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Influence of dragon fruit, beetroot, and sweet basil incorporation on physicochemical, textural, and quality attributes of functional ice cream

Ervin Batra, Neelam Chaturvedi*, Riya Singh, Palak Tiwari, Saloni Dua
Department of Food Science and Nutrition, Banasthali Vidyapith, Rajasthan, India

Abstract
Ice cream is a widely consumed dairy food product among consumers of all ages. Ice cream being a complex colloidal system, it is challenging to develop healthier formulations without compromising texture, stability, and overall quality. This research aimed to develop a low-fat ice cream to determine the effect of incorporation of sweet basil seed, dragon fruit and beetroot towards the physical, physicochemical and textural characteristics of ice cream with particular emphasis on parameters such as overrun, melting point, water holding capacity, pH, total soluble solids, titratable acidity and sensory evaluation. Among the formulations the ice cream (V2) with 55% buffalo milk, 23% coconut milk, 10% dragon fruit puree, 1.5% beetroot extract and 0.5% sweet basil seed mucilage exhibited highest sensory acceptance as compared with control. The ice cream formulation V2 showed higher pH (6.63 ± 0.03), TSS (3.95 ± 0.05 °Brix), overrun (33.50 ± 0.50) and water holding capacity (78.40 ± 0.40) as compared to control C1. V2 also exhibited a higher meltdown rate (0.85 ± 0.02) and enhanced textural properties including hardness (2.85 ± 0.20), softness (7.80 ± 0.07) and adhesiveness (0.016 ± 0.003). The findings of the research indicated that the improved overrun, water holding capacity and textural property resulted in smoother, creamier and yielded stable ice cream structure.

Keywords: Dragon fruit, sweet basil seed, beetroot, betalains

Introduction
Ice cream is a widely consumed frozen dessert, renowned for its smooth texture, creamy mouthfeel, and rich flavour. It consists of a complex, multiphase system comprising partially coalesced fat droplets, air cells, ice crystals, and unfrozen serum containing proteins, polysaccharides, mineral salts, and water (Xavier & Ramana, 2021). Despite advancements in processing technology, producing low-fat and nutritionally enriched ice cream without compromising the texture, structure, and flavour remains a challenge (Khair *et al*., 2020) [12]. Consequently, the emergence of hydrocolloids as effective fat replacers, texture enhancers, and stabilizers has prompted the exploration of various seeds and seed-derived components for functional food development. In this regard, sweet basil seeds (*Ocimum basilicum*) are a promising natural alternative due to their high mucilage content (43%), dietary fibre (22.6%), protein (20.9%), and polyunsaturated fatty acids, which collectively improve viscosity, mouthfeel, and melting resistance in ice cream (Bravo *et al*., 2021) [3]. However, in general, conventional ice cream formulations are deficient in bioactive compounds, limiting their potential as functional foods in response to growing consumer demand for health-oriented food products (Guler-Akin *et al*., 2021) [9].
In order to overcome this nutritional and bioactive constraint, natural components such as dragon fruit (*Hylocereus spp.*) and beetroot (*Beta vulgaris*) have garnered significant attention, as both are rich in bioactive compounds such as betalains, flavonoids, vitamin C, nitrates, and phenols, which exhibit antioxidants, anti-inflammatory, and cardioprotective properties (Chen *et al*., 2024; Clifford *et al*., 2015) [5, 6]. Nevertheless, the physicochemical interactions and functional properties of sweet basil seeds in frozen dairy systems, particularly in combination with bioactive ingredients like dragon fruit and beetroot, remain underexplored (Chen *et al*., 2024; Evstigneeva *et al*., 2020) [5, 7]. Therefore, the present study evaluates the effects of varying concentrations of basil seed gum, dragon fruit, and beetroot on functional ice cream developed from a blend of buffalo and coconut milk on the proximate composition, physicochemical characteristics, texture, and sensory properties.

Methodology
The present study was carried out in the laboratory of the Department of Food Science and Nutrition in Banasthali Vidyapith, Rajasthan. The ingredients utilized in the present study were dragon fruit, sweet basil seed, beetroot, and coconut milk, which were purchased from local commercial vendors of Jaipur, Rajasthan, and buffalo milk was purchased from a local dairy near Banasthali campus.

Sweet basil seed mucilage extraction
Sweet basil seed mucilage was extracted by following the method given by Nazir *et al*. (2017) [15]. Seeds were added to distilled water at seed to water ratio (w/v) of 1:20 or 1:30. The soaked seeds were heated on water for 50-60°C with continuous stirring for the entire extraction period. The soaked seeds were filtered through a muslin cloth or mesh screen to separate mucilage and obtained mucilage was dried at at 50 °C for 10 h in a conventional hot air oven. The dried mucilage was stored in an airtight container for further applications.

Dragon fruit puree preparation
Dragon fruit puree was prepared by following method described by Jati *et al*. (2024) [11] with some modifications. The obtained dragon fruit was washed under running water and peeled. The fruit flesh was cut into pieces before homogenising in a blender and the resulting dragon pure was filtered through a mesh of size 32 for uniform consistency and was store at 4°C for further use.

Preparation of beetroot extract

Beetroot was extracted through aqueous extraction method given by Udonkang *et al*. (2018) [19] with some modifications. Fresh beetroots were dried in hot air oven at 50-55°C for 24 hours and then grounded in mortar to obtain fine powder. About 0.5 g of the dried beetroot powder were suspended in 50 ml distilled water, followed by centrifugation at 1500 rpm for 10 minutes. The solutions were filtered using Wattman No. 1 filter paper and was used in preparation of ice cream.

Preparation of Ice cream

Ice cream was prepared by following the method given by Hong *et al*. (2021) [10] with slight modifications. The formulations of ice cream were prepared with incorporation of dragon fruit puree, beetroot extract, sweet basil seed gum. Buffalo milk along with coconut milk was used as a base ingredient for ice cream preparation. The ingredients were mixed thoroughly to obtain uniform mix, which was pasteurized at 90°C for 3 seconds. Then, the mix was homogenized for 15 min using a homogenizer. Further ice cream cooled to 5 ± 1 °C and aged for approximately 24 h at 5 ± 1 °C. The formulated ice cream was packaged and hardened at −26 °C for 24 h in a deep freezer, and then kept at −20 °C.

Table 1: Formulation of Ice cream

Ingredients	C1	C2	V1	V2	V3	V4
Buffalo milk (ml)	90	-	45	55	45	35
Coconut milk (ml)	-	90	45	23	27	31
Dragon fruit (g)	-	-	-	10	15	20
Beetroot extract (ml)	-	-	-	1.5	2	2.5
Sweet basil seed mucilage (g)	-	-	-	0.5	1	1.5

BM- Buffalo Milk, CM- Coconut Milk, DFP- Dragon Fruit Pulp, BSG- Basil Seed Gum. BRE- Beetroot Extract. Control 1;C1– 90 BM, Control 2;C2 – 90 CM, Variation 1;V1 – 45 BM: 45 CM, Variation 2;V2 - 55 BM: 23 CM:10 DFP: 1.5 BRE: 0.5 BSG, Variation 3;V3 – 45 BM: 27 CM: 15 DFP: 2 BRE: 1 BSG, Variation 4;V4 - 35 BM: 31 CM: 20 DFP: 2.5 BRE: 1.5 BSG, Common ingredients; Cream: Sugar: Vanilla essence; (C1,C2,V1)- 20:20:1; (V2, V3, V4)- 25:25:1

Sensory Evaluation of Formulated Functional Ice-cream

26 semi-trained panel members were selected from Banasthali Vidyapith, Rajasthan. All candidates underwent a triangle difference test to assess their sensory discrimination abilities. Consent was obtained from all panellists after they were fully informed and before their involvement in the study. Fresh samples of functional ice cream formulations were prepared for this evaluation. In each session, five different treatments of ice cream were appraised by panellists using the 9-point hedonic scale (Singh *et al*., 2025) [17]. Samples were presented in randomized order and coded.

Physicochemical Characteristics

To determine the titratable acidity AOAC (2019) method was used. In a beaker, ice cream was brought to room temperature and it was vigorously stirred. The sample of melted ice-cream was subsequently was then combined with distilled water. After the addition of 0.5ml of phenolphthalein indicator to the beaker, 0.1 N sodium hydroxide was added to titrate the mixture until a pink hue appeared. Three separate equations were made to determine the titrable acidity of the ice-cream. A small hand refractometer with a 0-32°Brix scale was used to measure the total soluble solids (TSS) of ice-cream (Atallah *et al*., 2022) [2]. The pH of the prepared sample was determined using a pH meter (Starter 3000, OHAUS, Switzerland) at 25° C (Zare & Lashkari., 2021) [22].

Physical Characteristics

Overrun

Overrun is the volume of ice cream obtained more than the volume of the mix. The Calculation of ice cream overrun was carried out according to the following equation (Góral *et al*., 2018).

$$\text{Overrun (\%)} = \left(\frac{W1 - W2}{W2}\right) \times 100$$

Where: W1 represents the mass of a unit volume of ice cream (g). Measurements were performed in triplicate or more.

Meltdown

With minor modifications, the behaviour of meltdown was assessed following Yeon *et al*. (2017) [21]. The samples of ice-cream that were stored at -25°C for 7 days were cut into cylindrical portions (~20 g) and it was placed on wire mesh at 10-minute intervals for 90 minutes over a pre-weighed beaker at ambient temperature (22 ±1°C).

$$\text{drip-off (\%)} = \left(\frac{m_d}{m_S}\right) \times 100\%$$

where m_d is the weight of the ice cream drip-off (g), and m_s is the weight of the ice cream sample (g). The measurements were performed in triplicate.

Water-Holding Capacity

Water-holding capacity (WHC) of ice cream was determined by following the method described by Ng *et al.* (2024) with slight modifications. For WHC analysis, distilled water was added to the sample and vortexed or stirred by magnetic stirrer. After stirring the sample was left undisturbed for 10 minutes and then subjected to centrifugation at 3000×g for 20 minutes. The supernatant was discarded and remaining residue was filtered and weighed for further calculation.

Calculation:

$$\text{Water Holding Capacity} = \frac{(\text{Weight of hydrated sample} - \text{Initial sample weight})}{\text{Initial sample weight}}$$

Texture Analysis

Texture analyser was used to measure hardness, softness, cohesiveness and adhesiveness of ice cream. All the measurements were done in triplicates.

Statistical Analysis

The data obtained in the present study was analysed statistically by mean, standard deviation and student t-test using SPSS software.

Results and Discussion

Sensory Evaluation

Figure 1 shows different sensory attributes of control (C1, C2) and functional ice cream formulations (V1, V2, V3, V4). Sensory evaluation assessed the appearance, colour, flavour, taste and texture for formulated ice creams. Ice cream control (C1) made with 100% buffalo milk scored highest mean score as compared with other formulations with composite score of 18.8±0.65 for appearance, 18.5±0.57 for colour, 17.6±0.12 for flavour, 18.9±0.32 for texture and 19.2±0.28 for taste followed by formulation V2 that is composed of 55% buffalo milk, 23% coconut milk, 10% dragon fruit puree, 1.5% beetroot extract and 0.5% sweet basil seed mucilage scoring close to control C1 making it most acceptable formulation with mean score of 17.9±0.69 for appearance, Overall acceptability was highest for C1(18.34± followed by V2(), V demonstrating that incorporation of dragon fruit, beetroot and sweet basil in ice cream enhanced individual sensory attributes and overall consumer acceptability.

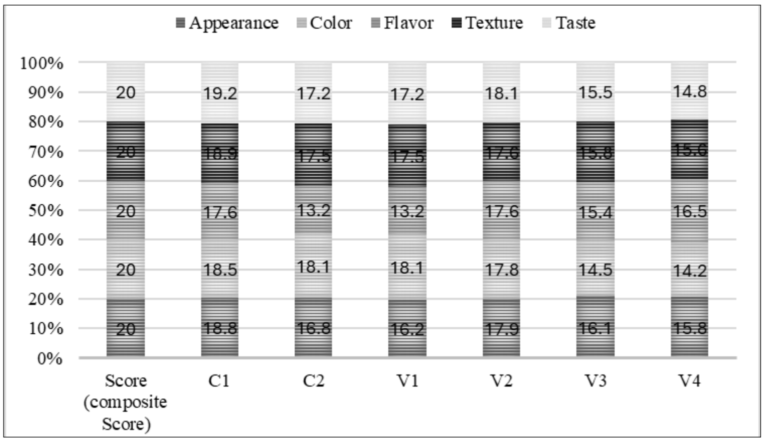

Fig 1: Sensory Evaluation of developed ice cream through composite score

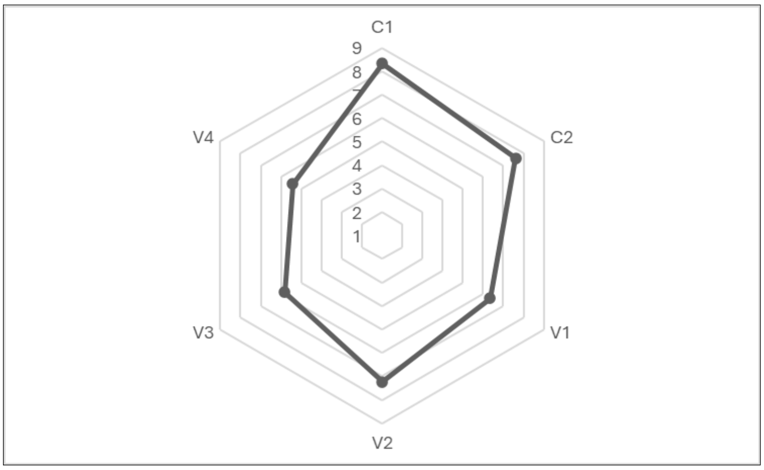

Fig 2: Overall acceptability of developed ice cream through 9-point hedonic scale

Physicochemical Analysis

The physicochemical analysis of the control ice cream (C1) and the functional ice cream (V2) showed significant difference. Addition of the stabilizers and emulsifiers greatly affects the ice cream pH and acidity (Sivakumar & Dharani, 2025) [18]. The pH of the formulated functional ice cream showed slight increase as compared to control from 6.1 to 6.63. Additionally, V2 had significantly higher total soluble solids (3.95±0.05 °Brix) than C1 (3.5±0.04 °Brix), reflecting a 12.9% increase in dissolved compounds, which can influence sweetness perception and overall texture.

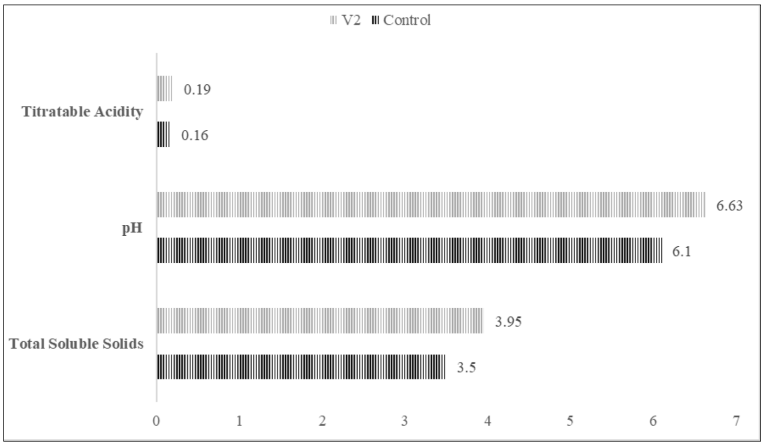

Fig 3: Physicochemical analysis of control (C1) and most acceptable developed ice cream (V2)

Physical Characteristics

Physical characteristics of ice cream that were analysed are its meltdown, overrun and water holding properties. Numerous physical changes occur during the freezing and aeration process of making icecream such as the partial coalescence of fat emulsion and solution concentration brought on by the freezing of liquid water, the activity of proteins and surfactants in the developments and stabilization of foam (Milliatti & Da Silva Lannes, 2018) [14] which promotes water retention within ice cream matrix by retaining unbound water during freezing. V2 showed higher water holding capacity (78.40±0.40) as compared to C1 (72.50±0.32) implying that the addition of hydrocolloids after the fluid's properties, influencing the development of ice crystals, the network of fat that forms, and ultimately the air cells. There is very little overabundance of icecream without stabilizers (22.8±0.40) as shown in figure 4 whereas formulated functional ice cream V2 showed notably high overrun rate (33.50±0.50). Furthermore, the control icecream (C1) displayed a significant level of free water, which causes the product to melt quickly in the absence of stabilizing agents such as sweet basil mucilage. Ice cream with free water content gets a white consistency during storage because of the growth of ice crystals that form a coarse crystalline structure (Buniowska-Olejnik *et al*., 2023) [4]. The incorporation of sweet basil seed mucilage inhibits the process of ice crystal growth in formulated functional ice cream V2 and as a result, the melting rate slows down, which is especially noticeable for the formulation as it shows melting rate of 0.33±0.05.

Furthermore, V2's water holding capacity (78.40 ± 0.40) surpassed that of C1 (72.50 ± 0.32), suggesting better freeze-thaw stability and reduced ice crystal formation, critical for maintaining quality during storage. This improvement in water holding capacity suggests better freeze- thaw stability and reduced ice crystal formation in the functional ice cream. These results are consistent with findings by Liu *et al*. (2021) [13] that highlight the role of certain plant-based stabilizers in enhancing water retention in frozen desserts.

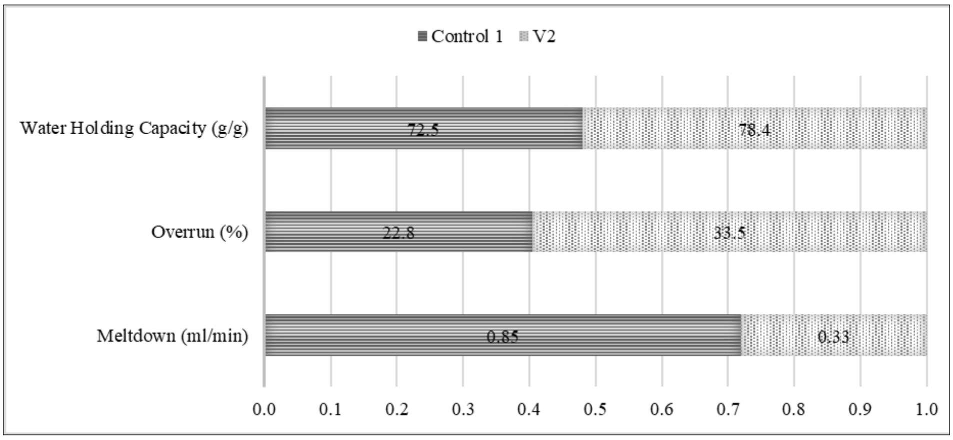

Fig 4: Physical characteristics of control (C1) and most acceptable developed ice cream (V2)

Texture Analysis

The texture analysis of ice cream containing different concentrations of dragon fruit, beetroot and sweet basil seed are shown in figure 5. The formulation V2 showed higher hardness (2.85±0.20) and softness (7.80±0.07) as compared to control ice cream C1 indicating that incorporation enhanced the creamier texture of ice cream. Additional texture properties like adhesiveness differed significantly with control suggesting enhanced mouth-coating property of formulated ice cream that affects consumer perception. These findings collectively indicate that V2 not only enhances nutritional value but also optimizes physical characteristics essential for consumer acceptance in functional ice cream development (Zhao *et al*., 2023) [23].

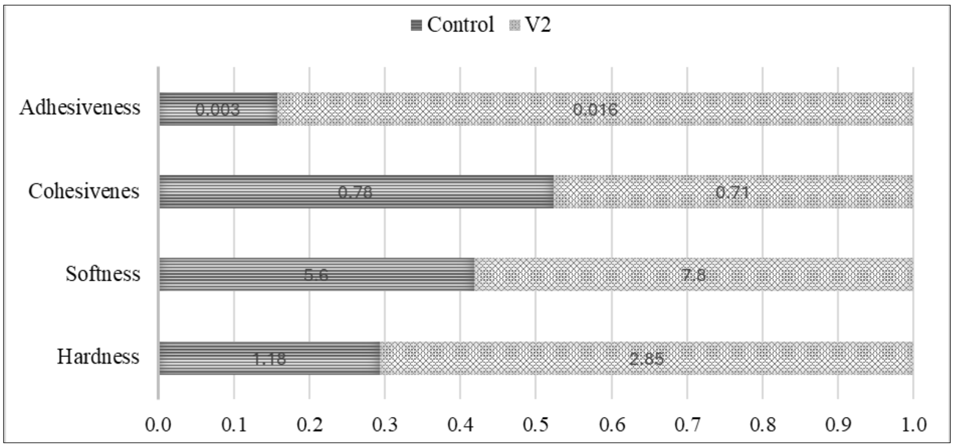

Fig 5: Texture analysis of control (C1) and most acceptable ice cream (V2)

Conclusion

The present study involves the development of ice cream with incorporation of dragon fruit, beetroot and sweet basil mucilage. The ice cream formulation was evaluated for its sensory attributes, physicochemical properties as well as textural and physical characteristics. Among the developed ice cream formulations V2 with 55% buffalo milk, 23% coconut milk, 10% dragon fruit puree, 1.5% beetroot extract and 0.5% sweet basil seed mucilage showed highest sensory acceptability. Further the result demonstrated higher pH (6.63 ± 0.03), TSS (3.95 ± 0.05 °Brix), overrun (33.50 ± 0.50) and water holding capacity (78.40 ± 0.40) as compared to control C1. V2 also exhibited a higher meltdown rate (0.85 ± 0.02) and enhanced textural properties including hardness (2.85 ± 0.20), softness (7.80 ± 0.07) and adhesiveness (0.016 ± 0.003).

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