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The Development of Red Dragon Fruit Ice Cream and its Physical, Chemical, and Sensory Quality

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Abstract

Red dragon fruit powder (RDFP) offers a multifunctional role in ice cream production due to its high levels of phenolic compounds, antioxidants, and dietary fiber, which enhance the nutritional profile, visual appeal, and texture of the product. This study investigated the effects of varying RDFP concentrations (2%, 4%, and 6%) on the physicochemical, sensory, and antioxidant properties of ice cream. Results demonstrated that the highest RDFP (6%) concentrations significantly increased total phenolic content (2.48 mg GAE/g) and antioxidant activity (33.08% inhibition, 7.80 mg Trolox/g), reflecting the functional potential of RDFP. The melting rate decreased with increasing RDFP concentration, with the 6% formulation showing the lowest rate, which was attributed to improved emulsion stability and structural integrity. Sensory evaluation indicated that the 6% RDFP formulation achieved the highest acceptance score (7.62), primarily due to enhanced creaminess, balanced flavor, and vibrant color. These findings suggest that incorporating RDFP into ice cream formulations meets consumer demand for functional foods and provides practical applications for the food industry by offering a natural, sustainable ingredient to improve frozen dessert quality. Future studies should explore RDFP's long-term effects on shelf life and its potential in broader food applications.

Introduction

Ice cream remains a globally popular frozen dessert, cherished for its creamy texture, sweet flavor, and overall sensory appeal. However, the growing consumer awareness of health and wellness has shifted preferences toward food products that deliver both sensory satisfaction and functional benefits (Uliano et al., 2024). The quality of ice cream is influenced by several factors, including ingredient composition, processing methods, and the use of stabilizers and emulsifiers, which impact melting rate, texture, and flavor (Soukoulis & Fisk, 2016; Warren & Hartel, 2018). Previous studies have explored the incorporation of

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functional ingredients such as fruit powders, proteins, and dietary fibers to enhance the quality and appeal of ice cream. For example, ice cream enriched with pomegranate peel phenolics at levels up to 0.4% (w/w) and pomegranate seed oil up to 2.0% (w/w) has the potential to be marketed as a functional ice cream product (Çam et al., 2013). Similarly, grape and strawberry powders have been utilized to naturally color frozen desserts (Bilbao-Sainz et al., 2019; Vital et al., 2018). In addition, dietary fibers derived from fruits and vegetables contribute to improved rheological properties, such as viscosity and melting resistance, while also acting as stabilizing agents. These fibers enhance water binding and gelling properties, further improving the structural and sensory qualities of ice cream (Salehi, 2021; Soukoulis & Fisk, 2016).

Red dragon fruit (*Hylocereus polyrhizus*) powder (RDFP) has emerged as a promising natural additive due to its rich composition of phenolic compounds, betacyanins, and dietary fiber. These bioactive compounds are recognized for their potent antioxidant properties and ability to impart a vibrant red hue, enhancing the visual appeal of food products (Huang et al., 2021; Nishikito et al., 2023a). Additionally, RDFP's fiber content contributes to improved texture and structural stability, making it particularly well-suited for frozen dessert formulations (Leong et al., 2018). Despite its potential, limited research has been conducted on RDFP's application in ice cream, leaving gaps in understanding its multifunctional benefits and effects on physicochemical and sensory properties (Jalukhu, Johan, & Rahmayuni, 2021).

Existing research highlights the antioxidant properties of red dragon fruit in beverages and baked goods. Red dragon fruit peel was processed into yogurt, enhancing its taste and therapeutic values (Gunungpati, 2020), a comprehensive analysis of its impact on frozen desserts, particularly ice cream, is lacking (Huang et al., 2021; Joshi & Prabhakar, 2020; Wang et al., 2024). This research gap includes the need to investigate how varying concentrations of RDFP influence critical parameters such as melting rate, texture, nutritional attributes, and consumer acceptance.

This study aims to address the research gap by evaluating the multifunctional role of red dragon fruit powder (RDFP) in ice cream. We examine its effects on physicochemical properties, antioxidants, and sensory characteristics across varying concentrations. The findings will provide empirical evidence supporting RDFP's potential as a functional ingredient in ice cream, contributing to innovations in product development and meeting consumer demands for healthier functional foods.

Materials and methods

1. Preparation of red dragon fruit powder

The raw material, red dragon fruit (*Hylocereus polyrhizus*), was purchased from the local market in the province of Kalasin, located in the northeastern region of Thailand. Red dragon fruit was prepared by cutting through the midpoint of the fruit and peeling it. The flesh of the red dragon fruit was placed in a stainless-steel bowl. The peeled fruit was mixed with distilled water at a 1:1 ratio (Musa et al., 2011) and blended until the dragon fruit was finely pureed. The puree was then filtered to remove the seeds. Once the seeds were completely removed, maltodextrin (20%) and lecithin (1.5%) (Krungthepchemi Co., Ltd., Bangkok, Thailand) were added (Chng et al., 2020; FAF et al., 2020), and the mixture was blended using a KitchenAid stand mixer (5K5SS, Michigan, USA) for 3-5 min. until a homogeneous mixture was achieved, ensuring even distribution of RDFP and other components. The blended sample was processed through a drum dryer at specific process conditions (drum surface temperature 120°C and drum clearances 0.2 mm) to produce red dragon fruit powder, which was filtered through a 50-mesh sieve and then analyzed for chemical quality.

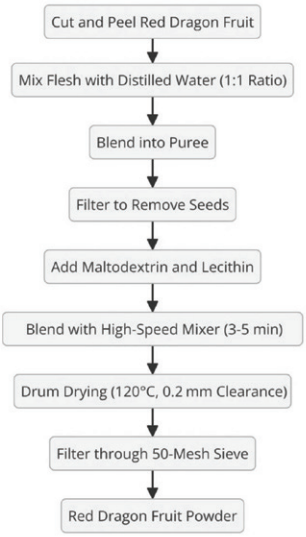

Fig. 1 Preparation of red dragon fruit powder

The flow chart of the preparation of red dragon fruit powder is present in Fig. 1, and red dragon fruit powder is present in Fig. 2.

Fig. 2 Red dragon fruit powder

2. Preparation of ice cream

The formulation of ice cream (Table 1) was modified from (Moeenfard & Tehrani, 2008). In the first part, whipping cream and yogurt were beaten on medium speed in a KitchenAid stand mixer (5K5SS, Michigan, USA) with a paddle attachment for 3 min. until soft peaks formed. Next, water, syrup, vanilla flavor, and red dragon fruit powder (2%, 4%, and 6%) (Gamage et al., 2024) were mixed and pasteurized at 65-70°C for 5 min. and then cooled immediately. Afterward, the 2 parts were combined and beaten together with a whisk attachment until the ice cream mixture was well-blended. The mixture was made into ice cream with an ice cream maker (Nemox, Creaserie, Gelato PRO 3000, Italy) at a controlled temperature of -5°C to -8°C for 25 min. 50 g of the ice cream was poured into round plastic containers with a lid (diameter 5 cm). Following freezing, the ice cream was hardened in a blast freezer set at -18°C for 24 h.

The ice cream samples were then analyzed for their physical, chemical, and sensory properties. The flow chart of the preparation of ice cream is presented in Fig. 3, and a visual of the ice cream is shown in Fig. 4.

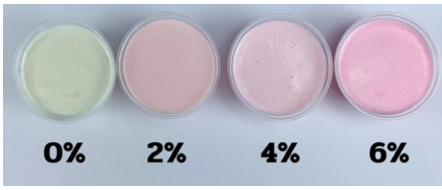

Fig. 4 Ice cream with red dragon fruit powder

Table 1 Formulation of ice cream with red dragon fruit powder

Ingredients (g)	Red dragon fruit powder (%, w/w)			
	0	2	4	6
Water	26	26	26	26
Whipping cream	26	26	26	26
Yogurt	29	27	25	23
Syrup	18	18	18	18
Vanilla flavor	0.5	0.5	0.5	0.5
Gelatin	0.5	0.5	0.5	0.5
Red dragon fruit powder	0	2	4	6
Total ingredients	100	100	100	100

3. Determination of physical properties

3.1 Ice cream melting rate

A 50 g ice cream sample was shaped into a sphere, and its initial weight was recorded using a four-point analytical balance (Sartorius ED224S, AG, Germany). The sample was placed on a No. 8 mesh screen and maintained at a temperature of 25±2°C. The melted portion was collected and weighed at 10-min. intervals over a period of 60 min. The melting percentage of the ice cream was calculated using the formula:

Melting percentage = (Weight of melted ice cream / Initial weight of ice cream) x 100

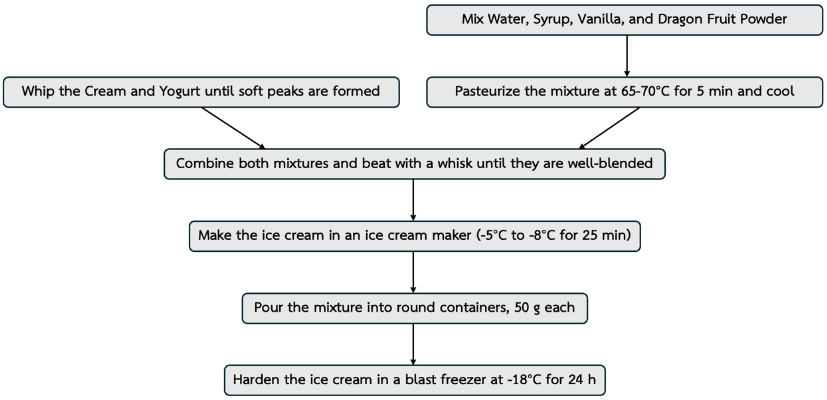

Fig. 3 Preparation of ice cream

3.2 Color analysis

A 50 g ice cream sample was placed in a plastic cup, and its color properties were assessed using an UltraScan UltraScan Pro (Hunterlab, Reston, VA, USA). The results were expressed in terms of Hunter L*, a*, and b* values.

3.3 Texture analysis

A 50 g ice cream sample was placed in plastic cup and analyzed for firmness using a texture analyzer (g Force) with a P/2 probe (TA.XT plus, Stable Micro Systems, Surrey, UK).

4. Determination of chemical properties

4.1 Preparation of extracts

A 15 g ice cream sample was melted at room temperature. The melted sample was combined with 80% methanol in a 15:15 ratio and homogenized using an electric mixer. The mixture was subjected to ultrasonic treatment in a bath sonicator (POWER SONIC 405, Lab Tech, Namyangju, Korea) at 5°C for 30 min. Following sonication, the sample was centrifuged at 8,000 rpm for 15 min. using a Camlab ALC 4239R high-speed refrigerated centrifuge (Camlab, Cambridge, UK). The resulting supernatant was collected in a new centrifuge tube, protected from light, and stored at -20°C for further analysis.

4.2 Determination of total phenolic content (TPC)

The total phenolic content was determined using a modified Folin-Ciocalteu method (Salih et al., 2021). A 5 µL aliquot of the extract was mixed with 50 µL of Folin-Ciocalteu reagent and 1.5 mL of deionized water. After an incubation period of 8 min., 50 µL of a 20% sodium carbonate solution was added to the mixture. The reaction was allowed to proceed at room temperature for 30 min., after which the absorbance was measured at 765 nm using a UV-Vis spectrophotometer (Biochrom Libra S22, Cambridge, UK). A calibration curve was constructed using gallic acid standards (0.15–10 mg/mL), and the results were expressed as mg of gallic acid equivalents (GAE) per g of dry weight.

4.3 Determination of total flavonoid content (TFC)

The total flavonoid content was determined using a colorimetric method based on the procedure described by Nabi & Shrivastava (2016). 1.5 mL of each extract was combined with 1.5 mL of a 10% aluminum chloride solution and incubated at room temperature for 30 min in the dark. The absorbance was then measured at 425 nm using a UV-Vis spectrophotometer (Biochrom Libra S22, Cambridge, UK). A standard curve was generated using quercetin as a reference, with concentrations ranging from 3 to 100 µg/mL. The flavonoid content was expressed as mg of quercetin per gram of dry extract.

5. Sensory evaluation

A sensory evaluation was conducted with 50 untrained participants aged 18 to 30 years, selected based on their regular consumption of ice cream and availability for the study. The evaluation assessed appearance, color, aroma, taste, texture, and overall acceptability. A 9-point hedonic scale was used, where 1 represented "dislike extremely" and 9 represented "like extremely."

Ice cream samples (50 g) were removed from storage at -18°C prior to serving. Each sample was coded with a random 3-digit number and presented to panelists under controlled lighting conditions to minimize bias. Panelists were instructed to cleanse their palate with water between samples to prevent carryover effects

6. Statistical analysis

For the determination of the physical and chemical properties, data were analyzed using a completely randomized design (CRD) with three replications. Analysis of variance (ANOVA) was performed using SPSS, and mean comparisons were conducted using Duncan's New Multiple Range Test (DMRT) at a 95% confidence level. For the sensory evaluation, a randomized complete block design (RCBD) was employed.

Results and discussion

1. Total phenolic content and antioxidant activity of red dragon fruit powder

The red dragon fruit powder (RDFP) demonstrated high phenolic content (236.49±13.9 mg GAE/g) and antioxidant activity, as shown by the DPPH inhibition (51.92±1.88%) and Trolox equivalent (55.85±1.70 mg/g) (Table 2). RDFP exhibits phenolic content and antioxidant properties comparable to pomegranate peel powder (approximately 250 mg GAE/g) and grape powders, which reported similar DPPH inhibition percentages of 50–60% (Çam et al., 2014). The high levels of phenolic compounds and betacyanins in RDFP contribute to its antioxidant capacity, enhancing its suitability for use in functional foods. The antioxidant properties of RDFP not only provide health benefits but also improve the stability and functionality of ice cream formulations by enhancing emulsion stability and delaying oxidation. These findings align with studies on other fruit powders, such as those from berries and grapes, that enhance nutritional and sensory attributes in frozen desserts (Leong et al., 2018).

Table 2 Total phenolic content and antioxidant activity of red dragon fruit powder

Sample	TPC Assay Gallic acid (mg/g)	DPPH assay	
		%inhibit	Trolox (mg/g)
Red dragon fruit powder	236.49±13.9	51.92±1.88	55.85±1.70

Remark: Values are means ± SD of triplicate samples (n = 3) (dry basis)

2. Physical properties of ice cream with red dragon fruit powder

The melting rate analysis of ice cream formulations containing red dragon fruit powder (RDFP) showed significant variations across different concentrations (Fig. 5). At the 10-min. mark, the control formulation exhibited a meltdown rate of approximately 3.4%, whereas formulations containing 2%, 4%, and 6% RDFP showed rates of 3.0%, 1.0%, and 0.8%, respectively. This trend continued as time progressed, with the 60-min. mark showing meltdown rates recorded at 16.7% for the control, 16.4% for 2% RDFP, 14.3% for 4% RDFP, and 13.6% for 6% RDFP. These results indicate that increasing RDFP concentrations are associated with a reduction in melting rate, with the 6% RDFP formulation exhibiting the greatest resistance to melting.

This effect is likely due to RDFP's high oligosaccharide content, which enhances emulsion stability and viscosity, thus contributing to the structural integrity of the ice cream and reducing melting rates (Kanta et al., 2024). Additionally, the substantial fiber and antioxidant content in RDFP positively impacts texture and melting behavior, aligning with previous findings on the role of these components in stabilizing frozen desserts (Apriyani, 2018). Antioxidants, in particular, may alter the freezing and glass transition temperatures of ice cream, similar to the way multimineral preparations derived from red algae have been reported to improve melting resistance (Markowska et al., 2023).

Previous research has shown that incorporating red dragon fruit extracts improves melting times in frozen desserts, supporting similar stabilizing effects in ice cream. For instance, ice cream with 8% red dragon fruit peel exhibited prolonged melting times compared to traditional formulations (Hafids et al., 2019), while adding 20% red dragon fruit juice to soy ice cream resulted in a recorded melting time of 54 min (Halim, 2022). In gelato, higher concentrations of red dragon fruit skin (up to 35%) also improved melting resistance, suggesting a strong correlation between RDFP content and enhanced stability in frozen desserts (Yunianti et al., 2024).

However, at higher RDFP concentrations (4% and 6%), the stabilizing effect may reach a saturation point, beyond which further increases in RDFP content yield diminishing improvements in melting resistance. These findings align with previous research on fruit powder incorporation in frozen desserts. Adding strawberry powder increases the viscosity of dessert mixes by forming hydrated and gel-like networks, which help reduce meltdown values. A threshold is observed at around 3% strawberry powder, beyond which no significant improvement in meltdown prevention is noted (Bilbao-Sainz et al., 2019). Additionally, maltodextrin and lecithin likely contribute to the observed melting rate changes. Maltodextrin improves water-binding capacity and stabilizes the ice cream matrix (Liu & Wang, 2006; Zaini et al., 2023), while lecithin acts as an emulsifier, enhancing fat dispersion and structural stability (Pan et al., 2024; Yu et al., 2022). The interaction of these additives with RDFP likely amplifies the stabilizing effects, reducing melting rates.

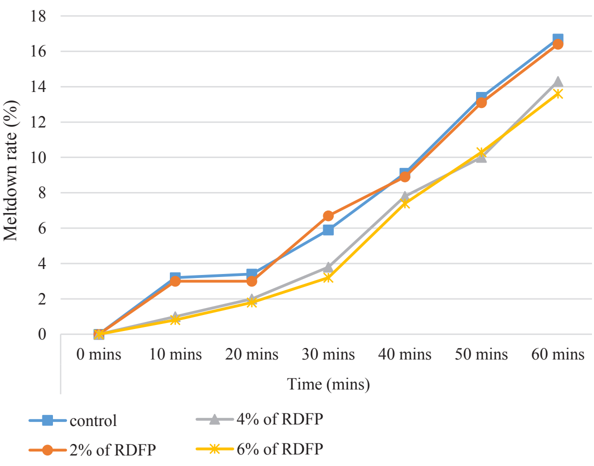

Fig. 5 Meltdown rate of ice cream with red dragon fruit powder

Including red dragon fruit powder (RDFP) in ice cream formulations led to significant changes in color and hardness properties (Table 3), reflecting the functional impact of RDFP on the product's physical characteristics. As the concentration of RDFP increased, the lightness (L*) of the ice cream decreased, while redness (a*) progressively intensified. This trend can be attributed to the natural pigments in RDFP, particularly betacyanins, which impart a red color (a*) to the ice cream. Higher concentrations of these pigments lead to a more pronounced red color (a*), resulting in lower lightness values (L*) (Hafids et al., 2019; Yunianti et al., 2024). Increasing concentrations of other colorants or fruit powders, such as sugar beet molasses and pomegranate peel, have shown to reduce the L* value, indicating darker hues in ice cream (Acan et al., 2020; Ismail et al., 2020). Adding encapsulated natural extracts, like Indigofera tinctoria, also resulted in a significant decrease in L* values, suggesting that higher concentrations of colored additives lead to darker ice cream (Shadordizadeh et al., 2023).

The blue-yellow spectrum (b*) also shifted to more negative values at increased RDFP concentrations, suggesting a reduction in the yellow component and enhancement of the red hue. This observation is consistent with studies on anthocyanin-rich fruit powders, which demonstrate that higher concentrations produce a stronger red hue by reducing yellow tones (Pramitasari et al., 2022). The shift in b* values may be influenced by increased light scattering from particle concentration, as noted in emulsion-based studies where higher particle concentrations affect perceived color (McClements et al., 1998).

Furthermore, the hardness of the ice cream increased with higher RDFP levels. This can be attributed to the higher total solids content from RDFP, which enhances viscosity and stabilizes the ice cream structure (Salehi, 2021). Adding fruit powders, including RDFP, can promote gel-like network formation, contributing to firmer texture and improved stability in ice cream (Bilbao-Sainz et al., 2019). Moreover, maltodextrin and lecithin play a crucial role in enhancing the texture of ice cream by functioning as stabilizers and emulsifiers. Maltodextrin increases viscosity and reduces free water content in the ice cream mixture, resulting in a smoother texture and a creamier mouthfeel (Liu & Wang, 2006; Zaini et al., 2023). Lecithin improves emulsification by facilitating the uniform dispersion of fat droplets throughout the mixture (Pan et al., 2024; Yu et al., 2022), thereby preventing phase separation and enhancing structural stability.

Table 3 Color of ice cream with red dragon fruit powder

Sample	Color			Hardness (g Force)
	L*	a*	b*	
control	87.44±0.35[a]	0.11±0.31[d]	7.69±0.67[a]	216.34±11.03[d]
2% of RDFP	75.32±1.72[b]	17.45±0.99[c]	0.89±0.10[b]	580.99±14.99[c]
4% of RDFP	70.64±0.46[c]	21.74±0.17[b]	-1.91±0.09[c]	621.21±17.00[b]
6% of RDFP	65.75±0.73[d]	25.76±1.84[a]	-2.46±0.18[c]	677.03±17.20[a]

Remark: Values are means ± SD of triplicate samples (n = 3) (dry basis)
Letters within a column with different superscripts mean significantly different ($p < 0.05$)

3. Chemical properties of ice cream with red dragon fruit powder

The incorporation of red dragon fruit powder (RDFP) into ice cream formulations was shown to significantly elevate total phenolic content and antioxidant activity, establishing RDFP as a promising functional ingredient in frozen desserts (Table 4). With increasing concentrations of RDFP, there was a corresponding rise in phenolic content, which can be attributed to bioactive compounds, notably anthocyanins, betacyanins, flavonoids, and phenolic acids (Paśko et al., 2021; Saenjum, Pattananandecha et al., 2021; Salam et al., 2022). The bioactive compounds are known for their antioxidant inherent in red dragon fruit. These compounds, recognized for their antioxidant potential, contribute substantially to the ice cream's free radical scavenging capacity. This observation aligns with prior studies demonstrating that higher concentrations of red dragon fruit powder correlate with increased phenolic content (Velasco et al., 2012). Similarly, the incorporation of red dragon fruit peel powder into food products, such as biscuits, was shown to notably increase total phenolic content based on concentration (Hong Quan et al., 2024). Moreover, existing literature indicates that red dragon fruit extracts, particularly from the peel, possess higher polyphenol and flavonoid levels than the flesh, suggesting that elevated RDFP concentrations enhance bioactive compound levels (Kim et al., 2011).

The strong association between the phenolic content and antioxidant activity of red dragon fruit is further supported by studies showing that higher phenolic concentrations obtained through various extraction methods are key to increased antioxidant efficacy (Kim et al., 2011; Nishikito et al., 2023b; Ramli et al., 2014). Notably, red dragon fruit kombucha demonstrated the highest antioxidant activity when red dragon fruit was used as a substrate, reinforcing the link between phenolic content and antioxidant capacity (Agatha et al., 2021). Furthermore, RDFP has been found to retain its antioxidant effects post-digestion, highlighting the bioaccessibility of its phenolic compounds, which is essential for health benefits in functional food applications (Chumroenvidhayakul et al., 2022).

Table 4 Total phenolic and antioxidant activity of ice cream with red dragon fruit powder

Sample	Total phenolic content (Gallic acid mg/g)	DPPH assay	
		%inhibit	Trolox (mg/g)
control	0.60±0.02^{d}	11.46±1.69^{d}	3.97±0.23^{d}
2% of RDFP	2.19±0.03^{c}	21.40±1.56^{c}	5.69±0.27^{c}
4% of RDFP	2.38±0.05^{b}	25.32±0.93^{b}	6.40±0.16^{b}
6% of RDFP	2.48±0.00^{a}	33.08±0.67^{a}	7.80±0.11^{a}

Remark: Values are means ± SD of triplicate samples (n = 3) (dry basis)
Letters within a column with different superscripts mean significantly different ($p < 0.05$)

4. Sensory evaluation of ice cream with red dragon fruit powder

The incorporation of red dragon fruit powder (RDFP) into ice cream formulations positively influenced key sensory attributes, including color, texture, taste, and overall acceptance, underscoring RDFP's potential as an enhancer of product quality (Table 5). With increasing RDFP concentrations, color scores improved significantly, likely due to natural pigments, particularly betacyanins, which impart a vibrant hue (Paśko et al., 2021). Natural red pigments from fruits like dragon fruit, tomatoes, and berries create visually appealing products essential for consumer acceptance (Albuquerque et al., 2021; Castro et al., 2021; Rahmawati et al., 2023). Color plays a pivotal role in consumer purchasing decisions as it is often associated with freshness and quality (Prajapati & Jadeja, 2022). Moreover, consumer preference trends indicate a shift towards natural colorants due to perceived health benefits compared to synthetic alternatives (Luzardo-Ocampo et al., 2021; Zhang et al., 2024).

Beyond visual appeal, RDFP also enhances mouthfeel and creaminess due to its fiber and polysaccharide content. Red dragon fruit's dietary fiber binds free water within the ice cream matrix, increasing viscosity and yielding a smoother texture (Syed et al., 2018). A higher fiber content correlates with a creamier texture and improved mouthfeel, attributed to the increased consistency coefficient. Additionally, polysaccharides in RDFP contribute to structural stability by preventing ice crystal formation, which further enhances creaminess (Wichamanee et al., 2016). The optimal formulation with red dragon fruit not only enhances creaminess but also adds a unique flavor profile, making the ice cream more attractive (Yunianti et al., 2024). This finding aligns with previous research on fruit-enriched dairy products, which demonstrated that the addition of fruits significantly improves flavor, mouthfeel, and overall consumer satisfaction (Rezvani & Goli, 2024; Sakr et al., 2023). Similarly, the incorporation of natural colorants into food products, particularly bakery items, has been shown to improve sensory attributes and increase consumer acceptance, as supported by sensory evaluation studies (Jridi et al., 2024). These natural colorants are particularly valued for their health-promoting properties, such as antioxidant and anti-inflammatory effects, which make them appealing as functional ingredients in nutraceutical foods and beverages (Thakur & Modi, 2024). However, ice cream containing a medium concentration (4%) of fruit powder received lower consumer acceptance compared to formulations with high (6%) and low (2%) concentrations, primarily due to its sensory attributes. The addition of fruit powder influences color, texture, and flavor; however, at moderate levels, these enhancements may be insufficient to significantly improve sensory quality, leading to reduced appeal. In contrast, higher concentrations can intensify flavor and enhance visual appeal, while lower concentrations may preserve a more traditional taste profile, resulting in varied consumer preferences (Hasan et al., 2020).

Furthermore, the antioxidant properties of RDFP contribute to the chemical stability of the ice cream and offer potential health benefits. These bioactive compounds not only enhance nutritional value but also influence sensory characteristics such as flavor and aftertaste, which are critical to consumer acceptance. Previous studies have demonstrated that natural antioxidants play a key role in improving sensory quality by enhancing taste and aroma (Chakraborty, 2016; Saucedo-Pompa et al., 2018).

Table 5 Sensory evaluation score of ice cream with red dragon fruit powder

Sample	color	odorns	texture	taste	overall acceptance
control	6.32±1.15^{c}	7.08±1.25	6.88±0.77^{b}	6.52±1.05^{b}	6.98±1.13^{b}
2% of RDFP	6.60±1.32^{bc}	6.94±1.09	6.92±1.08^{b}	7.22±1.20^{a}	7.42±0.99^{a}
4% of RDFP	6.94±1.07^{ab}	6.74±1.00	6.96±1.00^{b}	7.18±1.11^{a}	7.26±1.07^{ab}
6% of RDFP	7.32±1.05^{a}	6.90±1.24	7.36±1.06^{a}	7.38±1.06^{a}	7.62±1.14^{a}

Remark: Values are means ± SD of triplicate samples (n = 3) (dry basis)
Letters within a column with different superscripts mean significantly different ($p < 0.05$)
ns = non-significant

Conclusion

The addition of red dragon fruit powder (RDFP) significantly enhanced the nutritional and sensory qualities of ice cream, establishing its potential as a functional ingredient. Higher RDFP concentrations increased phenolic content, antioxidant activity, and red color intensity, while also improving texture. Sensory evaluations identified 6% RDFP as the most accepted formulation, praised for its vibrant color, creamy texture, and balanced flavor. These results highlight RDFP's potential to create healthier, visually appealing frozen desserts, supporting its use in functional ice cream development. Future studies could focus on optimizing formulations and exploring long-term stability.

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