VALORIZATION OF DRAGON FRUIT (HYLOCEREUS SPP.) PEEL AS TUTTI FRUTTI AND ITS COMPARISION WITH PAPAYA TUTTI FRUTTI

Ms. Meegada Akhila[1], Ms. M. V. Keerthi[2], Ms S. Akhila[3]

Department of Food Technology, JNTUA College of Engineering, Kalikiri, Andhra Pradesh, India
meegadaakhilareddy@gmail.com, 9866401690

Abstract

The increasing emphasis on sustainable food systems and circular economy models has intensified interest in the valorization of fruit-processing by-products. This study evaluated the feasibility of utilizing red dragon fruit (*Hylocereus polyrhizus*) peel, a nutrient-rich agro-waste, for the development of a sugar-preserved tutti frutti, with conventional papaya tutti frutti serving as the control. Physicochemical analysis showed that dragon fruit peel (DFP) tutti frutti exhibited higher total soluble solids (67.2°Brix), and slightly acidic pH (5.09), and greater titratable acidity (0.1028%, expressed as citric acid equivalent) compared to the control, indicating effective syrup infusion and product stability. Proximate composition revealed marginally higher carbohydrate (72.16%) and fat (5.34%) contents in the DFP product, while protein and ash contents were slightly lower than those of papaya tutti frutti. Micronutrient analysis indicated lower vitamin C and calcium levels, attributed to thermal processing, whereas sodium content was higher (34 ppm), which may contribute to flavour perception. Microbiological evaluation confirmed product safety, with total plate counts below 20 CFU/g and absence of *Escherichia coli*, *Salmonella* spp., and *Staphylococcus aureus*. Sensory evaluation using a 9-point hedonic scale demonstrated high acceptability of the DFP tutti frutti, particularly for colour, texture, and overall acceptability. The findings demonstrate that dragon fruit peel can be successfully valorized as a sustainable, additive-free ingredient in sugar-preserved foods, contributing to waste reduction and value addition in line with circular economy principles.

Keywords: Dragon fruit peel, tutti frutti, agro-waste valorization, food sustainability, sensory evaluation, circular economy, functional food

1. INTRODUCTION

The global shift toward sustainable food systems and circular economy practices has intensified research on the valorization of agricultural and food-processing by-products. Large quantities of fruit waste generated during postharvest handling and processing pose serious environmental challenges, despite their potential as sources of bioactive compounds and functional ingredients. Converting such by-products into value-added foods offers a dual benefit of waste reduction and enhanced nutritional utilization.

Dragon fruit (*Hylocereus* spp.), widely cultivated in tropical and subtropical regions, has gained commercial importance due to its attractive appearance, nutritional value, and antioxidant properties.

During consumption and industrial processing, the peel accounts for approximately 22–25% of the total fruit weight and is commonly discarded as waste. However, dragon fruit peel is rich in betacyanins, phenolic compounds, dietary fiber, pectin, and minerals, indicating strong potential for application in functional foods, natural colorants, and nutraceutical formulations. Previous studies have explored extraction of pigments, antioxidants, and pectin from dragon fruit peel using conventional and green extraction technologies, as well as its use in edible films, coatings, and meat preservation systems.

Despite increasing interest in bioactive extraction, limited research has focused on the direct incorporation of dragon fruit peel into traditional food products under practical processing conditions. Sugar-preserved products such as tutti frutti are widely used in bakery and confectionery applications due to their extended shelf life, appealing texture, and consumer familiarity. Papaya is conventionally used for this purpose; however, comparative studies evaluating alternative raw materials derived from fruit waste are scarce.

Therefore, the present study aimed to develop dragon fruit peel-based tutti frutti and evaluate its physicochemical characteristics, proximate and micronutrient composition, microbial safety, and sensory acceptability in comparison with conventional papaya tutti frutti. This work seeks to demonstrate the feasibility of utilizing dragon fruit peel as a sustainable, food-grade ingredient, thereby contributing to waste reduction and value addition in line with circular economy principles.

2. LITERATURE SURVEY

The valorization of fruit and vegetable processing by-products has gained significant attention due to growing concerns over food waste, environmental sustainability, and resource efficiency. Fruit peels, seeds, and pomace are often discarded despite being rich in bioactive compounds, dietary fiber, pigments, and functional constituents. Several studies have emphasized that effective utilization of these by-products can contribute to sustainable food systems while providing economic and nutritional benefits.

Dragon fruit (*Hylocereus* spp.) has emerged as a commercially important tropical fruit, and its peel constitutes approximately one-quarter of the total fruit weight. Numerous investigations have reported that dragon fruit peel is a valuable source of betacyanins, phenolic compounds, pectin, minerals, and antioxidant constituents. Chen et al. reported that red dragon fruit peel exhibits higher antioxidant activity than the pulp, primarily due to its concentrated phenolic and betalain content. Similarly, Chen et al. identified a wide range of phenolic compounds in dragon fruit peel using advanced chromatographic techniques, confirming its potential as a functional food ingredient.

Several researchers have focused on the extraction and stabilization of bioactive compounds from dragon fruit peel. Bhagya Raj and Dash optimized ultrasound-assisted extraction of phytochemicals from dragon fruit peel and reported high recovery of phenolics and antioxidants. Chua et al. and Woo et al. explored pectin extraction from dragon fruit peel, demonstrating its suitability for use as a gelling and stabilizing agent in food applications. However, pigment instability during thermal processing and storage remains a major limitation, as reported by Harivaindaran et al. and Gao et al., particularly in heat-treated products.

Beyond extraction, recent studies have explored the application of dragon fruit peel in food formulations. Biswas et al. incorporated dragon fruit peel powder into fish nuggets and observed improved antioxidant properties and acceptable sensory attributes. Dalei et al. developed biodegradable packaging films using dragon fruit peel pectin, highlighting its functional and preservative potential. These studies demonstrate the versatility of dragon fruit peel; however, most applications focus on indirect use rather than direct incorporation into conventional food products.

Sugar-preserved products such as tutti frutti are widely used in bakery and confectionery industries due to their extended shelf life and consumer acceptability. Papaya is traditionally used for tutti frutti production; however, bibliometric analyses by Barroso-Torres et al. and Villegas-Yarlequé et al. indicate a lack of comparative studies evaluating alternative fruit by-products for such applications. Limited literature exists on the utilization of dragon fruit peel in syrup-based or sugar-preserved foods, despite its favorable physicochemical properties.

Overall, existing research highlights the nutritional and functional potential of dragon fruit peel, yet practical, product-oriented studies under real processing conditions remain limited. Therefore, there is a clear research gap in evaluating dragon fruit peel as a direct raw material for traditional sugar-preserved foods. The present study addresses this gap by developing dragon fruit peel-based tutti frutti and comparing it with conventional papaya tutti frutti in terms of physicochemical quality, nutritional composition, microbial safety, and sensory acceptability.

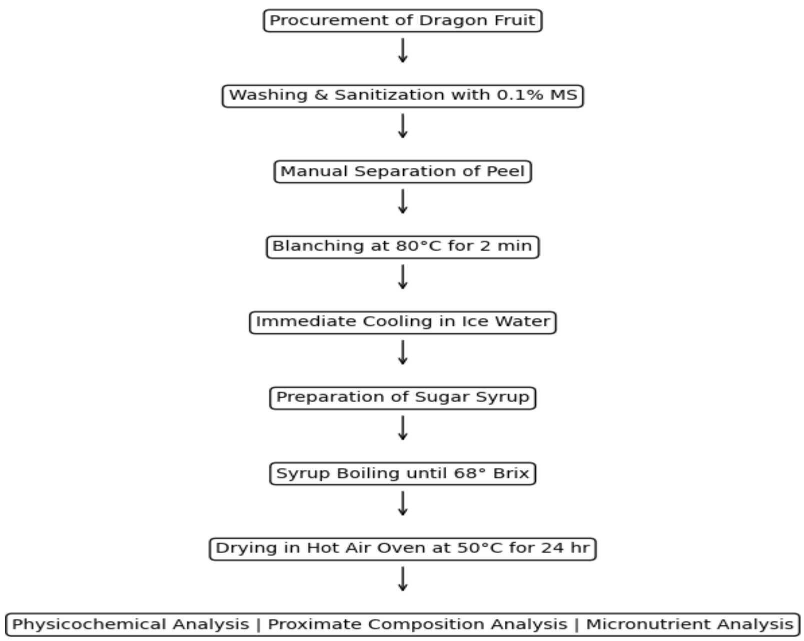
3. MATERIALS AND METHODS

3.1 Materials

Fresh red dragon fruits (*Hylocereus polyrhizus*) and mature papaya fruits (*Carica papaya* L.) were procured from a local agricultural market in Kalikiri, Andhra Pradesh, India, during March 2024. Uniformly ripened, healthy fruits free from physical damage and visible spoilage were selected for the study. The fruits were washed thoroughly under running potable water, sanitized by immersion in 0.1% potassium metabisulfite solution for 2 min, and subsequently rinsed with distilled water. Dragon fruit peels were manually separated using sterile stainless-steel knives and stored at 4 ± 1 °C until further processing. Papaya fruits were processed under identical hygienic conditions and served as the control sample. All ingredients used in product preparation were of food-grade quality, and all chemicals and reagents used for analytical determinations were of analytical reagent (AR) grade.

3.2 Preparation of Dragon Fruit Peel Tutti Frutti

Dragon fruit peels were cut into uniform cubes (approximately 3 × 3 mm) and blanched in hot water at 80 ± 2 °C for 2 min to reduce enzymatic activity and surface microbial load, followed by immediate cooling in potable water. Sugar syrup was prepared using refined sugar and potable water and heated until a total soluble solids (TSS) concentration of approximately 68°Brix was achieved. The blanched peel cubes were then immersed in the hot sugar syrup and simmered for 10–15 min to



facilitate sugar infusion. The product was subsequently cooled and stored in sterile, airtight containers at ambient temperature for further analysis. Papaya tutti frutti was prepared following the same procedure and used as the control.

3.3 **Physicochemical Analysis**

The thickness of the tutti frutti cubes was measured using a calibrated Vernier caliper and expressed in centimeters. Total soluble solids (TSS) were determined using a digital refractometer at room temperature and expressed as °Brix. The pH of the samples was measured using a calibrated digital pH meter. Titratable acidity was determined by titration of a known volume of sample against standardized sodium hydroxide solution using phenolphthalein as an indicator and expressed as percentage citric acid equivalent. Colour characteristics were evaluated using a colorimeter and reported in terms of CIE L* (lightness), a* (red–green), and b* (yellow–blue) values.

3.4 Proximate Composition

Moisture content was determined by the hot air oven method. Ash content was estimated using a muffle furnace at 550 °C. Crude protein was determined using the Kjeldahl method with a nitrogen-to-protein conversion factor of 6.25. Fat content was measured by Soxhlet extraction using petroleum ether as solvent. Carbohydrate content was calculated by difference. All analyses were carried out following AOAC standard procedures.

3.5 Micronutrient Analysis

Vitamin C content was estimated using the 2,6-dichlorophenolindophenol titrimetric method and expressed as mg/100 g. Calcium and sodium contents were determined using flame photometry and expressed as parts per million (ppm).

3.6 Microbiological Analysis

Microbial quality was assessed by determining total plate count (TPC) using nutrient agar incubated at 37 ± 1 °C for 24 h. The presence of *Escherichia coli*, *Salmonella* spp., and *Staphylococcus aureus* was evaluated using selective media and standard microbiological procedures. Results were expressed as colony-forming units per gram (CFU/g).

3.7 Sensory Evaluation

Sensory evaluation of the developed dragon fruit peel (DFP) tutti frutti and the control papaya tutti frutti was carried out using a 9-point hedonic scale to assess colour, taste, texture, flavour, and overall acceptability. The evaluation was performed by a semi-trained laboratory panel under controlled conditions as a preliminary assessment of product acceptability. Panelists were provided with coded samples and instructed to rinse their mouths with potable water between evaluations to minimize carry-over effects. Sensory scores were recorded and expressed as mean ± standard deviation.

4. RESULTS AND DISCUSSION

4.1 Physicochemical Characteristics

The physicochemical properties of dragon fruit peel (DFP) tutti frutti were compared with conventional papaya tutti frutti (Table 4.1). The DFP cubes showed a lower mean thickness (1.20 ± 0.12 cm) than papaya cubes (1.51 ± 0.23 cm), which may have facilitated more effective sugar syrup penetration during processing. The total soluble solids content of DFP tutti frutti (67.20°Brix) was slightly higher than that of the control (65.45°Brix), indicating efficient sugar infusion and osmotic dehydration, which are important for product stability in sugar-preserved foods. The pH of DFP tutti frutti was slightly acidic (5.09), reflecting the inherent nature of dragon fruit peel, while titratable acidity (0.1028%, expressed as citric acid equivalent) was higher than that of papaya, likely due to naturally occurring organic acid components concentrated during thermal processing. Colour measurements revealed lower L* values and higher a* values for the DFP product, confirming intense red coloration attributed to betalain pigments. Overall, these results demonstrate that dragon fruit peel can be effectively utilized to produce a sugar-preserved tutti frutti with desirable physicochemical properties and stability primarily governed by high soluble solids and thermal processing rather than acidity.

Table 4.1 Physicochemical characteristics of dragon fruit peel and papaya tutti frutti

Parameter	Dragon Fruit Peel Tutti Frutti	Papaya Tutti Frutti
Thickness (cm)	1.20 ± 0.12	1.51 ± 0.23
Total soluble solids (°Brix)	67.20 ± 0.18	65.45 ± 0.21
pH	5.09 ± 0.02	5.17 ± 0.03
Titratable acidity (%)	0.1028 ± 0.01	0.0580 ± 0.01
L* value	31.60 ± 0.14	52.30 ± 0.19
a* value	13.88 ± 0.12	4.25 ± 0.08
b* value	1.29 ± 0.06	18.60 ± 0.15

Values are mean ± standard deviation.

Figure 1. *Dragon Fruit Peel-Based Tutti Frutti.*

4.2 Proximate Composition

The proximate composition of DFP and papaya tutti frutti is presented in Table 4.2. The DFP product showed slightly higher carbohydrate (72.16 ± 0.28%) and fat (5.34 ± 0.16%) contents than the control, which may enhance energy density and flavour perception. Moisture content was comparable between the two samples, indicating similar shelf-life characteristics.

Protein and ash contents were marginally lower in the DFP product. However, earlier studies have reported that dragon fruit peel contains significant dietary fibre and polyphenolic compounds, which may compensate for the lower protein content and contribute functional benefits.

Table 4.2 Proximate composition of dragon fruit peel and papaya tutti frutti (%)

Parameter	Dragon Fruit Peel Tutti Frutti	Papaya Tutti Frutti
Moisture	16.40 ± 0.23	16.20 ± 0.15
Ash	1.04 ± 0.03	4.00 ± 0.01
Protein	5.05 ± 0.02	6.58 ± 0.01
Fat	5.34 ± 0.16	5.04 ± 0.24
Carbohydrate	72.16 ± 0.28	71.40 ± 0.23

Values are mean ± standard deviation.

4.3 Micronutrient Composition

The micronutrient composition of the samples is shown in Table 4.3. Vitamin C and calcium contents were lower in the DFP product compared to papaya tutti frutti. This reduction may be attributed to thermal degradation during blanching and syrup boiling, as reported in earlier studies.In contrast, sodium content was higher in DFP (34 ppm) than in papaya (16 ppm), which may contribute to improved flavour perception and osmotic balance in the sugar-preserved product. Despite some micronutrient losses, dragon fruit peel remains a promising functional ingredient.

Table 4.3 Micronutrient composition of dragon fruit peel and papaya tutti frutti

Nutrient	Dragon Fruit Peel Tutti Frutti	Papaya Tutti Frutti
Vitamin C (mg/100 g)	26.43 ± 0.16	61.00 ± 0.15
Calcium (ppm)	2.00 ± 0.05	36.00 ± 0.12
Sodium (ppm)	34.00 ± 0.10	16.00 ± 0.08

4.4 Microbiological Safety

The microbiological quality of dragon fruit peel (DFP) tutti frutti is presented in Table 4.4. The total plate count ranged between 15 and 18 CFU/g, which is well within the acceptable limits for sugar-preserved food products. Pathogenic microorganisms, including *Escherichia coli*, *Salmonella* spp., and *Staphylococcus aureus*, were not detected in any of the samples.

The low microbial load observed in the DFP tutti frutti can be attributed to the combined effects of blanching, high sugar concentration (high °Brix), and thermal processing during syrup preparation, which together create unfavorable conditions for microbial growth. High osmotic pressure resulting from elevated sugar levels restricts microbial proliferation by reducing water activity, while blanching effectively reduces the initial microbial load. These results confirm the microbiological safety of the developed product and support its suitability as a shelf-stable sugar-preserved food.

Table 4.4 Microbiological quality of dragon fruit peel tutti frutti

Microbial parameter	Observation
Total plate count (CFU/g)	15–18
Escherichia coli	Absent
Salmonella spp.	Absent
Staphylococcus aureus	Absent

4.5 Sensory Evaluation

Sensory evaluation indicated that dragon fruit peel (DFP) tutti frutti was well accepted, particularly with respect to colour and texture, owing to its intense natural pigmentation and satisfactory firmness after processing. Taste and flavour scores were slightly lower than those of papaya tutti frutti, possibly due to characteristic peel notes; however, overall acceptability remained high. These findings suggest that dragon fruit peel can be effectively utilized in sugar-preserved products without compromising sensory quality. As this represents a preliminary assessment, further evaluation with a larger consumer panel is recommended..

Table 4.5 sensory evaluation scores of dragon fruit peel and papaya tutti frutti based on a 9-point hedonic scale

Attribute	Dragon Fruit Peel Tutti Frutti	Papaya Tutti Frutti
Colour	8.70 ± 0.15	7.30 ± 0.21
Taste	7.50 ± 0.24	8.20 ± 0.17
Texture	8.10 ± 0.13	8.30 ± 0.11
Flavour	7.40 ± 0.19	8.10 ± 0.16
Overall acceptability	8.00 ± 0.12	8.30 ± 0.14

Scores based on a 9-point hedonic scale.

4.6 Environmental and Functional Implications

Valorization of dragon fruit peel into a sugar-preserved product supports circular economy principles by converting post-harvest waste into a value-added food ingredient. As peels constitute approximately 25% of the total fruit weight, large-scale utilization could significantly reduce agro-industrial waste. The nutritional and sensory performance of the DFP product highlights its potential for clean-label, zero-waste food innovations, in line with global sustainability initiatives.

5. CONCLUSION

The present study demonstrated the successful valorization of dragon fruit (*Hylocereus* spp.) peel, a major postharvest by-product, through its incorporation into a sugar-preserved food product, tutti frutti. The developed dragon fruit peel (DFP) tutti frutti exhibited physicochemical characteristics comparable to conventional papaya tutti frutti, with higher total soluble solids and distinct natural pigmentation derived from betacyanins. Proximate analysis revealed a satisfactory nutritional profile, characterized by slightly higher carbohydrate and fat contents, while micronutrient evaluation indicated adequate nutritional value despite reduced vitamin C and calcium levels due to thermal processing. The product showed excellent microbiological safety, with the absence of major foodborne pathogens, and achieved high sensory acceptability, particularly in terms of colour, texture, and overall appeal.

From an environmental perspective, the utilization of dragon fruit peel in value-added food products aligns with circular economy principles by reducing agro-industrial waste and promoting sustainable food processing practices. Overall, the findings highlight the potential of dragon fruit peel as a natural, functional, and eco-friendly ingredient for sugar-preserved foods. Further research may focus on improving bioactive compound retention, optimizing flavour profiles, and evaluating large-scale processing feasibility to support commercial application in functional and convenience food products.

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