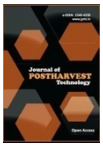

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RESEARCH ARTICLE

Ripening associated physico-biochemical changes in red fleshed organic dragon fruit of Mizoram, India

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ABSTRACT

A study was conducted with red fleshed organically grown dragon fruit (*Hylocereus polyrhizus*) at north-eastern Himalayan region of Mizoram, India; for evaluating ripening associated physico-biochemical changes to select optimum mature fruits for local as well as distant market. Fruits were collected from organic dragon fruit farm of Ailawg village, Mamit district of Mizoram. Data analyses revealed that fruit growth and development was comparatively slow for the first three weeks after fruit set, followed by rapid growth of one week and again a slow growth for final week. Fruits at 35 days after fruit set (DAFS) had maximum size in terms of fruit length (77.25±4.26 mm), diameter (70.25±2.68 mm) and volume (203.25±2.86 cc) with high fruit weight (211.80±6.91 g), pulp recovery (56.35±2.44%) and pulp: peel ratio (1.11±0.05). Besides, fruits at this stage had highest TSS:acid ratio (99.22±7.88) and ascorbic acid (24.79±2.06 mg100g^{-1}) along with good pulp and peel colour as determined by anthocyanin content (pulp: 10.34±1.38 mg100g^{-1}, peel: 5.67±1.05 mg100g^{-1}). However, these values were quite good after 28 DAFS as the fruits were turning colour. Therefore, it may be concluded that organic red fleshed dragon fruit has to be harvested 35 days after fruit set for local market while it will be good to harvest at 28 DAFS for distant market.

Keywords: Dragon fruit, ripening, firmness, TSS:acid, ascorbic acid, anthocyanin

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INTRODUCTION

Dragon fruit is a unique, colorful, tasty, attractive and nutritious fruit of cactaceae family. This plant is originated in Central America and Mexico (Wong and Siow, 2015); a vigorous growing vine which require an erect pole for support to grow and then a ring like structure to fall or hang downward to form a umbrella shape. Fruits are with bright red skin along with green scales and either red or white fleshed, good colour and pleasant, tasty pulp with numerous black colour edible seed embedded (Perween et al., 2018) and having enormous nutritive properties (Kiranmai, 2022) which impacted the growers to choose this crop for different part of India and abroad for commercial cultivation. Dragon fruit is a newly introduced fruit in Mizoram where its cultivation was started back in the year 2013 in Aizawl District, Mizoram. Majority of the farmers has been enrolled under MIDH scheme and received their basic planting material from the State Department supply and few farmers has imported the dragon fruit planting material from Thailand and other producing countries via Myanmar. Though, both white and red fleshed dragon fruits are cultivated in the state, however, red fleshed use to fetch premium price in market. Majority of the farmers are cultivating the fruit based on home grown organic inputs, and farmyard manure, and vermi compost. Organically grown red

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fleshed dragon fruit has good market demand in both state's internal city markets also in the market of adjoining states. However, judging the optimum maturity of organically grown red fleshed dragon fruit for local and external market is very crucial though not having enough information, so far, its cultivation in north-eastern Himalayan region is concerned, particularly under organic nutrition. Therefore, the present experiment was conduction to study the fruit growth and development, ripening and associated physico-chemical changes in organic red fleshed dragon fruit of Mizoram.

MATERIALS AND METHODS

Raw Fruits were collected from the newly planted red fleshed dragon fruit (*Hylocereus polyrhizus*) orchard located at Ailawng village, Mamit district of Mizoram, India. Three plants per pole were planted having a spacing of 4m X 2m and cultivated organically with farm yard manure @ 42.85 Kg per pole. Twelve number of random poles were marked for collection of fruits at weekly interval from fruit set. Experiment conducted following complete randomized design (), where five different days after fruit set (DAFS) were considered as treatments with four replications under each treatment and three fruits per replication. Data were subjected to analysis of variance (ANOVA) and least significant difference (LSD) was calculated at 5% probability level. Data were presented as mean along with standard deviation value. Means were separated using Duncan's Multiple Range Test (DMRT). Data analysis was done with SPSS Version 22.0 statistical software for windows.

Weight of fruits, pulp and peel were measured using digital balance. Fruit length, diameter, peel thickness was measured using digital slide caliper. Fruit firmness was recorded using digital handheld fruit penetrometer, whereas fruit volume was recorded using standard procedure of water displacement technique. Pulp to peel ratio was calculated mathematically by dividing pulp weight with peel weight at each stage, while pulp recovery percentage was calculated by dividing pulp weight with fruit weight and percentage conversion.

Total Soluble Solids (TSS) content of fruit juice was measured with digital refractometer whereas, titratable acidity, total sugar, reducing sugar and ascorbic acid content was measured using standard procedure as described in AOAC (2016) and Ranganna (1986). TSS: acid ratio was calculated by diving TSS value with percent acidity. Total chlorophyll content of the fruit peel was measured following the procedure of Sadasivam and Manickam (2007). For measuring pulp and peel anthocyanin, 2 g of pulp or peel was extracted with 20 ml of methanolic HCL (85:15 v/v) and the extracted tube was refrigerated (40C) for one hour and then centrifuged at 7500 rpm for 15 mins and the supernatant was taken and process repeated and combined supernatant for obtaining standard volume and total anthocyanin was measured at 530 nm absorbance in a digital spectrophotometer and expressed as mg per 100g (Ryu et al.,2013).

RESULTS

Current study had revealed that red fleshed dragon fruit under organic nutrient management had significant changes in fruit physical and biochemical parameters from fruit set to maturity which are described below.

Fruit weight

It was observed that fruit set to maturity, dragon fruits had continuously gained fruit weight. At seven days after fruit set (7DAFS), fruit weight was 75.72±4.27g; which had increased up to 211.80±6.91g at 35 DAFS (Table 1). Continuous

attainment in weight of the fruit marked the consistent growth and development of fruit. However, it was found that there was drastic change in fruit weight from 21 to 28 days after fruit set.

Table 1: Changes in fruit weight, length, diameter, volume and pulp weight of dragon fruit during its developmental stages

DAFS	Fruit Weight (g)	Fruit Length (mm)	Fruit Diameter (mm)	Fruit Volume (cc)	Pulp Weight (g)
7DAFS	75.72±4.27a	57.25±6.34a	44.75±1.92a	73.75±3.96a	10.72±1.03a
14DAFS	88.27±3.74b	61.75±4.49a	48.50±1.80b	86.25±3.70b	13.79±2.39a
21DAFS	91.17±3.41b	64.25±3.27a	53.25±1.09c	89.00±3.67b	22.56±1.93b
28DAFS	188.67±6.27c	74.75±2.49b	64.50±2.69d	182.00±3.54c	79.25±2.38c
35DAFS	211.80±6.91d	77.25±4.26b	70.25±2.68e	203.25±2.86d	119.36±6.45d
LSD (p=0.05)	**8.902**	**7.603**	**3.696**	**6.205**	**5.916**

Means followed by the same letters do not differ significantly at 5% level of probability, LSD: Least Significant Difference, DAFS: Days after fruit set.

Fruit length and diameter

Length and diameter of the dragon fruits had significant changes during fruit development. At 7 DAFS, fruit length and diameter of fruit was 57.25±6.34mm and 44.75±1.92mm, respectively, which increased and become 44.75±1.92mm and 70.25±2.68mm at 35 DAFS (Table 1). Up to 21 DAFS, length and diameter had slowly increased, whereas, from 21 to 28 DAFS, it increased rapidly and again become slow up to 35DAFS.

Fruit volume

Likewise, volume of dragon fruit had slow increase up to 21 DAFS, ranged between 73.75±3.96cc (at 7 DAFS) to 89.00±3.67cc (at 21 DAFS). But, from 21DAFS to 28 DAFS it was drastic rise in fruit volume and that slowly continued up to 35 DAFS to attain a final volume of 203.25±2.86cc.

Table 2: Changes in pulp recovery, peel weight, peel thickness, pulp: ratio and fruit firmness during dragon fruit growth

DAFS	Pulp recovery (%)	Peel Weight (g)	Peel thickness (mm)	Pulp: peel ratio	Fruit Firmness (N cm^{-2})
7DAFS	14.15±1.96a	65.37±0.63a	8.50±0.87a	0.16±0.02a	24.05±1.14a
14DAFS	15.62±3.37a	69.03±2.42ab	7.93±0.43a	0.20±0.03a	23.31±3.11b
21DAFS	24.75±2.53b	73.74±3.11b	4.42±0.55b	0.31±0.03b	16.70±2.00c
28DAFS	42.01±1.16c	92.67±4.01c	1.98±0.08c	0.86±0.06c	11.73±1.39d
35DAFS	56.35±2.44d	108.00±6.28d	1.92±0.04c	1.11±0.05d	7.33±0.91d
LSD (p=0.05)	**4.187**	**6.582**	**0.867**	**0.068**	**3.277**

Means followed by the same letters do not differ significantly at 5% level of probability, LSD: Least Significant Difference, DAFS: Days after fruit set.

Pulp Weight and Pulp recovery

At 7 DAFS pulp weight and pulp recovery (%) was 10.72±1.03g and 14.15±1.96% which increased to 119.36±6.45g and 56.35±2.44% at 35DAFS (Table 2). Pulp weight and recovery (%) was marked increased from 21DAFS till harvest.

Peel Weight and Peel thickness

It was noticed in the present study that peel weight consistently increased from 7 DAFS to 35 DAFS, whereas thickness of the peel gradually decreased with the increase in fruit maturity. At 7 DAFS peel weight was 65.37±0.63g which become 108.00±6.28g in case of the fruits at 35 DAFS, whereas peel thickness was 8.50±0.87mm at 7DAFS which become 1.92±0.04mm at 35 DAFS (Table 2).

Pulp: Peel Ratio

Pulp: peel ratio of the fruits gradually increased from 0.16±0.02 (7 DAFS) to 1.11±0.05 (35 DAFS).

Fruit Firmness

Firmness of the fruit was consistently reduced in the process of fruit ripening. Initially, unripe fruits were having firmness of 24.05±1.14 Ncm^{-2}, whereas, it drastically reduced at fruit ripening (11.73±1.39 Ncm^{-2} at 28 DAFS) and full maturity (7.33±0.91 Ncm^{-2} at 35DAFS).

Table 3: Variation in TSS, acidity, TSS:acidity, total and reducing sugar content in developing red fleshed dragon fruits

DAFS	TSS (^{0}Brix)	Acidity (%)	TSS:acid	Total Sugar (%)	Reducing Sugar (%)
7DAFS	3.30±0.75a	0.56±0.04a	5.92±1.63a	1.79±0.12a	1.53±0.02a
14DAFS	5.05±0.17b	0.47±0.03a	10.80±1.23a	2.44±0.29b	2.14±0.34b
21DAFS	6.88±0.56c	0.28±0.03b	24.77±4.28b	5.09±0.35c	3.50±0.24c
28DAFS	8.40±0.51d	0.17±0.03c	48.70±4.35c	6.65±0.25d	4.51±0.19d
35DAFS	12.65±0.36e	0.13±0.02d	99.22±7.88d	9.70±0.31e	9.03±0.14e
LSD (p=0.05)	**0.889**	**0.052**	**7.918**	**0.482**	**0.374**

Means followed by the same letters do not differ significantly at 5% level of probability, LSD: Least Significant Difference, DAFS: Days after fruit set.

TSS, titrable acidity and TSS:acid ratio

From table 3, it is evident that TSS content of the developing organic dragon fruit had significant increase. At 7 DAFS it was recorded 3.30±0.75 ^{0}Brix, which had become 12.65±0.36 ^{0}Brix at 35 DAFS. Whereas, titratable acidity was decreased significantly in the process of fruit development and ripening. It was 0.56±0.04% in 7 DAFS, that decreased to 0.13±0.02% at 35DAFS. Consequently TSS:acid ration which was low at 7 DAFS (5.92±1.63) had become highest at 35 DAFS (99.22±7.88).

Total and reducing sugar

Data presented in Table 3 manifested that total and reducing sugar content of dragon fruit had significant increase during the period of fruit growth and development. At 7 DAFS, total and reducing sugar content of fruit was 1.79±0.12% and 1.53±0.02%, which got increased at 35 DAFS as 9.70±0.31% and 9.03±0.14%, respectively.

Ascorbic acid content and total chlorophyll

With the process of fruit development and ripening, it was found that dragon fruit had significant increase in ascorbic acid content. At 7 DAFS, fruit ascorbic acid content was 11.25±1.61 mg100g^{-1} which finally at 35 DAFS become 24.79±2.06 mg100g^{-1} (Table 4). Total chlorophyll content of peel was found highest at 7 DAFS (34.45±2.57mg/kg) which gradually reduced and become least at 35 DAFS (10.61±1.22 mg/Kg).

Table 4: Ascorbic acid, total chlorophyll, peel and pulp anthocyanin content at different developmental stages of dragon fruit

DAFS	Ascorbic acid (mg100g^{-1})	Total chlorophyll (mgKg^{-1})	Peel Anthocyanin (mg100g^{-1})	Pulp Anthocyanin (mg100g^{-1})
7DAFS	11.25±1.61a	34.45±2.57a	0.26±0.12a	0.42±0.15a
14DAFS	14.82±1.54b	21.54±1.99a	0.94±0.18ab	1.65±0.51a
21DAFS	17.76±1.65bc	16.80±2.33b	1.98±0.71b	5.98±0.93b
28DAFS	19.35±1.68c	12.09±1.34c	4.12±1.01c	8.76±0.81c
35DAFS	24.79±2.06d	10.61±1.22d	5.67±1.05a	10.34±1.38d
LSD (p=0.05)	**2.991**	**3.416**	**1.273**	**1.497**

Means followed by the same letters do not differ significantly at 5% level of probability, LSD: Least Significant Difference, DAFS: Days after fruit set.

Peel and pulp anthocyanin

It is evident from the Fig.1 that fruit pulp has started gaining characteristic colour 21 DAFS onwards. Besides, the peel also remained green up to 21DAFS. Likewise, it was found from Table 4 that peel and pulp anthocyanin content started increasing after 21DAFS (Peel: 1.98±0.71 mg100g^{-1}; Pulp: 5.98±0.93 mg100g^{-1}) compared with the value at 7 DAFS (Peel: 0.26±0.12 mg100g^{-1}; Pulp: 0.42±0.15 mg100g^{-1}). It was observed that anthocyanin content recorded maximum at 35 DAFS both in peel (5.67±1.05 mg100g^{-1}) and pulp (10.34±1.38 mg100g^{-1}) of organic dragon fruit (Table 4). Moreover, it was noted that pulp contain more anthocyanin than peel in mature and fully ripe dragon fruit.

DISCUSSION

It was found that fruit weight, volume, length and diameter had consistently increased in developing organic dragon fruit, which had marked the normal sign of fruit growth and development. Jamaludin et al. (2011) had similar observation with red fleshed dragon fruit at Selangor, Malaysia. However, in the present study, it was clearly noticed that fruits had initial period of slow growth (7-14 DAFS) followed by a period of rapid growth (14 to 28 DAFS) and subsequently again a slow growth of one week (28 to 35 DAFS). Trong et al. (2022) reported of having comparatively slow growth in fruit development in terms of increment

in fruit length and diameter from 6 to 21 days after anthesis (DAA), whereas rapid growth after 22 DAA. With increasing growth, the thickness of the peel reduced though the peel weight continued to increase and pulp weight and pulp recovery percentage significantly increased particularly last three weeks (21-35 DAFS) and thus pulp: peel ratio also had consistent increment during the period. Almahi and Abu-Goukh (2017) described that peel thickness had decreased while pulp: peel ratio increased during fruit growth and development of grapefruit. Magalhaes et al. (2019) found that from 28 to 42 DAA, pulp weight had consistent increment in dragon fruits, whereas skin thickness had reduced. Present study revealed that developing red fleshed organic dragon fruit had consistent reduction in fruit firmness from 7to 35 DAFS. Padmanabhan et al. (2016) observed similar findings of consistent reduction in firmness of developing strawberry fruits due to deterioration in cell wall structure at ripening. Present study showed significant increase in fruit sugar (both total and reducing) and which may have contributed to increase fruit TSS whereas, reduction of titratable acidity, which in turn caused marked increase in TSS:acid ratio. Rapid conversion of starch and organic acid to sugars had increased the fruit sugar content while decreasing the acidity and resulted in high fruit TSS:acid ratio in dragon fruit during maturation (Trong et al., 2022). Lata et al. (2022) found highest TSS:acid ratio after 31 DAFS in dragon fruit with continuous increment of it during the entire fruit development period. Besides, in the current study, it was found that ascorbic acid content had gradually increased in the developing red fleshed organic dragon fruits. Trong et al. (2022) had similar observation in red fleshed dragon fruit at Vietnam, where fruit ascrobic acid content was 11.47g/Kg in 6 DAA and had become 26.18 g/Kg at 32 DAA. In the present study, it was found that fruits peel remained green up to 21 DAFS whereafter in started taking colour and got completely red peel and flesh at 35 DAFS. Accordingly, total chlorophyll content of peel was decreased with advent of ripening whereas, increment in peel and pulp anthocyanin. Jamaludin et al. (2011) had found that chlorophyll content in peel of dragon fruit decreased with days after pollination in a quadratic manner. Zitha et al. (2022) observed consistent increment of anthocyanin content of pulp in developing red fleshed dragon fruit.

Fig. 1: Red fleshed organic dragon fruit [7DAFS (A), 14 DAFS (B), 21 DAFS (C), 28 DAFS (D), 35 DAFS (E)]

CONCLUSION

Present study revealed that developing organic dragon fruit had continuous growth, however, initial three weeks growth was comparatively slow followed by a rapid growth of one week and again a slow growth up to final stage of full ripening. It was clearly found that at 35 DAFS , fruits become fully ripened with having good size in terms of fruit length, diameter and volume, high fruit weight, thin peel, high pulp recovery with excellent TSS:acid ratio and sugar content of the fruit pulp. Besides, fruits at 35 DAFS having highest ascorbic acid content and best peel and pulp colour in terms of recorded anthocyanin content. However, these values were quite good after 28 DAFS as the fruits were turning colour. Therefore, it may be concluded that organic red fleshed dragon fruit has to be harvested 35 days after fruit set for local market while it will be good to harvest at 28 DAFS for distant market.

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