Journal of Sohag Agriscience (JSAS) 2024, 9(2): 308-323

ISSN 2357-0725
https://jsasj.journals.ekb.eg
JSAS 2024; 9(2): 308-323

Received: 11-11-2024
Accepted: 30-12-2024

Abd El-Khair A. A.
Abd-Alla A. A.
Noha A. Hassan
Ateteallah H. A.

Dairy science Department
Faculty of Agriculture
Sohag University
sohag
Egypt

Corresponding author:
Noha A. Hassan
nohahassan.agr@gmail.com

Development of functional milkshake beverage from unripe banana and white sweet potato with acceptable quality

Abd El-Khair A. A., Abd-Alla A. A., Noha A. Hassan and Ateteallah H. A.

Abstract

This study aimed to produce a functional beverage with acceptable quality and low energy. Milkshakes were prepared using ice cream with 14% sugar (control), then ice cream was partially replaced by adding unripe banana (green) and white sweet potato at 15%, 20% and 25%. The prepared beverages were stored for 21 days and analyzed for chemical, physical and sensory evaluation, energy properties, color and foam stability. The results showed that the total soluble solids of the milkshake decreased with the addition of unripe banana but increased with the increase of white potato from 15 to 25% in the milkshake. Similarly, ash, fiber, carbohydrates, acidity and viscosity also increased with the increase of the percentage of unripe banana and white potato. While the pH of the unripe banana and white potato milkshake decreased with the increase of the percentage of unripe banana and white potato in the milkshake. The control sample outperformed the experimental beverages in foam volume. The highest energy value was in the control sample, while the lowest energy value was for the beverages containing 25% unripe banana. The white potato beverages with 20% addition had the highest overall acceptability score, followed by the unripe banana beverages with 25% addition. The control sample outperformed the experimental beverages in color brightness L*. The white potato beverages were more stable than the unripe banana beverages.

Keywords: functional cold beverages, milkshake, unripe banana, sweet potato

INTRODUCTION

Milk-based beverages contain several components in addition to the basic components with beneficial physiological functions, such as peptides, oligosaccharides, vitamins, and minerals. These components can be used as functional ingredients for the development of functional food products with certain health benefits (Ozer and Kirmaci, 2010). Functional beverages provide specific health benefits in addition to one or all of the functions listed above (Playne *et al*., 2003). Functionality of these beverages is due to the fortification of some bioactive or functional ingredients. The global functional beverages market size is estimated at USD 158.05 billion in 2024 and is expected to reach around USD 296.67 billion by 2034, expanding at a CAGR of 6.50% from 2024 to 2034 (Precedence Research Report, 2024). Milkshakes are delicious cold milk-based beverages, typically made by combining milk, ice cream, and sugar and then quickly blending the product in a blender to make it pourable (Patil *et al*., 2019). Flavoring is added from syrup and raw fruit, but some milkshakes get their flavor from flavored ice cream alone. They are usually sweetened with chocolate syrup, strawberry syrup, malt syrup, sugar syrup, etc. They may also contain lots of fruit and additional flavors. Milkshakes are very high in fat and sugar, so they tend to be higher in calories than other beverages (Gilbert *et al*., 2018). Nowadays, consumer trends are orientated to functional food and/or the reformulation of typical products to increase nutritional value. The focus on health has become a powerful engine today even for luxury food products such as cold beverages can be developed to meet consumer demand (Oraman, 2019). As a result, health-conscious individuals are modifying their dietary habits and eating less fat. Consumer acceptance of any food product depends primarily on taste —the most important sensory attribute. Although consumers want foods that contain minimal or no fat or calories, they also want foods to taste good. The development of low-fat foods with the same desirable attributes as the corresponding full-fat counterparts has created a clear challenge for food manufacturers. Fats have functional properties that influence the processing and eating characteristics of food, and these functions must be taken into account when reducing fat in a product (Hamilton *et al*., 2000; Bimbo *et al*., 2017; Cammarelle *et al*., 2024). Fats in food products can be replaced by reformulating with selected ingredients that provide some fat-like properties (Sandrou and Arvanitoyannis, 2000). High fat intake is associated with an increased risk of some types of cancer, and saturated fat intake is associated with elevated blood cholesterol and coronary heart disease (Kraus *et al*., 2001). Consumption of a high-fat diet has also been identified as a risk factor for excessive energy intake, positive energy balance, and the development of obesity. Current dietary guidelines recommend limiting total fat intake to less than 30% of calories and saturated fats to less than 10% of total energy intake for the population as a whole. The American Heart Association (AHA) recommends that people with elevated LDL cholesterol or cardiovascular disease limit saturated fats to less than 7% of calories. To achieve a healthier diet, current dietary guidelines recommend increasing the intake of fruits and vegetables and modifying the type and amount of fat consumed (Wylie-Rosett, 2002). Current health trend in beverage making involves development of low sugar, low fat, modified fat composition, modified protein composition, and fortified beverages (Paquin, 2009). Fruits and vegetables are an essential part of the human diet. They are particularly rich sources of dietary fiber, vitamins and various phytochemicals. Numerous studies have shown that they play a vital role in promoting health and preventing certain chronic diseases, such as hypertension, cancer, coronary heart disease, stroke, etc. (Mirmiran *et al*., 2014). In addition, they provide a lot of sensory sensations, as fruits and vegetables are rich in colorful and delicious compounds. Bananas and sweet potatoes are plants with balanced nutritional value, which have many benefits for maintaining the health of the body, such as maintaining the digestive system, preventing high blood cholesterol, and fighting diabetes. Several previous studies have reported the use of banana and sweet potato as functional food and medicinal properties (Safrida *et al*., 2022). Banana is one of the oldest crops cultivated by humans and remains a staple food crop for millions of people in the tropical world. It belongs to the genus Musa of the family Musaceae within the order Scitamineae (Venkataramana *et al*., 2015). Bananas are the second highest fruit production after citrus fruits, accounting for about 16% of global fruit production (FAO, 2021). Despite being high in calories, which come primarily from carbohydrates and dietary fiber, bananas are low in protein and fat. Vitamins C, A, B1, B2, and B6, as well as minerals such as magnesium, phosphorus, calcium, and iron can also be found in bananas. Banana consumption may be associated with a reduced risk of gastrointestinal diseases, regulation of carbohydrate metabolism, and weight control (Falcomer *et al*., 2019). Banana (Musa acuminata) is a good source of carbohydrates, minerals such as potassium, and vitamins. It contains many important vitamins (groups A, C, E, K, and B), is rich in fiber, and contains many minerals (magnesium, phosphorus, calcium, and potassium). It has also been reported to relieve constipation due to its fiber content and prevent anemia by stimulating hemoglobin production due to its iron content (Olaniran *et al*., 2024). Unripe bananas (Green bananas), tasteless and odorless, appear as an option that can be used as thickeners, improving the nutritional value and taking on the flavor and aroma of foods prepared with them (Oi *et al*., 2012). They can be used in the preparation of products with low fat and sugar content (Freitas and Tavares, 2005). Sweet potato (Ipomoea batatas L.) is another important economic crop in many countries. It is the seventh most important food crop in the world after wheat, rice, maize, potatoes, barley and cassava (FAO, 2016). Sweet potatoes have high nutritional value and sensory diversity in terms of taste, texture, and flesh color (white, cream, yellow, orange, and purple). Depending on the flesh color, sweet potatoes contain high levels of beta-carotene, anthocyanins, phenolics, dietary fiber, vitamins, minerals, and other bioactive compounds (van Jaarsveld *et al*., 2005; Low *et al*., 2007; Hotz *et al*., 2012). Sweet potato puree has been used as an ingredient in a variety of processed food products, including baby foods, casseroles, desserts, pies, cakes, ice cream, breads, pancakes, and soups. It has also been used in fruit/vegetable-based beverages. Sweet potato contains high levels of carbohydrates (the major carbohydrate components is starch), beta-carotene, vitamins (A, B6, C and E) and minerals (potassium, phosphorus, manganese, and zinc) which have several health benefits. It contains also, powerful antioxidants, fiber and pectin. Sweet potatoes are rich in carbohydrates and poor in protein. So, potatoes are the most efficient fuel for energy production (Zakir *et al*., 2008). White sweet potatoes are related to orange sweet potatoes, but with some notable differences, especially in texture and taste. Orange sweet potatoes have more moisture, orange-flesh and are very sweet, but white sweet potatoes are drier, have white-flesh and a mild nutty flavor (Ellong *et al*., 2014). Although the flesh of the white sweet potato resembles the color of another familiar white-fleshed sweet potato: the brown potato, the white sweet potato instead belongs to the morning glory family. Cooked white sweet potatoes are drier than orange sweet potatoes but still creamy with a hint of butter mixed in. They have a mild flavor and a dry, crumbly texture, are less starchy than brown potatoes but not as sweet as their orange counterparts (Dako *et al*., 2016). White sweet potatoes contain only 6 micrograms of beta-carotene compared to orange sweet potatoes which contain over 8,500 micrograms (Damtew *et al*., 2024). Surprisingly, although bananas and potatoes belong to different families, their energy, fiber, and potassium content are remarkably similar (Slavin and Lloyd, 2012). On the other hand, inclusion of hydrocolloids in beverage formulation is desirable from stability and viscosity point of view. Hydrocolloids are stabilizing polymers from plant (e.g., guar gum) or microbial sources (e.g., xanthan gum) (Mudgil *et al*., 2014). These hydrocolloids are also known as thickeners because of its high viscosity in aqueous systems (Mudgil *et al*., 2012; Barak and Mudgil, 2014). Hydrocolloids reduce sedimentation and or creaming upon storage in milk-based functional beverages (Mudgil and Barak, 2019). Therefore, the present study aimed to develop a functional, low-calorie milkshake with acceptable quality and long-term stability based on unripe banana or white-fleshed sweet potato as a fat replacer. Fresh fruits or vegetables such as bananas or sweet potatoes can be added for extra flavor to create milkshakes with different flavors.

MATERIALS AND METHODS

1. Materials:

1.1. Milk:

Whole buffalo milk used in this study was obtained from the Animal Production Farm, Faculty of Agriculture, Sohag University, Egypt.

1.2. Fruit and vegetables:

Unripe bananas and white fleshed sweet potatoes were purchased from the local market, Sohag, Egypt.

1.3. Ingredients:

Cane sugar, vanilla and stabilizer (gelatin) were purchased from the local market in Sohag Governorate, Egypt.

1.4. Guar gum:

Guar gum was supplied by Premcem Gums Pvt. Ltd, India

1.5. Xanthan gum:

Xanthan Gum was supplied by Foodchem International Corporation, China.

2. Methods:

2.1. Preparation of banana pulp:

The bananas were washed thoroughly with clean water and the outer layer or peel was separated with the help of a knife. The banana pulp was prepared by crushing the peeled fruits and kept for pasteurization at 95°C for 15 minutes and packed in jars at stored at -20°C until use.

2.2. Preparation of sweet potatoes puree:

White-fleshed sweet potatoes were washed with tap water before roasting in a gas oven at 180°C for 45-60 min. The roasted ingredients were individually peeled by hand, mixed well using a kitchen machine and stored at -20°C until use.

2.3. Milkshake preparation:

Milkshakes were prepared as described by Kashid *et al*. (2007) with slight modification. First, whole buffalo milk was separated into cream and skimmed milk by centrifugation at 40°C. The required amount of separated cream calculated using Pearson's square method was used to prepare a regular ice cream mix (12% fat, 14% sugar). Next, pasteurized unripe banana pulp and white-fleshed sweet potato puree were added to the ice cream in the proportions of 85/15, 80/20 and 75/25 (w/w). Then, a mixture of guar gum and xanthan gum in a ratio of 1:1 was added to the mix at 0.3%. It was then thoroughly mixed in a laboratory blender. Seven milkshake formulations were prepared. Three formulations were made using unripe banana and three formulations using white-fleshed sweet potato. A control sample was made without adding any fruits or vegetables. Each formula was repeated three times. All milkshakes were filled into glass bottles and stored at refrigerator temperature (5-8°C) for 21 days for analysis. The detailed formulation of the milkshake is shown in Table 1.

Table 1: Formulation of milkshake made with unripe bananas and white-fleshed sweet potatoes as fat replacers

Formulas	Ingredients (%)		
	IC	UBA	WF-SP
Control*	100	-	-
MS (UBA 15%)	85	15	-
MS (UBA 20%)	80	20	-
MS (UBA 25%)	75	25	-
MS (WFSP 15%)	85	--	15
MS (WFSP 20%)	80	--	20
MS (WFSP 25%)	75	--	25

Control*: A milkshake sample made with ice cream without any added fruits or vegetables

MS: milkshake; IC: ice cream; URB: unripe bananas; WF-SP: white-fleshed sweet potatoes

3. Analytical methods:
3.1. Chemical composition:

Milkshake formulations were analyzed in triplicate for total solids, protein, and fat by drying oven method, Macro-Kildal method, and Gerber's method, respectively. Ash content was analyzed in a muffle furnace at 550°C. T.S and total carbohydrates were calculated by the differences. The fat content of fruits and vegetables used was estimated using the Soxhlet method. Crude fibers were determined according to the AOAC (2000) method.

3.2. Physicochemical properties:

Color evaluation was performed at 25±2°C in triplicate using a Hunter Lab Color Quest XE colorimeter (Color Tec PCM Color Meter Tec NJ. USA) in reflectance mode and is expressed as L (brightness), a (redness) and b (yellowness) values. Four measurements were performed, and the results were averaged. The apparent viscosity was measured at 25 ± 1°C using a Brookfield digital viscometer (model MFDV-IS; Brookfield Engineering Laboratory, Middleboro, USA). The viscometer was operated at 30 rpm (spindle No. 1). Each result in triplicate was recorded in cP after 30s rotation. Titratable acidity was calculated as percentage of lactic acid by titration with 0.1N NaOH with added phenolphthalein indicator. The pH-values were measured using a digital pH-meter with a glass electrode of Testo 230 (Testo Ltd., Lenzkirch, Germany). The TSS was determined as °Brix at an ambient temperature (20 ± 1°C) using a digital Abbe Refractometer (HI96801 Refractometer).

3.3. Foaming properties:

Foaming capacity of each sample was determined under the ambient conditions (25 ± 1°C). 50 mL of sample was transferred in to a beaker and mixed at 3,000 rpm for 2 min, 30°C, the foaming capacity (FC) were determined by using following equation:

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

Vf = final foam volume

Vi = initial foam volume

The foaming stability was determined by transferring the sample to a graduated cylinder. Where; Vf is the volume of foam after mixing, Vi is the initial liquid volume, and Vr is the volume of liquid retained in the foam after 30 minutes. The effect on the stability of the foam properties was observed using the following formula:

Foaming stability % = Vr x 100 / Vi

3.4. The energy values:

Total energy values (kcal/g) were estimated according to Goff and Hartel (2013) 4 kcal/g for carbohydrates and proteins and 9 kcal/g for fats.

Total energy value = fat kcal + carbohydrates kcal + protein kcal

3.5. Sensory evaluation:

Milk shake samples were judged after 1, 7, 14 and 21 days of storage at (5 ± 1°C) by 10 panelists from Dairy Science Department, Faculty of Agriculture, Sohag University. Samples were evaluated for appearance, color, flavor, texture, taste, and overall acceptability. Sensory evaluation was done using 9 point hedonic scale (Sakhale *et al*., 2012).

3.6. Storage stability:

To estimate the long-term stability of beverages without phase separation, 500 ml of the beverage was taken and placed in a sealed bottle, then stored in the refrigerator and monitored daily.

4. Statistical analysis:

The entire experiment was repeated twice. All physical and chemical analyses were performed three times for each independent batch**.** SAS (2016) version 9.4 (SAS Institute Inc., Cary, NC) was used to perform the statistical analysis of all data using the ANOVA mixed procedure (proc mixed). Treatments were considered significantly different if $p \leq 0.05$.

RESULTS AND DISCUSSION

1. Approximate analysis of selected fruits and vegetables:

UBA and WFSP were the second major ingredient used in the preparation of milkshake formulations and had a significant impact on the taste, flavor and color of the final product.

Proximate analysis of UBA pulp and WFSP puree was performed to estimate total solids, fat, protein, ash, dietary fiber and carbohydrate content. The results obtained from the proximate analysis of unripe bananas and white-fleshed sweet potatoes are shown in Table 2.

Table 2: Approximate composition of unripe bananas and white fleshed sweet potatoes used

Constituents*	UBA	WF-SP
T.S	31.55[b]	51.11[a]
Fat	0.19[a]	0.22[a]
Protein	1.15[b]	2.15[a]
Ash	0.95[b]	1.16[a]
Fiber	2.90[b]	3.50[a]
Carbohydrates	27.91[b]	47.58[a]

*Mean of three replicates
UBA: Unripe Banana
WF-SP: White Fleshed-Sweet Potato

The results obtained from the analysis of UBA were consistent with those of Egbebi and Bademosi (2012) and the results from the analysis of WFSP were also consistent with those of Rose and Vasanthakaalam (2011) and Hazo and Yirgalem (2021).

2. Chemical composition of milkshake formulations:

Table 3 shows the chemical composition of milkshake formulations made with UBA and WFSP. Total solids increased significantly ($p \leq 0.05$) with the addition of WFSP, and decreased with the addition of UBA, and this increase or decrease was proportional to the level of addition. This may be due to the higher total solids content of WFSP compared to UBA. The total solids content of the experimental beverages ranged from 34.22% to 40.09% compared to 37.17% in the control sample. The addition of UBA and WFSP significantly decreased ($p \leq 0.05$) the fat content of the beverages. This may be due to the fact that the fat content of UBA and WFSP is very low. The fat content of the experimental beverages ranged from 9.1% to about 10.4%, while the control sample had the highest fat content (12.2%) as it was prepared without replacing the milk fat. There were slight differences in protein content in all experimental beverages studied compared to the control sample. This may be due to the fact that the protein content of UBA and WFSP is low. The results also showed a higher ash content in the experimental beverages compared to the control sample, ranging between 0.86 and 1.11% compared to 0.80% in the control.

Table 3: Chemical composition of low-calorie milkshake formulations made with unripe bananas and white potatoes as fat replacers during storage at 4 ± 1°C for 21 days

Formulas	Storage period (days)	Chemical composition (%)					
		T.S	Fat	Protein	Ash	Fiber	Carb
Control*	1	37.17^{d}	12.20^{a}	3.97^{a}	0.80^{g}	0.00	20.21^{g}
MS (85% IC + 15% UBA)		36.32^{e}	10.40^{b}	3.67^{b}	0.86^{f}	0.41^{f}	21.38^{d}
MS (80% IC + 20% UBA)		35.08^{f}	9.80^{d}	3.58^{c}	0.89^{d}	0.54^{d}	20.82^{e}
MS (75% IC + 25% UBA)		34.22^{g}	9.20^{f}	3.47^{e}	0.90^{c}	0.68^{b}	20.65^{f}
MS (85% IC + 15% WFSP)		38.43^{c}	10.20^{c}	3.51^{d}	0.87^{e}	0.50^{e}	23.86^{c}
MS (80% IC + 20% WFSP)		39.08^{b}	9.60^{e}	3.36^{f}	1.00^{b}	0.66^{c}	25.12^{b}
MS (75% IC + 25% WFSP)		40.09^{a}	9.10^{f}	3.22^{g}	1.11^{a}	0.83^{a}	26.01^{a}
Control*	7	37.22^{d}	12.30^{a}	3.96^{a}	0.79^{g}	0.00	2 0.22^{g}
MS (85% IC + 15% UBA)		36.32^{e}	10.40^{b}	3.67^{b}	0.86^{f}	0.41^{f}	21.40^{d}
MS (80% IC + 20% UBA)		35.09^{f}	9.80^{d}	3.58^{c}	0.89^{d}	0.54^{d}	20.83^{e}
MS (75% IC + 25% UBA)		34.24^{g}	9.40^{f}	3.47^{e}	0.90^{c}	0.68^{b}	20.47^{f}
MS (85% IC + 15% WFSP)		38.48^{c}	10.30^{c}	3.52^{d}	0.87^{e}	0.50^{e}	23.80^{c}
MS (80% IC + 20% WFSP)		39.10^{b}	9.60^{e}	3.36^{f}	1.00^{b}	0.66^{c}	25.14^{b}
MS (75% IC + 25% WFSP)		40.11^{a}	9.10^{f}	3.26^{g}	1.01^{a}	0.83^{a}	26.77^{a}
Control*	14	37.25^{d}	12.50^{a}	3.96^{a}	0.79^{g}	0.00	20.00^{g}
MS (85% IC + 15% UBA)		36.35^{e}	10.70^{b}	3.67^{b}	0.85^{f}	0.41^{f}	21.13^{d}
MS (80% IC + 20% UBA)		35.10^{f}	9.70^{d}	3.58^{c}	0.89^{d}	0.54^{d}	20.94^{e}
MS (75% IC + 25% UBA)		34.26^{g}	9.20^{f}	3.47^{e}	0.90^{c}	0.68^{b}	20.69^{f}
MS (85% IC + 15% WFSP)		38.49^{c}	10.20^{c}	3.52^{d}	0.87^{e}	0.50^{e}	23.91^{c}
MS (80% IC + 20% WFSP)		39.12^{b}	9.60^{e}	3.37^{f}	1.00^{b}	0.66^{c}	25.16^{b}
MS (75% IC + 25% WFSP)		40.14^{a}	9.10^{f}	3.23^{g}	1.11^{a}	0.83^{a}	26.70^{a}
Control*	21	37.27^{d}	12.50^{a}	3.96^{a}	0.79^{g}	0.00	20.02^{g}
MS (85% IC + 15% UBA)		36.35^{e}	10.70^{b}	3.68^{b}	0.85^{f}	0.41^{f}	21.12^{d}
MS (80% IC + 20% UBA)		35.11^{f}	9.70^{d}	3.59^{c}	0.89^{d}	0.54^{d}	20.94^{e}
MS (75% IC + 25% UBA)		34.28^{g}	9.40^{f}	3.48^{e}	0.90^{c}	0.68^{b}	20.50^{f}
MS (85% IC + 15% WFSP)		38.51^{c}	10.20^{c}	3.53^{d}	0.87^{e}	0.50^{e}	23.92^{c}
MS (80% IC + 20% WFSP)		39.15^{b}	9.60^{e}	3.38^{f}	1.00^{b}	0.66^{c}	25.18^{b}
MS (75% IC + 25% WFSP)		40.17^{a}	9.20^{f}	3.25^{g}	1.11^{a}	0.83^{a}	26.61^{a}

Control*: milk shake formula made with ice cream without added any fruits or vegetables
MS: milk shake; IC: Ice cream; URB: Unripe banana; WFSP: White-fleshed sweet potatoes
Values are means of three replicates
Values with different superscript letters within the same column are significantly different ($p \leq 0.05$).

The addition of UBA and WFSP to milkshake formulations significantly increased the carbohydrate content of the beverages ($P \leq 0.05$). The increase in carbohydrates is likely related to the high fiber, starch, and resistant starch content of both UBA and WFSP. The total carbohydrate content of the WFSP beverages was significantly higher ($P \leq 0.05$) than that of the control sample or UBA beverages, ranging from 23.86 to 26.01% compared to 20.21% in the control sample. The fiber content also increased significantly ($P \leq 0.05$) with the addition of both UBA and WFSP, and this increase was proportional to the level of addition of each. The fiber content of the experimental beverages ranged from 0.41 to 0.83% and was significantly higher ($P \leq 0.05$) than the control sample, which was found to be completely devoid of fiber as shown in Table 3.

3. Physicochemical properties of milkshake formulations:

The physicochemical properties of the milkshake formulations made with UBA and WFSP are shown in Table 4.

3.1. Colour parameters of milkshake formulations:

The results in Table 4 also showed significant differences ($P \leq 0.05$) between the experimental beverages and the control sample in terms of the color parameters, as the control sample outperformed the experimental beverages in color degree (L*) and obtained (40.51). The L-value of the experimental beverages ranged from 33.84 to 40.17, and was higher in beverages made from WFSP than those made from UBA. It has been reported that milk-fruit beverages with the highest lightness value contain milk as a main ingredient and have low fruit content (Fernandez-Vazquez *et al.*, 2017). In this sense, this may explain the low brightness values in our experimental beverages. The results showed that a* values of the experimental beverages were superior to the control sample, which had a lower value of 8.13, while a* values of the experimental beverages ranged between 8.40 and 8.98. The a* values of the experimental beverages increased with increasing levels of UBA and WFSP addition, and this was particularly evident in the UBA beverages. The b* values showed that the beverages containing UBA were superior to the WFSP beverages as well as the control sample, and the b* values increased with increasing addition rate. The highest value of b* was found in the milkshake sample containing 25% UBA, which was 28.21, while the lowest value was found in the control sample, which was 15.54. The larger the b+ value, the more yellowing, while the smaller or even negative value (b-) showed green (Vargas and Lopez, 2003).

Table 4: Physicochemical properties of low-calorie milkshake formulations made with unripe bananas and white sweet potatoes as fat replacers

Formulas	Physicochemical properties						
	Colour parameters			TSS (°Brix)	Apparent viscosity (cP)	pH-value	T.A (%)
	L*	a*	b*				
Control*	40.51[a]	8.13[g]	15.54[g]	20.64[b]	40[g]	6.59[a]	0.16[g]
MS (85% IC + 15% UBA)	36.46[e]	8.64[d]	26.26[c]	18.59[e]	50[f]	6.25[c]	0.21[e]
MS (80% IC + 20% UBA)	35.13[f]	8.92[b]	27.18[b]	17.23[f]	54[e]	6.22[c]	0.23[c]
MS (75% IC + 25% UBA)	33.84[g]	8.98[a]	28.21[a]	16.02[g]	58[d]	6.20[c]	0.26[a]
MS (85% IC + 15% WFSP)	40.17[b]	8.40[f]	16.40[f]	18.94[d]	64[c]	6.59[a]	0.19[f]
MS (80% IC + 20% WFSP)	39.53[c]	8.60[e]	17.29[e]	19.95[c]	68[b]	6.49[b]	0.22[d]
MS (75% IC + 25% WFSP)	37.79[d]	8.67[c]	17.74[d]	21.22[a]	71[a]	6.46[b]	0.24[b]

Control*: milk shake formula made with ice cream without added any fruits or vegetables
MS: milk shake; IC: Ice cream; URB: Unripe banana; WFSP: White-fleshed sweet potatoes
Values are means of three replicates
Values with different superscript letters within the same column are significantly different ($p \leq 0.05$).

3.2. Total soluble solids of milkshake (Brix):

The TSS (°Brix) values of the experimental beverages ranged from 16.02 to 21.22% compared to 20.64% in the control sample. Compared to the control sample, the TSS values of the experimental milkshake decreased with the addition of UBA and increased with the addition of WFSP. This decrease or increase was proportional to the percentage of UBA and WFSP added (Table 4).

3.3. Apparent viscosity:

Viscosity is a measure of the resistance to flow of a beverage. The viscosity property is directly related to sensory properties such as mouthfeel and consistency. Too low viscosity gives a watery feel to the beverage, and too high viscosity reduces the fluid behavior of the beverage. Hence, the viscosity is required at a certain optimum value, which enhances the sensory quality of the beverage. The optimum viscosity value is also associated with high phase stability during storage of the beverage. Some hydrocolloids used in beverage processing are responsible for the viscosity property of beverages. The results in Table 4 also showed that the viscosity values of the experimental beverages were significantly higher ($P \leq 0.05$) than the control sample, especially in the WFSP beverages compared to their UBA counterparts. The higher viscosity values can be attributed to the ability of WFSP to promote the gel network in the serum, thus increasing the viscosity. The viscosity values of the experimental beverages ranged between 50 and 71 cP, with the highest viscosity value (71 cP) found in a milkshake containing 25% WFSP, while the control sample had the lowest viscosity value (40 cP).

3.4. The pH and Acidity:

The pH and acidity of beverages are of great importance during processing and storage (Mudgil *et al*., 2016). The pH of the beverage is directly related to the molecular and structural stability of other ingredients used in the beverage formulation. Low pH and high acidity make casein and whey insoluble, causing sedimentation defects in beverages. These are very important to control in the fermented type of functional dairy beverages. The pH of the beverage also plays an important role in the solubility and dispersion of ingredients in the beverage. Low solubility and dispersibility is directly associated with phase stability of beverages during storage (Mudgil and Barak, 2019). From the results in Table 4, it can be noted that there is a significant increase ($P \leq 0.05$) in the titratable acidity of beverages made from UBA and WFSP at all addition ratios compared to the control sample. Titratable acidity of the experimental beverages ranged from 0.19 to 0.24% compared to 0.16% in the control sample, while the pH values of the experimental beverages ranged from 6.20 to 6.59 compared to 6.59 in the control sample.

4. Foaming properties of milkshake formulations:

Foaming properties are typically divided into foaming capacity (FC) and foaming stability (FS), which are mainly affected by physical and chemical properties. FC is defined as the ability of protein to incorporate air when whipped and is measured by volume (%), while FS corresponds to the ability to stabilize the foam (volume) over time (usually limited to 30 minutes). In general, the molecular properties required for a good FC may differ from those required for a suitable FS. In fact, FC is mainly controlled by the diffusion coefficients of soluble proteins toward the air-water interface, possible conformational changes, and interface rearrangements. On the other hand, foam stabilization mostly depends on the formation of a thick, cohesive viscoelastic film encompassing each gas bubble (Bessada *et al*., 2019).

Table 5: Foaming properties of milkshake formulations made with unripe bananas and white potatoes

Formulas	Foaming properties		
	Foam volume (ml)	Foaming capacity (%)	Foaming stability (min)
Control*	22[a]	29.33[a]	13:30[a]
MS (85% IC + 15% UBA)	19[b]	25.33[b]	12:22[b]
MS (80% IC + 20% UBA)	15[c]	20.00[c]	11:35[c]
MS (75% IC + 25% UBA)	11[d]	14.66[d]	10:30[d]
MS (85% IC + 15% WFSP)	10[e]	13.33[e]	09:50[e]
MS (80% IC + 20% WFSP)	8[f]	10.66[f]	07:30[f]
MS (75% IC + 25% WFSP)	6[g]	08.00[g]	06:49[g]

Control*: milk shake formula made with ice cream without added any fruits or vegetables
MS: milk shake; IC: Ice cream; URB: Unripe banana; WFSP: White-fleshed sweet potatoes
Values are means of three replicates
Values with different superscript letters within the same column are significantly different ($p \leq 0.05$).

The results in Table 5 showed significant differences (P ≤ 0.05) in the foam volume of the experimental beverages added with different proportions of UBA and WFSP, and the control sample superior to the experimental beverages in foam volume, which reached 22 ml. UBA beverages outperformed WFSP beverages in terms of foam volume, which ranged from 11 ml to 19 ml and from 6 ml to 10 ml, respectively. Ho *et al*. (2024) found that increasing the solids concentration in reconstituted skimmed milk powder emulsions from 1.5 to 15% (i.e. 0.5–5% protein) did not affect the foaming properties, although lactose, viscosity, and surface tension increased, while air bubble size was slightly reduced. The results showed that the control sample outperformed the experimental beverages in terms of foam capacity, which reached 29.33%, and decreased with increasing addition percentage of both UBA and WFSP. UBA beverages were superior to WFSP beverages in their ability to form foam. The results also showed that the control sample outperformed the experimental beverages in foam stability, which reached 13:30 min. UBA beverages were superior to WFSP beverages in their ability to stabilize. The foaming time for UBA beverages ranged from 10:30 min to 12:22 min, while the foaming time for WFSP beverages ranged from 6:49 min to 9:50 min. Foam is a colloidal dispersion phenomenon in which small air bubbles are dispersed in a constant water phase. The foaming capacity and its stability are of high importance in various foods and beverages (Vianna-Filho *et al*., 2013). The foam-based food products are widely consumed and hydrocolloids are a key ingredient of their formulation for their stabilization. The polysaccharide-based hydrocolloids contain active surface properties and can act as emulsifying and foaming factors (Dickinson, 2010). The general foam stabilizers are thickening agents such as gums, starch, pectin, and gelatin. Such agents function by increasing the viscosity of the constant phase or forming a three-dimensional mesh that interrupts the constituent's motion in the foam (Dachmann *et al*., 2018). Hydrocolloids exhibited similar behavior and caused an improvement in foam stability through an increase in viscosity owing to their high water-binding capacity and the thickening feature. Guar gum and xanthan gum, which are well known as stabilizer for such beverage, are added for a long shelf life without causing undesirable coagulation and reducing the volume of foam (Eghbaljoo *et al*., 2022). Dairy foam is a very essential ingredient in whipped cream, ice cream, and milk-based beverages such as cappuccinos, chocolate milk drinks, and milkshakes (Huppertz, 2010). The foaming and stability of milk depend on its composition and are influenced by the physical and chemical properties of whey protein (Khezri *et al.*, 2017). The foam in milk plays a significant role in the sensory properties of popular beverages such as cappuccino and milkshakes. A study by Hatakeyama *et al*. (2019) evaluated the sensory properties of foamed milk. These authors described that foamed milk with small bubble size produced high sensory scores for “smoothness,” “smoothness,” and “elasticity,” and low scores for “meltability.” Likewise, polysaccharides also play an important role in the stabilization of foam by increasing the viscosity of the solution, thereby creating improved foam characteristics. Combinations of proteins, polysaccharides, and sweeteners have also been used in one study for investigating the foaming behavior of the suspension. It was reported that the combination of such a system affects the physical properties of the suspension and the foaming nature (Neves *et al*., 2018; Deotale *et al*., 2020).

5. Energy values of milkshake formulations:

Since one of the objectives of this study was to produce low-calorie beverages, it was important to estimate the energy values of the different experimental beverages. Table 6 shows the reduction in fat content and energy values of milkshake formulations made from UBA and WFSP. The different experimental beverages showed significant differences in fat reduction rates. The percentage of fat reduction in the experimental beverages ranged from 14.75% to 25.40%, with the highest percentage of fat reduction being 25.40% in the milkshake containing 25% WFSP.

Table 6: Energy values for milkshake formulations made with unripe bananas and white potatoes

Formulas	Fat and energy reductions			
	Fat (%)	Fat reduction (%)	Energy values (kcal/g)	Energy reduction (%)
Control*	12.2	-	206.52	-
MS (85% IC + 15% UBA)	10.4	14.75	193.78	6.29
MS (80% IC + 20% UBA)	09.8	19.67	185.79	10.04
MS (75% IC + 25% UBA)	09.2	24.59	179.29	13.19
MS (85% IC + 15% WFSP)	10.2	16.39	201.26	2.55
MS (80% IC + 20% WFSP)	09.6	21.31	200.32	3.0
MS (75% IC + 25% WFSP)	09.1	25.40	198.81	3.73

Control*: milk shake formula made with ice cream without added any fruits or vegetables
MS: milk shake; IC: Ice cream; URB: Unripe banana; WFSP: White-fleshed sweet potatoes

The energy values (kcal/g) of the different beverages showed significant differences. The highest energy value was found in the control sample (206.52 kcal/g), while the lowest was found in the milkshake containing 25% UBA (179.29 kcal/g). Milkshakes made with WFSP resulted in energy reductions in the range of only 2.55–3.73%, while the energy reductions in UBA formulations ranged from 6.29–13.19%. The results revealed that partial replacement of sucrose and milk fat with UBA or WFSP resulted in a significant reduction in the calorie content of milkshakes. Alizadeh *et al.* (2014) produced fruit-based milkshakes using different fruit (banana, apple, and kiwi) concentrates. Different proportions of stevia and sucrose were used as sweeteners. The researchers suggested that it is possible to replace sugar with intense natural sweeteners such as stevia to produce fruit-based milkshakes with lower caloric values.

6. Sensory properties of milkshake formulations:

Table 7 shows the sensory characteristics of milkshake formulas made from UBA and WFSP during storage. The results of the fresh samples showed that the beverages made with UBA or WFSP were superior in flavor, scoring higher than the control sample. The results also showed that the WFSP beverages outperformed the UBA beverages in terms of flavour scores, scoring higher. The 20% WFSP formulation received the highest scores for body and texture, followed by the 25% UBA formulation, while the control sample received the lowest scores. The control sample was superior to the experimental beverages in terms of colour, followed by the WFSP beverages, while the UBA beverages had the lowest colour scores. In terms of overall acceptability, beverages containing UBA and WFSP received higher scores than the control sample. The beverage containing 20% WFSP received the highest overall acceptability scores, followed by the beverage containing 25% UBA.

Table 7: Sensory properties of low-calorie milkshake formulations made with unripe bananas and white potatoes as fat replacers during storage at 4 ± 1°C for 21 days

Formulations	Storage period (days)	Sensory attributes			
		Flavor (9)	Body & Texture (9)	Color & Appearance (9)	Overall acceptance (9)
Control*	1	8.28	8.35	8.88	7.50
MS (85% IC + 15% UBA)		8.35	8.55	8.36	8.38
MS (80% IC + 20% UBA)		8.43	8.65	8.21	8.83
MS (75% IC + 25% UBA)		8.83	8.89	8.51	8.86
MS (85% IC + 15% WFSP)		8.95	8.50	8.54	8.04
MS (80% IC + 20% WFSP)		8.97	8.98	8.81	8.90
MS (75% IC + 25% WFSP)		8.98	8.31	8.73	8.58
Control*	7	8.21	8.17	8.10	7.89
MS (85% IC + 15% UBA)		8.30	8.20	8.29	7.78
MS (80% IC + 20% UBA)		8.39	8.42	8.00	8.67
MS (75% IC + 25% UBA)		8.57	8.34	8.87	8.00
MS (85% IC + 15% WFSP)		8.62	8.14	8.10	8.00
MS (80% IC + 20% WFSP)		8.95	8.48	8.04	8.66
MS (75% IC + 25% WFSP)		8.98	7.94	7.65	7.78
Control*	14	8.15	5.93	7.90	7.33
MS (85% IC + 15% UBA)		7.97	7.79	8.01	6.78
MS (80% IC + 20% UBA)		7.57	8.37	7.69	6.89
MS (75% IC + 25% UBA)		7.53	8.14	7.84	6.78
MS (85% IC + 15% WFSP)		7.75	7.45	8.05	7.00
MS (80% IC + 20% WFSP)		7.88	7.74	7.85	7.78
MS (75% IC + 25% WFSP)		7.77	7.68	7.69	7.67
Control*	21	8.00	7.45	8.37	7.20
MS (85% IC + 15% UBA)		7.52	7.66	7.92	6.55
MS (80% IC + 20% UBA)		8.24	8.07	7.55	6.77
MS (75% IC + 25% UBA)		8.00	7.74	7.47	7.60
MS (85% IC + 15% WFSP)		7.40	7.20	7.74	7.60
MS (80% IC + 20% WFSP)		7.72	7.45	7.47	7.71
MS (75% IC + 25% WFSP)		7.00	7.20	7.38	7.00

Control*: milk shake formula made with ice cream without added any fruits or vegetables
MS: milk shake; IC: Ice cream; URB: Unripe banana; WFSP: White-fleshed sweet potatoes

The results in Table 7 also showed that after 7 days of storage, the 20% WFSP beverage was superior to all beverages in body & texture and color. In terms of overall acceptability, 20% UBA and 20% WFSP beverages recorded the highest values compared to the control sample after 7 days of storage. Overall acceptance showed that beverages containing 25% UBA, 15% and 20% WFSP had the highest scores at the end of the 21-day storage period. In general, most of the beverages showed good sensory properties at the end of the 21-day storage period, despite some slight deterioration in some of their sensory properties.

7. Storage stability (phase separation) of milkshake:

Separation of aqueous phase on the top surface of the beverage is known as phase separation. It is a defect and not acceptable by consumers. This phenomenon is associated with storage stability of the beverage (Mudgil *et al.*, 2016). High storage stability is desirable for beverages for acceptability point of view.

Storage stability of the beverage is interrupted when the ingredients in the beverages interact with each other. Hence the selection of ingredient for beverage formulation is very crucial to preserve the original rectitude of the ingredients during storage period. Fig. 1 showed that the milkshake formulations containing UBA or WFSP showed the longest stability period compared to the control sample which had the shortest stability period. WFSP milkshakes were more stable than UBA milkshakes, with a stability period of 15 to 17 days versus 12 to 16 days. The results also showed that the stability period of the beverages increased with the increase in the percentage of UBA or WFSP addition. This may be due to the presence of dietary fiber in fruits and vegetables, which gives them firmness and structure, forms a matrix, and retains water in them, unlike milk, which is devoid of it (Arora *et al*., 2015). Karki *et al.* (2015) studied the change of sensor parameters and the increase in the storage time of milk cocktail with banana and wheat bran at room temperature. Among the three factors, wheat bran showed the maximum effect to increase gray cellulose, banana showed a relatively low effect, while sugar had a non-significant effect.

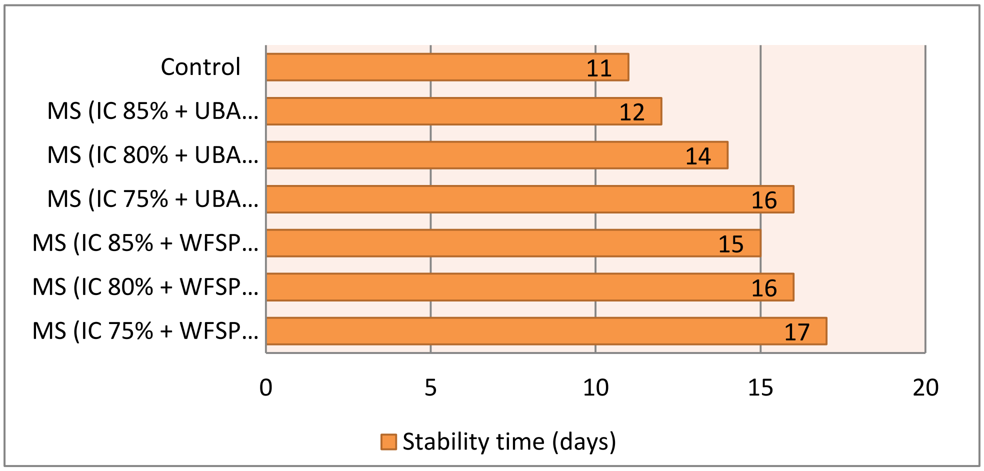

Fig. 1: Stability time of low-calorie milkshake formulations made with unripe bananas and white potatoes as fat replacers during storage at 4 ±1°C for 21 days

Control: milk shake formula made with ice cream without added any fruits or vegetables

MS: milk shake; IC: Ice cream; URB: Unripe banana; WFSP: White-fleshed sweet potatoes

On the other hand, xanthan gum exhibits thickening properties with pseudo-plastic behavior due to its branch structure. This characteristic enables xanthan gum to be more stable in different ranges of temperature, pH and upon enzymatic degradation. Morell *et al.* (2014) used native and modified cornstarch, λ-carrageenan and guar gum to make milk cocktails. The structure of milk cocktails prepared with λ-carrageenan and guar gum was better preserved.

CONCLUSION

The use of unripe bananas and white sweet potatoes in the manufacture of low-calorie milk shake beverages can improve the properties of these products, providing functional products with high nutritional value. It clearly affected the various chemical and physical properties, and also clearly improved the colour and energy properties, as it clearly reduced energy, in addition to the distinct sensory qualities of the final product. It can be concluded that it is possible to manufacture unripe banana milkshakes and low-calorie white sweet potatoes milkshakes with a healthy effect. A good, healthy product with excellent nutritional and sensory acceptability and a long shelf life can be obtained.

REFERENCES

Alizadeh, M., Azizi-lalabadi, M., Hojat-ansari, H. and Kheirouri, S. (2014). Effect of stevia as a substitute for sugar on physicochemical and sensory properties of fruit based milk shake. Journal of Scientific Research and Reports, 3 (11): 1421-1429.

A.O.A.C. (2000). Association of Official Analytical Chemists. In Official Methods of Analyses, Gaithersburg. M.D. 17th ed.

Arora, S. K., Patel, A. A. and Chauhan, O. P. (2015). Trends in milk and milk products fortification with dietary fibers. American Journal of Advanced Food Science and Technology, 3 (1): 14-27.

Bessada, S. M., Barreira, J. C. and Oliveira, M. B. P. (2019). Pulses and food security: Dietary protein, digestibility, bioactive and functional properties. Trends in Food Science & Technology, 93: 53-68.

Bimbo, F., Bonanno, A., Nocella, G., Viscecchia, R., Nardone, G., De Devitiis, B. and Carlucci, D. (2017). Consumers' acceptance and preferences for nutrition-modified and functional dairy products: A systematic review. Appetite, 113: 141-154.

Cammarelle, A., Viscecchia, R., De Devitiis, B., Panniello, U. and Gorgoglione, M. (2024). Consumers' Behavior Toward Healthy Foods: A Critical Review. Food Reviews International; 1-18.

Dachmann, E., Hengst, C., Ozcelik, M., Kulozik, U. and Dombrowski, J. (2018). Impact of hydrocolloids and homogenization treatment on the foaming properties of raspberry fruit puree. Food and Bioprocess Technology, 11, 2253-2264.

Dako, E., Retta, N. and Desse, G. (2016). Comparison of three sweet potato (Ipomoea batatas (L.) Lam) varieties on nutritional and anti-nutritional factors. Global Journal of Science Frontier Research: D Agriculture and Veterinary, 16 (4): 1-11.

Damtew, A., Habtamu, G. M., Dejene T. B. and Dadi, T. L. (2024). Major nutritional content of orange fleshed sweet potato (OFSP) and It's Importance: Review, Glob. Acad. J. Agri. Biosci.; 6 (1) 1-7.

Deotale, S., Dutta, S., Moses, J. A., Balasubramaniam, V. M. and Anandharamakrishnan, C. (2020). Foaming characteristics of beverages and its relevance to food processing. Food Engineering Reviews; 12 (2): 229-250.

Dickinson, E. (2010). Food emulsions and foams: Stabilization by particles. Current Opinion in Colloid & Interface Science, 15 (1): 40-49.

Egbebi, A. O. and Bademosi, T. A. (2012). Chemical compositions of ripe and unripe banana and plantain. International Journal of Tropical Medicine and Public Health, 1: 1-5.

Eghbaljoo, H., Sani, I. K., Sani, M. A, Rahati, S., Mansouri, E., Molaee-Aghaee, E., Fatourehchi, N., Kadi, A., Arab, A., Sarabandi, K., Samborska, K. and Jafari, S. M. (2022). Advances in plant gum polysaccharides; Sources, techno-functional properties, and applications in the food industry - A review. Int. J. Biol. Macromol.; 222 (Pt B):2327-2340.

Ellong, E. N., Billard, C. and Adenet, S. (2014). Comparison of physicochemical, organoleptic and nutritional abilities of eight sweet potato (Ipomoea batatas) varieties. Food Nutr. Sci.; 5 (2):196

Falcomer, A. L.; Riquette, R. F. R.; de Lima, B. R.; Ginani, V. C. and Zandonadi, R. P. (2019). Health benefits of green banana consumption: A systematic review. Nutrients, 11: 1222.

FAO (2016). Crop Production Data. Available online at: http://www.fao.org/faostat/en/#data/QC (accessed December 29, 2016).

FAO (2021). FAOSTAT Statistical Database. Available online at: https://www.fao.org/faostat/en/ (accessed on 26 June 2021).

Fernandez-Vazquez, R., Stinco, C. M., Hernanz, Vila, D., Heredia, F. J., Chaya, C. and Vicario, I. M. (2017). Internal preference mapping of milk-fruit beverages: Influence of color and appearance on its acceptability. Food Sci. Nutr.; 6 (1): 27-35.

Freitas, M. C. J. and Tavares, D. Q. (2005). Characterization of starch granules from bananas Musa AAA-Nanicao and Musa AAB-Terra. Food Science and Technology (Campinas), 25 (2): 217-222.

Gilbert, J. R., Stice, E. and Burger, K. S. (2018). Elevated thalamic response to high-sugar milkshakes in ethnic and racial minorities. J. Racial Ethn Health Disparities 5 (3):580-587.

Goff, H. D. and Hartel, R. W. (2013). Composition and formulations. In: Ice Cream. Springer, Boston, MA.

Hamilton, J., Stewart-Knox, B., Hill, D. and Parr, H. (2000). Reduced fat products: consumer perception and preferences. British Food Journal, 102 (7): 494-506.

Hatakeyama, S., Akiyama, M., Yoneyama, R., Watanabe, K., Koizumi, R., Miyaji, K. *et al*. (2019). Effects of manufacturing conditions on the foaming properties of milk and sensory characteristics of foamed milk. LWT Food Sci Technol 99:555–561.

Hazo, H. and Yirgalem, A. (2021). Comparison of different sweet potato (Ipomoea Batatas L) varieties in terms of nutritional value. J. Nutr. Food Sci., 11 (6):047.

Ho, T. M., Xiong, X., Bhandari, B. R. and Bansal, N. (2024). Foaming properties and foam structure of milk determined by its protein content and protein to fat ratio. Food Bioprocess Technol., 17 (12):4665-4678.

Hotz, C., Loechl, C., de Brauw, A., Eozenou, P., Gilligan, D., Moursi, M., Munhaua, B., van Jaarsveld, P., Carriquiry, A. and Meenakshi, J. V. (2012). A large-scale intervention to introduce orange sweetpotato in rural Mozambique increases vitamin A intakes among children and women. Brit. J. Nutr.; 108:163–176.

Huppertz, T. (2010). Foaming properties of milk: a review of the influence of composition and processing. Int J Dairy Technol.; 63 (4):477–488.

Karki, A., Ram, S. Y. and Banerjee, J. (2015). Development of fiber enriched milkshake and its quality evaluation. Int. J. Adv. Eng. Technol. Innov. Sci., 1 (2): 14–20.

Kashid, U. B., Sontakke, A. T. and Shinde, D. B. (2007). Manufacture of golden milk shake from cow milk blended with safflower milk. J. Dairying, Foods & H.S. 26 (3/4): 159-163.

Khezri, M., Shahriari, S. and Shahsavani, L. (2017). The effect of xanthan gum and temperature on foam stability of milk-based espresso coffees. J. Food Biosci. Technol. Sci. Res. Branch; 7(1):15–22.

Kraus, R.M., Eckel, R.H., Howard, B., *et al.* (2001). American Heart Association's (AHA): AHA Dietary Guidelines – Revision 2000: A statement for Healthcare Professionals From the Nutrition Committee of the American Heart Association, Journal of Nutrition, 131, 132-146.

Low, J. W., Arimond, M., Osman, N., Cunguara, B., Zano, F. and Tschirley, D. (2007). A food-based approach introducing orange-fleshed sweet potatoes increased vitamin A intake and serum retinol concentrations in young children in rural Mozambique. J. Nutr,; 137: 1320–1327.

Mirmiran, P.; Bahadoran, Z. and Azizi, F. (2014). Functional foods based diet as a novel dietary approach for management of type 2 diabetes and its complications. Review. J. Diabetes, 5: 267-281.

Morell, P., Fiszman, S. M., Varela, P. and Hernando, I. (2014). Hydrocolloids for enhancing satiety: Relating oral digestion to rheology, structure and sensory perception. Food Hydrocolloids, 41: 343–353.

Mudgil, D. and Barak, S. (2019). Dairy-based functional beverages. Chapter 3 (pp. 67-93).

Mudgil, D., Barak, S. and Darji, P. (2016). Development and characterization of functional cultured buttermilk utilizing Aloe vera juice. Food Biosci. 15: 105–109.

Mudgil, D., Barak, S. and Khatkar, B. S. (2012). Process optimization of partially hydrolyzed guar gum using response surface methodology. Agro Food Ind. Hi Tech.; 23: 13–15.

Mudgil, D., Barak, S. and Khatkar, B. S. (2014). Guar gum: processing, properties and food applications—a review. J. Food Sci. Technol.; 51: 409–418.

Neves ICO, de Faria JT, VidigalMCTR, Fidelis PC, Minim VPR and Minim LA (2018). Foaming properties of suspensions composed by β-lactoglobulin and polysaccharides, in the presence of sucrose or polyols. Colloids Surf A Physicochem. Eng. Asp., 550:199–208.

Oi, R. K., Tambourgi, E. B. and Moraes, D. M. Jr. (2012). Study of the drying of green banana biomass in spray dryer. Engevista, 14 (2): 165-171.

Olaniran, A. F., Okonkwo, C. E., Osemwegie, O. O. *et al*. (2024). Production, acceptability, nutritional and pasting properties of orange-flesh sweet potato, cowpea and banana flour mix. Sci. Rep.; 14, 4602.

Oraman, Y. (2019). The consumers' functional food trend: Market orientation, Market opportunities. European Proceedings of Social and Behavioural Sciences, 54: 446-459.

Ozer, B. H. and Kirmaci, H. A. (2010). Functional milks and dairy beverages. Int. J. Dairy Technol. 63, 1–15.

Paquin, P. (2009). Functional and Speciality Beverage Technology, first ed. Woodhead Publishing, Cambridge.

Patil, S. R., Patil, N. J. and Sahoo, A. K. (2019). Process optimization, sensory evaluation and physico-chemical analysis of carrot milkshake. Journal of Emerging Technologies and Innovative Research, 6 (6): 248-255.

Playne, M. J., Bennett, L. E. and Smithers, G. W. (2003). Functional dairy foods and ingredients. Aust. J. Dairy Technol.; 58: 242–264.

Precedence Research Report, Code 1825, Published in December 2024. https://www.precedenceresearch.com› Industry › Food & Beverage.

Rose, I. M. and Vasanthakaalam, H. (2011). Comparison of the nutrient composition of four sweet potato varieties cultivated in Rwanda. American journal of food and nutrition, 1(1): 34-38.

Safrida, S., Heirina, Y. and Noviasyah, N. (2022). Sensory evaluation of food combination products from banana and sweet potato flour as a healthy food. IOP Conf. Series: Earth and Environmental Science; 956 (1): 12012.

Sakhale, B. K., Pawar, V. N. and Ranveer, R. C. (2012). Studies on the development of soy milk-based mango (RTS) beverage. Electronic Journal of Environmental, Agricultural and Food Chemistry; 11(5): 523-528.

Sandrou, D. K. and Arvanitoyannis, I. S. (2000). Low-fat/calorie foods: curent state and perspective, Critical Reviews in Food Science and Nutrition, 40: 427-447.

SAS (2016). SAS® version 9.4 Functions and CALL Routines: Reference, Fifth Edition. SAS Institute Inc., Cary, NC, USA.

Slavin, J. L. and Lloyd, B. (2012). Health benefits of fruits and vegetables. Adv. Nutr.; 3 (4): 506-516.

van Jaarsveld, P. J., Faber, M., Tanumihardjo, S. A., Nestel, P., Lombard, C. J., and Spinnler Benade A. J. (2005). B-carotene rich orange-fleshed sweet potato improves the vitamin A status of primary school children assessed with the modified-relative-dose-response test. Amer. J. Clin. Nutr.; 81:1080–1087.

Vargas, F. D., and Lopez, O. P. (2003). Natural colorants for food and nutraceutical uses. CRC Press. Boca Raton London New York Washington DC. 327 pp.

Venkataramana, R. K.; Sampangi-Ramaiah, M. H.; Ajitha, R.; Khadke, G. N. and Chellam, V. (2015). Insights into Musa balbisiana and Musa acuminata species divergence and development of genic microsatellites by transcriptomics approach. Plant Gene, 4: 78-82.

Vianna-Filho, R. P., Petkowicz, C. L. and Silveira, J. L. (2013). Rheological characterization of O/W emulsions incorporated with neutral and charged polysaccharides. Carbohydr. Polym.; 93(1):266-272.

Wylie-Rosett, J. (2002). Fat substitutes and health: an advisory from the Nutrition Committee of the American Heart Association. Circulation; 105 (23):2800-2804.

Zakir, S.; Sarwar, M.; Allen, J.; Buti, M.; Arshad, U. and Javaid, A. (2008). Impact of sweet potato cultivars on blood glucose level in diabetic and healthy participants. International Journal of Agriculture and Biology, 10 (3): 316-320.