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IMPACT OF HARVESTING TIME ON POSTHARVEST QUANTITATIVE AND QUALITATIVE ATTRIBUTES OF RED FLESHED DRAGON FRUIT (*HYLOCEREUS COSTARICENSIS*)

Guddu Kumar[1], Subhadip Chowdhury[1], Dr Pran Krishna Thakur[1], Payal Maiti[1], Abhijit Rongpi[2*], Sumon Mondal[1], Biswajit Karmakar[1] and Sanjoy Suchiang [3]
[1]Department of Post Harvest Technology, Bidhan Chandra Kriahi Viswavidyalaya, Mohanpur -741252, West Bengal, India
[2]Department of Horticulture (Fruit Science) SAS, Nagaland University, 797106, Nagaland, India
[3]Department of Fruit Science Bidhan Chandra Kriahi Viswavidyalaya, Mohanpur -741252, West Bengal, India
*Corresponding author E-mail: rongpiavijit@gmail.com
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ABSTRACT

The present investigation was conducted to evaluate the effect of harvesting time on the physical, biochemical and sensory quality of dragon fruit (*Hylocereus costaricensis*) over two consecutive years (2021–2023) at Bidhan Chandra Krishi Viswavidyalaya, West Bengal. The fruits were harvested in four different months - July (T1), August (T2), September (T3) and October (T4) and assessed for major quality parameters. Significant differences were observed across treatments. The highest fruit weight was recorded in September harvesting (T3) with a pooled value of 258.90 g, followed by October harvesting (T4) with 240.40 g. Pulp weight also highest in T3 (171.40 g), with a pulp-to-peel ratio of 1.96, indicating better edibility. September harvesting (T3) fruits had the highest fruit diameter (8.95 cm) and length (13.32 cm), along with the highest firmness (5.81 g/cm²), reflecting optimal maturity and structural integrity. Among biochemical traits, total soluble solids (TSS) were highest in July harvesting (T1) with 12.70°Brix, while titratable acidity declined progressively, reaching 0.27% in October harvesting (T4). Total sugar content was highest in July (T1) (7.65%) and decreased with delayed harvest. The pH increased from 6.82 (T1) to 7.10 (T4). Antioxidants, including anthocyanin (285.25 mg/100g), total phenol (48.45 mg/100g) and ascorbic acid (18.75 mg/100g), were highest in July harvesting and declined with fruit maturity. Organoleptic evaluation revealed that fruits harvested in September (T3) received the highest scores for weight (7.5), color (7.5), texture (7.3) and overall acceptability (7.7). The study concludes that September (T3) is the optimal harvest time, balancing superior physical quality, acceptable biochemical characteristics and maximum consumer preference, thereby enhancing the commercial and nutritional value of dragon fruit.
***Keywords*: *Hylocereus costaricensis*, total sugar, anthocyanin and total phenol.

Introduction

Dragon fruit (*Hylocereus costaricensis*), also known as pitaya, is a climbing cactus recognized globally as a nutrient-dense "superfruit." It is native to Mexico and cultivated in tropical and subtropical regions, its commercial importance stems from its vibrant appearance, nutritional richness and adaptability to arid climates. Four primary species dominate cultivation: *Hylocereus undatus* (white flesh, red skin), *H. polyrhizus* (red flesh, red skin), *S. megalanthus* (white flesh, yellow skin) and *H. costaricensis* (red-purple flesh, red skin). These diploid (2n = 22) species thrive in warm, dry climates with moderate rainfall (500–1500 mm) and slightly acidic soils (pH 5.5–6.0), making them ideal for tropical Asian countries, including India, where cultivation is expanding rapidly (Schweiggert *et al*., 2009). As a crassulacean acid metabolism (CAM) plant, dragon fruit exhibits xerophytic adaptations, enabling growth in water-scarce environments. Its epiphytic stems extend up to 10 meters, producing large, fragrant, night-blooming flowers that yield fruits with rosy-red or yellow skin and flesh studded with black seeds. The fruit's non-climacteric nature necessitates careful timing of harvest to optimize quality, as it does not ripen post-harvest (Wakchaure *et al*., 2023). Dragon fruit is prized for its high vitamin C, dietary fiber, antioxidants (e.g., betacyanins) and minerals. Red-fleshed varieties (*H. polyrhizus* and *H. costaricensis*) contain betacyanin pigments, akin to red beet, which enhance their nutraceutical value (Chowdhury *et al*., 2024). Its low-calorie profile and versatility in processed products juices, jams, wines and natural food colorants drive global demand. However, in India, despite rising cultivation (~400 hectares), processed products remain scarce, highlighting opportunities for value addition (Wakchaure, *et al*., 2021). Harvesting time critically influences post-harvest quality due to the fruit's rapid physiological changes. Key biochemical parameters - soluble solids, acidity, betacyanin content and antioxidant activity peak at specific maturity stages. Delayed or premature harvesting can compromise texture, flavor and nutrient retention, exacerbating post-harvest losses during storage and transport. Proper packaging is essential to mitigate mechanical damage, weight loss and microbial spoilage, particularly for long-distance markets. While dragon fruit's agronomic potential is well-documented, studies on optimal harvest windows and their impact on post-harvest biochemistry are limited, especially in India. Determining species-specific maturity indices (e.g., skin color, brix-acid ratio) could enhance shelf life and marketability. Furthermore, aligning harvest practices with processing requirements (e.g., betacyanin extraction for colorants) may bolster economic returns for farmers. As dragon fruit cultivation expands in India and globally, understanding the interplay between harvest timing, post-harvest physiology and biochemical stability is vital. This study addresses gaps in optimizing harvest schedules to preserve quality, reduce losses and meet growing consumer and industrial demand. By integrating agronomic, biochemical, and post-harvest insights, stakeholders can advance sustainable production and value-chain development for this emerging superfruit.

Materials and Methods

Experimental details

The present investigation was carried out during 2021–2023 at the Department of Post Harvest Technology, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya (BCKV), Nadia, West Bengal, with biochemical analyses conducted in the departmental laboratory. Experiments were conducted over the four months of July, August, September, and October from 2021 to 2023. Meteorological data were recorded during the experiments (Fig. 1). Fresh, fully mature dragon fruits of uniform size, shape, and colour were harvested from the university orchard during the first week of July, August, September and October. The experiment, designed to study the effect of harvesting time on fruit quality, was laid out in a Completely Randomized Design (CRD) with four treatments T1 (July), T2 (August), T3 (September) and T4 (October)each replicated three times, using fruits from plants of similar age and growth conditions.

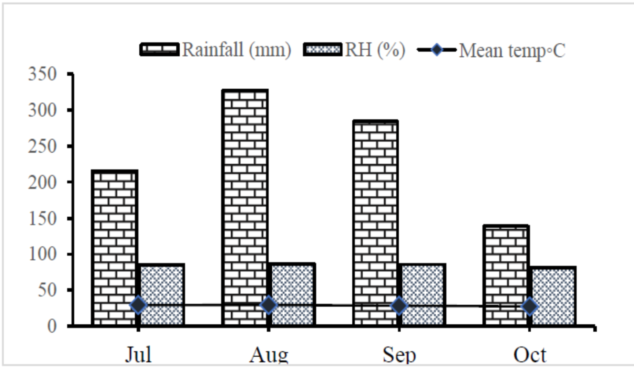

Fig. 1: Monthly average mean temperature, relative humidity (RH), and sunshine (SS, hour) during 2021-22 and 2022-23

Trait measurements

Observations were recorded on physical parameters such as fruit weight, pulp weight, peel weight, pulp-to-peel ratio, fruit length and fruit texture (kg/cm²), along with biochemical traits including total soluble solids (°Brix), titratable acidity (%), total sugars (%), pH, total phenols (mg/100g), ascorbic acid (mg/100g), anthocyanin content (mg/100g) and organoleptic evaluation using a 9-point hedonic scale. Yield data such as fruits per pole, individual fruit weight, total fruit yield per 10 poles, and extrapolated yield per hectare were also recorded.

Data analysis

All experimental data were subjected to statistical analysis using analysis of variance (ANOVA) as per the standard procedures outlined by Gomez and Gomez (1984).

Results and Discussion

Effect of harvesting time on the physical parameters of dragon fruit

The effect of harvesting time on various physical attributes of dragon fruit was evaluated over two years, with significant statistical differences observed across different months (July, August, and September). Data are summarized in Tables 1a and 1b and Figures 1a and 1b. Fruit weight significantly increased from July (T1) to September (T3), with the highest weight recorded in September harvesting (T3) 261.76 g in Year 1, 256.04 g in Year 2, and 258.90 g in the pooled data. Conversely, the lowest weight was observed in T1, registering 177.56 g, 171.84 g and 174.70 g in Year 1, Year 2, and pooled data, respectively. This progressive increase suggests that the extended duration between flowering and harvest in later months facilitates enhanced physiological maturity, leading to greater assimilate accumulation, cellular expansion, and overall fruit mass. Similar findings were reported by Franco *et al.* (2022) and Razali *et al*. (2017), who observed superior fruit quality at advanced maturity stages Pulp weight exhibited a similar ascending trend, peaking in T3 (September) at 174.26 g, 168.54 g and 171.40 g for Year 1, Year 2 and the pooled average, respectively. The minimum pulp weight was observed in T1 (July). This increase corresponds to advancing maturity, where prolonged development allows for enhanced sugar deposition, water retention, and parenchyma cell development, resulting in improved pulp yield. Comparable values were reported by Singh *et al.* (2022) and Kavino and Arunkumar (2024), underscoring the critical influence of harvest timing on pulp development. Peel weight also rose consistently with delayed harvesting. The maximum values were recorded in September harvesting (T3) (90.46 g, 84.74 g and 87.60 g), while the lowest were in July harvesting (T1). This steady increase indicates synchronous development of peel and pulp as the fruit matures, likely due to continued lignification and structural reinforcement of the pericarp. These observations are corroborated by the findings of Kavino and Arunkumar (2024), and Perween *et al.* (2018). The fruit length was greatest in September harvesting (T3) 14.40 cm in Year 1, 12.24 cm in Year 2, and 13.32 cm in the pooled data, while the shortest fruits were recorded in July harvesting (T1). The observed elongation in early development stages reflects the vertical cell expansion phase, which tends to plateau as the fruit reallocates resources to lateral expansion and mass gain. This developmental shift is consistent with patterns reported by Thakkar (2019) and Sethunath and Bhaskar (2024), who observed similar longitudinal growth trends across different genotypes. Fruit diameter also showed a marked increase from early to late harvests, with September harvesting (T3) registering the maximum fruit width (10.03 cm, 7.87 cm and 8.95 cm pooled). The smallest diameter was recorded in July harvesting (T1) (6.15 cm pooled), suggesting insufficient lateral growth due to immature harvesting. This lateral expansion in later stages corresponds to final phases of fruit development where transverse cell division and expansion dominate. Comparable trends were reported by Thakkar (2019), affirming the role of maturity in dimensional development. The pulp-to-peel ratio peaked in September harvesting (T3) (2.04, 1.88 and 1.96), indicating a higher proportion of edible content relative to peel. The lowest ratio was observed in August harvesting (T2) (1.39, 1.23 and 1.31), which may be attributed to disproportionate peel development or slower pulp accumulation during mid-season harvest. Higher ratios in later harvests suggest improved consumer appeal, processing suitability and market value. These findings align with those of Sabalpara (2025) and Perween *et al.* (2018), emphasizing the importance of optimal harvest timing. Firmness was highest in fruits harvested in September harvesting (T3), with recorded values of 6.89 g/cm² in Year 1, 4.73 g/cm² in Year 2 and 5.81 g/cm² in the pooled analysis. The lowest firmness values were noted in T1 (July harvesting), indicating underdeveloped cell wall structures and reduced mechanical strength. The observed firmness in September harvesting (T3) reflects complete physiological maturity, with enhanced cell wall integrity and optimal water balance contributing to better shelf life and transport resilience. These results are supported by similar firmness trends in mangoes (Yashoda *et al.,* 2006), apples (Johnston *et al*., 2002) and dragon fruit (Nurul *et al*., 2013; Chen *et al.,* 2024), which also underscore the impact of environmental and temporal factors on fruit texture and post-harvest quality.

Effect of Harvesting Time on the Biochemical Parameters of Dragon Fruit (*Hylocereus spp*.)

The biochemical parameters of dragon fruit, including total soluble solids (TSS), titratable acidity, total sugar, pH, anthocyanin, total phenol and ascorbic acid content, were evaluated over two years. The results, presented in Tables 2a and 2b and Figures 4.2a and 4.2b, revealed significant seasonal variations influenced by harvest timing. Total soluble solids (TSS) were highest in July harvesting (T1), with pooled values reaching 12.70°Brix, followed by a gradual decline in subsequent months, reaching the lowest level of 10.48°Brix in October harvesting (T4). The elevated TSS in early-harvested fruits may be attributed to lower water content and minimal dilution of sugars, which are concentrated during the early developmental stages. This is in line with Hoa *et al.* (2000), who reported TSS values of 12–16°Brix at 25 days after anthesis. Kristanto (2003) and Stintzing *et al.* (2004) recorded TSS ranging from 9–16°Brix in dragon fruit. Additionally, Abirami *et al.* (2021), noted TSS values of 11.2° Brix in *H. undatus* and 9.1° Brix in *H. costaricensis*, supporting the range observed in this study. Titratable acidity followed a declining trend with delayed harvesting. The highest acidity was observed in July harvesting (T1) (0.32%) and the lowest in October harvesting (T4) (0.27%). This reduction is indicative of the natural ripening process, during which organic acids are metabolized into sugars and other compounds, thus lowering acidity. Similarly, Muhammad *et al.* (2014) observed similar trends, with acidity ranging from 0.23% to 1.41% during early development stages, followed by a notable decline post 28 days. Similarly, Ortiz and Takahashi (2015) also reported a decrease in acidity from 0.40% to 0.27% between early and late harvests, aligning with current findings. Total sugar content mirrored the trend observed in TSS, with the highest concentration in July harvesting (T1) (7.65%) and a steady reduction to 6.76% in October harvesting (T4). The decreasing trend may be attributed to the accumulation of water in the fruit during extended growth periods, leading to dilution of sugar concentration. This interpretation is supported by Sharma *et al.* (2017), who reported total sugar levels of 8% and non-reducing sugars of 3.5% in *H. undatus*, which closely match the present data. In contrast to other biochemical parameters, fruit pH increased with delayed harvesting. The lowest pH was recorded in July harvesting (T1) (6.82), while the highest was observed in T4 (7.10). This inverse relationship between acidity and pH is typical in ripening fruits, where acid content decreases, leading to a more neutral pH. Similar pH values ranging from 4.20 to 4.64 were reported by Sharma *et al.* (2017) and Liaotrakoon *et al.* (2011) in fresh juice and purée samples of *Hylocereus* species. Anthocyanin content was significantly higher in July (T1), with pooled values of 285.25 mg/100g, and reached its lowest point in August (T2) at 177.95 mg/100g. The elevated anthocyanin levels in early-harvested fruits may be a stress-induced response, particularly due to higher UV exposure in the earlier part of the season, which stimulates pigment synthesis. These findings are corroborated by Mahlil *et al.* (2020), who recorded anthocyanin levels of 198.87 mg/100g in dragon fruit peel. Total phenol content, an important indicator of antioxidant potential, was highest in T1 (48.45 mg/100g) and declined progressively to 41.43 mg/100g by T4. This trend suggests a reduction in polyphenolic compounds as the fruit matures, possibly due to oxidative degradation or metabolic shifts favoring sugar and pigment accumulation. These observations favor early harvesting for applications targeting health-promoting compounds. Ascorbic acid content also showed a decreasing trend over the season, with the highest pooled value recorded in T1 (18.75 mg/100g) and the lowest in T4 (16.70 mg/100g). The reduction in ascorbic acid with delayed harvesting may result from enzymatic degradation during ripening or prolonged exposure to heat and oxidative stress. Lum and Norazira *et al.* (2008) observed a similar decline in ascorbic acid content from 14.7 to 9.6 mg/100g as ripening advanced, while Jaffar *et al.* (2009) reported levels ranging from 8 to 9 mg/100g in *H. polyrhizus*, emphasizing genotype and environmental influences.

Organoleptic evaluation

The organoleptic evaluation of the physical parameters of dragon fruits harvested in different months, including weight, color, texture, and overall acceptability, is presented in Table 3. The results show significant variations in sensory attributes across the treatments. For weight, the maximum score was recorded in T3 (September) with 7.5, while the minimum score was recorded in T4 (October) with 4.7. For color, the maximum score was recorded in T3 (September) with 7.5, while the minimum score was recorded in T4 (October) with 4.7. For texture, the maximum score was recorded in T1 (July) with 6.8, while the minimum score was recorded in T4 (October) with 4.2. Forever all acceptability, the maximum score was recorded in T3 (September) with 7.7, while the minimum score was recorded inT4 (October) with 4.6. The results indicate that dragon fruit harvested in September (T3) received the highest scores for weight, color, texture, and overall acceptability, whereas fruit harvested in October (T4) received the lowest scores across all sensory parameters. This suggests that harvesting time significantly influences the organoleptic qualities of dragon fruit, with September being the optimal month for harvesting based on sensory evaluation. The evaluation demonstrates that harvest timing significantly impacts the sensory quality of dragon fruit. Fruits harvested earlier (July) and later (October) were less preferred compared to those harvested during the peak months of August and September. This trend suggests that the maturation process, growing conditions, and climate during these months may contribute to enhanced sensory qualities. The September harvest (T3) stands out as the best time for harvesting dragon fruit, with the highest scores across all attributes, indicating it is the optimal harvest period for achieving the most desirable sensory properties.

Conclusion

The findings of this study clearly demonstrate that harvesting time significantly affects the post-harvest physical, biochemical and sensory characteristics of dragon fruit (*Hylocereus spp.*). Fruits harvested in September (T3) consistently exhibited the most favourable physical traits maximum weight, size, pulp content, and firmness indicating superior physiological maturity. Although early-harvested fruits in July (T1) showed higher TSS, total sugars and antioxidant content, they lacked optimal size and market appeal. Conversely, October-harvested fruits (T4) showed signs of overripening, with diminished firmness, lower antioxidant levels and poor organoleptic ratings. Organoleptic assessment further supported September (T3) as the ideal harvest window, reflecting peak consumer preference. These results underscore the importance of strategic harvest scheduling to maximize fruit quality, shelf life and commercial value. Adoption of September harvests could enhance profitability for growers while ensuring nutritional and sensory excellence for consumers. The study provides valuable insights for optimizing post-harvest management and supports the development of quality-based marketing strategies for this emerging superfruit.

Table 1a: Physical parameters of dragon fruit harvested in different months

Treatment	Fruit weight(g)			Pulp weigh(g)			Peel weight(g)			Fruit length(cm)		
	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled
T1	177.56	171.84	174.70	103.46	97.74	100.60	76.91	71.19	74.05	13.29	11.13	12.21
T2	190.06	184.34	187.20	109.66	103.94	106.80	84.11	78.39	81.25	14.08	11.92	13.00
T3	261.76	256.04	258.90	174.26	168.54	171.40	90.46	84.74	87.60	14.40	12.24	13.32
T4	243.26	237.54	240.40	157.06	151.34	154.20	87.06	81.34	84.20	13.58	11.42	12.50
SE.m.(±)	2.70	4.31	3.59	1.76	2.12	1.90	1.45	0.76	1.16	0.20	0.18	0.19
CD@ 5%	8.81	1406	10.08	5.76	6.92	5.85	4.74	2.48	3.48	0.65	0.59	0.57

T1- (July), T2- (August), T3 -(September), T4 (October)

Table 1a: Physical parameters of dragon fruit harvested in different months

Treatment	Fruit weight(g)			Pulp weigh(g)			Peel weight(g)		
	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled
T1	7.23	5.07	6.15	1.44	1.28	1.36	6.65	4.49	5.57
T2	7.83	5.67	6.75	1.39	1.23	1.31	6.79	4.63	5.71
T3	10.03	7.87	8.95	2.04	1.88	1.96	6.89	4.73	5.81
T4	7.90	5.74	6.82	1.91	1.75	1.83	6.85	4.69	5.77
SE.m.(±)	0.05	0.08	0.07	0.03	0.02	0.02	0.08	0.06	0.07
CD@ 5%	0.17	0.12	0.211	0.09	0.06	0.07	0.29	0.21	0.23

T1- (July), T2- (August), T3 -(September), T4 (October)

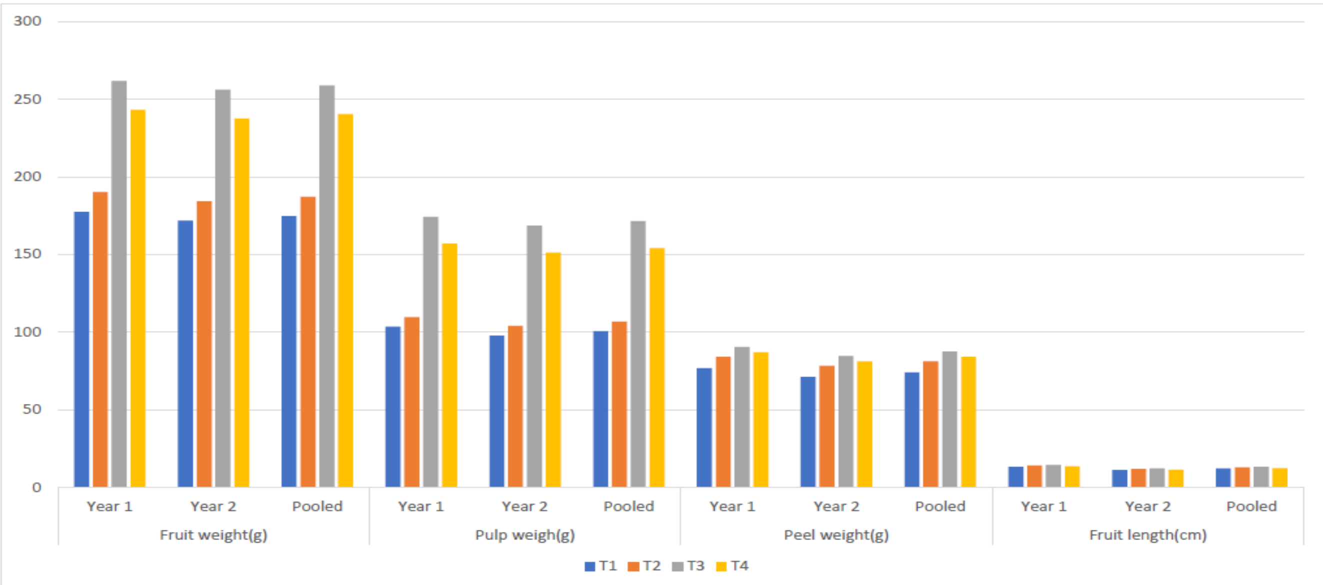

Fig. 1a : Physical parameters of dragon fruit harvested in different months.

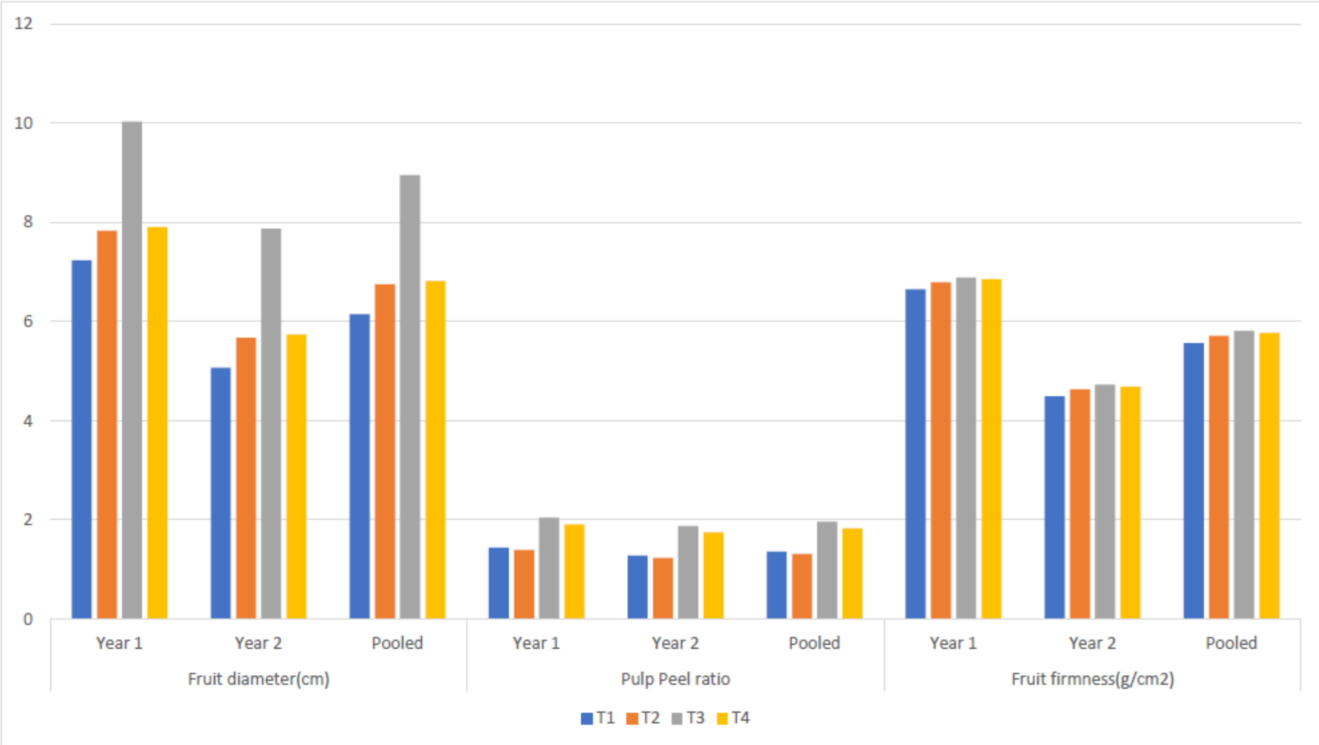

Fig. 1b: Physical parameters of dragon fruit harvested in different months

Table 2a: Effects of harvesting time on biochemical parameters of dragon fruit

Treatment	Total soluble solids(0Brix)			Titrable acidity (%)			Total sugar (%)			pH		
	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled
T1	15.56	9.84	12.70	0.35	0.29	0.32	7.68	7.62	7.65	6.85	6.79	6.82
T2	14.51	8.79	11.65	0.33	0.27	0.30	7.28	7.22	7.25	6.90	6.84	6.87
T3	13.89	8.17	11.03	0.31	0.25	0.28	7.64	7.58	7.61	7.01	6.95	6.98
T4	13.34	7.62	10.48	0.30	0.24	0.27	6.79	6.73	6.76	7.13	7.07	7.10
SE.m.(±)	0.27	0.10	0.20	0.005	0.005	0.005	0.12	0.10	0.11	0.11	0.12	0.11
CD@ 5%	0.90	0.32	0.62	0.018	0.027	0.024	0.42	0.33	0.33	0.37	0.38	0.35

T1- (July), T2- (August), T3 -(September), T4 (October)

Table 2b: Eeffects of harvesting time on biochemical parameters of dragon fruit

Treatment	Anthocyanin (mg/100gm)			Total phenol(mg/100gm)			Ascorbic acid (mg/100gm)		
	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled
T1	287.94	282.56	285.25	51.14	45.76	48.45	20.47	17.03	18.75
T2	180.64	175.26	177.95	49.42	44.04	46.73	20.34	16.90	18.62
T3	232.04	226.66	229.35	45.16	39.78	42.47	19.35	15.91	17.63
T4	254.99	249.61	252.30	44.12	38.74	41.43	18.42	14.98	16.70
SE.m.(±)	2.55	3.24	2.91	0.75	0.64	0.69	0.27	0.20	0.24
CD@ 5%	8.33	10.57	8.75	0.24	2.09	2.04	0.90	0.65	0.72

T1- (July), T2- (August), T3 -(September), T4 (October)

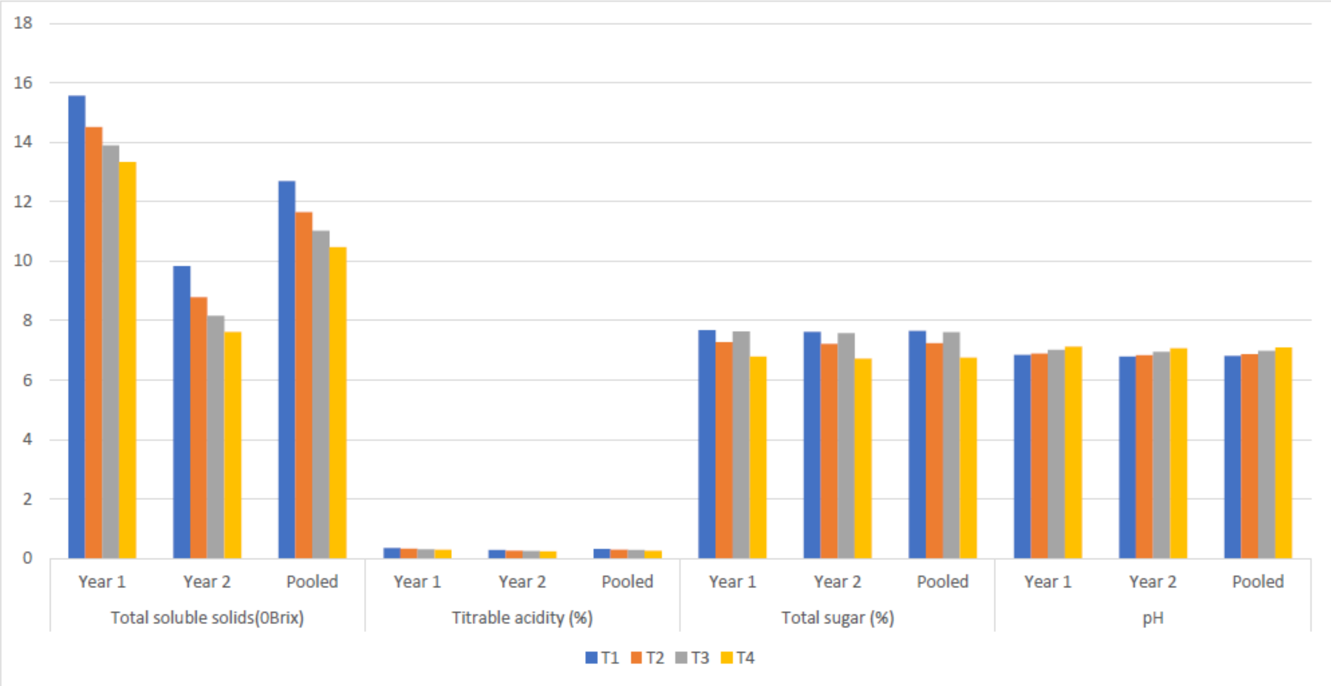

Fig. 2a: Effects of harvesting time on biochemical parameters of dragon fruit

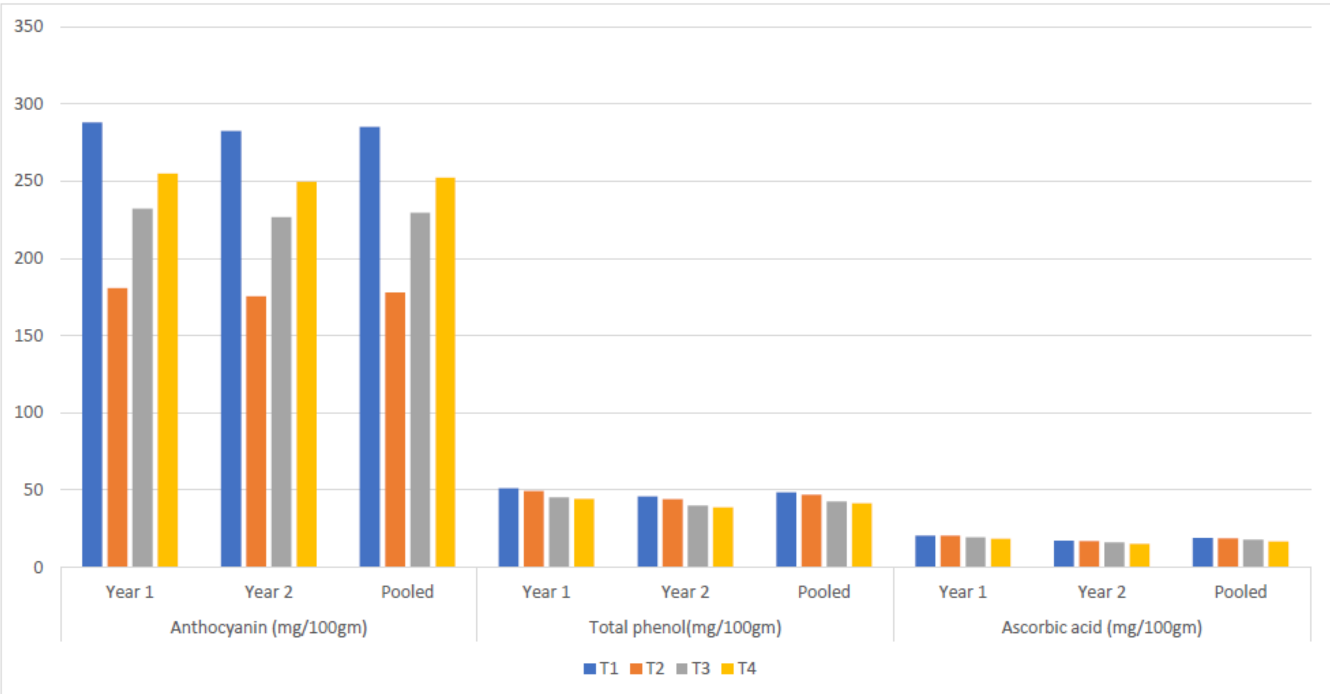

Fig. 2b: Effects of harvesting time on biochemical parameters of dragon fruit.

Table 3: Organoleptic evaluation of the physical parameters of dragon fruits harvested in different months

Treatments	weight	Colour	Texture	Overall acceptability
T1	6.6	6.6	6.8	7.2
T2	6.2	6.2	6.6	6.9
T3	**7.5**	**7.5**	**7.3**	**7.7**
T4	4.7	4.7	4.2	4.6

T1- (July), T2- (August), T3 -(September), T4 (October)

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Declaration of Competing Interest

The authors declare that there is no competing interest

References

Abirami, K., Swain, S., Baskaran, V., Venkatesan, K., Sakthivel, K., & Bommayasamy, N. (2021). Distinguishing three dragon fruit (*Hylocereus* spp.) species grown in Andaman and Nicobar Islands of India using morphological, biochemical and molecular traits. *Scientific Reports,* **11**(1), 2894.

Chen, S. Y., Xu, C. Y., Mazhar, M. S., & Naiker, M. (2024). Nutritional value and therapeutic benefits of dragon fruit: A comprehensive review with implications for establishing Australian industry standards. *Molecules,* **29**(23), 5676.

Chowdhury, M. M., Sikder, M. I., Islam, M. R., Barua, N., Yeasmin, S., Eva, T. A., ... & Hossain, M. K. (2024). A review of ethnomedicinal uses, phytochemistry, nutritional values, and pharmacological activities of *Hylocereus polyrhizus*. *Journal of Herbmed Pharmacology,* 13(3), 353–365.

Deep, L., Narayana, C. K., Karunakaran, G., Rao, D. S., & Anuradha, S. (2022). Maturity determination of red and white pulp dragon fruit. *Journal of Horticultural Sciences,* **17**(1), 157–165.

Franco, R. K., Castro, A., & Esguerra, E. (2022). Harvest maturity affects the quality and storage behavior of white-fleshed dragon fruit [*Hylocereus undatus* (Haworth) Britton and Rose]. *Food Research,* **6**(2), 423–433.

Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research*. John Wiley & Sons.

Hoa, T. T., Clark, C. J., Waddell, B. C., & Woolf, A. B. (2006). Postharvest quality of dragon fruit (*Hylocereus undatus*) following disinfesting hot air treatments. *Postharvest Biology and Technology,* **41**(1), 62–69.

Johnston, J. W., Hewett, E. W., & Hertog, M. L. (2002). Postharvest softening of apple (*Malus domestica*) fruit: A review. *New Zealand Journal of Crop and Horticultural Science,* **30**(3), 145–160.

Kavino, M., & Arunkumar, G. (2024). Phenological stages of pink pulp dragon fruit (*Hylocereus costaricensis* Web.): Codification and description according to the extended BBCH scale under field conditions. *Applied Fruit Science,* ***66***(5), 2019–2034.

Kristanto, D. (2003). *Dragon fruit: Cultivation in pots and gardens*. Jakarta, Indonesia: Agromedia.

Liaotrakoon, W., De Clercq, N., Lewille, B., & Dewettinck, K. (2011). Freeze-drying qualities and state diagram of pulp and peel freeze-dried dragon fruits (*Hylocereus* spp.). *Food Science and Technology: Mekong Delta, Vietnam, 2nd Conference, Abstracts*. Presented at the 2nd Conference on Food Science and Technology: Mekong Delta, Vietnam (MekongFood 2): *Food Safety and Food Quality in Southeast Asia: Challenges for the Next Decade*, Can Tho, Vietnam.

Lum, M. S., & Norazira, M. A. (2011). Effects of hot water, submergence time and storage duration on quality of dragon fruit (*Hylocereus polyrhizus*). *Journal of Agricultural Science,* **3**(1), 146–152.

Mahlil, Y., Kobayashi, M., & Mahata, M. E. (2020). The processing effects of anthocyanins extracted from dragon fruit (*Hylocereus polyrhizus*) peel on total amount of anthocyanins and SEM image in poultry nutrition. *Journal of World's Poultry Research,* **10**(3), 513–519.

Muhammad, K., Zahari, N. I. M., Gannasin, S. P., Adzahan, N. M., & Bakar, J. (2014). High methoxyl pectin from dragon fruit (*Hylocereus polyrhizus*) peel. *Food Hydrocolloids,* **42**, 289–297.

Nurul Zaizuliana, R. A., Mohamad Faris, S., Noor Atikah, A. L., Norshazila, S., Zarinah, Z., & Che Abdullah, A. B. (2013). *Bioscience Research. Cellulose (CMC),* **8**(8.1), 8–1.

Ortiz, T. A., & Takahashi, L. S. A. (2015). Physical and chemical characteristics of pitaya fruits at physiological maturity. *Genetics and Molecular Research,* **14**(4), 14422–14439.

Perween, T., Mandal, K. K., & Hasan, M. A. (2018). Dragon fruit: An exotic super future fruit of India. *Journal of Pharmacognosy and Phytochemistry,* **7**(2), 1022–1026.

Razali, N. A., Antunes, A. C. N., Berry, A. D., & Sargent, S. A. (2016). Postharvest storage temperature and coating effects on fruit quality of red-fleshed pitaya (*Hylocereus costarricensis*). *Proceedings of the Florida State Horticultural Society, 129*, 190–194.

Sabalpara, R. H., Cholera, S. P., Davara, P. R., Kandoliya, U. K., & Dabhi, M. N. (2025). Optimizing drying conditions for red flesh dragon fruit: A response surface methodology approach to enhance nutritional quality. *Plant Archives, 25*(Special Issue ICTPAIRS-JAU, Junagadh), 555–565. https://doi.org/10.51470/PLANTARCHIVES.2025.SP.ICTPAIRS-078

Schweiggert, R. M., Villalobos-Gutierrez, M. G., Esquivel, P., & Carle, R. (2009). Development and optimization of low-temperature enzyme-assisted liquefaction for the production of colouring foodstuff from purple pitaya (*Hylocereus* spp. [Weber] Britton and Rose). *European Food Research and Technology,* 230, 269–280. https://doi.org/10.1007/s00217-009-1162-x

Sethunath, K., & Bhaskar, J. (2024). Evaluation of diversity in dragon fruit (*Hylocereus* spp.) genotypes grown in Kerala, India. *Journal of Applied Horticulture,* **26**(1), 127–131.

Sharma, R. K., Thakur, M., Raut, G., & Deshmukh, V. M. (2017). Studies on compositional profile of dragon fruit (*Hylocereus undatus*) and its utilization in manufacturing of jelly. *An International Refereed, Peer Reviewed & Indexed Quarterly Journal in Science, Agriculture & Engineering,* **5**(19), 259–262.

Singla, G., Panesar, P. S., Sangwan, R. S., & Krishania, M. (2022). Effect of packaging materials on the shelf□life of vermicelli supplemented with enzyme processed kinnow pulp residue. *Journal of Food Process Engineering,* 45(6), e13862.

Stintzing, F. C., & Carle, R. (2004). Functional properties of anthocyanins and betalains in plants, food and in human nutrition. *Trends in Food Science & Technology,* **15**, 19–38.

Thakkar, K. B. (2019). *Development of process technology for dragon fruit (Hylocereus polyrhizus) juice production* [Doctoral dissertation, Junagadh Agricultural University].

Wakchaure, G. C., Choudhari, J. D., Kukde, R. B., & Reddy, K. S. (2023). Postharvest technology of dragon fruit. *Technical Bulletin,* 41, 45.

Wakchaure, G. C., Kumar, S., Meena, K. K., Rane, J., & Pathak, H. (2021). Dragon fruit cultivation in India: Scope, constraints and policy issues. *Technical Bulletin, 27*, 47.

Yashoda, H. M., Prabha, T. N., & Tharanathan, R. N. (2006). Mango ripening: Changes in cell wall constituents in relation to textural softening. *Journal of the Science of Food and Agriculture,* **86**(5), 713–721.