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Development and Optimization of Compressed Food Rations from Red-Fleshed Dragon Fruit (*Hylocereus polyrhizus*)

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Abstract

This study developed a production process for compressed food ration (CFR) from *Hylocereus polyrhizus* (red-fleshed dragon fruit) with the aim of creating a convenient, nutrient-rich product with extended shelf life. The effects of baking temperature (90–120°C), baking time (30–75 min), and juice-to-ingredient mixing ratio (0.75:5–1.5:5, w/w) on key nutritional parameters such as vitamin C content, total polyphenol content, reducing sugar concentration, and DPPH free radical scavenging activity and were systematically evaluated. The optimal processing conditions were identified as a baking temperature of 100°C, a baking time of 60 min, and a juice-to-ingredient ratio of 1:5 (w/w). Under these conditions, the CFR exhibited the highest nutritional values, with vitamin C content of 150.42±0.4 mg/100 mL, total polyphenols of 456.1±1.5 mg GAE/100 g, reducing sugars of 1.51±0.03 g/L, and DPPH inhibition capacity of 32.07±0.4%. Sensory evaluation conducted according to Vietnamese Standard TCVN 3215:1979 yielded a total score of 16.67/20, with taste achieving the highest weighted score (6.38), confirming the product's appealing flavor, stable appearance, and desirable texture. In conclusion, CFR formulated from red-fleshed dragon fruit demonstrated high nutritional value, strong antioxidant potential, and favorable sensory attributes, supporting its development as a functional, convenient, and sustainable food product.

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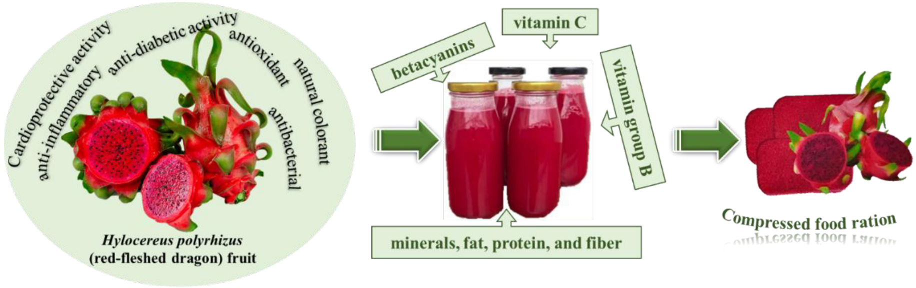
Graphical abstract



Introduction

Hylocereus polyrhizus, commonly known as red-fleshed dragon fruit, belongs to the family Cactaceae and the genus *Hylocereus*. Its distinctive deep red pulp differentiates it from other species such as *Hylocereus undatus* (white flesh with pink or red skin) and *Hylocereus megalanthus* (white flesh with yellow skin) (Abreu et al., 2024; Nizamlıoğlu et al., 2021). The species is widely cultivated in Southeast Asia, particularly in Vietnam, Malaysia, and Thailand (Lam et al., 2021). Numerous studies have reported that *H. polyrhizus* contains amino acids, lipids, nucleotides, organic acids, phenolic acids, flavonoids, and betacyanins (Marques et al., 2023; Zhao et al., 2024). Owing to these bioactive compounds, the fruit exhibits diverse biological activities, including cardioprotective, anti-diabetic, antioxidant, anti-inflammatory, antibacterial, and anticancer properties (Hipni et al., 2023; Safira et al., 2021). In addition, *H. polyrhizus* is a palatable fruit with a light, refreshing sweetness and is a rich source of vitamin C, B vitamins, minerals, protein, fat, and dietary fiber, all of which contribute to human health benefits (Jalgaonkar et al., 2022; Kumar et al., 2022). Its vibrant red pigments also make it an attractive natural colorant for applications in the food and pharmaceutical industries (Vijayakumar et al., 2020).

Compressed food rations (CFRs), also known as dry food cakes, are compact food products formulated by pressing ingredients such as flour, sugar, milk powder, oil, salt, and eggs into dense cakes (Barakat & Alfheeaid, 2023). Originally developed by the U.S. military, CFRs were produced as lightweight, shelf-stable food bars to reduce the logistical burden on soldiers in field operations (Hadi et al., 2018). Their long shelf life, portability, and high energy content made them indispensable during adverse conditions. Beyond military contexts, CFRs have gained importance for trekking, camping, and other outdoor activities where access to fresh food is limited. In Vietnam, CFRs were first introduced in the 1960s, primarily for resistance efforts, with most supplies imported from countries such as the Soviet Union and China (Fatmah et al., 2021). Today, CFRs remain in high demand, particularly in remote highlands, midlands, and coastal or island regions where transportation is difficult.

The quality of CFRs depends on raw material selection, processing technologies, packaging, storage conditions, sensory attributes, and microbial safety. Nutritional adequacy is typically ensured through high-quality proteins and complex carbohydrates, while antioxidants are often incorporated to prevent oxidative degradation (Maroto, 2022). Advanced packaging methods, such as metallized films and modified atmosphere packaging, protect against moisture and oxygen, thereby prolonging shelf life (Robertson, 2023). Proper storage conditions, particularly control of temperature and humidity, are also critical to stability. Sensory attributes, including flavor, texture, and rehydration capacity, play a decisive role in consumer acceptance (Meilgaard et al., 2004). Finally, microbial safety is achieved by maintaining low water activity and, when necessary, incorporating preservatives (Beuchat et al., 2013). This study aimed to optimize the processing conditions for CFRs incorporating red-fleshed dragon fruit (*Hylocereus polyrhizus*). Specifically, it examined the effects of baking temperature, baking time, and juice-to-ingredient ratio on nutritional composition, antioxidant activity, and sensory properties. The ultimate objective was to establish a technological process for producing a convenient and nutritionally balanced CFR with desirable sensory characteristics, thereby broadening consumer options for functional and portable food products.

Materials and methods

1. Raw materials

Fresh, healthy red-fleshed dragon fruits (*Hylocereus* *polyrhizus*) were procured from Ham Thuan Nam District, Binh Thuan Province, Vietnam (10°56′20″N, 107°44′38″E). The fruits had an average soluble solid content of 13.17±0.29 °Brix and a pH of 5.048±0.002. Upon arrival, the fruits were thoroughly washed, peeled, and the pulp was homogenized using a mixer (Philips HR 3705-300W, Philips Electronics Co., Ltd., Netherlands). Juice extraction was conducted on the same day of purchase, and the juice was stored at temperatures below 10°C until further use.

All chemicals employed in this study were of analytical grade, purchased from Sigma-Aldrich Co. (St. Louis, MO, USA), and used without further purification. Food additives and supplementary ingredients included mung bean powder (Goodprice Viet Nam Co., Ltd., Vietnam), wheat flour (Meizan CLV Company Limited, Ho Chi Minh City, Vietnam), egg white powder (Ovovita Company Limited, Vietnam), granulated sugar and salt (Bien Hoa Consumer Goods Joint Stock Company, Vietnam), margarine (Tuong An Vegetable Oil Joint Stock Company, Vietnam), vegetable oil (Tuong An Vegetable Oil Joint Stock Company, Vietnam), full-cream milk powder (Mama's Choice Full Cream Milk Powder, Tan Nhat Huong Company Limited, Vietnam), and liquid vanilla flavor obtained from traditional markets in Ho Chi Minh City, Vietnam.

2. Technological process of CFR production from red-fleshed dragon fruit

The production of compressed food ration (CFR) from red-fleshed dragon fruit (*Hylocereus polyrhizus*) involved several sequential steps to ensure product quality (Fig. 1). In the initial mixing stage, 40 g of butter, 30 g of vegetable oil, and 60 g of egg white powder were combined with 20 g of dragon fruit raw material. The mixture was stirred for 60 min until homogenous. Subsequently, 40 g of mung bean powder, 200 g of wheat flour, 50 g of full-cream milk powder, 0.2 g of vanilla, and 30 g of dragon fruit juice were gradually incorporated to improve both nutritional and sensory attributes. The resulting mixture was homogenized and sieved to achieve a uniform texture. The prepared batter was then transferred into silicone molds (8.9×6.3×11.4 cm) and baked at temperatures ranging from 90°C to 120°C for 30–75 min. After baking, the CFRs were cooled at ambient conditions to prevent condensation and maintain product integrity. The cooled products were subsequently packaged for preservation and distribution. The final product was a CFR enriched with red-fleshed dragon fruit, characterized by its tropical flavor, compact form, and enhanced nutritional value.

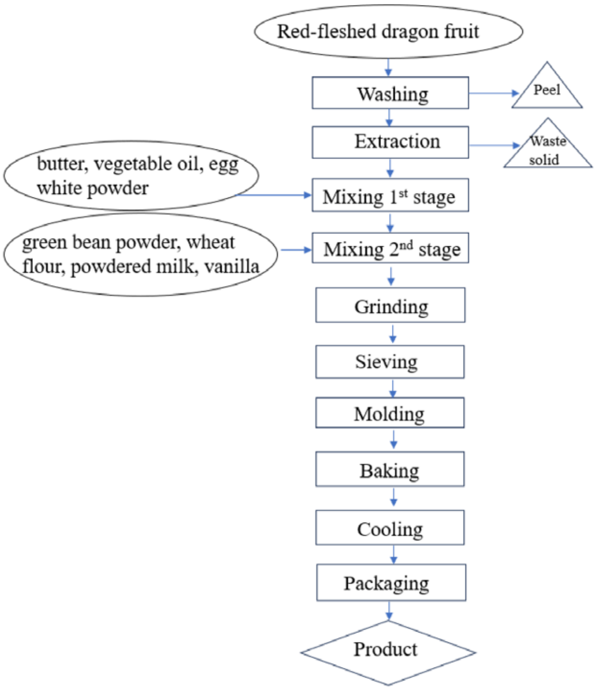


Fig. 1 Schematic diagram of CFR production from red-fleshed dragon fruit

3. Analytical methods

Determination of Vitamin C content

The vitamin C content was determined by UV–Vis spectrophotometry following the method of Fatmah et al. (2021), with minor modifications to suit laboratory conditions. Briefly, 0.23 mL of 3% bromine solution was added to 4 mL of juice sample and centrifuged to oxidize ascorbic acid into dehydroascorbic acid. Subsequently, 0.13 mL of 10% thiourea solution was added to eliminate excess bromine. Thereafter, 1 mL of 2,4-dinitrophenylhydrazine (DNPH) solution was introduced to form osazone derivatives. The reaction mixture was incubated at 37°C for 3 h in a thermostatic water bath, cooled for 30 min, and then mixed with 5 mL of 85% H_2SO_4 with continuous stirring. The resulting solution developed a characteristic color, and absorbance was recorded at 521 nm using a UV–Vis spectrophotometer. Vitamin C concentration in the samples was calculated from a standard calibration curve prepared with authentic ascorbic acid standards, with measurements taken at the same wavelength (521 nm).

Free radical scavenging ability by DPPH (2,2-Diphenyl-1-picrylhydrazyl)

The free radical scavenging activity of red-fleshed dragon fruit juice was evaluated using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) method, as described by

Baliyan et al. (2022) with minor modifications. Briefly, 0.5 mL of juice sample was mixed with 3.0 mL of methanol and 0.5 mL of 0.6 mM DPPH solution in a test tube. The control consisted of 0.5 mL of DPPH solution combined with 3.5 mL of methanol. After thorough mixing, the reaction mixtures were incubated in the dark at room temperature for 30 min. The absorbance of each solution was measured at 517 nm using a UV–Vis spectrophotometer. All analyses were conducted in triplicate. The percentage of DPPH radical scavenging activity (antioxidant activity) was calculated using Equation (2.1):

$$\%\,inhibition = \frac{OD_c - OD_t}{OD_c} \times 100 \quad (2.1)$$

When:
OD_c : Control sample absorbance
OD_t : Test sample absorbance

Determination of total polyphenol content (TPC) by Folin-Ciocalteau method

The total polyphenol content (TPC) was determined following the procedure described by Chavez-Santiago et al. (2022), with minor modifications. Briefly, 1 mL of juice sample (diluted up to 10-fold when necessary) was transferred into a test tube, followed by the addition of 5 mL of 10% Folin–Ciocalteu reagent and 4 mL of 7.5% Na_2CO_3 solution. The mixture was thoroughly shaken and incubated in the dark at room temperature for 60 min. Absorbance was measured at 765 nm using a spectrophotometer. The TPC was quantified by linear regression from a gallic acid (Sigma-Aldrich) standard calibration curve, and the results were expressed as gallic acid equivalents (GAE). The TPC was calculated according to Equation (2.2):

$$\text{TPC} = \frac{C_x \times n \times V \times 100}{m \times (100 - X)} \times 10^{-3} \quad (2.2)$$

When:
C_x : gallic acid concentration determined from the standard curve (µg/mL),
n : dilution from the original juice
V : volume of the original juice (mL)
X : sample moisture content (%)
m : sample weight (g)

Determination of reducing sugar content

The reducing sugar content was determined based on the colorimetric reaction between reducing sugars and 3,5-dinitrosalicylic acid (DNS) reagent, following the method of Lam et al. (2021) with minor modifications. Briefly, 1 mL of juice sample was transferred into a test tube and mixed with 2 mL of DNS reagent. The mixture was boiled in a water bath for 5 min, then cooled to room temperature and homogenized by gentle shaking. The absorbance was measured at 540 nm using a spectrophotometer. Glucose concentration was quantified from a standard calibration curve, and results were expressed as glucose equivalents. The glucose content was calculated according to Equation (2.3):

$$\text{Glucose content (mg/kg)} = C_x \, x \, \frac{V_2}{V_1} x \frac{V_{dm}}{m} \quad (2.3)$$

When:
C_x : glucose content calculated according to the standard curve (mg/L)
V_2 : volume of the volumetric flask in the standard series (mL)
V_1 : volume of sample taken for analysis (mL)
V_{dm} : volume of the volumetric flask after sample processing (mL)
m : sample mass (g)

Sensory evaluation by taste scoring test

Sensory evaluation of product quality was conducted using the taste scoring method in accordance with Vietnamese Standard TCVN 3215:1979 – *Food Products – Sensory Analysis – Pointing Mark Method* (Vietnamese Standard TCVN 3215:1979, n.d.). This method provides a simplified scoring approach commonly employed in the Vietnamese food industry, enabling rapid assessment of consumer acceptability without requiring trained sensory panels. In contrast, international sensory standards (e.g., ISO or ASTM protocols) typically rely on more rigorous methodologies involving structured scales, trained assessors, and statistical validation. For the present study, TCVN 3215:1979 was adopted to reflect local consumer preferences, while future research will incorporate international standards for broader comparability.

The sensory evaluation was performed by a panel of 12 healthy male volunteers, aged 20–30 years, from the Institute of Applied Technology and Sustainable Development, Nguyen Tat Thanh University. A unified 6 -level scale (0–5 points) was applied, where 0 indicated severely damaged product quality, while scores of 1–5 reflected decreasing levels of defect. A score of 5 denoted a product with no detectable errors or defects. The attributes evaluated included: Color: uniformity of surface coloration, specifically the characteristic pink color of the product. External appearance: surface condition, shape, and absence of defects such as cracks or deformation. Internal appearance: porosity and dough stickiness. Odor: aroma evaluated through both smelling and mastication. Taste: flavor assessed by biting, chewing, and swallowing small portions.

This study involved only sensory evaluation of food products in compliance with TCVN 3215:1979. As no medical interventions, human biological sampling, or personal data collection were involved, the procedure did not require formal Human Research Ethics Committee approval. Nevertheless, all activities were carried out responsibly and in accordance with established ethical and scientific research practices.

Data analysis

All experiments were performed in triplicate to ensure reproducibility, and the results are expressed as mean ± standard deviation (SD). Statistical significance was established at $p<0.05$. Data analysis was conducted using Microsoft Excel 2019 and Origin software (OriginLab Corporation). Microsoft Excel was applied for basic statistical calculations, including mean, SD, and preliminary t-tests using the Data Analysis Toolpak, while Origin was employed for advanced analyses such as t-tests, analysis of variance (ANOVA), regression analysis, and graphical visualizations (e.g., error bars and contour plots) to optimize experimental conditions.

Results and discussion

1. Evaluation of the quality of juice from red-fleshed dragon fruit

Red-fleshed dragon fruit (*Hylocereus polyrhizus*) is a tropical fruit recognized for its high nutritional value and potential applications in both the food and pharmaceutical industries. The analytical parameters presented in Table 1 provide an overview of the fruit's quality characteristics and serve as a basis for assessing its suitability for processing and product development. The juice exhibited a soluble solid content of 13.17°Brix, reflecting a high concentration of sugars and other soluble compounds. This level of sweetness not only supports fermentation processes but also enhances the natural palatability of juice, wine, and jam products without the need for added refined sugar (Salehi, 2020; Cervera-Chiner et al., 2021). The pH value of 5.0 indicated a slightly acidic profile typical of tropical fruits, favorable for microbial stability and sensory quality. Remarkably, the vitamin C content reached 459.04 mg/100 mL, a concentration far exceeding that of common vitamin C–rich fruits such as oranges and guavas. This exceptional value underscores the fruit's potential as a functional food ingredient due to the well-documented antioxidant, immunomodulatory, and iron absorption–enhancing properties of vitamin C (Goyal & Jerold, 2021). Although the DPPH free radical scavenging activity was relatively modest (9.07%), the total polyphenol content of 167.98 mg GAE/100 g highlighted the fruit's potential antioxidant capacity. The combined presence of vitamin C and polyphenols provides a synergistic foundation for protecting cells against oxidative stress and associated degenerative processes. Additionally, the reducing sugar content of 7.98 g/L is advantageous for browning reactions during thermal processing, contributing to desirable color and flavor development in derived products. Overall, red-fleshed dragon fruit demonstrates considerable promise as a raw material for food processing, offering high nutritional density, natural sweetness, and substantial antioxidant potential.

Table 1 Quality analysis indicators of red-fleshed dragon fruit

Parameter	Average value
Brix ([a])	13.17 ± 0.29
pH value	5.048 ± 0.002
Vitamin C content (mg/100mL)	459.04 ± 0.17
DPPH free radical scavenging ability (% inhibition)	9.07 ± 0.15
Total polyphenol content (mgGAE/100g)	167.98 ± 0.38
Reducing sugar content (g/L)	7.98 ± 0.19

2. Effect of baking temperature on the quality of CFR

Baking is a widely used dry-heat processing method that modifies the sensory and nutritional attributes of food products, thereby enhancing consumer acceptability (Zhang et al., 2024). The impact of baking temperature (90–120°C) on the nutritional quality of CFR (cake formulated with red-fleshed dragon fruit) is shown in Fig. 2. At elevated temperatures, significant reductions were observed in both vitamin C and total polyphenol content. Specifically, vitamin C decreased from 114.07±0.2 mg/100 mL at 100°C to 100.86±0.3 mg/100 mL at 120°C, while total polyphenols declined from 391.85±1.5 mg GAE/100 g at 90°C to 349.60±2.5 mg GAE/100 g at 120°C. These reductions are attributed to the thermal lability of vitamin C and polyphenolic compounds, which are susceptible to oxidation, hydrolysis, and polymerization at elevated temperatures (ElGamal et al., 2023; Zhang et al., 2022). Interestingly, moderate heating (90–100°C) promoted the release of polyphenols from plant cell walls, yielding a transient increase in content before degradation predominated at higher temperatures. Comparable results were reported by Rahman et al. (2021), who demonstrated that elevated baking temperatures reduced both sensory and nutritional qualities in banana-based food bars.

Fig. 2B illustrates the effect of baking temperature on DPPH radical scavenging activity and reducing sugar content. Between 90°C and 100°C, DPPH inhibition increased sharply (6.06±0.4% to 11.13±0.3%), and reducing sugar content rose slightly (1.08±0.02 g/L to 1.12±0.01 g/L; $p<0.05$). This enhancement likely reflects the thermal release of phenolic and flavonoid compounds. However, at 120°C, both parameters declined markedly (7.07±0.3% and 1.06±0.02 g/L, respectively) due to thermal degradation of bioactive molecules and sugar consumption through Maillard reactions or caramelization (Liu et al., 2022; Twardovska et al., 2024).

Sensory evaluation further emphasized the influence of baking temperature on product quality. At 90°C, CFR retained its characteristic dragon fruit color and aroma, but the texture was slightly spongy, and residual bean

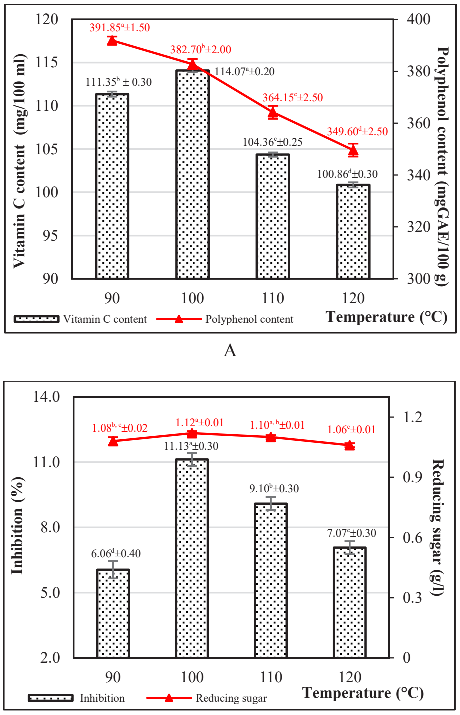


Fig. 2 Changes in Vitamin C content and total polyphenol content (A), DPPH inhibition capacity and reducing sugar content (B) at different baking temperature

powder flavor was detected, indicating incomplete cooking. At 100°C, the product achieved optimal sensory qualities, including vibrant color, pleasant aroma and taste, uniform texture, and full cooking. In contrast, higher baking temperatures (110–120°C) led to surface cracks, faded coloration, brittle texture, and a slightly bitter taste from crust caramelization, all of which reduced consumer appeal and economic value. Collectively, these findings demonstrate that a baking temperature of approximately 100°C is optimal for CFR production, balancing nutrient retention, antioxidant capacity, and sensory acceptability.

2. Effect of baking time on the quality of CFR

Baking time significantly influenced both the sensory characteristics and the chemical composition of CFR (cake formulated with red-fleshed dragon fruit).

Sensory attributes. At shorter baking times (30–45 min), the product retained a bright, characteristic color of red-fleshed dragon fruit; however, the texture remained soft and moist, indicating incomplete cooking and failing to meet the desired structural requirements of CFR. At 60 min, the product achieved optimal sensory quality, exhibiting a uniform and vibrant pink color, spongy and smooth texture, and a pleasant aftertaste with evenly developed flavor. By contrast, prolonged baking for 75 min resulted in an overcooked product with surface burning, reduced porosity, loss of characteristic flavor, and fading of the distinctive dragon fruit coloration.

Chemical indicators. The effect of baking time (30–70 min) on vitamin C, total polyphenols, reducing sugars, and DPPH radical scavenging activity is presented in Fig. 3. Vitamin C content remained relatively stable from 30 to 45 min, increased significantly at 60 min (112.33±0.25 mg/100 mL), and then decreased sharply at 70 min (88.34±0.30 mg/100 mL; $p<0.05$) (Fig. 3A). Similarly, total polyphenol content gradually increased from 356.64±1.5 mg GAE/100 g at 30 min to 474.48±2.5 mg GAE/100 g at 60 min, before declining to 424.01±2.5 mg GAE/100 g at 70 min. The observed decline at prolonged baking times is attributable to cellular disruption, which facilitates the release of polyphenol oxidase enzymes, leading to polyphenol degradation, as well as increased exposure to oxidative conditions during heating (Alfeo et al., 2020).

As shown in Fig. 3B, both DPPH inhibition capacity and reducing sugar concentration increased steadily up to 60 min (14.06±0.3% and 1.10 ± 0.01 g/L, respectively), followed by a slight decrease at 70 min (13.01±0.3% and 1.01±0.02 g/L; $p>0.05$). The initial increase in reducing sugar content can be explained by the thermal hydrolysis of polysaccharides, producing simple sugars such as glucose and fructose (Yue et al., 2022). However, prolonged exposure at 100°C facilitated Maillard reactions between reducing sugars and amino acids, as well as sugar caramelization, thereby reducing free sugar levels. A similar trend was observed for antioxidant activity: moderate baking promoted the release of bioactive compounds such as phenolics, enhancing DPPH inhibition, whereas extended baking led to their decomposition and reduced activity (Francenia Santos-Sánchez et al., 2019).

These findings demonstrate that a baking time of 60 min is optimal for CFR production, maximizing vitamin C, polyphenol content, reducing sugar concentration, and antioxidant activity, while also providing superior sensory properties. Baking beyond this threshold accelerates degradation reactions, compromising both nutritional quality and consumer acceptability.

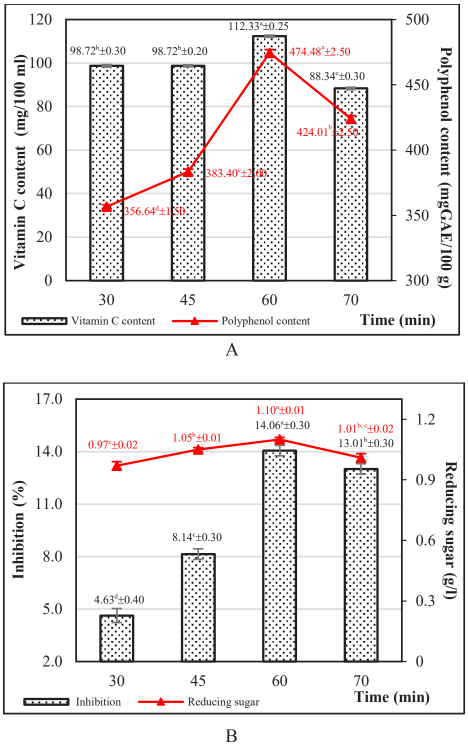


Fig. 3 Changes in Vitamin C content and total polyphenol content (A), DPPH inhibition capacity and reducing sugar content (B) at different baking time

3. Effect of red-fleshed dragon fruit juice mixing ratio on the quality of CFR

The mixing ratio of red-fleshed dragon fruit (RDF) juice with other ingredients is a critical factor influencing both the nutritional and sensory qualities of CFR (cake formulated with red-fleshed dragon fruit). 4 ratios were investigated: 0.75:5, 1:5, 1.25:5, and 1.5:5 (w/w).

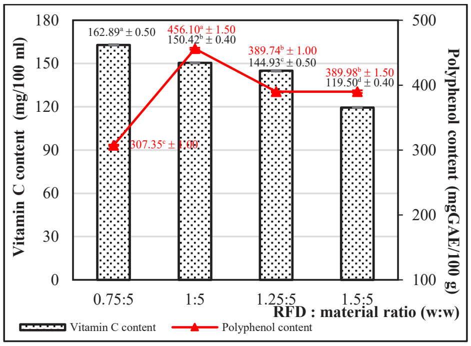
Sensory attributes. At the lowest ratio (0.75:5), the finished product exhibited a pale coloration that did not meet quality expectations. Ratios of 1:5 and 1.25:5 produced products with an appealing, uniform pink color and a spongy, smooth texture, characteristic of CFR. However, at the highest ratio (1.5:5), the structure became excessively soft and moist, compromising product integrity.

Nutritional and functional indicators. As shown in Fig. 4, the juice mixing ratio significantly affected vitamin C content, total polyphenols, reducing sugars, and DPPH radical scavenging activity. Vitamin C content decreased progressively with higher RDF juice proportions, from 162.89±0.5 mg/100 mL at 0.75:5 to 119.5±0.4 mg/100 mL at 1.5:5 (Fig. 4A). This decline is consistent with the susceptibility of ascorbic acid to oxidative degradation when exposed to oxygen, water, and ascorbic acid oxidase enzymes commonly present in fruit juices (Giannakourou & Taoukis, 2021). Given that RDF juice contains 80–90% water (Attar et al., 2022), increasing its proportion likely elevated the moisture content of the mixture, thereby accelerating vitamin C loss. This observation corroborates findings by Nowicka et al. (2017), who reported greater nutrient degradation in juice blends with higher water content.

In contrast, total polyphenol content peaked at the 1:5 ratio (456.1±1.5 mg GAE/100 g) before declining at higher juice levels. This suggests the existence of an optimal aqueous environment that facilitates polyphenol extraction, whereas excessive dilution may reduce solubility or hinder incorporation into the product matrix. Correspondingly, antioxidant activity, measured by DPPH inhibition, also reached its maximum at the 1:5 ratio (32.07±0.4%), reflecting its association with polyphenol content (Fig. 4B). At higher ratios, activity decreased despite an increase in reducing sugar concentration, possibly due to the formation of advanced glycation end-products (AGEs), which impair polyphenol function (Ahmed et al., 2020). These findings are in agreement with previous studies showing that solvent-to-fruit ratios strongly influence phenolic yield, with excessive dilution lowering recovery efficiency (Mokrani & Madani, 2016).

The reducing sugar content increased only slightly, from 1.41±0.05 g/L to 1.42±0.04 g/L, with higher RDF juice ratios, attributable to the fruit's intrinsic sugar content. While reducing sugars can enhance sweetness and browning reactions during processing, excessive levels may also participate in Maillard reactions, thereby reducing antioxidant effectiveness (Liu et al., 2022).

The optimal RDF juice mixing ratio was determined to be 1:5 (w/w), as it provided a balance between nutrient retention, antioxidant activity, and desirable sensory characteristics. Lower ratios underutilized the nutritional potential of RDF, while higher ratios resulted in nutrient dilution, structural defects, and diminished functional quality of CFR.



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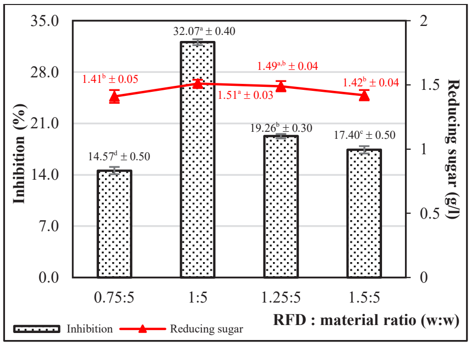

B

Fig. 4 Changes in Vitamin C content and total polyphenol content (A), DPPH inhibition capacity and reducing sugar content (B) at different red-fleshed dragon fruit juice mixing ratio

3.5 Sensory assessment of product quality according to TCVN 3215:1979

The sensory evaluation of CFR products, conducted in accordance with Vietnamese Standard TCVN 3215:1979, is presented in Table 2. Product quality was assessed based on 5 criteria: color, odor, taste, external appearance, and internal appearance. Each criterion was first scored on an unweighted average scale and subsequently adjusted using weighting factors to reflect its relative importance in the overall sensory evaluation. The results revealed that taste received the highest rating, with an unweighted average score of 4.25 and a weighting factor of 1.50, yielding the highest weighted score of 6.38. This finding highlights the central role of flavor in consumer acceptance and its status as the most influential attribute in sensory evaluation. External appearance ranked second in importance, with a weighting factor of 1.00 and an average sensory score of 3.92, corresponding to a weighted score of 3.92. This underscores the importance of product form and visual appeal in shaping consumers' first impressions. Other attributes contributed to the overall assessment but to a lesser extent: color (weighted score 2.40), odor (2.04), and internal appearance (1.93). Although these factors did not dominate the evaluation, they nonetheless played supportive roles in shaping consumers' holistic perception of product quality.

The total weighted sensory score was 16.67, indicating that the CFR product met the requirements of TCVN 3215:1979 and was generally rated as "good." Overall, the product demonstrated strong performance, particularly in terms of flavor, while the use of weighted coefficients provided clear insights into the attributes most critical for consumer satisfaction. This approach further highlights areas where targeted improvements could enhance product quality.

Table 2 Sensory evaluation data of compressed food ration (CFR) products according to TCVN 3215:1979

Criteria	Total Score	Unweighted Score Average	Weight Factor	Weighted Score Average
Color	48.00	4.00±0.74	0.60	2.40±0.44
Odor	49.00	4.08±0.67	0.50	2.04±0.33
Taste	51.00	4.25±0.62	1.50	6.38±0.93
External Appearance	47.00	3.92±0.51	1.00	3.92±0.51
Internal Appearance	58.00	4.83±0.39	0.40	1.93±0.16
Average score				16.67

Conclusion

Red-fleshed dragon fruit (*Hylocereus polyrhizus*) is a valuable functional food resource due to its rich vitamin, fiber, and antioxidant content, as well as its potential application as a natural food colorant. The present study successfully developed a CFR product formulated from red-fleshed dragon fruit juice. Optimization of processing parameters demonstrated that the most suitable conditions for CFR production were a juice-to-ingredient ratio of 1:5 (w/w) and baking at 100°C for 60 min. Under these conditions, the product exhibited the highest levels of bioactive compounds, including vitamin C (150.42±0.4 mg/100 mL), total polyphenols (456.1±1.5 mg GAE/100 g), reducing sugars (1.51±0.03 g/L), and DPPH radical scavenging activity (32.07±0.4%).

Sensory evaluation following TCVN 3215:1979 confirmed the high quality and consumer acceptability of the CFR product, with a total weighted score of 16.67. Among the evaluated attributes, taste (6.38) and external appearance (3.92) were identified as the most influential drivers of consumer satisfaction, complemented by positive contributions from color, odor, and internal appearance.

Overall, the findings highlight the feasibility of incorporating red-fleshed dragon fruit into value-added bakery products with both nutritional and sensory appeal. Future studies should investigate the effects of molding techniques, packaging materials, and storage conditions on product stability and consumer acceptance to further enhance commercial potential.

Acknowledgments

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