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Exploring Reduced-Fat Banana Flavored Milk for Sustainable Food Security: Physicochemical, Microbiological and Sensory Insights

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Abstract

This study explores the physicochemical, microbiological, and sensory properties of an innovative reduced-fat banana milk cube (RFBMC), designed to address food security by providing a nutritious, shelf-stable snack. The formulation, utilizing Pisang Berangan (*Musa paradisiaca*) puree and milk powder, aims to retain essential nutrients and improve long-term usability, ensuring more sustainable access to nutritious food. Four formulations, which are RFBMC 0 (0% BP), RFBMC 1 (20% BP), RFBMC 2 (30% BP), and RFBMC 3 (40% BP), were developed and analyzed to determine their properties. Physicochemical analyses, including hardness, pH, water solubility index, and proximate composition, revealed significant differences among the formulations, with RFBMC 1 exhibiting the most desirable characteristics. Sensory evaluations conducted with 50 panelists identified RFBMC 1 as the preferred formulation due to its balanced aroma, flavor, texture, and hardness, achieving the highest overall acceptance score. Microbiological analysis confirmed the safety of RFBMC 1 and RFBMC 0, with no detection of harmful pathogens such as *Escherichia coli*, *Salmonella* spp., coliforms, or *Staphylococcus*. Although RFBMC 1 recorded a higher total plate count (532,000 CFU/g) compared to RFBMC 0 (1,000 CFU/g), it remained within acceptable limits. The low-fat content of RFBMC 1 (0.77%), its optimal carbohydrate content (36.40%), and high antioxidant levels (51.26%) contributed to its nutritional appeal and consumer preference. The findings reveal that reduced-fat banana milk cubes (RFBMC) serve as a healthier, sustainable alternative to traditional dairy snacks, meeting the growing consumer demand for functional foods and supporting food security by providing an accessible, nutrient-packed, and shelf-stable option.

INTRODUCTION

Bananas are among the most consumed fruits in tropical and subtropical regions, typically classified into dessert bananas and plantains. In Malaysia, the key dessert varieties are Mas (AA) and Berangan (AA), while plantains include Awak (AAB), Nangka (ABB), and Raja (ABB), with 'A' and 'B' indicating genetic origins from Musa acuminata and Musa balbisiana. Bananas are known for their antioxidant properties, helping the plant cope with heat and sun by producing compounds like ascorbic acid, tocopherol, beta-carotene, phenolics, dopamine, and gallocatechin [1, 2]. Pisang Berangan (*Musa paradisiaca*), widely sold fried as a street snack in Malaysia, is prized for its sweet taste, creamy texture, and culinary versatility [3]. Each 100g provides essential nutrients including vitamin C, B vitamins, vitamin A, potassium, and fiber [4]. It grows well in Malaysia's tropical climate, yielding 20–30 tons per hectare annually under ideal conditions.

Blending banana with milk creates a naturally sweet, nutritious drink rich in carbohydrates, fiber, protein, and vitamins. Transforming this blend into dehydrated cubes enhances portability, shelf life, and storage efficiency while reducing waste and spillage risks [5][6]. The uniform cube shape ensures consistent portioning, supports dietary control, and adds to its visual and practical appeal [7]. The Reduced-Fat Banana

Milk Cube (RFBMC) was developed to meet the demand for convenient, nutritious snacks. By combining milk and bananas into a compact, portable form, RFBMC offers a flavorful, low-fat alternative to traditional dairy snacks. Despite dehydration, the cubes retain the nutritional value of milk, including protein, calcium, and vitamins, while bananas contribute natural sweetness, potassium, and fiber [8, 9].

Designed for busy lifestyles, RFBMC is ideal for on-the-go consumption, portion control, and low-fat diets. The cube format improves portability, extends shelf life, and minimizes food waste—making the product both practical and sustainable [10]. Dehydration enhances the milk's flavor and texture, producing a dense cube with low moisture, which increases its stability. The cube's size and shape also affect its physicochemical properties, such as solubility and flavor intensity [11]. Safety and sensory quality are top priorities. The cubes undergo strict quality control to ensure microbiological safety, while sensory evaluations assess taste, aroma, texture, and appearance to optimize consumer appeal [12, 13]. The product is customizable in flavor and packaging to meet diverse preferences [14].

RFBMC appeals to a wide range of consumers—including health-conscious individuals, parents, seniors, and eco-conscious buyers—offering a versatile option for breakfast, snacks, or recovery after physical activity [9]. It addresses concerns with high-fat dairy products, which are linked to obesity and heart disease, by providing a reduced-fat alternative without sacrificing taste [8]. The product also aligns with trends toward healthier, plant-based, and lactose-free options, supporting those managing weight or dietary restrictions [15,10].

This research aims to refine RFBMC through sensory evaluation, optimizing texture, flavor, and overall acceptance. In addition, the study investigates the effects of milk homogenization on cube texture and structure, analyzing properties such as fat globule size, protein interactions, and gel strength [16, 17]. The goal is to evaluate the antioxidant activity, physicochemical stability, and sensory quality of RFBMC to develop a balanced, shelf-stable, and appealing dairy snack.

MATERIALS AND METHODS

Sample preparation and formulation

The preparation of Reduced-Fat Banana Milk Cubes (RFBMC) was adapted from Chetachukwu et al. [18], with modifications to suit this study. Ripe Pisang Berangan bananas (*Musa paradisiaca*) were peeled, chopped, and mashed into a puree [18]. Milk powder was blended into the puree until fully homogenized. Maltodextrin was added as a stabilizer, and butylated hydroxytoluene (BHT) was included to prevent fat oxidation [19]. The mixture was blended into a smooth liquid and poured into 1.5 cm cube-shaped molds, then dehydrated in a vacuum oven at 60 °C for 6 hours or until firm. Dried cubes were stored in airtight containers at room temperature.

A control sample was prepared using the same method, excluding banana puree. The formulation was based on methods by Jokar & Azizi [20] and Wanikorn et al. [19]. Jokar & Azizi [20] used varying ratios of persimmon puree with milk (10%, 20%, and 30%), which we replicated using banana puree [20]. Wanikorn et al.'s [19] use of maltodextrin and BHT to enhance texture and shelf life was also applied in our formulation [19].

Table 1 outlines the ingredient weights for the control and three treatment groups with different banana puree levels. These formulations were designed to assess sensory attributes and consumer acceptance while ensuring product stability and quality.

Table 1. Formulation of RFBMC.

Formulation	RFBMC 0	RFBMC 1	RFBMC 2	RFBMC 3
Water (%)	10	10	10	10
Milk Powder (%)	60	40	30	20
Banana Puree, BP (%)	0	20	30	40
Maltodextrin (%)	30	30	30	30
Butylated Hydroxytoluene, BHT (%)	0.01	0.01	0.01	0.01

Physical analysis of reduced-fat banana milk cube

Several physical analyses; hardness, color, pH, and water solubility index were performed on RFBMC to assess its texture, appearance, acidity, and solubility. These tests offer key insights into the product's quality, stability, and consumer suitability.

Hardness

The hardness of the RFBMC was measured using a Texture Analyzer (TAX.T2) equipped with a cylindrical probe. For this analysis, larger samples with dimensions of 3.8 cm per side were specifically prepared. Prior to conducting the measurements, the instrument was calibrated to ensure the accuracy and reliability of the results [19].

Color

The color measurement of the RFBMC was conducted using a HunterLab ColorFlex colorimeter. The L, a, and b color parameters were determined to assess the sample's color attributes. Prior to measurement, the instrument was calibrated to ensure accuracy. A single cube of the sample was placed in the sample cup, and the color readings were recorded [19].

pH measurement

The pH of the RFBMC was measured using a digital pH meter (OHAUS, Starter 3100). For the analysis, 5g of the sample was diluted in 5 mL of distilled water and placed in a beaker. The pH meter's glass electrode was calibrated prior to use and rinsed thoroughly before measuring the sample to ensure accurate readings [19].

Water solubility index determination

The Water Solubility Index (WSI) of RFBMC was determined by grinding the sample into a fine powder. One gram of the powdered sample was dissolved in 30 mL of distilled water within a 50 mL centrifuge tube. The mixture was vortexed for 45 seconds to achieve homogeneity and then centrifuged at 3000 rpm for 15 minutes. The resulting supernatant was carefully transferred into a pre – weighed aluminum cup and dried at 105°C for 24 hours. The WSI was calculated using the following Equation 1 [19].

$$\text{Water Solubility Index (\%)} = \frac{w_1 - w_2}{w} \times 100 \qquad \text{(Equation 1)}$$

w_1 = Weight of dish and dried liquid (g)
w_2 = Weight of empty dish (g)
w = Weight of dried sample (g)

Proximate analysis of reduced-fat banana milk cube

Proximate analysis was performed to determine the moisture content, protein, ash, fat, crude fiber, and carbohydrate levels.

These analyses provide essential information about the nutritional composition, and overall quality of the product.

Moisture content
The moisture content of RFBMC powder was determined using the AOAC 2000 method with the hot air oven technique. A moisture dish was preheated at 105°C for 3 hours, then cooled in a desiccator and weighed as (a). The RFBMC powder sample was added to the dish, and the combined weight was recorded as (b). The dish was returned to the oven at 105°C to dry overnight. After drying, the dish was cooled, reweighed as (c), and the moisture content was calculated using Equation 2 [21].

$$\text{Moisture Content (\%)} = \frac{b-c}{b-a} \times 100 \qquad \text{(Equation 2)}$$

a = Weight of moisture dish (g)
b = Weight of moisture dish and sample before placed in the oven (g)
c = Weight of moisture dish and sample after placed in the oven (g)

Protein content
The reduced-fat banana milk cube sample was weighed and placed into a digestion tube, where a catalyst and sulfuric acid were added. The tube was heated at the highest temperature for 1.5 hours or until the solution became clear. Selenium tablets produced a yellowish solution, while potassium sulfate and copper sulfate resulted in a green-blue solution. Distillation and titration were performed using the KJELTEC 2300 instrument, following the SOP. Distillation used a 40% NaOH solution, and titration employed 1% boric acid with methyl red and bromocresol green as indicators. The results were displayed as protein percentage on the KJELTEC instrument [21].

Ash content
The ash content of the RFBMC was determined using the dry ashing method. A blank crucible was weighed and recorded as (a), then 2-5 g of the sample was added and the combined weight recorded as (c). The sample was burned over a Bunsen burner until no white smoke remained, then placed in a furnace at 550°C overnight for complete ashing. After cooling in a desiccator, the crucible with ash was weighed and recorded as (b). The ash content (%) was calculated using Equation 3 [22].

$$\text{Ash Content (\%)} = \frac{b-a}{c} \times 100 \qquad \text{(Equation 3)}$$

a = Weight of blank preheated crucible (g)
b = Weight of crucible with sample after ashing (g)
c = Weight of sample only (g)

Fat content
The fat content of the RFBMC was determined using the Soxhlet method (991.336) with the Soxtec™ 2050 Automatic System by Foss. The sample was placed in a cellulose thimble, covered with cotton wool, and weighed in an empty extraction cup (a). The thimble was then placed in the Soxtec™ 2050, and petroleum ether was used for extraction, running automatically for about 2 hours. After extraction, the fat-containing cup was dried at 100±5°C for 30 minutes to remove residual solvent (AOAC, 2000). The cup was then cooled, reweighed (b), and the initial sample weight was recorded (c). The fat content (%) was calculated using Equation 4 [21].

$$\text{Fat Content (\%)} = \frac{b-a}{c} \times 100 \qquad \text{(Equation 4)}$$

a = Weight of blank extraction cup (g)
b = Weight of extraction cup with the fat extracted after drying(g)
c = Weight of sample only (g)

Crude fiber
The RFBMC was ground into powder before analysis. The empty FibreBag and crucible were weighed and recorded as m1 and m6, respectively. Approximately 1 g of the RFBMC sample was placed in the FibreBag, and its weight recorded as m2. The sample was digested using the Gerhardt Fibretherm, and the digested weight was recorded as m3. The sample and crucible were then ashed at 550°C for 4 hours, and the combined mass of the crucible and ash was recorded as m4. The blank value for the empty FibreBag was 0.2371g, and the mass of the crucible and ash from the empty FibreBag was calculated by summing m5 and m6. The crude fiber content was then calculated using the formula in Equation 5 [21].

$$\text{\% Crude Fibre} = \frac{(m_3 - m_1) - (m_4 - m_5)}{m_2} \times 100 \qquad \text{(Equation 5)}$$

m_1 = Mass FibreBag (g)
m_2 = Mass initial sample weight (g)
m_3 = Mass Crucible and dried FibreBag after digestion (g)
m_4 = Mass Crucible and Ash (g)
m_5 = Blank Value of the empty FibreBag (g) = 0.2371g
m_6 = Mass Crucible (g)
m_7 = Mass Crucible and ash of the empty FibreBag (g)

Carbohydrate content
The carbohydrate content was determined by difference methods, according to AOAC (2000), using the following Equation 6 [21]:

$$\text{Carbohydrate Content (\%)} = 100\% - (\text{moisture content} + \text{protein content} + \text{ash content} + \text{fat content} + \text{crude fiber content}) \qquad \text{(Equation 6)}$$

Antioxidant activity of reduced-fat banana milk cube
The antioxidant activity of the milk sample was evaluated using the DPPH assay. A 0.1 mM DPPH solution was prepared by dissolving 0.002 g of DPPH in 50 mL of methanol. For testing, 0.5–1 mL of milk was mixed with 9 mL of methanol, and 1 mL of this mixture was combined with 1 mL of DPPH solution (1:1 ratio). A blank was prepared by mixing 1 mL of DPPH with 1 mL of distilled water. Samples were incubated in the dark at room temperature for 30 minutes, then absorbance was measured at 517 nm using a UV-Vis spectrophotometer to calculate antioxidant activity using Equation 7 [23].

$$\text{Antioxidant Activity (\%)} = \left[\frac{Abs_{control} - Abs_{sample}}{Abs_{control}}\right] \times 100\% \qquad \text{(Equation 7)}$$

$Abs_{control} = Blank\ Absorption$
$Abs_{sample} = Sample\ Absorption$

Sensory evaluation of reduced-fat banana milk cube
To assess consumer acceptability of RFBMC, a sensory evaluation was conducted with 50 student panelists from Universiti Malaysia Sabah (UMS). Using a 9-point hedonic scale (1 = dislike extremely to 9 = like extremely), six attributes were evaluated: aroma, colour, taste, firmness, texture, and overall acceptability. Panelists received a short briefing before proceeding to sensory booths. Each was served four coded samples to prevent bias and asked to rinse their mouth with water between samples [18].

Microbial of reduced-fat banana milk cube
Microbial testing was conducted on the best formulation (RFBMC 1) and the control (RFBMC 0) at the Sabah Department of Veterinary Services using the 3M™ Petrifilm™ Rapid Yeast and Mold Count Plate method. One gram of each sample was

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mixed with 9 mL of sterile 0.1% peptone water and shaken for homogenization. Serial 10-fold dilutions were prepared, and 1 mL from each was placed on Petrifilm plates. The inoculum was spread evenly using a flat spreader, and plates were left to solidify for 1 minute. Incubation was done at 25–28°C for 48 hours, with an additional 12 hours if colonies were faint. Colony counting followed AOAC (2014) guidelines using a standard counter and backlight [24].

Statistical analysis

The data were analyzed using IBM Statistical Package for Social Sciences (SPSS) All the experiments were carried out in triplicate; the mean and standard deviation were calculated for descriptive statistic. Then, the data from the experiment analyzed for significance differences among samples using two-way Analysis of Variance (ANOVA). The two-way ANOVA was the followed by Tukey's test in order to determine the statistically significance difference.

RESULT AND DISCUSSION

The physicochemical properties of reduced-fat banana milk cubes (RFBMC) were significantly influenced by fat reduction, particularly in terms of texture and appearance. As shown in **Table 2**, the hardness of RFBMC decreased notably with the reduction of fat content, with RFBMC 0 (full-fat formulation) exhibiting the highest hardness (3382.33 ± 51.89), while RFBMC 3 (lowest fat content) recorded the softest texture (1253.84 ± 1.49).

Table 2. Hardness measurement of RFBMC with different formulations. Data expressed as mean ± standard deviation, (n=3). Mean values in the same column with different superscripts are significantly different with p<0.05.

Parameter	Samples	Results
Hardness	RFBMC 0	3382.33 ± 51.89^{a}
	RFBMC 1	2515.93 ± 6.08^{b}
	RFBMC 2	1284.75 ± 6.12^{c}
	RFBMC 3	1253.84 ± 1.49^{c}

This trend suggests that fat contributes to the structural integrity of the product by acting as a binding and textural agent [25]. The removal of fat likely increased water activity and altered interactions among ingredients, resulting in a softer product matrix. Additionally, the inclusion of maltodextrin across all samples provided some structural support, though not sufficient to counterbalance the absence of fat [25]. Colour analysis, as summarized in **Table 3**, further revealed that fat reduction significantly affected visual attributes. **Figure 1** shows the visual observation of RFBMC with different formulations.

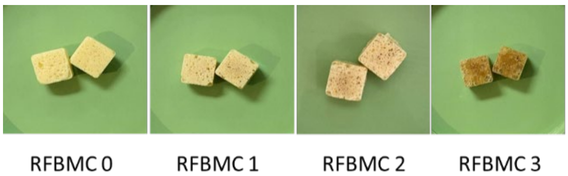

Figure 1. Visual observation of RFBMC with different formulations.

The L* value (lightness) decreased with fat reduction, with RFBMC 0 appearing the brightest (L* = 46.42), while reduced-fat samples such as RFBMC 1 and RFBMC 3 appeared darker. This can be attributed to reduced light scattering in lower-fat matrices and the higher visibility of natural pigments [26]. Moreover, the a* values (redness) increased significantly in reduced-fat samples, possibly due to enhanced browning reactions during processing [26]. In contrast, b* values (yellowness) remained relatively stable, indicating that banana-derived pigments were unaffected by fat reduction [26]. These findings underscore the critical role of fat in determining both texture and visual appeal of the product and highlight the importance of carefully optimizing formulations to balance nutritional goals with desirable sensory attributes.

Table 3. Colour measurement results of RFBMC with different formulations. Data expressed as mean ± standard deviation, (n=3). Mean values in the same column with different superscripts are significantly different with p<0.05.

Parameter	Samples	Results		
		L*	a*	b*
Colour Measurement	RFBMC 0	46.42 ± 2.58^{a}	2.61 ± 0.58^{a}	17.38 ± 0.93^{a}
	RFBMC 1	$21.51 + 1.10^{c}$	4.69 ± 0.41^{b}	14.09 ± 1.77^{a}
	RFBMC 2	30.27 ± 0.65^{b}	4.43 ± 0.53^{ab}	17.39 ± 1.08^{a}
	RFBMC 3	$23.40 + 0.81^{c}$	7.03 ± 1.14^{c}	16.72 ± 2.07^{a}

Fat reduction in reduced-fat banana milk cubes (RFBMC) significantly influenced several physicochemical and nutritional attributes. The pH values (**Table 4**) showed a progressive decrease from RFBMC 0 (6.69 ± 0.02) to RFBMC 3 (6.14 ± 0.01), corresponding to the increase in banana puree, which is inherently more acidic than milk powder.

Table 4. pH measurement of RFBMC with different formulations. Data expressed as mean ± standard deviation, (n=3). Mean value in the same column with different superscripts are significantly different with p<0.05.

Parameter	Samples	Results
pH	RFBMC 0	6.69 ± 0.02^{a}
	RFBMC 1	6.49 ± 0.01^{b}
	RFBMC 2	6.35 ± 0.01^{c}
	RFBMC 3	6.14 ± 0.01^{d}

This shift reflects the gradual replacement of milk powder—naturally more neutral—with organic acid-rich banana puree, supporting the hypothesis that fruit incorporation elevates acidity in food systems [27]. Meanwhile, water solubility index (WSI) values (**Table 5**) varied across formulations, with RFBMC 2 showing the highest solubility (69.37 ± 0.88%), suggesting that an optimal ratio of milk powder and banana puree improves powder dispersion. Extremes in formulation (RFBMC 0 and RFBMC 3) exhibited slightly lower WSIs, possibly due to excess insoluble milk proteins or banana fibers, respectively.

Table 5. Water solubility index determination measurement of RFBMC with different formulations. Data expressed as mean ± standard deviation, (n=3). Mean value in the same column with different superscripts are significantly different with p < 0.05.

Parameter	Samples	Results
Water Solubility Index Determination (%)	RFBMC 0	67.72 ± 0.80^{ab}
	RFBMC 1	69.11 ± 1.19^{b}
	RFBMC 2	69.37 ± 0.88^{b}
	RFBMC 3	66.32 ± 1.08^{a}

In terms of proximate composition, moisture content (**Table 6**) was highest in RFBMC 1 (8.53 ± 0.08%) and decreased as banana content increased, likely due to the fiber in bananas binding water more tightly [28].

Table 6. Moisture content measurement of the RFBMC with different formulations. Data expressed as mean ± standard deviation, (n=3). Mean value in the same column with different superscripts are significantly different with p<0.05.

Parameter	Samples	Results
Moisture Content (%)	RFBMC 0	7.98±0.35[b]
	RFBMC 1	8.53±0.08[a]
	RFBMC 2	6.96±0.15[c]
	RFBMC 3	6.61±0.06[c]

Protein content (**Table 7**) showed a significant decline from 12.40 ± 0.05% in RFBMC 0 to 6.56 ± 0.34% in RFBMC 3, consistent with the dilution of milk powder, the primary protein source [29]. This reduction may impact both the nutritional value and texture of the product.

Table 7. Protein content measurement of the RFBMC with different formulations. Data expressed as mean ± standard deviation, (n=3). Mean value in the same column with different superscripts are significantly different with p<0.05.

Parameter	Samples	Results
Protein Content (%)	RFBMC 0	12.40±0.05[a]
	RFBMC 1	10.24±0.09[b]
	RFBMC 2	8.38±0.18[c]
	RFBMC 3	6.56±0.34[d]

Ash content (**Table 8**), which reflects mineral content, peaked in RFBMC 1 and RFBMC 2, suggesting that a balanced incorporation of banana puree and milk powder maximized mineral retention, likely due to the combined contributions of milk-derived minerals and banana-sourced potassium [30]. Collectively, these findings underscore the importance of formulation balance to achieve desirable acidity, solubility, and nutritional composition in reduced-fat functional foods.

Table 8. Ash content measurement of the RFBMC with different formulations. Data expressed as mean ± standard deviation, (n=3). Mean value in the same column with different superscripts are significantly different with p<0.05.

Parameter	Samples	Results
Ash Content (%)	RFBMC 0	16.36 ±0.48[b]
	RFBMC 1	21.57±0.19[a]
	RFBMC 2	21.48±0.18[a]
	RFBMC 3	17.38±0.66[b]

The fat content analysis of the Reduced-Fat Banana Milk Cube (RFBMC) demonstrated a significant decrease in fat levels as the milk powder concentration was reduced in favor of banana puree (**Table 9**). The highest fat content was observed in RFBMC 0, which contained the most milk powder, while RFBMC 3, which had the highest banana puree content, exhibited the lowest fat content [31]. This reduction aligns with the natural low-fat profile of banana puree compared to milk powder, suggesting the impact of milk powder as a primary source of fat. The decrease in fat content, although aligning with the objective of creating a reduced-fat product, may also affect the creaminess and texture of the final product, potentially influencing its mouthfeel.

Table 9. Fat content measurement of the RFBMC with different formulations. Data expressed as mean ± standard deviation, (n=3). Mean value in the same column with different superscripts are significantly different with p<0.05.

Parameter	Samples	Results
Fat Content (%)	RFBMC 0	1.53 ±0.12[a]
	RFBMC 1	0.77±0.02[b]
	RFBMC 2	0.63±0.01[c]
	RFBMC 3	0.52±0.01[d]

The crude fiber content of the RFBMC samples showed relatively high and consistent levels across all formulations, with no significant differences in fiber content among the samples (**Table 10**). Banana puree, known for its high dietary fiber content, contributed to this consistency, and the slight variations observed could be attributed to processing methods and ingredient interactions. The lack of significant changes in fiber content suggests that substituting milk powder with banana puree did not notably alter the fiber composition, further supporting the use of banana puree for maintaining fiber content in reduced-fat formulations [32].

Table 10: Crude Fiber Content measurement of the RFBMC with different formulations. Data expressed as mean ± standard deviation, (n=3). Mean value in the same column with different superscripts are significantly different with p<0.05.

Parameter	Samples	Results
Crude Fiber Content (%)	RFBMC 0	25.25 ±1.39[a]
	RFBMC 1	22.50±1.28[a]
	RFBMC 2	23.82±1.66[a]
	RFBMC 3	22.53±1.67[a]

In terms of carbohydrate content, a clear trend was observed with an increase in carbohydrate levels as the banana puree content rose (**Table 11**). RFBMC 3, which contained the highest amount of banana puree, exhibited the highest carbohydrate content, primarily from the natural sugars and starches present in bananas [2]. This increase in carbohydrates, while enhancing the sweetness and caloric content of the product, also makes the formulation more suitable for consumers seeking a naturally sweet alternative, though it may be less appropriate for those on low-sugar diets.

Table 11. Carbohydrate content measurement of the RFBMC with different formulations. Data expressed as mean ± standard deviation, (n=3). Mean value in the same column with different superscripts are significantly different with p<0.05.

Parameter	Samples	Results
Carbohydrate Content (%)	RFBMC 0	36.48 ±0.55[b]
	RFBMC 1	36.40.±1.33[b]
	RFBMC 2	38.73±1.74[b]
	RFBMC 3	46.40±2.22[a]

Meanwhile, for the antioxidant activity, the RFBMC samples showed significant variability, with RFBMC 2 exhibiting the highest antioxidant content (**Table 12**). This result can be attributed to the balanced formulation where milk powder and banana puree interacted optimally, preserving beneficial compounds like Vitamin C and polyphenols. Conversely, RFBMC 3, with the highest banana puree content, displayed the lowest antioxidant activity, indicating that excessive banana puree may lead to the degradation of these antioxidants due to processing conditions [30].

Table 12. Antioxidant activity measurement of the RFBMC with different formulations. Data expressed as mean ± standard deviation, (n=3). Mean values in the same column with different superscripts are significantly different with p<0.05.

Parameter	Samples	Results
Antioxidant Content (%)	RFBMC 0	30.36 ±0.07[b]
	RFBMC 1	51.26±0.00[a]
	RFBMC 2	12.69±0.25[c]
	RFBMC 3	1.47±0.26[d]

From **Table 13**, sensory evaluation revealed that RFBMC 1 was the most preferred formulation, achieving the highest scores across all attributes, including aroma, taste, texture, firmness, and overall acceptance. This preference can be attributed to the balanced formulation that offered reduced fat, high antioxidant levels, and an appealing sensory profile. RFBMC 0, while still favored by some panelists for its color and sensory qualities, lacked the overall balance and appeal of RFBMC 1. RFBMC 3, on the other hand, was the least preferred, mainly due to its lower scores in texture and firmness, likely a result of its reduced fat and carbohydrate content.

Table 13. Sample mean scores with standard deviation for aroma, colour, taste, firmness, taste, texture, and overall acceptance. Data expressed as mean ± standard deviation, (n=3). Mean value in the same row with different superscripts are significantly different with p<0.05.

Attributes	RFBMC 0	RFBMC 1	RFBMC 2	RFBMC 3
Aroma	5.10 ±1.75[a]	5.16 ±1.73[a]	5.32 ±1.86[a]	5.36 ±2.03[a]
Colour	6.30 ±1.99[a]	5.98 ±1.55[ab]	5.70 ±1.77[ab]	5.00 ±2.30[ab]
Taste	5.62 ±2.18[a]	5.84 ±1.96[a]	5.90 ±1.92[a]	5.34 ±2.04[a]
Firmness	5.48 ±1.97[a]	5.74 ±1.97[a]	5.36 ±2.24[a]	4.96 ±2.12[a]
Texture	5.36 ±2.13[a]	5.60 ±2.13[a]	5.30 ±2.34[a]	4.54 ±2.29[a]
Overall Acceptance	5.52 ±2.06[a]	5.96 ±1.84[a]	5.72 ±2.09[a]	5.06±2.06[a]

Microbial analysis of the two formulations showed that RFBMC 0 met microbiological safety standards, with a Total Plate Count (TPC) well within acceptable limits (**Table 14**). However, RFBMC 1 exhibited a significantly higher TPC, exceeding the regulatory limit for safe consumption. Despite the absence of harmful pathogens such as coliforms, *E. coli*, *Salmonella* spp., and *Staphylococcus*, the elevated TPC in RFBMC 1 highlights the need for further optimization in microbial control during production and storage to ensure the product's safety and regulatory compliance [33].

Table 14. Microbial analysis of RFBMC 0 (control) and RFBMC 1 (best formulation).

Type of Analysis	RFBMC 0	RFBMC 1
Total Plate Count (TPC) [CFU/g]	1 000	532 000
Coliform Count [CFU/g]	0	0
Escherichia coli Count [CFU/g]	0	0
Salmonella spp.	Negative	Negative
Staphylococcus count [CFU/g]	0	0

CONCLUSION

This study evaluated the effects of various reduced-fat banana milk cube (RFBMC) formulations on their physicochemical, sensory, and microbial properties. Among the four tested variants, RFBMC 1 emerged as the most preferred, showing superior performance in texture, firmness, and overall acceptability. It had the highest sensory scores, chosen by 17 out of 50 panelists, and balanced nutritional attributes—reduced fat (0.77%), high antioxidants (51.26%), and optimized carbohydrate content (36.40%). Microbial analysis confirmed the safety of RFBMC 1 and the control (RFBMC 0), with no detection of pathogens. While RFBMC 1 had a higher Total Plate Count (532,000 CFU/g), it remained within acceptable limits, likely due to its enriched formulation. *Staphylococcus* levels were 0 CFU/g in both samples, affirming microbiological safety. Physicochemical tests supported RFBMC 1's strong texture and cohesion, aligning with sensory feedback. However, challenges like temperature control during processing and potential inconsistencies in hygiene were noted. Future research should focus on standardized protocols, improved storage conditions, and broader sensory panel demographics. Additional studies could also assess long-term stability, prebiotic potential, and the impact of packaging on shelf life. In conclusion, RFBMC 1 stands out as a promising, nutritious, and consumer-friendly snack. With further improvements, it holds strong potential in the health-focused food market.

CONFLICT OF INTEREST

The authors have declared that no conflict of interest exists.

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