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Chemical and Functional Properties of Banana Pseudo-Stem Flour-Incorporated Composite Flour and Its Application in Veggie Balls

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Abstract

The Embul banana (*Musa acuminate* L.) is an important agricultural crop in Sri Lanka, and pseudo-stem is its main by product. This study evaluated the chemical and functional properties of composite flour with banana pseudo-stem flour (BPSF) and its potential in veggie ball production while addressing bioresource waste and promoting plant-based meat alternatives. BPSF was prepared by treating the pseudo-stem with 0.2% citric acid, drying at 60 °C for 24 hours, and grinding. The production of veggie balls involved mixing BPSF and Wheat Flour (WF) at ratios of 52:48, 55:45, 58:42, and 60:40 with chickpea, and other ingredients, then shaping and steaming. Among the treatments, the veggie ball containing 60% (w/w) BPSF in the composite flour had the highest acceptability in sensory evaluation (9-point hedonic scale) by thirty semi-trained panelists and was chosen for further analysis. Compared to BPSF alone, the composite flour containing 60% (w/w) BPSF exhibited distinct functional properties, water-holding capacity (686.5±0.04 g/100 g), oil-holding capacity (265.0±0.11 g/100 g), swelling power (5.70±0.03 g/g), and water solubility index (3.38±0.04%). It contained a significantly ($p < 0.05$) higher moisture (9.56±0.08%), carbohydrate (58.66±0.06%), and protein (6.27±0.11%) while showing lower fiber (16.38±0.07%) and ash contents (7.29±0.25%) than BPSF. The proximate composition of the developed veggie balls included moisture (56.87±2.33%), carbohydrate (19.79±2.25%), protein (10.31±0.10%), fat (6.68±0.06%), fiber (3.96±0.02%), and ash (2.39±0.10%). Under frozen conditions, vacuum-packed veggie balls had a shelf-life of approximately three weeks. Thus, BPSF-incorporated composite flour is a viable WF substitute in veggie ball production, serving as a functional and chemical properties enhancer.

Keywords: Banana pseudo-stem; Wheat flour; Wheat flour substitute; Veggie balls; Product quality

Abbreviations: AOAC: Association of Official Analytical Chemistry; BPSF: Banana Pseudo-stem Flour; BPS: Banana Pseudo-stem; CFU: Colony Forming Units; OHC: Oil-holding Capacity; SP: Swelling power; WHC: Water-holding capacity; WSI: Water Soluble Index

Introduction

Banana, which belongs to the family Musaceae, ranks as the fifth most important agricultural food crop in the world and is cultivated in more than 130 countries, particularly in tropical and subtropical regions, including Sri Lanka [1]. Bananas are the most extensively grown fruit, occupying nearly 60,000 hectares of land for cultivation in Sri Lanka. This area accounts for 54% of the total land dedicated to fruit cultivation in the country. After harvesting the bunches, the pseudo-stem is the main byproduct of the banana, which has been discarded as waste, fed to cattle, or used for composting but it can be useful as an alternative food resource [2]. The discarded biomass includes approximately 60 to 80 tons of pseudo-stems [3]. Therefore, the viable utilization of these agricultural residues is of utmost importance for reducing waste, increasing value, and generating additional income.

The banana pseudo-stem possesses health-enhancing attributes, including antihyperglycemic, antimicrobial, hypolipidemic, and antihypertensive properties [4]. Its rich dietary fiber content, antioxidant compounds, and range of essential macro and micronutrients collectively contribute to its positive impact on well-being. The banana pseudo-stem stands out for its significant content of cellulose, hemicellulose, protein, fat, and dietary fibers [5]. As antioxidants, it contains beneficial polyphenols and flavonoids, including ferulic acid, cinnamic acid, and catechin, which are known for their noteworthy antioxidant properties [6]. Although these banana waste materials are abundant in nutrients, particularly minerals such as Calcium, Phosphorous, Magnesium, Potassium, and Sodium, and dietary fibers, the consumption of pseudo-stem is not so popular [7,8]. Banana stems can serve as a versatile food ingredient in salads, curries, stir fries, smoothies, and soup [9]. Nonetheless, it is important to highlight that there have been limited endeavors thus far to convert banana pseudo-stems into food items. Consequently, there is a notable requirement for focused consideration in regard to incorporating banana pseudo-stems into products.

Currently, the production of composite flour, which is made by mixing either binary or ternary mixtures of flours from other crops with or without wheat flour, is common [10]. Composite flours are valuable due to their enhanced nutrition and digestibility. Many developing countries, including Sri Lanka, are encouraging the use of local flour instead of wheat flour. They are trying out composite flours, where some of the wheat flour is replaced with locally grown crops. This helps to reduce the expense of importing wheat and supports the use of homegrown ingredients in food production [11]. They address wheat shortages in tropical regions and promote the efficient use of local resources, reducing waste. Foods made from composite flours are significant for providing high-quality proteins, essential amino acids, vitamins, minerals, and dietary fiber [12].

Wheat flour typically comprises approximately 72% carbohydrates, 8-13% protein, 12-13% moisture, 2.5% sugar, 1.5% fat, 1.0% soluble protein, and 0.5% mineral salts [13]. The addition of banana pseudo-stem flour to wheat flour significantly alters its functional properties, including binding properties and nutritional value [14]. Considering the binding properties, the water-holding capacity and oil-holding capacity are responsible for the good binding properties of the composite flour. The high water-holding capacity of the composite flour can be used in the formulation of many foods, such as processed cheese, bakery products, sausage, meatballs, and dough [15]. The oil-holding capacity is a crucial functional trait that improves mouthfeel while preserving the flavor of food products. The ability of flour to bind with oil is used in food applications such as the production of pastries, meatballs, and sausage [16].

Meatballs can be made of ground beef, pork, or chicken and other ingredients, including additives such as phosphate, salt, water, and spices, along with wheat or corn starch. Although meat is a highly valuable food product due to its nutritional composition, meat-based products have negative effects on humans because of their elevated levels of salt, saturated fats, synthetic additives, and cholesterol, which can lead to a range of chronic illnesses, including obesity, cardiovascular disease, type 2 diabetes, and various forms of cancer [17]. Therefore, consumer preferences for meat alternatives, especially vegan products, are currently increasing. The rising consumer demand for healthier meat alternative products, offering functional benefits, has prompted research endeavors seeking innovative ingredients to reduce or substitute challenging components such as salt, fat, Nitrites, and even meat itself. Different plants, cereals, pulses, seeds, and algae, including coproducts and byproducts, can be used to replace these components.

The chemical and functional properties of the composite flour with banana pseudo-stem flour and wheat flour can be used when preparing veggie balls with chickpeas, texturized soya, and other ingredients. The use of chickpea, soya, and banana stem flour offers diverse nutritional benefits, including protein, dietary fiber, and minerals, which can make this veggie ball a healthier alternative. Exploring the feasibility of this product also opens doors for the food industry to create innovative and marketable plant-based products, potentially reducing the environmental impact of traditional meat-based dishes.

Materials and Methods

Sample Collection

Fresh pseudo-stems from the Embul (*Musa acuminate* L.) variety of bananas were used for this study. The required amount of banana pseudo-stems was collected from a local home garden in Makandura, Sri Lanka. The collected samples were carefully transported to the processing laboratory, where they were refrigerated until processing. Additionally, essential raw materials such as chickpeas, texturized soya, and other necessary ingredients were purchased from the local market.

Preparation of Banana Pseudo-Stem Flour

The outer sheath of the banana pseudo-stem was peeled off manually by using a clean knife to obtain the center core, which was then soaked in 0.2% concentrated citric acid for about 10 minutes. After that, they were rinsed with running tap water and sliced using a stainless-steel knife. Those slices were soaked in 0.2% concentrated citric acid for about 10 minutes (to control browning). After that, they were dried at 60°C for 24 hours. Dried pseudo-stem slices were then ground in a grinder and sieved by passing through a 400μm sieve. The flour obtained was packed in polythene pouches, sealed, and stored at room temperature or in an airtight container at 4°C for further use [18].

Preparation of Composite Flour

Composite flour samples were manually prepared by substituting wheat flour with 52%, 55%, 58%, and 60% banana pseudo-stem flour (BPSF).

Preparation of Veggie Ball

First, the soy chunks were hydrated using boiling water, and the chickpeas were cooked. Then, ground chickpeas (32%), soya meat (28%), composite flour (18%), spices (5%), sunflower oil (4%), salt (3%), and potassium sorbate (0.01%) were mixed to form a smooth ball. Four formulations were prepared by changing the proportion of wheat flour to BPSF in composite flour (replacing wheat flour with 52% (T1), 55% (T2), 58% (T3), and 60% (T4) banana pseudo-stem flour). The mixture was shaped into balls and steamed for 15 minutes. Then, the prepared samples were kept in the freezer for 24 hours. Finally, the balls were packed in a vacuum package and kept in a freezer for future use.

Sensory Evaluation to Select the Best Treatment

The consumer acceptability for veggie balls was determined by using an acceptance test. Sensory attributes such as appearance, aroma, flavor, texture, and overall acceptability were evaluated. The test was carried out with 30 semi-trained panelists. All four veggie ball samples were simultaneously placed on all the consumers in a randomized manner. Advice was given to rate their preference on a 9-point hedonic scale with "9" equaling "like extremely" and "1" equaling "dislike extremely". Composite flour in most preference veggie ball samples was used for further analysis.

Evaluation of functional properties of banana pseudo-stem (BPS) flour and selected composite BPSF–wheat flour

Water Holding Capacity (WHC) and Oil Holding Capacity (OHC): The water-holding capacity and oil-holding capacity were determined according to the method applied by Zanariah, Nur Zaleqha, and Lisnurjannah [19]. First, 2 g of flour sample (BPSF or composite flour) was weighed on an analytical balance (Ohaus, USA) and then mixed with 25 mL of distilled water (for WHC) and oil (for OHC) in a pre-weighed centrifuge tube. Then, the lid was closed and vortexed for about 5 minutes until the water/oil and flour were mixed well. After that, the mixture was centrifuged at 3000 rpm for 25 minutes at room temperature (25 °C). The supernatant was carefully decanted, and the remaining mass in the tube was weighed. The WHC and OHC were calculated by dividing the weight of water/oil absorbed by the weight of the flour, expressed as a percentage. All analyses were performed in triplicate.

Swelling Index (SI) and Water Solubility Index (WSI): The WSI was determined by referring to the method applied in previous study [20]. First, 0.5 g of flour sample was taken into a centrifuge tube. The centrifuge tube with the sample was weighed, and then 20 mL of distilled water was added. After that, it was allowed to warm for 30 minutes in a boiling water bath at 80 °C. The contents were cooled and centrifuged at 5000 rpm for 10 minutes. The residues obtained after centrifugation were weighed and divided by the initial weight of the sample to calculate the SI. To determine the solubility of the flour samples, the dried petri dish was weighed, and 10 mL of supernatant was pipetted into it. Then, the sample was dried at 105 °C in a hot air oven until a constant weight was attained and cooled in a desiccator, and again weighed the petri dish with dry solids. The residue obtained represented the amount of flour granules solubilized in water (grams of dry weight at 105 °C per gram of dry sample).

Bulk Density and Tapped Density

The bulk density of flour was assessed by measuring the weight of the flour relative to its volume. About 1 g of flour was placed into a 10 mL graduated cylinder, and the bulk density was calculated by dividing the weight of the banana pseudo-stem flour by the volume it occupied in the cylinder. The tapped density was obtained by tapping the graduated cylinder to a constant volume using a glass rod. A graduated cylinder was weighed, and the flour sample was filled to 5 mL by constant tapping until there was no further change in volume. The contents were weighed, and the difference in weight was determined. The tapped density was computed as grams per milliliter of the sample [21].

Proximate Analysis

The recommended methods of the Association of Official Analytical Chemists (AOAC, 2000) are adopted to determine the quantity of crude protein, moisture, ash, and fat content of the BPSF, composite flour, and veggie balls. The moisture content was determined by using the oven drying method, in which the sample was dried at 105 °C until it reached a constant weight. The difference in weight before and after drying was recorded and is expressed as the percent moisture content. The protein content was estimated by the Kjeldahl method. The crude fat content was determined by Soxhlet extraction, and the total ash content of the sample was determined by heating at 550 °C for 4 hours in a muffle furnace (dry ashing method). The total carbohydrate content was calculated by the difference between 100 and the sum of the percentages of moisture, ashes, lipids, and crude protein. All sample measurements were performed in triplicate.

Mineral Analysis of BPSF

BPSF was assessed for selected mineral analysis (Mn, Cr, Ni, Cd, As, Zn, Co, Hg, Pb, and Cu) using inductively coupled plasma-mass spectrometry.

Texture Analysis of the Veggie Ball

Parameters such as hardness, gumminess cohesiveness, and chewiness were evaluated by using a texture analyzer (TX 700) (Lamy Rheology, France) with a 2 mm diameter cylindrical probe and a speed of 2 mm/sec.

Cooking Yield

The cooking yield of the veggie ball sample was determined by weighing the sample before and after cooking. The veggie ball was cooked in hot water at 80 °C for 5 minutes and then the surface of the sample was dried. The ratio of cooked weight to raw weight gives the cooking yield, which was then multiplied by 100 to express the result as a percentage [3].

Cooking Loss

To measure the cooking loss of the veggie balls, first, the sample was wrapped in heat-stable foil paper and kept in a water bath at 80 °C for 30 minutes. Then, the surface was dried and weighed. Weight loss is expressed in percentage.

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Shelf-life analysis of the veggie ball

Total Plate count: In the analysis, 10 g veggie ball samples were ground with a sterile mortar and pestle using 90 mL of sterile 0.1% peptone water. Serial dilutions were made in the same medium, and duplicates were inoculated on plates via the pour plate method. Approximately 15-20 mL of cooled nutrient agar (45 °C) was poured into the inoculum. After that, the sample with agar was mixed thoroughly by rotating the petri dishes and left on a horizontal surface, allowing the agar to solidify. The solidified plates were incubated in an incubator for 72 hours at 30 °C, and then, plates with 30-300 colonies were selected and counted, and the results are expressed as CFU/g.

Yeast and mold count: A 10 g veggie ball sample was ground with a sterile mortar and pestle using 90 mL of sterile 0.1% peptone water. Serial dilutions were made in the same medium. Then, 0.1 mL of the dilutions were spread evenly onto sterilized Potato Dextrose Agar plates using a sterilized spreader in duplicate. These plates were then incubated at 25 °C for 3-5 days. The dilutions with colonies in the 10-150 range at two consecutive dilutions were used for counting. Colony counts were recorded, and the results are expressed as colony-forming units per gram (CFU/g) of the original sample.

Water activity: The water activity of the veggie balls was measured using a water activity meter at room temperature. About 2 g of the sample was evenly placed into plastic cells, and the reading was then recorded when equilibration was achieved.

pH: To determine the pH of each veggie ball sample, 10 g of sample was weighed, and a slurry was prepared by dissolving it in 50 mL of distilled water and mixing thoroughly. A calibrated pH meter was used to measure the pH of the slurry. Then, the pH electrode was immersed in a slurry until a stable pH value was recorded.

Statistical Analysis

All the experiments were performed in triplicate, except for the sensory evaluation (n=30). The experimental data were analyzed by using statistical analysis software (IBM SPSS Statistics). Independent t-test was used to determine the significant differences among the means of functional and physiochemical properties while the Friedman test was used for analyzing the sensory evaluation data, with a significance level set at $P< 0.05$.

Results and Discussion

Sensory properties of the veggie balls

The sensory evaluation aimed to identify the optimal treatment based on appearance, aroma, flavor, texture, and overall acceptability. The mean scores of the sensory attributes are shown in (Figure 1). Among the four treatments (T1, T2, T3, and T4), T4, which contained 60% BPSF in the composite flour, consistently outperformed the other treatments. It exhibited the highest mean scores across all attributes, indicating superior quality. Notably, as the proportion of BPSF increased in the composite flour, there was a noticeable improvement in the attributes, particularly in T4. Furthermore, it caused an increase in darkness due to the light brown color of BPSF and a reduction in the wheat flour content in the formulation. The incorporation of BPSF also led to a distinct banana-like flavor, supported by previous research findings [18]. However, when comparing these results with those of other products made from BPSF-incorporated composite flour, similar results to the present study were reported by Go et al. [21], whereas Chakraborty [14] showed a reduction in sensory scores for the appearance, aroma, taste, texture, and overall acceptability of biscuits as the proportion of BPSF in the formulation increased. Consequently, the composite flour with 60% BPSF and it incorporated veggie ball was chosen for further analysis, including the assessment of chemical and functional properties.

Water-holding Capacity (WHC) of BPSF and the Composite Flour

The importance of the WHC in the food industry is due to its significant impact on food quality, especially viscosity, consistency, and the bulking of products. This attribute is particularly vital in baking applications, where it plays a key role in determining the overall quality and characteristics of the final food items [15]. In the present study, the WHC of the BPSF and the composite flour (T4) were 9.52 ± 0.05 g of water per g of dry matter and 6.86 ± 0.04 g of water per g of dry matter, respectively (Table 1). These values were significantly different ($P = 0.000$) from each other, and Ho et al. [22] have shown that the WHC of wheat flour was approximately 1.87 ± 0.13 g of water per g of dry matter, which was significantly different ($P< 0.05$) from the recorded WHC of the BPSF. Therefore, the substitution of wheat flour with BPSF caused an increase in the WHC, and similar results have also been reported in earlier studies conducted for composite flour made from oats, sorghum, amaranth, and wheat flour, as well as BPSF-incorporated composite flour [11,14]. The elevated WHC of the composite flour than wheat flour may be due to the presence of a comparatively higher amount of fiber in BPSF, which contains many hydroxyl groups facilitating water interactions through hydrogen bonding [11].

Oil-holding Capacity of BPSF and Composite Flour

OHC is an important functional property because oil functions to retain flavors that are often lost during cooking. It also enhances texture, mouthfeel, cooking yield, and overall palatability while extending the shelf life of food products, particularly baked goods and meat products where the absorption of oil is desirable [12]. The results of the OHC are presented in Table 1. BPSF and the composite flour had an OHC of 4.78 ± 0.10 and 265.0 ± 0.11 g of oil per g of dry matter, respectively. According to the results, the OHC of BPSF was significantly higher ($P= 0.000$) than that of the composite flour. The obtained values are in accordance with the results of previous studies [22,23] and far exceed from the OHC

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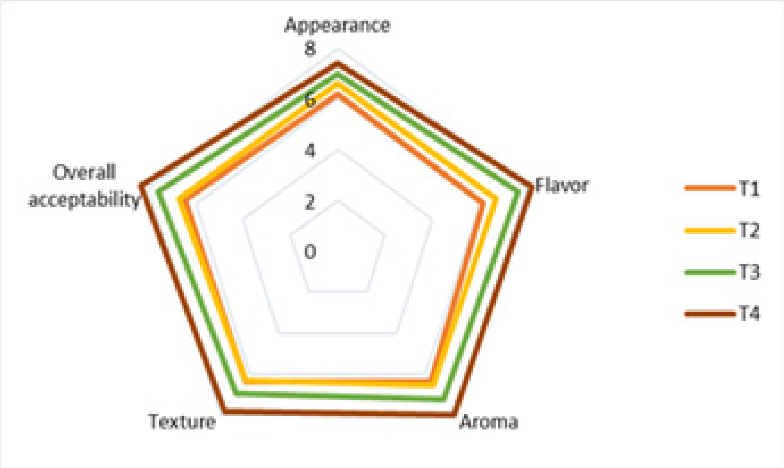
of wheat flour, which was recorded as 1.35 ± 0.13 g of oil per g of dry matter by Ho et al. [22]. According to Chakraborty et al. [14], the OHC in composite flour made from wheat flour and BPSF was higher than the wheat flour, and with the increase of the blending proportion of BPSF, the OHC increased. The possible reason for this phenomenon includes fibers in BPSF, which enhance the ability to absorb and retain oil while forming a matrix that effectively holds onto oil.



1- Dislike extremely, 2- dislike very much, 3- dislike moderately, 4- dislike slightly, 5- neither like nor dislike, 6- like slightly, 7- like moderately, 8- like very much, 9- like extremely.

Figure 1: Radar plot depicting the sensory characteristics of veggie balls prepared with 52%, 55%, 58%, and 60% (w/w) banana pseudo-stem flour-substituted composite flours.

Table 1: Functional properties of BPSF and the composite flour.

SR No	Parameter	BPSF	Composite flour (60% BPSF+40% WF)	Wheat flour
1	Water holding capacity (g of water/g of dry flour sample)	9.52 ± 0.05^b	6.86 ± 0.04^a	1.87 ± 0.13 [22]
2	Oil holding capacity (g of oil/g of dry flour sample)	4.78 ± 0.10^b	2.65 ± 0.11^a	1.35 ± 0.13 [22]
3	Water solubility index (%)	2.96 ± 0.10^a	3.38 ± 0.04^b	10.10 [22]
4	Swelling power (g/g)	6.99 ± 0.10^b	5.70 ± 0.03^a	7.14 [12]

The presented data are the mean values of three replicates ± standard deviation (SD). Values with different superscripts (a-b) within the same row are statistically significant from each other at p< 0.05. BPSF- banana pseudo-stem flour, WF- wheat flour.

Swelling Power (SP) of BPSF and the Composite Flour

The SP of flour can be referred to as the ability to absorb and retain water, particularly due to the starch granules present in the flour. It shows the degree of water absorption and expansion exhibited by the starch when subjected to certain conditions, including heat. In the present study, the SP of the BPSF and the composite flour (T4) at 80 °C were 6.99 ± 0.10 g/g and 5.70 ± 0.03 g/g, respectively, and those values differed significantly (P = 0.000) from each other (Table 1).The composite flour contained a blend of BPSF (60% w/w) and wheat flour (40% w/w). The combination and proportions of these components could contribute to the observed difference in swelling power compared to BPSF alone.

In addition, the presence of other constituents, including fibers, proteins, and lipids, in both flour samples may also affect the overall SP. Aziz et al. [24] reported that the SP of the BPSF was 13.82 g/g. The higher SP in this study compared with that in the present study may be due to the boiling (100 °C) process applied in the preparation of the BPSF because high temperature leads to the solubilization of amylose during starch gelatinization. In another study [12], it was recorded as 7.14 g/g for wheat flour, which is higher than the observed data for the BPSF and composite flour. However, the results obtained by Ahmed et al. [25] for wheat flour are not similar to the above study because they found a SP of 5.35 ± 0.02 g/g in wheat flour. It also showed that the SP of the composite flour made from broken rice flour and wheat flour increased with an increase in the proportion of broken rice flour. The variations in SP among different types of flour may be due to factors such as variety, temperature, and milling method, which contribute to starch degradation. Additionally, these differences are associated with protein content because a higher protein content in flour results in a reduced SP due to the formation of a rigid protein network that binds the starch granules together,

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consequently limiting water absorption [25].

Water Solubility Index (WSI) of BPSF and the Composite Flour

The solubility index is a measure of the soluble starch content in flour. The mean scores of the water solubility index at 80 °C are shown in Table 1. The solubility index of the BPSF and composite flour were greatly varied as 2.96 ± 0.10% and 3.38 ± 0.04%, respectively, with significant differences (P= 0.004), and among them, the composite flour had the highest mean score. However, the solubility index of BPSF was recorded as 33.28 ± 0.38% at 100 °C by Aziz et al. [24], and the desirable variation between the two results may be related to the temperature. For wheat flour, it was 10.10% at 85 °C [22]. Factors that may affect the solubility index include the structure of the starch granules and the difference in the inter-associative forces within the amorphous and crystalline structures.

Bulk Density and Tapped Density of Flour

Assessments of bulk density and tapped density are very important for determining packaging requirements and material handling. This is advantageous for transportation and storage, as it reduces packaging space and related costs. To provide packaging advantages, the bulk density of flour should be maximized, while the tapped density should be minimized. The present study showed, the composite flour had significantly (P< 0.05) higher bulk density (0.49 ± 0.09 gcm^{-3}) and tapped density (0.68 ± 0.05 gcm^{-3}) than that of BPSF which was recorded as 0.46 ± 0.03 gcm^{-3} and 0.58 ± 0.04 gcm^{-3}, respectively. These results may be due to the fineness (particle size) of the BPSF than that of the wheat flour and the heat treatment applied during flour processing [22] because those two parameters of the flour made from dehydrating substances were found to have an increasing trend with an increase in the temperature of dehydration. Raihan and Saini [11] found that the bulk density and tapped density of composite flour made by replacing wheat flour with oats, sorghum, and amaranth at various proportions increased with a decrease in the percentage of wheat flour and an increase in other flour types. According to this study, wheat flour had a bulk density and tapped density of 0.52 ± 0.11 g mL^{-1} and 0.74 ± 0.26 gmL^{-1}, respectively, which are higher than those of BPSF.

Chemical Composition of BPSF and the Composite Flour

The results of the proximate composition of the BPSF and composite flour are shown in (Table 2). It showed that there were significant differences (P< 0.05) in the moisture, protein, fiber, ash and carbohydrate contents except for crude fat content. The moisture content of the BPSF (6.93 ± 0.05%) was found to be the lowest compared to that of the composite flour (9.56 ± 0.08%). The moisture content of the BPSF is different from that in the study conducted by Aziz et al. [24]. These variations may be due to the type of flour, size of pseudo-stem pieces, and drying conditions (temperature and time). However, by comparison, the moisture content of both flour samples was lower than commercial wheat flour, which was recorded as 12.35 ± 0.25% by Aziz et al. [24]. On the other hand, Chakraborty et al. [23] reported that the percentage of moisture content significantly increased with an increasing proportion of BPSF but another study found that, a notable rise in moisture content when wheat flour was incorporated into broken rice flour at different ratios [25]. Reduced moisture levels indicate increased storage stability and a prolonged shelf life. Flour specifications typically recommend a moisture content below 14% to prevent microbial growth and maintain product quality. According to the present study, BPSF and composite flour can be considered shelf-stable.

Table 2: Proximate analysis of banana pseudo-stem flour and composite flour.

Parameters (%)	BPSF	Composite flour (60% BPSF + 40% WF)	Wheat flour [26]
Moisture content	6.93 ± 0.05^{a}	9.56 ± 0.08^{b}	12.74
Protein	4.30 ± 0.17^{a}	6.27 ± 0.11^{b}	13.6
Fat	1.50 ± 0.40^{a}	1.84 ± 0.12^{a}	1.18
Fiber	22.54 ± 0.13^{a}	16.38 ± 0.07^{b}	0.13
Ash	11.51 ± 1.59^{a}	7.29 ± 0.25^{b}	0.42
Carbohydrate	53.22 ± 1.98^{a}	58.66 ± 0.06^{b}	78.8

The presented data are the mean values of three replicates ± standard deviation (SD). Values with different superscripts (a-b) within the same row are significantly different at p< 0.05. BPSF- banana pseudo-stem flour, WF- wheat flour.

The composite flour exhibited the highest protein content (6.27 ± 0.11%), while BPSF had the lowest (4.30 ± 0.17%). This increase in protein content in the composite flour was expected due to its 40% wheat flour, which has higher protein levels of 12.25% [25]. Protein content in BPSF aligned with the finding of Aziz et al. [24]. The variations in protein content may be linked to the boiling process applied during the processing of BPSF, which causes the dissolution of certain water-soluble proteins [24]. The BPSF and composite flour were composed of 1.50 ± 0.40% and 1.84 ± 0.12% fat, respectively. The results for BPSF were different from the finding of Aziz et al. [24] possibly due to pseudo-stem maturity, variety, agricultural practices, climate, processing, and storage. A higher fat content in flour shortens the shelf life due to rancidity. Therefore, the present findings indicate that the developed flour and BPSF have longer shelf-life.

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The crude fiber of the BPSF and composite flour was found to be 22.54 ± 0.13% and 16.38 ± 0.07%, respectively, and it was significantly higher (P= 0.000) in the BPSF than in the composite flour. These value of BPSF closely relates to the results of previous study conducted by Aziz et al. [24]. The low fiber content in the composite flour may be attributed to the wheat flour, which contains a low amount of crude fiber compared to BPSF. However, both can be effectively utilized for fortification when preparing various food products. Ash content determination indicated that BPSF (11.51 ± 1.59%) had a significantly (P= 0.005) higher ash content than composite flour (7.29 ± 0.25%), and the value for BPSF was close to result obtained by Aziz et al. [24] who have recorded it as 12.30 ± 0.01%. However, both flour samples had ash contents greater than that of wheat flour, which was 0.42%, as reported by Novie, Alviola and Monterde [26]. Moreover, another study found that the total ash content in composite flour made from BPSF and wheat flour significantly increased with the increasing percentage of BPSF compared to the control flour sample, which contained only wheat flour [14]. It may be the result of the comparatively higher ash content in BPSF than in wheat flour.

According to the present study, a high ash content in both flour samples indicates a significant presence of minerals. The carbohydrate contents found in the BPSF and composite flour were 53.22 ± 1.98% and 58.66 ± 0.06%, respectively, and there was a significant difference (P= 0.004) among these values. However, the obtained result for BPSF was lower than those reported in the literature by Aziz et al. [24]. Therefore, the higher carbohydrate content in the composite flour may be due to the 40% wheat flour content.

Mineral composition of BPSF

The evaluation of microminerals in BPSF indicated the presence of Cr, Mn, Zn, Cu, and Ni, along with several other elements listed in (Table 3). Except for Cr, Co, and As, the levels of these elements in BPSF were higher than those found in the banana pseudo-stem, according to data from a previous study [4]. The observed differences could be attributed to the variations among banana varieties. Similar to macro-elements, microelements play crucial biological roles. Zinc is essential for numerous bodily reactions, including DNA construction and maintenance, and is necessary for tissue growth and repair. Additionally, iron, manganese, copper, and zinc are key components of important proteins and enzymes involved in macronutrient metabolism and overall body function [4].

Table 3: Mineral composition of BPSF.

Minerals	Content (mg/kg)
Mn	95.09 ± 0.57
Cr	1.56 ± 0.00
Ni	0.89 ± 0.01
Cd	0.02 ± 0.00
Pb	3.52 ± 0.01
As	0.01 ± 0.00
Hg	0.01 ± 0.00
Cu	403.14 ± 8.09
Co	2.87 ± 0.08
Zn	819.10 ± 15.89

The values are expressed as the means ± standard deviations (SD) (n=3).

Chemical Composition of the Veggie Ball

The chemical compositions of the veggie balls are presented in (Table 4). The moisture content of the veggie ball was 56.87 ± 2.33%, which may be due to the presence of texturized soya protein and BPSF in the formulation. The process of boiling and rehydrating the texturized soya contributes to the elevated moisture content of the formulation. Additionally, in terms of the functional properties of the composite flour containing BPSF (Table 1), it had greater WHC than wheat flour. Consequently, during processing, the veggie ball mixture can retain added water through the formation of hydrogen bonds, preventing any loss. Furthermore, the prepared veggie ball had 10.31 ± 0.10% protein, 6.68 ± 0.06% fat, 3.96 ± 0.02% fiber, 2.39 ± 0.10% ash and 19.79 ± 2.25% carbohydrate content.

Table 4: Proximate composition of Veggie ball formulated with banana pseudo-stem flour substituted for wheat flour.

Composition (%)	Values
Moisture content	56.87 ± 2.33
Protein	10.31 ± 0.10
Fat	6.68 ± 0.06
Fiber	3.96 ± 0.02
Ash	2.39 ± 0.10
Carbohydrate	19.79 ± 2.25

The presented data are the mean values of three triplicate ± standard deviation (SD). The composite flour consisted of 60% banana pseudo-stem flour and 40% wheat flour.

Maintaining a low-fat content in veggie balls is vital for promoting heart health and weight management. This type of dietary choice helps to reduce calorie intake, contributing to improved overall health and aligning with preferences for a nutritious lifestyle. On the other hand, the fiber and ash content could be relatively high, and such high fiber and ash content in veggie balls containing BPSF-incorporated composite flour can be considered nutritionally beneficial over wheat flour containing veggie balls because a relatively high ash content indicates the presence of minerals. Furthermore, fiber offers various health benefits, aiding digestion, promoting satiety, supporting heart health by lowering cholesterol and reducing chronic disease risk, and stabilizing blood sugar levels [27]. Additionally, fiber contributes to gut health and regular bowel movements. Chakraborty et al. [14] observed a comparable pattern in ash and fat content. Their study indicated a significant decrease in fat content in banana pseudo-stem flour-substituted biscuits as the percentage of BPSF increased, contrasting with the control sample (100% wheat flour biscuits). Simultaneously, the ash content decreased with the increase in BPSF content. Moreover, the same trend for the protein and fiber levels was found by Go et al. [18], who involved the development of brownies with varying percentages of BPSF substitution (15%, 30%, 45%, and 60%). It was found that there was a decline in protein content as the proportion of BPSF increased in the brownies. In contrast, the presence of pseudo-stem flour showed an increasing trend in crude fiber content.

Texture Profile of Veggie Ball

In the present study, veggie balls with 60% BPSF in the composite flour had a hardness, cohesiveness, gumminess, and chewiness of 5.10 ± 0.67 N, 0.57 ± 0.12, 2.44 ± 0.50 N and 2.56 ± 0.52 N, respectively. According to a previous study [28], beef meatballs exhibited a hardness of 18.06 N, cohesiveness of 0.38, gumminess of 6.68 N, and chewiness of 6.05 N. The reduced hardness in veggie balls can be attributed to their lower protein and structural content compared to meat. The cohesiveness of the veggie balls was slightly higher in veggie balls, indicating superior internal bonding. Compared with beef meatballs, veggie balls have lower gumminess and chewiness than beef meatballs. This suggests that the developed veggie balls may offer a more tender and less resistant eating experience. This may be due to the water-holding capacity of the composite flour, which retained moisture within the mixture, resulting in a moist and tender texture compared to that of the meatballs.

Cooking Yield and Cooking Loss

The cooking yield and cooking loss of the veggie ball containing composite flour with 60% BPSF were found to be 98.68 ± 0.39% and 2.30 ± 0.39%, respectively. A similar finding was reported by Raju et al. [3] for BPSF-incorporated cutlets. Therefore, an increase in cooking yield could be due to the ability of the composite flour to retain moisture and fat in the matrix, resulting in minimal nutrient loss during cooking.

Shelf-life Analysis

Over a four-week duration, the shelf-life of the veggie ball was evaluated through assessments of the total plate count, yeast and mold count, pH, and water activity. These parameters provided a holistic understanding of the quality and stability of the product.

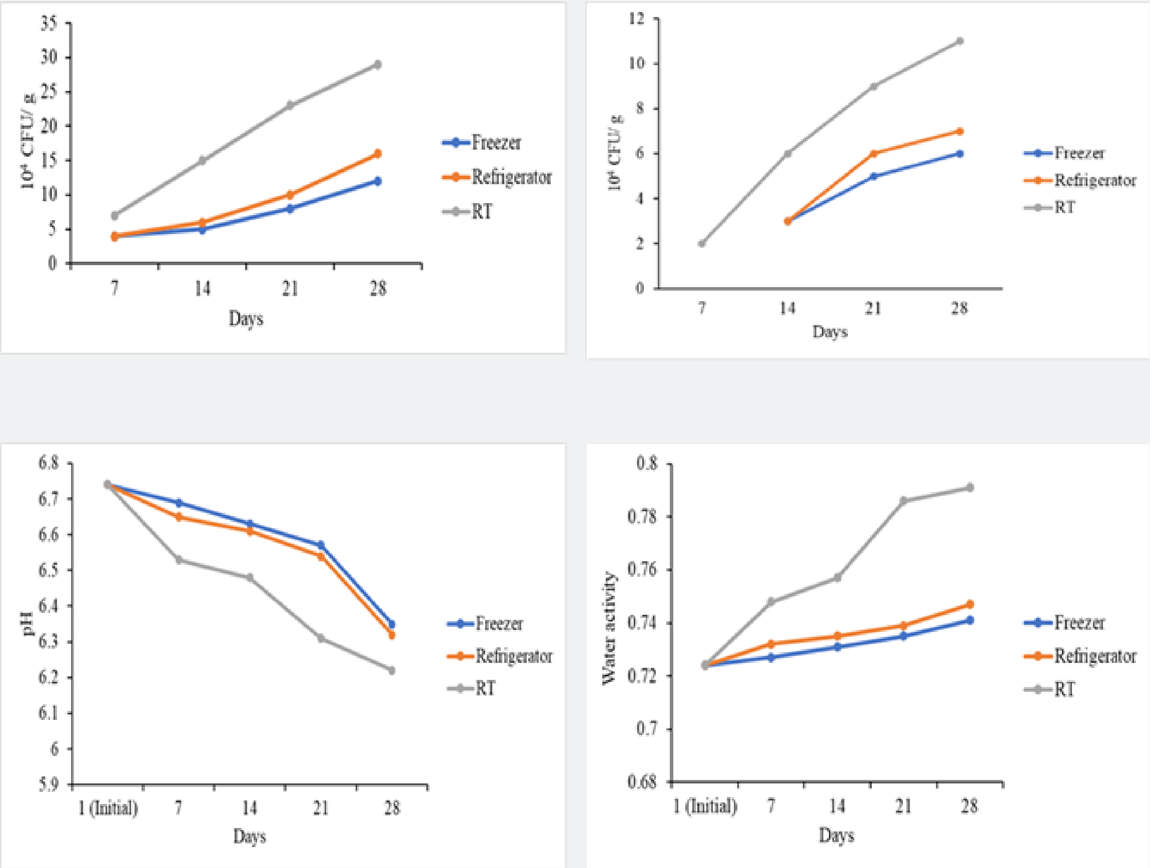

Figure 2: Variation in total plate count (a), yeast and mold count (b), pH (c) and water activity (d) of the veggie ball stored in a freezer, refrigerator, and at room temperature (RT) with time.

Total Plate Count: For the calculation of the total plate count, plates with 30 - 300 colonies were selected as plates with acceptable levels. During the 28-day period, total plate counts consistently increased at all temperatures, but initial colony counts were not applicable at a 10^{-3} dilution factor (Figure 2a). On the other hand, particularly at room temperature, a significant and sustained rise in the total plate count was observed compared to frozen and refrigerated conditions. This is attributed to the anaerobic environment, moisture content, and optimal temperature, creating favorable conditions for bacteria to grow in vacuum-packed veggie balls.

Yeast and mold count: For the calculation of yeast and mold counts, plates with 15 – 150 of colonies were selected as plates with acceptable colony counts. Initially, the colony counts of yeast and mold at the 10^{-3} dilution factor fell below acceptable levels (Figure 2b). After 7 days, only 2×10^4 microorganisms were identified at room temperature, while colony counts under frozen and refrigerated conditions remained at unacceptable levels. However, over 28 days, there was a noticeable increase in the three storage conditions. The substantial increase in counts at room temperature compared to those at other storage temperatures can be attributed to the anaerobic packaging environment, optimal temperature conditions, and potential moisture content, all of which foster microbial proliferation.

pH: The pH of the veggie balls decreased over time, and the decrease in pH was higher at room temperature than under the other two conditions (Figure 2c). The decrease in the pH of the veggie balls over time could be due to microbial activity, particularly fermentation processes converting sugars into acidic byproducts. Furthermore, enzymatic reactions may occur, breaking down organic compounds into simple compounds and releasing acidic components. At room temperature, the growth of microorganisms and enzymatic activities are accelerated than in refrigerator and freezer, affecting pH levels. A previous study conducted by Raju et al. [3] on banana pseudo-stem flour-incorporated cutlets also showed a decrease in pH as the storage life Increased.

Water Activity: Over time, water activity also increased under all three conditions. However, the changes were notably high at room temperature (Figure 2d). This elevation may be due to the gradual diffusion of moisture from the surroundings and byproducts of enzymatic reactions and microbial activities, leading to higher water availability. Higher water activity levels in the food matrix led to a reduction in the shelf life because it provides a favorable environment for microbial growth and contributes to faster lipid oxidation and hydrolysis. Overall, based on the results and observations, the veggie balls stored at room temperature had a shelf-life of approximately one week. In contrast, for those stored under freeze conditions, a standard preservation method, it was three weeks, considering one week as an accelerated shelf-life. There may be reasons for altering these parameters after the third week significantly. However, by reducing the moisture content while maintaining the product quality, the shelf-life can be enhanced further.

Conclusion

The banana pseudo-stem, which is typically discarded after harvesting a bunch of bananas, can be processed into flour and incorporated into composite flour preparation with wheat flour. Developed composite flour composed of 60% banana pseudo-stem flour and 40% wheat flour has distinct physiochemical, and functional properties compared to banana pseudo-stem flour alone. Moreover, its low moisture content, crude lipid levels, and water activity ensured its stability at room temperature while considerably extending its shelf-life. Therefore, there is potential to develop veggie balls from banana pseudo-stem flour incorporated with composite flour. The addition of the composite flour increased the fiber and ash content of the veggie ball sample, and it had a low level of fat, which is beneficial for human health. Furthermore, these veggie balls had a moist, tender, and less resistant eating experience. The superior water absorption and retention capacities of the composite flour contributed to high cooking yields and minimal cooking loss, enhancing the overall product quality. Additionally, the veggie balls stored in the freezer had a shelf-life of approximately three weeks. An effective way to improve the shelf life of a product is by reducing its moisture level while ensuring the quality remains well controlled. Overall, the developed composite flour serves as a viable substitute for wheat flour in the production of veggie balls, contributing as both a binding agent and a filling agent while offering nutritional richness

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