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Valorization of Red-Fleshed Dragon Fruit Through the Development of a Betacyanin-Rich Functional Cordial

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Abstract: Dragon fruit (*Hylocereus polyrhizus*) is a nutrient-rich fruit recognized for its high antioxidant activity, betalain pigments, vitamin C, and functional health benefits. The present study aimed to develop and evaluate a value-added dragon fruit cordial with desirable physicochemical, sensory, and microbiological qualities. Fresh red-fleshed dragon fruits were processed into cordial using standardized levels of sugar, citric acid, and carboxymethyl cellulose (CMC). The developed product was analyzed for pH, titratable acidity, total soluble solids (TSS), reducing and non-reducing sugars, total sugar, ash, vitamin C, betacyanin content, sensory attributes, and microbiological quality using standard analytical methods. The optimized cordial exhibited a pH of 4.91, titratable acidity of 0.59%, total soluble solids of 35°Brix, sugar-to-acid ratio of 58.04, total sugar content of 82%, ash content of 0.76%, vitamin C content of 11.44 mg/100 mL, and betacyanin content of 8.9 mg. Sensory evaluation using a nine-point hedonic scale indicated that Sample B achieved the highest scores for flavour, consistency, aftertaste, and overall acceptability, while the control sample scored highest for colour and appearance. Microbiological analysis confirmed that the cordial met recommended safety standards, with no detectable pathogenic microorganisms. The findings demonstrate that dragon fruit cordial is a nutritionally enriched, microbiologically safe, and consumer-acceptable beverage with considerable potential for value addition and commercial production.

Keywords: *Dragon Fruit, Hylocereus polyrhizus, Cordial, Value-Added Beverage, Sensory Evaluation, Physicochemical Properties, Betacyanin, Vitamin C, Microbiological Quality.*

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I. INTRODUCTION

Cordials are concentrated, non-alcoholic beverages prepared by blending fruit juice or extracts with sugar, water, and sometimes natural flavourings or food-grade acids. They are intended to be diluted before consumption, making them economical and versatile beverages (Luder et al., 1999). Although the nutritional value of cordials depends on their composition, many contain fruit extracts and vitamin C, while some modern formulations include reduced sugar, natural sweeteners, and higher fruit content to meet health-conscious consumer demands (David A. et al., 1996). The production process involves extraction and filtration of fruit juice, blending with sugar syrup, addition of acids such as citric acid, pasteurization, and hygienic bottling to ensure quality and safety (SLS et al., 1985).

Dragon fruit or pitaya (*Hylocereus* spp.), belonging to the Cactaceae family, is an exotic fruit native to Mexico, Central, and South America and is now widely cultivated in Asian countries, including India (Mizrahi et al., 1997). Known as the “Queen of the Night” because of its nocturnal flowering habit, it is also called strawberry pear, night-blooming cereus, and Cinderella plant (Zee et al., 2004). Dragon fruit is valued for its attractive appearance, pleasant flavour, and rich nutritional profile. It contains antioxidants, dietary fibre, vitamins B and C, calcium, phosphorus, and iron (Tripathi et al., 2014).

Red-fleshed dragon fruit is particularly rich in betalain pigments, including betacyanins and betaxanthins, which possess strong antioxidant properties (Vinod et al., 2021; Wybraniec and Mizrahi, 2004). It is associated with several

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health benefits such as anti-inflammatory, anti-diabetic, and anti-cancer activities (Gunasena et al., 2007).

Due to its short shelf life in fresh form, processing dragon fruit into value-added products such as jams, jellies, and cordials helps extend its usability. Increasing consumer demand for natural, colourful, and functional beverages highlights the potential of dragon fruit cordial as a nutritious, visually appealing, and commercially viable product.

II. MATERIALS AND METHODS

The present investigation entitled was conducted in the Food Technology Laboratory, CSI College for Advanced Studies, Punnakkad, Kozhencherry, Kerala, India. The study involved the development, standardization, physicochemical characterization, and sensory evaluation of dragon fruit cordial.

- *Sample Collection and Preparation:* We purchased fresh, completely ripe red-fleshed dragon fruits (Hylocereus polyrhizus) from Kozhencherry, Kerala, local markets. We bought food-grade citric acid, carboxymethyl cellulose (CMC), and commercial cane sugar (Saccharum officinarum) from approved retail stores. Every chemical and reagent utilized in analytical research was of analytical grade. The experiment was conducted using standard laboratory equipment and Borosil® glassware. Dragon fruit was chosen for the creation of value-added beverages because of its high antioxidant content, betalain pigments, dietary fibre, and functional qualities (Perween et al., 2018; Luu et al., 2021; Mahesh et al., 2021).
- *Product Formulation and Standardization:* To standardize the cordial formulation based on colour, flavour, consistency, and general acceptability, preliminary testing were carried out. Three experimental formulations were created and assessed. For more research, the formulation with the best sensory qualities was chosen.

Table 1 Showing the Ingredients Formulation of the Developed Product.

Ingredient	Quantity
Dragon fruit pulp	970 g
Sugar	70 g
Citric acid	1.1 g
Carboxymethyl cellulose (CMC)	2 g

- *Preparation of Dragon Fruit Cordial:* To get rid of toxins and clinging dirt, fresh dragon fruits were thoroughly cleaned under running water. To lower the microbial burden and enzyme activity, the fruits were blanched for two minutes at 60°C. To create a uniform puree, the pulp was crushed after the peel was manually removed. After adding the necessary amount of sugar to the pulp, it was cooked for five to ten minutes while being constantly stirred. Afterwards, citric acid was added to enhance product stability and flavour balance. The addition of carboxymethyl cellulose served as a thickening and stabilizing agent. Total soluble solids (TSS) and the required consistency were attained by heating the mixture. After cooling to room temperature, the cordial was put into glass bottles that had been sterilized for analysis and storage. The processing technique was modified from typical fruit beverage preparation methods outlined by Malik et al. (2022) and Raju et al. (2023).
- *Flow of Cordial Preparation:* Selection of ripe fruits → Washing → Blanching (60°C, 2 min) → Peeling → Pulp extraction → Addition of sugar → Heating (5–10 min) → Addition of citric acid → Addition of CMC → TSS adjustment → Cooling → Bottling → Storage.
- *Preparation of cocktails using cordial:* Approximately 30 mL of dragon fruit cordial was blended with 150 mL of cooled water/carbonated water. Add ice cubes and mint leaves. It can be consumed directly. It gives instant refreshment to body.

III. PHYSICOCHEMICAL ANALYSIS

- *Evaluation of Quality Parameters:* Nine members of a semi-trained panel performed the sensory examination. A nine-point hedonic scale, with 9 representing "like extremely" and 1 representing "dislike extremely," was used to evaluate the cordial samples' color and appearance, flavor, consistency, aftertaste, and general acceptability (Stone and Sidel, 2004). The most acceptable formulation was determined by calculating mean sensory scores.
- *Evaluation of physicochemical parameters*: Standard AOAC procedures were used to examine the developed cordial's physicochemical characteristics (AOAC, 2023). A calibrated digital pH meter was used to detect the pH, and phenolphthalein was used as an indicator in a titration with 0.1 N NaOH to estimate the titratable acidity (AOAC 942.15). A hand refractometer was used to quantify total soluble solids (TSS), which were then expressed as °Brix. The permanganometric method, which is based on the oxidation of ascorbic acid by potassium permanganate in an acidic media, was used to measure the amount of vitamin C. By dry ashing in a muffle furnace at 550°C until a steady weight was achieved, the amount of ash was ascertained. Fehling's solution was used in the Lane and Eynon titrimetric method to determine reducing and non-reducing sugars. The collected analytical results were used to compute the total sugar content and the sugar-to-acid ratio. Spectrophotometric analysis was used to determine the total betacyanin concentration. Distilled water or acidified methanol were used to extract pigments, and absorbance was measured at 538 nm. According to

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Stintzing et al. (2005), the concentration of betacyanin was determined using the Beer–Lambert law.

- *Microbiological Analysis:* The dragon fruit cordial's microbiological quality was assessed using conventional AOAC and APHA protocols (APHA, 2015). Using Plate Count Agar, serial dilution and pour plate methods were used to calculate the total plate count (TPC). Results were reported as colony-forming units per millilitre (CFU mL^{-1}) after samples were cultured for 48 hours at 35 ± 1°C (AOAC 966.23). Potato Dextrose Agar (PDA) acidified with tartaric acid was used to measure yeast and mold counts. After three to five days of incubation at 25 to 28°C, colonies were measured in CFU mL^{-1}.Using selected culture medium and conventional enumeration techniques, the presence of indicator and pathogenic microorganisms, such as coliform bacteria, Escherichia coli, and Staphylococcus aureus, was evaluated (AOAC 966.24; AOAC 998.08; AOAC 987.09). To assess product safety and shelf stability, results were compared with microbiological standards recommended for fruit beverages.

IV. RESULT & DISCUSSION

Cordials are liquid drinks, usually created from a variety of ingredients, that are primarily used as refreshment. In general, their nutritional value often differs from that of other beverages. In the present investigation, efforts were made to standardize the process for preparing a dragon fruit cordial, aiming to make it a versatile mixture, flavoring and sweetening agent. During the study numerous pre-trials were conducted. Red fleshed dragon fruit and cane sugar were selected as the primary ingredients, with carboxy methyl cellulose serving as the thickening agent. Citric acid was employed to enhance the flavor and lengthen the shelf life.

- *Preliminary trials for preparation of dragon fruit cordials:* Preliminary trials were conducted to select ingredients for the manufacture of a dragon fruit cordial. The trails were evaluated through sensory analysis assessing colour, flavor, texture, and overall acceptability. These preliminary trials were conducted in three phases, with a total of two different combinations (sample A and B) were subjected to sensory evaluated using the 9- point hedonic scale. The combinations were prepared by varying the proportions of dragon fruit pulp, and sugar.
- *Optimization of ingredients:* The selected ingredients were optimized by using sensory evaluation method. The sensory evaluation was conducted by semi trained panelists by using 9- point hedonic scale.

Table 2 Showing the Optimized Value of Ingredients Used for the Production of Cordial.

SI. NO.	INGREDIENTS	PROPORTION (g)
1	Dragon fruit (pulp)	200 g
2	Sugar	70 g
3	Carboxy methyl cellulose	2 g
4	Citric acid	1.1 g

- *Evaluation of physio chemical, Microbial, and sensory properties:* Physicochemical properties of the dragon fruit cordial sample B are summarized in Table 3. The key chemical parameters analyzed included total soluble solids, titratable acidity, P^H, ash, reducing sugar, non-reducing sugar, total vitamin c, sugar acid ratio and total sugar content. These analyses provide essential data on the shelf-stability, nutrient density. The ash content determines the total mineral content. Total vitamin c is the indication of nutritional quality and antioxidant potential. Sweetness and fermentability are determined by using reducing sugar. P^H is crucial for predicting the product's shelf-life and risk of microbial spoilage, it is derived from the raw materials.
- *Sensory evaluation:* The sensory evaluation of the developed dragon fruit cordial samples (Sample A and Sample B) and the control sample was carried out using a 9-point hedonic scale to assess colour and appearance, flavour, consistency, aftertaste, and overall acceptability. The results, illustrated in the radar chart fig no 1, revealed significant differences in consumer preference among the samples. The control sample obtained the highest score for colour and appearance (≈9), indicating superior visual appeal compared to the formulated samples. Sample B received a score of approximately 8, while Sample A recorded the lowest score (≈7), suggesting that although both formulations were visually acceptable, the control possessed a more attractive appearance. In contrast, Sample B exhibited the highest scores for flavour (≈7), consistency (≈7), aftertaste (≈7.5), and overall acceptability (≈7.5–8), outperforming both Sample A and the control sample. Sample A achieved intermediate scores for these attributes, whereas the control sample consistently received the lowest ratings for flavour, consistency, aftertaste, and overall acceptability (≈5–6). The improved sensory performance of Sample B may be attributed to the optimized formulation, which likely provided a balanced sweetness, desirable texture, and pleasant aftertaste. Although the control sample was preferred for its appearance, its lower scores for other sensory attributes suggest that visual appeal alone was insufficient to influence overall consumer preference. The higher overall acceptability of Sample B demonstrates that flavour, consistency, and aftertaste played a greater role in determining panellists' preference. These findings indicate that Sample B represents the most acceptable formulation and has good potential for consumer acceptance and commercialization as a value-added dragon fruit cordial.

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- *Physiochemical analysis of dragon fruit cordial:* The desirable quality attributes in terms of acidity, sweetness, nutritional composition, and pigment stability. These parameters shown in table 3; play an important role in determining the sensory acceptability, shelf stability, and nutritional value of fruit cordials. The pH value of 4.91 indicates that the cordial is moderately acidic. Acidic conditions are desirable in fruit beverages as they help inhibit the growth of spoilage microorganisms and contribute to product stability during storage. Although the pH is slightly higher than that of highly acidic fruit juices, it remains within the acceptable range for fruit-based cordials and contributes to a balanced flavour profile.

The titratable acidity of 0.59% further confirms the mild acidic nature of the formulation. Titratable acidity is a key quality parameter influencing the taste and preservation of fruit beverages. A moderate level of acidity helps enhance the refreshing taste of the cordial while balancing the high sugar content. This level of acidity is appropriate for cordial formulations, where excessive acidity may negatively affect palatability.

The total soluble solids (35°Brix) indicate a high concentration of dissolved sugars and soluble components in the cordial. High °Brix values are typical in cordial formulations since they are concentrated beverages designed to be diluted before consumption. The high soluble solids content contributes to sweetness, viscosity, and improved shelf stability.

The sugar-to-acid ratio of 58:04 suggests a strong predominance of sweetness over acidity. This high ratio indicates that the cordial has a pleasant sweet taste with only mild tartness which is desirable for consumer acceptability. The ratio also suggests that the formulation successfully balanced sweetness and acidity to achieve a palatable beverage.

The analysis of sugar composition revealed 31% reducing sugars and 51.3% non-reducing sugars, resulting in a total sugar content of 82%. The presence of reducing sugars such as glucose and fructose contributes to sweetness and flavour development, while non-reducing sugars, mainly sucrose, provide body and enhance the overall sweetness of the beverage. The high sugar content is characteristic of cordials and also acts as a natural preservative by reducing water activity.

The total ash content of 0.76% indicates the presence of mineral constituents in the cordial. Minerals contribute to the nutritional value of the beverage and may originate from the fruit pulp as well as other ingredients used during formulation.

The vitamin C content of 11.44 mg/100 ml demonstrates that the cordial retains a moderate level of ascorbic acid even after processing. Vitamin C is an important antioxidant that contributes to the nutritional and functional properties of the beverage. Although some loss of vitamin C may occur during processing and storage, the retained amount still enhances the health value of the cordial.

Another notable parameter is the total betacyanin content of 8.9 mg, which represents the natural red-violet pigment present in dragon fruit. Betacyanin not only provide the characteristic attractive colour of the cordial but also possess antioxidant properties. The retention of these pigments indicates that the formulation and processing conditions were suitable for maintaining he natural colour and functional compounds of the fruit.

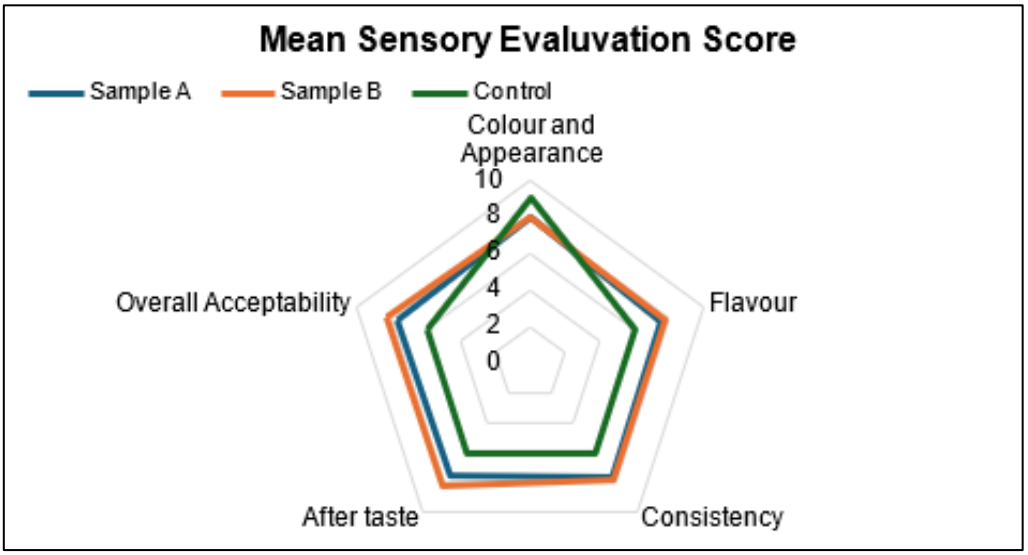


Fig 1 The Radar Chart Corresponding to the Sensory Analysis of Developed Dragon Fruit Cordial. This Chart Indicates the Mean Rank of Appearance, Colour, Appearance, Body, Texture, Consistency and Overall Acceptability for the Developed Dragon Fruit Cordial.

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Fig 2 Dragon Fruit Cordial

Table 3 Showing the Physiochemical Parameters for Red Flesh Dragon Fruit Cordial.

SI NO	PARAMETER	RESULT
1	pH	4.91
2	Titratable acidity	0.59%
3	Total soluble solids	35^0 Brix
4	Sugar to acid ratio	58:04
5	Total ash	0.76%
6	Vitamin C	11.44mg/100ml
7	Total sugar	82%
8	Total betacyanin	8.9mg

Table 4 Showing the Microbial Values of the Developed Product.

SI No	PARAMETERS	TEST METHOD	UNIT	RESULT	REQUIREMENTS
1	Total plate count (TPC)	AOAC 966.23	CFU/ml	Nil	≤300 CFU/mL
2	*Escherichia coli*	AOAC 998.08	CFU/ml	Nil	≤3 CFU/ml
3	*Staphylococcus aureus*	AOAC 987.09	CFU/ml	Nil	10^2-10^3 CFU/ml
4	*Acetobacter*	AOAC 2015.13	CFU/ml	Nil	10^3 CFU/ml
5	Yeast	AOAC 2014.05	CFU/ml	10 CFU/ml	≤300 CFU/mL
6	Mold	AOAC 2014.05	CFU/ml	3 CFU/ml	≤10 CFU/mL

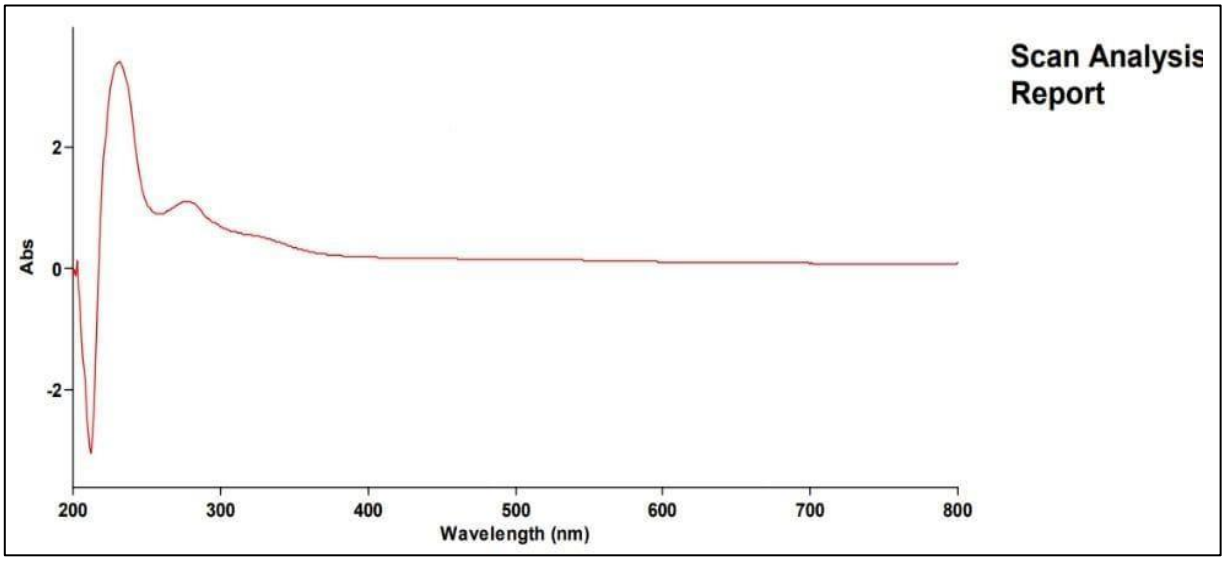


Fig 3 Graph Showing the Level of Total Betacyanin in the Developed Sample.

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➢ *Evaluation of Microbial Stability of the Product*

The microbiological test was examined to determine whether any dangerous microorganisms were present.The unit operations of the cordial processing, which includes several injury stresses such as peeling, cutting, blending, greatly raise the risk of microbial expansion. But this cordial has better microbial stability due temperature treatment after cooking product has been stored at refrigerated condition.

Based on the result provided in the table 4, it could see that *H. polyrhizus cordial* meets the microbial requirements as per FSSAI for total plate count, pathogens, yeast & mould. The total plate count is less than the maximum permissible limit of ≤300 CFU/mL as per FSSAI.*E. coli*, *staphylococcus aureus*, and *acetobacter* was not detected in the sample, which within the permissible limit of ≤3 CFU/ml ,10^2-10^3 CFU/ml, 10^3 CFU/ml respectively. There for based on the microbial test results, it can be justified that *H. polyrhizus* cordial is free from harmful microorganisms safe for consumption.

V. CONCLUSION

The present study successfully developed and evaluated a value-added dragon fruit cordial using red-fleshed dragon fruit (*Hylocereus polyrhizus*). The optimized formulation containing dragon fruit pulp, sugar, citric acid, and carboxymethyl cellulose produced a cordial with desirable physicochemical, sensory, and microbiological characteristics. The product exhibited a pH of 4.91, titratable acidity of 0.59%, total soluble solids of 35°Brix, and a sugar-to-acid ratio of 58.04, indicating a well-balanced formulation with good sweetness, acidity, and storage stability. The cordial also retained appreciable levels of vitamin C (11.44 mg/100 mL), betacyanin (8.9 mg), and mineral content (0.76% ash), highlighting its nutritional and functional value.Sensory evaluation demonstrated that Sample B achieved the highest scores for flavour, consistency, aftertaste, and overall acceptability, while the control sample was preferred only for colour and appearance. These findings indicate that the optimized formulation was well accepted by the sensory panel and possesses strong consumer appeal. Furthermore, microbiological analysis confirmed that the product met the recommended safety standards, with no detectable pathogenic microorganisms and microbial counts within permissible limits, demonstrating that the cordial is safe for consumption under appropriate processing and storage conditions.The study confirms that dragon fruit is a promising raw material for the production of nutritious, attractive, and shelf-stable cordial. The developed product offers an effective means of value addition, enhances the utilization of dragon fruit, and has good potential for commercial production. Future studies may focus on shelf-life evaluation, packaging optimization, and consumer acceptance on a larger scale to support industrial commercialization.

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