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RESEARCH PAPER

Effects of red dragon fruit (*Hylocereus polyrhizus*) supplementations on the quality and organoleptic properties of beer

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Abstract

Red dragon fruit (*Hylocereus polyrhizus*) is rich in bioactive compounds and possesses strong antioxidant potential, making it a promising ingredient in the beverage industry. This study investigated the effects of red dragon fruit supplementation on beer quality organoleptic property. Both puree and juice were tested at different concentrations (10%, 15%, and 20% v/v) to determine the appropriate form and supplementation level. Fermentation parameters such as yeast concentration (0.02–0.08% w/v), temperature (22–30°C), and fermentation time (2–8 days) were optimized to improve ethanol production and organoleptic properties. In addition, pasteurization conditions (58–65°C for 5–15 min) were evaluated to ensure microbial safety and maintain product quality. The optimal process used 10% fruit juice, fermented at 26°C for 4 days with 0.04% yeast, resulting in an ethanol content of approximately 5.66% v/v and enhanced sensory properties. Pasteurization at 65°C for 10 min effectively ensured microbiological safety without compromising quality. The research findings indicate the potential for developing dragon fruit-infused beer products to increase the value of dragon fruit and diversify beer products in Vietnam.

1. Introduction

Beer is one of the most widely consumed fermented beverages worldwide, with a long history dating back to ancient civilizations such as Sumeria, Egypt, and China (Hornsey, 2003). In tradition, beer produced from water, malted barley, hops, and yeast, beer has evolved to include new ingredients and styles to meet changing consumer preferences (Kunze, 2010). Beer can help improve cardiovascular health thanks to the phenolic compounds in it, these compounds have anti-inflammatory properties, reduce bad cholesterol and increase good cholesterol, thereby reducing the risk of cardiovascular disease and also contain silicon, an important mineral that helps strengthen bones and prevent osteoporosis, and also help control blood sugar levels and reduce the risk of type 2 diabetes (Sohrabvandi *et al.,* 2012; Ambra *et al.,* 2021). In recent years, there has been a growing trend of incorporating natural ingredients, particularly fruits, into beer production to enhance flavor, nutritional value, and visual appeal (Zeng *et al.,* 2024). Fruit beers have emerged in the market, meeting consumer demand for both innovative flavors and added nutritional benefits from fruit ingredients (Croonenberghs *et al.,* 2024). Among the potential fruit additions, red dragon fruit (*Hylocereus polyrhizus*) is considered a promising option due to its high nutritional value and attractive coloration (Lim *et al.,* 2025).

Red dragon fruit (*Hylocereus polyrhizus*), belonging to the family Cactaceae, is a tropical fruit widely cultivated in South of Vietnam, especially in the Mekong Delta, where warm temperatures and abundant sunshine provide ideal conditions for growth (Rojas-Sandoval *et al.,* 2021). This fruit is known for very diverse in size, the fruit's skin has a thick layer of scales, protecting the red flesh inside, which is sweet, slightly sour and has many small edible seeds that contain many nutrients, in terms of nutrition, red-fleshed dragon fruit has nutritional values such as protein, carbohydrate, organic acids, minerals (Fe, Mg, Ca), vitamin A, vitamin C (Arivalagan *et al.,* 2021). The presence of lycopene, a powerful antioxidant, further increases the nutritional value of this

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fruit (Joshi and Prabhakar, 2020). These properties not only make this fruit appealing for direct consumption, but also for value-added applications such as juice, jam, wine, and beer recently (Nithya, 2025). However, up to now, there has been very little in-depth scientific research on integrating dragon fruit into the beer production process, especially there is not much data on the quality indicators of the final product such as alcohol content, acidity, taste, color, preservation ability and consumer perception (Pham *et al.,* 2024). Therefore, this study focuses on examining factors affecting product quality such as the ratio of dragon fruit added, fermentation time and fermentation temperature, thereby finding suitable conditions to create high-quality, stable beer products with unique characteristics in flavor and color. The results of the project contribute to expanding the scientific basis for the production of fruit beer from local materials, and opening up a new direction in the development of fermented beverage products from Vietnamese agricultural products.

2. Materials and methods

2.1 Materials and chemicals

Red dragon fruits (*Hylocereus polyrhizus*) were purchased from local markets in Can Tho City, Vietnam. Only fresh and fragrant fruits were selected, while worm -infested, rotten, waterlogged, or mechanically damaged fruits were excluded. The fruits were washed, peeled, and processed into two forms, puree and juice, for use in fermentation experiments.

All brewing materials were bought from ABV Beer Company (Ho Chi Minh City, Vietnam). The raw materials included malt (Pale Wheat malt and Pilsner malt, Castle Malting, Belgium), hops (Hallertau Saphir, Germany), and yeast (*Saccharomyces cerevisiae*, SafAle WB-06 strain, Fermentis, France).

The chemicals used included H_2SO_4, ethanol (Merck, Germany), tri-butyl phosphate (Sigma Aldrich, Germany), 3,5-dinitrosalicylic acid (Sigma Aldrich, Germany), $K_2Cr_2O_7$ (Xilong Scientific, China), sucrose (Bien Hoa, Vietnam).

2.2 Methods

2.2.1 Investigation of the influence of raw material type and fruit ratio on the fermentation process

A mixture of 420 g of Pilsner malt and 52.5 g of Pale wheat malt was mashed with water and subjected to the saccharification process to obtain wort. The wort was then filtered and boiled with 3.15 g of Hallertau Saphir hops for 80 min (two-thirds added at 70 min and one-third during the final 10 min). The °Brix of the hopped wort was recorded. Red dragon fruit was washed, pre-processed, and divided into two forms, puree and juice. The °Brix of both forms was measured, and each was sterilized with 140 mg/L $NaHSO_3$ for 2 h. Dragon fruit puree and juice were added to the hopped wort at different ratios (10, 15, and 20% v/v), along with *S. cerevisiae* yeast, during the fermentation stage. The mixtures were distributed into fermentation bottles and fermented at 26°C for 4 days. After the fermentation process was completed, the beer samples were evaluated for their physicochemical and sensory properties.

2.2.2 Investigation of the appropriate yeast concentration for the fermentation process

The preparation of wort and red dragon fruit juice was the same as described in section 2.2.1. The juice was then added to the hopped wort at the most appropriate ratio determined in section 2.2.1, along with *S. cerevisiae* yeast at concentrations of 0.02, 0.04, 0.06, and 0.08% (w/v) during the fermentation stage. The mixture was distributed into fermentation bottles and incubated at 26°C for 4 days. After fermentation, the beer samples were analyzed for their physicochemical and sensory properties.

2.2.3 Investigation of suitable temperature and time for the fermentation process

The preparation of wort and red dragon fruit juice was the same as described in section 2.2.1. The juice was then added to the hopped wort at the most appropriate ratio yeast concentration determined in previous sections. The mixture was distributed into fermentation bottles and incubated at different temperatures (22, 26, and 30°C) for varying durations (2, 4, 6 and 8 days). Samples were collected at each time point to analyze physicochemical parameters and evaluate sensory characteristics.

2.2.4 Investigation of suitable pasteurization conditions for red dragon fruit beer

The preparation of red dragon fruit beer was prepared using the most appropriate conditions. After fermentation, the beer was filtered and pasteurized at temperatures ranging from 58°C to 65°C for 5 to 15 min. Finally, the red dragon fruit beer samples were evaluated for their physicochemical, microbial, and sensory properties.

2.3 Statistical analysis and analytical method

Total soluble solids (TSS, °Brix) were determined using an Atago refractometer (Master-2α, Japan). pH value was measured using a Horiba pH meter (pH1100, Japan). Ethanol content was determined based on reaction with tri-n-butyl phosphate and potassium chromate (Sriariyanun *et al.* 2019). Reducing sugar

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Table 1. Post-fermentation parameters of red dragon fruit beer products with different types of raw materials and addition ratios.

Red dragon fruit type	Fruit ratio (% w/v)	Post-fermenation parameters			
		TSS (°Brix)	pH	Ethanol content (% v/v)	Reducing sugar content (g/100 mL)
Puree	10	$5.93^{a} \pm 0.12$	$4.25^{ab} \pm 0.13$	$4.03^{c} \pm 0.28$	$5.74^{a} \pm 0.83$
Puree	15	$5.67^{abc} \pm 0.29$	$4.31^{a} \pm 0.07$	$5.47^{b} \pm 0.11$	$5.90^{a} \pm 1.71$
Puree	20	$5.50^{abc} \pm 0.50$	$4.31^{a} \pm 0.09$	$2.92^{d} \pm 0.26$	$4.56^{ab} \pm 1.36$
Juice	10	$5.70^{ab} \pm 0.17$	$4.09^{c} \pm 0.02$	$5.53^{b} \pm 0.02$	$4.40^{ab} \pm 0.73$
Juice	15	$5.23^{bc} \pm 0.25$	$4.13^{bc} \pm 0.05$	$6.31^{a} \pm 0.12$	$5.05^{ab} \pm 0.51$
Juice	20	$5.17^{c} \pm 0.29$	$4.21^{abc} \pm 0.04$	$5.58^{b} \pm 0.21$	$3.74^{b} \pm 1.10$

Note: The data in the table represent the means of three replicates. In the same column, values with different superscript letters are significantly different ($p < 0.05$).

content was determined based on the DNS method (Miller, 1959). Total yeast and mold count and total aerobic microorganisms (log CFU/g) were determined using the colony counting method on OGYA and PCA media, respectively. Sensory evaluation was conducted according to Vietnamese Standard TCVN 6063:1995 (Vietnam Ministry of Science and Technology, 1995), using a 1 (lowest) to 5 (highest) scoring scale to assess six key attributes including color, foam formation, aroma, taste, bitterness, and acceptable level.

Data were processed using the Microsoft Excel 2010 (Microsoft Corporation, USA) and statistical analysis using the Statgraphics Centurion XV (Statgraphics Technologies, Inc., USA).

3. Results and discussion

3.1 The influence of raw material type and suitable fruit ratio

Fruit is added to beer to enhance nutritional value and diversify flavor. However, selecting suitable raw materials and appropriate fruit ratios is crucial to maintain both the beer's characteristic taste and the fruit's nutrients. Changes in Brix, pH, ethanol, and reducing sugar content during fermentation are shown in Table 1. It can be seen that the ratio of fruit juice addition significantly influenced the fermentation process of red-fleshed dragon fruit beer. As juice was added at varying levels, the TSS of the wort decreased from an initial 13 °Brix to 5.17–5.93 °Brix after fermentation. This reduction is associated with increased ethanol production due to the efficient metabolism of simple sugars (fructose, glucose, and sucrose) by *S. cerevisiae*. These findings are consistent with the results reported by Yin *et al.* (2021), who observed a similar decrease in sugar content in red raspberry-supplemented beer compared to control samples. Moreover, samples supplemented with juice exhibited higher °Brix and free sugar concentrations than those with fruit puree. This difference is attributed to the composition of the raw materials. While pureed fruit retains insoluble fiber that traps sugars and water, thereby reducing their availability for fermentation. On the other hand, fruit juice contains predominantly soluble sugars and fewer solids, thereby enhancing fermentation efficiency and resulting in a cleaner mouthfeel (Tabaszewska *et al.,* 2022). The pH was also affected by both the form and the proportion of fruit added. Fermentation with juice led to a greater pH decline due to the presence of organic acids such as citric and malic acids, whereas puree had a buffering effect owing to its fiber content. All samples remained within the optimal pH range for yeast activity (4.0–5.0). Similar pH behavior was reported by da Cunha *et al.* (2023), who observed a decrease to pH 4.0 linked to fruit juice addition. Additionally, de Melo *et al.* (2017) confirmed that juice supplementation improved both fermentation performance and product quality.

The results show that the addition of red-flesh dragon fruit in juice form produced a higher ethanol concentration compared to the pureed form. However, adding too much fruit also inhibited the fermentation process. As clearly shown in Table 1, for the pureed form, the highest ethanol content was observed at 15% fruit addition, but when the level increased to 20%, the ethanol concentration dropped to around 2.92%. Similarly, in the juice form, ethanol production decreased to 5.58% at 20% addition, compared to 6.31% at 15%. However, in the experimental treatments, the beer sample supplemented with 10% red dragon fruit juice achieved an ethanol content that met both the fruit beer standards of commercial product and the desired target, while maintaining a balanced flavor profile.

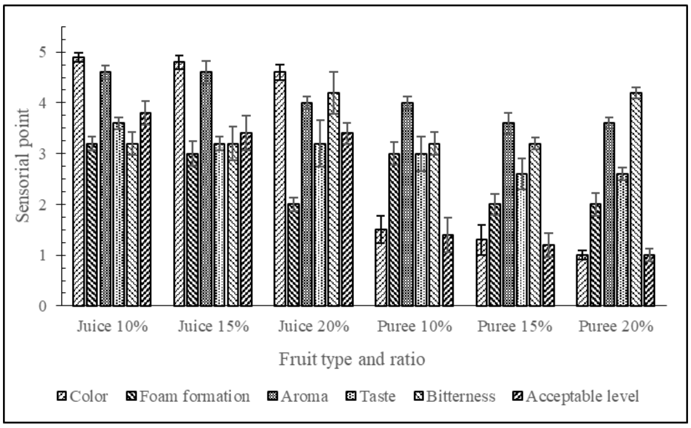

Figure 1. Sensory evaluation of red dragon fruit beer products with different types of raw materials and addition ratios.

Additionally, Figure 1 shows that the form and ratio of red dragon fruit supplementation influenced the clarity

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Table 2. Post-fermentation parameters of red dragon fruit beer products with different yeast concentrations.

Yeast concentration (% w/v)	Post-fermentation parameters			
	TSS (°Brix)	pH	Ethanol content (% v/v)	Reducing sugar content (g/100 mL)
0.02	5.50^{a} ± 0.00	4.03^{a} ± 0.63	4.48^{c} ± 0.47	7.06^{a} ± 0.45
0.04	5.67^{a} ± 0.29	4.55^{a} ± 0.05	5.53^{b} ± 0.08	5.38^{a} ± 1.11
0.06	5.47^{a} ± 0.06	4.58^{a} ± 0.06	6.37^{a} ± 0.45	5.20^{a} ± 1.23
0.08	5.37^{a} ± 0.32	4.55^{a} ± 0.03	5.61^{ab} ± 0.54	5.94^{a} ± 1.26

Note: Data in the table are the means of three replicates. In the same column, values with different superscript letters are significantly different ($p < 0.05$).

of the final product. Both puree and juice contain soluble compounds such as sugars, proteins and plant gums. Specifically, adding the fruit at high concentrations can cause turbidity in beer product. Although some solids are removed during fermentation and sedimentation, excessive addition particularly of the puree can result in beers with lower clarity compared to those supplemented with juice at lower concentrations (Gasinski *et al.,* 2020). Thus, optimizing the juice ratio is essential not only for enhancing color but also for maintaining product clarity, both of which contribute to the overall quality of the beer. The study by Pérez-Alva *et al.* (2023) also reported that fruit additions during beer fermentation increase polyphenol content, thereby improving the beer's color, flavor, and nutritional value. While increasing fruit content can intensify aroma and flavor, excessive amounts may overpower the characteristic malt and hop notes, reducing the distinctive sensory profile of the beer. This observation is consistent with the findings of Gasinski *et al.* (2020), who showed that higher concentrations of volatile compounds in mango-fortified beer did not always lead to improved flavor perception. Among all treatments, supplementation with 10% red dragon fruit juice yielded the most balanced product, with an ethanol content of approximately 5.53% v/v, a mild fruity sweetness and compliance with fruit beer standards.

3.2 The appropriate yeast concentration for the fermentation of red dragon fruit beer

Yeast concentration plays a vital role in the fermentation of fruit beer, directly affecting fermentation rate, alcohol production, aroma and overall product quality. An insufficient yeast concentration can slow fermentation and increase contamination risk, while excessive yeast may lead to overly rapid fermentation, reducing flavor control (Croonenberghs *et al.,* 2024). In fruit beer, where balance between sweetness, acidity, and alcohol is essential, selecting the appropriate yeast level helps preserve fruit aroma and ensure product consistency. In this study, *S. cerevisiae* was applied at 4 concentrations (0.02, 0.04, 0.06, and 0.08% w/v) to ferment red-fleshed dragon fruit beer. Table 2 shows that after 4 days of fermentation, a decrease of TSS was observed across all treatments, indicating sugar consumption by *S. cerevisiae*. This reflects typical fermentation kinetics, where yeast utilizes glucose primarily for ethanol production and biomass formation (Briggs *et al.,* 2004). Interestingly, at 0.04% of yeast concentration, TSS slightly increased (from 5.50 to 5.67 °Brix), likely due to initial yeast activity enhancing the breakdown of complex compounds into soluble forms, as well as possible release of intracellular components (e.g., amino acids, polysaccharides) contributing to higher solute content.

However, at higher yeast concentrations (0.06% and 0.08%), TSS declined to 5.47 °Brix and 5.37 °Brix, respectively, indicating rapid sugar consumption. Yet, excessive yeast can lead to nutrient competition, reduced sugar utilization efficiency, and self-inhibition due to ethanol accumulation and stress conditions (Kunze, 2010). This trend is consistent with findings by Huang *et al.* (2024), who reported that co-fermentation with different concentrations yielded a lower ethanol concentration while maintaining sensory quality.

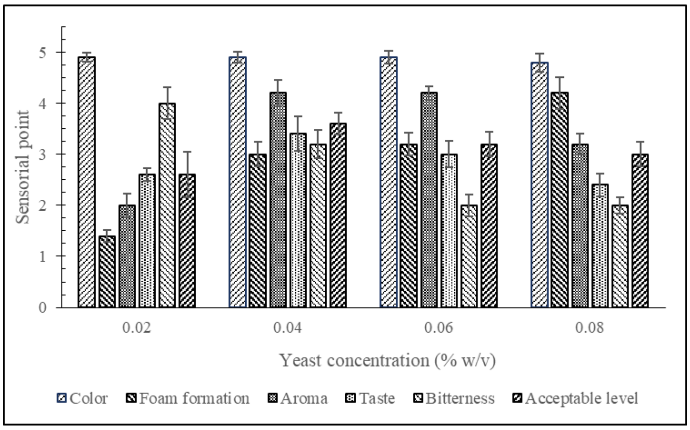

Figure 2. Sensory evaluation of red dragon fruit beer products with different yeast concentrations.

In terms of ethanol content, the 0.04% yeast treatment yielded 5.53% ethanol near the upper limit of the target range (4.5–5.5% v/v) while maintaining balanced flavor. Lower yeast levels (e.g., 0.02%) resulted in insufficient ethanol production (4.48% v/v), whereas higher levels (0.06–0.08%) led to ethanol contents exceeding the desirable range, potentially causing an overly alcoholic taste and unbalanced sensory profile. This trend aligns with findings by Duong and Hoang (2020) and Nguyen and Nguyen (2022). Moreover, the 0.04% treatment retained a moderate level of residual reducing sugars (5.38 g/100 mL), preserving

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Table 3. Post-fermentation parameters of red dragon fruit beer products with different fermentation temperature and time.

Factors		Post-fermentation parameters			
Temperature (°C)	Time (day)	TSS (°Brix)	pH	Ethanol content (% v/v)	Reducing sugar content (g/100 mL)
22	2	$7.83^{b} \pm 0.29$	$4.45^{b} \pm 0.10$	$4.58^{de} \pm 0.97$	$5.55^{b} \pm 0.63$
26	2	$10.83^{a} \pm 2.25$	$4.76^{a} \pm 0.20$	$4.09^{e} \pm 0.79$	$11.69^{a} \pm 1.06$
30	2	$7.83^{b} \pm 0.29$	$4.35^{bc} \pm 0.14$	$5.29^{cd} \pm 0.11$	$5.05^{b} \pm 0.71$
22	4	$6.00^{cd} \pm 0.00$	$4.25^{cd} \pm 0.16$	$4.98^{cde} \pm 0.08$	$2.41^{e} \pm 0.19$
26	4	$6.33^{cd} \pm 0.29$	$4.11^{de} \pm 0.08$	$5.66^{bc} \pm 0.28$	$3.43^{c} \pm 0.48$
30	4	$6.17^{cd} \pm 0.29$	$4.18^{de} \pm 0.05$	$7.42^{a} \pm 0.23$	$2.48^{d} \pm 0.15$
22	6	$6.17^{cd} \pm 0.29$	$4.20^{cde} \pm 0.07$	$5.75^{bc} \pm 0.43$	$2.31^{de} \pm 0.40$
26	6	$6.33^{cd} \pm 0.29$	$4.06^{e} \pm 0.02$	$6.44^{ab} \pm 0.57$	$2.19^{de} \pm 0.41$
30	6	$6.50^{c} \pm 0.00$	$4.08^{e} \pm 0.02$	$7.39^{a} \pm 0.19$	$2.02^{de} \pm 0.05$
22	8	$5.50^{cd} \pm 0.00$	$4.28^{abc} \pm 0.12$	$6.31^{b} \pm 0.74$	$1.63^{de} \pm 0.32$
26	8	$5.50^{cd} \pm 0.00$	$4.21^{cde} \pm 0.06$	$6.59^{ab} \pm 0.78$	$2.13^{de} \pm 0.31$
30	8	$5.33^{d} \pm 0.29$	$4.14^{de} \pm 0.04$	$7.38^{a} \pm 0.46$	$2.02^{de} \pm 0.21$

Note: Data in the table are the means of three replicates. In the same column, values with different superscript letters are significantly different ($p < 0.05$).

a pleasant natural sweetness and avoiding excessive dryness. Yeast stress was also minimized, reducing the risk of unwanted by-products like aldehydes or organic acids. Overall, the figures in Figure 2 indicated that both 0.04% and 0.06% treatments produced acceptable color, aroma, and taste, but 0.06% was slightly over-alcoholic with lower perceived bitterness. Therefore, 0.04% w/v yeast concentration was selected as the most appropriate level for red-fleshed dragon fruit beer fermentation, balancing ethanol production, fermentation efficiency, and sensory quality.

3.3 Suitable temperature and time for the fermentation process of red dragon fruit beer

Many studies on the influence of different temperatures and time for the fermentation process of craft beer have been carried out. Specifically, de Melo *et al.* (2017) also conducted a study on beer fermentation supplemented with passion fruit at temperatures of 15°C and 22°C, recording ethanol content results of 7.61% and 8.29% v/v, respectively. In this experiment, the post-fermentation parameters of red dragon fruit beer products with different fermentation temperature and time were determined and the results are presented in Table 3. Ethanol concentration increased with fermentation time across all temperature conditions, peaking on day 8. Ethanol levels were lowest on day 2, then increased significantly by days 4 and 6. This trend reflects typical yeast dynamics, where early fermentation is dominated by yeast adaptation and biomass growth, followed by active sugar conversion to ethanol under anaerobic conditions (Bamforth, 2023). Changes in pH, TSS, and reducing sugars also support this progression. pH declined to 4.00–4.76, TSS dropped from 13.0 to 5.33–5.50 °Brix by day 8, and reducing sugars followed a similar decreasing trend, indicating active sugar consumption. These findings align with Adadi *et al.* (2017), who noted that the fermentation of sea buckthorn -supplemented beer led to a notable decrease in °Brix and pH, indicating active sugar consumption by yeast.

Temperature influenced ethanol yield and fermentation kinetics. Ethanol levels slightly increased at

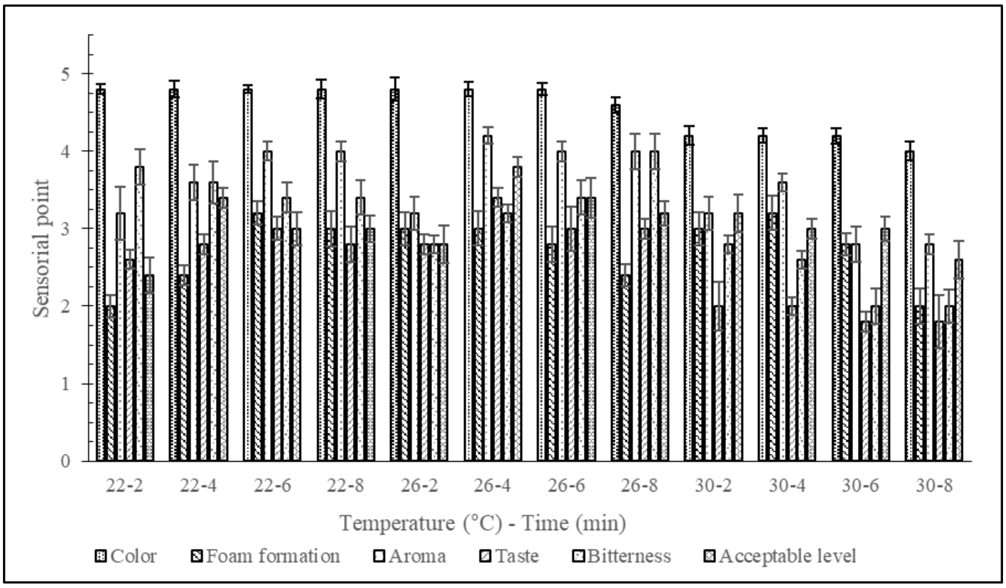

Figure 3. Sensory evaluation of red dragon fruit beer products with different fermentation temperature and time.

Table 4. Post-fermentation parameters of red dragon fruit beer products with different pasteurization temperatures and time.

Temperature (°C)	Time (min)	Total yeast and mold count (Log CFU/g)	Total aerobic microorganisms (Log CFU/g)
58	5	<1.00	3.48
58	10	<1.00	3.18
58	15	<1.00	3.35
63	5	<1.00	2.91
63	10	<1.00	2.40
63	15	<1.00	2.65
65	5	<1.00	1.90
65	10	<1.00	<1.00
65	15	<1.00	<1.00

Note: Data in the table are the means of three replicates.

26°C, they were generally highest at 30°C, suggesting enhanced enzymatic activity and yeast growth at elevated temperatures. However, rapid fermentation at high temperatures can deplete nutrients and produce off-flavors if not controlled (Olaniran *et al.,* 2017). pH also tended to decrease more at higher temperatures, likely due to organic acid production, which, if excessive, may inhibit yeast and alter flavor (Bamforth, 2023). At 26°C, pH remained within the ideal range (4.06–4.11), supporting yeast stability. Ethanol levels rose sharply by day 4 (4.96–7.42% v/v), with the highest value recorded at 30°C. Beyond day 6, ethanol increased and plateaued, especially at 30°C, suggesting fermentation saturation. Although °Brix and reducing sugars continued to decrease, the rate slowed, indicating reduced yeast activity. These findings align with Tahir *et al.* (2010), who noted that extended fermentation without sufficient nutrients may lead to metabolic slowdown and undesirable by-products.

Figure 3 shows that beers fermented at 22°C and 26°C across all time points met acceptable standards for fruit beer in terms of color, aroma, and taste. However, samples fermented at 22°C exhibited poor foam formation, likely due to lower fermentation efficiency and CO_2 production. The 26°C and 4-day treatment achieved balanced aroma, good foam stability, and an ethanol content of 5.66% v/v, making it the most favorable. In contrast, fermentation at 30°C resulted in less harmonious flavors and inconsistent bitterness (2.6–3.2), negatively affecting drinkability. Aroma and foam quality were also less appealing compared to lower-temperature treatments. Also, at 30°C fermentations, yeast cell density may have been lost due to autolysis and could have resulted in an increase in free fatty acid concentrations in the beer because of solubilization of membrane lipids, thus resulting in lower foam head stability. It has been previously reported that the presence of lipids or free fatty acids in beer could lead to a decrease in beer foam head stability (Dickie *et al.,* 2001; Van Nierop *et al.,* 2004).

In conclusion, fermenting red dragon fruit beer at 26°C for 4 days was found to be the most suitable condition, achieving a stable ethanol concentration, desirable sensory attributes and overall product quality.

3.4 The influence of suitable pasteurization conditions for red dragon fruit beer

Pasteurization also helps limit the risk of continued fermentation in the bottle, avoiding the phenomenon of beer becoming cloudy or exploding due to high pressure. For the above reasons, it is necessary to survey the appropriate pasteurization time and temperature for red-fleshed dragon fruit beer products. The results of the post-pasteurization indicators at different times and temperatures are presented in Table 4. Yeast or mold were not detected at any pasteurization temperature or time tested. This is consistent with findings from Safwa *et al.* (2024), who reported that most yeast and mold cells are inactivated at above 60°C due to membrane disruption and enzyme denaturation. Heat-resistant spores, such as those from *Aspergillus* and *Penicillium*, may require longer exposures or additional treatments (e.g., filtration or UV). Wray (2025) emphasized that aerobic bacteria and spoilage yeasts are typically inhibited above 50°C, but spore-forming bacteria (e.g., *Bacillus*, *Clostridium*) may survive unless treated with prolonged heat or combined methods. Rachon *et al.* (2021) noted the lack of standardized PU thresholds, highlighting the risk of over-pasteurization and potential flavor degradation. Therefore, both microbiological safety and sensory quality were considered in selecting optimal conditions.

Based on data in Table 4, pasteurization at 65°C for 10 min effectively eliminated spoilage organisms while preserving ethanol content (5.09% v/v), meeting fruit beer requirements. Although higher temperatures or longer times may enhance microbial control, they also risk degrading betacyanins, the pigments responsible for the red color of dragon fruit. Studies by Chew *et al.* (2019) and Pandiselvam *et al.* (2023) confirmed that betalains are heat-sensitive and prone to oxidation, particularly in the presence of oxygen, leading to discoloration and off-flavors.

The sensory evaluation presented in Figure 4 confirmed that pasteurization at 65°C for 10 min maintained acceptable color, flavor, and foam properties without formation of undesirable compounds such as

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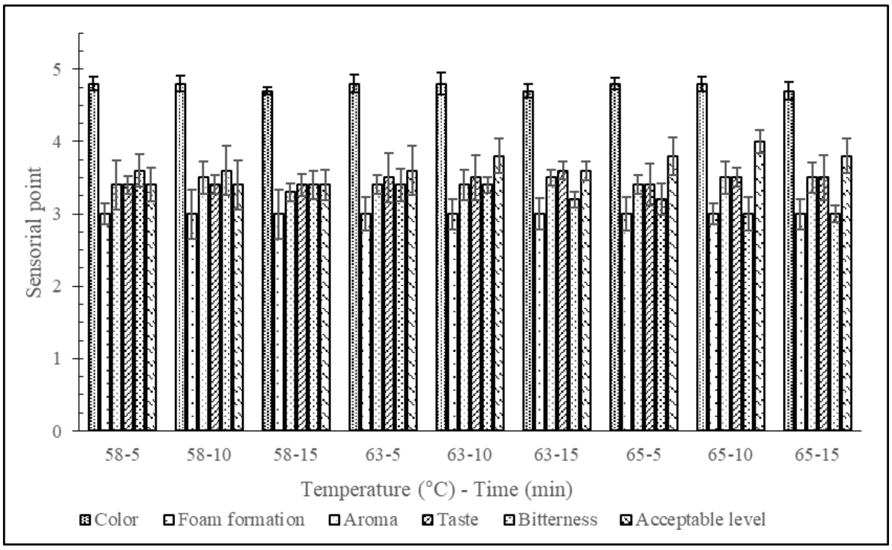

Figure 4. Sensory evaluation of red dragon fruit beer products with different pasteurization temperature and time.

melanoidins. No microbial growth was detected at either 10 or 15 min, but 10 min was selected to reduce energy costs and processing time. Additionally, storing the beer in amber bottles at low temperature post-pasteurization further enhanced stability and flavor retention. Thus, pasteurization at 65°C for 10 min was identified as the optimal condition for red dragon fruit beer, balancing microbial safety, product quality and economic efficiency.

Conclusion

Two types of red dragon fruit raw materials processed by two methods: pureeing and juicing, red dragon fruit juice was found to be more suitable for the fermentation process of red dragon fruit beer. The suitable conditions for the fermentation process of red dragon fruit beer are to add a ratio of 10% dragon fruit juice, a yeast ratio of 0.04% w/v at 26°C for 4 days, resulting in an ethanol content reaches 5.66% v/v. Moreover, the red dragon fruit beer product pasteurized at 65°C for 10 min demonstrated microbial safety, as key indicators such as total aerobic microorganisms and total yeasts and molds remained below 1.00 Log CFU/g after pasteurization.

Conflict of interest

The authors declare no conflict of interest.

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References

Adadi, P., Kovaleva, E.G., Glukhareva, T.V., Shatunova, S.A. and Petrov, A.S. (2017). Production and analysis of nontraditional beer supplemented with sea buckthorn. *Agronomy Research,* 15(5), 1831–1845. https://doi.org/10.15159/AR.17.060

Arivalagan, M., Karunakaran, G., Roy, T.K., Dinsha, M., Sindhu, B.C., Shilpashree, V.M., Satisha, G.C. and Shivashankara, K.S. (2021). Biochemical and nutritional characterization of dragon fruit (*Hylocereus* species). *Food Chemistry*, 353(2), 129426. https://doi.org/10.1016/j.foodchem.2021.129426

Ambra, R., Pastore, G. and Lucchetti, S. (2021). The role of bioactive phenolic compounds on the impact of beer on health. *Molecules,* 26(2), 486. https://doi.org/10.3390/molecules26020486

Briggs, D.E., Boulton, C.A., Brookes, P.A. and Stevens, R. (2004). Brewing: Science and Practice. CRC Press: Boca Raton, FL, USA. https://doi.org/10.1201/9780203024195

Bamforth, C.W. (2023). Beer: Tap into the Art and Science of Brewing (4^{th} ed.). Oxford University Press: New York, NY, USA. https://doi.org/10.1093/oso/9780199996742.001.0001

Chew, Y.M., Hung, C.H. and King, V.A.E. (2019). Accelerated storage test of betalains extracted from the peel of pitaya (*Hylocereus cacti*) fruit. *Journal of Food Science and Technology,* 56(3), 1595–1600. https://doi.org/10.1007/s13197-019-03673-1

Croonenberghs, A.P., Bongaerts, D., Bouchez, A., De Roos, J. and De Vuyst, L. (2024). Fruit beers, beers with or without a co-fermentation step with fruits. *Current Opinion in Biotechnology,* 86, 103081. https://doi.org/10.1016/j.copbio.2024.103081

Dickie, K.H., Cann, C., Norman, E.C., Bamforth, C.W. and Muller, R.E. (2001). Foam negative materials. *Journal of the American Society of Brewing Chemists,* 59(1), 17–23. https://doi.org/10.1094/ASBCJ-59-0017

de Melo, V.F., Araújo, G.S., Bispo, J.A.C., Del Bianchi, V.L. and de Carvalho, G.B.M. (2017). Effect of different concentrations of bush passion fruit pulp and temperature in the production of beer. *African Journal of Biotechnology*, 16(20), 1150-1158. https://doi.org/0.5897/AJB2016.15613

Duong, T.N.D. and Hoang, Q.B. (2020). Study on red dragon fruit (*Hylocereus polyrhizus*) wine fermentation. *Journal of Agriculture and Development,* 19(4), 56–63. Retrieved from https://jad.hcmuaf.edu.vn/index.php/jadvn/article/view/300/273

da Cunha, N.B., Oliveira, J.R. and Andrade, F. (2023). Production and characterization of craft beers with different additions of native fruits and agro-industrial residues: A review. *Ciencia Rural,* 53(9), e20220194. http://doi.org/10.1590/0103-8478cr20220194

Gasinski, A., Kawa-Rygielska, J. and Pietrzak, W. (2020). Effect of mango addition on volatile compound profile and sensory properties of beer. *European Food Research and Technology,* 246(3), 479–489. https://doi.org/10.1007/s00217-019-03411-y

Hornsey, I.S. (2003). A History of Beer and Brewing. Cambridge, UK: Royal Society of Chemistry. https://doi.org/10.1039/9781847550026

Huang, P.H., Lin, Y.C., Lin, Y.W., Zhang, Y.W. and Huang, D.W. (2024). The potential of co-fermentation with *Pichia kluyveri* and *Saccharomyces cerevisiae* for the production of low-alcohol craft beer. *Foods,* 13(23), 3794. https://doi.org/10.3390/foods13233794

Joshi, M. and Prabhakar, B. (2020). Phytoconstituents and pharmaco-therapeutic benefits of pitaya: A wonder fruit. *Journal of Food Biochemistry,* 44(7), e13260. https://doi.org/10.1111/jfbc.13260

Kunze, W. (2010). Technology brewing and malting (4^{th} ed.). VLB Berlin: Berlin, Germany.

Lim, T.W., Lim, R.L.H., Pui, L.P., Tan, C.P. and Ho, C.W. (2025). Red dragon fruit (*Hylocereus polyrhizus*), a superfruit rich in betacyanins pigments with antioxidative potential for hepatoprotection: A review. *Future Foods*, 11, 100562. https://doi.org/10.1016/j.fufo.2025.100562

Miller, G.L. (1959). Use of dinitrosalicylic acid reagent for determination of reducing sugar. *Analytical Chemistry*, 31 (3), 426–428. https://doi.org/10.1021/ac60147a030

Nguyen, P.T. and Nguyen, V.T. (2022). Isolation, selection, and identification of yeasts in the fermentation of king orange (*Citrus nobilis* var. *typica* Hassk.) wine. *Can Tho University Journal of Science,* 58(1), 121–131. https://doi.org/10.22144/ctu.jvn.2022.013

Nithya, C. (2025). Recent innovations and opportunities in red dragon fruit (*Hylocereus polyrhizus*) juice processing and value addition: A review. *International Journal of Agriculture and Nutrition,* 7(4), 10–19. https://doi.org/10.33545/26646064.2025.v7.i4a.214

Olaniran, A.O., Hiralal, L., Mokoena, M.P. and Pillay, B. (2017). Flavour-active volatile compounds in beer: Production, regulation and control. *Journal of the Institute of Brewing*, 123(1), 13–23. https://doi.org/10.1002/jib.389

Pandiselvam, R., Mitharwal, S., Rani, P., Shanker, M.A., Kumar, A., Aslam, R. and Khaneghah, M.A. (2023). The influence of nonthermal technologies on color pigments of food materials: An updated review. *Current Research in Food Science*, 6(1), 100529. https://doi.org/10.1016/j.crfs.2023.100529

Pérez-Alva, R., Ramírez-Rodrigues, A., Martínez-Jiménez, M.A., García-Torres, L.A. and Ramírez-Rodrigues, M.M. (2023). Physicochemical and micronutrient characterization of commercial red fruit beers. *Food and Humanity*, 1(3), 271–280. https://doi.org/10.1016/j.foohum.2023.06.004

Pham, T.V., Cao, T.X., Le, N.T.H., Pham, A.M., Trinh, H.T., Nguyen, D.T., Hoang, L.A.T., Bui, M.Q., Nguyen, N.T., Truong, M.N. and Hoang, T.M. (2024). Enhancing the quality and consumer satisfaction of dragon fruit beverage production: The effects of geological origin and processing conditions. *Science Progress*, 107(4). https://doi.org/10.1177/00368504241300854

Rachon, G., Kostrzewa, P. and Kowalska, H. (2021). Heat resistance of yeast ascospores and their utilisation for the validation of pasteurisation processes for beers. *Journal of the Institute of Brewing,* 127(2), 149–159. https://doi.org/10.1002/jib.646

Rojas-Sandoval, J. and Praciak, A. (2021). *Hylocereus undatus* (dragon fruit). *CABI Compendium,* 27317. https://doi.org/10.1079/cabicompendium.27317

Sohrabvandi, S., Mortazavian, A.M. and Rezaei, K. (2012) Health-related aspects of beer: A review, *International Journal of Food Properties*, 15(2), 350–373. https://doi.org/10.1080/10942912.2010.487627

Sriariyanun, M., Phongphisutthinant, R. and Punyalue, S. (2019). A rapid spectrophotometric method for ethanol determination in fermented beverages. *Oriental Journal of Chemistry,* 35(2), 744–750. http://dx.doi.org/10.13005/ojc/350234

Safwa, M.S., Ahmed, T., Talukder, S., Sarkar, A. and Rana, M.R. (2024). Applications of non-thermal technologies in food processing industries - A review. *Journal of Agriculture and Food Research*, 18, 100917. https://doi.org/10.1016/j.jafr.2023.100917

Tahir, H.E., Xiaobo, Z. and Mahunu, G.K. (2010). Effects of extended fermentation on quality of fruit wines. *African Journal of Biotechnology,* 9(45), 7697–7703. https://doi.org/10.5897/AJB10.1206

Tabaszewska, M., Kłosowski, G. and Szot, B. (2022). Use of fruit juice vs. puree in beer fermentation: Physicochemical and sensory outcomes. *Applied Sciences,* 12(10), 4873. https://doi.org/10.3390/app12104873

Van Nierop, S.N.E., Evans, D.E., Axcell, B.C., Cantrell, I.C. and Rautenbach, M. (2004). Impact of different wort boiling temperatures on the beer foam stabilizing properties of lipid transfer protein 1. *Journal of Agricultural and Food Chemistry,* 52(10), 3120–3129. https://doi.org/10.1021/jf035125c

Vietnam Ministry of Science and Technology. (1995). National Standard TCVN 6063:1995. Beer – Sensory analysis – Method by presenting mark. Hanoi, Vietnam.

Wray, J. (2025). Chapter 12 - Reducing microbial spoilage of beer using pasteurisation. In Hill, A.E. (Ed). Brewing Microbiology - Managing Microbes, Ensuring Quality and Valorising Waste (2^{nd} Edition), p. 201–212. West Sussex, United Kingdom: Woodhead Publishing Series in Food

Science, Technology and Nutrition. https://doi.org/10.1016/B978-1-78242-331-7.00012-5

Yin, H., Wang, L. and Chen, J. (2021). Improving oxidative stability and sensory properties of ale beer by enrichment with dried red raspberries (*Rubus idaeus* L.). *Journal of the American Society of Brewing Chemists,* 79(4), 370–377. https://doi.org/10.1080/03610470.2020.1864801

Zeng, Y., Ahmed, H.G.M., Li, X., Yang, L., Pu, X., Yang, X., Yang, T. and Yang, J. (2024). Physiological mechanisms by which the functional ingredients in beer impact human health. *Molecules,* 29(13), 3110. https://doi.org/10.3390/molecules29133110

