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Physicochemical and Sensory Evaluation of Ice Cream Enriched with Butterfly Pea Flower and Sorghum at Varying Levels

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ABSTRACT

The global demand for ice cream made with natural ingredients and unique flavors is rapidly increasing. However, traditional ice cream is typically low in fiber. Additionally, its high fat and sugar content contributes to obesity and related health issues, with excessive sugar intake being linked to chronic diseases like cardiovascular conditions and diabetes. Therefore, this study aimed to evaluate the physicochemical properties and sensory acceptability of ice cream formulated with butterfly pea flowers and varying percentages of sorghum incorporation. There were four different formulations with different concentrations of sorghum level, consisting of sample A (0% sorghum), sample B (0.5% sorghum), sample C (1.0% sorghum), and sample D (1.5% sorghum). Chemical properties include moisture content (64.82-65.14%), ash content (0.9702-0.9897%), crude fat content (1.584-8.268%), protein content (4.895-7.486%), fibre content (5.470-6.660%), total carbohydrates content (18.91-27.50%), and total solid contents (34.86-35.18%). The addition of sorghum enhanced the ice cream's stickiness, overrun, moisture content, ash, fibre, and total carbohydrate levels, at the $p < 0.05$ level, demonstrating its potential to improve both texture and nutritional value. Sensory evaluation revealed that the formulation with 0.50% sorghum achieved the highest overall acceptability, striking an optimal balance between flavour, texture, and iciness.

INTRODUCTION

Ice cream is a dairy product produced through the processes of homogenisation, freezing, aeration, and pasteurisation, ensuring uniform consistency [1]. It consists of sugar, oil, eggs, water, emulsifiers, stabilizers, corn syrup, dextrose, and flavourings, forming a tri-phase network of solid, liquid, and gaseous phases. In Malaysia, ice cream is a neighbourhood favourite for people of all ages. When it comes to daily consumption, ice cream is consumed the most, at 15.1% and 10.0% of respondents, once daily and twice to three times daily, respectively [2]. Health-promoting ice cream is gaining popularity, with consumers seeking healthier and more nutritious options [3]. Sorghum (*Sorghum bicolor* L.), a member of the Poaceae family, was domesticated around 3,000–5,000 years ago. For around 500 million people in Asia and Africa, sorghum is a staple crop. It is a primordial grain, gaining popularity as consumers seek diverse and nutritious alternatives to common cereals like wheat and maize. Known for its unique anatomical structures—the germ, endosperm, and

pericarp—sorghum is highly valued for its rich nutritional profile, including carbohydrates, protein, dietary fibre, and water. It also contains essential vitamins, minerals, and phytochemicals like phenolic compounds and antioxidants, being a potent enhancement to a healthy diet, and offering numerous health advantages. For example, they are rich in carbohydrates (72.09 g/100g), protein (10.62 g/100g), water (12.4 g/100g), and dietary fibres (6.7 g/100g) [7]. Additionally, they contain a variety of phytochemicals, including phenolic compounds and antioxidants [6].

Butterfly Pea (*Clitoria ternatea*), a traditional Chinese and Ayurvedic remedy recognised for its vibrant indigo hue, has historically been employed as a vegetable in culinary applications and to enhance the visual appeal of desserts or tea, resulting in strikingly vivid beverages. Rich in health-enhancing antioxidants, flavonoids, and peptides, butterfly peas have shown considerable potential as a natural remedy for many health concerns in animal studies [8].

Despite its popularity, traditional ice cream is low in fibre, which is essential for digestive health, regulating blood glucose levels, and reducing cardiovascular risk. Traditional dairy ice cream mostly consists of water, sugars, milk solids, and fats, with a low amount of fibre content. It typically comprises 7-15% fat, 4-5% milk protein, 5-7% lactose, 12-16% stabilisers and emulsifiers, 0.5% flavourings, 28-40% total solids, and 60-72% water, contributing to health concerns such as obesity and diabetes issue particularly prevalent in Malaysia [9].

Despite growing interest in functional foods, few ice creams incorporate ingredients that boost fibre and antioxidant content [10]. Sorghum, rich in fibre and with a low glycaemic index, can improve the nutritional profile of ice cream [11]. Moreover, the butterfly pea flower, a natural source of anthocyanins, offers antioxidant benefits and replaces artificial colourants. The incorporation of sorghum and butterfly pea flowers into ice cream offers both nutritional and sensory benefits. A 100g serving of ice cream fortified with 2-4% fibre would supply 7-16% of the daily recommended fibre intake [10].

Butterfly pea flower provides natural anthocyanins, replacing synthetic dyes while offering antioxidant properties. Adding these ingredients creates a functional ice cream that appeals to health-conscious consumers seeking natural, nutritious alternatives. Moreover, sorghum can enhance creaminess and texture, improving overall product acceptability. This innovation aligns with current trends toward healthier, cleaner-label desserts that offer added functional and therapeutic benefits. Therefore, this research aims to determine the physicochemical properties of ice cream with anthocyanin from *Clitoria ternatea* and different concentrations of Sorghum powder and to investigate the sensory acceptance of ice cream with anthocyanin from *Clitoria ternatea* and different concentrations of Sorghum powder.

MATERIALS AND METHODS

Materials

Dry sorghum (*Sorghum spp.*) was obtained from Laboratorium Terpadu Undana, Indonesia, while dried butterfly pea flowers (*Clitoria ternatea*) were sourced from a local market in Kuala Terengganu, Malaysia. Laboratory equipment, including an ice cream maker, texture analyzer, and colorimeter was utilized for analysis. The study was conducted at the Food Laboratory, Faculty of Fisheries and Food Science, Universiti Malaysia Terengganu, from August 2024 to January 2025.

Sample Preparation

Butterfly pea flower extract was prepared by soaking 9 g of dried flowers in water at a 1:3 ratio at 50°C for 1 hour. Sorghum rice powder was obtained by sieving and grinding 50 g of cleaned sorghum grains, then added to ice cream at concentrations of 0.5%, 1.0%, and 1.5%.

Formulation

Four formulations were developed (Table 1), which included changes such as incorporating sorghum at percentages of 0%, 0.5%, 1.0%, and 1.5% [14].

Table 1. Formulation developed with *C. ternatea* extract and the addition of sorghum rice powder.

Formulation	%	A	B	C	D
Sugar (g)	10%	30	30	30	30
Skim powdered Milk (g)	1%	3	3	3	3
Milk Powder (g)	6.51%	19.53	19.53	19.53	19.53
Stabilizer (g)	0.4%	1.2	1.2	1.2	1.2
Whipping Cream (g)	20.62%	61.86	61.86	61.86	61.86
Egg Yolk (g)	3%	9	9	9	9
Fresh milk (g)	47.55%	142.65	142.65	142.65	142.65
Flavouring (g)	0.51%	1.53	1.53	1.53	1.53
<i>Clitoria ternatea</i>	9.01%	27.03	27.03	27.03	27.03
Hot Water (mL)					
Sorghum Rice Powder (g)	0%, 0.5%, 1.0%, 1.5%	0	1.5	3	4.5

*Control, A= Standard formulation; B= Formulation with 0.5% sorghum rice powder; C= Formulation with 1.0% sorghum rice powder; D= Formulation with 1.5% sorghum rice powder.

Ice Cream Making

Four formulations were developed, including a control (0% sorghum) and three experimental formulations (0.5%, 1.0%, and 1.5% sorghum). Ice cream was prepared by mixing sugar, egg yolk, whipping cream, and milk, heating the mixture to 80°C, then quickly cooling and freezing it. The final mixture was churned in an ice cream maker.

Sample Physical Analysis

The following analyses were performed on the four treatments: colour (B2014190, Minolta, Tokyo, Japan), melting rate, overrun, and texture [15].

Determination of Colour

Colour analysis was conducted using a Minolta Colorimeter (Model B2014190, Tokyo, Japan). 10 g of ice cream were placed in 90 mm Petri dishes with a 20 mm thickness and measured in triplicate. The CIELAB colour system (L*, a*, b*) was used to determine lightness (L*), red-green (a*), and yellow-blue (b*) values [16].

Determination of Melting Rate

25 g of ice cream was placed on a metal mesh with 0.7 mm openings and left to stand at 20 ± 2°C. A digital timer was used to record the time taken for the ice cream to melt completely, and the melting rate was measured in seconds [16].

Determination of Overrun

Overrun was determined by comparing the weight of the ice cream mixture before and after freezing using the formula [17]:

$$\text{Overrun (\%)} = \frac{\text{Weight of unit mix} - \text{weight of equal volume of ice cream}}{\text{Weight of unit volume of ice cream}} \times 100$$

Determination of Texture

A texture analyzer (TA.XT Plus) with a 2 mm cylindrical probe was used to measure stickiness and hardness. Penetration tests were performed at the centre of samples kept at -10°C throughout the test. The following parameters were established: 15 mm penetration depth; 5 g force; 3.3 mm/s probe speed during penetration, and 3.0 mm/s probe speed before and after penetration [18].

Sample Chemical Analysis

Chemical analysis followed AOAC (1990) methods, including moisture (oven drying), ash (muffle furnace), fat (Soxhlet extraction), protein (Kjeldahl method), fibre (enzymatic digestion), total carbohydrates (calculated by subtracting protein, fat, and ash from total solid content), and total solids (calculated by subtracting moisture).

Sensory Evaluation

A group of 30 untrained panellists evaluated aroma, melting, hardness, smoothness, iciness, and overall acceptability using a 9-point Hedonic scale. Ice cream samples were coded and stored at -10°C before evaluation.

Statistical Analysis

Data were analyzed using Minitab 21.1.0. One-way ANOVA and Fisher's LSD were applied to compare means at a 95% confidence level ($P < 0.05$). Sensory acceptance was assessed using a 9-point hedonic scale.

RESULT AND DISCUSSION

Physical Properties

Table 2 presents the physical composition of Butterfly Pea Flower–Sorghum Rice Ice Cream (Samples A–D). Properties studied included colour, texture, melting, and overrun. One-way ANOVA showed significant differences ($p < 0.05$) in colour, hardness, melting rate, and overrun, but not in stickiness ($p > 0.05$). The L^* value in these samples primarily originated

from milk, sorghum, and butterfly pea flowers. Lightness (L^*) value levels ranged from 40.18 g/100g to 43.48 g/100g, with sample B (43.48 ± 0.113^{a0}) having the highest L^* value. Statistical analysis revealed significant differences in L^* value among the samples ($p < 0.05$). An increase in sorghum content resulted in a reduction of lightness, likely due to the natural coloration of sorghum. This trend aligns with the study by Tolve et al. [19], which found that fibre incorporation lowered the L^* value in ice cream formulations.

The a^* value ranged from -0.3900 g/100g to 0.6100 g/100g, with higher sorghum concentration (1.5% and 1.0%) resulting in increased redness [20]. This trend is consistent with studies on date fiber [21], where increasing fiber concentration enhances red hues. Lower sorghum resulted in negative values, shifting towards green due to anthocyanin influence. The value for b^* is either $+b^*$ (yellowness) or $-b^*$ (blueness) [22]. The b^* value ranged from -7.570 g/100g to -4.440 g/100g, indicating a dominant blueish hue due to anthocyanins. As sorghum concentration increased, b^* values became less negative, indicating a reduction in blue intensity. This shift aligns with findings where fiber-rich ice creams exhibited greater yellowness [21]. Conversely, lower fiber samples had more negative values, reflecting stronger blue tones [23].

The hardness levels ranged from 1245 g/100g to 3831 g/100g, with sample B (3831 ± 279 g) exhibiting the highest maximum penetration force. Statistical analysis indicated significant differences in hardness among the samples A, B, and CD ($p < 0.05$), aligning with the established inverse correlation between hardness and overrun [19]. The presence of smaller ice crystals and increased air incorporation in high-overrun samples contributed to a softer texture, consistent with previous studies by Sofjan et al. [24]. Additionally, moisture content influenced hardness, with increased water molecule mobility reducing thermodynamic stability [19].

Table 2. Result of physical properties (L^* [%], a^* [%], b^* [%], Hardness [N], Stickiness [N.s], Melting Rate [g/min], and Overrun [%]) of Butterfly Pea Flower (*Clitoria ternatea*) incorporated with Sorghum Rice (*Sorghum bicolor* L.) Ice Cream between samples.

Parameters	A (0%)	B (0.5%)	C (1.0%)	D (1.5%)
L^* (%)	42.59 ± 0.530 ^a	43.48 ± 0.113 ^a	40.42 ± 0.007 ^b	40.18 ± 0.283 ^b
A^* (%)	-0.3900 ± 0.0141 ^d	-0.1500 ± 0.0141 ^c	0.0750 ± 0.0212 ^b	0.6100 ± 0.0424 ^a
B^* (%)	-7.570 ± 0.000 ^e	-5.710 ± 0.000 ^b	-4.440 ± 0.170 ^a	-4.650 ± 0.000 ^a
Hardness (g)	1245 ± 956 ^b	3831 ± 279 ^a	2185 ± 298 ^{ab}	1753.5 ± 49.0 ^{ab}
Stickiness (g)	-387 ± 377 ^a	-699.4 ± 22.6 ^a	-543.2 ± 106.3 ^a	-381.5 ± 88.5 ^a
Melting Rate (g/min)	0.3074 ± 0.008 ^{ab}	0.2521 ± 0.0104 ^c	0.3220 ± 0.0065 ^a	0.2661 ± 0.0157 ^{bc}
Overrun (%)	13.540 ± 0.467 ^c	35.755 ± 0.544 ^b	36.445 ± 0.926 ^{ab}	38.080 ± 0.693 ^a

Note: All values given are means of duplicate results where n=3. Standard deviation (mean ± SD) is included for each average. Different letters indicated significant differences between formulations at ($p < 0.05$) within the column.

Table 3. Result of chemical properties (Moisture [%], Ash [%], Crude Fat [%], Crude Protein [%], Crude Fiber [%], Total Carbohydrates [%], and Total Solid Content [%]) of Butterfly Pea Flower (*Clitoria ternatea*) incorporated with Sorghum Rice (*Sorghum bicolor* L.) Ice Cream between samples.

Parameters	A (0%)	B (0.5%)	C (1.0%)	D (1.5%)
Moisture (%)	65.14 ± 1.670 ^a	64.82 ± 0.668 ^a	65.09 ± 0.600 ^a	65.03 ± 0.036 ^a
Ash (%)	0.9582 ± 0.0648 ^a	0.9897 ± 0.0017 ^a	0.9702 ± 0.0610 ^a	0.9893 ± 0.0081 ^a
Crude fat (%)	8.268 ± 0.3170 ^a	5.440 ± 4.520 ^a	2.874 ± 0.0374 ^a	1.584 ± 0.9100 ^a
Crude protein (%)	6.160 ± 0.5350 ^{ab}	7.486 ± 0.4470 ^a	4.895 ± 0.6720 ^b	4.959 ± 0.3030 ^b
Crude fiber (%)	5.470 ± 0.672 ^a	6.253 ± 1.006 ^a	6.521 ± 0.581 ^a	6.6660 ± 0.1032 ^a
Total Carbohydrates (%)	18.91 ± 0.5990 ^b	22.18 ± 4.630 ^{ab}	27.40 ± 2.040 ^a	27.50 ± 0.6470 ^a
Total Solid Content (%)	34.86 ± 1.670 ^a	35.18 ± 0.6680 ^a	34.91 ± 0.6000 ^a	34.97 ± 0.0361 ^a

Note: All values given are means of duplicate results where n=3. Standard deviation (mean ± SD) is included for each average. Different letters indicated significant differences between formulations at ($p < 0.05$) within the column.

Stickiness values, measured as peak adhesive force, varied from -699.4 g/100 g to -381.5 g/100 g, with no significant differences among samples ($p > 0.05$). However, an increasing trend in stickiness with higher sorghum content was observed, attributed to the fiber's water-retention properties, which form a gel-like network, thereby increasing viscosity and gas retention [21]. The melting rate ranged from 0.2521 g/min to 0.3220 g/min, indicating significant differences among samples ($p < 0.05$). Ice creams with higher overrun percentages exhibited lower melting rates due to the insulating properties of incorporated air, which could reduce heat transfer and water mobility [1, 21]. Increased overrun also contributed to lower melting rates due to the insulating effect of air incorporation [1,21]. Meanwhile, the overrun levels ranged from 13.54% to 38.08%, with sample D exhibiting the highest overrun.

Statistical differences among samples ($p < 0.05$) were attributed to fiber concentration, sugar content, and processing conditions. Unlike prior research, which found that dietary fiber reduced overrun [19], the current study suggests that sorghum fiber, combined with a high sugar content, facilitated uniform air incorporation, thereby enhancing overrun.

Chemical Properties of Butterfly Pea Sorghum Ice Cream

Table 3 presents the chemical composition of Butterfly Pea Flower–Sorghum Rice Ice Cream (Samples A–D). Moisture was the main component, followed by protein, fiber, ash, carbohydrates, and total solids. One-way ANOVA showed significant differences ($p < 0.05$) in protein and carbohydrates, but not in moisture, ash, fat, fiber, or total solids ($p > 0.05$).

Moisture content showed no significant differences among samples ($A > C > D > B$). Unlike Borchani et al. [21], who found that fiber increased moisture, this study attributed stable moisture levels to the binding effect of other ingredients, such as CMC. Ash content also showed no significant variation ($B > D > C > A$). Unlike the findings by Borchani et al. [21], who reported an increase in ash content with fiber addition, the low ash levels observed here were attributed to sorghum's naturally low mineral content of 2.1% and partial milk solid replacement [14].

Meanwhile, crude fat ranged from 1.584% to 8.268%, with Sample A having the highest fat content. No significant differences were observed, aligning with findings from Dervisoglu et al. [25]. Increasing sorghum concentrations led to a reduced fat content, consistent with studies by Borchani et al. and Tolve et al. [19,21], which suggest that fiber acts as a fat replacer, lowering fat levels in ice cream. The crude protein content of butterfly pea flower-incorporated sorghum ice cream showed significant differences among samples, with protein levels decreasing as sorghum content increased. However, this trend was contradicted by Dervisoglu et al. [25], who found no significant changes in protein content with fiber incorporation at low concentrations of 0.4, 0.8, and 1.2%. [20].

Although sorghum is a known protein source (~10.6 g/100g), the decline may be attributed to its lower protein quality and digestibility. Sorghum protein is less digestible than animal dairy, and even when cooked, it demonstrates lower protein digestibility compared to other grains [21]. The crude fiber content, primarily derived from sorghum, showed no significant differences among samples; however, an increasing trend was observed with higher sorghum content.

The dilution effect within the ice cream matrix may result in a lack of significance. Similar findings by Mahdian et al. suggest that fiber plays a role in improving functional properties without significantly affecting overrun values. There is no significance in fiber content due to the dilution effect within the complex ice cream matrix, which comprises diverse ingredients such as dairy products, sweeteners, and stabilizers. The fiber, being distributed throughout the product, contributes to its functional properties without significantly altering its overrun values. For example, in a related study by Patel et al. [26], the development of finger millet (ragi) ice cream demonstrated that fiber effectively functioned as a fat replacer while reducing the amount of stabilizer needed, owing to its excellent thickening and water-binding properties.

The total carbohydrate content varied significantly, ranging from 18.91 to 27.50 g/100g. The increase in carbohydrates with higher sorghum content aligns with previous studies, as sorghum contains 60–75% polysaccharides [12]. Moreover, this finding is consistent with Ogo et al. [27], who reported similar carbohydrate levels in their control samples. The total solid content ranged from 34.86 to 35.18 g/100 g, with no significant differences among the samples. The results align with Dervisoglu et al. [25], who found no significant impact of citrus fiber on total solids at low concentrations. However, Akalin et al. [28] observed increased total solids with the addition of dietary fibers such as oranges and apples at higher concentration levels. Sample B had the highest total solid content, likely due to higher fat levels, which enhanced texture and stability [1].

Sensory Acceptability

The degree of liking of 30 panelists for butterfly pea flower (*Clitoria ternatea*) and sorghum rice ice cream, consisting of samples A to D with increasing sorghum content ratios, is shown in Table 4, with mean and standard deviation values. Sensory attributes included aroma, melting, hardness, smoothness, iciness, and general acceptability. One-way ANOVA results showed that there were no significant differences ($p > 0.05$) between samples in the attributes of aroma, melting, hardness, smoothness, iciness, and general acceptability. In general, formulation C received the highest general acceptability (7.567 ± 1.547%) compared to the others.

Table 4. Result of sensory acceptability (Aroma [%], Melting Rate [%], smoothness [%], Iciness [%], General Acceptability [%]) of Butterfly Pea Flower (*Clitoria ternatea*) incorporated with Sorghum Rice (*Sorghum bicolor* L.) Ice Cream between samples.

Parameters	A (0%)	B (0.5%)	C (1.0%)	D (1.5%)
Aroma (%)	6.967 ± 2.042 ^a	6.733 ± 1.946 ^a	7.033 ± 1.671 ^a	6.733 ± 1.874 ^a
Melting Rate (%)	6.933 ± 1.893 ^a	7.167 ± 1.577 ^a	7.367 ± 1.810 ^a	7.400 ± 1.329 ^a
Hardness (%)	7.067 ± 1.660 ^a	6.933 ± 1.760 ^a	7.033 ± 1.790 ^a	6.833 ± 1.931 ^a
Smoothness (%)	7.167 ± 1.783 ^a	6.900 ± 1.470 ^a	7.300 ± 1.557 ^a	6.967 ± 2.266 ^a
Iciness (%)	7.267 ± 1.596 ^a	6.867 ± 1.596 ^a	7.367 ± 1.474 ^a	7.000 ± 1.486 ^a
General Acceptability (%)	7.400 ± 1.567 ^a	7.200 ± 1.584 ^a	7.567 ± 1.547 ^a	7.16 ± 1.802 ^a

Note: All values given are means of duplicate results where n=3. Standard deviation (mean ± SD) is included for each average. Different letters indicated significant differences between formulations at ($p < 0.05$) within the column.

The sensory evaluation of sorghum-incorporated ice cream revealed no significant differences across all tested attributes, including aroma, melting rate, hardness, smoothness, iciness, and general acceptability.

The absence of significant differences suggests that the levels of sorghum used (0%, 0.5%, 1.0%, and 1.5%) did not substantially alter the sensory properties, thus sorghum could be incorporated at higher concentrations without altering the sensory properties. For aroma, the mild nature of sorghum and its possible adsorption of flavor compounds contributed to the lack of perceivable differences, aligning with prior research on butterfly pea ice cream with the addition of lime and lemon juice at 0.07% [29]. In terms of melting rate, the fiber content likely influenced structural stability, yet within the tested range, the effect was not strong enough to create noticeable variations.

The hardness attribute followed a similar pattern, as the ice crystal formation and viscosity changes remained within an acceptable range without significantly impacting consumer perception [1]. Moreover, smoothness and iciness were also unaffected significantly, as slight variations in solid content and fat levels were insufficient to create a clear preference among panellists. Lastly, general acceptability scores indicated that all formulations were well-received, with no single sample standing out enough to cause a statistically significant difference.

CONCLUSION

In conclusion, this study successfully determined the physicochemical properties and sensory acceptance of ice cream containing anthocyanin from *Clitoria ternatea* and varying levels of sorghum. The results highlight the potential of incorporating anthocyanin and sorghum to create functional, health-oriented frozen desserts. Among the formulations, Sample B (0.5% sorghum) showed numerically the highest scores, exhibiting optimal colour, protein content, and sensory appeal while maintaining a balanced texture. Future research should focus on optimizing fiber concentration to enhance functionality, particularly in relation to hardness, where these were the limitations encountered in this study. As fiber increases, hardness tends to decrease, potentially improving texture. Stabilizers, such as locust bean gum or guar gum, can help maintain consistency. Additionally, exploring different sorghum varieties could further enhance fiber content, aligning with nutritional guidelines and consumer demand for healthier frozen desserts.

CONFLICT OF INTEREST

The authors have declared that no conflict of interest exists.

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ETHICS STATEMENT

Although this study involved human participants, no ethics approval number was provided, as the university did not require or issue an ethics reference number for this type of research.

REFERENCES

1. Syed QA, Anwar S, Shukat R, Zahoor T. Effects of different ingredients on texture of ice cream. *J Nutr Health Food Eng.* 2018;8(6):422–35.
2. Hasan R, Wan Muhammad Amir W Ahmad, Mohamad Shafiq Bin Mohd Ibrahim M, Nor Azlida Aleng N, Munisamy H, Halim N, et al. A scenario of sugar-added food and beverage consumption

among preschool children in Kelantan, Malaysia. *Int J Multidiscip Res Modern Educ.* 2017;3(1):163–70.

3. Sipple LR, Racette CM, Schiano AN, Drake MA. Consumer perception of ice cream and frozen desserts in the "better-for-you" category. *J Dairy Sci.* 2022;105(1):154–69.
4. Soukoulis C, Fisk ID, Bohn T. Ice cream as a vehicle for incorporating health-promoting ingredients: conceptualization and overview of quality and storage stability. *Compr Rev Food Sci Food Saf.* 2014;13:627–55.
5. Adebowale OJ, Taylor JRN, de Kock HL. Stabilization of wholegrain sorghum flour and consequent potential improvement of food product sensory quality by microwave treatment of the kernels. *LWT.* 2020;132:108–15.
6. Rashwan AK, Yones HA, Karim N, Taha EM, Chen W. Potential processing technologies for developing sorghum-based food products: an update and comprehensive review. *Trends Food Sci Technol.* 2021;110:168–82.
7. Xiong Y, Zhang P, Warner RD, Fang Z. Sorghum grain: from genotype, nutrition, and phenolic profile to its health benefits and food applications. *Compr Rev Food Sci Food Saf.* 2019;18:2025–46.
8. Gaytos CGE, Lumagbas ANA. Acceptability of Asian blue pea flower (*Clitoria ternatea*) ice cream. *SSRN*;2019:3517731.
9. Nik Hassan NF, Ahmad N, Abu Kassim AR, Hamzah Y. The customers' consumption trends on healthy ice cream. *Jurnal Intelek.* 2021;16(2):89–98.
10. Genovese A, Balivo A, Salvati A, Sacchi R. Functional ice cream health benefits and sensory implications. *Food Res Int.* 2022;161:111–18.
11. Espitia-Hernández P, Chávez González ML, Ascacio-Valdés JA, Dávila-Medina D, Flores-Naveda A, Silva T, et al. Sorghum (*Sorghum bicolor* L.) as a potential source of bioactive substances and their biological properties. *Crit Rev Food Sci Nutr.* 2022;62(17):2269–80.
12. Awika JM. Sorghum: its unique nutritional and health-promoting attributes. In: *Gluten-Free Ancient Grains: Cereals, Pseudocereals, and Legumes.* Berlin: Springer; 2017. p. 21–54.
13. Ibrahim IN, Kamaruding NA, Ismail N, Shaharuddin S. Value addition to ice cream by fortification with okara and probiotic. *J Food Process Preserv.* 2022;46(2):e16420.
14. Chamchan R, Sinchaipanit P, Disnil S, Jittinandana S, Nitithamyong A, On-nom N. Formulation of reduced sugar herbal ice cream using lemongrass or ginger extract. *Br Food J.* 2017;119(10):2172–82.
15. Thilakarathna HIU, Jayarathna GN, Mudannayake DC. Probiotic ice cream incorporated with blue pea flower (*Clitoria ternatea*) as a natural colorant and dehydrated banana flour as a potential prebiotic ingredient. *Food Life.* 2023;2(2):67–75.
16. Pathare PB, Opara UL, Al-Said F. Colour measurement and analysis in fresh and processed foods: a review. *Food Bioproc Technol.* 2013;6(1):36–60.
17. Azari-Anpar M, Soltani Tehrani N, Aghajani N, Khomeiri M. Optimization of the new formulation of ice cream with native Iranian seed gums using response surface methodology. *J Food Sci Technol.* 2017;54(1):196–208.
18. Velotto S, Parafati L, Ariano A, Palmeri R, Pesce F, Planeta D, et al. Use of stevia and chia seeds for the formulation of traditional and vegan artisanal ice cream. *Int J Gastron Food Sci.* 2021;26:100383.
19. Tolve R, Zaroni M, Ferrentino G, Gonzalez-Ortega R, Sportiello L, Scampicchio M, et al. Dietary fibers effects on physical, thermal, and sensory properties of low-fat ice cream. *LWT.* 2024;199:114113.
20. Zarei M, Amirkolaei AK, Trushenski JT, Sealey WM, Schwarz MH, Ovissipour R. Sorghum as a potential valuable aquafeed ingredient: nutritional quality and digestibility. *Agriculture.* 2022;12(5):669.
21. Borchani C, Masmoudi M, Besbes S, Attia H, Deroanne C, Blecker C. Effect of date flesh fiber concentrate addition on dough performance and bread quality. *J Texture Stud.* 2011;42(4):300–8.
22. Jha SN. Colour measurements and modeling. In: *Nondestructive Evaluation of Food Quality: Theory and Practice.* Berlin: Springer; 2010. p. 17–40.
23. Thuy NM, Minh VQ, Ben TC, Nguyen MTT, Ha HTN, Van Tai N. Identification of anthocyanin compounds in butterfly pea flowers by ultra performance liquid chromatography/ultraviolet coupled to mass spectrometry. *Molecules.* 2021;26(15):4472.

24. Sofjan RP, Hartel RW. Effects of overrun on structural and physical characteristics of ice cream. *Int Dairy J.* 2004;14(3):255–62.
25. Dervisoglu M, Yazici F. Note: the effect of citrus fibre on the physical, chemical and sensory properties of ice cream. *Food Sci Technol Int.* 2006;12(2):159–64.
26. Patel IJ, Dharaiya CN, Pinto SV. Development of technology for manufacture of ragi ice cream. *J Food Sci Technol.* 2015;52(7):4015–28.
27. Ogo O, Emmanuella B, Esienanwan E, Daniel E. Nutritional and sensory evaluation of novel ice cream products formulated from kunu-zaki fortified with fruit pulp. *Food Nutr Sci.* 2021;12(5):439–51.
28. Akalin AS, Erişir D. Effects of inulin and oligofructose on the rheological characteristics and probiotic culture survival in low-fat probiotic ice cream. *J Food Sci.* 2008;73(4):M136–42.
29. Faizah N, Rashid M, Zulkifli NA, Zaizuliana N, Anwar R, Syazwani H, et al. Physicochemical properties, antioxidant activities and sensory evaluation of butterfly pea ice cream flavoured with citrus juice. *Biosci Rep.* 2022;42(3):BSR20220734.