International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating: 5.29
IJABR 2025; 9(7): 1014-1023
www.biochemjournal.com
Received: 09-04-2025
Accepted: 13-05-2025

AD Chavan
Ph.D. Scholar Department of AHDS, P.G.I., Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Dr. AT Lokhande
Assistant Professor, Department of AHDS, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Dr. DK Kamble
Head Department of AHDS, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Amit Kadam
Ph.D. Scholar Department of AHDS P.G.I., Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Corresponding Author:
AD Chavan
Ph.D. Scholar Department of AHDS, P.G.I., Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Incorporating dragon fruit in dairy: Benefits, challenges, and future prospects in product development

AD Chavan, AT Lokhande, DK Kamble and Amit Kadam

DOI: https://www.doi.org/10.33545/26174693.2025.v9.i7m.4873

Abstract
Dragon fruit, known for its vibrant color and rich nutritional profile, has gained attention as a potential ingredient in dairy products. This review explores the various benefits of incorporating dragon fruit into dairy products, focusing on its antioxidant, antibacterial, and sensory-enhancing properties. Dragon fruit is rich in bioactive compounds, including antioxidants, vitamins, and anthocyanins, which can improve the nutritional quality of dairy items, offering health benefits such as increased antioxidant activity and enhanced immunity. The fruit's natural colorants and flavor compounds also contribute to the aesthetic appeal and unique taste of dairy products, enhancing consumer acceptance. Additionally, dragon fruit has been shown to improve the texture, reduce syneresis, and maintain stability during storage. Despite its potential, several challenges, such as the fruit's perishability, seasonal availability, and impact on physicochemical properties like pH and texture, must be addressed for consistent use in dairy products. Future research directions include exploring sustainable processing techniques, optimizing storage conditions, and developing novel dairy formulations with dragon fruit. The incorporation of dragon fruit into dairy products not only provides functional and sensory benefits but also supports the trend of cleaner, more sustainable food products.

Keywords: Dragon fruit, dairy products, antioxidants, shelf life, sensory properties

1. Introduction
Innovation in dairy products is essential for meeting evolving consumer preferences and driving market growth. It enhances the nutritional profile of products, diversifies offerings, improves shelf life, promotes sustainability, and reduces waste. The integration of fruits into dairy products has emerged as a significant trend in the development of functional foods, offering both nutritional and sensory enhancements. Dairy products, such as yogurts, cheeses, and ice creams, are enriched with fruits to improve their taste, color, aroma, and nutritional profile, including increased fiber, vitamins, and antioxidants (Salehi, 2021; Voşgan *et al*., 2016) [77, 62]. The addition of fruits not only enhances the sensory attributes but also contributes to the functional properties of dairy products, such as improved texture and stability due to the water-binding and gelling abilities of certain fruits (Salehi, 2021) [62].
Amazonian fruits, for instance, have shown great potential in expanding the nutritional and functional profile of dairy products. These fruits, when incorporated into dairy, improve sensory aspects and support the growth of beneficial microorganisms, thereby increasing consumer acceptance and diversifying the dairy market (Oliveira *et al*., 2024) [43]. Similarly, the inclusion of fruits like persimmon in dairy products has been shown to enhance the bioaccessibility of carotenoids, particularly when combined with whole milk, which aids in the absorption of these beneficial compounds (García-Cayuela *et al*., 2018) [20].
Moreover, the addition of fruits to dairy products can significantly increase the content of bioactive compounds, which are associated with various health benefits, including antioxidant activity and improved gut health (Prestes *et al*., 2021, Santo *et al*., 2011) [49, 17]. This trend aligns with the growing consumer demand for foods that not only satisfy taste preferences but also contribute to health and wellness. As such, the incorporation of fruits into dairy products represents a promising avenue for the development of innovative functional foods that cater to modern dietary needs and preferences. Extensive research has been conducted on incorporating various fruits into dairy products to improve their

nutritional value, enhance sensory appeal, and offer functional health benefits. Fruits such as mango, strawberry, blueberry, and pomegranate have been successfully added to products like yogurt, ice cream, and milk-based beverages. The incorporation of fruits represents a growing area of innovation, aimed at enhancing nutritional value, sensory appeal, and functional health benefits addressing consumer demand for healthier and more diverse dairy offerings. Similarly, dragon fruit, with its vibrant color, rich antioxidants, and beneficial compounds, presents significant potential for enhancing dairy products. This review explores the opportunities and challenges associated with the incorporation of dragon fruit into dairy formulations, highlighting its nutritional impact, processing methods, and market potential.

2. Nutritional and Functional Properties of Dragon Fruit

2.1 Chemical composition of Dragonfruit

Dragon fruit is typically grown in three varieties across various countries. All of these varieties have a leathery texture and slightly leafy skin. The three types include (Fig. 1) *Hylocereus undatus* (red-skinned with white flesh), *Hylocereus costaricensis* (red-skinned with red flesh), and *Hylocereus megalanthus* (yellow-skinned with white flesh) (Hunt, 2006; Hamidah *et al*., 2017) [32, 26].

Dragon fruit is rich in essential minerals, including potassium, phosphorus, sodium, and magnesium, with levels exceeding those found in mangosteen, mango, and pineapple. (Gunasena *et al*., 2007; Stintzing *et al*., 2003; To *et al*., 1999) [23, 68, 74] and all sources of vitamins (Choo and Yong, 2011). Dragon fruit serves as an excellent source of minerals, glucose, fructose, dietary fiber, and vitamins (Rao and Sasanka, 2015) [56].

The fresh dragon fruit comprises 82.5-83.0% moisture, 0.16-0.23% protein, 0.21-0.61% fat, and 0.7-0.9% fiber. Every 100 grams of fresh pulp provides 6.3-8.8 mg of calcium, 30.2-36.1 mg of phosphorus, 0.5-0.61 mg of iron, and 8-9 mg of vitamin C (TFIDRA, 2005) [4]. The red-fleshed variety is particularly abundant in betalains, aligning with the growing commercial demand for antioxidant-rich products and natural food colorants (Perween *et al*., 2018) [47]. The red layer of the fruit is a rich source of vitamins such as B1, B2, B3, C, and various minerals (Le Bellec *et al*., 2006) [37]. Additionally, this fruit exhibits relatively high antioxidant activity when compared to other subtropical fruits (Davis, 2007) [14]. Dragon fruit is abundant in nutrients, including vitamins B1, B2, B3, and C, along with high fiber content and minerals such as calcium, iron, and phosphorus. It contains low levels of carbohydrates and no fats. Additionally, its seeds are composed of 50% essential fatty acids, primarily linoleic acid and linolenic acid (Sonawane, 2017) [67]. The numerous small black seeds in these fruits are rich in high-quality essential fatty acids (Ortiz-Hernandez and Carrillo-Salazar, 2012) [44].

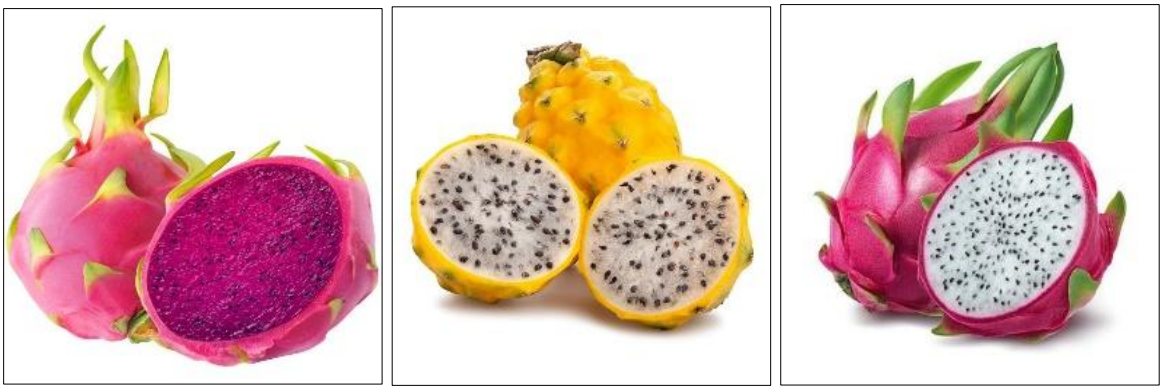

Fig 1: Varieties of Dragon Fruit with Distinct Skin and Flesh Colors

Table 1: Chemical of different varieties of Dragon fruit

Components	*Hylocereus undatus*	*Hylocereus megalanthus*	*Hylocereus costaricensis*
Carbohydrate (g/100 g)	17.02 ± 0.63a	15.76 ± 1.05a	6.61 ± 1.03a
Protein (g/100 g)	0.22 ± 0.02b	0.35 ± 0.04a	0.40 ± 0.02a
Fat (g/100 g)	0.09 ± 0.01a	0.06 ± 0.01a	0.07 ± 0.02a
Moisture (%)	82.00 ± 0.58b	83.00 ± 1.15b	91.33 ± 0.88a
Crude fiber (g/100 g)	0.07 ± 0.01b	0.13 ± 0.02ab	0.32 ± 0.07a
Ash (g/100 g)	0.60 ± 0.06b	0.70 ± 0.12b	1.27 ± 0.09a
Energy (Kcal/100 g)	69.74 ± 2.44a	64.97 ± 4.25a	28.68 ± 4.07b

Yasmin *et al*., (2024) [83]

2.2 Bioactive components in dragon fruit

Dragon fruit is a rich source of numerous bioactive compounds, contributing to its extensive health benefits. The antioxidant profile of dragon fruit is primarily attributed to its phenolic compounds, flavonoids, and anthocyanins. The total phenolic content varies significantly among species, with *Hylocereus polyrhizus* exhibiting the highest phenolic and antioxidant potential (Chen *et al*., 2024; Arivalagan *et al*., 2021) [8, 4]. These phenolic compounds act as free radical scavengers, reducing oxidative stress associated with chronic diseases (Rathi *et al*., 2023) [58].

- **Anthocyanins:** Present in the peel and pulp, these compounds, including cyanidin 3-glucoside, delphinidin 3-glucoside, and pelargonidin 3-glucoside, provide vibrant coloration and potent antioxidant activity (Saenjum *et al*., 2021; Huang *et al*., 2021) [60, 31].
- **Betacyanins:** These pigments are abundant in red-fleshed varieties and exhibit chemopreventive

properties, making them valuable for functional food applications (Paśko *et al*., 2021; Joshi & Prabhakar, 2020) [45, 35].

- **Fatty Acids:** The seeds contain 50% essential fatty acids, such as linoleic acid and linolenic acid, which contribute to cardiovascular health (Sonawane, 2017; Ortiz-Hernandez and Carrillo-Salazar, 2012) [44].
- **Flavonoids and Tannins:** Flavonoids like kaempferol, quercetin, and isoflavones are present across the fruit, offering antioxidative and anti-inflammatory properties. Tannins are found in two forms—hydrolyzable (gallotannins, ellagitannins) and condensed (proanthocyanidins, anthocyanidins) (Crane and Balerdi, 2005) [12].
- **Phytosterols:** Compounds like tyrosol and hydroxytyrosol contribute to lipid metabolism regulation.
- **Other Bioactives:** The seeds also contain epicatechin gallate, epigallocatechin, caffeine, and gallic acid, known for their anti-inflammatory and antioxidative effects (Saenjum *et al*., 2021; Nishikito *et al*., 2023) [60, 42].

The peel of dragon fruit is rich in terpenoids, including limonene, carvone, and lutein, as well as pigments like betacyanin. Additionally, the fruit contains bioactive carotenoids such as β-carotene and lycopene, further enhancing its antioxidant profile (Hossain *et al*., 2021) [30].

2.3 Health benefits of dragon fruit

Dragon fruit offers a range of health benefits due to its rich nutritional and bioactive composition.

- **Probiotic Support:** The pulp of dragon fruit contains polysaccharides and mixed oligosaccharides that promote the growth of beneficial gut bacteria like Lactobacilli and Bifidobacteria, which aid in gut health and inhibit harmful gastrointestinal pathogens (Wichienchot *et al*., 2010; Sonawane, 2017) [80, 67].
- **Antioxidant Properties:** The fruit's high levels of antioxidants, including betacyanins, anthocyanins, and flavonoids, help mitigate oxidative stress, reducing the risk of chronic diseases like cancer and cardiovascular issues (Patel and Ishnava, 2019; Liaotrakoon, 2013) [46, 39].
- **Cardiovascular Health:** Dragon fruit is low in calories, contains no cholesterol, and is rich in essential fatty acids and antioxidants, which help regulate blood pressure and reduce cardiovascular problems (Sonawane, 2017) [67].
- **Immune System Support:** he high vitamin C content strengthens immunity and aids in collagen synthesis, while other micronutrients like iron and magnesium support overall health (TFIDRA, 2005) [4].
- **Anti-inflammatory Effects:** Bioactive compounds like gallic acid, epicatechin gallate, and quercetin exhibit anti-inflammatory properties, helping reduce inflammation and related conditions (Nishikito *et al*., 2023) [42].
- **Cancer Prevention:** Betacyanins and flavonoids in the fruit have chemopreventive properties and can induce cytotoxic effects on cancer cells without harming normal cells thus reducing the risk of certain cancers (Joshi & Prabhakar, 2020; Paśko *et al*., 2021) [35, 45]. This selective toxicity is vital for developing safer cancer prevention strategies.
- **Improved Gut health:** Dragon fruit has been linked to improved gut microbiota, promoting the growth of beneficial bacteria that produce short-chain fatty acids (SCFAs), further enhancing digestive health (Chumroenvidhayakul, 2022) [11]. Its bioactive compounds also contribute to gut barrier integrity, reducing the risk of gastrointestinal disorders (Chumroenvidhayakul, 2022) [11].
- **Improve Eye Health:** Dragon fruit is a source of carotenoids, which are known to support eye health by reducing the risk of age-related macular degeneration (Joshi & Prabhakar, 2020, Chatterjee *et al*., 2024) [35, 6].
- **Weight Management:** Being low in calories and fat-free, dragon fruit can reduce body fat and improve lipid profiles, making it beneficial for obesity management (Ho *et al*., 2024) [29].

Dragon fruit, with its diverse bioactive components and health benefits, aligns with the consumer demand for functional foods, making it an excellent choice for innovative food product development.

3. Applications in Dairy Products

Dragon fruit has proven to be a versatile ingredient in various dairy products, enhancing both sensory attributes and nutritional profiles. For ice cream, the optimal level of dragon fruit oligosaccharide ranges from 4.00 g/100g, combined with stabilizers (0.20-0.46 g/100g or 0.54-0.80 g/100g) and sucrose (8.00-12.00 g/100g), to achieve the best sensory quality (Wichamanee *et al*., 2016)B [79]. Additionally, the incorporation of 6% red dragon fruit peel significantly improves the physical properties and sensory acceptance of kulfi, contributing positively to its texture and color (Waladi *et al*., 2015) [78]. In ice cream formulations, a combination of 80-100 parts dragon fruit, 100-120 parts yogurt, and 60-80 parts milk, along with sweeteners like rock candy and honey, enhances both flavor and nutrition (Zhang and Lin, 2014) [86].

For yogurt, the optimal level of dragon fruit puree has been identified as 31.42 g, significantly improving viscosity and acidity levels (Yankey *et al*., 2023) [82]. Furthermore, a fortification level of 20% red dragon fruit peel extract enhances viscosity and total acidity, while reducing pH and syneresis (Pradana *et al*., 2023) [48]. A 20% concentration of dragon fruit juice has been found to maximize vitamin C content and antioxidant properties in yogurt (Afwan *et al*., 2016) [1], while the best sensory properties are achieved with a 10% red dragon fruit juice addition (Produksi *et al*., 2023) [50].

In dragon fruit milk beverages, formulations typically include 15-20 parts of dragon fruit juice combined with 10 parts of milk to ensure a balance of flavor and nutrition (Yinsheng & Zhenlong, 2012) [84]. Additionally, the incorporation of red dragon fruit into cheese spreads has received positive feedback, with studies indicating that a concentration of around 40% yields the best sensory properties, including taste and texture (Umar *et al*., 2019) [76]. Lastly, (Yunianti *et al*., 2024) [85] found that adding 35% red dragon fruit skin to dadiah gelato results in the best quality, enhancing color, aroma, and taste.

4. Techniques for Incorporating Dragon Fruit into Dairy Products

4.1 Methods for Obtaining Dragon Fruit Puree

4.1.1 Thermal Processing (TP) and High-Pressure Processing (HPP)

- **Process:** This method involves heating the dragon fruit puree at 65°C for 20 minutes.
- **Benefits:** It effectively maintains the phenolic content, antioxidant activities, and color stability of the puree (Chen *et al*., 2024) [8].

4.1.2. High-Pressure Processing (HPP):

- **Process:** Involves treating the puree at 350 MPa for 5 minutes.
- **Benefits:** HPP is particularly efficient in suppressing microbial growth and reducing enzyme activities, thus extending the shelf life of the puree beyond 60 days (Chen *et al*., 2024) [8].

4.1.3. Cryoconcentration

- **Process:** This method involves concentrating dragon fruit juice at temperatures between -10 to -35 °C.
- **Benefits:** It preserves vitamins, bioactive compounds, and nutritional ingredients effectively. The process takes about 1.6 hours and results in a high-quality product with a concentration efficiency of 46.6% and minimal vitamin C loss (11.3%) (Chau *et al*., 2023) [7].

4.1.4 Basic Fruit Pulp Preparation

Process: The process includes separating the fruit from the peel, beating the fruit, removing seeds, and adding acid and vitamin C. The mixture is then stirred to prepare the fruit pulp, which can be further processed into a beverage by adding water, heating, and incorporating colloids and sweeteners (Nishikito *et al*., 2023) [42].

4.2 Methods for Obtaining Dragon Fruit Powder

4.2.1 Foam Mat Drying

- **Process:** Foam mat drying involves creating a foam from dragon fruit puree using foaming agents like egg white, followed by drying the foam at controlled temperatures. Ethanol pretreatment and varying air temperatures are used to optimize drying kinetics and moisture diffusivity (Macedo *et al*., 2021, Altay, 2022, Thuy *et al*., 2024) [40, 2, 73].
- **Benefits:** This method is economical and suitable for high-viscosity products. It results in powders with good flowability and low stickiness, maintaining the nutritional and sensory qualities of the fruit (Macedo *et al*., 2021, Altay, 2022, Thuy *et al*., 2024) [40, 2, 73].

4.2.2 Refractance Window Drying (RWD)

- **Process:** RWD uses a thin layer of dragon fruit pulp spread over a heated surface, with water as the heat transfer medium. The process is conducted at a high temperature of 95°C, resulting in a short drying time (Dadhaneeya *et al*., 2023 Gautam *et al*., 2020) [13, 21].
- **Benefits:** RWD preserves the nutritional quality, phenolic content, and antioxidant activity of the fruit. It also results in a better color retention compared to other methods, making it suitable for natural colorant production (Dadhaneeya *et al*., 2023 Gautam *et al*., 2020) [13, 21].

4.2.3 Microwave-Assisted Foam Drying

- **Process:** This method combines microwave energy with foam drying, using different microwave power levels to enhance drying kinetics. Egg white is used as a foaming agent to stabilize the foam (Altay, 2022) [2].
- **Benefits:** It offers rapid drying with improved moisture diffusion and energy efficiency. The resulting powder has excellent flowability and low moisture content, preserving the fruit's color and nutritional properties (Altay, 2022) [2].

4.2.4 Spray Drying

- **Process:** Dragon fruit juice is mixed with drying agents like maltodextrin and whey protein isolate, then atomized into a hot air chamber. The process is conducted at high temperatures to produce fine powder particles (Lee *et al*., 2013, Shofinita *et al*., 2021) [38, 64].
- **Benefits:** Spray drying is effective for producing heat-sensitive powders with high yield and retention of bioactive compounds. It is suitable for large-scale production and results in powders with good storage stability (Lee *et al*., 2013, Shofinita *et al*., 2021) [38, 64].

4.2.5 Drum Drying

- **Process:** Ground dragon fruit peel is spread on a heated drum, where it is dried and scraped off as a powder. The process involves steam pressure and controlled rotation speed (Chia *et al*., 2015) [9].
- **Benefits:** Drum drying enhances the antioxidant and fiber content of the peel, making it a functional ingredient. It is efficient for processing by-products like peels, reducing waste (Chia *et al*., 2015) [9].

4.2.6 Hot Air Oven Drying

- **Process:** Dragon fruit peel or pulp is dried in a hot air oven at temperatures ranging from 50 °C to 70 °C. The drying time and temperature are adjusted to optimize the product's physicochemical properties (Rosidi *et al*., 2021) [59].
- **Benefits:** This method is simple and cost-effective, suitable for small-scale operations. It retains the fiber content and antioxidant activity, although it may result in longer drying times compared to other methods (Rosidi *et al*., 2021) [59].

4.2.7 Freeze-Drying and Spray-Drying

- **Process:** Fresh dragon fruit pulp is freeze-dried or spray-dried after mixing with beta-cyclodextrin (Xu *et al*., 2015) [81].
- **Benefits:** These methods preserve the fruit's flavor and nutrients, resulting in a product with high rehydration ratios and dietary fiber content.

4.3 Methods for Extracting Natural Pigments from Dragon Fruit

4.3.1 Ultrasound-Assisted Extraction (UAE)

- **Process:** This method involves using ultrasound waves to enhance the extraction of phytocompounds from dragon fruit peel. The process parameters include ultrasonic temperature (30-70°C), solvent to solid ratio (10**:**1-30**:**1 mL/g), solvent concentration (30-60%), and ultrasonic treatment time (5-25 min). The optimal conditions were found to be 60°C, a solvent to solid ratio of 25**:**1 mL/g, 60% solvent concentration, and 20

minutes of ultrasonic treatment (Raj *et al*., 2020, Carrera *et al*., 2021) [5, 55]

- **Benefits:** UAE is efficient in extracting high levels of total polyphenolic content, antioxidant activity, and betacyanin content. It allows for precise control over extraction conditions, leading to high yield and quality of pigments (Raj *et al*., 2020, Carrera *et al*., 2021) [5, 55].

4.3.2 Water Extraction

- **Process:** This method uses water as a solvent to extract pigments from dragon fruit peels. The extraction is optimized at 25°C, pH 5, and a duration of 4 hours. The pigment content is analyzed using UV-Vis spectrometry (Sambasevam *et al*., 2020) [63].
- **Benefits:** Water extraction is eco-friendly and cost-effective, making it a sustainable option for extracting natural pigments. It also provides a stable pigment extract that can be used as a natural colorant (Sambasevam *et al*., 2020) [63].

4.3.3 Maceration with Citric Acid

- **Process:** This involves soaking dragon fruit peel in a 10% citric acid solution with varying ratios (1**:**3, 1**:**6, 1**:**9) and maceration times (3 to 4 days). The optimal extraction was achieved with a 1**:**3 ratio and 4 days of maceration (Dewi *et al*., 2020) [15].
- **Benefits:** This method is simple and effective for extracting anthocyanins, providing a high yield and stable pigment suitable for use as a natural dye (Dewi *et al*., 2020) [15].

4.3.4 Microencapsulation

- **Process:** Pigments are extracted and then encapsulated using maltodextrin through spray-drying or freeze-drying techniques. This process helps in preserving the pigments and enhancing their stability ((Hariadi *et al*., 2023, Torres *et al*., 2020) [27, 75].
- **Benefits:** Microencapsulation improves the stability and shelf-life of the pigments, making them suitable for various applications, including food coloring and cosmetics ((Hariadi *et al*., 2023, Torres *et al*., 2020) [27, 75].

4.4 Methods for Extracting Oil from Dragonfruit Seeds

4.4.1 Cold Extraction with Petroleum Ether

- **Process:** This method involves using petroleum ether as a solvent to extract oil from the seeds of white-flesh and red-flesh dragon fruits. The seeds are subjected to a cold extraction process, which helps in preserving the nutritional quality of the oil.
- **Benefits:** The cold extraction process is beneficial as it retains a significant amount of essential fatty acids, such as linoleic acid, oleic acid, and palmitic acid, which are crucial for nutritional purposes. Additionally, the oil extracted contains a high level of tocopherols, particularly α-tocopherol, which contributes to its oxidative stability and nutritional value (Liaotrakoon *et al*., 2013) [39].

5. Impact on Different properties

5.1 Nutritional Enhancements

Incorporation of dragon fruit into dairy-based items provides multiple benefits, such as improving health benefits due to its antioxidant properties and potential immunomodulatory effects (Sulistyarini *et al*., 2024) [69]. Studies show that dragon fruit not only boosts flavor and color but also enriches the overall nutritional content of dairy products like yogurt, ice cream, and soft candies (Tarte *et al*., 2023; Yunianti *et al*., 2024) [85, 71].

5.1.1 Protein and Fat Content

Adding dragon fruit, especially red dragon fruit, to dairy products like goat milk-based soft candy has been shown to significantly increase the organic matter, protein, and fat content, particularly at higher concentrations (40% and 45%) (Sulistyowati *et al*., 2023) [70]. this enhancement improves the nutritional value of the product, making it more beneficial for consumers.

5.1.2 Iron Fortification

Red dragon fruit peel has also been explored for its effect on iron content in dairy products. While it can increase protein levels, its impact on iron levels when fortified with Fe NaFeEDTA remains minimal (Gunawan *et al*., 2021) [24]. This indicates that while dragon fruit improves some aspects of nutrition, additional ingredients or methods may be required to achieve significant iron fortification

5.2 Functional Properties

5.2.1 Antioxidant Activity

Dragon fruit is particularly noted for its antioxidant properties. When incorporated into non-dairy ice cream, it significantly increases radical scavenging activity and the total phenolic content of the product, which suggests that it could offer enhanced health benefits related to oxidative stress reduction and improved immune function (Rahayu *et al*., 2024) [53].

5.2.2 Color and Emulsification

Dragon fruit's vibrant color makes it an excellent natural colorant, improving the visual appeal of dairy products such as ice cream and soft candy. Additionally, it acts as a natural emulsifier, enhancing the texture and consistency of these products (Sulistyowati *et al*., 2023; Rahayu *et al*., 2024) [70, 53].

Dragon fruit is rich in vitamins, antioxidants, and bioactive compounds, which can substantially improve the nutritional profile of dairy products (Tarte *et al*., 2023; Yunianti *et al*., 2024) [85, 71]. Its addition to dairy products enhances functional properties such as antioxidant capacity and potential immunomodulatory effects (Sulistyarini *et al*., 2024) [69]. Studies have demonstrated that dragon fruit can elevate the quality and nutritional value of dairy products, aligning with the required standards for products like yogurt. Jayasinghe *et al*. (2015) [34] reported that dragon fruit-incorporated yogurt met the Sri Lankan yogurt standards for total solids (23.58%), solid-non-fat (SNF) content (9.639%), and fat content (3.2%), ensuring the product adheres to quality guidelines for texture and consistency. This further reinforces the potential of dragon fruit to enhance the nutritional and functional attributes of dairy-based products.

5.3 Sensory and Organoleptic Properties

5.3.1 Taste and Texture: The addition of dragon fruit improves sensory attributes such as taste, aroma, and texture, making products more appealing to consumers. For

instance, soft candy with 30% dragon fruit was preferred for its enhanced sensory qualities (Sulistyowati *et al*., 2023) [70].

5.3.2 Melting Properties: In ice cream, higher concentrations of dragon fruit can alter melting rates, with a notable impact on the product's texture and consumer acceptance (Rahayu *et al*., 2024) [53].

6. Consumer Acceptance and Sensory Evaluation

Dragon fruit's incorporation into products like gelato has shown improvements in sensory attributes, particularly in color and taste, which are preferred by consumers (Yunianti *et al*., 2024) [85]. Hyloceregurt formulations, while well-received in terms of smell, taste, and consistency, may require further refinement to meet microbiological standards (Sulistyarini *et al*., 2024) [69].

Adding red dragon fruit juice to yogurt significantly improves its flavor and overall acceptance. A concentration of 15% red dragon fruit juice was found to be optimal, providing a pleasant taste and liked texture (Putri *et al*., 2019) [51]. Similarly, yogurt with 10% red dragon fruit juice showed the best sensory properties, including aroma, color, and taste (Siregar *et al*., 2023) [50]. The addition of red dragon fruit to ice cream significantly enhances its sensory qualities, such as color, aroma, texture, and taste. A 40% concentration of dragon fruit was found to provide the best sensory properties (Umar *et al*., 2019) [76].

7. Shelf-Life and Storage Stability

Dragon fruit, particularly its juice and colorants, offers promising benefits in extending the shelf life and improving the stability of dairy products. Several studies have highlighted the potential of dragon fruit's antioxidant, antibacterial, and color-preserving properties in enhancing the longevity and quality of dairy-based items.

7.1 Antioxidant and Antibacterial Properties

Dragon fruit juice, when subjected to lacto-fermentation, exhibits significant antibacterial activity against common pathogens like *Escherichia coli* and *Salmonella Typhimurium*. This fermentation process not only maintains the juice's antioxidant properties but also contributes to an extended shelf life of dairy products incorporating it (Muhialdin *et al*., 2020) [41]. The natural antibacterial effects of dragon fruit juice help reduce microbial spoilage, making it a valuable ingredient for improving the shelf life of dairy products.

7.2 Shelf-Life Extension

Fermented dragon fruit juice has been shown to extend the shelf life of fresh juice by up to three months (Muhialdin *et al*., 2020) [41]. This suggests its potential to enhance the longevity of dairy products that include it as an ingredient. By slowing down spoilage, this natural preservation method can be effectively used in dairy items such as yogurt, ice cream, and other dairy-based desserts.

7.3 Impact on Texture and Quality

Dragon fruit's antioxidant and color-preserving properties help maintain the texture and appearance of dairy products. For example, in yogurt, the addition of red pitahaya colorant shows minimal betacyanin loss during refrigerated storage, with lower syneresis compared to plain yogurt. This indicates that dragon fruit not only enhances the sensory qualities of dairy products but also stabilizes their texture during storage (Gengatharan *et al*., 2017) [22]. These properties are key in maintaining product consistency and consumer appeal.

7.4 Storage Conditions

Controlled atmosphere storage has been shown to improve the shelf life of dragon fruit by maintaining its acidity and reducing color degradation. These findings suggest that similar storage techniques could be applied to dairy products containing dragon fruit, enhancing their stability (Ho *et al*., 2021) [28]. Such methods can help prevent quality deterioration, ensuring that dairy products with dragon fruit retain their nutritional and sensory properties over time.

7.5 Processing Methods

High-pressure processing (HPP) of dragon fruit purée is more effective than traditional thermal pasteurization in extending shelf life. HPP suppresses microbial growth while maintaining the antioxidant properties of dragon fruit, which could be particularly beneficial for dairy products incorporating dragon fruit purée (Ismail *et al*., 2024) [33]. This method ensures better retention of quality and a longer shelf life, making it an ideal option for enhancing the stability of dragon fruit-enriched dairy products.

8. Potential Challenges and Limitations

The perishable nature of dragon fruit necessitates careful formulation to ensure year-round availability and stability of dairy products (Sahrwat *et al*., 2023) [61]. Incorporating dragon fruit can potentially improve the shelf-life of dairy products through its antioxidant properties, although specific studies on this aspect are limited (Tarte *et al*., 2023) [85].

8.1 Physicochemical Challenges

8.1.1. Water Content and Texture: Adding dragon fruit peels to milk products like pies can reduce water content, making the product crisper. This change in texture might not be desirable for all milk-based products (Rahmah *et al*., 2022) [54]

8.1.2 PH and Acidity: The addition of dragon fruit skin can affect the pH and acidity levels of milk products. For instance, in yogurt, the pH and acidity levels were not significantly affected by the addition of skim milk, but the viscosity increased (Arifani *et al*., 2023, Hafiizha *et al*., 2020) [3, 25]. In pasteurized milk, dragon fruit skin powder can maintain pH levels for a limited time, but the antioxidant activity decreases with prolonged storage (Faridah *et al*., 2020) [19].

8.2 Nutritional and Sensory Challenges

8.2.1 Nutritional Content: The incorporation of dragon fruit skin can increase the antioxidant and flavonoid content in fermented milk, but it may also decrease carbohydrate and protein content (Dianasari *et al*., 2020) [16]. The calcium content can vary significantly depending on the formulation (Elisanti *et al*., 2024) [18].

8.2.2 Sensory Attributes: The addition of dragon fruit can alter the color, aroma, and taste of milk products. For example, in yogurt, the addition of dragon fruit juice as a sugar substitute resulted in a sour taste and a dark pink

color, which may not be appealing to all consumers (Kalsum *et al*., 2024) [36] Similarly, in ice cream, the addition of dragon fruit peel affected the sensory properties, resulting in a deep red color and a distinct flavor (Simanjuntak *et al*., 2023) [65]. These challenges need to be carefully addressed to optimize the use of dragon fruit in dairy products.

9. Future trends and perspectives

The future of dragon fruit in dairy products holds exciting potential for innovation and sustainability. One promising direction is the integration of bioactive synergy, where the combination of dragon fruit's antioxidants, vitamins, and probiotics could enhance the health benefits of dairy, promoting anti-inflammatory, antioxidant, and gut-health properties. In tandem with this, smart packaging could be developed to extend the shelf life of dairy products by incorporating dragon fruit's natural compounds, such as betacyanins, into packaging materials, reducing the need for preservatives and aligning with the growing demand for sustainable packaging. Additionally, the growing interest in personalized nutrition presents an opportunity to tailor dragon fruit-enriched dairy products to meet specific health needs, such as boosting immunity or aiding digestion, creating functional foods that cater to individual health goals. The trend of plant-based dairy alternatives could also be explored, where dragon fruit is combined with plant-based milks to enhance the nutritional profile, offering a creamy, antioxidant-rich alternative for those avoiding animal-based dairy. Another future possibility is the development of zero-waste dairy products, where both the flesh and peels of dragon fruit are utilized, turning the fruit's by-products into a valuable source of natural fiber and prebiotics, thus reducing waste and adding nutritional value. As consumer demand for fermented foods rises, dragon fruit could find its place in fermented dairy beverages, like kefir and lassi, combining its flavor and health benefits with probiotics. Moreover, the integration of AI and machine learning into product development could revolutionize how dragon fruit and dairy interact at the molecular level, enabling the creation of optimized products that match evolving consumer preferences. Lastly, dragon fruit's potential as a natural gelling agent in products like yogurt and pudding offers a clean-label, plant-based alternative to artificial thickeners, further enhancing the appeal of dragon fruit-infused dairy. These trends point to a future where dragon fruit not only enriches the sensory and nutritional profiles of dairy but also supports sustainability and innovation in the food industry.

10. Conclusion

Incorporating dragon fruit into dairy products presents a promising frontier for both nutritional and functional enhancements. The fruit's rich profile of antioxidants, vitamins, and bioactive compounds, such as betacyanins, has the potential to significantly improve the health benefits of dairy products, contributing to better antioxidant activity, enhanced immunity, and overall health. Dragon fruit also offers unique sensory attributes, including vibrant color and distinct flavor, which can positively influence consumer preference, especially in products like yogurt, ice cream, and beverages. Furthermore, its incorporation into dairy products can improve texture, reduce syneresis, and maintain product stability during storage, thanks to its natural preservatives and fermentation potential.

However, the successful integration of dragon fruit into dairy products does not come without challenges. The perishable nature of the fruit, along with seasonality and microbiological safety concerns, presents hurdles for its consistent year-round use. Additionally, physicochemical changes such as alterations in pH, acidity, and texture can affect the final product's quality and consumer acceptance. Despite these challenges, continued research and development in processing methods, storage conditions, and product formulations hold the key to overcoming these obstacles.

Looking ahead, future research could explore innovative applications, such as the use of dragon fruit as a natural colorant and emulsifier, its role in personalized nutrition, and its potential in plant-based dairy alternatives. The sustainability aspect also stands out, with opportunities to minimize waste by utilizing dragon fruit's peels and other by-products. With ongoing advancements, dragon fruit is poised to become a staple in the dairy industry, offering consumers a healthier, more sustainable alternative while diversifying the range of dairy products available on the market.

11. References

1. Afwan MS. Karakteristik yoghurt tersubstitusi sari buah naga (*Hylocereus polyrhizus*) dengan jenis dan konsentrasi starter yang berbeda-beda Bandung (ID)**:** Universitas Pasundan; 2016.
2. Altay K. Investigation of drying kinetics and powder product properties of dragon fruit powders dried by microwave assisted foam drying method [2022.
3. Arifani D, Zulaikhah SR, Luthfi SC. Sifat fisikokimia yoghurt buah naga merah (*Hylocereus polyrhizus* L.) dengan penambahan berbagai level susu skim. J Ilmu Teknol Peternak. 2023;11(1)**:**1-5.
4. Arivalagan M, Karunakaran G, Roy TK, Dinsha M, Sindhu BC, Shilpashree VM, *et al*. Biochemical and nutritional characterization of dragon fruit (*Hylocereus* species). Food Chem. 2021;353**:**129426.
5. Carrera C, Pastol J, Setyaningsih W, Ruiz-Rodríguez A, Ferreiro-González M, Fernández Barbero G, *et al*. Optimization by means of chemometric tools of an ultrasound-assisted method for the extraction of betacyanins from red dragon fruit (*Hylocereus polyrhizus*). Agronomy. 2021;11(6)**:**1053.
6. Chatterjee D, Mansuri S, Poonia N, Kesharwani P, Lather V, Pandita D. Therapeutic potential of various functional components present within dragon fruit**:** A review. Hybrid Adv. 2024;100185.
7. Chau TT, Do TKL, Nguyen TD. Designing and manufacturing the cryoconcentration equipment (cold concentrator) and apply it to concentrate a high-quality product from dragon (*Hylocereus*) fruit juice. J Tech Educ Sci. 2023;18(6)**:**43-54.
8. Chen SY, Islam MA, Johnson JB, Xu CY, Mazhar MS, Naiker M. Comparative analysis of shelf-life, antioxidant activity, and phytochemical contents of Australian-grown and imported dragon fruit under ambient conditions. Horticulturae. 2024;10(10)**:**1048.
9. Chia SL, Chong GH. Effect of drum drying on physico-chemical characteristics of dragon fruit peel (*Hylocereus polyrhizus*). Int J Food Eng. 2015;11(2)**:**285-293.

10. Choo WS, Yong WK. Antioxidant properties of two species of *Hylocereus* fruits. Adv Appl Sci Res. 2011;2(3)**:**418-425.
11. Chumroenvidhayakul S, Thilavech T, Abeywardena M, Adisakwattana S. Investigating the impact of dragon fruit peel waste on starch digestibility, pasting, and thermal properties of flours used in Asia. Foods. 2022;11(14)**:**2031.
12. Crane JH, Balerdi CF. Pitaya (dragon fruit) growing in the Florida home landscape. Hortic Sci Dep UF/IFAS Ext. 2005;(HS1068)**:**1-8.
13. Dadhaneeya H, Kesavan RK, Inbaraj BS, Sharma M, Kamma S, Nayak PK, *et al*. Impact of different drying methods on the phenolic composition, *in vitro* antioxidant activity, and quality attributes of dragon fruit slices and pulp. Foods. 2023;12(7)**:**1387.
14. Davis A. Pitahaya (dragon fruit) research and production in California. UC Small Farm Program, 2007 Specialty Crops Conference; 2007. p. 1-6.
15. Dewi NPBT, Singapurwa NMAS, Mangku IGP. Extraction and stability of natural dyes from the skin of red dragon fruit. SEAS. 2020;4(2)**:**130-141.
16. Dianasari U, Malaka R, Maruddin F. Physicochemical quality of fermented milk with additional red dragon fruit (*Hylocereus polyrhizus*) skin. IOP Conf Ser Earth Environ Sci. 2020;492(1)**:**012050.
17. do Espirito Santo AP, Perego P, Converti A, Oliveira MN. Influence of food matrices on probiotic viability-A review focusing on the fruity bases. Trends Food Sci Technol. 2011;22(7)**:**377-385.
18. Elisanti AD, Suryanegara MA, Ardianto ET, Rindiani R. Effects of dragon fruits and *Moringa oleifera* extracts, mineral mix variations on soft milk candy. IOP Conf Ser Earth Environ Sci. 2024;1338(1)**:**012050.
19. Faridah R, Mangalisu A, Maruddin F. Antioxidant effectiveness and pH value of red dragon fruit skin powder (*Hylocereus polyrhizus*) on pasteurized milk with different storage times. IOP Conf Ser Earth Environ Sci. 2020;492(1)**:**012051.
20. García-Cayuela T, Nuño-Escobar B, Welti-Chanes J, Cano MP. *In vitro* bioaccessibility of individual carotenoids from persimmon (*Diospyros kaki*, cv. Rojo Brillante) used as an ingredient in a model dairy food. J Sci Food Agric. 2018;98(9)**:**3246-3254.
21. Gautam A, Abdul S. Comparative study of different drying techniques of dragon fruit peel. J Pharmacogn Phytochem. 2020;9(4S)**:**280-3.
22. Gengatharan A, Dykes GA, Choo WS. The effect of pH treatment and refrigerated storage on natural colourant preparations (betacyanins) from red pitahaya and their potential application in yoghurt. LWT. 2017;80**:**437-445.
23. Gunasena HP, Pushpakumara DKNG, Kariawasam M. Underutilized fruit trees in Sri Lanka**:** Dragon fruit *Hylocereus undatus* (Haw.) Britton and Rose. New Delhi (IN)**:** World Agroforestry Centre ICRAF; 2007. p. 110-141.
24. Gunawan DCD, Dewi DP, Astriana K. Fortifikasi Fe minuman susu fermentasi kulit buah naga merah (*Hylocereus polyrhizus*) ditinjau dari kadar protein dan Fe. Pros Semin Nas Multidisiplin Ilmu. 2020;2(1)**:**20-7.
25. Hafiizha A, Kayaputri IL, Tensiska T, Amalia NR. The effect of skim milk concentration on sensory quality and pH of probiotic yoghurt added with red dragon fruit (*Hylocereus polyrhizus*). J Ilmu Teknol Hasil Ternak. 2020;15(1)**:**52-60.
26. Hamidah H, Tsawab, Rosmanida. Analysis of *Hylocereus* spp. diversity based on phenetic method. AIP Conf Proc. 2017;1854**:**020012.
27. Hariadi H, Nissa RC, Anggara CEW, Ferdiansyah AE, Rifqi M. Utilization of dragon fruit (*Hylocereus polyrhizus*) peels waste as a natural dye. IOP Conf Ser Earth Environ Sci. 2023;1241(1)**:**012075.
28. Ho PL, Tran DT, Hertog ML, Nicolaï BM. Effect of controlled atmosphere storage on the quality attributes and volatile organic compounds profile of dragon fruit (*Hylocereus undatus*). Postharvest Biol Technol. 2021;173**:**111406.
29. Ho PY, Lin PX, Koh YC, Lin WS, Tang KL, Chen YH, *et al*. Exploring the effects of whole food-based dragon fruit on metabolic disorders in high-fat diet-induced mice. Mol Nutr Food Res. 2024;68(21)**:**2400604.
30. Hossain FM, Numan SMN, Akhtar S. Cultivation, nutritional value, and health benefits of dragon fruit (*Hylocereus* spp.)**:** A review. Int J Hortic Sci Technol. 2021;8(3)**:**259-256
31. Huang Y, Brennan MA, Kasapis S, Richardson SJ, Brennan CS. Maturation process, nutritional profile, bioactivities and utilisation in food products of red pitaya fruits**:** A review. Foods. 2021;10(11)**:**2862.
32. Hunt DR. The new cactus lexicon illustrations. Vol. I & II. Milborne Port (UK)**:** DH Books; 2006. 925 p.
33. Ismail NHS, Nawawi NIM, Ijod G, Anzian A, Ismail-Fitry MA, Ahmad NH, *et al*. Shelf life and quality assessment of pasteurised red dragon fruit (*Hylocereus polyrhizus* L.) purée**:** Comparative study of high-pressure and thermal processing. Int Food Res J. 2024;31(2)**:**298-308.
34. Jayasinghe O, Fernando S, Jayamanne V, Hettiarachchi D. Production of a novel fruit-yoghurt using dragon fruit (*Hylocereus undatus* L.).
35. Joshi M, Prabhakar B. Phytoconstituents and pharmaco-therapeutic benefits of pitaya**:** A wonder fruit. J Food Biochem. 2020;44(7)**:**e13260.
36. Kalsum N, Verdini L, Oktaviani FS, Harefa NSF. Black soybean tempeh ice cream (*Glycine max* var. Mallika) rich in antioxidants to increase endurance. Glob Int J Innov Res. 2024;2(4)**:**733-746.
37. Le Bellec F, Vaillant F, Imbert E. Pitahaya (*Hylocereus* spp.)**:** A new fruit crop, a market with a future. Fruits. 2006;61(4)**:**237-250.
38. Lee KH, Wu TY, Siow LF. Spray drying of red (*Hylocereus polyrhizus*) and white (*Hylocereus undatus*) dragon fruit juices**:** Physicochemical and antioxidant properties of the powder. Int J Food Sci Technol. 2013;48(11)**:**2391-2399.
39. Liaotrakoon W, De Clercq N, Van Hoed V, Dewettinck K. Dragon fruit (*Hylocereus* spp.) seed oils**:** Their characterization and stability under storage conditions. J Am Oil Chem Soc. 2013;90(2)**:**207-15.
40. Macedo LL, Corrêa JLG, Araújo CDS, Vimercati WC, Pio LAS. Process optimization and ethanol use for obtaining white and red dragon fruit powder by foam mat drying. J Food Sci. 2021;86(2)**:**426-433.
41. Muhialdin BJ, Kadum H, Zarei M, Hussin ASM. Effects of metabolite changes during lacto-fermentation on the biological activity and consumer acceptability for dragon fruit juice. LWT. 2020;121**:**108992.

42. Nishikito DF, Borges ACA, Laurindo LF, Otoboni AMB, Direito R, Goulart RDA, *et al*. Anti-inflammatory, antioxidant, and other health effects of dragon fruit and potential delivery systems for its bioactive compounds. Pharmaceutics. 2023;15(1)**:**159.
43. Oliveira BCR, Martins CPC, Soutelino MEM, Rocha RS, Cruz AG, Márs ico ET, *et al*. An overview of the potential of select edible Amazonian fruits and their applications in dairy products. Crit Rev Food Sci Nutr. 2024;1-15.
44. Ortiz-Hernández YD, Carrillo-Salazar JA, Livera-Muñoz M. Carbon exchange rate of pitahaya (*Hylocereus undatus* L. Harwort) in contrasting seasons and irrigation regimes. Isr J Plant Sci. 2012;60(3)**:**385-392.
45. Paśko P, Galanty A, Zagrodzki P, Luksirikul P, Barasch D, Nemirovski A, *et al*. Dragon fruits as a reservoir of natural polyphenolics with chemopreventive properties. Molecules. 2021;26(8)**:**2158.
46. Patel SK, Ishnava KB. In-vitro antioxidant and antimicrobial activity of fruit pulp and peel of *Hylocereus undatus* (Haworth) Britton and Rose. Asian J Ethnopharmacol Med Foods. 2019;5(2)**:**30-34.
47. Perween T, Mandal KK, Hasan MA. Dragon fruit**:** An exotic super future fruit of India. J Pharmacogn Phytochem. 2018;7(2)**:**1022-1026.
48. Pradana DW, Manab A, Sawitri ME. Antibacterial activity of synbiotic yoghurt peel extract of red dragon fruit (*Hylocereus polyrhizus*) evaporation with honey. Asian Food Sci J. 2023;22(2)**:**1-8.
49. Prestes AA, Vargas MO, Helm CV, Esmerino EA, Silva R, Prudencio ES. How to improve the functionality, nutritional value and health properties of fermented milks added of fruits bioactive compounds**:** A review. Food Sci Technol. 2021;42**:**e17721.
50. Siregar SF, Apriantini A, Soenarno MS. Physicochemical properties, antioxidant activity and organoleptic of yogurt with the addition of red dragon fruit juice (*Hylocereus polyrhizus*). J Ilmu Produksi Teknol Hasil Peternak. 2023;11(3)**:**141-152.
51. Putri DCLA, Putra INK, Suparthana IP. Pengaruh penambahan sari buah naga merah (*Hylocereus polyrhizus*) terhadap karakteristik yoghurt campuran susu sapi dan kacang merah (*Phaseolus vulgaris*). J Ilmu Teknol Pangan (ITEPA). 2019;8(1)**:**8-17.
52. Qalbi R, Giovani S, Guo Q, Adelina NM. Effect of drying time on physicochemical characteristics of dragon fruit peels powder (*Hylocereus polyrhizus*). J Agri-Food Sci Technol. 2023;4(2)**:**81-96.
53. Rahayu WM, Mustaqim L, Khairi AN, Permadi A, Hidayah N. Characteristics of ice cream from black soybean sprout juice-red dragon fruit with yolk emulsifier. J Halal Sci Res. 2024;5(2)**:**123-133.
54. Rahmah L, Ansori ANM, Choiriyah NA, Iskandar HT, Hadiwirawan GY, Rebezov M, *et al*. Substitution of dragon fruit peels on vitamin C, water content, and fiber in milk pie to improve human health. Res J Pharm Technol. 2022;15(8)**:**3690-3696.
55. Raj GB, Dash KK. Ultrasound-assisted extraction of phytocompounds from dragon fruit peel**:** Optimization, kinetics and thermodynamic studies. Ultrason Sonochem. 2020;68**:**105180.
56. Rao CC, Sasanka VM. Dragon fruit 'The Wondrous Fruit' for the 21st century. Glob J Res Anal. 2015;4(10)**:**261-262.
57. Rao KV, Sowmya G, Ramesh L, Mallikarjun M, Srivani P, Chandana V, *et al*. Preliminary phytochemical screening and thin layer chromatography of dragon fruit flesh, peel and spines.
58. Rathi KM, Singh SL, Gigi GG, Shekade SV. Nutrition and therapeutic potential of the dragon fruit**:** A qualitative approach. Pharmacogn Res. 2023;16(1)**:**1-6.
59. Rosidi NAS, Ghani AA, Yusof N, Yusof N. Effect of blanching and drying temperatures on physicochemical properties of red dragon fruit (*Hylocereus polyrhizus*) peel powder. J Agrobiotechnol. 2021;12(1S)**:**62-73.
60. Saenjum C, Pattananandecha T, Nakagawa K. Antioxidative and anti-inflammatory phytochemicals and related stable paramagnetic species in different parts of dragon fruit. Molecules. 2021;26(12)**:**3565.
61. Sahrwat R, Topno SE, Bahadur V. Standardisation of recipes for preparation of value-added products from dragon fruit (*Hylocereus undatus*). Int J Environ Clim Change. 2023;13(9)**:**1827-1833.
62. Salehi F. Quality, physicochemical, and textural properties of dairy products containing fruits and vegetables**:** A review. Food Sci Nutr. 2021;9(8)**:**4666-4686.
63. Sambasevam KP, Yunos N, Mohd Rashid HN, Baharin SNA, Suhaimi NF, Raaov M, Shahabuddin S. Evaluation of natural pigment extracted from dragon fruit (*Hylocereus polyrhizus*) peels. Sci Res J. 2020;17(2)**:**34-43.
64. Shofinita D, Bindar Y, Samadhi TW, Choliq NS, Jaelawijaya AA. Increasing the yield of powder and bioactive materials during extraction and spray drying of dragon fruit skin extracts. J Eng Technol Sci. 2021;53(6)**:**412-425.
65. Simanjuntak V, Ayu DF, Rossi E. Karakteristik fisik, kimia dan organoleptik kombinasi susu kedelai dan ekstrak kulit buah naga merah (*Hylocereus polyrhizus*) dalam pembuatan es krim. J Teknol Pertanian. 2022;11(2)**:**86-98.
66. Siregar SF, Apriantini A, Soenarno MS. Physicochemical properties, antioxidant activity and organoleptic of yogurt with the addition of red dragon fruit juice (*Hylocereus polyrhizus*). J Ilmu Produksi Teknol Hasil Peternakan. 2023;11(3)**:**141-52.
67. Sonawane MS. Nutritive and medicinal value of dragon fruit. Asian J Hortic. 2017;12(2)**:**267-271.
68. Stintzing FC, Schieber A, Carle R. Evaluation of color properties and chemical quality parameters of cactus juices. Eur Food Res Technol. 2003;216**:**303-11.
69. Sulistyarini I, Palupi DHS, Hesti A. Characteristics of Hyloceregurt**:** fermented milk from stems and peel of dragon fruits. J Farmasi Galenika. 2024;10(1)**:**73-83.
70. Sulistyowati E, Ningsih RPA, Trinata YP, Suharyanto S, Soetrisno E. Salad dressing soft candy made of dairy goat milk with the addition of red dragon fruit (*Hylocereus polyrhizus*)**:** Nutritional content, physical and organoleptic properties. E3S Web Conf. 2023;373**:**04004.
71. Tarte I, Singh A, Dar AH, Sharma A, Altaf A, Sharma P. Unfolding the potential of dragon fruit (*Hylocereus* spp.) for value addition**:** A review. eFood. 2023;4(2)**:**e76.

72. TFIDRA (Taiwan Food Industry Development and Research Authorities). Health benefits of dragon fruit. 2005.
73. Thuy NM, Le Huynh Nhu TNG, Van Hao H, Van Thanh N, Van Tai N. Optimizing the foam-mat drying of red dragon fruit**:** Effect of drying temperatures and foaming agents.
74. To LV, Ngu N, Duc ND, Trinh DTK, Thanh NC, Mien DVH, *et al*. Quality assurance system for dragon fruit. ACIAR Proc. No. 100; 1999. (Ho Chi Minh City, Vietnam;
75. Torres RC, Yumang RMG, Jose CKF, Canillo DCP. Physicochemical properties and stability of microencapsulated betacyanin pigments from red dragon fruit peels and flesh. Open J Pharm Sci Res. 2020;2**:**141-148.
76. Umar R, Siswosubroto SE, Tinangon MR, Yelnetty A. Kualitas sensoris es krim yang ditambahkan buah naga merah (*Hylocereus polyrhizus*). Zootec. 2019;39(2)**:**284-292.
77. Voşgan Z, Dumuța A, Mihali C, Mihalescu L, Dippong T, Moldovan A. The influence of the fruits addition on the quality characteristics of yogurt. Sci Pap Anim Sci Biotechnol. 2016;49(2)**:**86-96.
78. Waladi W, Johan VS, Hamzah F. Utilization of red dragon fruit peel (*Hylocereus polyrhizus*) as an additive in the making of ice cream. Jom Faperta. 2015;2(1)**:**12-18.
79. Wichamanee Y, Acharaphan M, Santad W. Effect of dragon fruit oligosaccharide, stabilizer and sucrose on physical and sensory quality of ice cream. Int Food Res J. 2016;23(1)**:**126-135.
80. Wichienchot S, Jatupornpipat M, Rastall RA. Oligosaccharides of pitaya (dragon fruit) flesh and their prebiotic properties. Food Chem. 2010;120(3):850-857.
81. Xu L, Zhang L, Shen J, Cao J. Red-core dragon fruit *all-fruit powder* and preparation method thereof. Chinese patent CN 103549315 B. 4 Nov 2015.
82. Yankey S, Mensah EO, Ankar-Brewoo GM, Ellis WO. Optimized fermentation conditions for dragon fruit yogurt. Food Humanity. 2023;1**:**343-348.
83. Yasmin A, Sumi MJ, Akter K, Rabbi RH, Almoallim HS, Ansari MJ, *et al*. Comparative analysis of nutrient composition and antioxidant activity in three dragon fruit cultivars. PeerJ. 2024;12**:**e17719.
84. Yinsheng W, Zhenlong L. Dragon fruit milk beverage and preparation method thereof.
85. Yunianti BM, Faridah A, Holinesti R, Andriani C. The effect of adding red dragon fruit skin on the quality of Dadiah gelato. J Pendidikan Tata Boga Teknologi. 2024;5(2)**:**174-181.
86. Zhang W, Lin H. Dragon fruit ice cream and manufacturing method thereof. Chinese patent CN 104247854 A. Priority date 17 Sep 2014; publication date 31 Dec 2014; granted as CN 104247854 B on 7 Sep 2016.