QUALITY RETENTION OF DRAGON FRUIT (*Hylocereus polyrhizus*) USING DIFFERENT PACKAGING SYSTEMS

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QUALITY RETENTION OF DRAGON FRUIT (*Hylocereus polyrhizus*) USING DIFFERENT PACKAGING SYSTEMS

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ENDORSEMENT

The project report entitled **Quality Retention of Dragon Fruit (*Hylocereus polyrhizus*) using Different Packaging Systems** by **Lau Sze Mei**, Matric No. **UK 15713** has been reviewed and corrections have been made according to the recommendations by examiners. This report is submitted to the Department of Agrotechnology in partial fulfillment of the requirement of the degree of Bachelor Science of Agrotechnology (Post-Harvest Technology), Faculty of Agrotechnology and Food Science, Universiti Malaysia Terengganu.

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DECLARATION

I hereby declare that the work in this thesis is my own except for the quotation and summaries which have been duly acknowledged.

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ABSTRACT

Dragon fruits (*Hylocereus polyrhizus*) are high valued and perishable fruits. There is growing demand for dragon fruits from nearby countries such as China, Singapore, Hong Kong and it also has good potential to be exported to Europe countries. Thus, postharvest treatments are needed to reduce deterioration of fruits physical appearance and damages due to disease attacks. This study was conducted to determine the effects of different packaging systems on postharvest quality of dragon fruit stored at temperature of 10±1°C for 12 days. The commercial maturity (Index 4) of red-fleshed dragon fruits were individually packed in the 0.059 mm thick low-density polyethylene (LDPE) plastic film in non-perforated, perforated and partial vacuum (5 sec) conditions and the unpacked fruits were used as control in this study. Changes in the percentage of weight loss, skin and flesh color, firmness, total soluble solids (TSS), and visual assessments for disease infestation and wrinkles development on fruits were observed during storage. Partial vacuum packed maintained fruits physical appearance better with much reduced disease infestation after 12 days of storage as compared with the unpacked and perforation packed fruits which were rejected by day 9 and day 12 respectively. Besides, partial vacuum packed was also significantly more effective in controlling the fruit weight loss where the percentage of weight loss was the least during 12 days of storage as compared with other treatments. However, other fruits quality characteristics were not affected by the packaging treatments. The unpacked fruits have the lowest firmness on day 12 whereas partial vacuum packed fruits showed no significant reduction in fruit firmness. TSS of fruit was minimally affected. This study indicates that partial vacuum packaging could be recommended as a potential packaging system in reducing postharvest losses of dragon fruit particularly during distribution and marketing for domestic and export markets.

ABSTRAK

Buah naga (*Hylocereus polyrhizus*) merupakan buah yang tinggi nilainya tetapi mudah rosak. Permintaan terhadap buah naga di kalangan negara jiran seperti China, Singapura, Hong Kong semakin tinggi dan buah ini juga berpotensi tinggi untuk dieksport ke negara-negara Eropah lain. Justeru, rawatan lepas tuai diperlukan bagi mengurangkan kerosakan buah dari segi fizikal dan kerosakan yang disebabkan oleh serangan penyakit. Kajian ini telah dijalankan untuk menentukan kesan sistem pembungkusan yang berlainan terhadap kualiti lepas tuai buah naga yang disimpan pada suhu 10±1°C selama 12 hari. Kajian ini melibatkan pembungkusan buah naga pada tahap kematangan komersial (Indeks 4) secara individu di dalam filem plastik polietilina berketumpatan rendah (LDPE) yang tebalnya 0.059 mm dalam keadaan tidak berlubang, berlubang dan separa vakum (5 saat), manakala buah yang tidak dibungkus bertindak sebagai kawalan. Perubahan peratusan kehilangan berat buah, warna kulit dan isi buah, jumlah pepejal terlarut, ketegaran buah dan penilaian visual untuk serangan penyakit dan pengedutan pada buah telah diuji sepanjang tempoh penyimpanan. Pembungkusan separa vakum dapat mengekalkan penampilan fizikal buah dengan lebih baik dan mengurangkan serangan penyakit sepanjang tempoh penyimpanan berbanding dengan buah kawalan dan buah dalam pembungkusan berlubang dimana buah-buah tersebut telah tidak boleh diterima pada hari ke-9 dan ke-12 masing-masing. Selain itu, pembungkusan separa vakum juga memberi kesan yang ketara dalam mengawal kehilangan berat buah dimana peratus kehilangan berat adalah paling sedikit sepanjang tempoh penyimpanan jika dibandingkan dengan rawatan-rawatan lain. Walau bagaimanapun, rawatan pembungkusan yang berlainan tidak mempengaruhi ciri-ciri kualiti lain dalam buah. Dari segi ketegaran buah, buah kawalan pada hari ke-12 adalah paling rendah manakala pembungkusan separa vakum tidak menunjukkan pengurangan yang ketara. Jumlah pepejal terlarut hanya dipengaruhi secara minima. Kajian ini menunjukkan pembungkusan separa vakum berpotensi tinggi untuk mengurangkan kerugian lepas tuai buah naga yang disebabkan oleh kerosakan dan serangan penyakit terutamanya semasa pengedaran dan pemasaran untuk pasaran tempatan dan pasaran eksport.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
cm	Centimeter
CO_2	Carbon dioxide
g	Gram
ha	Hectare
kg	Kilogram
HDPE	High-density polyethylene
LDPE	Low-density polyethylene
MAP	Modified atmosphere packaging
mg	Milligram
mm	Millimeter
mms^{-1}	Millimeter per second
O_2	Oxygen
RH	Relative humidity
sec	Seconds
˚C	Degree Celsius
˚F	Degree Fahrenheit
µm	Micrometer
=	Equal to
±	More or less
%	Percent
˚	Degree
<	Less than
>	More than

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Dragon fruit (*Hylocereus* spp.), which belongs to the cactus family, Cactaceae is native to the tropical forest regions of Mexico and Central and South America (Mizrahi et al., 1997). It is grown commercially in Vietnam, Taiwan, South China, Israel and more recently, in Thailand, Australia, US and Malaysia (Mizrahi and Nerd, 1999; Nerd et al., 2002; Nobel and Barrera, 2002).

In Malaysia, the red pitaya or dragon fruit is commonly called as "buah naga", a description associated with the green colour of the immature fruit, and the 'dragon-like' appearance of the 'scales' or bracts on the fruit surface. The stems modified to act as leaves, bear spectacular ovoid fruit year-round which are a bright red colour when mature, and contain white, crimson, or pale-yellow flesh depending on the cultivar and is interspersed with small black seeds.

Among the red pitaya species, *Hylocereus polyrhizus* (red flesh) fruits are edible and it has a great source of vitamin C and water soluble fiber (Mizrahi and Nerd, 1999). There are a number of species grown commercially namely, *Hylocereus undatus* (white-fleshed), *H. costaricensis* and *H. polyrhizus* (red-fleshed) and yellow pitaya, *Selenicereus megalanthus* (Mizrahi et al., 1997). Dragon fruit consists of phytoalbumins which are highly valued for their antioxidant properties. It has less sugar content than other popular tropical fruits, and thus is more suitable to the diabetics and high blood pressure patients (Kueh et al., 2003).

Dragon fruit can be processed into a range of industrial products such as juice, jam, syrup, ice cream, yogurt, jelly, preserve, candy and pastries and it is widely used in fruit salads at restaurants (Luders, 2004). Besides, wine making using dragon fruit is a popular industry in Malaysia. Processed products can be produced from fresh fruit pulp or frozen pulp. The red and pink pulp of dragon fruit can be used as a food colouring agent, and as a raw material for the food colouring industry (Gao-Xi and Wan, 2004). These attributes have led people to consider it as a health fruit and this is one of the reasons why it commands a premium price (To et al., 2002).

In ambient conditions, fruit stays fresh for a few days after which its appearance deteriorates, resulting in down grading of value. Studies had been done on different packaging systems in prolonging the storage life of dragon fruit. Zee et al. (2004) reported that storing dragon fruit in perforated bags at 8 °C able to keep the dragon fruit for 25-30 days. However, it is also reported that dragon fruit that are packed in perforated polyethylene plastic bag and stored at 10°C has a shorter storage life compared to those which are packed in polyethylene plastics bags without any holes at the same temperature (Lau et al., 2008). Studies have shown that partial vacuum packaging is effective in extending the shelf life of minimally processing fruit but packing fresh fruit using partial vacuum technology is still new and the related information regarding the effect of this packaging technique on fresh fruit packaging is also scanty.

1.2 Problem Statement

Locally, fruits are sold mainly for fresh consumption. There is growing demand for dragon fruit in nearby countries such as China, Hong Kong and Singapore. Furthermore, it has good potential to be exported to European countries, as its taste is liked by Europeans (Julia and Morton, 2006).

However, the deterioration of physical appearance and damages due to disease attacks on fruits after keeping for a few days under ambient conditions could render losses in value and spoilage (Drew et al., 2001). These losses are costly to retailers for such a high valued fruit. Fungal infections of dragon fruit have restricted its potential to be exported to other countries in long journey due to spoilage. In addition, fresh dragon fruit is marketed with little or nil postharvest handling consideration along the local supply chain presently (Lau et al., 2008). If they are sold in the local markets, the storage period will be less but when grown for overseas markets proper storage is necessary. Moreover, local information on processing and postharvest management of this fruit is limited and not been extensively studied.

1.3 Significance of study

Dragon fruit is usually become the host of fruit fly *Bactrocera* spp. (Drew et al., 2001), and diseases such as brown spots on the fruit which caused by *Dothiorella* and anthracnose (Barbeu, 1990), collar rot (*Phytopthora* sp.) and root rots (*Fusarium* sp.). The deterioration of physical appearance and damages due to disease attacks on fruits after keeping for a few days under ambient conditions could render losses in value and spoilage. These losses are costly to retailers for such a high valued fruit.

Therefore, researches on fruit preservation are important in order to minimize post harvest losses and post harvest treatment such as proper packing and storage is needed to extend the shelf life of such a high valued dragon fruit. Increasing its shelf life not only reduce spoilage locally but also increase the potential for marketing it overseas.

Modified atmosphere packaging method is found to be effective to prolong the shelf life of many crops and delaying fruit spoilage (Thompson, 2003). Interest has been shown in the use of plastic films as an alternative to waxing (Ben-Yehoshua et al., 1979). Besides, Sornsrivichai (1990) also reported that fungal decay of pre-treated mangoes was delayed for about five weeks in sealed fruit compared with two to three weeks in non-sealed fruits. In addition, vegetables that are packaged in perforated film lost less weight and maintained higher quality during storage than fruit stored in open carton boxes and, at the same time, had lower decay levels than those that are kept in non-perforated packages (Ben-Yehoshua et al., 1996). Although several studies have examined general postharvest aspects of dragon fruit (Wu and Chen, 1997; Nerd and Mizrahi, 1999b; To et al., 2002), no widely available information currently exists as to the tolerance of dragon fruit after vacuum storage. However, studies had found that vacuum packaging is effective in extending the storage life of various meat products (Marta et al., 2003) and many minimally processing fruits.

Therefore, this study was conducted to determine the effects of different packaging systems using LDPE plastic film on post harvest quality of dragon fruit.

1.4 Objectives

1) To study the effects of different packaging systems on post harvest quality of dragon fruit.

2) To determine the effects of each packaging system in prolong the storage life of dragon fruit at its optimum storage temperature (10±1°C).

CHAPTER 2

LITERATURE REVIEW

2.1 Dragon fruit (*Hylocereus polyrhizus*)

Dragon fruit (*Hylocereus polyrhizus*), is one of the popular tropical fruits. Currently, dragon fruit is being cultivated in at least 22 countries of the tropics, Australia, Cambodia, China, Colombia, Ecuador, Gautemala, Hawaii, Indonesia, Israel, Japan, Laos, Malaysia, Mexico, New Zealand, Nicaragua, Peru, the Philipines, Spain, Sri Lanka, Taiwan, Thailand, the south western USA and Vietnam (Mizrahi and Nerd, 1999). The commercial plantation in Israel, Malaysia and Taiwan produced between 16000-2700kg/ha (Mizrahi and Nerd, 1996; 1999).

In Malaysia, the national dragon fruit acreage was increased from 47.3 ha in 2002 to 927.2 ha in 2006 with Johor is the major dragon fruit producer. In 2006, the national production area was 363.2 ha with the total production of 2,534.2 tons. This had led to the national production value to RM 12,670,755 in year 2006 (Cheah and Wan, 2008).

Dragon fruit consists of variety of chemical compositions which are important in our daily diet. The red skin fruit weighed up to 1 kg has translucent dark-red flesh considered as a rich source of nutrients and minerals such as vitamin B1, vitamin B2, vitamin B3 and vitamin C, protein, fat, carbohydrate, crude fiber, flavonoid, thiamin, niacin, pyridoxine, kobalamin, glucose, phenolic, betacyanins, polyphenol, carotene, phosphorus, iron and phytoalbumin (Le et al., 2006). In 100 g of fruit pulp, it consists of 82.5-83 g of water, 0.16-0.23 g of protein, 0.21-0.61 g of fat, 0.7-0.9 g of crude fiber, 0.28 g of ash, 6.3-8.8 mg calcium, 30.2-36.1 mg phosphorus, 0.55-0.65 mg of iron (Fe) and 8-9 mg of ascorbic acid (Morton, 1987).

Dragon fruit is a non-climacteric fruit (Nerd and Mizrahi, 1999a). Therefore, fruits must be picked at optimum ripeness. At peak ripeness, the fruits become pink-red although the scales remain green. Ripened fruits can be harvested between 30-50 days after fruit set (pollination). The fruit is a medium to large, oblong shaped epigenous berry. Fruits develop from both ovary (pulp) and the receptacle that surrounds the ovary (peel). The fruit change its peel colour from green to red about 25 days after anthesis. The peel turns fully red in the next four to five days after the first color change about 25-41 days after anthesis, the dry weight of fruit pulp increases significantly whilst peel dry weight and percentage water in the peel decreases. Fruit firmness also decreases during this period. (Nerd et al., 2002; Pushpakumara et al., 2005).

Dragon fruit plant is a perennial, fast growing climber, with triangular or rarely, four or five sided stems are fleshy, vine like with many branched segments. Each segment has three wavy wings or ribs with corneous margins and one to three spines, or sometimes spineless (Cheah and Wan, 2008).

Hylocereus polyrhizus has received world-wide recognition as an ornamental plant for its large, scented, night-blooming flowers. At the onset of flowering, three to five spherical buttons emerge from the stem margins and two to three of these may develop into flower buds in about 13 days. The light green cylindrical flower buds reach about 28 cm after 17 days when anthesis occurs. The flowers are large, hermaphrodite and extremely showy. They are white-pink in some types- very fragrant, nocturnal and bell-shaped. Cross pollination is done by bats and bees which occurred from 9 pm to 12 midnight. The development of a floral bud to a fully opened flower takes 25-35 days (Pushpakumara et al., 2005).

2.1.1 Storage temperature

The shelf life of dragon fruit varies among its varieties. The recommended storage temperature for dragon fruit is 10 °C, since 6 °C can induce chilling injury (Nerd et al., 1999). The lower temperature (6 °C) has been recommended for the yellow pitaya, *Selenicereus megalanthus* (Nerd and Mizrahi, 1999a).

Storing fruit under ambient conditions can have detrimental effect on fruit quality and shorter shelf life (Robert, 2000). Bringing the fruit down to its recommended low temperatures can slow down the product metabolism and the activity of microorganisms responsible for fruit quality deterioration in dragon fruit. As a result, fruits are maintained with a lower respiration rate, ripening is retarded and vapor pressure between fruit and ambient is minimized, water loss is reduced. These factors contribute toward maintaining freshness by reducing the rate at which fruit quality deteriorates and the nutritional value of the fruit is preserved (FAO, 2004).

Dragon fruit has a storage-life of about 14 days at 10 °C, while at 5 °C and 90% RH a storage-life of 17 days can be achieved (Le et al., 2000) if harvested 30 to 35 days from flowering. However, 5 °C may lead to chilling injury upon return to 20 °C, indicated by deterioration of peel and flesh, and inferior taste (Nerd et al., 2002). Hence, 10 °C for a maximum of 14 days is a better recommended storage temperature.

2.1.2 Post harvest losses of dragon fruit

Locally, fruits are sold mainly for fresh consumption. However, keeping fruits for a few days under ambient conditions causes deterioration of physical appearance and damages due to disease attacks on fruits which could render losses in value and spoilage (Drew et al., 2001). Fungi such as *Colletotrichum* spp., *Fusarium* spp. and *Helminthosporium* spp. are normally found on the diseased fruit. Brown soft spots usually developed from both ends of the fruit while white spots developed over the fruit. Barbeau (1990) reported that bacterial (*Xanthomonas campestris*) and *Dothiorella* spp. diseases on dragon fruit and in addition, post harvest disease has been associated with *Fusarium lateritium, Aspergillus riger, and Aspergillus flavus* (Le et al., 2000). These losses are costly to retailers for such a high valued fruit.

Besides, evidence indicated that after harvesting, the respiratory rate of dragon fruits decreases and the weight loss increases showing visible shrivelling after eigth day (Arevalo-Galarza and Ortiuz-Hernandes, 2004). If they are sold in the local markets, the storage period will be less but when grown for overseas markets proper storage is necessary.

2.2 Packaging

The function of package is primarily to contain and protect the produce. Fresh fruits and vegetables often consists two levels of packaging. The first is the pack in which the produce is offered to the consumer. The second is the pack that contains the consumer pack and is used to transport the product to the retail market (Thompson, 2003). Shelf life of crops can be further extended by using certain types of packaging such as plastic films to modified atmosphere around the crops and also to protect the crops from infection or infestation (Thompson, 2003). The package may also help in presentation of the crop to enhance its value or help its sale.

Being the living organisms, fresh fruit and vegetables released heat and gases thus packaging used need to be ventilated. A well packaging design takes into consideration on the respiration rates of different fruit as well to control package head space oxygen and carbon dioxide concentration to targeted levels that reduce product respiration rate and increase shelf life (Falik et al., 2003).

According to Robert (2000), packaging of dragon fruit must have the ability to contain the fruits, facilitate handling and to protect fruit from injuries such as impact, compression, abrasion and wounds as well as from the adverse environmental condition such as temperature and relative humidity (RH) during transport and storage.

Being a non-climacteric fruit, packaging of dragon fruit does not require sufficient large opening to allow good gas exchange as the maximum respiration rate of this occurs during early fruit growth and declined after fruit received optimum maturity (Robert, 2000; Le et al., 2000). Semi-permeable materials such as polyethylene film are able to generate special atmosphere inside packages to help in maintaining fruit freshness (Robert, 2000).

2.2.1 Modified Atmosphere Packaging (MAP)

Modified atmosphere packaging is used in the storage of fresh fruits and vegetables; the term refers to their storage in plastic films, which restrict the transmission of respiratory gases. This results in the accumulation of CO_2 and depletion of O_2 around the crop, which may increase their storage life. However, the effects of these gas changes may have beneficial or adverse effect of increasing the risk of decay on the crop. Those beneficial effects that can be resulted in packing crop in the plastic films are referred to as modified atmosphere packaging (Kader et al., 1989).

Modified atmosphere storage can also referred to sealing fruit and vegetables in a gas-impermeable container where respiratory gases change the atmosphere over time. The effects of polyethylene film wraps on the postharvest life of fruits may also be related to moisture conservation around the fruit and the change in the CO_2 and O_2 levels. According to Thompson et al. (1972), plantains that are stored in moist coir or perforated polyethylene film bags had a longer storage life than the unwrapped ones. Studies had also found that modified atmosphere condition was effective to retard the firmness decrease and texture change as well as reduction in weight loss in Eksotika papaya particularly when the fruits were stored at moderately low temperature (Lazan et al., 1993; Rohani et al, 1997).

The transmission of CO_2 and O_2 through plastic films will vary with film type, but generally films are four to six times more permeable to CO_2 than to O_2. Plastic film bags are made from the by-products of the mineral oil refining industry. The permeability of plastic films to gases and water vapour will vary to the type and thickness of the plastic that is used. Basically, the acceptable time during which fruit can remain in a modified atmosphere varies with cultivars and storage conditions, but it is usually two to four weeks, which meets the requirement of the export shipment and marketable life (Thompson, 2003).

2.2.2 Plastic-film packaging

The use of plastic-film packaging is a simple and very efficient way to reduce transpiration (Ben-Yehoshua et al., 1979). The resistance of plastic films to water-vapor diffusion usually far exceeds the barrier properties of the fruit surface itself (Ben-Yehoshua, 1978). The advantages of plastic packaging as a means of minimizing water loss and associated produce deterioration have been demonstrated with various fruits and vegetables.

According to Fellows (1988), plastics as packing materials are relatively low cost, good barrier properties against moisture and gases, heat-sealabe to prevent leakage of contents and consist of wet and dry strength. Besides, plastics are suitable for high-speed filling, easy to handle and convenient for the manufacturer, retailer as well as consumer. Different kinds of plastic film packages such as bags, wraps, liners, and bulk-box covers are applied during storage, transportation, and wholesale and retail marketing of fresh produce.

2.2.2.1 Low-density Polyethylene (LDPE)

Polyethylene is the most used polymer in food packaging applications. It is produced by polymerization of ethylene. Low-density polyethylene (LDPE) is one of the examples of polyethylene produced.

LDPE is one of the plastic films used in MAP. It is heat-sealability at low temperatures (approximately 80°C, 175°F) and it is chemically inert, odor-free and shrinks when heated. In addition, it is strong, and acts as the good moisture barrier but poor gas barrier (Jelen, 1985; Brown, 1992). This selective permeability characteristic makes it a good choice of packaging material for many products such as fresh meat, fruits and vegetables. It is less expensive than most films and is therefore widely used for many packaging applications, including applications in shrink- or stretch wrapping of products (Somogyi et al., 1996).

2.3 Packaging systems

2.3.1 Seal-packaging

An important effect of sealing is that the produce micro-atmosphere becomes water saturated and this might be one of the controlling factors delaying deterioration. Ben-Yehoshua et al. (1981) reported that seal-packaging delayed various parameters of various physiological deterioration in *Citrus*, tomatoes and bell peppers better than cooling to optimal storage temperature.

The effect of seal-packaging and waxing on gas exchange and post harvest quality of *Citrus* has been studied. The commercial practice of waxing produce reduces transpiration inadequately and it is effective in restricting O_2 and CO_2 transport. On the other hand, sealing fruits or vegetables individually in high-density polyethylene (HDPE) film (about 10 μm thick) reduces water loss by a factor of 10 without changing the endogenous O_2, CO_2 or ethylene content. Consequently, seal-packaging is more effective than waxing in preventing shrinkage and extending storage life (Ben-Yehoshua, 1985). However, sealing of produce in the imperforated bags may lead to acceleration of decay and development of off-flavors.

2.3.2 Perforation packaging

The use of perforated film is a simple approach to modulating in-package RH, which depends on the ambient RH level. Holes placed in the plastic barrier of a produce package dramatically affected the in-package CO_2 and O_2 concentrations but only had a mild influence on the in-package RH level (Ben-Yehoshua et al., 1996). Ben-Yehoshua et al. (1996) also reported that bell pepper packages made from perforated polyolefin films allowed the beneficial combination of reduction both condensation and *Botrytis* decay and satisfactory weight-loss control.

Besides, Son et al. (1983) found that fruits of the pear cultivars Okusankichi and Imamuraaki decayed most if placed in unsealed 0.05 mm plastic bags and least in sealed bags with five pin holes. Perforation retains many of the good results of sealing such as reduction of water loss and alleviation of water stress without the possible deleterious effects of anaerobiosis such as off-flavours, fermentation or CO_2 damage (Ben-Yehoshua et al.,1994). In addition, Badgujar et al. (1987) also suggested that packing of brinjal in perforated polyethylene bags (1% holes) prolonged shelf life and maintained quality compared to unpacked fruit.

2.3.3 Vacuum packaging

Vacuum packaging is the packaging method to remove air from the package head space and to a varied and limited degree from the food itself to eliminate the oxidative spoilage organisms are precluded from vacuum packaging (Brown, 1992). The vacuum environment removes atmospheric oxygen, protecting the food from spoiling by limiting the growth of aerobic bacteria or fungi, and preventing the evaporation of volatile components.

Perishable foods must still be refrigerated or frozen for storage after packing in a vacuum or partial vacuum environment. It is found that vacuum packaging can extend the shelf life of berries from three to six days to two weeks in a refrigerated condition. Mortazavi et al. (2007) reported that weight loss and the amount of crumbled berry fruit, *Phoenix dactylifera* L. were least in the vacuum packaging compared to other MAP but experienced the significant reduced in fruit firmness.

On the contrary, partial vacuum packaging is a vacuum packaging with low atmospheric pressure, where most of the air has been pumped out. According to Gorris et al. (1994), lower O_2 content had found to be inhibited the growth of spoilage microorganism and stabilized the quality of the produce after packing minimally processed fruits and vegetables under moderate vacuum packaging.

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

3.1.1 Collection of dragon fruit

The red-fleshed dragon fruits (*Hylocereus polyrhizus*) with commercial maturity stage four were collected from the Agricultural Department of Batu Pahat, Johor. Being a non-climacteric fruit, type of fruit used in this study was picked at their optimum ripeness. The fruit were transported in the carton boxes to the Postharvest Laboratory of Universiti Malaysia Terengganu (UMT), Terengganu. The average weight of fruit was 504 g per fruit.

3.2 Methods

3.2.1 Preparation of samples

At the laboratory, the fruits were washed with water containing 0.5% of sodium hypochlorite (Chlorox ™) solution for 2 minutes in order to remove dirt and the fruit were then air dried. Fruits were carefully sorted out to ensure as much uniformity as possible in term of size, weight and color, as well as to remove the damaged and defected fruits.

3.2.2 Packaging and storage

All the fruit were individually packed in 0.059 mm thick sized 29 cm × 20 cm low density polyethylene (LDPE) bags to create the modified atmosphere environment. In the first treatment, the fruit was heat-sealed in the LDPE bag without holes (T_1). In the second treatment, the packaging method was done similar to the first treatment but 8 holes of 5 mm in diameter per hole were made with the aid of hole puncture (T_2). In the third treatment, the fruit were vacuum packed using the vacuum packaging machine (Model DZ-400/2) for 5 seconds and the packaging was sealed for 3 seconds (T_3) in order to create the partial vacuum environment. For the control (T_0), fruit was taken without packing. The dragon fruit for each treatment were randomly assigned to the carton boxes sized 43 cm × 27 cm × 25 cm and stored at its optimum storage temperature of 10 ± 1°C in the cool room for twelve days. The experiment comprised of four treatments with three replications. Each replicate contained one fruit.

Table 3.1: The arrangement of replicates according to three packaging treatments and control

Treatment	Arrangement of replicates	Specification
T_0	Day of observation = 5 Number of replicate = 5 × 3 = 15 Number of fruits = 15 × 1 = 15	Fruit left unpacked and stored in cool room at 10±1˚C.
T_1	Day of observation = 5 Number of replicate = 5 × 3 = 15 Number of fruits = 15 × 1 = 15	Fruit sealed in individual in LDPE plastic film without holes, and stored in cool room at 10±1˚C.
T_2	Day of observation = 5 Number of replicate = 5 × 3 = 15 Number of fruits = 15 × 1 = 15	Fruit sealed in individual in LDPE plastic film with holes and stored in cool room at 10 ± 1˚C.
T_3	Day of observation = 5 Number of replicate = 5 × 3 = 15 Number of fruits = 15 × 1 = 15	Partial vacuum fruit individually using LDPE plastic film for 5 seconds, sealing time 3 seconds and stored in cool room at 10 ± 1˚C.

3.2.3 Quality analysis

Both physical and chemical qualities of fruit were analyzed before storage on day 0 and immediately after removal from cool room. The LDPE plastic bags were removed subsequently after the fruit were transferred to ambient temperature for physico-chemical analysis. Three fruits from each treatment were withdrawn for assessment at three days interval for up to twelve days. The objective measures included skin and flesh color, skin and flesh firmness, total soluble solids (TSS), weight loss as well as visual assessment for disease infestation and presence of wrinkles.

3.2.3.1 Percentage of weight loss

Three fruits were randomly selected for weight loss measurement for each treatment. The fruit was weighed individually on a top pan balance after they were treated with their respective treatments. The initial weight of dragon fruit was taken on day 0 and was noted down up to two decimal places. The final weight of fruit was determined at three days intervals on the day of the fruits were being withdrawn for assessment. Result was expressed in percentage using the standard calculation formula.

$$\%\text{ of weight loss} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

3.2.3.2 Skin and flesh firmness

The skin and flesh firmness value of the dragon fruits were measured at six points of the equatorial region using TA-XT2 plus Texure Analyzer (Stable Micro Systems, Godalming, UK) which was set to penetrate the fruit in 20 mm in 1.0 mms^{-1} using P/2N probe. The two peaks of maximum force (g) were defined as the firmness for the skin and flesh of dragon fruit with the first peak value represented the firmness of skin and the second peak denoted the firmness of flesh.

3.2.3.3 Skin and flesh color

Skin color was measured at six different locations around the equator of each fruit while flesh color was measured longitudinally after the fruit has cut into half. Both skin and flesh color were measured using the Minolta Chroma Meter (Model CR 200 Trimulus Color Analyzer) which expresses color in three numerical notation system as L^*, a^* and b^* values. L^* denotes the lightness and darkness of the color while a^* and b^* denote the hues which represented two color axes with a^* the red-green axis and b^* the yellow-blue axis. The total color change of fruit was calculated using the L^*, a^* and b^* values with the standard formula.

$$\Delta C = \sqrt{[(L_1 - L_0)^2 + (a_1 - a_0)^2 + (b_1 - b_0)^2}$$

3.2.3.4 Disease infestation

Fruit disease infestation was determined by observing the presence of brown spot on the peel surface according to the descriptions of score chart. The score was from 1 to 5 with 1 representing disease-free fruits and increasing score values for increasing diseased area. Score 1 representing disease-free fruit. Score 2 for the presence of brown spot of not more than 0.5 cm diameter and not more than two spots.

Score 3 for fruit with brown spot off less than 1 cm and covered less than 5%. Score 4 for dull looking fruit with wrinkles presence of over 20% to 30% and score 5 with diseased area over 10% of fruit. Fruit was rejected with score over 4 (Table 3.2).

Table 3.2: Scoring descriptions of disease infestation

Score	Disease Infestation
1	Disease-free fruit
2	Brown spot of not more than 0.5cm diameter and not more than 2 spots
3	Brown spot of less than 1cm and covers less than 5% of fruit
4	Spots or diseased surface of over 5% to 10%. Fruit is rejected with score over 4.
5	Diseased area of over 10% of fruit.

Source: Lau et al. (2008)

3.2.3.5 Presence of wrinkles

The presence of wrinkles on fruit was determined by observing fruit peel physical appearance according to the score chart. The score was from 1 to 5 with 1 representing the wrinkle-free fruits and increasing score values for fruits with increasing percentage of wrinkles. Score 1 for fruit with no wrinkles and contained glossy skin surface. Score 2 for slight wrinkling (less than 5%) at the posterior end of fruit. Score 3 for fruit with over 5% to 20% wrinkles at the posterior end. Score 4 for dull looking fruit with wrinkles presence of over 20% to 30% and score 5 for wrinkles of over 30% of fruit (Table 3.3).

Table 3.3: Scoring descriptions for the presence of wrinkles

Score	Presence of Wrinkles
1	No wrinkles on fruit. Glossy skin surface
2	Slight wrinkling at the posterior end of fruit (less than 5%)
3	Wrinkles at posterior end of fruit (over 5% to 20%)
4	Wrinkles of over 20% to 30% of fruit. Dull looking
5	Wrinkles of over 30% of fruit

Source: Lau et al. (2008)

3.2.3.6 Total Soluble Solids (TSS)

TSS of fruit was measured using only the flesh of fruit to determine the changes in sugar content within three days interval of observations. The stored fruit was cut into smaller pieces at room temperature using knife and the homogenous fruit juice was prepared by crushing the peeled dragon fruit flesh using the mortar and pestle. Fruit juice was filtered through muslin cloth before few drops of fruit juice were taken on the hand-held refractometer prism. The refractometer prism was first cleaned well with distilled water and wiped dry before the new reading was made. The TSS of the fruit juice was measured using the hand-held refractometer and results were expressed as degrees of Brix. The measuring process was repeated twice for each sample.

3.2.5 Statistical Analysis

The experimental design for this study was complete randomized design (CRD). Statistical analysis was done by using SPSS version 16.0. The effect of each treatment was determined by submitting the mean values to analysis of variance using one-way ANOVA and was subsequently compared using the Tukey's multiple range test at the ($P<0.05$) significance level.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Percentage of weight loss

The percentage of weight loss was significantly increased ($P<0.05$) with the storage time. The percentage of weight loss in unpacked fruits was significantly higher ($P<0.05$) as compared to other fruits that packed in LDPE film using different packaging systems (Figure 4.1 and Appendix A).

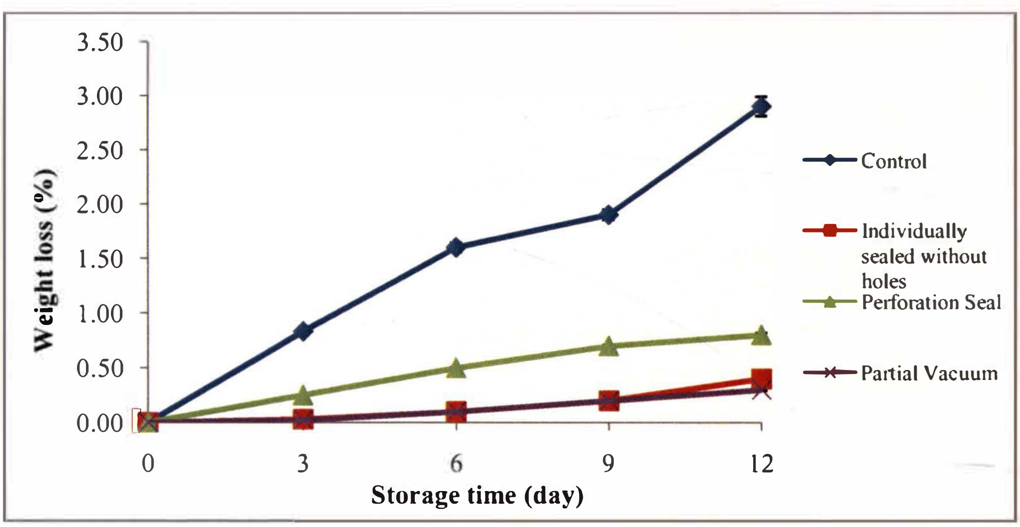

Figure 4.1: Effect of different packaging systems on percentage of weight loss of dragon fruit at 10°C

Individually sealed packaging without holes and partial vacuum packaging were effectively reduced weight loss of dragon fruits at 10°C. Bagging fruit in the LDPE film with holes was significantly better than the unpacked fruits but the percentage of weight loss was significantly higher than that of the non-perforation packaging and partial vacuum packaging. On the other hand, fruit that firmly surrounded by the LDPE film in partial vacuum packaging showed lower average percentage value of weight loss as compared to non-perforation packaging.

Dragon fruit (*Hylocereus polyrhizus*) consisted of 87.3% of moisture content (Mohd Adzim et al., 2006). Water loss in fruits occurred during respiration and transpiration of fresh produce through evaporation of water vapour to the environment. In general, low temperature associated with high humidity not only causes fruits and vegetables reduce the respiration rate but also transpiration rate, both which result in weight loss (Le et al., 2007). In addition, the rate of water loss was nevertheless affected by the surface area of the fruits which in direct contact to the air in the environment where air movement aided in water evaporation of fruit, as well as mechanical injury and decay on fruits.

Bagging fruit in LDPE film formed an effective barrier in preventing moisture loss from the fruit, thus creating a water-saturated atmosphere surrounding the fruit (Lazan and Ali, 1991). This was evidence by the lower percentage of weight loss in fruit packed individually in the LDPE film. Similarly, Eksotika papaya which packed in LDPE bags has been reported reduce significantly its weight loss during storage at 10°C (Rohani et al., 1997).

Besides, LDPE bag with holes had higher contact area to the environment compared to the fruit that was thoroughly wrapped in the LDPE bag. However, most area of the fruit still protected with the LDPE film unlike the unpacked fruit which entirely exposed to the environment. Therefore, result suggested that weight loss of fruit which bagged in LDPE film with holes was significantly lower ($P<0.05$) than the unpacked fruit.

Partial vacuum packaging effectively reduced weight loss in dragon fruit during storage by inhibiting respiratory and transpiration water vapor losses. The similar result was shown by Mortazavi et al. (2007) where vacuum packaging significantly reduced the weight loss and the amount of crumbled berry fruit, *Phoenix dactylifera* L.

4.2 Skin and flesh firmness

Skin and flesh firmness of dragon fruit decreased as storage time increased. There was a gradual decrease in the average firmness values of dragon fruits from day 0 up to 12th day of storage. The unpacked fruits have the lowest firmness value as compared to other packed fruits (Figure 4.2 (a) and (b)).

The firmness of skin was significantly decreased from day 3 to day 6 for fruits that were under control, perforation sealed and partial vacuum packaging system whereas fruit that individually packed in the LDPE bag without holes showed no significant decreased ($P>0.05$) in skin firmness (Appendix B).

On the other hand, flesh firmness of the fruits packed without holes and partial vacuum packaging showed no significant reduction ($P>0.05$) during the 12 days in storage (Figure 4.2 (a) and Appendix B). Flesh firmness of the unpacked fruits and perforation sealed packaging fruits was significantly higher ($P<0.05$) during the first 3 days in storage than the following storage days (Appendix C).

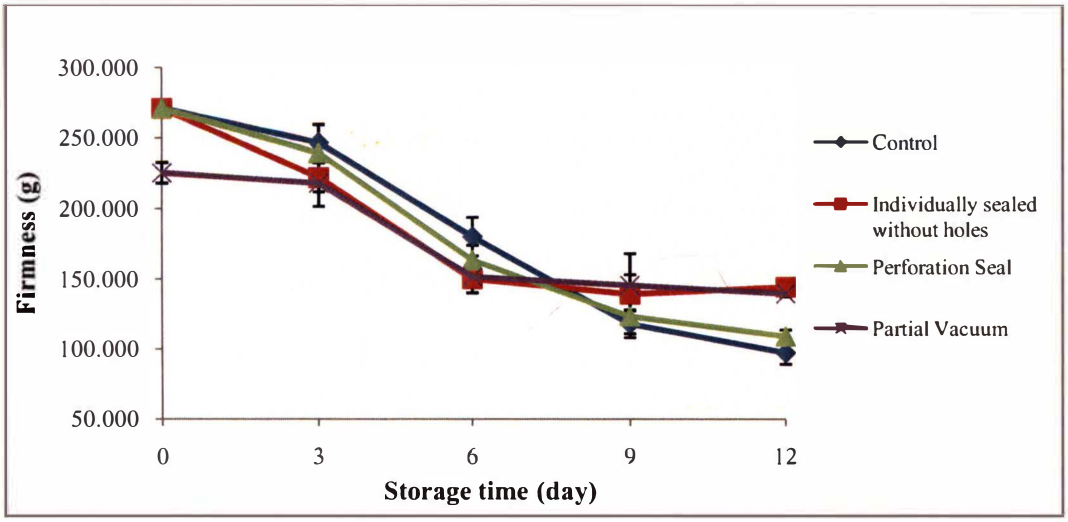

Figure 4.2 (a): Effect of different packaging systems on skin firmness of dragon fruit at 10°C

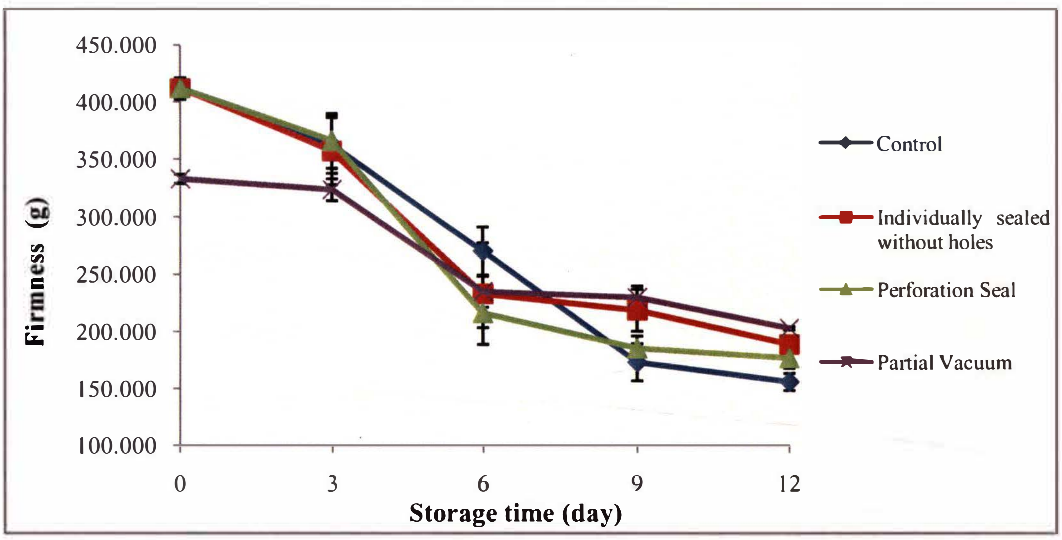

Figure 4.2 (b): Effect of different packaging systems on flesh firmness of dragon fruit at 10°C

On day 0, flesh and skin firmness of fruits packed in partial vacuum packaging was significantly lower ($P<0.05$) as compared to other treatments. This may be due to the effect of hot air in the partial vacuum packaging on the texture of the fruit. Fruits in non-perforation packaging stored for 12 days showed the significantly higher flesh firmness as compared to control and other treatments.

Hot air which trapped in the packaged in partial vacuum packaging may cause the firmness of skin and fruit pulp to be lower than control and fruits in other treatments. This was indicated by the lower average values of firmness in partial vacuum packaging treatment on day 0. However, the fruit in partial vacuum packaging showed no significant different ($P>0.05$) in firmness reduction for the following storage days and has the higher average firmness value as compared to the unpacked fruit and fruit that bagged in perforated LDPE plastic film on day 12. The result was in contrast to the result suggested by Mortazavi et al. (2007), who found that the berry fruit, *Phoenix dactylifera* L. was significantly reduced in fruit firmness when the fruit was packed in vacuum packaging. Thus, the result suggested that partial vacuum for 5 seconds showed a better method in maintaining fruit firmness as compared to fully vacuum technique.

The changes in texture and firmness of fruit were due to the changes in the cell activities of fruit. According to Nerd and Mizrahi (1999a), decline in firmness of dragon fruit occurred when the concentration of starch and mucilage decreased in relation to accumulation of soluble sugars during ripening. Ali et al. (1993) shown that softening of fruit was due to the activity of the cell hydrolyses, such as polygalacturonase, pectin methylesterase and ß-galactosidae as well as the solubilization and depolymerizaion of the cell wall pectin.

Changes in fruit texture were also greatly influenced by the gas exchange occurred during respiration and transpiration during fruit development and ripening (Kader, 1987). Studies had proved that MA condition was effective to retard the firmness decrease and texture change in Eksotika papaya particularly when the fruits were stored at moderately low temperature (Lazan et al., 1993).

In addition, fruit texture and firmness were as well affected by water loss. Higher water loss resulted in poor textural quality and reduction in firmness. This was evidence on the lower average firmness value in unpacked and perforation sealed packed fruits than the non-perforated sealed and partial vacuum packed fruits in which the former have higher percentage of water loss as compared to the latter (Figure 4.1).

4.3 Total Soluble Solids (TSS)

TSS of dragon fruit was not significantly affected by the storage time. TSS of fruit showed no significant decreased (P>0.05) from day 0 to day 12 of storage. The changes in TSS of fruit were little and not consistent throughout the storage period (Figure 4.3).

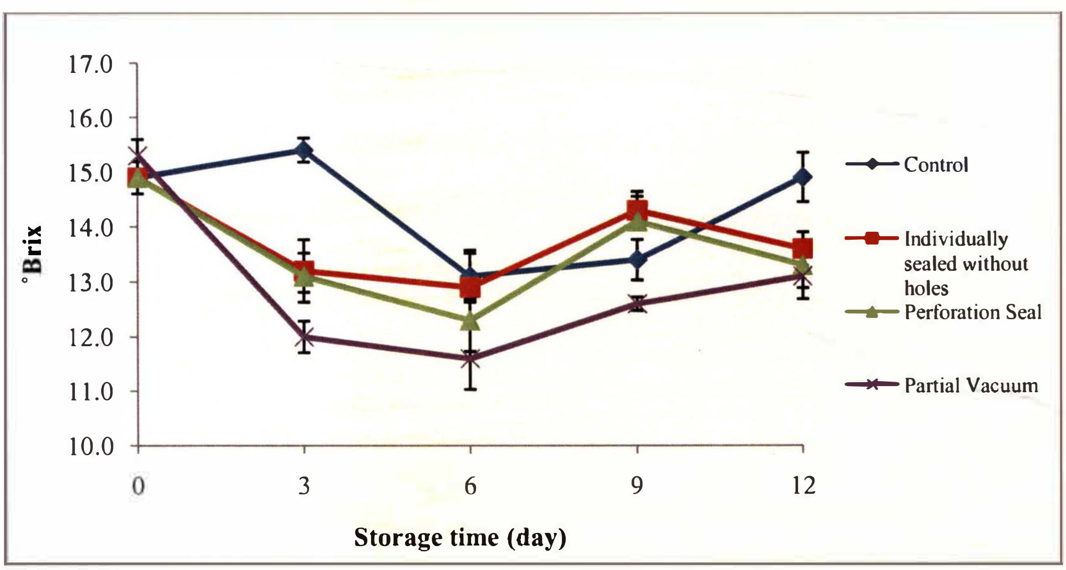

Figure 4.3: Effect of different packaging systems on TSS of dragon fruit at 10°C

TSS of fruit was decreased from day 3 to day 6 before start to increase to the higher average TSS on day 9 for all treatments. On day 12, the unpacked fruit tend to had higher average TSS value (14.90°Brix) followed by non-perforation packaging (13.60 °Brix), perforation packaging (13.30°Brix) and fruit in partial vacuum packaging (13.13° Brix).

The unpacked fruit tend to had higher average TSS (14.34°Brix) during the 12 days of storage followed by non-perforation packaging (13.80°Brix), perforation packaging (13.55°Brix) and partial vacuum packaging (12.93°Brix) (Appendix D).

There was no significant difference ($P>0.05$) in TSS of fruits in this study suggested that the fruits were non-climacteric as the maximum respiration rate occurs during early fruit growth and declined after fruit received optimum maturity (Robert, 2000; Le et al., 2000). TSS of fruit was attributable to the presence of soluble carbohydrates in the fruit tissues, and they served as important respiratory metabolites in ripening fruit (Lazan and Ali, 1991). According to Rohani et al. (1997), retardation in the respiratory activity of fruit under modified atmosphere condition could in turn retard the synthesis and use of these metabolites, thus resulting in the smaller amount of TSS presence in the tissues. This was evidence on the higher TSS value in the unpacked fruit as compared with fruit which treated with different packaging treatments.

Changes in the concentration of soluble solids and a number of non-structural carbohydrate components of the pulp occurred during fruit development. During ripening, starch accumulated before the color break is degraded to soluble sugars (Nerd and Mizrahi, 1998). According to Wu and Chen (1997), the major soluble sugars in the flesh of dragon fruit was glucose, fructose and sucrose. The content of sucrose was accounting for only 2.8 to 7.5% of the total sugars. Glucose to fructose ratios was 1.2 to 1.4. The high ratio of glucose to fructose of the fruit indicated the hydrolysis of starch by amylase where amylase plays an important role in the accumulation of glucose in dragon fruit.

4.4 Disease infestation

Disease attack on fruit was the main cause of spoilage. Fruit was rejected once the disease score is over 4. In general, disease infestation on fruit increased with storage time. Fruits in all treatment were able to keep at the low infestation level until day 3. There was no significant difference (P>0.05) in disease infestation in partial vacuum packed fruit throughout the storage. This indicated that fruit was remained at low infestation level for up to 12 days of storage (Figure 4.4).

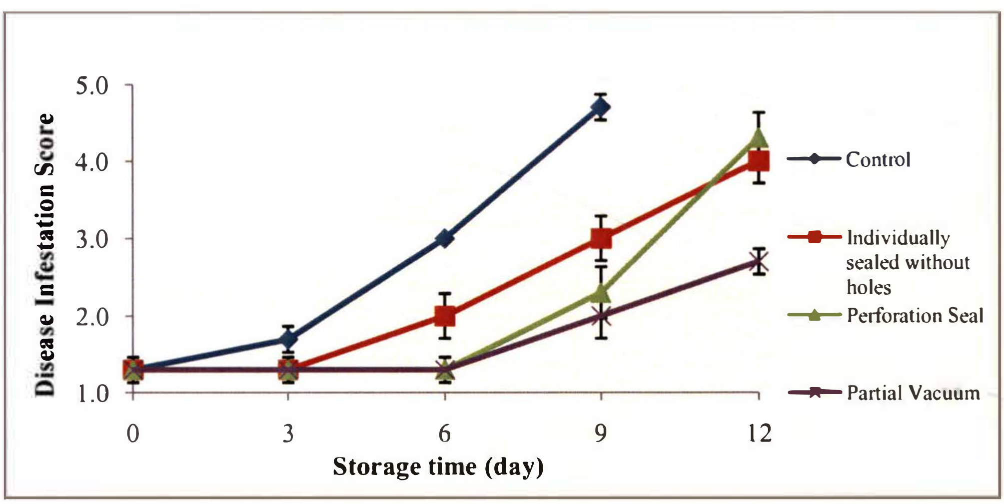

Figure 4.4: Effect of different packaging systems on disease infestation of dragon fruit at 10°C

There was significantly difference ($P<0.05$) between the unpacked fruit and the fruit bagged in LDPE film. Disease started to significantly set in on 6th day of storage for unpacked fruit and fruit was rejected by day 9 (Appendix E).

By day 12, there was a high increase in average score value for fruits in perforation packaging which was from 2.33 to 4.33. Therefore, fruits were rejected since the disease score is over 4. Fruit in sealed packaging had reached score 4 while fruit in partial vacuum packaging still maintained under score 4. Although fruit in partial vacuum packaging was fairly infested by disease (score<4), the infestation was mainly confined to the skin and not affecting the flesh portion.

Result showed that partial vacuum packaging substantially slow down the physical deterioration and disease infestation of fruit at 10°C throughout the storage period. In contrast to vacuum packaging which withdrawn all the atmospheric air out of the package, partial vacuum removed only most of the atmospheric oxygen in partial vacuum environment. The dragon fruit was protected from spoiling by limiting the growth of aerobic bacteria or fungi and reducing the evaporation of volatile components.

According to Thompson (2003), shelf life of fruits and vegetables can be further extended by using plastic films to modified atmosphere around the fruit and also to protect the fruit from infection or infestation. This was evidence on the lower average disease score of the LDPE film packed fruit than the unpacked fruit. Fruit such as the unpacked and perforation packaging fruit which in direct contact with the environment may have higher susceptibility to the disease infection such as anthracnose on dragon fruit, which caused by the fungi *Colletotrichum* spp since the fruit surface was not entirely protected by the LDPE film.

The postharvest quality loss and storage life in fresh dragon fruit was limited by the fungal decay on fruit. Le et al. (2000) reported that the main fungi associated with spoiled fruit were *Colletotrichum* spp, *Fusarium* spp and *Helminthosporium* spp, and the postharvest disease has also been associated with *Fusarium lateritium*, *Aspergillus riger*, and *Aspergillus flavus*. Brown soft spots usually developed from the both ends of the fruit while white spots developed over the fruit. The bacterium *Xanthomanas campestris* and *Dothiorella* spp. has also been reported to contribute several important disease on dragon fruit (Barbeau, 1990).

4.5 Presence of wrinkles

Wrinkles on fruit increased as storage time increased. There was significant increased ($P<0.05$) in wrinkles score from day 0 to day 12 of storage for all treatments. However, there was no significant difference ($P>0.05$) in wrinkle scores between treatments. Partial vacuum packaging was able to maintain the wrinkle score on fruit until day 9 (Figure 4.5 and Appendix F).

All treatments started off with the similar wrinkle scores of fruit on day 0. By day 3, wrinkle scores for fruit in control, seal packaging and perforation packaging was gradually increased for the following storage days. On the contrary, wrinkles appeared on partial vacuum packed fruit was the least as compared to other treatments and wrinkle scores were remained the same, which was 1.67 in average.

By day 6, fruit in perforation packaging and partial vacuum packaging has the same wrinkle scores, 2.33 in average, which was lower than that of control and seal packaging (3.33 and 2.67, respectively).

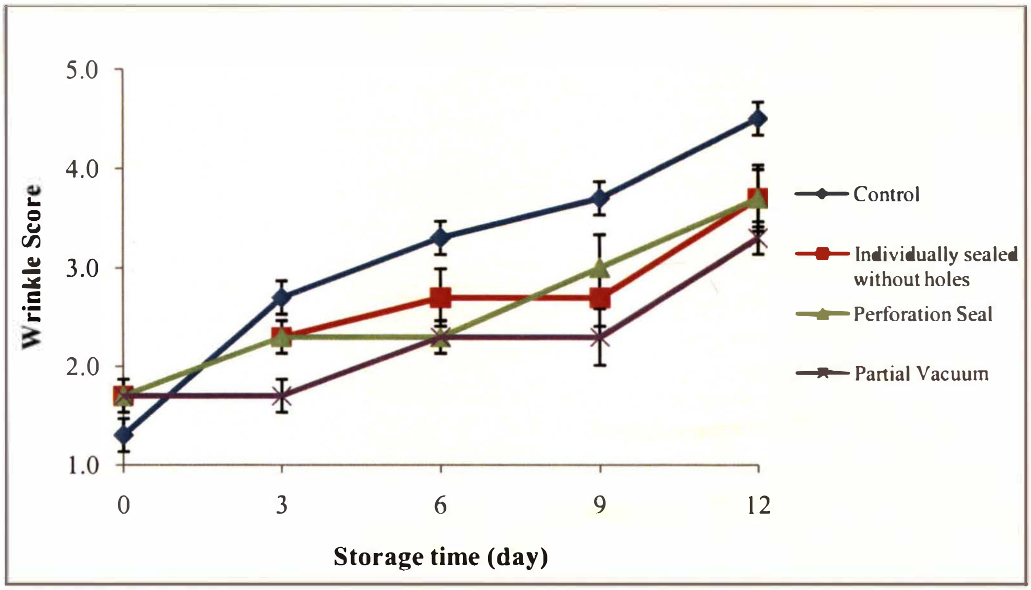

Figure 4.5: Effect of different packaging systems on wrinkles development of dragon fruit at 10°C

By day 9, fruit in non-perforation packaging and partial vacuum packaging showed lower wrinkle score as compared to that of control and perforation packaging. The average wrinkle scores were 2.67 and 2.33 for the former, and 3.67 and 3.00 for the latter, respectively (Appendix F).

By 12th day of storage, wrinkles appeared on fruit in partial vacuum packaging were lesser than other treatments while the control fruit consisted of the highest wrinkle score, which was 3.33 for the former and 3.67 for the latter.

The increased in wrinkles on fruit was highly affected by the water loss in the fruit as moisture loss from the harvested produce causes changes in structure, texture and appearance (Woods, 1990). As transpiration occurred and water evaporated from the fruit surface, cell tissues of the fruit lost its turgidity and thus, resulted in wrinkles appeared on fruit. This was evidence on fruit under partial vacuum packaging showed the lower average wrinkle values as partial vacuum packaging could effectively control the water loss of fruit (Figure 4.1) as compared to other treatments and thus, tissues of fruit remained turgor. Similarly, higher water loss occurred in the unpacked fruit have the higher wrinkles score as compared to other wrapped fruits. Water loss in tissue was highest in the unpacked fruit as discussed previously (Figure 4.1).

4.6 Skin and flesh color

Results showed that the total color change of fruit skin increased with increasing storage time. Changes in skin color for all treatments showed no significant difference (P>0.05). The total color change in partial vacuum packed fruit maintained at the lower level from day 3 to day 12 of storage (Figure 4.6 (a) and Appendix G).

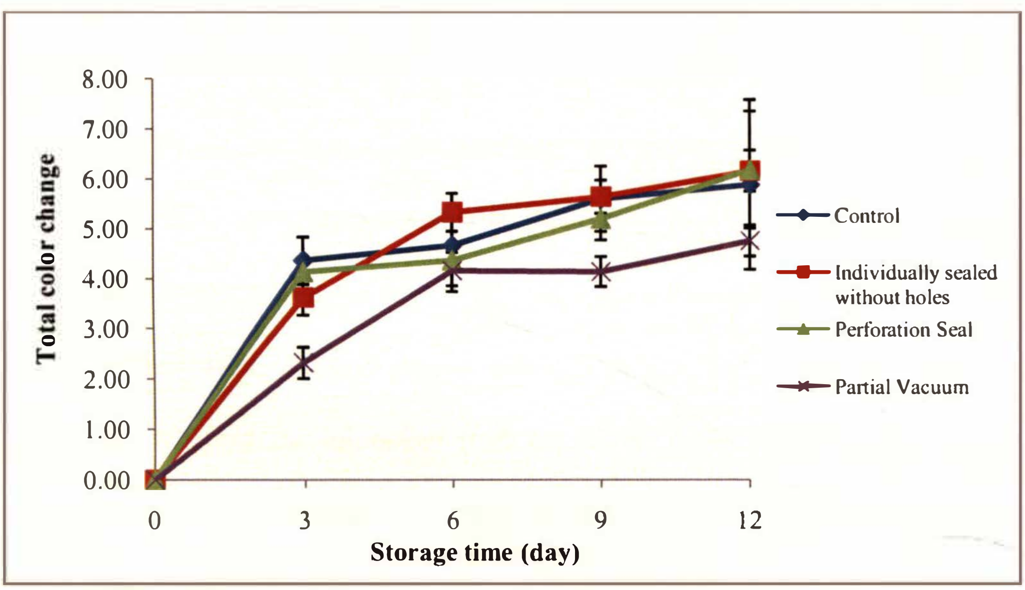

Figure 4.6 (a): Effect of different packaging systems on total color change of skin of dragon fruit at 10°C

Besides, there was no significant difference (P>0.05) in L value of skin between treatments (Appendix H). In general, the L value decreases from day 0 to day 12 of storage. However, all treatments showed inconsistency in change in L value from day 3 to day 9 of storage. The declining of L value indicated that there was a slight decrease in peel lightness where the skin color has turn into darker color by day 12. Low values of L* may be due to the development of betacyanins in both skin and flesh as pigmentation process occurred during ripening (Appendix H).

Besides, the skin color of fruit showed no significant difference (P>0.05) in a* value as well. The a* value which represented the color range of green to red was in general increased from day 0 to day 12 of storage. The increasing value of a* suggested that the intensity of color was low by day 12 (Appendix I).

As the indicator for yellow and blue color, the b* value was unaffected by treatment and time of storage where there was no significance difference (P>0.05) observed. The b* value was increased for perforation and partial vacuum storage fruit from day 0 to day 12 but b* value showed in a decreasing value for control and individually seal packed fruit (Appendix J). The unpacked fruit showed the lowest average b* value as compared to other packaging treatments.

For flesh color, the total color change in flesh showed no significant difference for all treatments (Appendix K). In general, the total color change in flesh increased as storage time increased. Fruit in partial vacuum storage showed the least total color change in flesh whereas the unpacked fruit experienced the most in color changes. There was no prominence increase in flesh color change for all treatments throughout the storage time. (Figure 4.6 (b)).

On contrary in reduction of L value in skin color, flesh color showed increased in L value during the 12 days storage. The increasing L value suggested that the flesh color was getting lighter by day 12 as compared with day 0 (Appendix L).

a* value of flesh color showed no significant difference (P>0.05) between storage days. However, the a* value was in general declined as storage time increased.

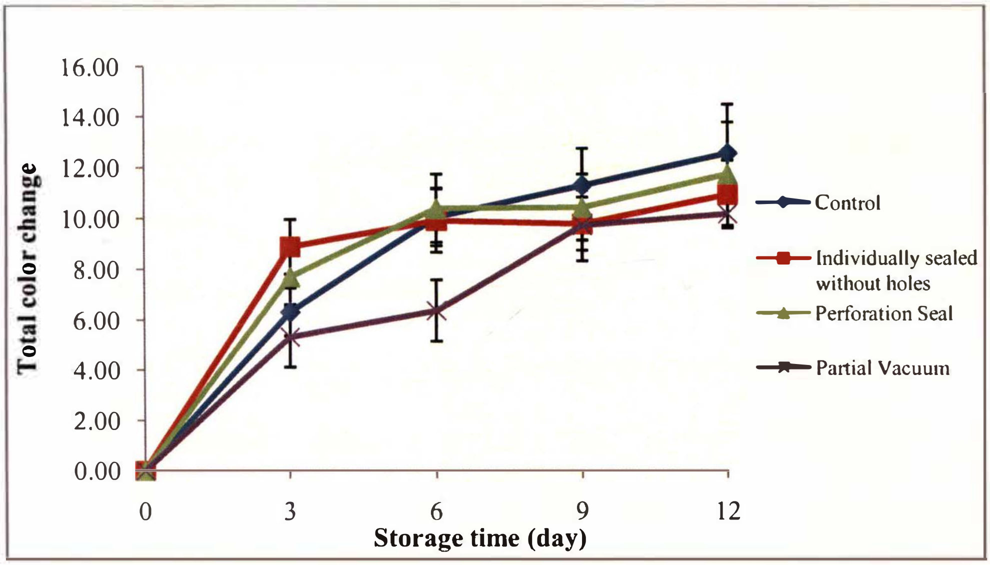

Figure 4.6 (b): Effect of different packaging systems on total color change of flesh of dragon fruit at 10°C

This indicated that the intensity of red color in flesh increased during the 12 days storage. (Appendix M). Besides, there was no significant difference (P>0.05) in b* value in flesh color between treatments and storage days. All treatments showed decreasing in b* value except for fruit with partial vacuum storage which showed the increased in b* value. The low value of b* in flesh color for all treatments indicated that the flesh color was in the range of dark zone (Appendix N).

The little changes in skin and flesh color of fruit suggested that the quality of dragon fruits were maintained in terms of color during the 12 days of storage. The formation of pigment which caused color changes in the skin as well as flesh of the fruit is one of the important changes as the fruit goes through the last stage of development or maturation. According to Wybraniec et al. (2001), betacyanins are the most important color pigment found in most cacti fruits contribute to the changes in fruit flesh color. The development of red-violet color betacyanins pigments in fruit flesh cause the color shifted from reddish purple to purplish red (Strack et al., 2003).

In addition, the result suggested that the lightness of skin color is brighter than that of flesh color for all treatments where the flesh of fruit were darker in color due to synthesis and accumulation of the betacyanins pigment in the cell vacuoles during ripening. According to Nerd and Mizrahi (1997), in many cultivars of cactus fruits, the skin color is similar to those of the flesh, but pigmentation starts earlier in the flesh. The pronounced increased of total betacyanins content in dragon fruit flesh caused the dragon fruit flesh turned reddish prior in the skin. This result is in agreement with Moßhammer et al. (2005) who reported that L* values constantly declined with increased of betacyanins ratios.

CHAPTER 5

CONCLUSION

5.1 Conclusion

In conclusion, partial vacuum packed maintained fruit physical appearance better with much reduced disease infestation during the storage period as compared with the unpacked and perforated packed fruit which were rejected by day 9 and day 12 respectively. Besides, all packaging treatments were significantly more effective in controlling the weight loss of fruit as compared with the unpacked fruit. However, other quality characteristics of the fruits such as skin and flesh color, total soluble solids (TSS), wrinkle development and skin and flesh firmness were not significantly affected by the packaging treatments. The TSS of fruit was minimally affected. In addition, partial vacuum packed fruit showed no significant reduction in fruit firmness as compared with other treatments. Partial vacuum packaging could be recommended as a potential packaging system in reducing postharvest losses of dragon fruit particularly during distribution and marketing for domestic and export markets.

5.2 Recommendations

The application of partial vacuum packaging technique in fresh fruit industry was still new and warrants further investigation particularly its effect on dragon fruit with lower maturity stage. Dragon fruit harvested at maturity stage of two or harvested four to five days after first sign of fruit color change from green to red, may give a better result in extending the shelf life of fruits. In addition, collection of fruits should be done as near to the location of study as possible to avoid bruising and fruits damages due to long journey transportation and poor quality of samples obtained due to the delay in delivery.

Besides, although LDPE plastic film has shown to be suitable as the packaging materials for dragon fruits, other packaging materials should also be tested since different packaging materials have their own characteristics and suitability to the particular food product. The best selection of packaging materials combined with different packaging systems such as partial vacuum packaging may give the better physical appearance on fruits and storage life of dragon fruits can be extend further.

Lastly, it is also suggested that the composition of gases such as CO_2 and O_2 in the packaged should be quantified in order to determine the best combination of gaseous contents in the packaged which can effectively maintain the quality and prolong the storage life of dragon fruits.

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APPENDIX A

Effects of different packaging systems on the percentage of weight loss of dragon fruits stored at 10±1˚C for 12 days

	Weight Loss (%)				
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**
Control	0.00 ± 0.00^{aA}	0.84 ± 0.05^{cB}	1.64 ± 0.15^{cC}	1.91 ± 0.16^{cC}	2.92 ± 0.31^{cB}
Individually sealed without holes	0.00 ± 0.00^{aA}	0.03 ± 0.03^{aAB}	0.09 ± 0.01^{aBC}	0.18 ± 0.04^{aD}	0.37 ± 0.12^{aCD}
Perforation-Sealed	0.00 ± 0.00^{aA}	0.25 ± 0.02^{bB}	0.53 ± 0.02^{bC}	0.71 ± 0.03^{bD}	0.84 ± 0.07^{bB}
Partial Vacuum	0.00 ± 0.00^{aA}	0.02 ± 0.03^{aAB}	0.09 ± 0.02^{aABC}	0.15 ± 0.08^{aC}	0.33 ± 0.02^{aBC}

The values are means of 3 replicates with 1 reading per replicate (n = 3) ± standard deviation.
Lower case letters (a, b, c) show significant difference (P<0.05) between treatments.
Capital letters (A, B, C, D) show significant difference (P<0.05) between storage times.

APPENDIX B

Effects of different packaging systems on the skin firmness of dragon fruits stored at 10±1°C for 12 days

	Firmness (Force, g)				
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**
Control	413.37 ± 32.83^{bB}	361.74 ± 86.19^{aB}	267.18 ± 72.53^{aA}	176.21 ± 56.15^{aA}	156.11 ± 25.71^{aA}
Individually sealed without holes	413.37 ± 32.83^{bA}	362.13 ± 100.70^{aA}	229.13 ± 153.66^{aA}	221.94 ± 63.62^{aA}	203.96 ± 18.77^{aA}
Perforation-Sealed	413.37 ± 32.83^{bB}	367.71 ± 82.05^{aB}	216.31 ± 43.69^{aA}	192.02 ± 37.47^{aA}	178.42 ± 30.35^{aA}
Partial Vacuum	333.55 ± 13.67^{aB}	325.33 ± 32.76^{aB}	$236.33.96 \pm 46.78^{aA}$	227.83 ± 34.82^{aA}	188.37 ± 4.78^{aA}

The values are means of 3 replicates with 6 readings per replicate ($n = 18$) ± standard deviation.
Lower case letters (a, b) show significant difference ($P<0.05$) between treatments.
Capital letters (A, B) show significant difference ($P<0.05$) between storage times.

APPENDIX C

Effects of different packaging systems on the flesh firmness of dragon fruits stored at 10±1°C for 12 days

	Firmness (Force, g)				
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**
Control	271.12 ± 11.22^{bB}	246.99 ± 44.45^{aB}	187.31 ± 47.14^{aAB}	120.04 ± 34.54^{aA}	96.46 ± 27.77^{aA}
Individually sealed without holes	271.12 ± 11.22^{bB}	223.56 ± 35.37^{aA}	152.17 ± 35.57^{aA}	151.40 ± 98.76^{aA}	144.37 ± 9.03^{bA}
Perforation-Sealed	271.12 ± 11.22^{bB}	238.59 ± 23.38^{aB}	166.44 ± 35.55^{aA}	124.42 ± 13.55^{aA}	110.01 ± 16.14^{abA}
Partial Vacuum	223.99 ± 25.20^{aA}	219.45 ± 57.58^{aA}	150.97 ± 16.44^{aA}	146.86 ± 25.67^{aA}	140.24 ± 8.13^{abA}

The values are means of 3 replicates with 6 readings per replicate (n = 18) ± standard deviation.
Lower case letters (a, b) show significant difference ($P<0.05$) between treatments.
Capital letters (A, B) show significant difference ($P<0.05$) between storage times.

APPENDIX D

Effects of different packaging systems on the total soluble solids of dragon fruits stored at 10±1°C for 12 days

	Total soluble solids (°Brix)				
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**
Control	14.93 ± 1.02^{aA}	15.37 ± 0.76^{aA}	13.10 ± 1.44^{aA}	13.40 ± 1.28^{aA}	14.90 ± 1.56^{aA}
Individually sealed without holes	14.93 ± 1.02^{aA}	13.23 ± 1.97^{aA}	12.90 ± 2.33^{aA}	14.33 ± 0.87^{aA}	13.60 ± 1.06^{aA}
Perforation-Sealed	14.93 ± 1.02^{aA}	13.13 ± 1.46^{aA}	12.27 ± 1.15^{aA}	14.13 ± 1.88^{aA}	13.30 ± 0.87^{aA}
Partial Vacuum	15.33 ± 1.03^{aB}	12.00 ± 1.00^{aAB}	11.63 ± 1.97^{aA}	12.57 ± 0.42^{aAB}	13.13 ± 1.43^{aAB}

The values are means of 3 replicates with 3 readings per replicate ($n = 9$) ± standard deviation.
Lower case letters (a) show no significant difference ($P>0.05$) between treatments.
Capital letters (A, B) show significant difference ($P<0.05$) between storage times.

APPENDIX E

Effects of different packaging systems on the disease infestation of dragon fruits stored at 10±1˚C for 12 days

	Disease Score				
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**
Control	1.33 ± 0.58^{aA}	1.33 ± 0.58^{aA}	3.00 ± 0.00^{aB}	4.67 ± 0.58^{bC}	5.00 ± 0.00^{bC}
Individually sealed, without holes	1.33 ± 0.58^{aA}	1.33 ± 0.58^{aA}	2.00 ± 1.00^{aAB}	3.00 ± 1.00^{abAB}	4.00 ± 1.00^{abB}
Perforation-Sealed	1.33 ± 0.58^{aA}	1.33 ± 0.58^{aA}	1.33 ± 0.58^{aA}	2.33 ± 1.15^{abAB}	4.33 ± 1.15^{abB}
Partial Vacuum	1.33 ± 0.58^{aA}	1.33 ± 0.58^{aA}	1.33 ± 0.58^{aA}	2.00 ± 1.00^{aA}	2.67 ± 0.57^{aA}

The values are means of 3 replicates with 1 reading per replicate (n = 3) ± standard deviation.
Lower case letters (a, b) show significant difference ($P<0.05$) between treatments.
Capital letters (A, B, C) show significant difference ($P<0.05$) between storage times.

APPENDIX F

Effects of different packaging systems on the presence of wrinkles of dragon fruits stored at 10±1˚C for 12 days

Treatment	Wrinkles Score				
	Day 0	Day 3	Day 6	Day 9	Day 12
Control	1.33 ± 0.58^{aA}	2.67 ± 0.58^{aAB}	3.33 ± 0.58^{aBC}	3.67 ± 0.58^{aBC}	4.67 ± 0.58^{aC}
Individually sealed without holes	1.67 ± 0.58^{aA}	2.33 ± 0.58^{aAB}	2.67 ± 0.58^{aBC}	2.67 ± 0.58^{aBC}	3.67 ± 0.58^{aC}
Perforation-Sealed	1.67 ± 0.58^{aA}	2.33 ± 0.58^{aAB}	2.33 ± 0.58^{aAB}	3.00 ± 1.00^{aAB}	3.67 ± 0.58^{aB}
Partial Vacuum	1.67 ± 0.58^{aA}	1.67 ± 0.58^{aA}	2.33 ± 0.58^{aAB}	2.33 ± 0.58^{aAB}	3.33 ± 0.58^{aB}

The values are means of 3 replicates with 1 reading per replicate (n = 3) ± standard deviation.
Lower case letters (a) show no significant difference (P>0.05) between treatments.
Capital letters (A, B, C) show significant difference (P<0.05) between storage times.

APPENDIX G

Effects of different packaging systems on the total color change of skin of dragon fruits stored at 10±1˚C for 12 days

	Total Color Change				
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**
Control	0.00 ± 0.00^{aA}	4.36 ± 1.64^{aAB}	4.66 ± 2.79^{aAB}	5.60 ± 2.27^{aAB}	5.88 ± 2.53^{aB}
Individually sealed without holes	0.00 ± 0.00^{aA}	3.62 ± 1.23^{aB}	5.33 ± 1.32^{aB}	5.64 ± 1.15^{aB}	6.16 ± 1.43^{B}
Perforation-Sealed	0.00 ± 0.00^{aA}	4.13 ± 0.86^{aAB}	4.36 ± 0.57^{aAB}	5.20 ± 1.48^{aAB}	6.18 ± 4.05^{aB}
Partial Vacuum	0.00 ± 0.00^{aA}	2.32 ± 1.07^{aAB}	4.16 ± 1.45^{aB}	4.14 ± 1.04^{aB}	4.76 ± 1.08^{aB}

The values are means of 3 replicates with 6 readings per replicate (n = 18) ± standard deviation.
Lower case letters (a) show no significant difference ($P>0.05$) between treatments.
Capital letters (A, B) show significant difference ($P<0.05$) between storage times.

APPENDIX H

Effects of different packaging systems on L* value of skin color of dragon fruits stored at 10±1˚C for 12 days

	L* value				
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**
Control	46.42 ± 1.56^{aA}	43.96 ± 2.04^{aA}	44.42 ± 0.62^{aA}	42.26 ± 2.87^{aA}	44.07 ± 6.72^{aA}
Individually sealed without holes	46.42 ± 1.56^{aA}	46.07 ± 1.74^{aA}	48.04 ± 1.68^{aA}	43.92 ± 1.58^{aA}	44.63 ± 4.60^{aA}
Perforation-Sealed	46.42 ± 1.56^{aA}	45.19 ± 2.12^{aA}	43.93 ± 2.58^{aA}	46.04 ± 0.57^{aA}	44.72 ± 1.04^{aA}
Partial Vacuum	45.83 ± 0.89^{aAB}	45.22 ± 0.87^{aAB}	45.05 ± 2.43^{aAB}	47.84 ± 2.30^{aB}	43.22 ± 1.37^{aA}

The values are means of 3 replicates with 6 readings per replicate (n = 18) ± standard deviation.
Lower case letters (a) show no significant difference (P>0.05) between treatments.
Capital letters (A, B) show significant difference (P<0.05) between storage times.

APPENDIX I

Effects of different packaging systems on a* value of skin color of dragon fruits stored at 10±1˚C for 12 days

	a* value				
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**
Control	32.41 ± 2.81^{aA}	33.14 ± 0.99^{aA}	28.87 ± 1.50^{aA}	29.13 ± 4.13^{aA}	34.37 ± 3.00^{aA}
Individually sealed without holes	32.41 ± 2.81^{aA}	30.85 ± 2.18^{aA}	33.92 ± 0.82^{aA}	36.41 ± 2.12^{bA}	34.72 ± 2.00^{aA}
Perforation-Sealed	32.41 ± 2.81^{aA}	32.98 ± 3.54^{aA}	34.10 ± 3.53^{aA}	34.88 ± 1.78^{abA}	36.88 ± 4.35^{aA}
Partial Vacuum	33.97 ± 1.74^{aA}	33.79 ± 1.81^{aA}	32.53 ± 2.62^{aA}	$34.35 \pm 0.72a^{bA}$	33.79 ± 3.50^{aA}

The values are means of 3 replicates with 6 readings per replicate ($n = 18$) ± standard deviation..
Lower case letters (a, b) show significant difference ($P<0.05$) between treatments.
Capital letters (A) show no significant difference ($P>0.05$) between storage times.

APPENDIX J

Effects of different packaging systems on b* value of skin color of dragon fruits stored at 10±1°C for 12 days

	b* value				
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**
Control	8.97 ± 0.87^{aA}	6.77 ± 1.70^{aA}	6.88 ± 0.31^{aA}	5.20 ± 2.86^{aA}	7.98 ± 1.47^{aA}
Individually sealed without holes	8.97 ± 0.87^{aA}	5.75 ± 0.68^{aA}	8.82 ± 2.36^{aA}	9.60 ± 0.70^{aA}	8.89 ± 1.31^{aA}
Perforation-Sealed	8.97 ± 0.87^{aA}	8.38 ± 1.51^{aA}	8.57 ± 1.78^{aA}	9.15 ± 2.44^{aA}	9.34 ± 1.87^{aA}
Partial Vacuum	7.62 ± 0.87^{aA}	9.44 ± 1.72^{aA}	8.11 ± 1.83^{aA}	7.82 ± 2.76^{aA}	8.82 ± 1.33^{aA}

The values are means of 3 replicates with 6 readings per replicate (n = 18) ± standard deviation.
Lower case letters (a) show no significant difference (P>0.05) between treatments.
Capital letters (A) show no significant difference (P>0.05) between storage times.

APPENDIX K

Effects of different packaging systems on the total color change of flesh of dragon fruits stored at 10±1°C for 12 days

	Total Color Change				
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**
Control	0.00 ± 0.00^{aA}	6.32 ± 3.26^{aAB}	10.05 ± 3.93^{aAB}	11.30 ± 5.00^{aAB}	12.56 ± 6.72^{aB}
Individually sealed without holes	0.00 ± 0.00^{aA}	8.89 ± 3.73^{aAB}	9.92 ± 4.34^{aAB}	9.79 ± 3.63^{aB}	10.95 ± 4.60^{aB}
Perforation-Sealed	0.00 ± 0.00^{aA}	7.70 ± 3.77^{aA}	10.40 ± 4.65^{aA}	10.44 ± 4.51^{aA}	11.75 ± 7.04^{aA}
Partial Vacuum	0.00 ± 0.00^{aA}	5.33 ± 4.19^{aAB}	6.37 ± 4.21^{aAB}	9.72 ± 4.86^{aB}	10.18 ± 1.77^{aB}

The values are means of 3 replicates with 6 readings per replicate (n = 18) ± standard deviation.
Lower case letters (a) show no significant difference (P>0.05) between treatments.
Capital letters (A, B) show significant difference (P<0.05) between storage times.

APPENDIX L

Effects of different packaging systems on the L* value of flesh color of dragon fruits stored at 10±1°C for 12 days

Treatment	L* value				
	Day 0	Day 3	Day 6	Day 9	Day 12
Control	30.52 ± 2.00^{aA}	33.77 ± 0.42^{bAB}	33.45 ± 0.99^{aAB}	31.18 ± 1.64^{aAB}	34.60 ± 1.27^{aB}
Individually sealed without holes	30.52 ± 2.00^{aA}	33.83 ± 0.62^{bA}	33.59 ± 1.88^{aA}	31.75 ± 2.48^{aA}	32.59 ± 1.66^{aA}
Perforation-Sealed	30.52 ± 2.00^{aA}	32.70 ± 1.90^{abA}	31.39 ± 4.00^{aA}	31.52 ± 1.90^{aA}	33.79 ± 0.28^{aA}
Partial Vacuum	32.11 ± 2.64^{aA}	30.84 ± 0.86^{aA}	31.68 ± 1.23^{aA}	31.65 ± 1.48^{aA}	33.71 ± 3.33^{aA}

The values are means of 3 replicates with 6 readings per replicate (n = 18) ± standard deviation.
Lower case letters (a, b) show significant difference (P<0.05) between treatments.
Capital letters (A, B) show significant difference (P<0.05) between storage times.

APPENDIX M

Effects of different packaging systems on the a* value of flesh color of dragon fruits stored at 10±1˚C for 12 days

	a* value				
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**
Control	26.92 ± 8.58^{aA}	25.13 ± 3.48^{aA}	20.91 ± 1.33^{aA}	19.57 ± 2.45^{abA}	15.43 ± 2.89^{aA}
Individually sealed without holes	26.92 ± 8.58^{aA}	22.28 ± 1.66^{aA}	16.93 ± 3.11^{aA}	21.26 ± 1.48^{bA}	20.96 ± 1.25^{aA}
Perforation-Sealed	26.92 ± 8.58^{aA}	23.08 ± 3.03^{aA}	17.25 ± 4.16^{aA}	20.41 ± 2.08^{abA}	19.51 ± 6.53^{aA}
Partial Vacuum	21.89 ± 5.11^{aA}	19.49 ± 3.28^{aA}	19.51 ± 8.02^{aA}	16.18 ± 1.50^{aA}	18.49 ± 7.62^{aA}

The values are means of 3 replicates with 6 readings per replicate (n = 18) ± standard deviation.
Lower case letters (a, b) show significant difference ($P<0.05$) between treatments.
Capital letters (A) show no significant difference ($P>0.05$) between storage times.

APPENDIX N

Effects of different packaging systems on the b* value of flesh color of dragon fruits stored at 10±1°C for 12 days

Treatment	b* value				
	Day 0	Day 3	Day 6	Day 9	Day 12
Control	1.55 ± 1.31^{aA}	1.13 ± 0.68^{aA}	1.41 ± 0.54^{aA}	1.25 ± 0.67^{aA}	0.63 ± 0.36^{aA}
Individually sealed without holes	1.55 ± 1.31^{aA}	0.88 ± 0.94^{aA}	0.95 ± 0.64^{aA}	1.14 ± 0.92^{aA}	1.08 ± 0.45^{aA}
Perforation-Sealed	1.55 ± 1.31^{aA}	1.52 ± 0.38^{aA}	1.29 ± 1.06^{aA}	1.26 ± 0.68^{aA}	0.76 ± 0.63^{aA}
Partial Vacuum	0.53 ± 0.18^{aA}	1.41 ± 0.79^{aA}	0.68 ± 0.40^{aA}	1.04 ± 0.21^{aA}	0.88 ± 0.29^{aA}

The values are means of 3 replicates with 6 readings per replicate ($n = 18$) ± standard deviation.
Lower case letters (a) show no significant difference ($P>0.05$) between treatments.
Capital letters (A) show no significant difference ($P>0.05$) between storage times.

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QUALITY RETENTION OF DRAGON FRUIT (HYLOCEREUS POLYRHIZUS) USING DIFFERENT PACKAGING SYSTEMS - LAU SZE MEI