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PROCESSING FORMULATION AND NUTRITIONAL COMPOSITION OF FOOD MADE FROM UNRIPE PLANTAIN AND SOYBEAN FLOUR

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Abstract - Malnutrition and food insecurity are pressing challenges, particularly in developing regions where access to nutritious meals is limited. This study investigated the nutritional, functional, and sensory properties of food blends made from unripe plantain (Musa paradisiaca), a fiber-rich crop with resistant starch and antioxidants, and soybeans, a protein-dense legume containing bioactive compounds like isoflavones. The aim was to develop affordable, nutritious food products capable of addressing these challenges. Matured unripe plantains and soybeans were sourced locally in Ede metropolis, Osun State, Nigeria. Plantains were processed into flour by peeling, slicing (5 mm), steam-blanching at 100°C for 15 minutes, drying at 60°C to constant weight, milling, and sieving. Soybeans were cleaned, dehulled, defatted with n-hexane, air-dried, milled into fine flour, and sieved. Blends of plantain and soybean flours were prepared in different ratios (e.g., 50:50, 70:30), and their nutritional, functional, and sensory properties were evaluated. Statistical analyses were conducted using SPSS, with one-way ANOVA ($p \leq 0.05$) used to determine significant differences. Results revealed that Sample A (50:50 blend) had the lowest moisture content (9.05±0.02), while Sample D (70:30 blend) had the highest (10.01±0.03), influencing shelf life. Sample A exhibited the highest ash content (4.74±0.01), indicating a rich mineral profile, while vitamin A content increased with higher plantain proportions, peaking at 0.12±0.00 in Sample D. Iron levels were high across all samples, with Sample D (13.56±0.02) having the highest concentration. Sensory evaluation showed that Sample D scored highest in taste (8.00±0.85), flavor (7.45±0.94), and overall acceptability (8.30±0.92), highlighting enhanced consumer preference with higher plantain content. The findings demonstrate the potential of plantain-soybean blends as nutrient-dense, affordable, and sensory-appealing food products, offering a viable solution to malnutrition and food insecurity in resource-constrained areas.

Key worlds: Formulation, Nutritional composition, Plantain, Soybeans,

1. Introduction

Many households in developing nations grapple with malnutrition and limited access to nutritious meals. Addressing protein-energy malnutrition and improving overall nutrition can be achieved by incorporating functional foods like unripe plantain and soybean flour into diets (Adejumo, 2021). Food processing plays a critical role in the transformation of raw ingredients like plantains and soybeans into consumable forms. It involves a range of methods, including washing, chopping, fermenting, packaging, and cooking. These processes not only extend the shelf life of food but also enhance its safety and nutritional quality. Modern food processing includes both primary and secondary methods and can advance to tertiary processing, which refers to the production of ready-to-eat foods such as frozen pizzas or packaged snacks (Liang et al., 2021). Formulating food products using unripe plantain and soybean flour requires careful consideration of nutritional composition, texture, and taste. Research has demonstrated effective strategies for optimizing the use of these ingredients. Ogunwolu et al. (2022) developed composite flour for bread production, achieving optimal sensory and nutritional qualities by combining 70% unripe plantain flour with 30% soybean flour. They also formulated a snack bar incorporating these ingredients, reporting that the inclusion of soybean flour significantly enhanced protein content and overall nutritional value. These findings highlight the potential of unripe plantain and soybean flour combinations in creating affordable, nutritious, and appealing food products.

Soybeans (*Glycine max*), a globally important crop, are renowned for their high protein and oil content, comprising approximately 60% of their dry weight. They are a rich source of essential amino acids, minerals, and fat-soluble vitamins, making them one of the most valuable plant-based food sources (Alabi et al., 2017; Hegazy & Ibrahim, 2019).

Figure 1: Soybeans (*Glycine Max*)

Soybeans contain phytochemicals such as isoflavones, which have cancer-preventive properties, support bone health through phytoestrogen effects, and help mitigate neovascularization in ocular conditions (Zhu et al., 2015). These attributes render soybeans a cornerstone of food innovation, providing functional and nutritional benefits for human health. Nutritionally, soybeans are composed of approximately 40% protein, 20% oil, 35% carbohydrates, and 5% ash. The proteins primarily belong to the globulin family, such as glycinin and beta-conglycinin, which play critical roles in nutrition and plant growth (Kjær, 2013). Soybean carbohydrates, mainly fibers and oligosaccharides, contribute to dietary fiber intake, though certain oligosaccharides can cause digestive discomfort due to gas production during microbial fermentation in the intestine (Choi & Rhee, 2016). The oil content in soybeans is rich in unsaturated fatty acids like linoleic and α-linolenic acids, which are beneficial for heart health, alongside minor saturated fats like palmitic and stearic acids. Soybeans also contain phytoestrogens, particularly isoflavones, which can bind to estrogen receptors in humans, influencing various physiological processes. These compounds have antioxidant properties, protect against DNA oxidation, and enhance antioxidant enzyme activity (Isanga & Zhang, 2018). The mineral composition includes potassium, calcium, magnesium, and trace elements such as iron and zinc. However, their bioavailability may be reduced by the presence of phytates, which bind to minerals and inhibit absorption. Soybeans are particularly beneficial during pregnancy, as they are rich in folic acid and vitamin B complexes, which are vital for fetal development and reducing the risk of birth defects (Dixit et al., 2019). Additionally, the antioxidants present in soybeans help combat free radicals, reducing the risk of various cancers and supporting the body during cancer treatments (Dixit et al., 2019). These properties make soybeans a versatile and powerful food in preventing and managing numerous health conditions. Nutritionally, soybeans are low in saturated fat and high in protein, vitamins, and essential minerals. According to the USDA, 100 grams of cooked green soybeans provide 141 kilocalories, 12.35 grams of protein, 6.4 grams of fat, 11.05 grams of carbohydrates, and 4.2 grams of fiber. They are an excellent source of calcium, iron, magnesium, phosphorus, potassium, and thiamin, supporting various physiological processes (Tan, 2019). These qualities highlight soybeans as a critical component of a balanced diet. In addition to their nutritional value, soybeans have versatile culinary applications. Their neutral flavor enhances the taste of prepared foods without overpowering other ingredients. Soybean oil, with its excellent emulsifying properties, is widely used in salad dressings, sauces, baked goods, and mayonnaise production, making it a cornerstone of the food industry (Mateos-Aparicio et al., 2018). Its adaptability extends to other fats and oils, allowing soybeans to complement and enhance a broad range of food products. These attributes underline the importance of soybeans in both health and food innovation, offering nutritional benefits and versatility across diverse culinary uses. Despite their benefits, soybeans contain antinutritional factors, including lectins, protease inhibitors, and phytates, which can interfere with digestion and nutrient absorption. Proper processing methods are essential to mitigate these effects and unlock the full potential of soybeans in food applications.

Plantain (*Musa spp*) flour, derived from unripe plantains, offers notable health benefits. Its high fiber content supports digestive health by regulating bowel movements, preventing constipation, and promoting satiety, which aids in weight management (Adejumo, 2021).

Figure 2: Unripe Plantain (Musa S*pp.*) and Plantain flour

Plantain flour is rich in essential nutrients, including vitamins A, C, and E, as well as potassium, magnesium, and calcium, which contribute to strong bones, healthy skin, and a robust immune system (Hariri et al., 2021). Additionally, its significant antioxidant activity may help combat oxidative stress, reducing the risk of chronic diseases such as heart disease and cancer (Pontieri, 2021). As a gluten-free alternative to wheat flour, plantain flour is suitable for individuals with gluten intolerance or celiac disease, offering a versatile option for diverse recipes. Its higher mineral content compared to wheat flour further enhances its appeal as a nutritious choice for improving overall dietary quality (Adewumi & Odunfa, 2019). Soybeans also offer a wide range of health benefits. Their high magnesium content aids in treating sleep disorders such as insomnia by enhancing sleep quality and duration. They possess anti-diabetic properties, promoting insulin receptor production and supporting diabetes management due to their low carbohydrate content. Rich in iron and copper, soybeans facilitate red blood cell production, improving blood circulation effectively. During pregnancy, soybeans serve as a valuable source of folic acid and vitamin B complexes, essential for fetal development and reducing the risk of birth defects. Furthermore, the antioxidants in soybeans help eliminate free radicals, reducing cancer risks and supporting the body during cancer treatments.

Unripe plantains provide a rich source of carbohydrates, vitamins, and minerals, while soybeans offer high protein content, isoflavones, and functional health benefits. When combined, these ingredients can enhance food quality and mitigate dietary deficiencies effectively (Hariri et al., 2021; Pontieri, 2021). Research underscores the potential of processing techniques such as fermentation to improve the nutritional and functional properties of these ingredients, facilitating the development of composite flours and recipes that promote healthy eating habits and tackle food insecurity (Adewumi & Odunfa, 2019; Odenigbo et al., 2020). Incorporating unripe plantains and soybean flour into meals delivers significant nutritional advantages. These ingredients enhance nutrient intake, contributing to better health outcomes for households, particularly in resource-limited settings. Their use also promotes dietary diversification by expanding food options and addressing the monotony of staple-based diets. Moreover, the affordability of plantains and soybeans makes them accessible to low-income households, while increased awareness of their nutritional benefits empowers families to make informed dietary choices.

The integration of unripe plantain and soybean flour into food formulations represents a promising approach to addressing nutritional deficiencies and food insecurity. By leveraging their complementary nutritional profiles and functional properties, these ingredients can be utilized to develop a diverse range of products, from bread to snack bars, supporting healthier dietary practices in various populations. Soybeans are a highly nutritious food, particularly valuable for vegans and vegetarians due to their complete protein profile, which contains all nine essential amino acids. They offer a variety of health benefits and have long been incorporated into diets worldwide. One significant benefit is their ability to treat sleep disorders such as insomnia, as the high magnesium content in soybeans improves sleep quality and duration (Dixit et al., 2019). They also aid in diabetes management through their low carbohydrate content and ability to promote insulin receptor production, demonstrating strong anti-diabetic properties (Dixit et al., 2019). Furthermore, soybeans improve blood circulation due to their iron and copper content, which are essential for generating red blood cells (Dixit et al., 2019). Nutritionally, plantain flour is rich in dietary fiber, which supports digestive health, promotes satiety, and aids in weight management (Jimoh et al., 2018). It contains vitamins such as C and A, and minerals including potassium and magnesium, which contribute to immune function, bone health, and heart health. Its phenolic compounds provide antioxidant properties, reducing oxidative stress and potentially lowering the risk of chronic diseases (FAO, 2019). The low glycemic index of plantain flour also aids in blood glucose control and lipid profile improvement, making it beneficial for managing diabetes (Nwosu & Ogunjobi, 2017).

2. Materials and Methods

Unripe plantain flour (*Musa paradisiaca*) is a known nutritious, gluten-free alternative to wheat flour, widely recognized for its versatility and health benefits (FAO, 2019). Production involves peeling, slicing, and drying plantains, followed by grinding into a fine powder. This process retains the light yellowish color and slightly sweet taste of the flour, making it suitable for a variety of recipes (Ene-Obong, 2019). For this study, matured unripe plantain and soybean were purchased from local markets in Ede town, Osun State, southwestern Nigeria.

Plantain flour was prepared following the processing steps described by Kure et al. (2016). Fresh unripe plantain was removed from bunches, washed, peeled manually, sliced into 5mm widths using a slicer, steam-blanched at 100°C for 15 minutes, and dried in a conventional oven (model PP 22 US, GenLab, England) at 60°C to constant weight. The dried slices were milled and sieved to pass through a 0.25 mm mesh sieve, then packaged in a low-density polyethylene bag, sealed, and stored at 4°C for subsequent use.

The procedure is shown in Figure 3 A1 and B1. Soybean seeds were cleaned and sorted manually to remove dirt such as leaves and stones. The cleaned soybean seeds were coarsely milled to separate the coat from the cotyledon. The dehulled seeds were milled into fine soybean flour using an attrition mill. The fine soybean flour was then defatted using cold extraction with n-hexane. The defatted flour was air-dried, the clumps were broken into fine flour, and it was sieved through a mesh screen. The product was then packaged in an airtight low-density polyethylene bag labelled A2 and B2 has shown in Figure 4.

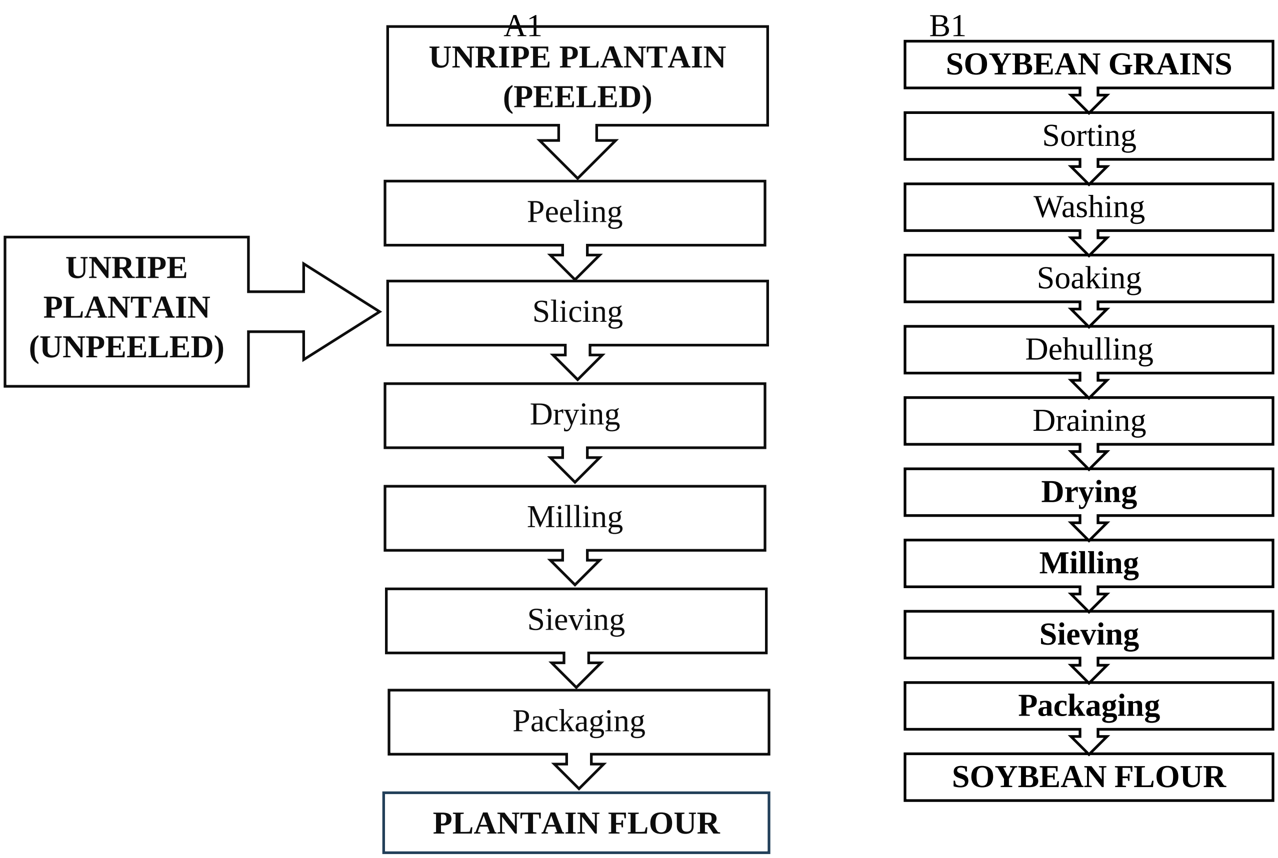

Figure 3. Flow diagram for Preparation of unripe plantain flour from peeled and unpeeled plantain (A1) and Soybean flour

production (B1)

2.1 Formulation of Unripe Plantain and Soybean Flour Blende

Samples were prepared by combining unripe plantain flour and soybean flour in different proportions to create various blends. The formulations are detailed in Table 1 below:

Table 1: Formulation Rationing of Product

Sample	Unpeeled Plantain%	Peeled Unripe Plantain	Soybean Flour
A	50	-	50
B	70	-	30
C	-	50	50
D	-	70	30

Each sample was meticulously mixed to ensure homogeneity before further analysis and processing. These formulations were designed to evaluate the nutritional composition and processing characteristics of the resulting food products.

2.2 Proximate Analysis

Samples were analyzed chemically according to the official methods of analysis described by the Association of Official Analytical Chemists (A.O.A.C., 18th Edition, 2005). All analyses were carried out in duplicate to determine crude protein, carbohydrate, fiber, ash, crude fat or ether extract, dry matter and moisture content.

2.3 Preparation and Sensory Analysis

The products formulated from the unpeeled and peeled unripe plantain with soybean combinations were prepared into swallow food form ready for consumption. To prepare the amala, 100 ml of water was placed in a clean pot and brought to a boil at 100°C. The flour was then sieved into a clean bowl to remove any lumps. Subsequently, the combined plantain and soybean flours were stirred into the boiling water until a smooth consistency was achieved. To moderate the texture, a small amount of warm water was added, and the mixture was allowed to cook for an additional five minutes. The cooked flour was portioned into sizable forms of amala for sensory evaluation. This preparation method was consistently applied to all the different ratios used in the study. Sensory evaluation of the food samples was conducted based on Iwe's (2014) method. Twenty semi-trained panelists from the Nutrition and Dietetics Department, Federal Polytechnic Ede, assessed the samples. The panelists evaluated taste, appearance, aroma, texture, and overall acceptability using a 9-point hedonic scale ranging from "like extremely" (9) to "dislike extremely" (1). Portable water was provided between samples to prevent taste interference.

2.4 Statistical Analysis

Organoleptic tests and experiments were conducted, and results were analyzed using SPSS software. Mean and standard deviation was calculated, while one-way ANOVA with Duncan's multiple range test (significance level $p \leq 0.05$) was applied to determine the statistical significance of differences among the samples

3.0 Results

3.1 Food Product

Figure 4. A2) Soybean and Plantain Unpeeled and B2) Soybean and Plantain Peeled

3.2 Proximate Analysis

Proximate analysis is a fundamental method for assessing the nutritional composition of food samples, providing insights into key parameters such as moisture, ash, protein, fat, fiber, and carbohydrate content. These parameters are crucial in evaluating the quality, shelf life, and overall nutritional value of food products. Moisture content affects product stability, while ash content reflects the mineral composition, both of which are significant for food formulation and storage considerations.

In this study, the results revealed that Sample A had the lowest moisture content (9.05±0.02), whereas Sample D exhibited the highest (10.01±0.03). Moisture content is directly linked to shelf life, with higher levels potentially increasing the risk of microbial growth and spoilage. Regarding ash content, Sample A demonstrated the highest value (4.74±0.01), indicative of a rich mineral profile, while Sample D showed the lowest (4.25±0.06). This observation aligns with established findings that unripe plantains are nutrient-dense and serve as a valuable source of essential minerals.

Table 2: Proximate Analysis of Formulation Composition

SAMPLE	Moisture	Ash	Fibre	Fat	Protein	CHO	E^{o}
A	9.05±0.02	4.74±0.01	5.05±0.01	2.12±0.02	13.13±0.00	65.66±0.41	2.85±0.29
B	9.53±0.06	4.31±0.00	5.58±0.00	3.32±0.01	11.97±0.06	65.29±0.14	2.89±0.07
C	9.99±0.02	4.40±0.01	5.21±0.02	2.08±0.02	12.83±0.50	65.46±0.051	2.82±0.78
D	10.01±0.03	4.25±0.06	5.03±0.01	2.04±0.01	12.09±0.04	66.56±0.12	2.84±0.26

% CHO = 100 (% CP+ % CFAT+ % CFIBRE+ % ASH+% M), % DM=100 - % M, % DF = FIBRE
± Standard deviation (degree of freedom, n=3)
Mean values with different superscripts in each column as significantly different at p≤0.05.
Samples A= Unpeeled Unripe Plantain (50%) Peeled Unripe Plantain (0%) Soybeans (50%)
Samples B = Unpeeled Unripe Plantain (70%) Peeled Unripe Plantain (0%) Soybeans (30%)
Samples C = Unpeeled Unripe Plantain (0%) Peeled Unripe Plantain (50%) Soybeans (50%)
Samples D = Unpeeled Unripe Plantain (0%) Peeled Unripe Plantain (70%) Soybeans (30%)

3.3 Micronutrients Assay

The micronutrient evaluation revealed an increase in vitamin A content from Sample A (0.09±0.01) to Sample D (0.12±0.00). This suggests that a higher proportion of peeled unripe plantain enhances vitamin A levels, a vital nutrient for maintaining healthy vision, immune function, and cell growth. Iron content was notably high across all samples, with Sample D showing the highest level (13.56±0.02). This observation aligns with existing studies highlighting soybeans' contribution to improving iron intake, particularly in plant-based diets. Adequate vitamin A and iron intake is essential for preventing deficiencies such as night blindness and anemia, underlining the nutritional value of these formulations.

Table 3: Micronutrient Assay

SAMPLES	Vitamin A	Iron
A	0.09±0.01	12.96±0.01
B	0.11±0.00	13.09±0.05
C	0.12±0.00	13.11±0.01
D	0.12±0.00	13.56±0.02

± Standard deviation (n=3)
Mean values with different superscripts in each column as significantly different at p≤0.05.
Samples A= Unpeeled Unripe Plantain (50%) Peeled Unripe Plantain (0%) Soybeans (50%)
Samples B = Unpeeled Unripe Plantain (70%) Peeled Unripe Plantain (0%) Soybeans (30%)
Samples C = Unpeeled Unripe Plantain (0%) Peeled Unripe Plantain (50%) Soybeans (50%)
Samples D = Unpeeled Unripe Plantain (0%) Peeled Unripe Plantain (70%) Soybeans (30%)

3.3 Sensory Evaluation Analysis

The sensory evaluation results showed that Sample D received the highest scores for taste (8.00±0.85), flavor (7.45±0.94), and overall acceptability (8.30±0.92). These findings suggest that incorporating higher proportions of peeled unripe plantain enhances the sensory qualities of the product, contributing to its improved palatability and consumer appeal.

Table 4: Sensory Evaluation Analysis

Samples	Taste	Flavor	Colour	Texture	Consistency	Overall
A	7.00±1.07	6.65±0.81	6.60±0.88	6.20±1.19	6.25±1.51	7.50±0.94
B	6.80±1.15	6.70±1.26	6.45±0.99	6.55±1.63	6.40±1.46	6.80±1.10
C	7.60±1.18	7.10±0.91	7.65±1.22	6.80±1.36	6.60±0.94	7.40±1.04
D	8.00±0.85	7.45±0.94	7.10±1.16	6.90±0.91	7.05±1.19	8.30±0.92

± Standard deviation (n=3)
Mean values with different superscripts in each column as significantly different at p≤0.05.
Samples A= Unpeeled Unripe Plantain (50%) Peeled Unripe Plantain (0%) Soybeans (50%)
Samples B = Unpeeled Unripe Plantain (70%) Peeled Unripe Plantain (0%) Soybeans (30%)
Samples C = Unpeeled Unripe Plantain (0%) Peeled Unripe Plantain (50%) Soybeans (50%)
Samples D = Unpeeled Unripe Plantain (0%) Peeled Unripe Plantain (70%) Soybeans (30%)

Discussion of findings

The proximate, micronutrient, and sensory evaluation analyses revealed key insights into the nutritional composition, functional properties, and consumer preferences of food products made from varying proportions of unripe plantain and soybean flour. Moisture content which is a critical factor influencing shelf life and microbial stability, ranged from 9.05±0.02% in Sample A to 10.01±0.03% in Sample D. Higher moisture content in Sample D is attributed to the increased proportion of peeled plantain, which retains more water. Ash content, indicative of mineral composition, was highest in Sample A (4.74±0.01%), reflecting the mineral richness of soybeans, and lowest in Sample D (4.25±0.06%). Fiber content, essential for digestive health, was highest in Sample B (5.58±0.00%) due to the inclusion of unpeeled plantain, which retains fibrous skin. Fat content was also highest in Sample B (3.32±0.01%), while Sample D had the lowest (2.04±0.01%), corresponding to differences in plantain preparation.

Protein content was highest in Sample A (13.13±0.00%) due to the 50% soybean composition, while Sample B had the lowest (11.97±0.06%). Carbohydrate content was highest in Sample D (66.56±0.12%), aligning with its higher plantain content. Energy values followed similar trends, reflecting the contribution of macronutrients. Vitamin A content increased with higher proportions of peeled plantain, peaking in Sample D (0.12±0.00 mg). This highlights plantain's role in providing provitamin A carotenoid. Iron content was highest in Sample D (13.56±0.02 mg), consistent with soybeans' contribution to iron intake, essential for hemoglobin formation and oxygen transport. Sample D scored highest across sensory parameters, including taste (8.00±0.85), flavor (7.45±0.94), and overall acceptability (8.30±0.92). Its higher peeled plantain content contributed to enhanced palatability, smoother texture, and consistent flavor. In contrast, higher unpeeled plantain proportions in other samples were associated with lower scores due to fibrous texture and bitter taste. These findings demonstrate the potential of unripe plantain and soybean flour in creating nutritionally balanced, consumer-accepted food products. Higher soybean content in the formulations increased protein levels, while higher peeled plantain content enhanced carbohydrate content and significantly improved sensory attributes. Samples with greater proportions of peeled plantain, such as Samples C and D, demonstrated higher levels of vitamin A and iron, underscoring the contribution of plantain to boosting micronutrient intake and enhancing dietary quality. Sensory analysis revealed that Sample D, with a higher peeled plantain and moderate soybean content, was the most preferred across parameters like taste, flavor, texture, and overall acceptability, highlighting the sensory appeal of formulations rich in peeled plantain. This study confirms that blends of unripe plantain and soybean flour can be developed into nutritionally balanced food products, providing an effective solution to address protein and micronutrient deficiencies, particularly iron and vitamin A, in household diets.

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