# Chapter 7: General discussion

Three harvest maturities: D 0 (five weeks after anthesis), D 1 (four weeks after anthesis) and D 2 (three weeks after anthesis) were studied. The ripening process of *H. polyrhizus* under normal condition was examined mainly in three areas; physiology, biochemistry and activity of cell wall enzymes. In addition, storage at various temperatures and under film packaging conditions was also evaluated in order to determine the appropriate condition to maintain fruit quality with the possibility of extending shelf life.

The analysis taken on the commencement of the experiment reflected the condition of the three different stages of fruits during development while attached to the mother plant. The foremost observation was the weight of the fruit in which the weight was descending towards less mature fruit (D 2). Once detached, the fruit tend to lose weight and this was seen during the postharvest storage for all stages of fruits. The rate of weight loss was higher in D 1 and D 2 fruits as opposed to D 0. The bracts/peel colour varies according to the level of maturity of the fruit. Ripe fruit (D 0) appeared to be in a complete red colour compared to those in D 1 and D 2 fruits that in green. The similar transformation from green to red colouration was observed during time course after harvest for D 1 and D 2 fruits suggesting the same process undergoing even after harvest. However, the appearance of the colour was not up to the extent noticed in D 0 fruit.

Apart from that, the pulp firmness was noticed to be higher in D 1 and D 2 fruits than D 0 fruit on day of harvest. This explains the natural reduction of the pulp firmness according to fruit maturity to develop into soft-edible fruit as a result of cell wall disintegration. The firmness reduction behaviour was also noticed during the time

course period for all three stages of fruits after harvest but in a higher rate for D 1 and D 2 fruits compared to D 0 fruit. This could be due to the much later activation of softening-related enzymes in D 1 and D 2 fruits while in D 0 fruit the activities have preceded way before detachment from mother plant as it reached the maturity level. As for pH level the reading was within pH 4 for all three different harvesting maturities; hence the fruit can be considered as low acidic fruit. However, during postharvest storage the pH level increased to a level above 5. It is reported that increase in pH during ripening is a general behaviour and in additional the pH increase are contributed by organic acids which are metabolized by the fruit during ripening and storage, resulting in a decrease in total acidity and a rise in pH (Marsh *et al.,* 2004)

In this study, the TSS level in D 0 fruit was higher than D 1 and D 2 fruits on the commencement of the experiment day revealing the positive correlation between TSS and fruit maturity. The stipulation was further confirmed with the increase of TSS for D 1 and D 2 fruits during postharvest storage. However, the level reached by D 1 and D 2 fruits was not up to D 0 fruit TSS. These probably due to insufficient substrates due to fruits tend to respire and use up the reserved storage. The same pattern was monitored in total sugars for all three stages of fruits on day of harvest. As for total extractable protein, D 0 fruit had higher level followed by D 2 fruit and least level of protein in D 1 fruit on day of harvest. The level of total extractable protein increased for all maturity stages of fruits during time course, probably indicating that particular proteins were being synthesized for senescences as such increases protease activity and also contributed by the cell bound proteins that are released from the cell wall due to extraction.

Further analysis was carried out to determine the activity of cell wall enzymes that probably causes the textural changes in *H. polyrhizus*. It is known that firmness reduction is an effect of cell wall disassembly that occurs during ripening. The changes that contribute to degradation of cell wall and loss of membrane integrity include increase in soluble pectins, decrease in molecular size of protein, loss of cell wall galactosyl residues and also the changes in molecular size of hemicellulose polymers (Brummell and Harpster, 2001) that is accompanied by softening –related enzyme activities.

PME activity in D 0 fruit at harvest is at least 80% of maximum activity of the fruit. This explains the less firmness in D 0 fruit compared to D 1 and D 2 fruits on the commencement of the experiment. Besides that, the PME activity in D 1 and D 2 fruits at harvest was no more than 20% and 5% of the maximum activity respectively. However, during postharvest storage the activity increased to maximum after 9 to 11 days in which the fruit become considerably and suggest that PME plays a role in fruit firmness loss. The decrease in activity of PME after harvest to over ripe stage for D 0 fruit in this work was also observed in other species during ripening such as in tomato (Gaffe *et al.,* 1994). It has been suggested that pectin methylesterase removes the methyl groups of the wall galacturonans to enhance the depolymerisation by both endo- and exopolygalacturonase (Huber, 1983).

PG activity in D 0 fruit at harvest is high only with respect to that in corresponding to D 1 and D 2 fruits. In absolute terms when expressed as % of maximum activity developed in the fruit, the activity is no more than 30% and there is negligible PG activity in D2 fruit at harvest. The PL activity in D 0 fruit at the day of harvest was lower than D 1 and D 2 fruits. PL enzyme activity in D 0 fruit was almost constant

although the activity was low. Meanwhile D 1 and D 2 fruits showed increased level of PL activity indicating function of the enzyme in reducing firmness. On the other hand, cellulase activity was higher in D 0 fruit than D 1 and D 2 fruits at the initial day of harvest with regard of less firmness measured in D 0 fruit on the same day. Time course profile suggests that the cellulase activity increased for D 1 and D 2 fruits in support with the reduction of firmness. This result further confirms the role of combination effect of a number of softening- related enzymes. The changes in cell wall degrading enzymes relate directly to the loss of pulp firmness of *H. polyrhizus* in these findings.

Three storage levels; low (6˚C), intermediate (16˚C) and ambient (23 ± 1˚C ˚C) were evaluated for the purpose of determining the appropriate storage conditions of fresh dragon fruit. During storage, fruits regardless of harvesting maturities had better preserved fruit quality at 6˚C storage. Conversely, fruit quality at different harvesting maturities had reduction when stored at 16˚C. Attributes showing the greatest tendency to be affected in storage temperature include fruit firmness and bracts/peel colour.

Fruits stored at low storage temperature maintained their peel colour during storage. The optimal colour change is from green to reddish green to red occurred for fruits stored at intermediate and ambient temperature. In addition, fruit stored at intermediate temperature shown to have increased L*a*/b* reading in D 0 fruit on day 14. This is because of the increase in darkening (black appearance) surrounding the surface of the fruit. According to Tembo *et al.,* (2008) reported that increasing temperature lead to faster deterioration caused by natural senescence of fruits during storage. However, the red peel colour of D 1 and D 2 had a delayed bracts/peel colouration when stored at 6˚C cold room. The delayed process may be because of lack of precursors or inactivated enzymes as the bracts/peel colouration involves a biochemical processes that result in the synthesis and degradation of pigments during ripening of fruits (Sturm *et al.,* 2003).

The firmness loss that generally occur in all fruits were noticed to be more in a slower rate when fruits are stored in low temperature and this could be due to delayed activity of cell wall degrading enzymes under low temperature (Perez *et al.,* 2004). pH values reached higher value by the end of the storage period for all storage temperatures except for storage at 6˚C, probably because the conversion of organic acid to sugar was retarded. The low storage temperature maintained relatively high TSS for *H. polyrhizus* content than fruits stored at medium and ambient temperatures.

The content of total and reducing sugars decreased more rapidly in the intermediate followed by ambient than in low storage temperature. This could be attributed to higher respiratory activity occurring at the ambient and intermediate storage than in low storage since all the reactions taking place are temperature dependent thus substrate depletion occurred. Total sugar content decreased for all stages with minimal loss at 6˚C compared to those at 16˚C. 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 ambient and 16˚C. Results obtained from these studies suggest that *H. polyrhizus* kept their visual acceptance for at least one week at room temperature and two weeks at 6˚C while had lowered fruit quality when stored at 16˚C.

Apart from regulating storage, film packaging also was carried out as a point of modifying the atmosphere surrounding the fruit. Generally packaging fruit is applied either passively by packing fruit in a suitable film or actively by inserting required gases into the package. Once the packaging is done, the level of oxygen and carbon dioxide is altered consequently bring down the concentration oxygen and increase the carbon

dioxide level (Fonseca *et al.,* 2000). Thus directly influence the metabolic processes as well as microbial growth, and to reduce enzymatic degradation in order to extend the shelf life of the fruit (Catherine, 2002).

As one of the factor that determines the freshness of fruit, firmness was evaluated. Firmness loss was noticed regardless of harvesting maturities and film packaging. Nevertheless, the major loss was for ripe fruit stored at ambient temperature (23 ± 1˚C) followed by those stored at intermediate temperature (16˚C). However, reduction in pulp firmness was less for fruit kept at low temperature (6˚C). This loss is generally due to fruit softening which are contributed by enzymatic degradation of pectin except extreme soft texture may give rise to consumer rejection prior to consumption. Film packaging at higher temperature is able to affect cellular level that will eventually disrupt and thus watersoaked areas appear because the oxygen level increases as the respiration rate is high. Another aspect of fruit quality evaluated was TSS. The TSS level showed the value within 13 Brix˚ for all the fruit despite of storage temperature. The atmosphere modification perhaps had averted the consumption of respiration substrate because of low oxygen within the package (Kader, 1995).

Nevertheless, creation of very low level of oxygen within a package will cause anaerobic condition. Subsequently production of ethanol will increase and organoleptic properties of the fruit will deteriorate (Carol, 1996). In addition, reduction of oxygen level beyond the limit will disrupt various metabolism such as discolouration, damages the cytoplasm and other physiological disorders leading to deterioration of produce quality (Soliva-Fortunay *et al.,* 2002). This further confirms the reduction of firmness when the fruit stored at high temperature that was observed in this study. It was also reported that, reducing oxygen level beyond a limit initiates anaerobic glycolysis and

thus producing off –flavour (Kader and Ben-Yehoshua, 2000). Another possibility of the reduction of quality in fruit packed at stored at high temperature.

From this study it is known that the effectiveness of film packaging can be contributed by two factors which are film permeability or thickness and temperature. Gas diffusion in and out of the package will depend on film permeability or thickness. A film with a very low permeability will cause fruit to deteriorate faster. This is because the amount of oxygen in the package will tend to initiate metabolic processes that lead to overall fruit deterioration. On the other hand, film which if fully permeable will allow diffusion of gases during storage making the air within the package will eventually be the same as the air outside (Kader and Watkins, 2000). There are films that behave like a barrier for gas diffusion that cause undesirable conditions (Kader *et al.,* 1989). Therefore, the type of film used in this study showed atmosphere modification was able to extend the shelf life and also maintained the fruit quality.

Respiration rate differs to different temperatures and also film permeability. At an optimal temperature, this combination provides a favourable atmosphere however at higher temperature; excessive oxygen decrease and carbon dioxide increase will lead to fruit deterioration (Cameron *et al.,* 1993; Exama *et al.,* 1993). As far as packaging film is concerned, temperature regulation also becomes essential. At a higher temperature, it was reported that the respiration rate will increase more than the film permeation eventually creating a fermentative condition (Brecht *et al.,* 2003). Besides that, increasing the temperature will increase the relative humidity within the package and the water vapour which will promote microbial growth or decay on the fruit (Tano *et al.,* 2007). From the experiment carried out, the packaged fruit tend to maintain its quality when stored at low temperature. This is possibly due to lower respiration rate

that retards the metabolic processes as well as low relative humidity that prevents decay.

In summary, *H. polyrhizus* harvested at three different harvest maturities showed changes in terms of peel colour and pulp firmness. Even the less mature fruit showed changes in terms of physiological and biochemical characteristics. However, the best fruit quality was obtained from D 0 fruit compared to those harvested earlier. In this study, harvest index parameters that are suitable in determining the best quality of fruit are by observing the fruit colour, size as non destructive method while for destructive method; measuring the total soluble solids. This is because from the present study, the TSS shown to be well associated with the quality of the fruit that contributes to the quality ultimately to the marketability of the fruit. The reduction of pulp firmness was associated with presences of cell wall degrading enzymes activity such as pectin methylesterase, polygalacturonase yet pectate lyase and cellulase showed uncertain pattern of activity. As for the effect of storage temperature, *H. polyrhizus* showed the optimal temperature at 6˚C in which the quality retained for up to 2 weeks compared to storage at RT˚C and 16˚C. In terms of modifying the atmosphere, the film packaging method was successful in extending the shelf life of *H. polyrhizus* up to two week while maintaining the freshness and fruit quality when stored at 6˚C.

The findings from these studies can be used as a baseline for the future research in dragon fruit. However, additional research is needed to investigate the effects of postharvest handling procedures on the quality in fresh fruits. Also, the possible effects on nutritional quality of those procedures that have not been evaluated need to be elucidated. Any new harvesting or postharvest handling method should be evaluated as to its potential impact on nutritional quality. Furthermore, the local information

available on the processing and postharvest management of this fruit is also scarce; hence this is another area that deserves study with the findings of this study as a baseline.

In addition to the method for extending shelf life, further research is required on integrating MAP and temperature to make it a commercially successful technology. Models describing the respiration rate of the fruit and gas exchange between the MA in the package and ambient atmosphere should be developed. Based on that, it is possible to maintain a self-controlled atmosphere, i.e. constant gas mixture throughout the storage period, by selecting appropriate initial gas mixture, properties of the packaging film and right storage temperature.