Chapter 5: Effect of storage temperatures on the physiological and biochemical properties of *H. polyrhizus*

5.1 Introduction

Fresh fruits are normally harvested when the fruit reaches ripeness stage or mature unripe stage for long distance distribution. At this stage, the fruit are independent with their own catalytic mechanism even after detachment from the mother plant (Prasanna *et al.,* 2007). Therefore, harvested fruit will continue to undergo processes such as respiration, ripening, and water loss due to transpiration, enzymatic reaction, chlorophyll degradation, senescence, microbial decay and also mechanical damage that lead to postharvest loss of fruit quality.

The above processes are functions of relative humidity, temperature (Jobling, 2001) and air composition of the handling or storage environment (Yahia, 1998). Among them, proper temperature management is crucial in the maintenance of fresh fruit quality in terms freedom from defects (Brew *et al.,* 2006). It is known that the rate of metabolic processes generally increases exponentially with rise in temperature (Wills et *al.,* 1998). In that case, low temperature storage is recommended because it can prolong storage life by reducing respiration rate and senescence as well as microbial decay (Roura *et al.,* 2000; Watada *et al.,* 1996). However, optimum storage temperatures vary among commodity types. For fruit, improper storage temperatures may adversely affect quality factors such as appearance, flavour, and colour. In addition, fruit deterioration may proceed rapidly.

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Thus, the objective of this experiment was to determine the optimum storage temperature for *H. polyrhizus* of three different harvesting maturities. Fruit quality over 14 days storage period were evaluated at three different temperatures; low (6˚C), intermediate (16˚C) and high (23 ± 1˚C), with RH of 85 to 95%.

5.2 Materials and methods

5.2.1 Plant material

Refer to chapter 3 subtopic 3.2.1(page 31)

5.2.2 Physicochemical analysis

15 fruit of each harvest maturity were stored at three different storage conditions; at high temperature (23 ± 1˚C) represent ambient (RT) storage, at an intermediate temperature (16˚C) represent controlled storage and at a low temperature (6˚C) represent cold storage. Fruit were assessed for quality at the start of the experiment, and on day 7 and day 14 of storage. Fruit for assessment were removed from storage and left at room temperature for 6 hours before analyses were carried out. This was done to allow the fruit to adapt to room temperature conditions. All measurements were carried out in triplicates.

The following assessments were carried out as described in Chapter 3.

1. Visual observation (Subjectively)

2. Colour measurements (L*a*/b*)

3. Pulp firmness (kg f)

4. Total soluble solids (Brix ˚)

5. pH

6. Total sugars

7. Total reducing sugars

5.3 Results

Visual appearance of D 0 fruit stored at different storage temperatures are shown in Figure 5.1. D 0 fruit was complete red with green at the tip of the bracts on day of harvest and it remained when stored at 6˚C. However, D 0 fruit held at 16˚C and RT˚C showed distinct disorders; the tip of the bracts turning yellow and drying on day 14. As for D 0 fruit at 16˚C on day 14 showed larger surface of water soaked area.

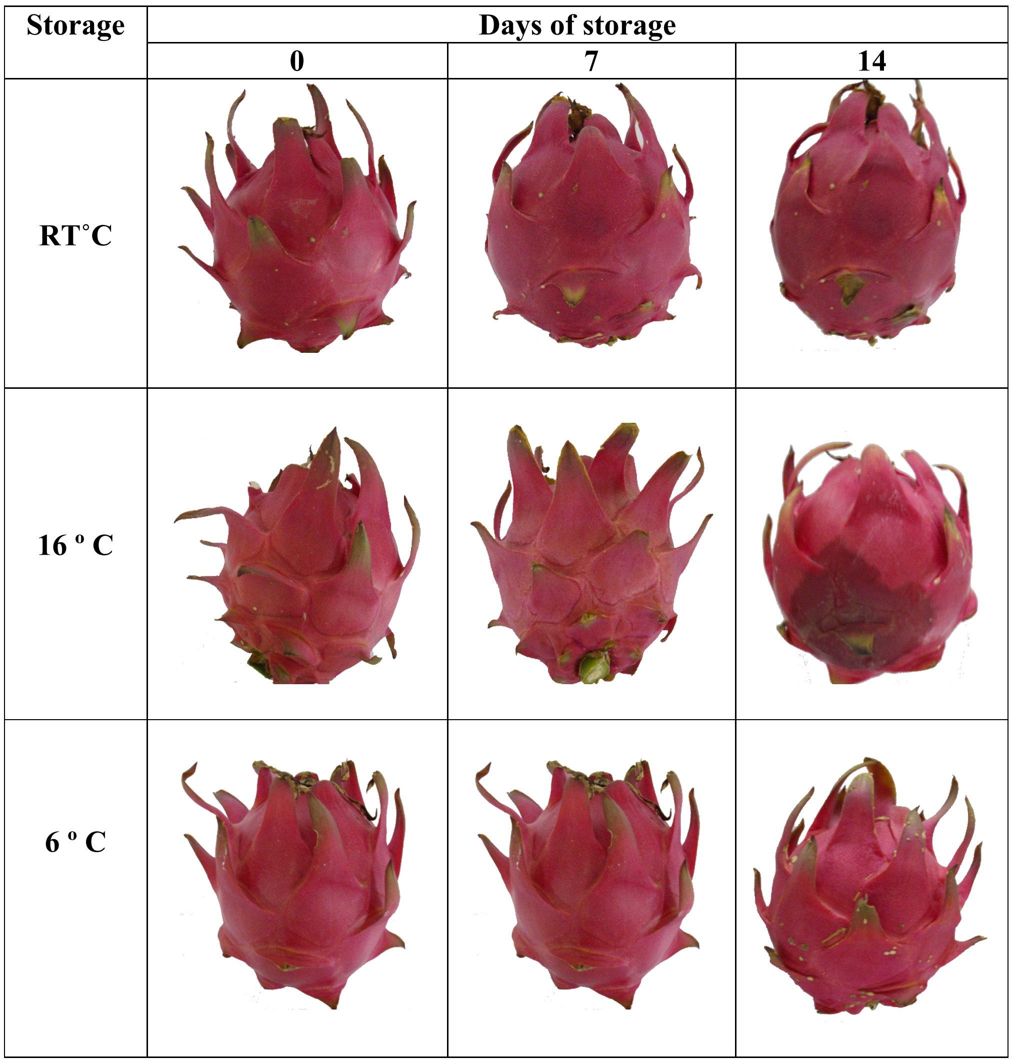
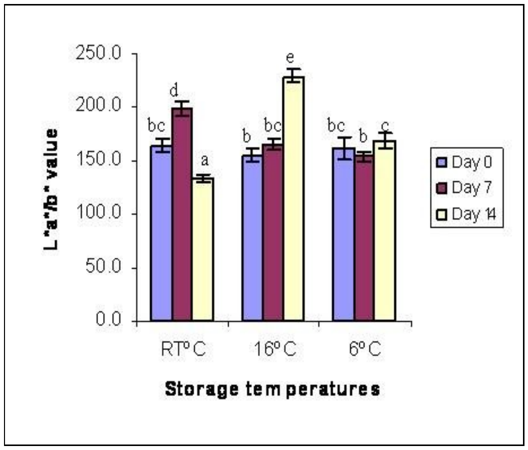


Figure 5.1: Visual observation of D 0 fruit kept at different storage temperatures for two weeks consecutively and analysed every 7 days.

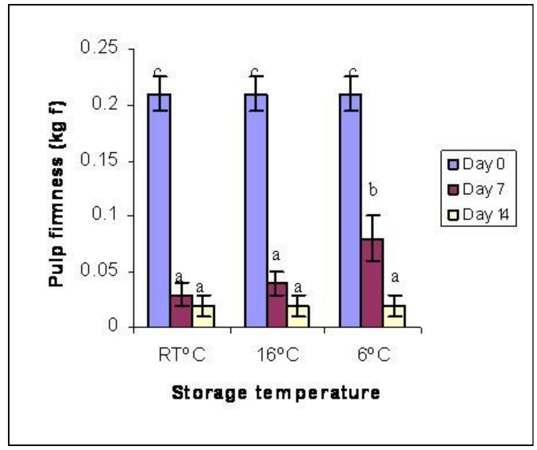
Chromatically assessed peel colour of D 0 fruit further confirmed the bracts/peel colour changes throughout the experiment. Fruit kept at RT˚C showed L*a*/b* value reduction at the end of storage even though at day 7 the L*a*/b* value increased. On the other hand, fruit kept at 16˚C showed sudden increase of L*a*/b* value on day 14 meanwhile for those kept at 6˚C, the L*a*/b* was still within the range below 170 as shown in Figure 5.2(a). Pulp firmness reduced regardless of storage temperatures (Fig 5.2 b). For fruit stored at RT˚C and 16 ˚C, the reduction was drastic even after one week storage. As for fruit in 6˚C, the pulp firmness reduction was slower and on day 7 the firmness was higher compared to other storages.

pH value for D 0 fruit for all three storage temperatures increased throughout the experimental period. However for fruit stored at 6˚C pH remained within the range of 5 for the two weeks storage. TSS measurement shown in Figure 5.2(d) showed D 0 fruit stored at RT˚C were relatively constant while fruit at 6˚C were constant throughout storage. Nevertheless, TSS for fruit stored at 16˚C gradually decreased.

Total sugar content for D 0 fruit kept at different storage temperature generally declined throughout storage. As for fruit at 16˚C, the total sugar content was noticed to decrease progressively during storage. However fruit at 6˚C maintained the total sugar for one week during storage. The loss of total sugar was higher in fruit stored at 16˚C (40%) followed by RT˚C (30%) and the least in fruit at 6˚C (15%). Rate of decrease was observed to be the highest at 16˚C, followed by RT and 6˚C. Time course profiles of loss in total reducing sugars mirrored the pattern observed for total sugars.



5.2 (a)



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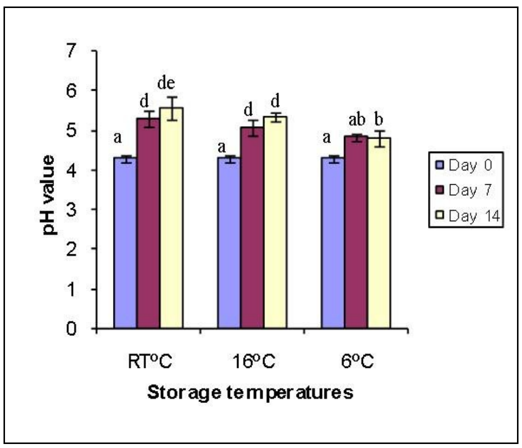
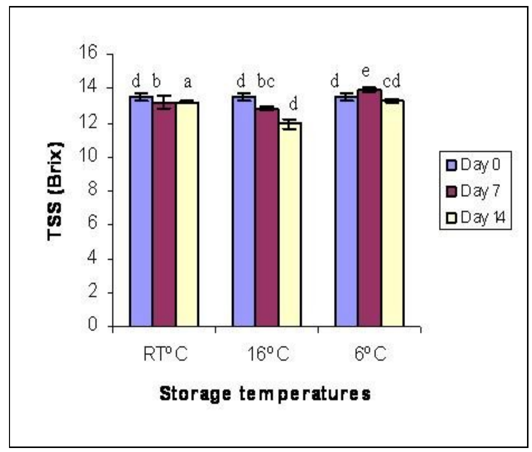


5.2 (c)



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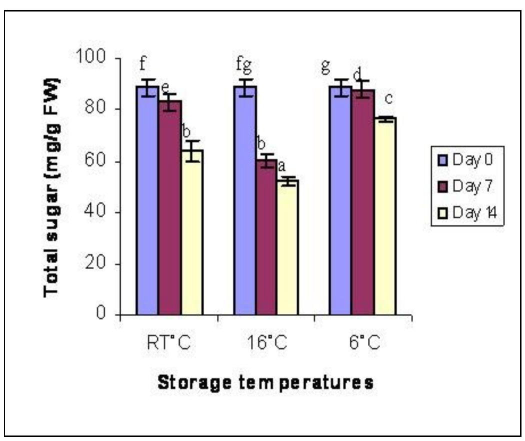

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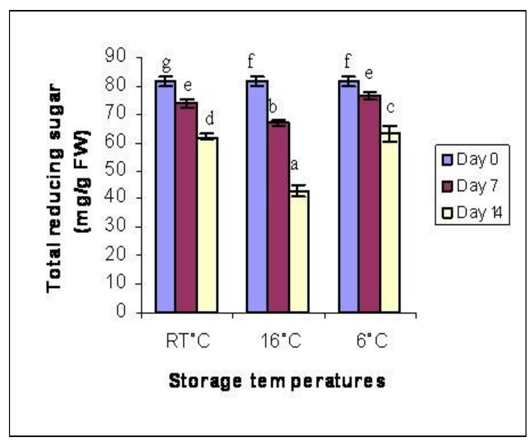


5.2 (f)

Figure 5.2: (a)L*a*/b* measurement, (b) pulp firmness , (c)pH, (d)total soluble solids, (e)total sugar and (f)total reducing sugar content of D 0 fruit kept at different storage temperatures for two weeks consecutively and analysed every 7 days.

Figure 5.3 shows the visual appearance of D 1 fruit stored at three different temperatures. D 1 fruit stored at RT˚C eventually turned from green to red with the blossom end turning to yellow and finally to black. As for fruit stored at 16˚C, the bracts/peel colour changed from green to orange while the tip of the bracts turned yellow. However, fruit stored at 6˚C remained green for the entire storage period.

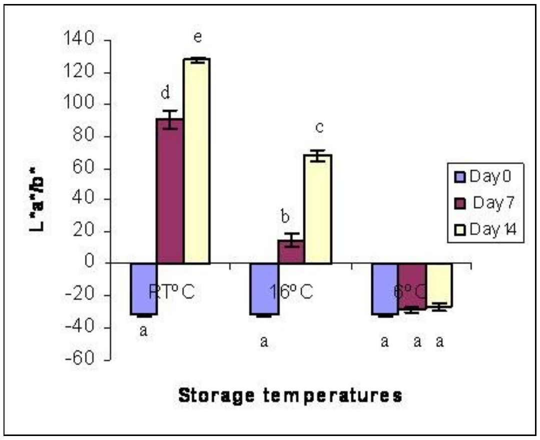
Storage	Days of storage		
	0	7	14
RT º C			
16 º C			
6 º C			

Figure 5.3: Visual observation of D 1 fruit kept at different storage temperatures for two weeks consecutively and analysed every 7 days.

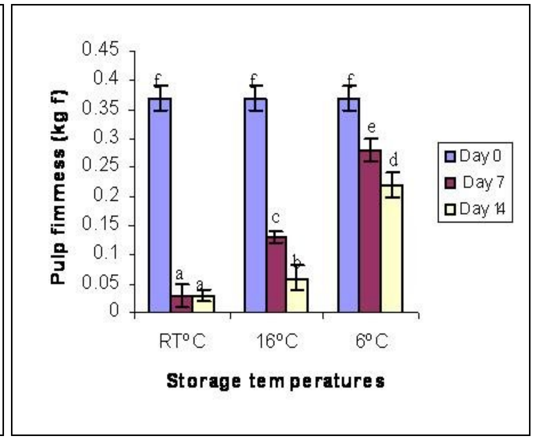
Bracts/peel colour measured chromatically showed D 1 fruit stored at RT˚C and 16˚C changed from negative L*a*/b* value to positive L*a*/b* value (Fig 5.4 a). However, fruit at RT˚C showed a greater change than fruit at 16˚C while fruit at 6˚C showed value within the negative range. Figure 5.3(b) represent pulp firmness for D 1 fruit stored at three different temperatures. Firmness reduction was higher in fruit stored at RT˚C followed by 16˚C. Nevertheless, fruit kept at 6˚C showed lower loss of pulp firmness.

pH value for D 1 fruit stored at RT˚C and 16˚C gradually increased throughout experimental period as opposed to fruit stored at 6˚C which showed no change in pH value. (Fig. 5.4c). TSS for D 1 fruit stored at RT˚C and 16˚C showed reduction there after compared to fruit stored at 6˚C which remain constant. However fruit stored at RT˚C, the TSS increased on day 7.

Total sugar content for D 1 fruit stored at RT˚C and 16˚C had a higher decrease throughout storage. Even though fruit stored at 6˚C also decreased but the loss was only 11% compared to fruit at RT˚C with 21% and fruit kept at 16˚C with 45% loss of total sugar. Total reducing sugar content for fruit kept at all storage temperatures decreased during storage. However, the reduction is higher in fruit stored at 16˚C with 50% loss than fruit kept at RT˚C with 27% loss and fruit at 6˚C with 15 % loss of total reducing sugar.



5.4 (a)



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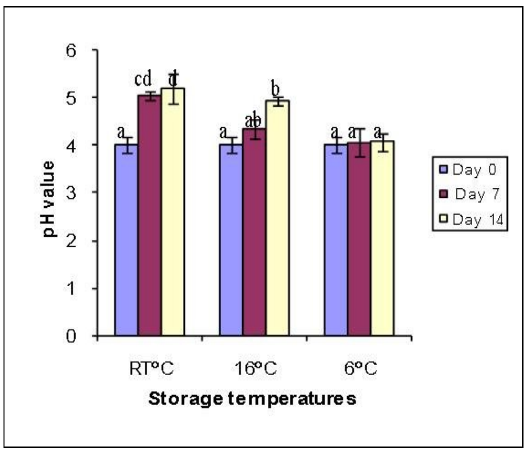

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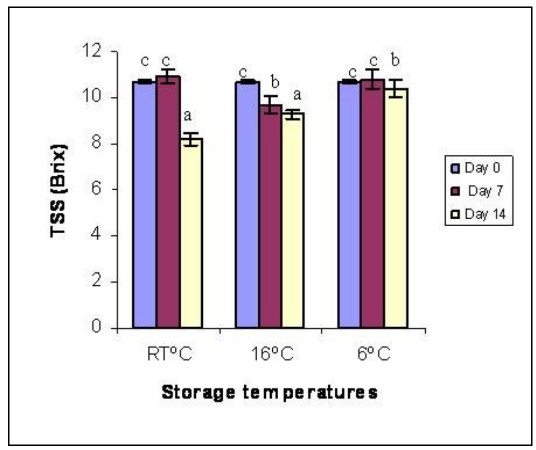

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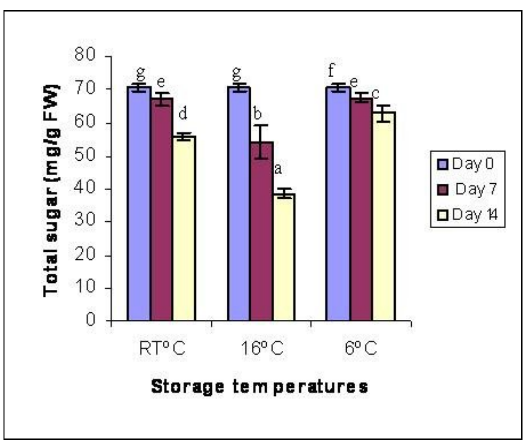

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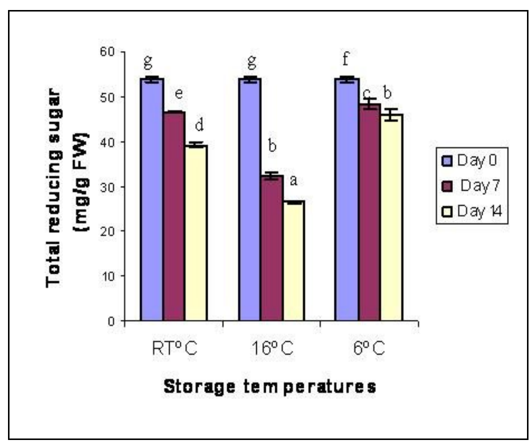


5.4 (f)

Figure 5.4: (a) L*a*/b* measurement, (b) pulp firmness, (c) pH, (d) total soluble solids, (e) total sugar and (f) total reducing sugar of D 1 fruit kept at different storage temperatures for two weeks consecutively and analysed every 7 days

At day of harvest, D 2 fruit was green in colour but as storage proceeded the colour changed. For fruit kept at RT˚C, the colour changed from green to red with yellowing at the tip of the bracts. As for fruit kept at 16˚, red colouration appeared at blossom end of the fruit and at day 14, the whole fruit turned orange-red. In contrast fruit stored at 6˚C remained green throughout storage period.

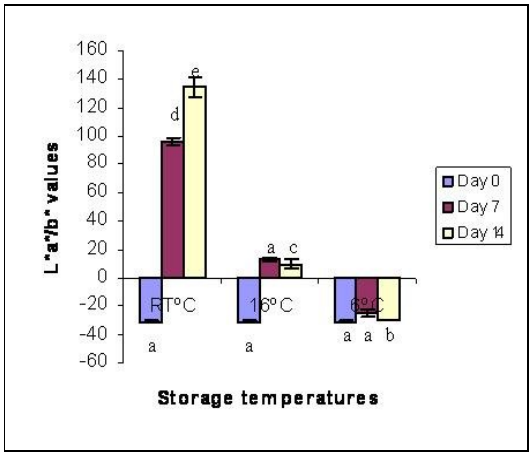
Storage	**Days of storage**		
	0	**7**	**14**
RT º C			
16 º C			
6 º C			

Figure 5.5: Visual observation of D 2 fruit kept at different storage temperatures for two weeks consecutively and analysed every 7 days.

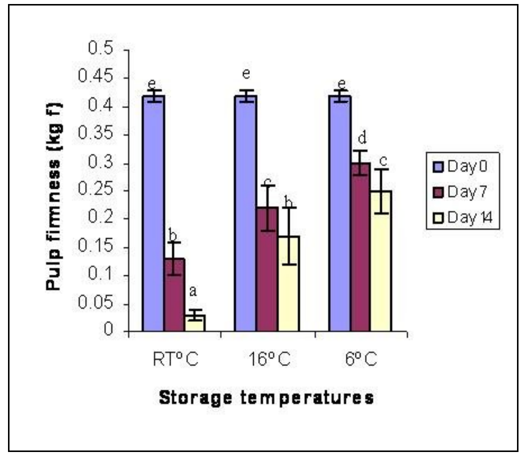
Bracts/peel colour measurement using chromameter showed changes from negative to positive L*a*/b* value for D 2 fruit stored at RT˚C and at 16˚C. However, the changes are more pronounced at RT˚C rather than 16˚C with lower L*a*/b* value. On the other hand, fruit stored at 6˚C remained negative L*a*/b* value following storage for two weeks. Pulp firmness for D 2 fruit decreased rapidly for storage at RT˚C followed by storage at 16˚C. As for fruit stored at 6˚C, pulp firmness loss was less affected with slower reduction throughout experimental period.

Generally, pH (Figure 5.6 c) value increased for D 2 fruit stored at RT˚C. As for those kept at 16˚C and 6˚C showed similar trend in which the value fluctuate following storage. Overall TSS for D 2 fruit increased after 7 days of storage in all the temperatures. However, the value obviously decreased at RT˚C and 16˚C after two weeks storage as compared to fruit kept at 6˚C which remained.

Total sugar content of D 2 fruit showed an increase after one week storage for all different temperatures. However, the amount of total sugar decreased the following week. Total reducing sugar content for D 2 also showed similar patterns as total sugar. Fruit stored at all different temperatures had increased level of total reducing sugar after one week storage. Nevertheless, total reducing sugar of fruit at RT˚C, 16˚C and 6˚C eventually decreased at day 14.



5.6 (a)



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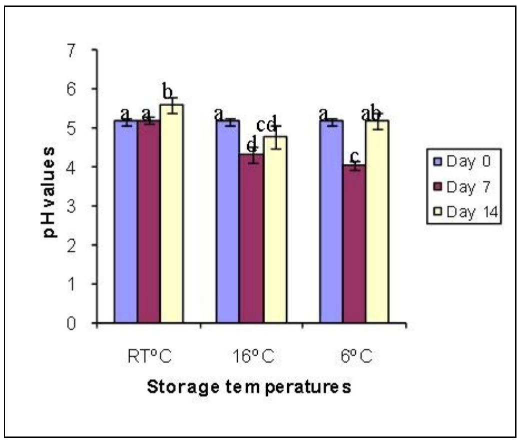
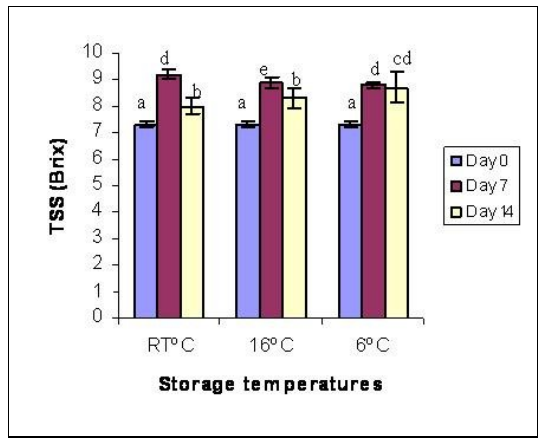


5.6 (c)



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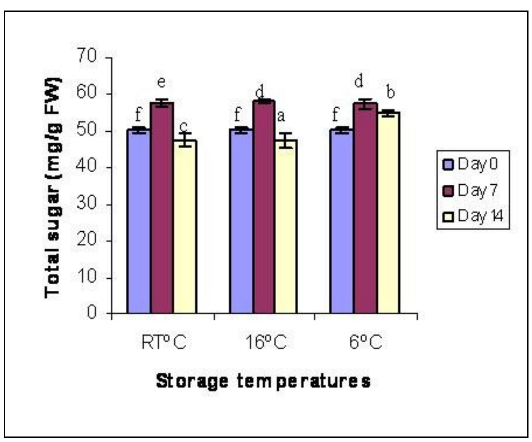
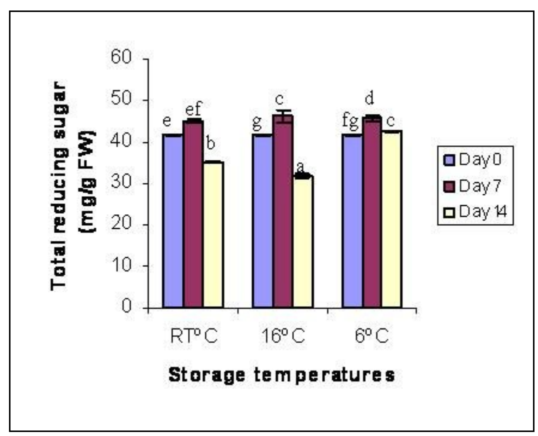


5.6 (e)



5.6 (f)

Figure 5.6: (a)L*a*/b* measurement, (b)pulp firmness, (c) pH, (d) total soluble solids, (e) total sugar and (f) total reducing sugar of D 2 fruit kept at different storage temperatures for two weeks consecutively and analysed every 7 days.

5.4 Discussion

The results obtained through this study, indicates that fruits, regardless of harvesting maturities, had better fruit quality at 6˚C storage. Conversely, fruit quality of *H. polyrhizus* of different harvesting maturities had reduction of fruit quality when stored at 16˚C. Attributes showing the greatest tendency to be affected in storage temperature include fruit firmness and bracts/peel colour.

Storage temperature has a direct effect on fruit metabolism in terms of respiration (Fonseca *et al.,* 2002) and indirect effect on the cellular structure that determines the fruit quality such as colour, firmness and organoleptic properties (Marsh *et al.,* 2004). Among them, peel colour is important to determine fruit quality. During storage, the L*a*/b* value increased mainly for D 1 and D 2 fruits. The effect of storage temperatures, on increase L*a*/b* value were found in D 1 and D 2 fruits at which the ambient (RT ˚C) and 16˚C showed tendentiously higher value compared to those at 6˚C. As for D 0 fruit, the L*a*/b* tend to have increased value when stored at 16˚C and at ambient than those at 6˚C, having almost at the same values as fruit on day of harvest.

The changes in bracts/peel colour were associated with changes in chlorophylls and betacyanin (Stintzing *et al,* 2002) of the fruit. During ripening, *H. polyrhizus* showed degradation of chlorophyll and following that betacyanin pigment become visible. High retention of green colour was observed on D 1 and D 2 fruits stored at 6°C. Inability of D 1 and D 2 fruits to effect colour change at 6˚C could be due to a number of reasons such as low activity or absence of enzymes catalsying chlorophyll degradation and/or biosynthesis of betacyanins, low amount of precursors for pigment formation under the unfavourable temperature conditions. However fruit stored at high temperature showed increased value due to accelerated higher chlorophyll degradation and accumulation of betacyanin. A similar pattern of fruit colour development was reported in strawberry in which the rate of pigment accumulation (anthocyanin) increased with increasing temperature (Cordenunsi *et al.,* 2005).

Another important fruit quality alteration is the tissue firmness. Fruit softening is characterised by reduction of pulp firmness. In this study, pulp firmness of *H. polyrhizus* harvested at three different stages decreased with storage time. The decrease was minimal when stored at 6˚C than at high temperatures. Although turgor loss (Shackel *et al.,* 1991) and starch degradation during ripening may contribute to fruit softening (Prabha *et al.,* 2000) however the reduction in pulp firmness is reported to be most associated with the breakdown of pectic substances and hemicelluloses in the middle lamella by enzyme-catalysed changes which weakens cell walls and reduces the cohesive forces binding cells together (Brummell, 2006).

In this study, faster reduction is seen in fruit stored at 16˚C and RT°C, assumingly due to the temperature promoting effect on the pectolytic enzyme activity (Tijskens and van Dijk 2000). Fruit stored at 6˚C, however showed delayed pulp firmness loss; this could be due to suppression of enzyme activities under low temperature (Perez *et al.,* 2004). D 0 fruit showed higher reduction at high temperature possibly due to a higher activity of cell wall degrading enzymes that lead to fruit softening.

pH reading for all *H. polyrhizus* harvested at different stages stored at three different storage temperatures was lower at the beginning of the storage time. The increase of pH reading commences the conversion of organic acids to sugars which is common process during ripening in many fruits (Blanco *et al*., 1992). Fruit stored at high temperatures, pH increased as opposed to those stored 6˚C in which value maintained. However, D 2 fruit, pH changes were unclear for those stored at 16˚C and 6˚C.

TSS for *H polyrhizus* stored at all the storage temperature at 16˚C decrease with prolonged storage time. As for D 2 fruit showed a rise in total TSS after a week but declined the following one week storage. The increase in TSS shows the increase in sugar content, organic acids, soluble pectins and other dissolved substances with different refractive indices from water (Holcroft and Kader, 1999). TSS for fruit stored at 6˚C showed relatively unchanged during storage which means low temperature has positive effect on TSS. In contrast, high temperatures increased the rates of respiration and other metabolic processes that caused depletion of substrates like sugars and proteins thus the overall TSS value decreased for fruit stored at RT°C and 16˚C.

The correlation between TSS and total sugar has been observed is not as close for D 2 fruit as for D 0 and D 1 fruits. Nevertheless, total sugar content decreased for all stages with minimal loss at 6˚C compared to those at 16˚C. This is because the rate of respiration of fruit is increased with increasing temperature and since all the reactions taking place are temperature dependent, thus substrate depletion is expected to be the lowest at 6˚C. As at low temperature, the rate of respiration is decreases as it is part of the biological process which is interdependent on temperature (Wills *et al.,* 1989). Along with that, total reducing sugar also showed the similar pattern as total sugar for all stages fruit. Minimal loss of total reducing sugar was observed when fruit stored 6˚C compared to RT°C and 16˚C.

Results of this study indicate that fruit quality changes in *H.polyrhizus* during ripening were affected by temperature in the range of 6˚C to RT˚C. It was revealed that D 0 and D 1 fruits had better maintenance of fruit quality at 6˚C even though the changes of D

1fruit was not to the extent of D 0 fruit. However D 2 fruit appeared to be not suitable harvest candidature as it is still immature. Fruit does not ripen at 6 °C nor develop into a market acceptable fruit at RT°C or 16°C.

Therefore, the optimum storage temperature for dragon fruit that attains the full maintenance of the appearance and fruit quality was shown at 6˚C for D 0 fruit. Physical appearances of D 1 and D 2 fruits were preserved at lower temperature as in 6˚C although the quality was not improved for the mentioned fruits.