

Effects of Sprouting on the Nutritional Quality and Organoleptic Property of Wheat-Based Enriched Biscuits with Soyabean Flour

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ABSTRACT

Background: The rising demand for nutrient-dense, functional foods has led to increasing interest in composite flour-based products. Soybean (*Glycine max* (L) Merrill), particularly when sprouted, offers potential nutritional benefits when incorporated into baked foods like biscuits.

Objective: This study aimed to evaluate the proximate, mineral, and sensory properties of biscuits produced from wheat flour blended with sprouted and unsprouted soybean flour.

Methodology: Biscuits were formulated using wheat flour and either sprouted or unsprouted soybean flour in ratios of 100:0, 50:50, and 50:50, respectively, and labeled WF (control), WUSF (Wheat and Unsprouted Soybean Flour), and WSSF (Wheat and Sprouted Soybean Flour). Proximate and mineral compositions were determined using standard AOAC methods. Sensory attributes were assessed by a 20 semi trained panelists using a 9-point hedonic scale.

Results: The WF sample exhibited the highest carbohydrate content (68.31%), whereas WSSF showed significantly ($p < 0.05$) higher moisture (7.94%), protein (25.52%), fat (19.92%), fiber (1.75%), and ash (3.11%) contents. Mineral analysis revealed that WSSF had superior calcium (180.69 mg/100g), potassium (280.22 mg/100g), iron (7.86 mg/100g), and zinc (9.52 mg/100g) levels compared to other samples. Despite its nutritional superiority, WSSF was least preferred in sensory evaluation across all parameters, while WF scored highest in appearance (8.40), taste (7.95), texture (7.55), and aroma (7.75).

Conclusion: Although biscuits made with sprouted soybean flour were less acceptable organoleptically, they offered enhanced nutritional quality. Public awareness campaigns that highlight the nutritional, health and economic advantages of sprouting foods are strongly recommended to encourage broader acceptance and regular use.

Keywords: Biscuits, Composite flour, Sprouting, Soybean

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INTRODUCTION

Bakery products form an important part of daily diets in many parts of the world because they are convenient, palatable, and relatively inexpensive to produce [1]. Among these products, biscuits hold a prominent position due to their wide acceptance across different age groups and socioeconomic backgrounds. Their extended shelf life, minimal preparation requirements, and ease of transportation have further contributed to their

popularity in both developed and developing countries [2]. Biscuits are commonly consumed as snacks, breakfast items, or complementary foods, and as such, they contribute significantly to daily dietary intake [3]. They are typically produced from refined wheat flour and provide an excellent medium for the incorporation of functional ingredients and nutrient-rich food materials. As a result, increasing research attention has focused on improving the nutritional quality of biscuits

through ingredient modification and the inclusion of nutrient-dense plant-based components. Biscuits are globally consumed as ready-to-eat and low-cost food bakery products made from flour, sugar, and fat. Biscuits are [4, 5]. The term *biscuit* is derived from the Latin word *bis coctus*, meaning twice cooked or baked, and its origin dates back to Roman times, when some foods needed to be completely dehydrated in order to be stored for longer periods of time [6]. They serve as an excellent vehicle for nutrient fortification, particularly in developing countries where micronutrient deficiencies are prevalent [7]. Biscuits made from refined wheat flour may be low in protein and micronutrients, depending on the processing methods involved; thus, the need for fortification using protein-rich legumes such as soybean [8]. Soybeans are particularly valued for their high protein content, essential amino acids, and rich mineral composition [9]. Biscuits have been used in clinical trials and have shown to have prospects in improving dietary intake by increasing intake of bioactive compounds, phenolic compounds, vitamins, and minerals. In recent years, there has been increasing interest in the use of alternative plant-based ingredients in the formulation of bakery products. This trend is driven by growing consumer awareness of nutrition, health concerns associated with certain cereal proteins, and the need to diversify food sources to improve dietary quality. The incorporation of legume-based ingredients into wheat-based products has been widely explored as a strategy for improving the nutritional value of baked foods [10]. Legumes are recognized for their high protein content, dietary fibre, essential minerals, and various bioactive compounds that contribute to human health [11]. Among these legumes, soybean has received considerable attention because of its exceptional nutritional composition and functional properties in food systems. The utilization of soybean-derived ingredients in bakery formulations, therefore, presents a promising approach to enhance protein quality and improve the micronutrient content of commonly consumed food products. Alternative flours have been explored because of the concerns surrounding wheat flour, such as celiac disease. Soybeans are a rich source of nutrients, especially protein and oil. They also contain amino acids, vitamins, and minerals, which are all necessary for human nutrition [12]. This makes it a crop of high nutritional value, thereby having a wide range of applications in food, feed, and industrial applications. Soybeans are widely used in the production of foods such as soy milk, soy yoghurt,

tofu, and soy flour, which may serve as affordable protein alternatives in diets. They also contain several bioactive compounds that positively contribute to human health [13]. Despite containing all these health benefits, they also contain anti-nutritional factors like tyrosine inhibitors, phytic acids, and lectins, which can reduce absorption if not processed properly [12].

Various traditional and modern processing techniques have been applied to legumes to improve their nutritional quality, digestibility, and functional performance in food products. These processing methods are particularly important because many legumes naturally contain antinutritional compounds that may interfere with nutrient absorption or reduce protein digestibility. Techniques such as soaking, roasting, fermentation, and germination have therefore been widely adopted to enhance the nutritional and sensory characteristics of legume-based foods [14]. Among these approaches, sprouting has attracted considerable attention due to its ability to induce beneficial biochemical changes within the seed, thereby improving nutrient availability and functional properties. Sprouting improves digestibility, increases bioavailability of nutrients, and reduces antinutritional factors such as phytates, saponins, and trypsin inhibitors in legumes [15, 16]. This makes sprouted soybeans an ideal functional ingredient for food fortification. Though sprouting improves the nutritional profile, its impact on the sensory attributes of soybean-based biscuits remains a concern [17]. Among the various traditional processing techniques, sprouting has gained considerable attention as it is a simple, low-cost, and natural method for generally enhancing the nutritional and functional properties of legumes. The textural and flavour characteristics of sprouted soybean products differ significantly from conventional baked goods, potentially affecting consumer acceptability [17]. Hence, this study focuses on comparing the proximate composition, mineral content, and sensory acceptability of biscuits made from wheat, sprouted, and unsprouted soybean flour.

MATERIALS AND METHODS

Sample collection

Soybean seeds and wheat flour were obtained from a local market (urban market along Uzuakoli Road) situated in Abia State, Nigeria. The soybean seeds were then sorted to divide into two groups. One group was sprouted for 72 hours, while the

other remained unsprouted. Both groups were processed into flour.

Preparation of flour

The preparation of sprouted soybean flour was done using the methods described by [18] with modifications. The process began with the thorough cleaning of mature soybeans to remove stones, dirt, and damaged seeds. The cleaned soybeans were soaked in clean water at room temperature for 3 hours, with a ratio of three parts water to one part soybean. After soaking, the water was drained, and the soybeans were spread on racks and watered every 6 hours for a total of 48 hours to initiate sprouting. The soybeans were then washed and sundried for 3 hours. It was then dehydrated (100 °C for 5 hours) and roasted at low heat (for 15 minutes). The dried, sprouted soybeans were milled into fine flour using an attrition mill and finally sieved using a 2mm mesh size. Unsprouted soybean was sorted and soaked in water for 18 hours, after which they were washed and boiled for 30 minutes, then sundried for 3 hours. It was then dehydrated using the dehydration machine (60 °C for 6 hours), roasted

in low heat for 15 minutes, milled using the attrition mill, and sieved using a 2mm mesh size to get unsprouted soybean flour.

Production of sprouted and unsprouted soybean biscuits

The processing procedure (Figure 1) commenced with the mixing of all ingredients: sprouted soybean flour, unsprouted soybean flour, wheat flour, sugar, margarine, powdered milk, baking powder, salt, and water to obtain a homogenous dough. Subsequently, the dough was subjected to a forming stage, wherein it was moulded and shaped into the desired configurations. The formed dough was then baked in a preheated oven at a temperature range of 170°C for a duration of 45 minutes, allowing for complete gelatinization and development of structural integrity [19]. Upon completion of baking, the products were cooled using a cooling conveyor system to bring them to ambient temperature and prevent moisture condensation within the packaging. Finally, the cooled products were packaged appropriately to maintain quality and extend shelf life.

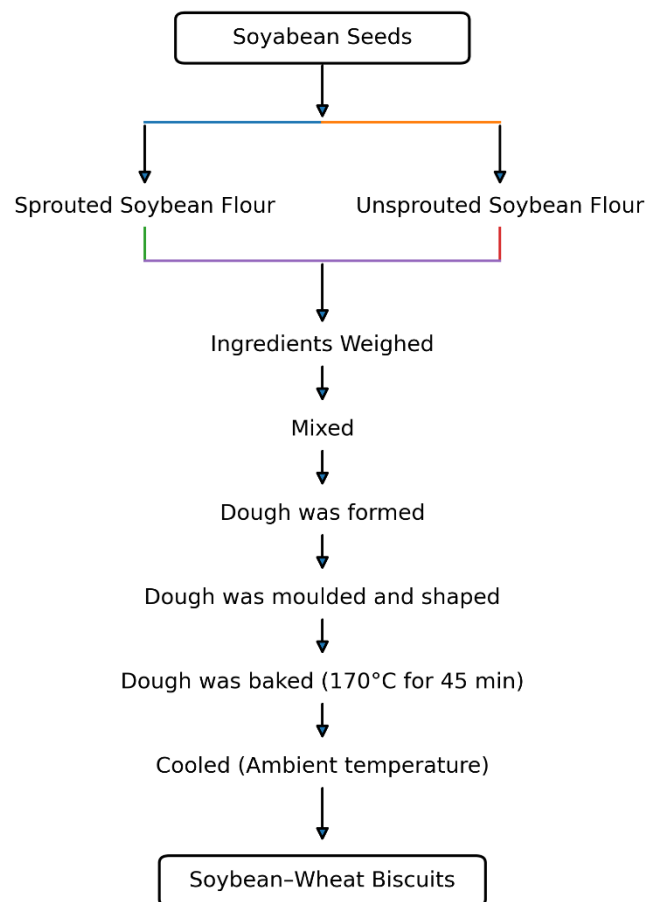


Figure 1. Flowchart of soybean-enriched biscuits

Chemical and mineral analysis

The proximate composition of the samples was determined using standard methods of the Association of Official Analytical Chemists (AOAC). Moisture content was determined by the hot air oven method; crude protein was determined using the micro-Kjeldahl method, and the nitrogen value was multiplied by a factor of 6.25 to obtain crude protein. Crude fat was determined using the Soxhlet extraction method, while crude fibre was determined by the acid-alkali digestion method. Ash content was determined by incineration of the samples in a muffle furnace at 550 °C until a constant weight was obtained. Carbohydrate content was calculated by difference as the remainder after subtracting the sum of moisture, crude protein, crude fat, ash, and crude fibre from 100. Mineral analysis was carried out following sample digestion. The samples were first dry-ashed in a muffle furnace at about 550 °C, and the ash obtained was dissolved in dilute nitric acid and filtered. The resulting solution was used for mineral determination. The concentrations of calcium (Ca), iron (Fe), zinc (Zn), and other trace elements were determined using an Atomic Absorption Spectrophotometer (AAS), while potassium (K) was determined using flame photometry where applicable. The mineral concentrations were expressed in mg/100 g of sample.

Sensory analysis

The sensory attributes of the biscuit samples were obtained by using a simple hedonic test scale as described by [21]. Sensory evaluation of the wheat-based enriched biscuits produced with soybean flour was carried out using a 20-member semi-trained panel comprising students from the Department of Human Nutrition and Dietetics, College of Applied Food Science and Tourism, Michael Okpara University of Agriculture, Umudike. The panelists were selected based on their availability and familiarity with sensory evaluation procedures. Individuals who were ill or had food-related conditions such as celiac disease were excluded from the panel.

The evaluation was conducted in the Sensory Evaluation Laboratory of the Department of Human Nutrition and Dietetics, College of Applied Food Science and Tourism, Michael Okpara University of Agriculture, Umudike, under controlled conditions. Prior to the assessment, the panelists were briefed on the evaluation procedure and the use of the sensory scale. The biscuit samples were coded with random three-digit numbers and presented to the panelists in clean disposable plates to avoid bias. Each panelist was asked to evaluate the samples for appearance, taste, texture, aroma, and overall acceptability using a 9-point hedonic scale, where 1 = dislike extremely and 9 = like extremely. The scores obtained from the panelists were recorded and used for statistical analysis to determine the sensory acceptability of the enriched biscuits.

Statistical analysis

Data obtained were subjected to statistical analysis using Analysis of Variance (ANOVA), and significant differences between means were determined using Duncan's Multiple Range Test at a 5% level of significance ($p < 0.05$). Sensory evaluation data were analyzed using Friedman's ranking test to assess differences in panelists' preferences across samples.

RESULTS

Proximate composition of the flour produced from wheat, sprouted and unsprouted soybeans

The proximate composition of flours made from wheat and blends with sprouted and unsprouted soybean shown in Table 1. Sample C (50% wheat, 50% sprouted soybean) had the highest moisture (11.3%), protein (42.1%), fat (20.5%), fiber (2.8%), and ash (3.9%) contents, indicating enhanced nutritional quality; Sample B (with unsprouted soybean) came in next in these parameters, while Sample A (100% wheat) had the highest carbohydrate content (78.1%) but the lowest in other nutrients.

Table 1: Proximate composition of the flour produced from wheat, sprouted and unsprouted soybeans (*Glycine max* (L) Merrill)

Sample	Moisture content (%)	Crude protein (%)	Fat (%)	Crude fibre (%)	Ash (%)	Carbohydrate (%)
A	10.79 ^b ±0.03	8.76 ^c ±0.02	0.99 ^c ±0.03	0.47 ^c ±0.01	0.95 ^c ±0.03	78.05 ^a ±0.02
B	10.65 ^c ±0.05	36.60 ^b ±0.03	19.39 ^b ±0.02	2.62 ^b ±0.01	3.12 ^b ±0.03	27.66 ^b ±0.04
C	11.30 ^a ±0.04	42.12 ^a ±0.02	20.51 ^a ±0.02	2.83 ^a ±0.03	3.92 ^a ±0.01	19.34 ^c ±0.09

Values are mean ± standard deviation of samples. a-c Means with similar superscripts within the same column are not significantly different ($p > 0.05$)

Proximate composition of biscuits made from composite flour of wheat, sprouted and unsprouted soybeans

In Table 2, Sample C, containing sprouted soybean flour, showed significantly higher protein (25.5%) and ash (3.1%) contents, indicating enhanced nutritional value. It also had the highest crude fiber

(1.7%) and moisture (7.9%), which could influence shelf stability. Sample B exhibited the highest fat content (21.5%), suggesting improved energy density, while Sample A, the control or wheat-only sample, had the highest carbohydrate (68.3%) but the lowest protein and fat.

Table 2: Proximate composition of biscuits made from composite flour of wheat, sprouted and unsprouted soybeans (*Glycine max* (L) Merrill)

Sample	Moisture content (%)	Crude protein (%)	Fat (%)	Crude fibre (%)	Ash (%)	Carbohydrate (%)
A	7.23 ^c ±0.06	10.24 ^c ±0.04	12.21 ^c ±0.01	0.82 ^c ±0.01	1.20 ^c ±0.03	68.31 ^a ±0.08
B	7.42 ^b ±0.01	17.62 ^b ±0.02	21.49 ^a ±0.01	1.38 ^b ±0.01	1.44 ^b ±0.02	49.66 ^b ±0.04
C	7.94 ^a ±0.03	25.52 ^a ±2.14	19.92 ^b ±0.03	1.75 ^a ±0.02	3.11 ^a ±0.01	42.77 ^c ±0.64

Values are mean ± standard deviation of samples. a-c Means with similar superscripts within the same column are not significantly different ($p > 0.05$). Keys: A = 100% (Wheat Flour-Control); B = 50% Wheat Flour: 50% Unsprouted Soybean Flour); C = 50% Wheat Flour: 50% Sprouted Soybean Flour)

Mineral composition of composite flour produced from wheat, sprouted and unsprouted soybeans

The mineral makeup of wheat flours and blends with sprouted and unsprouted soybeans is presented in Table 3. The highest concentrations of calcium (301.13 mg/100g), potassium (160.22 mg/100g), iron (18.12 mg/100g), and zinc (2.74

mg/100g) were found in Sample C, which contained 50% sprouted soybean flour. In addition to having substantially higher mineral values than Sample A (100% wheat), which had the lowest levels of calcium (25.18 mg/100g), potassium (90.92 mg/100g), iron (1.85 mg/100g), and zinc (0.94 mg/100g).

Table 3: Mineral composition of composite flour produced from wheat, sprouted and unsprouted soybeans (*Glycine max* (L) Merrill)

Sample	Calcium (mg/100g)	Potassium (mg/100g)	Iron (mg/100g)	Zinc (mg/100g)
A	25.18 ^c ±0.03	90.92 ^c ±0.01	1.85 ^c ±0.05	0.94 ^c ±0.03
B	281.44 ^b ±0.02	120.15 ^b ±0.03	16.61 ^b ±0.01	2.04 ^b ±0.02
C	301.13 ^a ±0.03	160.22 ^a ±0.04	18.12 ^a ±0.01	2.74 ^a ±0.02

Mineral composition of biscuits made from composite flour of wheat, sprouted and unsprouted soybeans

Table 4 presents the mineral composition of biscuits made from wheat, sprouted, and unsprouted soybean flour blends. Sample C showed the highest levels of calcium

(180.62 mg/100 g), potassium (280.22 mg/100 g), iron (7.86 mg/100 g), and zinc (9.52 mg/100 g). Sample B, containing unsprouted soybeans, had moderate mineral values, while Sample A had the least.

Table 4: Mineral composition of biscuits made from composite flour of wheat, sprouted and unsprouted soybeans (*Glycine max* (L) Merrill)

Sample	Calcium (mg/100g)	Potassium (mg/100g)	Iron (mg/100g)	Zinc (mg/100g)
A	31.81 ^c ±0.01	150.20 ^c ±0.01	4.45 ^c ±0.04	3.35 ^c ±0.02
B	154.37 ^b ±0.02	199.52 ^b ±0.03	6.12 ^b ±0.03	5.46 ^b ±0.02
C	180.62 ^a ±0.01	280.22 ^a ±0.03	7.86 ^a ±0.01	9.52 ^a ±0.01

Values are mean ± standard deviation of samples. Means with similar superscripts within the same column are not significantly different ($p > 0.05$). Keys: A = 100% Wheat Flour); B = 50% Wheat Flour: 50% Unsprouted Soybean Flour); C = 50% Wheat Flour: 50% Sprouted Soybean Flour)

Sensory attributes of biscuits made from composite flour of wheat, sprouted and unsprouted soybeans

Table 5 shows the sensory attributes of biscuits made from wheat, sprouted, and unsprouted texture (7.55), aroma (7.75).

soybean composite flours. Sample A (control) received the highest scores across all parameters—appearance (8.40), taste (7.95),

Table 5: Sensory attributes of biscuits made from composite flour of wheat, sprouted and unsprouted soybeans (*Glycine max* (L) Merrill)

Sample	Appearance	Taste	Texture	Aroma	Calculated Acceptability	General
A	8.40 ^a ±0.68	7.95 ^a ±1.05	7.55 ^a ±1.10	7.75 ^a ±1.07	7.91 ^a ±0.69	
B	6.30 ^b ±2.20	5.60 ^b ±2.11	6.05 ^b ±2.04	5.80 ^b ±1.79	5.94 ^b ±1.68	
C	6.65 ^b ±1.14	5.10 ^b ±2.05	5.80 ^b ±1.54	5.65 ^b ±1.87	5.80 ^b ±1.37	

Values are mean ± standard deviation of samples. Means with similar superscripts within the same column are not significantly different ($p > 0.05$). Keys: A = 100% Wheat Flour; B = 50% Wheat Flour: 50% Unsprouted Soybean Flour; C = 50% Wheat Flour: 50% Sprouted Soybean Flour

DISCUSSION

The proximate composition of flour samples produced from wheat, unsprouted soybean, and sprouted soybean revealed notable differences across moisture, protein, fat, fibre, ash, and carbohydrate contents. The use of soybean, a locally available and relatively affordable legume, in the formulation of biscuits provides a practical food-based strategy for improving nutrient intake [22]. This approach enhances the nutritional quality of commonly consumed baked products and promotes better nutritional status among consumers. The results suggest that incorporating sprouted soybean flour into wheat-based formulations significantly improves the protein and mineral quality, as revealed in Tables 1 and 4, making soybean a suitable functional ingredient for enhancing the nutritional value of baked products like biscuits. This aligns with the findings that sprouted soybean exhibited superior physicochemical properties, including higher protein, fat, and ash contents [23]. A study revealed 3.85% increase in protein content in samples with 20% germinated soybean flour incorporated into wheat flour [24]. This enhancement was attributed to the higher protein content of the germinated soybean flour. The study also noted improvements in fat and ash contents, along with a reduction in carbohydrate levels, indicating an overall enhancement in the nutritional profile of the bread. Partially replacing wheat flour with whole soybean pulp (WSP) also showed to have improved steamed bread's nutritional profile and address essential amino acid imbalances without significantly impacting its physical qualities [25]. The composition reflected

the typical nutritional profile of refined wheat flour, which is energy-dense but relatively low in protein and micronutrients [25]. The carbohydrate levels dropped to 19.34%, confirming the enhanced nutrient profile at the expense of carbohydrate concentration. The superior performance of sprouted soybean flour can be attributed to the biochemical changes during germination, such as enzyme activation and breakdown of complex macromolecules, which improve nutrient bioavailability and digestibility [26]. The study showed that biscuits made with composite flour containing sprouted soybean had the highest crude protein (25.52%), significantly surpassing both unsprouted soybean and wheat-only biscuits. This aligns with findings that germinated soybean flour can elevate protein content in baked products, improving their nutritional profile [27, 28]. The inclusion of sprouted soybean flour can substantially improve the protein density of biscuits, making them a better dietary source of protein. Increased protein intake is essential for growth, tissue repair, enzyme and hormone synthesis, and body maintenance. Hence, the consumption of such protein-enriched biscuits could contribute to improving protein intake and help in addressing protein-energy malnutrition, especially among populations that rely heavily on cereal-based foods. The notable enhancement in mineral content due to sprouting supports its application in improving the nutritional quality of baked products, especially in combating micronutrient deficiencies in at-risk populations. These findings align with earlier research that highlights sprouting as a natural and effective method for increasing the bioavailability of essential nutrients in legume-

based foods [29, 30, 31]. The findings unequivocally show that adding soybean flour, especially sprouted soybean flour, significantly improves the mineral content of wheat-based flour. These minerals play vital roles in human health. Strong bones and teeth, muscle contraction, and nerve function. Potassium helps in maintaining fluid balance, muscle function, and healthy blood pressure. Iron is crucial for the formation of hemoglobin, preventing iron-deficiency anaemia, and supporting energy metabolism. Zinc supports immune function, cell growth, and wound healing. The significantly higher mineral content in the composite flours suggests their potential as functional foods for addressing mineral deficiencies. The data suggest that incorporating sprouted soybean flour significantly enhanced the mineral quality of the biscuits, potentially aiding in the dietary management of mineral deficiencies, especially in populations vulnerable to calcium, iron, and zinc insufficiency [32].

The sensory evaluation of biscuits formulated with varying compositions of wheat and soybean flour (sprouted and unsprouted) provides valuable insight into consumer preference and the functional implications of ingredient substitution. This superior acceptability of Sample A underscores the traditional sensory appeal of wheat-based biscuits, often characterized by favourable mouthfeel, neutral flavour, and consistent colour. In contrast, substituting wheat flour with unsprouted soybean flour significantly diminished all sensory qualities, especially taste, likely due to the presence of anti-nutritional factors and beany flavours associated with raw soybeans.

This aligns with the findings of other studies, which generally indicate that substituting wheat flour with up to 10-20% soybean flour or pulp can maintain acceptable sensory qualities, but higher substitution levels often lead to a significant decrease in overall taste and texture [33, 34].

Sample C, containing 50% sprouted soybean flour, showed modest improvement over B, though still significantly lower than A in acceptability. Sprouting likely reduces anti-nutrients, improves flavour, digestibility, and enhances sensory appeal in sprouted legume-based foods [35]. Although sample C (50% sprouted soybean flour) showed modest sensory improvement over sample B, both composite biscuits scored significantly lower than the wheat-only control, indicating that the inclusion of soybean flours introduced off-notes and textural differences unfamiliar to consumers accustomed to traditional wheat biscuits. This pattern reflects a

common trade-off in composite flour products where nutritional enhancement may come at the expense of sensory appeal. Biscuits formulated from wheat–sweet potato–soybean composite flour exhibited increased protein and fibre content compared to control biscuits, yet only particular substitution ratios achieved the highest sensory acceptability, suggesting that legume incorporation must be carefully balanced for consumer liking [36]. In another study, composite biscuits made with wheat flour blended with soybean, bambara groundnut, and African yam bean flours demonstrated improved nutritional composition, but the highest sensory scores were achieved by formulations with lower levels of legume inclusion, further underscoring that higher legume content can negatively impact taste, aroma, and texture [37]. These results suggest that while partial substitution of wheat flour with soybeans, primarily sprouted soybeans, can offer nutritional benefits, such substitutions may affect consumer acceptance. Optimization through controlled sprouting time, flavour masking, or blending with other functional ingredients could enhance both nutrition and palatability.

CONCLUSION

The addition of sprouted soybean flour at 50% substitution level greatly improved the nutritional profile of the wheat-based biscuits, especially the protein and mineral content, compared to the control. However, because the sample was made entirely of wheat flour, it continued to be the most favoured in terms of appearance, taste, texture, and aroma; these nutritional advantages came at the expense of sensory acceptability. These results highlight sprouted soybean flour's nutritional potential as a useful ingredient, but more formulation changes might be required to increase biscuit production's consumer acceptability.

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