IPS Journal of Nutrition and Food Science
ISSN: 3115-5391
IPS J Nutr Food Sci, 6(1): 691-695 (2026)
DOI: https://doi.org/10.54117/jzx5gs54

Development and Evaluation of Chia Fortified Cassava Soy Biscuits

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Abstract
Biscuits are widely consumed cereal-based snacks; however, rising wheat import costs and increasing gluten intolerance in African especially, Nigeria necessitates exploring alternative flour sources. This study investigates the use of composite flours made from cassava, soybean, and chia seeds for biscuit production. Cassava flour was prepared through fermentation and drying, while soybean and chia seeds were soaked, dried, and milled. Composite flours were formulated in varying ratios, with cassava content ranging from 60% to 100%, and used to produce biscuits. The flours and biscuits were subjected to proximate, anti-nutrient, functional, vitamin, mineral and sensory analyses. Results of the flour blends have moisture, fat, ash, fibre, protein, carbohydrate content ranging from 8.05 to 11.10%, 4.10 to 4.30%, 3.15 to 4.31%, 2.06 to 3.04, 4.89 to 11.06% and 67.57 to 75.83%, respectively. The tannins (0.24-1.08 mg/g) and phytate (0.49-1.54 mg/g) content were within the acceptable recommended safe level. Vitamin B_1 and B_3 levels, as well as calcium and potassium content, improved with increased in soybeans and chia powder in the composite flour. Sensory evaluation showed that Sample A (60% cassava, 30% soybean, 10% chia) had the highest acceptability in taste and texture, while Sample C (80% cassava, 15% soybean, 5% chia) exhibited optimal nutritional value. These findings support the development of nutritious, gluten-free biscuits tailored to evolving consumer health needs and dietary preferences.

Keywords: *Cassava, Composite flour, Functional food, Gluten-free, Nutritional*

Article History
Received: 24 Dec 2025
Accepted: 17 Jan 2026
Published: 26 Jan 2026

Scan QR Code to view

How to cite this paper: Ohijeagbon, O. R., Umaru, S. S., Adetola, R. O., & Oladimeji, T. E. (2026). Development and evaluation of chia fortified cassava–soy biscuits. *IPS Journal of Nutrition and Food Science*, 6(1), 691–695. https://doi.org/10.54117/jzx5gs54

1. Introduction

Bakery products such as biscuits are consumed all over because they are convenient, cheaper in relation to other products, have long shelf life, and are acceptable by all age groups. The use of refined wheat flour, sugar and fat is considered a traditional method of making biscuits a source of energy but rather lacking in vitamins, minerals, and other essential nutrients like fiber and high-quality protein (Hu *et al*., 2022). In most developing countries the dependency on products based on wheat is further undermined by the expensive nature and low production of wheat in the region, which has seen a rise in the focus into the use of other product lines of local produce to develop bakery products (Padhy *et al*., 2024). Therefore, the production of functional ingredients enriched biscuits with composite flours and nutrients has attracted a lot of interest.

Cassava (*Manihot esculenta*) is one of the major staple crops in tropical and subtropical areas and plays a primary carbohydrate source to millions of humans. This makes it a valuable source of food and income for more than 800 million people in rural areas (Nassar and Ortiz, 2010). It has been appreciated due to its flexibility to low soils and droughts with this rendering it a significant food security crop. Explorations have been conducted on cassava flour as a replacement of wheat flour in baked goods, but the nutritional composition of cassava flour is low in protein, fat, and micronutrients (Ugwuona *et al*., 2023). Moreover, gluten is not present in cassava flour which impacts the structure and the texture of baked products (Chebitok *et al*., 2025). These deficiencies require fortification or mixing with other products rich in nutrients so as to enhance the overall nutritional and functional value of the products made out of cassava (Nabubuya *et al*., 2025).

Soybean (*Glycine max*) is a very significant legume, which is very healthy and has high-quality protein that comprises all the essential amino acids in a relatively equal composition to that of animal products (Guo *et al*., 2022). Soybeans are considered to be good source of healthy fats, minerals and bioactive compounds like isoflavones, which have been known to have several benefits to health (Swallah *et al*., 2023). Addition of soy flour to cereal- or root-based products has proven to markedly raise the protein levels in the product and to balance the amino acids. Soy flour is also used in composite flour formulations to offset the shortage of proteins that are found in cassava flour hence enhancing nutritional quality of baked goods like biscuits (Kalu, 2023). Nonetheless, soy content should be optimally incorporated to prevent the unwanted sensory properties, including beany taste or extreme hardness.

Chia seeds (*Salvia hispanica*) is an ancient crop which was formerly grown in Central and South America, but has become known across the world as a functional food ingredient thanks to its outstanding nutritional value. It has become a common plant grown in East Africa, including Tanzania, due to their high nutritional composition. Chia seeds are also high in dietary fiber, good quality protein, omega-3 fatty acids (α-linolenic acid), antioxidants and the most important minerals of calcium, iron and magnesium (Agarwal *et al*., 2023). Chia seeds are rich in soluble fibres, which is the reason why it has water-holding capacity and gel-forming properties that may affect the rheology and texture of the baked goods. Moreover, incorporation of chia seeds in the food preparations has been linked with possible health effects, such as, cardiovascular, better glycemic control and additional digestive effects.

The seeds can be blended with cassava to make cassava-chia seeds composite flour at the household level. Chia seeds reportedly have protein (15-25%), fats (30 - 33%), ash (4 - 5%), dietary fibre (18 - 30%), minerals, vitamins, antioxidants, and other phenolic compounds (Marcinek & Krejpcio, 2017). Chia seeds increased nutritional contents (protein, fat, ash) in cassava-chia seeds extruded flour (Otondi *et al.*, 2020). However, the detailed effect of un-extruded flour blends sensory attributes in porridge made from blends remains largely unknown. Yet, replacing chia seeds in wheat bread up to 300g per kg enhanced nutritional benefits without necessarily compromising the overall acceptability of the bread.

Moreover, the blending of cassava and chia seeds can result in different sensory characteristics due to the interaction between food components. Porridge viscosity, colour, taste, mouth feel, aroma are common sensory attributes that affect consumer acceptance and preference of the product (Loydal *et al*., 2025). Cassava contains low protein content (1-2%), which is far too little to meet the recommended dietary allowance (RDA) for infants aged 0 - 4 months, which is 8g per day and infants aged 4 - 12 months (11g per day), respectively. Infants aged 0 - 4 months and 4 -12 months need at least 400 and 550g per day of cassava intake to meet the basic protein requirement, which on the surface appears a lot for their age but which underlines the necessity for more nutrient-dense food formulation. Enhanced nutritional value-added functional foods are a significant approach to address the form of micronutrient deficiency and also enhance the quality of food intake among people who rely solely on starch-rich foods.

The increase in the demand of functional foods, foods that offer health benefits in addition to their essential nutritional value has fueled the interest behind adding chia seeds to products that are regularly used, like biscuits (Masood, 2022). Biscuits are a perfect fortification of nutrients because they are easy to formulate and consumed in large proportions. The addition of cassava flour, soy flour, and chia seeds offers a solution to the development of a more nutritionally balanced biscuit exhibiting high protein, dietary fiber, and healthy fat intake as well as less reliance on imported wheat flour (Ujong *et al*., 2023). These products can be important to treat malnutrition of protein-energy, and deficiency of micronutrients, especially in areas where cassava and soy are easily accessible.

Despite increasing interest in functional and fortified snack products, there is limited research on the development and sensory evaluation of biscuits produced from cassava–soy composite flour enriched with chia seeds (Tuter *et al*., 2025). These products have the potential to serve as convenient, nutrient-dense alternatives to conventional wheat-based snacks, especially in regions affected by gluten intolerance and high wheat import costs. This study aims to develop and evaluate biscuits produced from cassava–soy–chia seed composite flour, focusing on their proximate, minerals and vitamins.

2. Materials and Methods

Raw Materials

Fresh harvested cassava, soybean and chia seeds were obtained from local farms in Gambari, Ogbomoso. Cassava was weighed, peeled, washed and soaked to ferment for three days after which it was dried and grinded to flour. Soybeans were soaked, dried, and milled. Chia seeds were milled directly. The materials in powdered form were mixed together in different proportions to form composite flour.

Composite Flour Preparation for Biscuit Production

Flour blends were produced using different ratios as shown in Table 1. Other baking ingredients were purchased from a local store in Ogbomoso. Biscuits were prepared using standard baking procedures.

Table1: Composite flour blends for production of biscuits

Samples	Cassava flour	Soybean flour	Chia powder
A	60	30	10
B	70	20	10
C	80	15	5
D	75	15	10
E	100 (control)	0	0

Sample A = 60% cassava, 30% soybean, 10% chia seed.
Sample B = 70% Cassava, 20% soybean, 10% chia seed.
Sample C = 80% Cassava, 15% soybean, 5% chia seed.
Sample D = 75% Cassava, 15% soybean, 10% chia seed.
Sample E = 100% cassava flour

Methods
The flour blend samples were analyzed for proximate composition, anti-nutrient constituents (tannins and phytates), functional properties, vitamin content (vitamin B_1 and B_3) and mineral content (potassium and calcium) using standard procedures (AOAC, 2005). and sensory evaluation were carried out on the product (biscuits) by twenty (20) trained panelists using a 9-point hedonic scale to assess appearance, flavor, texture (crispness), taste, aftertaste, and overall acceptability.

Statistical Analysis: Data obtained from this study were subjected to the Statistical Package for Social Sciences (SPSS, IBM SPSS Statistical version 21) using one-way analysis of variance (ANOVA). The mean was separated using the Least Significant Difference (LSD) test of all determined parameters. All statistical test was carried out at a 95% confidence level.

3. Results and Discussion

The proximate analysis of the flour blends was as shown in Table 2. The protein ranged 4.89-11.06%, Sample A exhibited the highest protein content (11.10%) due to a higher proportion of soybean flour, followed by Sample C (10.05%) while Sample E (control) had the lowest protein (4.89%). The high protein content of soybean flour compared to cassava and chia seed, as emphasized in prior research (Masood, 2022). Samples A has the highest moisture content of 11.06% and Samples B (7.13%) has the lowest. The elevated moisture levels noted in the flour were similar to the findings of Tortoe *et al*. (2017). Fat content ranged 4.10-4.30%, the highest value 4.30% was Sample D while Sample C had the lowest of 4.10%. The ash content of the composite flour examined in this study ranged from 3.15% to 4.31%, with the highest value of 4.31% in Sample D and the lowest value of 3.15% in Sample E. This is higher compared with 1.85% ash content reported by Agbara *et al.* (2022). Ash and fiber content in the flour blends were significantly enhanced with the addition of chia and soybean. All samples exhibited significant differences ($p < 0.05$). The minerals present in the composite flour contribute to its higher ash content.

Fiber content, samples C and D were the most abundant, with 2.88 % and 3.04 %, respectively followed by sample B with 2.48%, while sample A had the lowest fiber content of 2.06%. The high fiber levels in Samples D and C can be attributed to the inherent richness in dietary fiber found in the composite flour as documented by previous studies (Ubbor *et al.*, 2022). Fiber in composite flour enhances its nutritional value by providing dietary fiber, which supports digestive health and helps regulate blood sugar levels. Additionally, fiber contributes to overall satiety and may aid in weight management. Significant differences were observed in all the samples ($p < 0.05$).

The anti-nutrient constituents of the flour blends (Table 3) revealed the total tannin content of the flour which ranged from 0.49 to 1.08 mg/100g. This increase or decrease in tannin concentration may be attributed to the incorporation of chia seeds, which are known to be a rich source of polyphenolic compounds. The presence of tannins contributes to the antioxidant activity of the flour blend which potentially offers health benefits such as reducing oxidative stress and inflammation in the body (Cosme *et al*., 2025). The phytates content of the flour blends ranged from 0.24 to 1.54 mg/g. Phytate plays a significant role in the flavor and aroma profile of foods and may also exhibit various health benefits, including antimicrobial and anti-inflammatory effects (Pujo *et al*., 2023).

Table 2: Proximate composition of the flour blend samples

Sample	Moisture (%)	Fat (%)	Ash (%)	Fibre (%)	Protein (%)	CHO (%)
A	11.06±0.09^{a}	4.15±0.07^{a}	4.10±0.00^{c}	2.06±0.01^{d}	11.06±0.09^{a}	67.57±0.07^{d}
B	7.13±0.01^{d}	4.25±0.07^{a}	3.18±0.03^{d}	2.48±0.05^{c}	7.13±0.01^{d}	75.83±0.05^{a}
C	10.05±0.07^{b}	4.10±0.00^{a}	4.20±0.01^{b}	2.88±0.04^{b}	10.05±0.07^{b}	68.72±0.12^{d}
D	8.05±0.07^{c}	4.30±0.13^{a}	4.31±0.01^{a}	3.04±0.03^{a}	8.05±0.05^{c}	72.25±0.07^{c}
E	11.10±0.00^{a}	4.20±0.00^{a}	3.15±0.07^{d}	2.10±0.07^{d}	4.89±0.00^{e}	74.56±0.07^{b}

Values with the same superscript alphabets are not significant differences (p<0.05). Sample A = 60% cassava, 30%soybean, 10% chia seed; Sample B = 70% Cassava, 20% soybean, 10% chia seed; Sample C = 80% Cassava, 15% soybean, 5% chia seed; Sample D = 75% Cassava, 15% soybean, 10% chia seed; Sample E = 100% cassava flour

Table 3: Anti-nutrient constituents of the flour blends

Samples	Tannins (mg/g)	Phytate (mg/g)
A	0.36 ± 0.00^{c}	0.73 ± 0.00^{c}
B	0.44 ± 0.04^{b}	0.89 ± 0.08^{b}
C	0.37 ± 0.02^{c}	0.75 ± 0.04^{c}
D	0.24 ± 0.45^{d}	0.49 ± 0.09^{d}
E	1.08 ± 0.03^{a}	1.54 ± 0.01^{a}

Values with the same superscript alphabets are not significant differences (p<0.05). Sample A = 60% cassava, 30%soybean, 10% chia seed; Sample B = 70% Cassava, 20% soybean, 10% chia seed; Sample C = 80% Cassava, 15% soybean, 5% chia seed; Sample D = 75% Cassava, 15% soybean, 10% chia seed; Sample E = 100% cassava flour

The functional properties of the flour blends were assessed on gelation, swelling capacity, bulk density and water absorption capacity (WAC). These characteristics are essential for understanding dough behavior and the quality of the final baked product. Results are presented in Table 4. The gelation result of the flour blends revealed that sample A has the least value of 11.95 and sample C has the highest value of 16.05, whereas there was no significant difference between sample D (12.06) and sample E (12.05). Swelling capacity ranged from 1.20% in Sample B and E to 1.28% in Sample C, reflecting differences in the interaction between chia and other ingredients. Although chia may not significantly enhance foaming capacity due to its fiber-rich composition, it contributes positively to dough stability and product integrity.

The bulk density varied slightly across formulations, with Sample A showing the highest value (0.55 g/mL), likely due to its higher chia content. Chia's ability to absorb water and form viscous gels may account for the denser matrix. Bulk density influences packaging efficiency and product volume. The water absorption capacity (WAC) increased with higher chia inclusion, ranging from 24.00 g/g in Sample A to 28.70 g/g in Sample E. This trend reflects chia's high water-binding capacity, attributed to its soluble fiber and mucilage content. Enhanced WAC contributes to better dough hydration and a softer final texture of the baked products.

Chia increased WAC and reduced spread due to its water-binding capacity. Sample A showed the highest bulk density (0.55 g/mL) and swelling capacity (1.23%).

Table 4: Functional properties of the flour blends

Sample	Gelation	Swelling Capacity (%)	Bulk Density (g/mL)	Water Absorption Capacity (g/g)
A	11.95 ± 0.07^{d}	1.23 ± 0.01^{b}	0.55 ± 0.03^{a}	24.00 ± 0.14^{c}
B	12.05 ± 0.08^{b}	1.20 ± 0.00^{b}	0.49 ± 0.01^{b}	26.30 ± 0.42^{b}
C	16.05 ± 0.07^{a}	1.28 ± 0.03^{a}	0.49 ± 0.01^{b}	28.45 ± 0.07^{a}
D	12.06 ± 0.08^{b}	1.21 ± 0.01^{b}	0.49 ± 0.01^{b}	26.45 ± 0.63^{b}
E	12.05 ± 0.07^{b}	1.20 ± 0.00^{b}	0.49 ± 0.01^{b}	28.70 ± 0.14^{a}

Values with the same superscript alphabets are not significant differences (p<0.05). Sample A = 60% cassava, 30%soybean, 10% chia seed; Sample B = 70% Cassava, 20% soybean, 10% chia seed; Sample C = 80% Cassava, 15% soybean, 5% chia seed; Sample D = 75% Cassava, 15% soybean, 10% chia seed; Sample E = 100% cassava flour

The vitamin content of the flour blends (Table 5) revealed that the fortified samples have vitamin B1 content ranged from 0.32 to 0.35 mg/100 g, with Sample B exhibiting the highest level (0.35 mg/100 g), likely due to its higher soybean and chia seed content. Mineral content of the flour blends (Table 6) revealed high levels of key micronutrients, particularly potassium and calcium, with Sample A showing the highest concentrations. This is attributed to its greater proportion of soy and chia seeds. Additionally, the inclusion of chia may enhance iron bioavailability, potentially contributing to the prevention of iron deficiency anemia. Overall, chia fortification significantly improved the micronutrient profile of the flour blends, offering a more nutritious alternative to conventional formulations and supporting better dietary intake of essential nutrients (Rabail *et al*., 2022). Sample A was richest in potassium, calcium, and B1 vitamins, attributed to chia and soybean. These micronutrients are crucial for growth, immunity, and metabolic function.

Table 5: Vitamin content of the flour blends

Sample	Vitamin B_3 (mg/100 g)	Vitamin B_1 (mg/100 g)
A	0.21 ± 0.00^{e}	0.33 ± 0.01^{ab}
B	0.26 ± 0.00^{a}	0.35 ± 0.11^{a}
C	0.26 ± 0.00^{b}	0.32 ± 0.10^{a}
D	0.23 ± 0.00^{d}	0.32 ± 0.15^{b}
E	0.25 ± 0.00^{c}	0.32 ± 0.01^{b}

Table 6: Mineral content of the flour blends

Sample	Potassium (mg/100 g)	Calcium (mg/100 g)
A	108.16 ± 7.79^{a}	239.61 ± 17.93^{a}
B	51.23 ± 0.00^{bc}	136.08 ± 0.00^{b}
C	63.89 ± 2.29^{b}	156.79 ± 17.93^{a}
D	95.51 ± 13.27^{a}	231.91 ± 17.93^{a}
E	39.70 ± 0.90^{c}	90.21 ± 2.33^{c}

Values with the same superscript alphabets are not significant differences (p<0.05).
Sample A = 60% cassava, 30%soybean, 10% chia seed; Sample B = 70% Cassava, 20% soybean, 10% chia seed; Sample C = 80% Cassava, 15% soybean, 5% chia seed; Sample D = 75% Cassava, 15% soybean, 10% chia seed; Sample E = 100% cassava flour

The sensory analysis of the four biscuit samples was conducted to evaluate consumer acceptability based on appearance, flavor, crispness, taste, aftertaste, and overall acceptability (Table 7). This assessment is crucial in determining how varying proportions of cassava flour, soybean flour, and chia seed affect sensory qualities. The result shows that the overall acceptability was sample A>D>B>C with the value of 8.23>7.87>7.83>7.07. Among all samples, Sample C with the blends of 80% cassava flour, 15% soybean flour, and 5% chia seed, has the lowest rating in appearance (7.17), flavour (6.70), crispness (6.63), taste (6.43), aftertaste (6.40), and overall acceptability (7.07). Sample A, formulated with 60% cassava flour, 30% soybean flour, and 10% chia seed, consistently received the highest ratings across all evaluated parameters. Specifically, Sample A scored 7.77 for appearance, 7.90 for flavour, 8.00 for crispness, 8.13 for taste, 8.03 for aftertaste, and 8.23 for overall acceptability on a 9-point hedonic scale.

These results suggest that the combination of flours in Sample A offered a balanced sensory experience that was well-received by the trained panelists. The favorable appearance can be attributed to the golden-brown color and uniform surface, while the enhanced flavor and aftertaste likely resulted from the nutty, slightly earthy contributions of chia and soybean flours. The high crispness and taste scores reflect an optimal texture and flavor release during chewing, further enhancing the eating experience. In comparison, other samples with different proportions of chia and soybean flours scored slightly lower across most categories, indicating that deviations from the 60:30:10 cassava-soy-chia ratio may compromise product appeal. These findings are consistent with earlier studies, which highlight that strategic blending of root and legume flours with nutrient-dense seeds like chia can yield products with superior sensory attributes (Matias *et al*., 2024).

Table 7: Sensory properties of biscuit samples

Samples	Appearance	Flavor	Crispness	Taste	After Taste	Overall Acceptability
A	7.77±0.82[a]	7.90±0.76[a]	8.00±0.91[a]	8.13±0.68[a]	8.03±0.67[a]	8.23±0.57[a]
B	7.40±0.93[ab]	7.43±0.77[a]	7.83±0.83[a]	7.80±0.88[a]	7.60±0.93[a]	7.83±0.83[a]
C	7.17±1.08[b]	6.70±1.12[c]	6.63±1.37[b]	6.43±1.43[b]	6.40±1.67[b]	7.07±0.91[b]
D	0.28±0.80[ab]	7.57±0.86[a]	7.63±0.93[a]	7.70±0.91[a]	7.57±0.97[a]	7.87±0.86[a]

The means within the same column with different superscripts are significantly different ($p<0.05$). Sample A = 60% cassava, 30%soybean, 10% chia seed; Sample B = 70% Cassava, 20% soybean, 10% chia seed; Sample C = 80% Cassava, 15% soybean, 5% chia seed; Sample D = 75% Cassava, 15% soybean, 10% chia seed

4. Conclusion

The use of chia seed can be enhanced and its usage in the blends significantly improved the nutritional profile of cassava-soy flour blends and biscuits, particularly in protein, fiber, minerals and sensory attributes. The biscuit can serve as a snack and may also exhibit various health benefits, including antimicrobial and anti-inflammatory effects. This biscuit can serve as food and source of income according to sustainable developmental goal 1(no poverty) and 2 (zero hunger).

Conflict of interests: the authors declare that they have no conflict of interests.

Funding: This research did not receive any funding from any agencies

Authors Contributions: All contributed towards the study design, experimental execution, data analysis and manuscript drafting

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