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(Original Article)

Development of a Functional Yogurt-Smoothie Beverage Using Ripe Banana and Orange-Fleshed Sweet Potato as Natural Fat and Sugar Replacers

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Abstract

This study developed yogurt-based functional smoothies by replacing plain yogurt with 15%, 20%, and 25% of ripe banana (RB) or orange-fleshed sweet potato (OFSP). The aim was to create beverages with low fat, sugar, and calories, while offering improved nutritional value and acceptable sensory and storage properties. Both RB and OFSP significantly increased dietary fiber, viscosity, and stability, while reducing fat and energy content. OFSP smoothies exhibited higher viscosity and stability (up to 21 days), whereas RB smoothies recorded higher in flavor and acceptability. Fat decreased by up to 24.23% in OFSP samples and 23.77% in RB samples. Sensory evaluation favored RB at 20% and 25% levels. The study concluded that RB and OFSP smoothies are effective functional beverages with improved nutritional and physical properties.

Keywords: *Functional cold beverages; Gums (guar and xanthan); Orange-fleshed sweet potato; Ripe banana; Smoothies.*

Introduction

Milk-based beverages are rich in bioactive components such as peptides, vitamins, and minerals, making them ideal carriers for functional food development (Ozer and Kirmaci, 2010). With growing interest in health and wellness, consumer demand has shifted toward low-calorie, nutrient-enriched products, including functional cold beverages (Oraman, 2019).

Smoothies-blended beverages made from fruit purée combined with milk, yogurt, or juice have gained popularity as convenient sources of fiber, vitamins, and antioxidants (Rani *et al*., 2016; Tiwari, 2018, Gallina *et al*., 2019). However, many commercial smoothies are high in added sugars and low in dietary fiber, contributing to metabolic health concerns (Wojcicki and Heyman, 2012; Imamura *et al*., 2015; Yang *et al*., 2025).

Fruits and vegetables play a central role in achieving a healthy diet due to their high content of dietary fiber, vitamins, and phytochemicals (Slavin and Lloyd, 2012). In addition to their nutritional value, they offer sensory appeal through their natural colors, flavors, and aromas. As a result, public health campaigns and consumer trends have increasingly favored foods enriched with fruits and vegetables, leading to

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reformulations of many traditional food products to enhance their nutritional quality (Gasparre and Rosell, 2022).

Bananas (*Musa spp.*) and orange-fleshed sweet potatoes (*Ipomoea batatas L.*) are nutrient-dense ingredients rich in carbohydrates, dietary fiber, vitamins (A, B6, C), and minerals like potassium and magnesium. Both have been studied for their functional and health-promoting properties (Alam, 2021; Safrida *et al*., 2022; Olaniran *et al*., 2024).

On the other hand, incorporating hydrocolloids such as guar and xanthan gum can enhance beverage stability and texture by reducing sedimentation and phase separation (Johnson and Lee, 2019; Staubmann *et al*., 2023).

This study aims to develop a low-calorie, functional yogurt-smoothie beverage using ripe banana and orange-fleshed sweet potato as natural sweeteners, fat replacers, and fiber sources, with added stabilizers to improve quality and shelf life.

Materials and Methods

1. Materials

- Milk: The whole buffalo's milk used in this study was obtained from the animal production herd at the Faculty of Agriculture, Sohag University, Egypt.

- Fruits and Vegetables: Ripe bananas (*Musa spp.*) and orange-fleshed sweet potatoes (*Ipomoea batatas* L.), were purchased from the local market in Sohag, Egypt.

- Sugar: Sucrose (cane sugar) was purchased from the local market, Sohag, Egypt.

- Hydrocolloids: Guar gum (Premcem Gums Pvt. Ltd., India) and xanthan gum (Foodchem International Corp., China) were used as stabilizers.

2. Methods

- Preparation of Banana Pulp: Bananas were washed, peeled, and crushed into pulp. The pulp was pasteurized at 95°C for 15 min, packed into jars, and stored at –20°C until use.

- Preparation of Sweet Potato Purée: OFSP tubers were washed, oven-roasted at 180°C for 45–60 minutes, peeled, and blended into a purée. The purée was stored at –20°C until use.

- Smoothie Formulation: Smoothies were prepared by blending plain yogurt (made from buffalo's milk) with either RB pulp or OFSP purée at concentrations of 15%, 20%, and 25% (w/w). A stabilizer mixture (0.3%) of guar and xanthan gums (1:1) and potassium sorbate (0.3%) as a preservative, was added. A control sample was prepared with 8% added sugar and no fruit/vegetable. The formulations are presented in Table (1). All formulations were blended, heated to 80°C, hot-filled into 500 mL glass jars, sealed, then cooled, and stored at 4 ± 1°C for 21 days. Each batch was prepared duplicate. Samples were analyzed on days 1, 7, 14, and 21 of the storage periods.

Table 1. Formulation of smoothies made with ripe bananas and orange-fleshed sweet potatoes as fat and sugar replacers

Formulations	Ingredients (%)		
	YO	RB	OFSP
Control*	100	-	-
SM (15% RB)	85	15	-
SM (20% RB)	80	20	-
SM (25% RB)	75	25	-
SM (15% OFSP)	85	-	15
SM (20% OFSP)	80	-	20
SM (25% OFSP)	75	-	25

Control*: Smoothie made with plain yogurt with 8% added sugar and without any added fruits or vegetables; SM: Smoothie; YO: yogurt; RB: Ripe banana; OFSP: Orange-fleshed sweet potato

3. Analytical Methods

- Chemical Composition: Samples were analyzed in triplicate for total solids, protein, fat, ash, carbohydrates, and crude fiber, following standard methods of Association of Official Analytical Chemists (AOAC, 2000).

- Physicochemical Properties: Color parameters (L*, a*, b*) were measured using a Hunter Lab colorimeter, as described by Wang *et al*. (2014). Apparent viscosity was determined at 25 ± 1 °C using a Brookfield viscometer operating at 30 rpm. The pH was measured with a digital pH meter, while titratable acidity (expressed as % lactic acid) was determined by titration according to the method of Goff and Hartel (2013). Total soluble solids (TSS) were measured as °Brix using a digital refractometer (Wang *et al*., 2014).

- Foaming Properties: Foaming properties were evaluated according to the method described by Ho *et al*. (2021). Foaming capacity and foaming stability were calculated using the following formulas:

Foaming capacity (%) = (Vf – Vi) × 100 / Vi

Foaming stability (%) = Vr × 100 / Vi

Where Vi = initial volume, Vf = final foam volume, Vr = volume retained after 30 min.

- Energy Value: Energy content (kcal/g) was calculated using standard Atwater conversion factors: 4 kcal/g for protein and carbohydrates, and 9 kcal/g for fat (Goff and Hartel, 2013).

- Sensory Evaluation: A trained panel of seven staff members from the Faculty of Agriculture, Sohag University, evaluated the smoothie formulations for flavor, body and texture, color, sweetness, and overall acceptability using a 9-point hedonic scale, where 1 indicated 'dislike extremely' and 9 indicated 'like extremely' (Saranyambiga *et al*., 2017).

- Storage Stability: Storage stability (phase separation) was monitored daily during the 21-day storage period at 4°C, following the method described by Reiner *et al*. (2010).

4. Statistical Analysis

All analyses were performed in triplicate using samples obtained from two independent production batches. Data were statistically analyzed using SAS software

version 9.4 (SAS Institute Inc., Cary, NC, USA) (SAS, 2016). Analysis of variance (ANOVA) was conducted using the PROC MIXED procedure, and differences among means were considered statistically significant at $p \leq 0.05$.

Results and Discussions

1. Chemical Composition of Selected Fruits and Vegetables

Ripe banana (RB) and orange-fleshed sweet potato (OFSP), the second major ingredients in the smoothie formulations, significantly influenced the taste, flavor, and color of the final product. Table (2) presents their chemical composition, including total solids, fat, protein, ash, dietary fiber, and carbohydrate content. OFSP exhibited higher values for total solids, protein, ash, fiber, and carbohydrates compared to RB. These findings are consistent with previous reports by Rose and Vasanthakaalam (2011); Egbebi and Bademosi (2012); and Hazo and Yirgalem (2021).

Table 2. Chemical composition of ripe bananas and orange-fleshed sweet potatoes used

Constituents*	RB	OFSP
T.S	30.23[b]	49.51[a]
Fat	0.31[a]	0.24[a]
Protein	1.13[b]	2.01[a]
Ash	0.88[b]	1.11[a]
Fiber	1.88[b]	2.30[a]
Carbohydrates	29.26[b]	46.15[a]

*Mean of three replicates ، RB: Ripe banana، OFSP: Orange fleshed-sweet potato
Values with different superscript letters within the same row are significantly different ($p \leq 0.05$).

2. Chemical Composition of Smoothie Formulations

Table (3) shows the compositional changes observed with the partial replacement of plain yogurt with RB and OFSP.

Total solids (T.S.) in all experimental formulations increased significantly ($p \leq 0.05$) with increasing levels of RB and OFSP, ranging from 19.83% to 26.97% throughout the storage period, but remained slightly lower than the control (26.30–26.37%), which contained 8% added sugar. This explains the higher T.S. content in the control, as refined sugar directly increased its total solids content. In contrast, the experimental formulations relied on the natural sugars and plant solids from the fruit and vegetable additives, which, despite contributing fiber and carbohydrates, did not match the concentrated solid load provided by added refined sugar.

Fat content decreased significantly ($p \leq 0.05$) with increasing levels of RB and OFSP, reflecting the low fat contribution from these ingredients. The control sample (7.19%) had the highest fat content, while the 25% OFSP formulation showed the lowest (5.43%). Protein content showed a slight decrease across treatments, which could be attributed to the minimal protein contribution of the plant-based additives. Ash content increased modestly in all formulations, likely due to the mineral richness of RB and OFSP. Carbohydrate levels increased significantly in RB- and OFSP-based smoothies, driven by the high starch and sugar content of the plant ingredients.

Overall, the smoothies maintained stable chemical profiles over the 21-day storage period, with only minor variations. Slight increases in total solids, fat, protein, and carbohydrates were observed, supporting the functional role of RB and OFSP as natural fat and sugar replacers.

Table 3. Chemical composition of smoothie formulations made with ripe bananas and orange-fleshed sweet potatoes as fat and sugar replacers during storage at 4 ± 1°C for 21 days

Storage period (days)	Formulations	Chemical composition (%)				
		T.S.	Fat	Protein	Ash	Carbohydrates
1	**Control***	26.30^{a}	7.17^{a}	4.33^{a}	0.80^{e}	13.99^{b}
	SM (15% RB)	19.83^{f}	6.25^{b}	4.15^{b}	0.85^{d}	08.58^{e}
	SM (20% RB)	20.99^{e}	5.81^{d}	4.08^{c}	0.88^{c}	10.22^{d}
	SM (25% RB)	21.69^{d}	5.47^{f}	4.02^{c}	0.90^{b}	11.30^{dc}
	SM (15% OFSP)	22.82^{c}	6.22^{c}	3.91^{dc}	0.86^{d}	11.83^{c}
	SM (20% OFSP)	24.76^{b}	5.93^{d}	3.76^{de}	0.89^{c}	14.18^{b}
	SM (25% OFSP)	26.40^{a}	5.43^{e}	3.62^{e}	0.95^{a}	16.39^{a}
7	**Control***	26.33^{a}	7.17^{a}	4.34^{a}	0.81^{e}	14.01^{b}
	SM (15% RB)	19.99^{f}	6.25^{b}	4.15^{b}	0.85^{d}	08.74^{e}
	SM (20% RB)	21.01^{e}	5.81^{d}	4.09^{c}	0.88^{c}	10.23^{d}
	SM (25% RB)	21.98^{d}	5.47^{f}	4.04^{c}	0.91^{b}	11.59^{dc}
	SM (15% OFSP)	22.95^{c}	6.22^{c}	3.91^{dc}	0.86^{d}	11.96^{c}
	SM (20% OFSP)	24.89^{b}	5.94^{d}	3.77^{de}	0.89^{c}	14.30^{b}
	SM (25% OFSP)	26.77^{a}	5.44^{e}	3.63^{e}	0.96^{a}	16.76^{a}
14	**Control***	26.36^{a}	7.19^{a}	4.35^{a}	0.82^{e}	14.00^{b}
	SM (15% RB)	20.11^{f}	6.26^{b}	4.16^{b}	0.85^{d}	08.85^{e}
	SM (20% RB)	21.11^{e}	5.82^{d}	4.09^{c}	0.88^{c}	10.33^{d}
	SM (25% RB)	22.15^{d}	5.47^{e}	4.06^{c}	0.92^{b}	11.76^{dc}
	SM (15% OFSP)	22.99^{c}	6.23^{c}	3.93^{dc}	0.86^{d}	12.00^{c}
	SM (20% OFSP)	24.91^{b}	5.93^{d}	3.79^{de}	0.89^{c}	14.32^{b}
	SM (25% OFSP)	26.87^{a}	5.45^{e}	3.65^{e}	0.97^{a}	16.86^{a}
21	**Control***	26.37^{a}	7.19^{a}	4.37^{a}	0.82^{e}	13.99^{b}
	SM (15% RB)	20.16^{f}	6.28^{b}	4.18^{b}	0.85^{d}	08.91^{e}
	SM (20% RB)	21.50^{e}	5.84^{d}	4.09^{c}	0.88^{c}	10.72^{d}
	SM (25% RB)	22.60^{d}	5.48^{e}	4.07^{c}	0.92^{b}	12.21^{dc}
	SM (15% OFSP)	23.09^{c}	6.24^{c}	3.93^{dc}	0.86^{d}	12.10^{c}
	SM (20% OFSP)	24.97^{b}	5.94^{d}	3.79^{de}	0.89^{c}	14.38^{b}
	SM (25% OFSP)	26.97^{a}	5.47^{e}	3.65^{e}	0.97^{a}	16.96^{a}

Control*: Smoothie made with plain yogurt with 8% added sugar and without any added fruits or vegetables; SM: Smoothie; YO: yogurt; RB: Ripe banana; OFSP: Orange-fleshed sweet potato. Values are means of three replicates. Values with different superscript letters within the same column are significantly different ($p \leq 0.05$)

3. Physicochemical Properties of Smoothie Formulation

The physicochemical properties of the smoothie formulations containing ripe banana (RB) and orange-fleshed sweet potato (OFSP) including color parameters (L, a, b*), total soluble solids (TSS), density, apparent viscosity, pH, and titratable acidity are presented in Table (4).

Table 4. Physicochemical properties of smoothie formulations made with ripe bananas and orange-fleshed sweet potatoes as fat and sugar replacers

Formulations	Physicochemical properties							
	Color parameters			TSS (°Brix)	Density (g/cm-3)	Apparent viscosity (cP)	pH-value	T.A (%)
	L*	a*	b*					
Control*	48.72^{a}	7.45^{g}	14.62^{g}	16.01^{a}	1.0611^{g}	37^{g}	4.72^{a}	0.80^{g}
SM (15% RB)	46.23^{b}	8.20^{f}	20.38^{f}	08.83^{g}	1.0620^{f}	45^{f}	4.61^{c}	0.83^{e}
SM (20% RB)	44.74^{c}	8.31^{e}	21.12^{e}	09.80^{e}	1.0631^{e}	47^{e}	4.57^{d}	0.86^{c}
SM (25% RB)	43.56^{e}	8.94^{d}	22.45^{d}	10.55^{d}	1.0645^{d}	51^{c}	4.51^{e}	0.89^{a}
SM (15% OFSP)	44.54^{d}	9.13^{c}	29.16^{c}	9.12^{f}	1.0681^{c}	48^{d}	4.65^{b}	0.81^{f}
SM (20% OFSP)	42.16^{f}	10.21^{b}	30.66^{b}	11.53^{c}	1.0711^{b}	53^{b}	4.58^{d}	0.84^{d}
SM (25% OFSP)	40.88^{g}	11.07^{a}	33.15^{a}	12.60^{b}	1.0753^{a}	58^{a}	4.53^{e}	0.87^{b}

Control*: Smoothie made with plain yogurt with 8% added sugar and without any added fruits or vegetables; SM: Smoothie; RB: Ripe banana; OFSP: Orange-fleshed sweet potato. Values are means of three replicates. Values with different superscript letters within the same column are significantly different ($p \leq 0.05$)

- Color Parameters: Color analysis revealed that the control smoothie exhibited the highest brightness (L* = 48.72), likely due to the absence of plant pigments derived from ripe bananas or orange-fleshed sweet potatoes. The L* value declined with the inclusion of RB and OFSP, especially in the OFSP smoothies, which exhibited deeper pigmentation. Redness (a*) values increased proportionally with the level of fruit/vegetable addition. The highest a* value (11.07) was recorded for SM (25% OFSP), attributed to the natural carotenoid content in sweet potatoes. Yellowness (b*) followed a similar trend, with SM (25% OFSP) exhibiting the most intense yellow hue (b* = 33.15), confirming the strong chromatic influence of carotenoids (Table 4).

- Total Soluble Solids (TSS): TSS values ranged from 8.83 to 16.60 °Brix. The control had a high TSS (16.01 °Brix), reflecting the added sugar content. Experimental formulations showed proportional increases in TSS with rising levels of RB and OFSP, indicating the contribution of natural sugars and soluble solids from both ingredients (Table 4).

- Density: The density of the smoothie formulations increased significantly ($p \leq 0.05$) with the addition and concentration of both ripe banana (RB) and orange-fleshed sweet potato (OFSP), ranging from 1.0611 g/cm³ in the control to 1.0753 g/cm³ in the 25% OFSP formulation. The control smoothie, which contained no added fruits or vegetables, exhibited the lowest density, likely due to its relatively higher water content and lower total solids. As the proportion of RB and OFSP increased from 15% to 25%, a corresponding rise in density was observed. This can be attributed to the high levels of total soluble solids, starch, and dietary fiber present in both RB and especially in OFSP, which contribute to greater mass per unit volume.

OFSP smoothies consistently exhibited higher density values than those made with RB at equivalent concentrations. For example, the density of the 25% OFSP formulation reached 1.0753 g/cm³, compared to 1.0645 g/cm³ for the 25% RB formulation (Table 4). This difference may be due to the greater carbohydrate and dry matter content in OFSP, including resistant starch and fibrous cell wall materials, which increase the overall solid load of the mixture. Additionally, the physical structure of OFSP may retain less air during blending compared to RB, further contributing to a higher density.

- Apparent Viscosity: Apparent viscosity increased significantly ($p \leq 0.05$) in all experimental formulations, particularly in OFSP smoothies. The highest viscosity (58 cP) was observed in SM (25% OFSP), reflecting the structural contribution of sweet potato starch and fiber (Table 4). This enhancement improves mouthfeel and beverage stability (Choi and Yoo, 2009).

- pH and Titratable Acidity: A significant decline in pH and an increase in titratable acidity were observed in the experimental samples compared to the control. This effect is likely due to the presence of organic acids and fermentable sugars in RB and OFSP, which may influence microbial activity during storage. The lowest pH value was observed in SM (25% OFSP) (4.51), while the highest acidity (0.89%) was recorded in the same formulation (Table 4).

4. Foaming Properties

Foaming properties, including foam volume, foam capacity, and foam stability, are presented in Table (5) and Figure (1). The control smoothie demonstrated the highest foaming volume (23.00 mL), foaming capacity (30.66%), and foam stability (18.00 minutes), likely due to the absence of high-fiber or dense plant-based ingredients. Among the enriched formulations, those containing RB showed superior foaming properties compared to OFSP samples. Smoothies with 15% and 20% RB had higher foam volumes (20.00 and 17.00 mL), capacities (26.66% and 22.66%), and relatively good foam stability (14.00 and 13.00 minutes). This improved foamability can be attributed to natural stabilizing pectin in RB (Deotale *et al*., 2020).

Meanwhile, OFSP-containing smoothies showed progressively lower foaming values with increased concentration. The 25% OFSP formulation had the lowest foam volume (10.00 mL), capacity (13.33%), and stability (5.00 minutes). This reduction is likely due to the higher fiber and starch content in OFSP, which inhibits air incorporation (Hatakeyama *et al*., 2019). Notably, increasing the concentration of either RB or OFSP beyond 20% negatively impacted all three foaming properties.

In contrast, the guar–xanthan gum blend likely played a stabilizing role by increasing viscosity and supporting the foam structure, thereby enhancing overall foam stability in certain formulations (Smith *et al*., 2021)

Table 5. Foaming properties of smoothie formulations made with ripe bananas and orange-fleshed sweet potatoes

Formulations	Foaming properties		
	Foam volume (ml)	Foaming capacity (%)	Foaming stability (min)
Control*	23^{a}	30.66^{a}	18^{a}
SM (RB 15%)	20^{b}	26.66^{b}	14^{b}
SM (RB 20%)	17^{c}	22.66^{c}	13^{c}
SM (RB 25%)	14^{d}	18.66^{d}	12^{bc}
SM (OFSP 15%)	14^{d}	18.66^{d}	10^{d}
SM (OFSP 20%)	11^{e}	14.66^{e}	7^{e}
SM (OFSP 25%)	10^{f}	13.33^{f}	5^{f}

Control*: Smoothie made with plain yogurt with 8% added sugar and without any added fruits or vegetables, SM: Smoothie; RB: Ripe banana; OFSP: Orange-fleshed sweet potato. Values are means of three replicates. Values with different superscript letters within the same column are significantly different ($p \leq 0.05$).

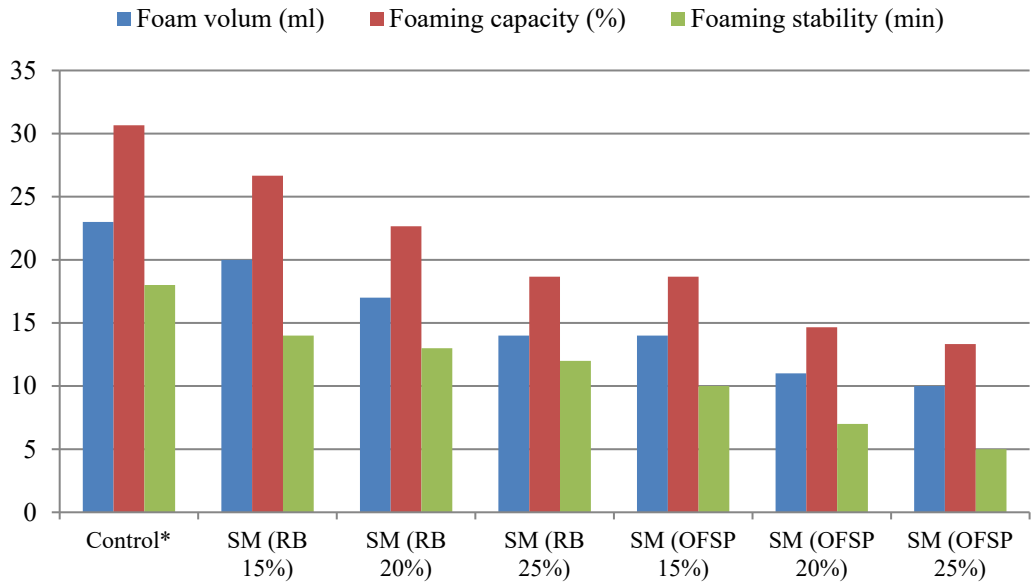

Figure 1. Foaming properties of smoothie formulations made with ripe bananas and orange-fleshed sweet potatoes. Control*: Smoothie made with plain yogurt with 8% added sugar and without any added fruits or vegetables; SM: Smoothie; RB: Ripe banana; OFSP: Orange-fleshed sweet potato.

5. Energy Values

Energy calculations, as shown in Table (6) and Figure (2), showed significant reductions in all experimental formulations compared to the control. The greatest calorie reduction (22.28%) was achieved in SM (15% RB), while the highest fat reduction (24.23%) occurred in SM (25% OFSP). These results confirm the successful formulation of low-calorie smoothies by substituting part of the milk matrix with plant-based alternatives (Laurie *et al.*, 2018).

Table 6. Fat and energy reductions for smoothie formulations made with ripe bananas and orange-fleshed sweet potatoes

Formulations	Fat and energy reductions			
	Fat (%)	**Fat reduction (%)**	**Energy values (kcal/g)**	**Energy reduction (%)**
Control*	7.17	-	137.81	-
SM (RB 15%)	6.25	12.89	107.10	22.28
SM (RB 20%)	5.81	19.00	109.46	20.57
SM (RB 25%)	5.47	23.77	110.48	19.83
SM (OFSP 15%)	6.22	13.25	118.91	13.71
SM (OFSP 20%)	5.93	17.34	124.95	09.33
SM (OFSP 25%)	5.43	24.23	128.94	06.43

Control*: Smoothie made with plain yogurt with 8% added sugar and without any added fruits or vegetables; SM: Smoothie; RB: Ripe banana; OFSP: Orange-fleshed sweet potato

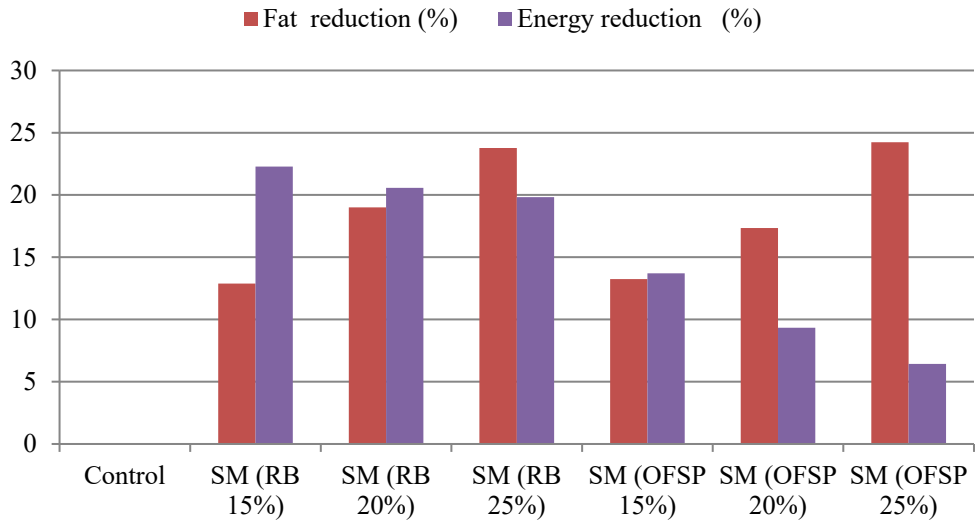

Figure 2. Fat and energy reductions for smoothie formulations made with ripe bananas and orange-fleshed sweet potatoes. Control*: Smoothie made with plain yogurt with 8% added sugar and without any added fruits or vegetables; SM: Smoothie; RB: Ripe banana; OFSP: Orange-fleshed sweet potato

6. Sensory Properties

Data in Table (7) and Figure (3) summarize the sensory ratings over the 21-day storage period. Initially, all formulations received high sensory scores, especially SM (20% RB) for flavor (8.80/9) and SM (15% RB) for body and texture. RB smoothies consistently outperformed OFSP counterparts in taste, texture, and overall acceptability. As storage progressed, sensory scores gradually declined. However, smoothies with 15% and 20% RB retained relatively higher acceptability, likely due to the natural sugars and volatile flavor compounds in ripe banana (Adeyemi and Oladiji, 2009).

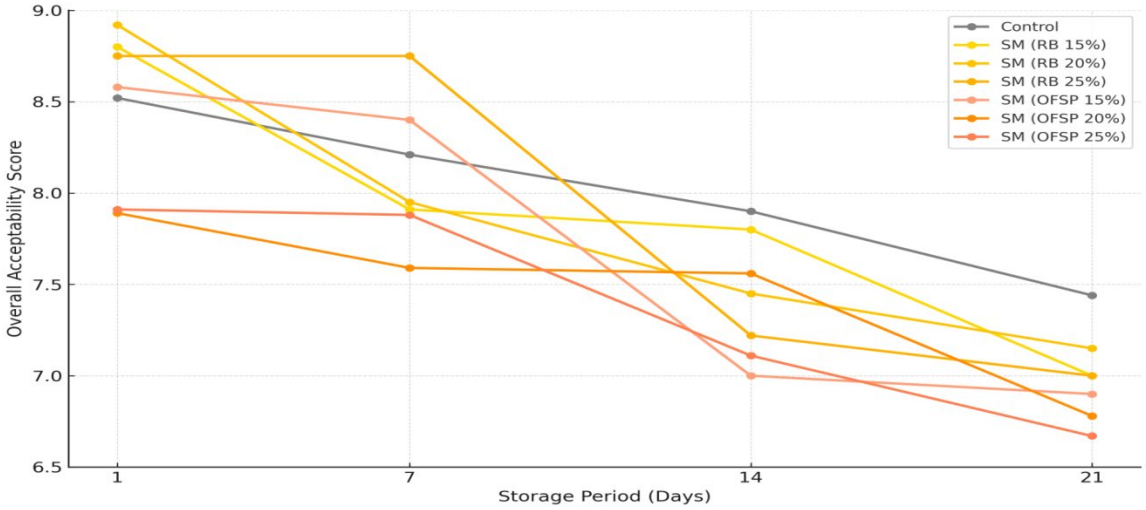

Figure 3. Overall acceptability trends of smoothie formulations made with ripe bananas and orange-fleshed sweet potatoes as fat and sugar replacers during storage at 4 ± 1°C for 21 days. Control*: Smoothie made with plain yogurt with 8% added sugar and without any added fruits or vegetables; SM: Smoothie; RB: Ripe banana; OFSP: Orange-fleshed sweet potato.

OFSP smoothies showed greater declines in sensory properties over time. Although visually appealing, their texture and flavor were less favored after extended storage—possibly due to starch retro-gradation and fiber hydration (Staubmann *et al.*, 2023). Notably, the 25% RB smoothie experienced a sharper drop in sensory scores than lower RB levels, indicating a threshold beyond which excessive sweetness or thickening affects consumer acceptance.

Table 7. Sensory properties of smoothie formulations made with ripe bananas and orange-fleshed sweet potatoes as fat and sugar replacers during storage at 4 ± 1°C for 21 days

Formulations	Storage period (days)	Sensory attributes				
		Flavor (9)	Body and Texture (9)	Color and Appearance (9)	Sweetness (9)	Overall acceptability (9)
Control*	1	8.50	7.60	8.70	8.98	8.52
SM (RB 15%)		8.30	8.75	8.90	8.00	8.80
SM (RB 20%)		8.80	8.00	8.92	8.13	8.92
SM (RB 25%)		8.33	7.90	8.75	8.13	8.75
SM (OFSP 15%)		7.80	7.67	8.96	7.90	8.58
SM (OFSP 20%)		7.95	8.11	8.96	7.98	7.89
SM (OFSP 25%)		7.68	7.56	8.98	8.20	7.91
Control*	7	8.42	7.55	8.62	8.88	8.21
SM (RB 15%)		8.18	8.69	8.82	7.98	7.91
SM (RB 20%)		8.75	7.98	8.85	8.09	7.95
SM (RB 25%)		8.25	7.88	8.70	8.11	8.75
SM (OFSP 15%)		7.86	7.61	8.94	7.93	8.40
SM (OFSP 20%)		7.89	8.00	8.95	7.95	7.59
SM (OFSP 25%)		7.62	7.50	8.89	8.05	7.88
Control*	14	8.11	7.42	8.59	8.30	7.90
SM (RB 15%)		8.00	8.50	8.70	7.80	7.80
SM (RB 20%)		8.32	7.72	8.75	7.95	7.45
SM (RB 25%)		8.12	7.71	8.50	7.98	7.22
SM (OFSP 15%)		7.56	7.56	8.80	7.80	7.00
SM (OFSP 20%)		7.77	8.00	8.89	7.84	7.56
SM (OFSP 25%)		7.60	7.30	8.80	7.99	7.11
Control*	21	7.50	7.00	7.95	7.65	7.44
SM (RB 15%)		7.31	7.50	7.89	7.30	7.00
SM (RB 20%)		8.00	7.61	7.95	7.54	7.15
SM (RB 25%)		7.90	7.61	7.50	7.62	7.00
SM (OFSP 15%)		7.11	7.30	8.01	7.22	6.90
SM (OFSP 20%)		7.20	7.71	8.14	7.60	6.78
SM (OFSP 25%)		7.01	6.99	8.42	7.72	6.67

Control*: Smoothie made with plain yogurt with 8% added sugar and without any added fruits or vegetables; SM: Smoothie; RB: Ripe banana; OFSP: Orange-fleshed sweet potato

7. Storage Stability (Phase Separation)

Figure (4) illustrates storage stability trends over 21 days. Smoothies with OFSP exhibited greater phase stability (16–21 days) compared to those with RB (13–17 days), likely due to higher fiber and starch content forming more robust matrices. The control sample showed the shortest stability period due to the absence of fiber. Use of hydrocolloids such as guar and xanthan gums effectively reduced phase separation, enhancing beverage shelf life.

Figure 4. Phase separation in smoothie formulations containing varying concentrations of ripe banana (RB) and orange-fleshed sweet potato (OFSP) as natural fat and sugar replacers during storage at 4 ± 1°C for 21 days. Order from left to right: Control, SM (15% RB), SM (20% RB), SM (25% RB), SM (15% OFSP), SM (20% OFSP), and SM (25% OFSP). Control: Smoothie (SM) made with plain yogurt with 8% added sugar and without any added fruits or vegetables.

These findings suggest that OFSP offers superior structural integrity during refrigerated storage, while RB contributes to favorable sensory and textural attributes. These results are consistent with those derived from the literature (Taherian *et al*., 2007; Norhayati *et al*., 2019; Staubmann *et al*., 2023).

Overall, the functional smoothie formulations using RB and OFSP proved effective in reducing fat and energy content, improving sensory acceptability, and maintaining physicochemical and structural stability throughout refrigerated storage.

Conclusion

This study confirmed the potential of ripe banana (RB) and orange-fleshed sweet potato (OFSP) as effective natural fat and sugar replacers in functional smoothie formulations. Their inclusion led to reduced fat, sugar, and energy content, while enhancing fiber, minerals, and overall functional properties. Smoothies showed good physicochemical and storage stability, with RB improved flavor and texture—especially at 15–20%—while OFSP contributed to color and visual appeal. Both ingredients offer clean-label, health-promoting options suitable for modern functional beverages.

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تطوير مشـروب سـموزي وظيفي من الياغورت باسـتخدام الموز الناضـج والبطاطا الحلوة ذات اللب البرتقالي كبدائل طبيعية للدهون والسكريات

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الملخص

هدفت هذه الدراسة إلى التحقق من إمكانية استخدام الموز الناضج (RB) والبطاطا الحلوة برتقالية اللب (OFSP) كمكونات طبيعية بديلة للدهون والسكريات في تحضير مشروبات سموزي منخفضة السعرات الحرارية وذات خصائص وظيفية. أدى دمجRB ، OFSP إلى تحسينات غذائية ملحوظة، شملت تقليل محتوى الدهن والسعرات الحرارية، وزيادة محتوى الألياف والكربوهيدرات. كما أظهرت المشروبات الناتجة خصائص فيزيائية وكيميائية مرغوبة، تمثلت في زيادة اللزوجة، وثبات قيم الرقم الهيدروجيني والحموضة، وتحسن الصفات اللونية، خاصةً في العينات المدعمة بـــOFSP وساهمت الألياف الغذائية الموجودة في OFSP، RB إلى جانب استخدام خليط من صمغ الغوار وصمغ الزانثان (بنسبة 1:1) في الحد من ظاهرة الانفصال الطبقي وتحقيق استقرار جيد خلال فترة تخزين استمرت 21 يومًا على درجة حرارة 4 ± 1°م. أظهرت التقييمات الحسية تفوق المشروبات المحتوية على RB ، خاصة عند نسبتي 15% ، 20%، من حيث النكهة والقوام والقبول العام. في حين تفوقت مشروبات OFSPفي صفاتها اللونية ومظهرها الجذاب. تؤكد هذه النتائج إمكانية استخدامRB ، OFSP بفاعلية في تطوير مشروبات سموزي وظيفية ذات قيمة غذائية محسنة وقبول استهلاكي مرتفع .كما أن هذه المكونات تمثل بدائل طبيعية وصحية للدهون والسكريات، مما يجعلها ملائمة للنظم الغذائية المعاصرة التي تركز على تعزيز صحة المستهلك.

الكلمات المفتاحية: *البطاطا الحلوة برتقالية اللب، سموزى، صموغ (الغوار، الزانثان)، مشروبات بارده وظيفيه، موز ناضج.*