal of biscuits, possibly due to desirable color development associated with natural pigments such as β-carotene. However, further increases in substitution levels resulted in reduced crispiness, likely due to higher water retention and fiber content, which can interfere with moisture loss during baking and lead to softer textures. Overall, biscuits containing 10–20% sweet potato flour maintained good sensory acceptability and were comparable to the control, indicating that this substitution range represents an optimal balance between improved nutritional quality and desirable sensory characteristics.

Conclusion

This study demonstrated that the incorporation of sweet potato (*Ipomoea batatas*) flour into wheat flour significantly influenced the functional, nutritional, physical, and sensory properties of the resulting composite flour and biscuits. Sweet potato inclusion improved bulk density, swelling capacity, and oil absorption capacity, indicating enhanced compactness and flavor retention, although it reduced water absorption, gelatinization temperature, and foaming capacity, thereby limiting its suitability for highly aerated or hydrated dough systems. In the biscuit samples, fortification led to a decrease in protein, lipid, and overall energy content, while significantly increasing ash, dietary fiber, and carbohydrate levels, reflecting improved mineral and fiber composition. Mineral analysis further revealed increased phosphorus and calcium contents but reduced iron and zinc levels with higher substitution. Physically, sweet potato incorporation had no significant effect on biscuit weight but resulted in reduced height and spread ratio, alongside a slight increase in length, indicating a denser product structure. Sensory evaluation showed a decline in acceptability at higher substitution levels, with optimal consumer preference observed at 10–20% inclusion, suggesting

Table 6: Sensory Properties of the Biscuits Made from Wheat Flour Fortified with Sweet-potato Flour.

Sample	Taste	Appearance	Mouthfeel	Crispiness	Overall Acceptability
A	$7.20^{a} \pm 0.45$	$6.20^{bc} \pm 0.45$	$7.00^{a} \pm 1.10$	$7.60^{a} \pm 0.55$	$7.60^{a} \pm 0.55$
B	$6.60^{b} \pm 1.14$	$7.40^{a} \pm 0.55$	$6.40^{b} \pm 0.55$	$7.20^{ab} \pm 0.84$	$7.20^{a} \pm 0.84$
C	$6.60^{b} \pm 0.55$	$7.40^{a} \pm 1.14$	$6.40^{b} \pm 0.89$	$6.60^{b} \pm 1.14$	$6.80^{b} \pm 0.84$
D	$6.60^{b} \pm 1.52$	$6.80^{ab} \pm 1.10$	$5.80^{c} \pm 0.84$	$5.60^{c} \pm 0.55$	$5.80^{c} \pm 1.10$
E	$5.40^{c} \pm 1.52$	$5.40^{c} \pm 0.55$	$5.80^{c} \pm 1.79$	$5.80^{c} \pm 1.79$	$5.80^{c} \pm 1.79$

Values are mean of the triplicate determination ± standard deviation. Means with different superscript on the same column are significantly ($p<0.05$) different. Keys for the wheat + sweet potato flour blends: A = 100% wheat flour (control sample), B = 90% wheat + 10% sweet potato flour, C = 80% wheat + 20% sweet potato flour, D = 70% wheat + 30% sweet potato flour, E = 60% wheat + 40% sweet potato flour.

that moderate substitution achieves a balance between improved nutritional quality and desirable sensory attributes.

Based on these findings, it is recommended that wheat–sweet potato composite flour products be fortified with protein-rich and mineral-dense ingredients to compensate for reductions in protein, iron, and zinc contents. Furthermore, future research should focus on the use of biofortified or nutritionally enhanced sweet potato varieties to improve the overall micronutrient profile of composite flour products, while also optimizing processing conditions to maintain functional and sensory quality.

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