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Valorisation of dragon fruit peel in drinking yoghurt: Development, physicochemical, proximate, functional properties, and shelf-life evaluation

Maryam Saeed Hafiz[1], Karunanayaka Mudiyanselage Imayuru Ushada Karunanayaka[2], Kartika Nugraheni[3], Ganwarige Sumali Nivanthi Fernando[2]*

[1]*Department of Clinical Nutrition, Faculty of Applied Medical Sciences, King Abdulaziz University, Jeddah, Saudi Arabia*
[2]*Department of Food Science and Technology, Faculty of Agriculture, University of Ruhuna, Matara, Sri Lanka*
[3]*Department of Nutrition, Faculty of Nursing and Health Sciences, Universitas Muhammadiyah Semarang, Indonesia*

**Corresponding author: mshafiz@kau.edu.sa*

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Abstract: Dragon fruit peel (*Hylocereus* spp.), often discarded as waste has gained interest for its anti-aging, anti-inflammatory, and anti-diabetic properties. Peels make up to 22–44% (w·w^{-1}) of the fruit's weight and this waste could make a significant effect on the environment. Therefore, this study aimed to develop a drinking yoghurt using dragon fruit peel extract as a natural colorant and evaluate its physicochemical, proximate, functional, and shelf-life properties. The sugar concentrations (4, 6, and 8% w·w^{-1}) and incubation times (4, 6, and 8 h) were changed to optimise the product. Sensory evaluation by 30 semi-trained panellists using a 5-point hedonic scale identified 6% (w·w^{-1}) sugar and an 8 h incubation as optimal. Compared to plain drinking yoghurt, the dragon fruit peel (DFP) drinking yoghurt showed higher crude fat (2.87%), fibre (0.72%), ash (0.66%), moisture (84.08%), total antioxidants (824.3 mg TE·100 g^{-1}), flavonoids (0.22 mg QE·mL^{-1}), and betalains content (0.0064 mg·mL^{-1}). During storage, DFP yoghurt's pH declined, with minimal betalain loss, and it remained stable for three weeks at 4 °C without preservatives. This study demonstrates the potential of dragon fruit peel as a functional ingredient in yoghurt, offering nutritional and environmental benefits.

Keywords: *Lactobacillus delbrueckii* subsp. *bulgaricus*; *Streptococcus thermophillus*; proximate composition; *Hylocereus undatus* by-product; dairy beverage; bioactive compouds

Dragon fruit (pitaya), belonging to the family Cactaceae, is a globally cultivated and consumed fruit crop (Jayasinghe et al. 2015). It is grown in over 20 tropical and subtropical countries, including Indonesia, Colombia, Israel, Malaysia, Mexico, Sri Lanka, Southern China, and Southern Florida (Luu et al. 2021). The most popular varieties of dragon fruit are red pitaya (*Hylocereus polyrhizus*), with red peel and flesh, white pitaya (*Hylocereus undatus*), with red peel and white flesh, and yellow pitaya (*Hylocereus megalanthus*), which has yellow peel and white flesh (Luo et al. 2014). Dragon fruit flesh is commonly consumed either raw or processed into juice, leaving the peel as the primary by-product. Dragon fruit peels constitute 22–44%

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of the fruit's weight, and improper disposal could significantly impact the environment (Le 2022).

Dragon fruit peel is rich in pectin and dietary fibre, and its red colour is due to the compound betalains (Hernawati et al. 2018). Valorising the peel, which contains many bioactive compounds beneficial for human health, can partially reduce environmental burden by utilising a portion of this waste in the development of natural food colorants and functional foods. Betalains, the prominent bioactive compounds in dragon fruit flesh and peel, include two major groups: betacyanins and betaxanthins, which provide red and yellow colours, respectively (Thaiudom et al. 2021). The red colour of dragon fruit peels is mainly due to the presence of different types of betacyanins (Thaiudom et al. 2021). When extracted, the average betacyanin content of the peel was 0.39435 mg·100 g^{-1} using water and 0.53545 mg·100 g^{-1} using methanol (Priatni and Pradita 2015).

Temperature, pH, and solvent type affect the stability of betacyanin extract from red dragon fruit peels. According to Priatni and Pradita (2015), betalain pigments are stable at a pH range of 4 to 6, both in the presence of oxygen and under anaerobic conditions. The pigments may deteriorate due to increased reactivity to oxygen caused by light absorption in the ultraviolet and visible regions. Betalain retention is highest at 4 °C in darkness, lower at room temperature (27 °C), and lowest in the presence of light (Rodriguez et al. 2021). Betalains are being developed as natural substitutes for synthetic food colorants, which may have unfavourable health effects. These pigments are highly valued for their anti-inflammatory, anti-diabetic, antioxidant, phase II detoxifying enzyme-inducing, and anticancer properties (Rodriguez et al. 2021). Therefore, dragon fruit peels can be considered a valuable by-product for extracting natural colorants with bioactive properties.

Milk, naturally rich in nutrients, is long advised as part of a healthy, balanced diet. Yogurt, one of the most widely consumed fermented milk products, is available in various forms such as set, drinkable, frozen, and concentrated. To cater to varying consumer preferences, natural or artificial fruit pieces or fruit juices are often added to yogurt drinks for flavour. Dragon fruit peel extract, with its high potential as a natural colorant, could enhance the consumer acceptance of drinking yogurt. Therefore, this research aimed to incorporate dragon fruit peel extract into drinking yogurt as a natural colorant and assess its impact on the physicochemical, proximate, functional, sensory, and shelf-life properties of the developed product to ensure both functional benefits and consumer acceptability.

MATERIAL AND METHODS

Samples

The fully ripen matured red dragon fruits (*Hylocereus polyrhizus* variety) which contains approximately 80–85% moisture along with bioactive compounds such as betacyanins and polyphenols were purchased from fruit shop in Kegalle, Sri Lanka and stored at ambient temperature. Cow's milk from regular dairy cattle was obtained from the farm shop of the Faculty of Agriculture, University of Ruhuna. The milk was pasteurised (i.e. not adjusted for fat content), and it was stored under refrigeration at 4 ± 2 °C until use. Starter culture was prepared by using *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophillus* probiotic fermentation powder were obtained from Pusat Antar Universitas (PAU), Gadjah Mada University, Indonesia.

Preparation of red dragon fruit peel juice/extract

Dragon fruits were washed with clean water and top and bottom parts were removed and steamed for 10 minutes to remove odour. Peels were blended with water in a 1:2 ($w \cdot v^{-1}$) ratio to create a smooth juice. The mixture was strained using muslin cloth and stored in the refrigerator (4 ± 2 °C) until further use. The total solid content of the dragon fruit peel extract was 5.6% with corresponding moisture content of 94.4%.

Preparation of drinking yoghurt

Based on preliminary trials, the ratio of dragon fruit peel extract to milk used for preparing drinking yoghurt was established as 1:3 ($v \cdot v^{-1}$). Similarly, appropriate sugar (sucrose) concentrations (4, 6 and 8% $w \cdot w^{-1}$) and incubation times (4, 6, and 8 h) were evaluated through sensory analysis in preliminary studies to identify suitable conditions for product development. A sensory panel comprising 30 semi-trained panellists with prior experience in dairy product evaluation was recruited. Panellists were briefed on the evaluation criteria before the session and assessed sensory attributes such as appearance, texture, taste, colour, sweetness, aroma, and overall acceptability using a 5-point hedonic scale (1 = dislike extremely; 5 = like extremely). Evaluations were conducted in a well-lit, temperature-controlled sensory laboratory under controlled conditions. Samples were coded with random three-digit numbers and

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presented in random order to minimise bias, with water and plain crackers provided as palate cleansers between samples.

Drinking yogurt was prepared by homogenising milk with granulated white sugar available in market, followed by pasteurisation at 85 °C for 10 min. The mixture was then cooled to 42 °C and dragon fruit peel extract was added. The mixture was then added with starter culture containing 1 : 1 ratio of *Lactobacillus bulgaricus* and *Streptococcus thermophillus* (10% $w{\cdot}w^{-1}$) and 0.3% ($w{\cdot}w^{-1}$) gelatin. A 10% starter culture was used based on preliminary trials to ensure optimal fermentation, achieving the desired texture and stability of the drinkable yoghurt. The mixture was covered with aluminium foil and incubated for selected time period (4, 6 and 8 h) at 40 ± 2 °C. Then, the mixture was placed in room temperature (30 ± 2 °C) for an hour and stored in the refrigerator (4 ± 2 °C) overnight. A control drinking yoghurt without dragon fruit peel juice was also prepared using the selected sugar level and incubation time through sensory analysis.

Determination of proximate composition of developed drinking yoghurt samples

The proximate composition of the developed dragon fruit peel extract-incorporated drinking yogurt (DFPY) and control drinking yogurt (CY) was analysed following AOAC (2006) methods. Moisture content was determined using the oven-drying method (AOAC 934.01), crude ash by dry ashing (AOAC 984.13), crude protein by the Kjeldahl method (AOAC 920.39), crude fat by the Soxhlet extraction method (AOAC 962.09), and crude fibre by acid-base digestion (AOAC 942.05). The total carbohydrate content was calculated by difference, subtracting the sum of moisture, ash, protein, fat, and fibre contents from 100%. All analyses were performed in triplicate, and results were expressed as a percentage on a wet weight basis.

Determination of physico-chemical properties of developed drinking yoghurt

Determination of colour properties. The colour parameters of developed drinking yoghurt and control drinking yoghurt sample such as L^*, a^* and b^* values were determined using colourimeter (BCM-200, Beijing Zhongke Kaihua Technology Co., Ltd., China).

Determination of viscosity. Viscosity of the samples were measured by using standard rotational viscometer (Rheosense digital display m-VROC viscometer, USA), which was involved by rotating a spindle or rotor at 100 rpm speed within 60 s.

Determination of total soluble solid. Total soluble solid content of the developed product was measured using a digital refractometer (PAL-17S, Atago Co. Ltd., Japan) at room temperature (30 ± 2 °C).

Determination of total solids-non-fat. Total solids-non-fat (SNF) was determined by the method described by Matela et al. (2019). Taking the difference between % total solids and % fat content.

Determination of total gross energy. The total gross energy was calculated by multiplying estimated fat, carbohydrate and protein values by 9, 4, and 4 kcal, respectively. The unit of measurement for energy was $kcal{\cdot}100\ g^{-1}$ of sample

Determination of* pH *and titratable acidity. The pH of drinking yoghurt samples was measured using a calibrated pH meter (Ad132, Adwa Instruments, Romania) with standard buffers (pH 4.0 and 7.0). For each sample, 50 mL of peel and control drinking yoghurts were placed in separate beakers, and pH was recorded by dipping the probe, with three replicates per sample. Titratable acidity was determined by dissolving 5 g of drinking yoghurt in 30 mL of distilled water, followed by titration with 0.1 N NaOH until a pale pink colour persisted for 15 s after adding phenolphthalein indicator (AOAC 2006). The results were expressed as a percentage of lactic acid (% $w{\cdot}w^{-1}$).

Determination of functional properties of developed drinking yoghurt samples

Determination of total betalain content. Sample extract was prepared to determine the betalain content of drinking yoghurt samples using the method described by El-Said et al. (2014). Briefly, 1 mL of drinking yoghurt sample was diluted with distilled water (4 mL) and pH was adjusted to 4 using 1 M·HCL and centrifuged at 2 800 × g for 10 min. The pH of the supernatant was adjusted to pH 7 using 0.5 M·NaOH and centrifuged again at 2 800 × g for 10 min. The supernatant was taken as the sample extract. The absorbance at 486 and 536 nm wavelengths were determined for calculate betaxanthins and betacyanins, respectively. Total betalain content was calculated using the summation of betaxanthin and betacyanin content.

Determinations of total flavonoid, total polyphenol content and DPPH radical scavenging activity. The flavonoid content was estimated using Saha et al. (2023) with quercetin as the standard. A 1 mL sample or standard was mixed with 0.3 mL of 5% $NaNO_2$, 0.3 mL of 10% $AlCl_3$, and 2 mL of 1M·NaOH, diluted to 10 mL with distilled water after 6 min, and

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incubated in the dark for 1 h. Absorbance was measured at 510 nm using spectrophotometer (HACH DR 3900, Hach Company, Germany), and flavonoid content was calculated using a quercetin standard curve.

Polyphenol content was determined using the Folin-Ciocalteu method (Singleton et al. 1999). A standard solution was prepared by dissolving 10 mg gallic acid in ethanol and diluting to 100 mL. A 2 mL sample or standard was mixed with 2 mL of 10% Folin-Ciocalteu, 2 mL of 7.5% Na_2CO_3, and diluted to 10 mL with water. The mixture was incubated in the dark for 120 min, and the absorbance was read at 760 nm. Polyphenol content was calculated using a gallic acid standard curve.

Antioxidant activity was assessed using the DPPH radical scavenging method (Fernando et al. 2022). A Trolox standard was prepared by dissolving 25 mg in ethanol and diluting to 100 mL. A 0.4 mL sample or standard was mixed with 4 mL of 0.1 mM DPPH and incubated in the dark for 30 min. Absorbance was recorded at 415 nm, and antioxidant activity was determined using a Trolox standard curve.

Determination of shelf-life of the dragon fruit peel extract incorporated drinking yoghurt

The shelf-life of the DFPY was determined by using chemical methods such as pH and titratable acidity, and microbial parameters. Total plate count was determined following the method described by Igbabul et al. (2014). Maximum recovery dilution (MRD) solution and nutrient agar were used. After serial dilution (10^{-1} to 10^{-7}), 1 mL of each dilution was inoculated into agar plates and incubated at 30 °C for 48 h. Colony forming units (CFU·g^{-1}) were counted from plates with 30–300 colonies. Yeast and mold count were performed using potato dextrose agar (PDA) as per the method described by Igbabul et al. (2014). Serial dilutions (10^{-1} to 10^{-7}) were inoculated into PDA plates and incubated at 30 °C for 48 hours. CFU·g^{-1} were counted from plates with 30–300 colonies. The above-mentioned parameters were analysed for 3 weeks period of storage at refrigerated conditions (4 °C).

Data analysis

The data are presented as mean ± SD from three replicate measurements. Sensory data were analysed using the non-parametric Kruskal-Wallis test with MINITAB (software version 17 for Windows). The student's *t*-test was applied to determine statistical significance between the control drinking yogurt and the developed drinking yogurt at $P < 0.05$, also using MINITAB (software version 17 for Windows).

RESULTS AND DISCUSSION

Prior to the main experimental work, preliminary trials were conducted to establish suitable formulation parameters for the development of dragon fruit peel extract-incorporated drinking yoghurt. A sugar concentration of 6% (w·v^{-1}) was selected based on initial sensory assessments indicating an optimal balance of sweetness and taste. Similarly, an incubation period of 8 h was chosen to achieve the desired product consistency and visual appearance. These parameters were standardised for all subsequent formulations to ensure uniformity and reproducibility throughout the study. The finalised formulation for development of DFPY is shown in Table 1.

Proximate composition of developed drinking yoghurt

The proximate composition analysis revealed that the developed drinking yoghurt (DFPY) had a significantly higher moisture content ($P < 0.05$) than the control CY, likely due to the water contribution from the added dragon fruit peel extract. This observation aligns with Matela et al. (2019), who noted that increased moisture can influence texture and shelf-life. There was no significant difference in ash and fat content between CY and DFPY ($P > 0.05$). Despite the slightly higher fat value in DFPY (2.87%) than CY (2.51%), the difference is not statistically significant and may reflect variation due to sample preparation or extract composition. Protein content was significantly lower ($P < 0.05$) in DFPY, likely due to dilution by the peel extract, which contains less amount of protein. However, both samples met the minimum 2.7% protein standard set by SLSI (1989) (824). Crude fibre was detected only in DFPY (0.72%), consistent

Table 1. Optimised formulation of DFPY and CY

Ingredient	DFPY	CY
Sugar level (% w·w^{-1})	6	6
Incubation time (h)	8	8
Peel juice – milk (v·v^{-1})	1 : 3	no peel extract added
Peel – water (w·w^{-1})	1 : 2	no peel extract added
Gelatine (% w·w^{-1})	0.3	0.3
Starter culture (% v·v^{-1})	10	10

DFPY – dragon fruit peel extract incorporated drinking yoghurt; CY – control yoghurt

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Table 2. Comparison of the proximate composition and gross energy of DFPY and CY

Property	CY	DFPY
Moisture content (%)	79.22 ± 0.34[a]	84.08 ± 0.1200[b]
Total ash content (%)	0.65 ± 0.01[a]	0.66 ± 0.0500[a]
Crude protein content (%)	3.85 ± 0.45[a]	2.30 ± 0.3700[b]
Crude fat content (%)	2.51 ± 0.06[a]	2.87 ± 0.0020[a]
Crude fibre content (%)	ND	0.72 ± 0.0020[b]
Total carbohydrate content (%)	13.76 ± 0.27[a]	9.37 ± 0.3300[b]
Total gross energy (kcal·100 g^{-1})	93.09 ± 1.23[a]	73.95 ± 1.9800[b]

ND – not detected; CY – control yoghurt; DFPY – dragon fruit peel extract incorporated drinking yoghurt; data are presented in mean ± SD; data with the different superscripts in a row are significantly different at $P < 0.05$; Student *t*-test

with the presence of peel extract. Gross energy was significantly higher in the control sample, primarily due to its greater protein and carbohydrate content. This may suggest that the DFPY could serve as a lower-calorie alternative (Table 2).

Physicochemical properties of developed drinking yoghurt

The results of the physicochemical properties of developed drinking yoghurt and control drinking yoghurt are shown in Table 3. Colour is an important sensory parameter to choose the food product. Beyond aesthetics, colour is an important determinant of uniformity, freshness, and quality of food products. The colour measurement results are given as CIE L^*, a^*, and b^* values, which stand for the colour qualities of yellowness/blueness, redness/greenness, and lightness/darkness, respectively. There was a significant difference in a^* and b^* values of two samples of drinking yoghurts but no significant difference between L^* values. The peel drinking yoghurt sample was visually pink in colour and control drinking yoghurt sample was white in colour.

The viscosity of drinking yoghurt is a critical factor that affects the quality of the product. Viscosity affects the mouth feel and texture of the drinking yoghurts. There was no significant difference ($P > 0.05$) between viscosity of two samples. It implies that the addition of dragon fruit peel extract did not dilute the thickness of the drinking yoghurt. Total soluble solid content is vital for product uniformity, nutrition, and compliance. In this study, control drinking yoghurt showed significantly higher ($P < 0.05$) soluble solids than the developed drinking yoghurt, likely due to the addition of dragon fruit peel extract. These results align with Ranaweera et al. (2022), who reported similar findings in soursop-incorporated drinking yoghurt.

The total solid non-fat content of drinking yoghurt reflects the concentration of proteins, carbohydrates, minerals, and other non-fat components which is essential for assessing nutritional quality. According to Sri Lanka Standart Institute (SLSI) standards (824:1989), drinking yoghurt should contain at least 6% non-fat solids. In this study, both drinking yoghurts met the standard, with control drinking yo-

Table 3. Comparison of the physicochemical properties of control drinking yoghurt and the developed product

Properties	CY	DFPY
pH	4.18 ± 0.07[a]	4.25 ± 0.10[a]
Titratable acidity (% lactic acid)	0.88 ± 0.06[a]	0.80 ± 0.05[a]
Viscosity (cP)	7.45 ± 0.24[a]	6.38 ± 0.47[a]
L^*value	26.53 ± 2.64[a]	26.77 ± 4.53[a]
a^* value	3.57 ± 1.19[a]	8.51 ± 1.74[b]
b^* value	2.26 ± 0.77[a]	1.80 ± 1.28[a]
Total soluble solids (%)	20.78 ± 0.34[a]	15.92 ± 0.12[b]
Total solid non-fat (%)	18.26 ± 0.38[a]	13.05 ± 0.12[b]

CY – control yoghurt; DFPY – dragon fruit peel extract incorporated drinking yoghurt; cP – centipoise; data are presented in mean ± SD; data with the different superscripts in a row are significantly different at $P < 0.05$; Student *t*-test

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ghurt showing significantly higher non-fat content ($P < 0.05$) likely due to the dilution effect of the dragon fruit peel pulp.

The pH is a crucial factor for food stability, safety, and shelf-life as it inhibits harmful microorganisms and maintains freshness. According to Supriyanti et al. (2024) the pH of liquid yoghurt should range from 3.8 to 4.8, with SLS standards recommending a pH below 4.5. Both control and peel drinking yoghurt met these standards. Titratable acidity is important for flavour, texture, and safety, as it monitors fermentation and prevents spoilage. SLSI (1989) specifies a titratable acidity range of 0.8% to 1.25%. Both samples were within this range with control drinking yoghurt showing slightly higher acidity due to its higher milk content, though no significant difference ($P > 0.05$) was observed between the two samples.

Functional properties of the developed drinking yoghurt

In this study, dragon fruit peels rich in betalains were incorporated as a natural colorant in drinking yoghurt. Betalains, particularly betacyanin are abundant in red dragon fruit peels (Thaiudom et al. 2021) and their content is higher in the peel than the pulp (Le 2022). The developed drinking yoghurt contained 0.0064 mg·mL^{-1} of betalain content. (Table 4)

Flavonoids and polyphenols are linked to various health benefits. In the present study, the peel drinking yoghurt had the highest flavonoid content and polyphenol content due to the addition of dragon fruit peel, which contains many bioactive compounds. Previous research conducted by Mardiana and Putriningtyas (2020) also found that dragon fruit peel increases the phenolic content in drinking yoghurt. Antioxidants are essential for health, neutralising harmful free radicals that can damage cells. The developed drinking yoghurt with dragon fruit peel exhibited greater antioxidant activity than the control drinking yoghurt.

Shelf-life analysis of developed drinking yoghurt

The shelf-life determination of drinking yoghurt ensures food safety, quality, and nutritional value during storage. pH decreases over time due to factors like microbial growth, storage temperature, packaging, and oxygen exposure. As fermentation continues, lactic acid bacteria produce lactic acid, causing pH to drop. Higher storage temperatures can accelerate this process. In this study, pH ranged from 4.20 ± 0.09 to 3.69 ± 0.05 during storage (4 ± 2 °C), which is consistent with the standard pH range for liquid yoghurt (3.8–4.8) reported by Supriyanti et al. (2024). Titratable acidity in drinking yoghurt may increase over time due to continuous fermentation by lactic acid bacteria, which break down lactose into lactic acid. In this study, titratable acidity ranged from 0.71 ± 0.03 to 0.79 ± 0.02, within the SLSI (1989) range of 0.8%–1.25%. A decrease in pH typically correlates with higher acidity.

In present research study the betalain content range from 0.0054 ± 0.0001 mg·mL^{-1} to 0.0064 ± 0.0001 mg·mL^{-1} during the storage period. Betalains are stable in acidic conditions and however, these pigments may become degrade due to pH variations during preparation and storage. As well as the betalains deterioration may be facilitated by exposure to oxygen.

The original bacteria in drinking yoghurt are beneficial to human health. Although the quantitative requirement for drinking yoghurt bacteria varies, it is widely believed that drinking yoghurt should include 10^7 CFU·mL^{-1} of viable bacteria (*Streptococcus thermophilus* and *Lactobacillus bulgaricus*) in drinking yoghurt (Igbabul et al. 2014). This is possible to determine that the sample's acceptable limit for the bacteria load by comparing the table results to this standard. According to the codex standards, total plate count (TPC) in drinking yoghurt samples should be higher than the minimum requirement of 10^7 CFU·g^{-1}. Yeast and mold populations in the developed dragon fruit drinking yoghurts did not exceed 10^3 CFU·g^{-1} until the 28 days of storage period

Table 4. Comparison of functional properties of control drinking yoghurt and developed product

Properties	CY	DFPY
Total flavonoids content (mg QE·mL^{-1})	0.170 ± 0.001^a	0.2200 ± 0.0010^b
Total phenolic content (mg GAE·100 mL^{-1})	4.650 ± 0.110^a	12.9800 ± 0.5100^b
Antioxidant activity (mg TE·100 g^{-1})	181.800 ± 14.500^a	824.3000 ± 38.2000^b
Betalain content (mg·mL^{-1})	ND	0.0064 ± 0.0010^a

ND – not detected; CY – control yoghurt; DFPY – dragon fruit peel extract incorporated drinking yoghurt; data are presented in mean ± SD; data with the different superscripts in a row are significantly different at $P < 0.05$; Student *t*-test

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Table 5. Changing the pH and microbial count during storage period

Storage time	pH value	Total plate count (CFU·g^{-1})	Yeast and mold count (CFU·g^{-1})
Initial	4.20 ± 0.09	$2.40 \times 10^7 \pm 4.58 \times 10^7$	41.33 ± 2.89
1st week	3.92 ± 0.07	$3.87 \times 10^7 \pm 6.03 \times 10^7$	46.33 ± 9.07
2nd week	3.89 ± 0.04	$5.00 \times 10^8 \pm 4.58 \times 10^7$	65.67 ± 8.02
3rd week	3.78 ± 0.07	$6.80 \times 10^8 \pm 4.58 \times 10^8$	76.00 ± 10.15
4th week	3.69 ± 0.05	$7.17 \times 10^8 \pm 6.11 \times 10^8$	92.00 ± 2.00

CFU – colony forming units

(Table 5) which is the SLSI recommended value for drinking yoghurts (SLSI 1989).

A limitation of the current study is that the shelf-life analysis was conducted only on the drinking yogurt incorporated with dragon fruit peel extract. No comparative analysis was made with a plain yogurt control, which could have provided a baseline to more effectively evaluate the potential preservative or stabilising effects of the peel extract. Future studies could include such comparisons to better elucidate the role of the extract in enhancing shelf-life properties and its functional applications.

CONCLUSION

The incorporation of dragon fruit peel extract into drinking yogurt enhanced its nutritional and functional properties while providing a natural colorant. The optimised formulation, developed with 6% (w·w^{-1}) sugar and an 8 h incubation period, exhibited improved crude fibre content and notable antioxidant activity. Additionally, the product maintained, stability and quality for up to four weeks under refrigeration conditions (4 ± 2 °C). These findings highlight the potential of utilising dragon fruit peel extract as a value-added ingredient in functional dairy products, enhancing both health benefits and consumer appeal.

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