EFFECT OF STORAGE TEMPERATURE AND LOW TEMPERATURE CONDITIONING ON QUALITY AND CHILLING INJURY OF 'LD1' RED FLESH DRAGON FRUIT

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Abstract

Vietnam is a significant producer of dragon fruit, mainly concentrated on white flesh cultivars up to now. 'LD1' characterized by red flesh was newly bred cultivar and has been widely cultivated in Vietnam but limited research on postharvest was reported. In this study, we examined the effect of storage temperature (2, 6 and 10°C) for 2 or 4 6 weeks on quality of LD1 fruit in comparison with the control (non-stored - 20°C). In addition, the potential for improving quality by using low temperature conditionings (LTC) at 6 and 10°C for 3 days before keeping fruits for storage at 2°C. For fruit that were not cool stored (kept at 20°C), fruit could be kept for approximately 5 days, but quality decreased rapidly so that by 9 days fruit began to rot. For cool stored fruit, 6°C was the best temperature resulting in a good quality for up to 4 weeks without chilling injury. At the lowest storage temperature (2°C), fruit suffered chilling injury which included wilting and desiccation of the bracts, and translucence of the outer flesh with low percentage of fruit rotten was observed. Chilling symptoms were appeared after even 2 weeks of storage and increasing with storage duration. Chilling symptoms and rot incidence increased dramatically with time at 20°C after removal from storage. Low temperature conditioning slightly reduced chilling symptoms at 2°C. These results provide initial recommendations for postharvest storage conditions, and directions for further research.

Keywords: *Hylocereus undatus,* postharvest, temperature, chilling injury, disease

INTRODUCTION

Dragon fruit (*Hylocereus undatus*) is an exotic fruit, belongs to the *Cactaceae* family and originated from tropical forest regions of Mexico and Central and South America (Mizrahi *et al*., 1997). In Vietnam, dragon fruit have been grown for over 100 years since introduction by the French. However, the commercial production has not significantly been developed until 1980's with mainly white-flesh cultivar - Binh Thuan (Luders and Mc Mahon, 2006), this being named after the main growing region in Vietnam.

While white-flesh cultivars ('Binh Thuan' or 'Cho Gao') are still the main ones for export, newly bred cultivars with coloured flesh are receiving increased interest due to both novelty and that the red pigments are perceived as a potential health benefit. 'LD1' is a hybrid 'Binh Thuan' and a red flesh Colombian cultivar, which was developed by SOFRI and released in 2005. It has desirable agronomic characteristics and is similar to 'Binh Thuan' in terms of fruit quality, fruit weight and shape, but has a softer texture.

However, the postharvest characteristics of 'LD1' are poorly understood and almost no studies relating to the optimum storage temperature was found. Storage temperature is the most important postharvest factor, and is dependent on variety and environmental conditions. In Israel, the best storage temperature for dragon fruit is 10°C (Nerd *et al*., 1999), whereas 5°C was recommended in California Freitas & Mitcham (2013) and in Vietnam for 'Binh Thuan' (To *et al*., 2002).

Along with storage temperature, low temperature conditioning treatment (LTC) is a possible tool to reduce chilling injury. In avocado, Woolf *et al.* (2002) reported that LTC at 6 - 8°C for 3 - 5 d could reduce external chilling injury during storage at 0°C. Similarly in using LCT on papaya, fruit is held at 12.5°C for 4 d, before storage at 2°C (Chen & Paull, 1986).

Thus, this work is aimed to determine the effect of storage temperature on overall fruit quality and chilling injury in a new dragon fruit selection (LD1), and the impact of low temperature conditioning (LTC).

MATERIALS AND METHODS

Fruit and packaging

Dragon fruit - red flesh fruit cultivar named. LD1 was harvested at a mature stage with full red skin (about 28 - 30 days after flowering) from a commercial production farm at SOFRI in the early rainy season (May, 2013). After harvest, fruits were transported immediately to the laboratory where they were graded, excess stem trimmed and hand-washed then air-dried under fans.

Fruit were stored individually in 25μm perforated polypropylene bags without sealing (4 × 5 mm

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diameter holes per bag) and packed in perforated one-layer cardboard boxes (10 fruits/box). Three boxes (replicates) were used for each treatment.

Experiment design

The experiment had two factors; storage temperature and low temperature conditioning (LTC) carried out simultaneously: (i) For evaluation of storage temperature response: three storage temperatures (2, 6 and 10°C) were used with a non-stored control (20°C) (ii) For LTC treatments: two conditioning treatments were applied by keeping fruits at 6°C or 10°C for 3 days then stored for 4 wks at 2°C ("6-2" and "10-2", respectively). All treatments had three boxes placed randomly in the temperature cabinets (10 fruits/box).

Assessment times

- Quality evaluation at the harvest: Thirty fruits of dragon fruit were subjected to non- and destructive evaluation.

- Non stored control: Fruit quality was assessed after 5 and 9 days of shelf life at 20°C.

- Storage temperature response (STR): After 2 and 4 weeks storage, fruit were moved from their bags and external appearance was assessed after 1 day at 20°C. External and destructive assessments were carried at 5 days for the 2 weeks of storage, and 3 days for the 4 weeks of storage.

- LTC treatment: After 4 weeks of storage, fruit were moved from their bags and kept for 1 and 5 d at 20°C (shelf life).

Fruit quality evaluation

Quality attributes of dragon fruit were assessed on the basic of non-destructive and destructive evaluations. The attributes such as sound (overall acceptable quality), bract appearance, rots (overall, blossom, body and stem rots), skin colour and stem green were non-destructively assessed and the destructive were included in colour, firmness and translucency of flesh; soluble solid concentration (SSC), Total acidity (TA), electrolyte leakage (EL) and chilling appearance, all were measured as followed the method given by Woolf et al. (2006). Details are as follows: skin colour (L*, C, h°C) was measured at three locations around the equator using a Minolta chromameter (CR300 with a D65 light source; Minolta camera Co, Osaka, Japan). Flesh firmness was also measured in triplicate around the equator after making a small incision and pulling back a flap of skin (Effegi penetrometer, 10 - 15 N, 11 mm diameter head), SSC was measured by Atago refractometer (N-20E; 0 - 20 %) and fruit acidity (citric acid equivalents by titration) on juice expressed from flesh of the whole fruit filtered through nylon cloth. Bract appearance: a 0 - 5 scale ranging from green/red colourations with on browning or blackening (0), through yellowing and browning of margins (3), to complete blackening and desiccation (5). Stem appearance: the residual succulent cladode left at the base of the fruit was rated on a 0-4 scale in which healthy, green stem was 0, green yellow colouration and sunken shrivelled tissue was 4. Blossom end rots (BER) entering through, or around the floral (distal) end of fruit were rated on a 0 - 3 scale, indicating that portion of the circumference at this location affected by rot. Thus scores of 1 - 3 were associated with 5 - 10, 16 - 25 and >50 % of the circumference affected, respectively. Body rot scores of 1 - 3 were associated with 5 - 10, 16 - 25 and >50% of the surface area affected, respectively.

RESULTS AND DISCUSSION

Effect of storage temperature and storage time to fruit quality

Quality changes of dragon fruit during the shelf life at 20°C

As mentioned above, fruit quality was assessed by using non-destructive and destructive analysis (Table 1). Statistically analysed results indicated that five non-destructive attributes i.e. skin colour, stem green, bract appearance, overall rots and body rots and four destructive attributes including flesh colour, flesh firmness, total acidity (TA) and electrolyte leakage (EL) of dragon fruit were significantly different during the shelf life at 20°C. For skin colour, skin lightness decreased over the shelf life of 5 and 9 days (Table 1). While, bract appearance and rots (overall rot and body rot) were not different after 5 d shelf life, by 9 d rots had increased with a body rot score of 1.3 indicating an affected area of ≈16-25%.

Flesh colour of all colour space measures (L*, C, h°) were observed after 5 days shelf life (Table 1). Similarly, reduced flesh firmness and total acidity, and increased electrolyte leakage were observed after 5 days of shelf life. At harvest, total acidity content of dragon fruit was 0.27% whereas 0.09 and 0.07% were reported at shelf life of 5 and 9 days respectively. Flesh firmness decrease suggests softening and changes to cell wall structure, and the increased electrolyte leakage is a typical change with ripen (Table 1).

Table 1. Attributes measured in 'LD1' dragon fruit at 20°C (non-stored)

Variable	Shelf life (d)			S.E.D.	*P*
	0	5	9		
Skin lightness (L*)	42.23[a]	39.39[b]	35.35[c]	1.04	<0.001
Stem green	0.0[c]	1.2[b]	1.9[a]	0.28	<0.001
Bract appearance	0.0[b]	0.6[b]	1.8[a]	0.31	0.020
Overall rot	0.0[b]	0.2[b]	0.6[a]	0.10	0.004
Body rot	0.0[b]	0.3[b]	1.3[a]	0.21	0.001
Flesh lightness (L*)	30.00[a]	27.62[b]	27.89[b]	0.39	<0.001
Flesh colour-C	41.67[a]	39.32[b]	39.56[b]	0.39	<0.001
Flesh colour-Hue (°)	8.08[c]	10.08[b]	11.66[a]	0.39	<0.001
Flesh firmness (Kg/cm^2)	0.81[a]	0.68[b]	0.66[b]	0.03	0.027
Total acidity (%)	0.27[a]	0.09[b]	0.07[b]	0.03	<0.001
EL (%)	24.65[c]	29.35[b]	34.77[a]	1.54	<0.001

Note: Tab. 1, 2, 3: Unless specified otherwise, units for values are score ratings. In the same row, values followed different letters presented significant difference at (P<0.05)

Quality of dragon fruit after two weeks of storage at 10, 6 and 2°C

- Two weeks storage and 1 day shelf life

After two weeks of storage and 1 day shelf life, quality of dragon fruit in turns of bract appearance, stem green, overall rots and body rots showed significant differences among different storage temperatures (Table 2). At 2°C, while there were no rots and stems maintained good quality, bract appearance turned brown at the margins compared to fruit stored at 10 or 6°C. At 10°C, rot incidence was increased compared to 2 and 6°C.

- Two weeks storage and 5 days shelf life

After two weeks of storage and 5 days shelf life, markedly difference in non-destructive attributes of fruit stored at different temperatures were recorded due to rot incidence including body rot, blossom rot and stem rot. Generally rot incidence on dragon fruits in all storage temperatures was very high and the highest was observed on fruit stored at 10°C, followed by 6°C and 2°C. No significant difference in the rated score of rots was observed between the storage temperature 6°C and 2°C (Table 2). No significant difference in SSC was noted (data not shown).

Table 2. Attributes measured in 'LD1' dragon fruit after 2 wks storage at 10, 6 and 2**°C** followed by 1 and 5 d shelf life at 20°C.

Variable	Storage temperature (°C)			S.E.D.	*P*
	10	6	2		
Shelf-life (1 day)					
Bract appearance	0.2[b]	0.5[b]	1.2[a]	0.15	0.002
Stem green	1.1[a]	0.8[a]	0.0[b]	0.18	0.005
Overall rot	0.2[a]	0.0[b]	0.0[b]	0.10	0.027
Body rot	0.2[a]	0.0[b]	0.0[b]	0.04	0.042
Shelf-life (5 day)					
Skin colour -C	42.26[a]	39.52[c]	40.92[b]	0.43	0.005
Blossom rot	3.0[a]	2.0[b]	1.6[b]	0.24	0.014
Body rot	3.0[a]	2.5[b]	2.8[ab]	0.09	0.045
Stem rot	1.0[a]	0.7[ab]	0.4[b]	0.11	0.020
Flesh colour-C	35.30[b]	38.28[a]	38.17[a]	0.59	0.004
Flesh translucency	0.0[b]	0.0[b]	1.0[a]	0.17	<0.001

For destructive analysis, two attributes i.e. flesh colour-C and flesh translucency, were found to be significant differences by different storage temperatures (Table 2). The data shown in the Table 2 indicated that the flesh of dragon fruit in storage temperatures at 10 or 6°C was no translucency; however, at 2°C the translucency of the outer flesh layer occurred. Hoa et al. (2006) observed translucency in both hot air treated and control fruit after 4 weeks at 5°C, and Nerd *et al.* (1999) and Freitas & Micham (2013) have also observed this disorder at higher temperatures ≈5°C. Thus, we suggest that this chilling disorder may be resulted from both temperature and duration where longer time is required to induce chilling at higher temperatures.

Quality of dragon fruit after 4 weeks storage at 10, 6 and 2°C

- Four weeks storage and 1 day shelf life

The largest change between 2 and 4 weeks storage was presented by increasing in rots which occurred at all temperatures (Table 3). Rot incidence was lower at 2°C than at higher temperatures (10 and 6°C). Stem colour, skin lightness and the proportion of sound fruit were all significantly different among three storage temperatures after 4 weeks of storage followed by 1day shelf life (Table 3). Dragon fruit stored at 2°C were greener than 6 and 10°C, but skin lightness was lower, possibly considered as a reflection of low temperature damage.

- Four weeks storage and 3 days shelf life

After 3 days in fruit shelf life, rots were still the most important attribute examined. In general, rot diseases had developed, but 10°C was significantly worse than 2 and 6°C (Table 3).

For destructive analyses, flesh quality of fruits stored at 6°C was better than that of the storage 2 or 10°C expressed by no flesh translucency and good colour and texture of flesh whereas SSC (data not shown) and TA remained unchangeable. At low storage temperature 2°C, chilling symptoms became very clear with large areas of translucence which had turned brown, and the flesh had become very soft (0.72 kg/cm^2). SSC and TA were, however, maintained at similar levels to that of 6°C, but much better than 10°C (Table 3). Lower storage temperatures are likely to reduce respiration rate and therefore maintain SSC and TA levels.

Table 3. Attributes measured in 'LD1' dragon fruit after 4 weeks storage at three temperatures (10, 6 and 2°**C**), two LTC treatments (10-2 (3 d at 10°C followed by storage at 2°C) and 6-2 (3 d at 6°C followed by storage at 2°C)), followed by 3 d shelf life at 20°C

Variable	**Storage temperature** (°C)				
	10	6	2	(10-2)	(6-2)
Shelf-life (1 day)					
Sound	1.0^a	1.0^a	0.7^b	0.2^c	0.2^c
Bract appearance	4.9^a	4.7^a	4.1^a	2.6^b	2.8^b
Stem green	2.0^a	1.9^a	1.5^b	1.8^a	1.8^a
Skin lightness (L*)	44.03^a	42.49^{ab}	40.89^b	42.91^a	42.91^a
Overall rot	1.0^a	1.0^a	0.6^b	0.6^b	0.8^{ab}
Blossom rot	2.4^a	2.6^a	0.9^b	0.4^b	1.1^b
Body rot	2.9^a	2.5^a	0.9^b	0.8^b	0.9^b
Stem rot	1.0^a	0.7^{ab}	0.5^b	0.7^{ab}	0.8^{ab}
Shelf-life (3 days)					
Skin colour-C	41.75^a	40.65^{ab}	39.37^{ab}	38.77^b	38.18^b
Skin colour-Hue (°)	10.51^a	6.54^b	7.01^b	7.48^b	6.87^b
Blossom rot	3.0^a	2.7^{ab}	1.6^c	2.1^{bc}	2.4^{ab}
Body rot	3.0^a	2.7^{ab}	2.5^b	2.5^b	2.7^{ab}
Stem rot	1.0^a	0.6^b	0.1^c	0.0^c	0.1^c
Flesh translucency	0.0^c	0.0^c	1.0^a	0.7^b	0.8^{ab}
Flesh lightness	43.12^a	41.98^{ab}	39.69^b	42.31^{ab}	41.17^{ab}
Flesh colour-C	37.01^b	40.53^a	38.53^{ab}	38.71^{ab}	37.26^b
Flesh firmness (kg/cm^2)	0.92^a	0.91^a	0.72^b	0.74^b	0.68^b
SSC (%)	12.74^b	12.95^{ab}	13.38^a	13.18^{ab}	13.23^{ab}
Total acidity (%)	0.08^c	0.15^b	0.25^a	0.16^b	0.22^a

Effect of low temperature conditioning (LTC)

As compared to non-LTC treatments stored at 2°C, LTC improved bract appearance and skin lightness for both LTC treatments (10 - 2 and 6 - 2) after 4 weeks of storage and shelf life 1 day (Table 3). After 3 days shelf life, a slight reduction in the translucency chilling symptom compared to non-LTC fruit (stored directly at 2°C) was recorded, but there was no significant difference between the 10 - 2 LTC (0.7) and 6 - 2 (0.8). Overall, the best treatment for improving quality at 2°C was the 10°C LTC treatment. These results are similar to observations on avocado (Woolf *et al.*, 2002) and papaya (Chen & Paull, 1986).

CONCLUSION

For 'LD1' red dragon fruit, the best storage temperature is 6°C with a limit of ≈ 4 weeks, no chilling injury was observed. However, a lower temperature (2°C) results in reducing quality (wilting and desiccation bracts), and a distinct chilling injury symptom - translucence of the outer layer of the flesh. Low temperature conditioning could reduce some of these chilling disorders to some extent.

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EFFECT OF STORAGE TEMPERATURES ON POSTHARVEST DISEASES OF DRAGON FRUIT (*Hylocereus undatus* Haw.) CULTIVATED IN THE MEKONG DELTA REGION, VIETNAM

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Abstract

This study was aimed to determine the effects of different storage temperatures and storage durations on postharvest diseases of dragon fruit planted in the Mekong delta region. Dragon fruit of uniform maturity and without defects were collected from two growers in Long An and Tien Giang provinces and stored at 0°C, 5°C and 10°C for 21 and 26 days before kept in 20°C stores for 3 days to simulate shelf life in the market. Other fruit were harvested and held at 20°C for 7 and 12 days considered as a non-stored control. The proportion of fruit with rots and changes in bract

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