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**Original Research Paper**

# Maturity determination of red and white pulp dragon fruit

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## ABSTRACT

**There is a huge potential for dragon fruits grown in India but insufficient information may hamper its production and postharvest handling. The aim of this study was to investigate the right harvest time and maturity indices for red and white pulp dragon fruit. Growth and developmental studies were undertaken using destructive (total soluble solids (TSS), titratable acidity and TSS: acid ratio) and non-destructive methods (fruit weight, specific gravity, peel colour and heat units). Fruits were collected at seven intervals (7, 14, 21, 26, 31, 36 and 41 days after flowering) to assess the right maturity. All these methods were used to standardize the optimum maturity and right time for the harvest of red and white pulp dragon fruit. Harvesting dragon fruits between 31-36 days after flowering (DAF) was found ideal for optimum maturity and quality. Both red and white pulp fruits harvested at 31 DAF showed better quality in terms of physic-chemical and sensory attributes.**

**Keywords:** Dragon fruit, heat units, maturity and physico-chemical properties

## INTRODUCTION

Dragon fruit (*Hylocereus* sp.) also known as pitaya belongs to the family Cactaceae. It has originated from Mexico and spread to Central and South America (Britton and Rose, 1963). Pitaya is considered a super fruit due to its rich nutraceuticals and high economic value. A variety of colours exist in dragon fruit such as white pulp with red and yellow peel, red and violet-red pulp with red peel colour (Grimaldo-Juarez *et al*., 2007). The red pulp fruit is rich in betalains which is a natural food colour and an excellent source of antioxidants (Le Bellec *et al*., 2006; Baker *et al*., 2013; Mello *et al*., 2015).

Presently, the area under dragon fruit production is expanding rapidly. Vietnam is the leading producer (shares 51% of the world production) of dragon fruit followed by China India produces about 12113 metric tons of dragon fruit annually from an area of approximately 3084 ha (Merten, 2003; Wakchaure *et al*., 2020).

Harvesting fruits at their optimum maturity provides the utmost quality to consumers and better profit to growers. Fruits should be harvested at an appropriate time and developmental stage for the highest fruit quality. Harvesting prior to full maturity is a common practice to get an extended storage life in the international trade of several fruit crops. This often leads to compromise on the potential quality of the concerned fruit in the interest of trade. Although maturity standards exist for dragon fruit, they vary with location and growing conditions. The stage of optimum maturity can be determined using destructive and non-destructive methods. Destructive methods include physiochemical and mechanical parameters such as total soluble solids (TSS), titratable acidity, and TSS: acid ratio. Physical parameters such as fruit weight, external peel colour, days after flowering to harvest and specific gravity are extensively used as non-destructive methods for indices of maturity in many fruits (Wanitchang and Jarimopas, 2008; Fawole and Opara 2013; Kapilan and Anpalagan 2015).

Dragon fruit is a recently introduced crop in India and its demand has been increasing due to its high nutritional and economic values. Harvesting fruits at optimum maturity helps in better post-harvest management of fruits. The maturity of fruits depends on edaphic factors such as soil, climate, temperature, rainfall *etc*. The aim of this study was to understand the growth and development pattern of red and white pulp dragon fruit for optimum maturity and harvest time in the region of Bengaluru, Karnataka, India.

## MATERIALS AND METHODS

White (*Hylocereus undatus*) and red pulp (*Hylocereus polyrhizus*) dragon fruit cultivars were selected from the experimental block of research farm, Hirehalli, ICAR-IIHR, Hessarghatta, Bengaluru, Karnataka, India. It is situated at the longitude 77°11' East and latitude 28°38' North at an altitude of 845 meters above mean sea level and about 40 km from ICAR-IIHR campus, Bengaluru in south India. It falls under a tropical humid climate and is characterized by pleasant summer, moderate rainfall and mild winter.

For the experiment, four-year-old and well-maintained plants were selected. Both cultivars were tagged at the time of bud initiation and at flowering. The fruits were harvested between the 7 and 41 days after flowering (DAF) from May to June 2019.The fruit samples were collected at 7, 14, 21, 26, 31, 36 and 41 DAF to study the maturity pattern. At each interval, fruits were harvested and immediately brought to the laboratory for further analysis.

### Collection of weather data

Weather data for growing conditions were collected from the Weather station of Karnataka State Natural Disaster Monitoring Centre, Yelahanka, Bengaluru, Karnataka. Temperature, rainfall and relative humidity (RH) were taken from1$^{st}$ May to 30$^{th}$ June 2019 for calculating heat units (Fig. 1).

### Non-destructive parameters

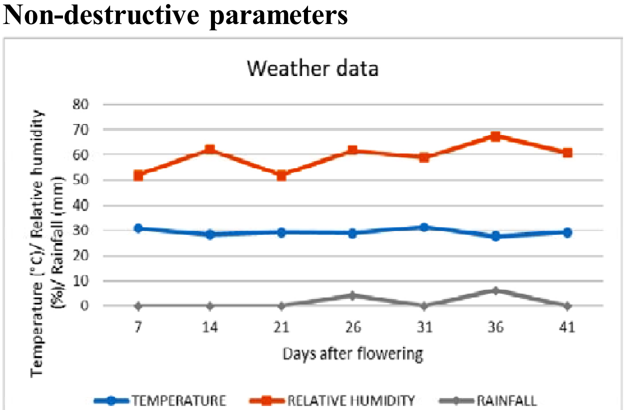


Fig. 1. Weather data (temperature, relative humidity and rainfall) during the study on growth, development and maturity of dragon fruit.

Physical parameters such as average days after flowering (DAF), fruit weight, specific gravity, and heat units were used for the determination of maturity. Weight of each fruit was weighed by electronic balance (Sartorius GPA 5202, Germany). Specific gravity was calculated by measuring the volume of the individual fruit by water displacement method (Mohsenin, 1986). Degree days accumulated were calculated using following formula given by McMaster and Wilhelm (1997) :

Degree days = Sum of (Maximum temperature + Minimum temperature) / 2- Base temperature

Peel colour of fruits was recorded by colorimeter (Minolta RS- 232C, Japan) and represented by 'L', 'a' and 'b' values. The L value represents brightness and its value ranges between 0 (black) to 100 (white). Green colour of peel is indicated by negative or smaller value of 'a' whereas positive or higher 'a' value denotes red colour. The b value represents variations from blue (-b) to yellow (+b). For each colour parameter, two values from opposite sides of individual fruit were recorded and averaged. Redness of peel colour was calculated using $L^*$, $a^*$ and $b^*$ values as per Minolta (2019).

Redness index was calculated by this formula:

$$\Delta E^*_{ab} = \sqrt{(L^*_2 - L^*_1)^2 + (a^*_2 - a^*_1)^2 + (b^*_2 - b^*_1)^2}$$

### Destructive parameters

Physiochemical parameters such as total soluble solids (TSS), Titratable acidity (TA) and TSS: acid ratio was measured by destructive methods. Fruits were cut into pieces and then squeezed to extract the juice. Juice was used to measure TSS through a digital refractometer (ATAGO PAL-3, Japan). Titratable acidity was estimated by juice of white pulp and titrated against 0.1 N NaOH till light pink colour as end point (AOAC, 2000). Red pulp extract was titrated against 0.1 N NaOH till pH 8.1 using microprocessor-based pH system (ESICO RS232PC, India)(Zahid *et al*., 2012).

### Sensory properties

A panel of semi-trained and trained judges was selected for the sensory evaluation. Fruits harvested at 31, 36 and 41days intervals were cut into uniform pieces and served for sensory evaluation. Different sensory attributes of red and white pulp dragon fruit such as fruit colour, texture or crispiness, taste and overall acceptance were taken using a nine-point-Headonic scale (1 = extremely dislike and 9 = extremely like) (Stone *et al*., 2012).

**Statistical analysis**

Data were analysed using software WINDOSTAT 9.3 version as per factorial randomized block design (FRBD) with two factors (colour and interval of harvesting days) having four replication sand eight fruits in each.

## RESULTS AND DISCUSSION

**Non-destructive parameters**

**Growth pattern and days after flowering**

The growth rate increased rapidly during early stages of fruit development and slowed down after full maturity. Both red and white pulp types followed a sigmoid growth pattern (Fig. 2). Previous studies suggested that both red and white pulp followed a sigmoid growth pattern (Nerd *et al*., 1999; Jamaludin *et al*., 2011; Magalhaes *et al*., 2019). It was observed that 80% of fruit development such as fresh weight and pulp percentage was completed before colour break stage. Colour break stage to full red colour stage was found crucial for development of optimum biochemical attributes (TSS and acidity). After full red colour development in the peel, variation in fruit shape and size was almost stopped (Nerd *et al*., 1999).

In dragon fruit, bud initiation was started from the last week of March and continued till last week of August. Both *Hylocereus* spp. required 17-20 days for bud initiation to flowering (Table 1). For optimum fruit maturity, red pulp fruits needed 29-31 DAF and white pulp needed 31-33 DAF. A previous study done by

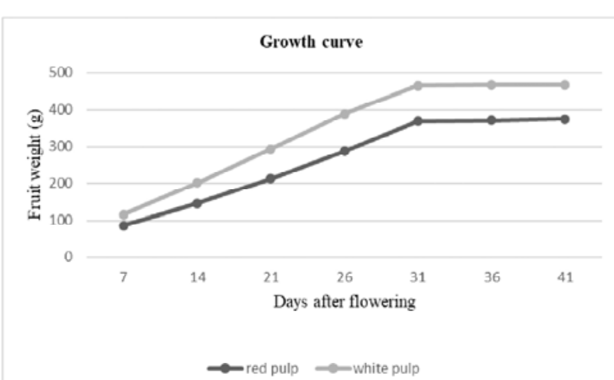


Fig. 2. Growth curve drawn using fruit weight of dragon fruit harvested at seven intervals (7,14,21,26,31,36 and 41 DAF). Presented values are mean± SEm of four replications.

Merten (2003) represented immature (23-27 DAF), mature (28-30 DAF) and over-mature (31-40 DAF) stages of dragon fruit in USA condition. Similar type of results were found in a study done in Thailand (Wanitchang *et al*., 2010). Kishore (2016) studied the growth and development of dragon fruit in Orissa (Bhubaneshwar), India and found that it is a fast-growing crop and takes only a month for attaining optimum maturity. Previous studies have also confirmed the similar maturity period of pithaya (To *et al*., 2002; Centurion-Yah *et al*., 2008; Martinez-Chavez, 2011). Determination of optimum maturity based on DAF was observed as a crucial parameter in many fruit crops (Fawole and Opara, 2013: Patel *et al*., 2014; Kapilan and Anpalagan, 2015).

**Heat units**

Heat units denote the heat requirement of fruits for reaching a particular developmental stage during their growth and development (Lysiak, 2012; Matzneller *et al*. 2014). The heat units accumulated during the period from flowering to optimum maturity was 731.6 (at 29 DAF, data not presented) and 782.2 heat units (31 DAF) in red and white pulp types, respectively (Table 2). Red colour type required lesser heat units for optimum maturity than white pulp fruits. Further studies are required as no reports are available on heat units required during optimum maturity of dragon fruit in India or any other country.

**Fruit weight**

**Table 1. Days required from flower bud emergence to flowering in red and white pulp dragon fruit.**

| Days required from bud emergence to flowering | | |
|---|---|---|
| | **Red pulp** | **White pulp** |
| Days after bud emergence to flowering | 18.02 | 19.31 |
| SE (m)± | 0.045 | |
| CD (0.05) | 0.213 | |

Fruit weight of white pulp was more than red pulp fruit at all harvesting intervals. In white pulp, fruit weight increased from116.44 to 467.37 g and in red pulp it was 56.31 to 367.23 g. A considerable increase in fruit weight was noticed up to 31 DAF in both red and white pulp. Whereas rate of increase in fruit weight was least and almost constant during 36 to 41 days of harvest (Table 1).Therefore, both colour types gained optimum fruit weight up to 31 DAF and recorded 348.44 g in red pulp and 465.5 g in white pulp type at optimum maturity. Many studies have reported a significant increase in fruit weight of dragon fruits and then growth was almost ceased after full maturity (Centurion Yah *et al.*, 2008; Martinez Chavez, 2011; Ortiz and Takahashi, 2015). Red pulp fruits had significantly lower fruit weight than white pulp. This result was in accordance with Nerd *et al.* (1999).

**Specific gravity**

The photosynthates (soluble solids) accumulates from source to sink during growth and development of fruits (Zhang *et al.*, 2005). The specific gravity showed a significant difference between colour types and different harvesting intervals (Table 2). A sharp increase in specific gravity was recorded till 31 DAF and it was almost stable during last intervals of harvest. It was maximum on 31$^{st}$ day for both red and white pulp types1.08 and 1.12 g/cc, respectively. This finding was in accordance with Wanitchang *et al.*, (2010) and Fawole and Opara, (2013).

**Peel colour**

The brightness of Peel colour was shown by *L**value which gradually declined up to full maturity and then somewhat constant at last harvest (Table 3). The value of a* ranged from 10 (green colour) at immature stage to 46 (red colour) in over-mature red pulp fruit and 12 (immature) to 38 (over-mature) in white pulp (Table 2). The *b** value was relatively constant up to 26$^{th}$ DAF and suddenly decreased on 31 DAF then remained constant till over-mature stage. Redness index increased significantly as maturity progressed and found higher at 31 DAF and it was at par with 36 and 41 DAF. These values indicated that optimum red colour development in peel occurred on 31 DAF in both red and white pulp fruits. Red pulp fruits had a significantly higher redness index of peel than white pulp fruits (Table 3).

Manifestation of red colour in the peel initiated after 26 days of flowering in both pithaya species. This result was in accordance with Centurion Yah *et al.* (2008). Both cultivars took 4–5 days to develop full red colour from colour break stage. Fruit peel colour was found as a crucial parameter for determining the

**Table 2. Changes in fruit weight, specific gravity and heat units during growth and development of dragon fruit harvested at seven days intervals.**

| Harvest days days intervals | Fruit weight | | Specific gravity | | Heat units |
|---|---|---|---|---|---|
| | Red pulp | White pulp | Red pulp | White pulp | Red pulp/White pulp |
| 7 | 56.31 | 116.44 | 0.58 | 0.68 | 166.85 |
| 14 | 135.04 | 238.43 | 0.79 | 0.79 | 346.85 |
| 21 | 176.12 | 252.73 | 0.87 | 0.92 | 534.80 |
| 26 | 231.15 | 288.74 | 0.98 | 1.02 | 659.40 |
| 31 | 348.44 | 465.50 | 1.08 | 1.12 | 782.20 |
| 36 | 361.42 | 468.04 | 1.10 | 1.15 | 897.65 |
| 41 | 367.23 | 467.37 | 1.11 | 1.14 | 1015.05 |
| C.D. (0.05) | | | | | |
| Colour | 28.22 | 0.025 | - | | |
| Days | 52.78 | 0.046 | - | | |
| Colour*Days | NA | NA | - | | |
| S.Em± | | | | | |
| Colour | 9.83 | 0.009 | - | | |
| Days | 18.38 | 0.016 | - | | |
| Colour*Days | 26.00 | 0.023 | - | | |

**Table 3. Changes in peel colour (*L**, *a**, *b** value and redness of peel index) during growth and development of dragon fruit harvested at seven days intervals.**

| Harvest days intervals | L* value | | a* value | | b* value | | Redness index | |
|---|---|---|---|---|---|---|---|---|
| | Red pulp | White pulp | Red pulp | White pulp | Red pulp | White pulp | Red pulp | White pulp |
| 7 | 50.71± 2.51 | 51.18± 1.49 | 10.46± 1.23 | 9.58± 0.30 | 31.18± 1.81 | 32.88± 1.67 | 0.00 | 0.00 |
| 14 | 47.19± 1.21 | 50.61± 1.05 | 10.96± 0.38 | 10.21± 0.76 | 29.01± 0.92 | 33.89± 0.28 | 4.16± 0.12 | 1.32± 0.07 |
| 21 | 46.41± 0.99 | 49.28± 1.45 | 12.23± 0.52 | 11.66± 0.34 | 27.73± 1.22 | 31.83± 1.33 | 5.57± 0.19 | 3.01± 0.11 |
| 26 | 44.73± 1.72 | 48.75± 1.67 | 13.02± 0.83 | 6.37± 2.07 | 29.37± 1.34 | 30.32± 1.93 | 5.89± 0.14 | 4.78± 0.15 |
| 31 | 36.82± 1.73 | 41.34± 0.85 | 43.70± 3.58 | 36.92± 3.32 | 9.94± 2.31 | 9.94± 0.87 | 40.02± 2.06 | 37.02± 1.41 |
| 36 | 35.03± 1.80 | 39.51± 0.89 | 44.23± 2.47 | 37.71± 1.20 | 9.79± 0.71 | 10.28± 1.03 | 42.24± 1.42 | 37.93± 1.33 |
| 41 | 36.88± 0.24 | 37.93± 0.90 | 46.08± 1.78 | 38.08± 2.19 | 9.10± 0.43 | 10.38± 1.45 | 44.13± 1.93 | 38.66± 2.41 |

maturity in plum (Usenik *et al*., 2009), citrus (Singh *et al*., 2017), sweet cherry (Chelpinski *et al*., 2019), tomato (Goisser *et al*., 2020) and apple (Pourdarbani *et al*., 2020).

## Destructive parameters

### Total soluble solids and titratable acidity

A significant rise in TSS was recorded during fruit maturity (Table 4). TSS was higher in red pulp than white pulp fruits. TSS values ranged from 4.5 to 14.3°B and 4.1 to 13.4°B in red pulp and white pulp fruits during different maturity stages (7 to 41 DAF). It remained increasing till optimum maturity and started decreasing during over-mature stages (Table-4). TSS recorded highest on 31 DAF in red (14.2°B) and white pulp fruits (13.2°B). Rise in TSS during maturity indicated that it was a suitable indicator of optimum maturity of dragon fruit (Nerd *et al*., 1999). Many studies have reported that TSS ranged from 10 to 17°B in different genotypes of dragon fruits (Marquez-Guzman *et al*., 2005; Livera-Munoz *et al*., 2010). TA of both *Hylocereus* spp. had likely to increase and reached highest on 26$^{th}$ DAF (0.6% in red and 0.7% in white) and then suddenly decreased on 31st day. Acidity was constantly decreasing in over-mature fruit and reached to a minimum at 41 DAF (Table 4). Optimum acidity (0.23% in red pulp and 0.31% in white pulp) was recorded on 31 DAF. The increasing trend of TA before the colour development of immature fruits and then decline in acidity is associated with the commencement of maturity (Arevalo-Galarza and Ortiz-Hernandez, 2004;Ortiz and Takahashi, 2015). The optimum concentration of TA imparts a good flavor and blend in dragon fruit. Similar pattern of changes in TA during fruit maturity has been reported in various studies (Sornyatha and Anprung, 2009; Osuna-Enciso *et al*., 2011; Kienzle *et al*., 2011; Babu *et al*., 2017; Bakshi *et al*., 2018). Nerd *et al*. (1999) had found that highest acidity was less than 1% in mature fruits of red and white pulp pithaya.

### TSS: acid ratio

For a better palatability, TSS: acid ratio of fruits is important. The TSS: acid ratio of both red and white pulp dragon fruit exhibited an increasing trend during fruit maturity. TSS/acid ratio was lowest at immature stage (18.2 and 12.5) and significantly higher at mature (61.3 and 41.9) and over mature stages (76 and 55) in red and white pulp fruits respectively (Table 4). The percentage increase in TSS/acid ratio was highest at 31 DAF (64 and 69%) in red and white pulp fruits, respectively. At immature stages TSS was less and acidity was more while at mature stage it was vice-versa. The higher TSS: acid ratio at 31 DAF was

**Table 4. Changes in TSS, titratable acidity and TSS: acid ratio during growth and development of dragon fruit harvested at seven days intervals.**

| Harvest days intervals | TSS (°B) | | Titratable acidity (%) | | TSS: acid ratio | |
|---|---|---|---|---|---|---|
| | Red pulp | White pulp | Red pulp | White pulp | Red pulp | White pulp |
| 7 | 4.55 | 4.15 | 0.25 | 0.33 | 18.20 | 12.57 |
| 14 | 5.57 | 5.15 | 0.31 | 0.34 | 17.96 | 15.14 |
| 21 | 8.85 | 7.90 | 0.43 | 0.55 | 20.58 | 14.36 |
| 26 | 11.56 | 10.15 | 0.50 | 0.62 | 23.12 | 16.37 |
| 31 | 14.20 | 13.20 | 0.23 | 0.31 | 61.30 | 41.93 |
| 36 | 14.30 | 13.40 | 0.20 | 0.28 | 68.09 | 47.85 |
| 41 | 13.70 | 13.20 | 0.18 | 0.24 | 76.11 | 55.00 |
| C.D. (0.05) | | | | | | |
| Colour | 0.12 | | 0.019 | | 3.32 | |
| Days | 0.21 | | 0.036 | | 6.21 | |
| Colour*Days | 0.31 | | 0.051 | | 8.78 | |
| SEm± | | | | | | |
| Colour | 0.04 | | 0.007 | | 1.16 | |
| Days | 0.08 | | 0.013 | | 2.16 | |
| Colour*Days | 0.11 | | 0.018 | | 3.06 | |

a result of decline in acidity and rise in TSS (Martinez Chavez, 2011; Osuna-Enciso *et al*., 2011).This result concurred with the findings of Centurion-Yah *et al*. (2008), Martinez Chavez (2011) and Ortiz and Takahashi(2015).

## Sensory properties

The sensory scores given for different attributes such as fruit appearance, pulp colour, texture and taste are summarized in Fig. 3. Evaluation of sensory quality of red and white pulp dragon fruit indicated that fruits harvested on 31 DAF had maximum consumer acceptance followed by 36 DAF in both colour types. Sensory attributes scored highest at optimum mature stage (31DAF) and least at over mature stage (41 DAF). Sensory properties are important for deciding the optimum maturity of fruits as each attribute is related to fruit quality (Shahbaz *et al*., 2014; Taiti *et al*., 2017).

## Days after flowering (DAF) to optimum maturity

The optimum maturity was considered to have reached when the incremental fruit growth rate was significantly lower. All the physico-chemical and sensory parameters were considered to calculate the days required from flowering to optimum maturity. Red pulp fruits required comparatively less duration for attainment of optimum maturity compared to white pulp. Above parameters showed that both colour types needed 31 DAF for attaining the optimum maturity.

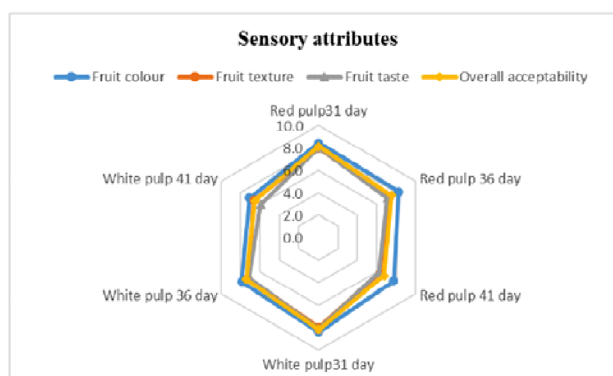


Fig. 3. Changes in fruit colour, texture, taste and overall acceptability during growth and development of dragon fruit harvested at seven days intervals. Presented values are mean of fifteen replications.

Over-mature fruits were prone to cracking, postharvest losses and had lesser shelf life. Fruit cracking was more prevalent in red pulp than white pulp fruits.

## CONCLUSION

Dragon fruit is an exotic fruit crop having rich nutraceutical properties. This crop has a great potential in both domestic and export market. Harvest at optimum maturity is an important factor for improving quality and shelf life of fruits. Results of the study reported that physico- chemical parameters were helpful to predict the optimum maturity of red and white pulp dragon fruits. Growth and development of both *Hylocereus* spp. followed a sigmoid growth pattern. The results showed that all the parameters were highest or optimum on 31DAF in both colour types. Red pulp fruits needed comparatively lesser time (29-31 DAF) than white pulp fruits (31-33 DAF) for optimum maturity. At optimum maturity, TSS was higher in red pulp and acidity, fruit weight and specific gravity was higher in white pulp fruits. Sensory attributes scored highest in optimum mature fruits (31DAF) and lowest in over mature fruits (41 DAF). Fruit weight, specific gravity, TSS, acidity and days after flowering can be used as important maturity indices for determining the optimum maturity of dragon fruit.

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**Conflict of interest**

Author reports no conflicts of interest.

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