THE EFFECTS OF MODIFIED ATMOSPHERE PACKAGING ON QUALITY OF HARVESTED DRAGON FRUIT (*Hylocereus polyrhizus*) STORED AT LOW TEMPERATURE

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By
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ENDORSEMENT

The project report entitled **The Effects of Modified Atmosphere Packaging on Minimally Processed Dragon Fruit (*Hylocereus polyrhizus*) Stored at Low Temperature** by **Noorlistari Binti Mohd Salleh,** Matric No. **UK14880** 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 Science Agrotechnology (Post harvest Technology), Faculty of Agrotechnology and Food Science , Universiti Malaysia Terengganu.

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DECLARATION

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ABSTRACT

This study involved minimally processed (MP) red dragon fruit which also known as red pitaya. MP dragon fruit is ready-to-eat product which provides convenience as consumers do not need to peel and cut the fruits before consume it. However, the fruits is very perishable and continue to respire which resulted in degradation of products. Many techniques can be applied to increase the shelf-life of MP fruits. One of the most adopted techniques is modified atmosphere packaging (MAP) which provide optimal balanced of gases inside the package. Physico-chemical analyses of total color change, firmness, ratio of total soluble solid (TSS) to titratable acidity (TA), anthocyanin content, percentage of weight loss, and sensory evaluation were carried out to determine the storage quality of MP dragon fruits in different MAP namely polypropylene container, sealed polypropylene film, polypropylene film with vacuum for 5 seconds and PVC cling wrap which serve as control. All the samples were stored at 5±1°C; RH 90% for 8 days and analyzed every 2 day intervals. The total color changes and percentage weight loss showed increasing patterns throughout the storage whereas, firmness, anthocyanin content and the ratio of TSS to TA showed decreasing patterns. There were significant differences ($p<0.05$) among all the treatments in all the parameters tested except for the ratio of TSS to TA which showed no different. The sensory acceptance conducted indicates that all the packed samples were still acceptable up until day 8 with sweetness and the overall acceptability scored higher for all types of MAP treatments. However, among all the treatments, polypropylene container was the most effective packaging system for extending the shelf-life of minimally processed dragon fruits with the least changes in almost all the quality attributes.

ABSTRAK

Kajian ini melibatkan pemprosesan minima buah naga merah atau lebih dikenali sebagai pitaya merah. Pemprosesan minima buah naga adalah produk yang sedia dimakan dan memudahkan pengguna kerana tidak perlu untuk mengupas atau memotong buah tersebut sebelum memakannya. Walau bagaimanapun, buah-buahan ini sangat mudah rosak dan kerana proses respirasi yang berterusan menyebabkan kerosakan pada produk. Pelbagai teknik boleh digunakan untuk meningkatkan tempoh hayat simpanan buah-buahan terproses minima ini. Salah satu teknik yang paling banyak digunapakai adalah pembungkusan atmosfera terubahsuai (MAP) yang mempunyai keseimbangan kandungan gas yang optimum di dalam bungkusan. Analisis fiziko-kimia seperti perubahan warna keseluruhan, tekstur buah, nisbah jumlah pepejal terlarut (TSS) kepada asid tertitrat (TA), kandungan antosianin, peratus kehilangan berat dan penilaian deria telah dijalankan untuk menentukan kualiti simpanan pemprosesan minima buah naga yang dibungkus di dalam pembungkusan atmosfera terubahsuai yang berbeza iaitu bekas polipropilena, filem polipropilena, filem polipropilena dengan pembungkusan vakum selama 5 saat dan filem polivinilklorida (PVC) sebagai kawalan. Semua sampel disimpan pada suhu 5±1°C; kelembapan relative 90% selama 8 hari dan dikeluarkan selang 2 hari untuk dianalisa. Perubahan warna keseluruhan dan peratus kehilangan berat menunjukkan peningkatan sepanjang tempoh penyimpanan manakala tekstur, kandungan antosianin dan nisbah TSS kepada TA menunjukkan penurunan. Perbezaan yang ketara ($p<0.05$) ditunjukkan oleh setiap jenis pembungkusan ke atas semua parameter yang dikaji kecuali pada nisbah TSS kepada TA yang menunjukkan tiada perbezaan.Penerimaan penilaian deria yang dijalankan menunjukkan semua sampel masih boleh diterima sehingga hari ke 8 di mana atribut kemanisan dan penerimaan keseluruhan mendapat skor yang tinggi bagi semua rawatan MAP. Walau bagaimanapun, daripada semua jenis pembungkusan MAP yang digunakan, bekas polipropilena adalah yang paling efektif untuk memanjangkan tempoh penyimpanan pemprosesan minima buah naga kerana ia menunujukkan perubahan yang paling sedikit untuk semua atribut.

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LIST OF ABBREVIATIONS

%	Percent
°C	Degree celcius
°F	Degree farenheit
A	Absorbance
g	Gram
HACCP	Hazard Analysis Critical Control Point
kg	Kilogram
MAP	Modified atmosphere packaging
ml	Milliliter
mm	Millimeter
MP	Minimally processed
N	Normality
NaOH	Nitrogen hydroxide
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinylchloride
RCB	Randomized Complete Design
SPSS	Statiscal Program for Social Science
TA	Titratable acidity
TSS	Total soluble solid

CHAPTER 1

INTRODUCTION

1.1 Background Study

Dragon fruit or known as pitaya is the common name that applies to a number of warm-climate cacti fruits that occur on plants from several genera. The pitaya fruits occur on either climbing or columnar cacti species. The two main genera, *Selenicereus* and *Hylocereus*, are native to southwestern USA and Mexico, down to Peru and Argentina. Pitaya is interesting group of cacti wit potential for greater worl-wide commercial production. (Mizrahi *et al.*, 1997)

Red pitayas recently have attracted significant attention worldwide, not only because of their red-purple color and economic values as food, but also due to their antioxidative activity resulting from their betacyanins contents (Wybraniec *et al.*, 2004). Moreover, red pitayas may offer health care benefits, for example by acting as cancer chemopreventives, anti-imflammatory agents and antidiabetics, and by reducing cardiovascular mortality risk (Cos *et al.*, 2004). Thus, red pitaya are popular products among restaurants and individual consumers.

Minimally processing has been defined as the handling, preparation, packaging and distribution of agricultural commodities in fresh-like state, and may include processes such as washing, peeling, and slicing (O' Connors-Shaw *et al.*, 1994). Minimally processing of raw fruits and vegetables has two purposes which are keeping the product fresh, without losing its nutritional quality and ensuring a product self-life sufficient to make distribution feasible within a region of consumption. (Huxsoll and Bolin, 1989).

The final operation, but not least important in minimally processed production is packaging. The most studied packaging method for prepared raw fruit and vegetables is modified atmosphere packaging (Kader *et al.*, 1989). The studies have been presented excellent overviews on the principles and modeling of minimally processed fruits and vegetables .MAP is one of today's most significant technologies for extending shelf-life for a wide range of food products. MAP is based on alteration of the gaseous environment surrounding the product to compensate for the natural respiration of the product itself, resident microorganisms, as well as the packaging material.

1.2 Problem Statement

The difficulty in developing a new product based on fresh produce, in contrast to other types of foods, is the fact that fruits and vegetables continue their physiological activity, consuming oxygen and releasing carbon dioxide and water vapor into the package headspace. Also, with minimally treatment, microbiological and sensory quality factors such as appearance, texture, and flavor are not stabilized and product deterioration may proceed rapidly (Jacxsens *et al.*, 1999).

Minimally processed red pitayas display chilling injuries, including wilting, darkened scales and browned pulp (Nerd *et al.*, 1999). Minimally processed red dragon fruit rapidly lose their bright white color during storage, and develop a brown surface appearance that reduces their acceptability to consumers. Additionally red pitayas pulp is highly perishable and thus has a short life, sliced red pitayas which both marketers and consumers would like to extend. (Chien *et al.*, 2007)

1.3 Significant of Study

The significant of this study is to extend the shelf-life of minimally processed dragon fruit and present the product in more convenience ready-to-eat that can be consumed safely. The quality of the product can be seen thus provide good selection for consumer. In the way of packaging systems for minimally processed fruits, we can find which packaging systems that meet the requirements for minimally processed products in this study.

1.4 Objective

The objective of this study is to determine the effects of packaging system to the quality of fresh cut dragon fruit store at low temperature. The type of packaging is very important to make sure the gases contents in package are under the appropriate conditions to increase shelf-life of fresh-cut produce.

CHAPTER 2

LITERATURE REVIEW

2.1 Dragon Fruit

Hylocereus species have been commercially grown in Americans and Vietnam. They were imported into Vietnam by the French, and are locally regarded as a native species. Much of the recent research and development of dragon fruit has occurred in Israel, Thailand, Taiwan, Malaysia and Australia. The fruits best served chilled, and are almost always eaten fresh. Commercial cultivation of dragon fruit is expanding in several parts of Asia such as Vietnam, Taiwan, the Philippines and Malaysia (Mizrahi *et al.*, 1997).

One of the widely grown varieties is the *Hylocereus undatus* (Figure 2.1) or red dragon with white flesh. Other varieties that have been commercialised are the *Hylocereus polyrhizus* (Figure 2.2) which has red dragon fruit with red flesh and *Hylocereus megalanthus* (Figure 2.3) is yellow pitaya that grown in Mexico (Paull, 2002).

Figure 2.1: *Hylocereus undatus*, red dragon fruit with white flesh

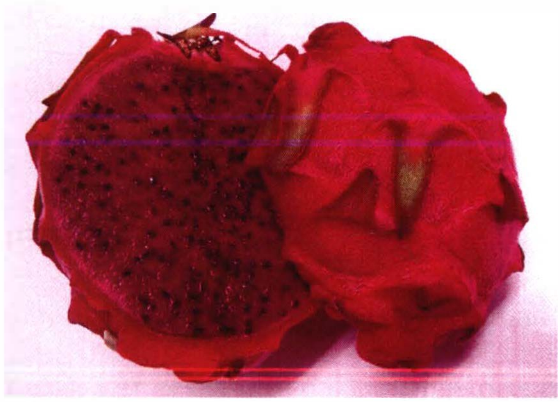


Figure 2.2: *Hylocereus polyrhizus*, red dragon fruit with red flesh

Figure 2.3: *Hylocereus megalanthus*, yellow dragon fruit

In Malaysia, the red pitaya or dragon fruit is commonly called as "buah naga". *Hylocereus polyrhizus* is the red flesh dragon fruit types that edible and it has great source of vitamin C and water soluble fiber (Mizrahi *et al.*, 1999). *Hylocereus polyrhizus* is rich in fibers, vitamin C, minerals, and phytoalbumins which are highly valued for their antioxidant properties (Jaafar *et al.*, 2009). As the production areas of dragon fruits increase recently, the consumption of dragon fruits is expected to increase and there is also in various products based on dragon fruits.

The dragon fruit is a large, oblong fruit with a red peel and large green scales. The scales turn yellow upon ripening. Skin color begins to change 25 to 30 days from flowering in both *H. undatus* and *H. polyhizus*. At about the same time, flesh firmness approaches a minimum and eating quality approaches a maximum 33 to 37 days after flowering (Nerd *et al.*, 1999). Fruit can be harvested from 25 to 45 days from flowering; 32 to 35 days was recommended by Nerd *et al.* (1999).

Fruit size depends on seed number (Weiss *et al.*, 1994). The flesh of different species can vary from white to various hues of red to very dark red. As the fruit matures, acidity reaches a peak just as the skin color change occurs, then declines 25 to 30 days after flowering (Nerd *et al.*, 1999; Le *et al.*, 2000). At this stage, total soluble solid (TSS) increases to about 14% (Nerd *et al.*, 1999; Le *et al.*, 2000). Common index of maturity is skin color change to almost full red (Nerd *et al.*, 1999). Harvesting indices include: color, TSS, titratable acidity (TA) and days-from-flowering (minimum 32 days). A TSS:TA of 40 has been suggested as a harvest index.

The recommended storage temperature for whole dragon fruit is 10 °C (50 °F), since 6 °C (42.8 °F) can induce chilling injury (Nerd *et al.*, 1999). Dragon fruit has a storage-life of about 14 days at 10 °C (50 °F), while at 5 °C (41 °F) 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 (41 °F) may lead to chilling injury upon return to 20 °C (68 °F), indicated by deterioration of peel and flesh, and inferior taste (Nerd *et al.*, 1999). Hence, 10 °C (50 °F) for a maximum of 14 days may be a better recommended storage temperature.

Flesh translucency is a symptom of chilling injury. Other symptoms include softening, wilting, darkening of scales, browning of outer flesh and poor flavor. These symptoms rapidly develop on *H. undatus* and *H. polyhizus* fruit held at 6 °C (42.8 °F) for 2 weeks then transferred to 20 °C (68 °F) (Nerd *et al.*, 1999). Fruit harvested 25 days from flowering are more sensitive to chilling (6 °C, 7 days); sensitivity is significantly reduced when fruit are harvested 30 to 35 days from flowering (6 °C, 17 days). Physiological disorder of dragon fruit usually caused by Bacterial (*Xanthomonas campestris*) and *Dothiorella spp.* diseases have been reported (Barbeau, 1990). Postharvest disease has been associated with *Fusarium lateritium*, *Aspergillus riger*, and *Aspergillus flavus* (Le *et al.*, 2000).

The peel and flesh of this species are red in colour. The flesh is delicate and juicy and contains numerous soft black seed. The red colour of pitaya fruit is attributed by betacyanins, which is a class of water-soluble pigments (Wybraniec *et al.*, 2001). The color influences our perception of the freshness and taste of food. It is widely accepted that color is one of the most important factors in consumer acceptance of a food products. Dragon fruit are often available as a fresh-cut product in South East Asian markets in trays with over-wrap. There is some potential, as fresh-cut fruit can be stored at 4 °C (39.2 °F) for 8 days (Le *et al.*, 2000).

2.2 Minimally Processed Fruits

Minimal processing involves deskinning, cutting, and wrapping of fruits and vegetables for immediate consumption (Noor, 2007). In Malaysia, export of minimally processed fruit was successfully conducted such as durian, jackfruit, and pineapple by Malaysian Agricultural Research and Development Institute (MARDI). As the increase production area of dragon fruit, there will be the good future for minimally processed of dragon fruit to cater the needs of the local and exports market.

Minimally processed fruits have a reduced shelf-life compared to whole fruits due to their physiological changes in wounded tissue (Baldwin *et al.*, 1995). Minimally processed of fruits are usually stored between 4°C and 8°C (Wiley, 1994).

However, whole red dragon fruit rapidly lose their firmness and flavor if stored at 6°C for several days (Nerd *et al.*, 1999).

2.2.1 Quality changes in minimally processed fruits

As a results of cutting, peeling, grating, and shredding, the fruits will change from relatively stable product with high shelf-life for several weeks or months to a perishable one that has only very short shelf-life, even as short as 1 to 3 days at cool temperature. Usually shelf-life of minimally processed of fruits should be at least 4 to 7 days or even longer depend on the market.

Minimally processed produce deteriorates because of physiology ageing, biochemical changes and microbial spoilage, which may result in degradation of color, texture, and flavor of the produce (Varoquaux and Wiley, 1994). During the peeling and cutting operations, many cells are ruptured, and intracellular products such as oxidizing enzymes are liberated (Ahvenainen, 1996).

There are also physiochemical and biochemical changes in minimally processed such as enzymatic browning, peroxidation reactions that cause bad smells of aldehyde and ketones, and also respiration activity. The respiration activity is increase depends on the produce, temperature and also type of packaging. Most of studies on fresh and minimally processed of fruit and vegetables have been concerned with market quality as determined objectively and subjectively by color, flavor and texture and microbiological determinations. Other determinations are nutritive value, such as vitamin, sugar, amino acid, fat, and fiber (Wiley, 1994).

The key requirements in the minimal processing of fruits and vegetables according to Ahvenainen, 1996 are raw material of good quality (correct cultivar or variety, correct cultivation, harvesting and storage conditions). Workers should apply the strict and good manufacturing practices and HACCP during the fruits or vegetables processing. Make sure that the processing house use low temperature during working and careful cleaning and/or washing before and after peeling.

Make sure the water in good quality (sensory, microbiology, pH) that used in washing and using mild additives in washing for disinfection or browning prevention. Gentle cutting/slicing/shredding and correct packaging materials and packaging methods should take as consideration. Correct temperature and humidity during distribution and retailing.

2.2.2 Improving the shelf-life of minimally processed of fruits

Minimally processed of fruits can be manufactured based on different requirements. If the products are prepared today and consumed tomorrow, we only need simple processing methods. If the products are required to have a shelf-life of several days up to a week or more, in case of products for retailing, then the manufacturer need to apply more advanced processing methods and treatments (Huxsoll and Bolin, 1989).

Research have demonstrate that there peeling should be as gentle as possible. The ideal method is hand peeling using a sharp knife. Studies show that slicing with dull knives causes impairs the retention of quality because it ruptures cell and release tissue fluid to a great extent. The equipments used for slicing also need to be sanitized first before the processing. Sometimes peeling can causes browning, enhance the microbial growth and enzymatic changes (Ahvenainan., 1994).

2.2.2.1 Fruit preparations

The incoming sample (fruits or vegetables) shoulde carefully cleaned from covered soil, mud or sand before processing. Usually the second washing step must perform after peeling or cutting (Wiley, 1994). Washing after peeling or cutting removes microorganisms and tissue fluid, thus reducing microbial growth and enzymatic oxidation during subsequent storage. Washing the produce in flowing or bubble is preferable to simply dipping it in water (Ohta and Sugawara, 1987). The washing water also should in low temperature preferably less than 5°C. Preservative or sanitizer can be used in washing water to reduce microbial activity and enzymatic activity, thereby improving both shelf-life and sensory quality of minimally processed fruits.

2.3 Packaging Systems

2.3.1 Modified atmosphere packaging (MAP)

MAP is the techniques in terms of low O_2 and high CO_2 levels, have also been proven to be beneficial in maintaining the quality of various fresh-cut fruits and vegetables (Alasavar *et al.*, 2005). To the consumer MAP offers convenience, high-quality food products with an extended shelf-life. It also reduces and sometimes eliminates the need for chemical preservatives, leading to more 'natural' and healthy products.

The objectives of MAP are to extend the shelf-life of food products and to prevent or at least retarded any undesirable changes in the wholesomeness, safety, sensory, charactheristics, and nutritive value of foods. MAP achieves the above objectives base on three principles which are reduces undesirable physiological, chemical/biochemical and physical changes in foods, controls microbial growth, just like any other packaging technique, it is prevents products contaminations.

The basic principle in MAP is that a modified atmosphere can be created either passively by using properly permeable packaging materials, or actively by using a specific gas mixture together with permeable packaging materials. They both aim to create optimal gas balance inside the package, where the respiration activity as low as possible, but the levels of O_2 and CO_2 are not detrimental to the products (Ahvenainen, 1996).

The three main gases used in MAP are nitrogen (N_2), oxygen (O_2) and carbon dioxide (CO_2). The role and the importance of each gas in MAP are related to its properties. Nitrogen is an inert and tasteless gas, without any microbial activity. It is not very soluble in water and it is primarily used to displace oxygen and prevent package collapse. Oxygen inhibits the growth of anaerobic microorganisms, but promotes the growth of aerobic microbes. Additionally, oxygen is responsible for undesirable reactions in food, including oxidation and rancidity of food, also rapid ripening or senescence of fruits and vegetables, color changes, and spoilage due to microbial growth. However minimum oxygen concentration is required by many fruits and vegetables to sustain their process in aerobic respiration.

While carbon dioxide is soluble in both water and lipids, and its solubility increases with decreasing temperatures. The dissolution of carbon dioxide in the product can result in package collapse. Carbon dioxide has a bacteriostatic effect, and it slows down the respiration of many products. All three gases are common and readily available, safe, economical, and are not considered to be chemical additives.

However, the optimum level of each gas for each food product must be determined and used in order to maximize the positive and minimize the negative effects.

The atmosphere inside a package can be modified by either passive or active means (Floros, 1990). The rate and the final gas composition in the package depend on the packaged product and the permeability of the packaging material. As the harvested fruits continue to live even in minimally processed type, the fruits consume oxygen in the surrounding and release carbon dioxide via respiration processed. If these activity occur inside the sealed package either permeable or impermeable to gases, composition inside the package will changed. As a result, the gas composition inside the package will be further modified and the final gas composition will be different in the two containers.

If the container is impermeable to gases (e.g. glass jars, rigid metal cans, barrier plastic films), the rate of gas production and/or consumption will dictate the gas composition at any time. However, if the container is permeable to gases , the gas exchange with the environment will also take place through the package (Figure 2.4) The main disadvantage of the passive atmosphere modification method is that the desired atmosphere is achieved very slowly (Figure 2.5). This can sometimes result in uncontrolled levels of oxygen, carbon dioxide or ethylene, with a detrimental effect on the quality of the product. Active modification of the atmosphere can provide a solution to this problem (John *et al.*, 2005)

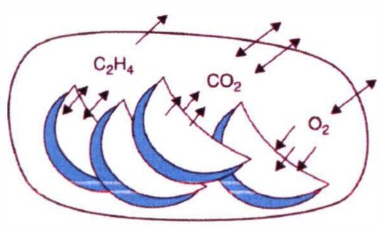
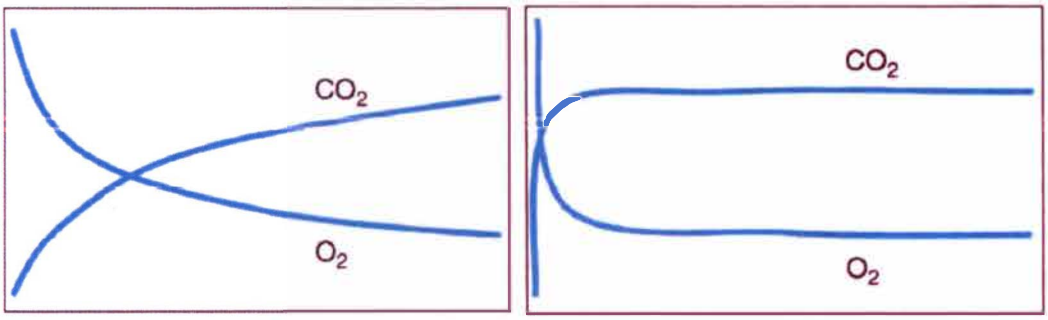


Figure 2.4: Gas exchange between the products and its surrounding in permeable package



(a) (b)

Figure 2.5: The illustration of gases profile for (a) passive and (b) active atmosphere modifications

This aim is the most difficult of all the tasks involved in manufacturing raw ready-to-eat or ready-to-use products of good quality and with longer shelf-life. The main problem is that none of the packaging materials that are available on the market is permeable enough. Most of the films do not result in optimal level of O_2 and CO_2 atmosphere, especially when the produce has high level of respiration. However, one of the solutions is to make microholes of the defined size and of defined number in material to avoid anaerobic reactions (Exama, *et al.*, 1993).

2.3.2 Vacuum packaging

Vacuum packaging is the removal of air within the package without deliberate replacement with another gas (Broody, 1989). Vacuum packaging is also occasionally looked upon as a type of MAP, but this is not generally regarded as modified atmosphere packaging since the atmosphere is not altered but only removed from the package (Sivertsvik *et al.*, 2002). Vacuum packaging is not suitable for soft fruits because the vacuum process causes irreversible deformation of the fruits. Storage time in excess 10 days should, however be avoided because of increasing off-flavour development in bags despite good visual quality (Ahvenainan, 1996).

The process of applying a vacuum can be considered a method of active atmosphere modification (Floros, 1990). The main purpose of such vacuum application is to reduce the residual oxygen in the headspace of a package, which eventually retards oxidative chemical reactions and aerobic microbial growth. When a vacuum is used with flexible packages, the packaging material collapses around the product and practically eliminates the existence of the headspace.

2.3.3 Packaging films

Films cited therein that are employed for gas packaging include PET, CPET, OPP, PP, HDPE, and occasionally LPDE, PVC, and PVDC composed as monolayers, multilayered, laminated, or metallized filmstock and trays. Among the critical properties of these major packaging resins, the most important characteristic for the purpose of gas packaging is their relative permeability to oxygen, carbon dioxide, and nitrogen or argon. The CO_2 and O_2 gas transmission-rate properties of films are generally well known and can be obtained from the materials specification sheets provided by the manufacturer.

Research show the wide range of plastic films and trays were used, and most of these were found to be satisfactory. The key point was to use highly impermeable films and trays. A very large array of tests was conducted to determine the best economical fit of plastic packaging for various product constraints. Effective MAP of produce requires consideration of the optimal gas concentration, product respiration rate, gas diffusion through film, as well as the optimal storage temperature in order to achieve the most benefit for the product and consumer.

2.4 Storage conditions

Based on the past research done by Malaysian Agricultural Research Center (MARDI), the fresh cut fruits usually can be kept 3 weeks at 2°C, 1 week at 10°C, and 2 days at 25°C. Storage at low temperature can increase the shelf-life of minimally processed dragon fruit and it is essential to maintain optimal product quality because it reduces several physiological activities such as transpiration, weight loss, and respiration. Previous study shows that coating on minimally processed red dragon fruit stored at 8°C can be extend the shelf-life until day 7 (Chien *et al.*, 2007).

Storage temperature also is very important when MAP or vacuum packaging is used. Toxin production by *Colostridium botulinum*, or growth of other pathogens such as *Listeria monocytogens*, is possible at temperatures above 3°C because of increased oxygen consumption in the package (Francis and O' Beirne, 1997). Processing, transport, display and intermediate storage should all be at the same low temperature (preferably 2-4°C) for produce not vulnerable to chilling injury. Changes in temperature should be avoided. Fluctuating temperatures cause in-pack condensation which also accelerates spoilage.

As the temperature abuse is major problem during the distribution chain, transportation, retail display and consumer handling, it may necessary to restrict shelf-life. For example, 5 to 7 days at a temperature 5-7°C, when psychrotrophic pathogens have insufficient time to multiply and produce toxin (Ahvenainen, 1996).If the MAP products is greater than 10 days, and there is a risk that the storage temperature will be over 3°C, products should be meet one or more following factors which are minimum heat treatment such as 90 °C for 10 min, pH 5 or less throughout the food, salt level of 3.5% (aqueous) throughout the food, a_w water activity value of 0.97 or less throughout the food, any combination of heat and preservatives factors which has been shown to prevent growth of toxin production by *C.botulinum*.

CHAPTER 3

MATERIALS AND METHODS

3.1 Source of sample and preparations

Red flesh dragon fruit (*Hylocereus polyrhizus*) was obtained from Batu Pahat, Johor. The fruits were harvested at the commercial maturity but not over matured. The whole fruits were stored at 10°C cool room before the process of cutting and packaging for the next day. The whole dragon fruit were clean with water before the process of peeling and slicing. The dragon fruits were deskinned and cut into 2 cm thick slices and dipped in chlorine dioxide solution (5 mg/L) for 5 minutes. The sliced fruits were then toasted-dry in a basket to removed the excess water and then leaved to dry off for 20 minutes. All the preparation steps were done in the best hygienic conditions as possible and all the chemical used in the sample preparations are of food grade.

3.2 Modified atmosphere packaging

The slices of dragon fruit were packed in four different types of MAP treatments as follows:

i. polystyrene (PS) tray with PVC cling wrap (control)

ii. polypropylene (PP) container

iii. PS tray with PP film and heat-seal

iv. PS tray with PP film and vacuum packed for 5 sec.

Every pack contained 5 slices and a total of 24 packs for every treatment was then stored at 5±1°C until day 8. The packs from every treatment were taken out from the storage at two day intervals for analysis.

3.3 Percentage of weight loss

The percentage of weight loss was determined by the following formula.

$$\% \text{ weight loss} = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \times 100\%$$

The initial weight of sample was the weight at day 0 where dragon fruits were packed and the final weight was the weight taken during the day of analysis.

3.4 Color Analysis

Color expressed as $L*$, $a*$, and $b*$ values, were determine using a CR-400 chromameter, where $L*$, a* and b* indicates the luminosity, chromacity on a green (-a) to red (+a) axis, and chromacity on a blue (-b) to yellow (+b) axis respectively. L is the measurement of lightness white is 100 and black is 0.

Measurement was carried out at 3 sites on the surface of each dragon fruit slice and 3 slices of each treatment. The results obtained then calculated using the formula below to find the total colour changes of minimally processed dragon fruit.

$$\text{Total color changes} = \sqrt{(L_0 - L_n)^2 + (a_0 + a_n)^2 + (b_0 + b_n)^2}$$

Where, L_0, a_0, b_0 = L, a, b values obtained on day 0

L_n, a_n, b_n = L, a, b values obtained on day of analysis

3.5 Texture analyses

Firmness of the dragon fruit was determined by using TA.XT*Plus* Texture Analyzer with P/5 probe (stainless steel cylinder probe with diameter 5 mm). The texture analyzer settings used were as follows;

Test mode	Measure force in Compression
Pre-test speed	5.0 mm/s
Test speed	0.5 mm/s
Post test speed	3.0 mm/s
Distance	45.0 mm
Trigger force	5 g

The maximum positive values (firmness) were recorded for each test. Three readings were obtained from every pack of sample and done on 3 packs from each treatment.

3.6 Total soluble solids (TSS)

TSS was determined by using handheld refractometer where the fruits were cut into small pieces and put it in muslin cloth and squeezed to get the juice. One or two drops of juice was enough to put on the refractometer prism. The reading (°Brix) was taken. The refractometer prism was cleaned well with distilled water before proceeding with the next sample. Three readings from every treatment were taken.

3.7 Titretable acidity

Ten grams of dragon fruit juice was weighted and made up to 25 ml of distilled water. The sample was then titrated against 0.1N NaOH until the pH meter showed reading of pH 8.1. The volume of NaOH used was recorded. The titration was repeated 3 times for each treatment. The ratio of titratable acidity to the TSS was calculated.

3.8 Anthocyanin contents

The determination of anthocyanins contents was done by using UV-Vis Spectrophotometer. Approximately 15 g of dragon fruit were weighted into blender and 40 ml of methanol was added and the sample was blended to a smooth paste (about 3 minutes on medium speed). The blended sample then was poured into a 100 ml beaker and 10 ml of methanol was used to wash residual anthocyanins pigments from the blender. The mixture was stirred by using glass rod for several minutes to fully extract the anthocyanin pigment into methanol. The mixture was then transferred into two 50 ml centrifuge tube and centrifuged at 3000 rpm for 5 minutes.

After centrifuge, the supernatant was then poured into 50 ml volumetric flask and made up with methanol to volume. Dragon fruit extract (0.5 ml) was pipetted into two labeled 10 ml volumetric flasks. One volumetric flask was made to volume with pH 1.0 buffer and the other with pH 4.5 buffer. Using the spectrophotometer, the absorbance of dragon fruit extract in pH 1.0 buffer was read at wavelengths from 510 nm. The step was repeated for dragon fruit extract in pH 4.5 buffer solution. The absorbance of each extract was recorded and the total absorbance of anthocyanin was then calculated based on the formula below.

$$A = (Abs\, pH\ 1.0 - Abs\ pH\ 4.5)$$

3.9 Sensory evaluation

For sensory evaluation, the dragon fruits at different storage time were presented to 15 semi-trained panelists from staff and students in UMT. Ranking tests was made to determine the consumer acceptability of the MP sliced dragon fruit based on the scores below. The test attributes involved were color, odour, taste, texture and overall acceptability.

1 Very much unacceptable

2 Unacceptable

3 Neither acceptable nor unacceptable

4 Acceptable

5 Very much acceptable

3.10 Experimental Activities and Statistical Analysis

The experimental activities/samplings were summarized in Table 1.1. The experimental design used is Randomized Complete Design (RCB) and the data collected from all the analyses was analyzed using one-way analysis variance (ANOVA), significant differences ($P<0.05$) between treatments were then determined using Tukey's Test. The statistical program used was Statistical Program for Social Science (SPSS).

Table 3.1: Experimental Sampling

Treatment/Parameter	Control	A	B	C
% weight loss	$3X^3$	$3X^3$	$3X^3$	$3X^3$
Color	$3X^3$	$3X^3$	$3X^3$	$3X^3$
Texture	$3X^3$	$3X^3$	$3X^3$	$3X^3$
TSS	$3X^3$	$3X^3$	$3X^3$	$3X^3$
TA	$3X^3$	$3X^3$	$3X^3$	$3X^3$
Anthocyanin	3X	3X	3X	3X

Control : PS tray + PVC cling wrap
A : PP container
B : PS tray + PP plastic (heat-seal)
C : PS tray + PP plastic (Vacuum pack, 5 sec)
X^3 : represent 3 slices / package
X : represent 1 package

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Percentage of weight loss

Figure 4.1 showed that control samples have higher rate of weight loss compared to the other treatments. There was no significant different on day 0 and 2 of storage time but there was significant different on day 4, 6, and 8 (Table 4.1). There was significant different in control and PP film between the MAP treatments and no significant different highlighted in PP film with vacuum and PP container. Minimally processed dragon fruits in PP container showed the lower rate of water loss compared to control. After day 4 of storage, the percentage of weight loss for the PP film and PP film with vacuum were decreased. This means that there is increasing weight in the packaging material.

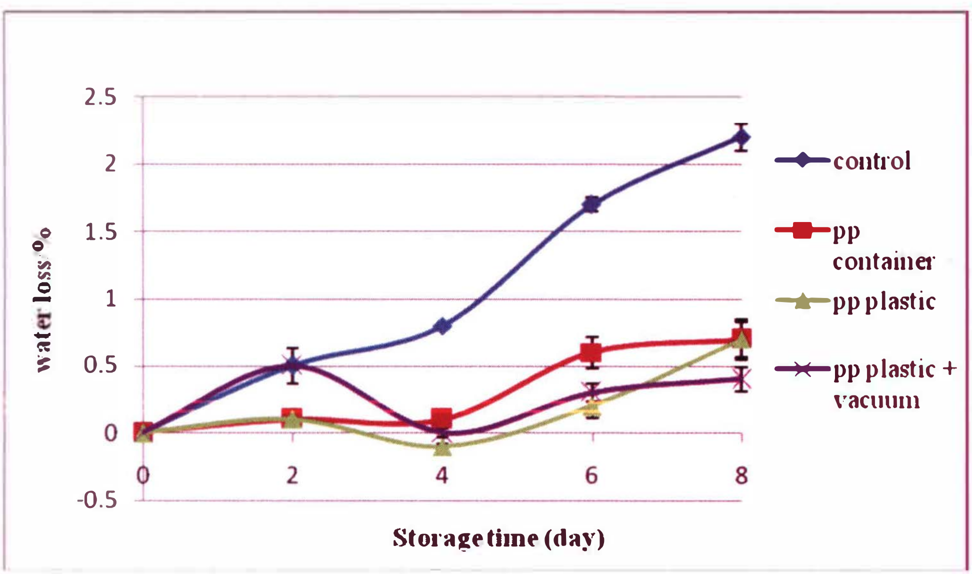


Figure 4.1: Effects of Different MAP on the Percentage Weight Loss of Minimally Processed Dragon Fruit During Storage at Low Temperature

Table 4.1: Percentage of weight loss in different MAP treatments of minimally processed red dragon fruits at low temperature storage 5±1°C

Treatment	Storage time (Day)				
	0	2	4	6	8
Control	0.00 ± 0.00^{Aa}	0.53 ± 0.12^{Ab}	0.77 ± 0.06^{Ab}	1.50 ± 0.17^{Aa}	1.83 ± 0.35^{Aa}
PP container	0.00 ± 0.00^{Aa}	0.10 ± 0.10^{Aa}	0.10 ± 0.10^{Ba}	0.60 ± 0.40^{Ba}	0.73 ± 0.45^{Ba}
PP film	0.00 ± 0.00^{Aa}	0.67 ± 0.06^{Aab}	0.00 ± 0.06^{Bb}	0.23 ± 0.32^{Bab}	0.73 ± 0.50^{Ba}
PP film + vacuum	0.00 ± 0.00^{Aa}	0.53 ± 0.45^{Aa}	-0.07 ± 0.10^{Ba}	0.33 ± 0.23^{Ba}	0.43 ± 0.32^{Ba}

Note: Values in Table 4.1 are means of 3 replicates (3 representative samples/replicate)
Means (n=3)±standard deviation
A – D: Means bearing the same subscript within the same column are not significantly different at 5% level ($p<0.05$)
a – b : Means bearing the same subscript within the same row are not significantly different at 5% level ($p<0.05$)

This happened due to the fluid accumulation in the packaging resulted from the production of water vapor during cold storage and broken sealed of some MAP film treatments. Minimally processed dragon fruit in PP container showed small rate of water loss due to the thicker and rigid container compared to PVC cling wrap and PP film. This can reduce the water loss because there was physical barrier around the produce to reduce air movements that causes the water loss. The weight loss usually cause by the transpiration or water loss on fresh products.

Evaporation is the process by which water is converted from its liquid form to vapor form. When placed in a closed container, water does evaporate until the air in the container is saturated with water vapor. When the air is saturated with water vapor, the molecules in the vapor condense to a liquid as fast as the liquid evaporates, and the two processes (evaporation and condensation) continue at equal rates. Results from PP container showed on day 6 and day 8, the percentage of weight loss almost no change because during this time the air inside the PP container and water vapor almost saturated. This is also related to the different permeability of gases in the different types of packaging.

Fruits remained active even in minimally processed products. They consume oxygen and produce carbon dioxide, which would result in carbon dioxide content increase and oxygen concentration decline in packaging. With high gas permeability film, oxygen could be supplied and carbon dioxide be vented through exchanging packaging gas with atmosphere. When the gas permeability rate equals to respiratory rate of fruit and vegetable, certain gas equilibrium concentration in the package is achieved. Then, fruit could maintain weak respiratory rate without progressing anaerobic respiration. Thereby, the maturation of fruit and vegetable is retarded and freshness is preserved. MAP could ensure food texture, nutritional ingredient and freshness date without applying preservative and additive.

The high percentage weight loss can cause the undesirable changes in color or palatability and also the crispness due to the loss of water. The low rate of weight loss was recommended to increase the shelf-life of minimally processed dragon fruits and PP container showed the low rate of water loss on storage time.

4.2 Texture analysis

Based on the results present in Figure 4.2, the firmness of minimally processed red dragon fruits decreased as the storage time increased. Dragon fruit slices in PP film with vacuum pack showed the lowest firmness value even and become softer on day 0 to day 8, but there is no significant different highlighted during the storage period neither between the MAP treatments tested. Based on the Figure 4.2 it showed that the MP dragon fruit packed in PP container were firmner until day 6. The firmness value of MP dragon fruits packed in PP film almost the same as control, while PP film with vacuum decreasing in the firmness throughout the storage time.

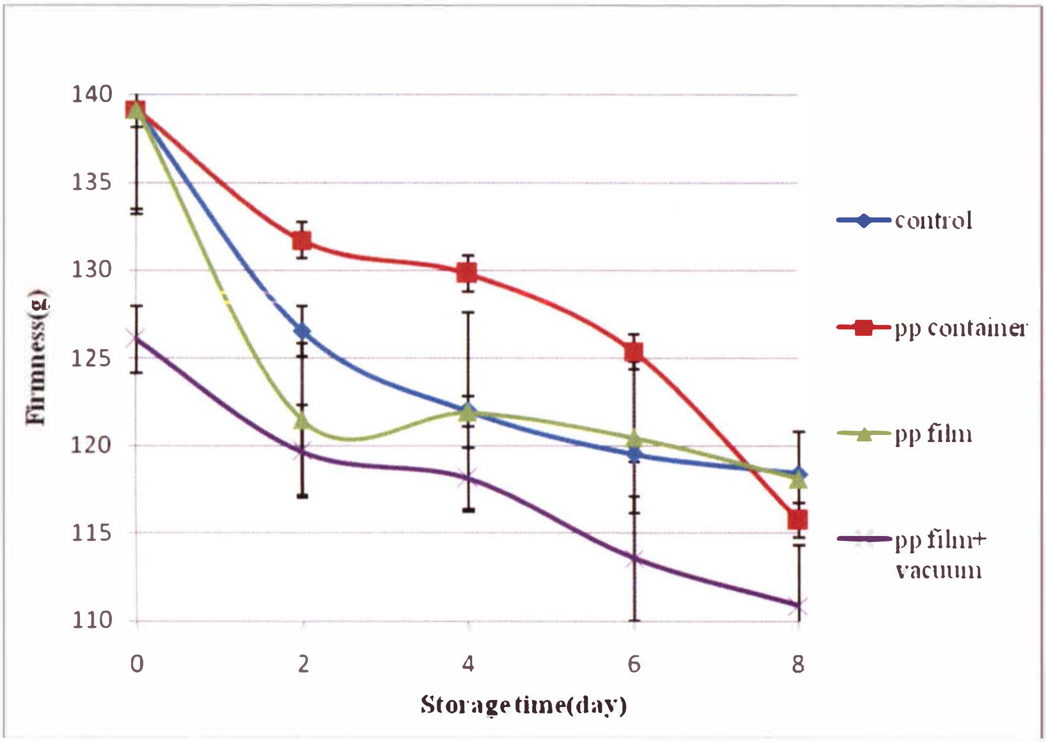


Figure 4.2: Effect of Different MAP Treatments on the Firmness of Minimally Processed Dragon Fruit During Storage at Low Temperature

During vacuum packaging process, the pressure cause the sliced of fruits in the package to soften and thus reduces the firmness and further soften over the storage time. The vacuum packed MP dragon fruits also show appearance of water soak and there was fluid produced right after the vacuum process due to pressure. Vacuum packaging provide low gases contents O_2 in the packaging headspace, so it can stabilizes the quality of produce by slowing down metabolic activity and the growth of spoilage microorganisms (Ahvenainen, 1996).

Although the appearance of texture in vacuum packaging less desirable, but the low contents of O_2 helps to slow down the respiring process minimally processed fruits and reduced the browning and off-flavor. The PP container could maintain the firmness by reduce or slow down the respiration process of minimally processed dragon fruits. The other treatments showed higher reducing firmness compared to the

PP container due to the film packaging that provides enough oxygen to respire. The slow firmness changes can be seen also in the PP film with vacuum pack, but due to the pressure during packaging process, it showed lower firmness than other MAP treatments.

Table 4.2: The effects of different MAP treatments of minimally processed red dragon fruits on fruits texture stored at 5±1°C

Treatment	Storage time (Day)				
	0	2	4	6	8
Control	1.39 ± 19.75^{Aa}	1.25 ± 4.97^{Aa}	1.22 ± 3.01^{Aa}	1.20 ± 1.50^{Aa}	1.18 ± 8.53^{Aa}
PP container	1.39 ± 19.75^{Aa}	1.32 ± 2.35^{Aa}	1.30 ± 0.90^{Aa}	1.25 ± 17.09^{Aa}	1.16 ± 26.16^{Aa}
PP film	1.39 ± 19.75^{Aa}	1.22 ± 20.54^{Aa}	1.22 ± 14.94^{Aa}	1.20 ± 19.61^{Aa}	1.18 ± 14.99^{Aa}
PP film+ vacuum	1.26 ± 6.66^{Aa}	1.20 ± 9.19^{Aa}	1.18 ± 5.99^{Aa}	1.14 ± 12.27^{Aa}	1.11 ± 11.89^{Aa}

Note Values in Table 4.2 are means of 9 replicates (9 representative samples/replicate)
Means (n=9)±standard deviation
A – D: Means bearing the same subscript within the same column are not significantly different at 5% level ($p<0.05$)
a – b : Means bearing the same subscript within the same row are not significantly different at 5% level ($p<0.05$)

4.3 Color

Table 4.3 reveals that there is no significant different in the changes of L^* value neither during the storage nor between different MAP treatments. There was a little changed in lightness of minimally processed red dragon fruits in different MAP treatments over the storage time. Meanwhile, there was no significantly different of a^* during the storage period, and there was no significant value in all the MAP treatments. There was no significant different of b^* value on storage time. However, there was significant different in PP film with vacuum compared to other MAP treatments. Based on the Figure 4.3, the total color change for all the MAP treatments were decrease but in the low rate.

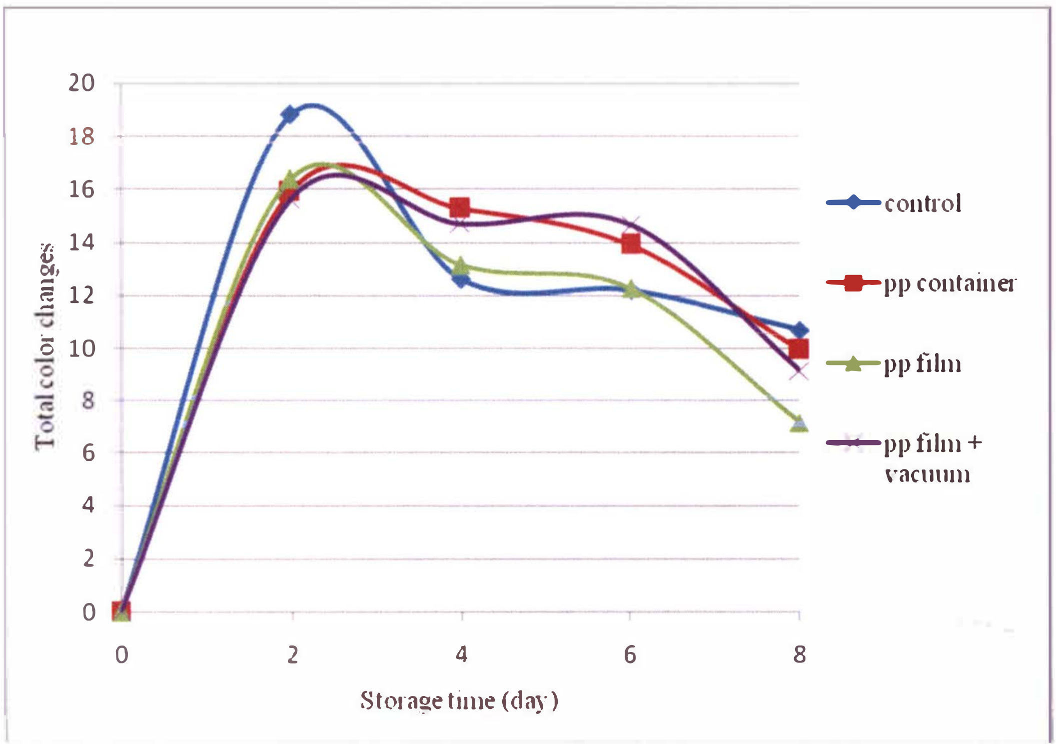


Figure 4.3: The Effects of different MAP Treatments on Total Color Change of Minimally Processed Dragon fruits During Storage at Low temperature

During day 2 until day 6 of storage, there is no respiration process occurs and the respiration process have been initiated back at day 8 of storage. The increasing of a^* value showed the redness of the dragon fruits during the storage. The increase in redness resulted from the increased respiration and the promotion of enzymatic processes responsible for reduced fruit quality, namely browning and other reactions.

The total color changed in dragon fruits was related with the degradation of pigment anthocyanins. Anthocyanin pigments are labile compounds that will undergo a number of degradative reactions. Their stability is highly variable depending on their structure and the composition of the matrix in which they exist (Wrolstad, 2000; Delgado-Vargas, & Paredes-Lo´pez, 2002). Anthocyanins will condense with other phenolic compounds to form colored polymeric pigments. This reaction can be accelerated by the presence of acetyldehyde. Light will promote pigment destruction while reduced water activity will enhance stability. Anthocyanin pigments in dried forms can exhibit remarkable stability.

Table 4.3: The effects of different MAP treatments of minimally processed red dragon fruit on total color change stored at 5±1°C

Treatment	Storage time (day)				
	0	2	4	6	8
Colour L*					
Control	34.56 ± 3.41^{Aa}	30.73 ± 1.09^{Aa}	34.63 ± 2.56^{Aa}	32.75 ± 3.93^{Aa}	31.89 ± 3.06^{Aa}
PP container	34.56 ± 3.41^{Aa}	31.28 ± 3.45^{Aa}	34.70 ± 1.79^{Aa}	33.34 ± 1.94^{Aa}	33.80 ± 3.64^{Aa}
PP film	34.56 ± 3.41^{Aa}	32.83 ± 2.94^{Aa}	33.25 ± 1.25^{Aa}	33.09 ± 0.87^{Aa}	33.57 ± 0.83^{Aa}
PP film + vacuum	34.56 ± 3.41^{Aa}	33.4 ± 2.21^{Aa}	33.26 ± 2.63^{Aa}	33.40 ± 1.50^{Aa}	32.67 ± 1.73^{Aa}
Colour a*					
Control	29.09 ± 3.14^{Aa}	10.68 ± 1.58^{Ab}	16.48 ± 6.93^{Ab}	17.03 ± 6.37^{Aab}	18.78 ± 2.15^{Aab}
PP container	29.09 ± 3.14^{Aa}	13.06 ± 8.59^{Ab}	13.81 ± 3.35^{Ab}	15.23 ± 1.05^{Ab}	19.19 ± 3.27^{Aab}
PP film	29.09 ± 3.14^{Aa}	13.27 ± 3.99^{Ab}	16.01 ± 6.33^{Ab}	16.91 ± 5.14^{Aab}	22.02 ± 3.41^{Aab}
PP film + vacuum	29.09 ± 3.14^{Aa}	13.52 ± 2.32^{Ab}	14.49 ± 1.54^{Ab}	14.47 ± 3.69^{Ab}	20.19 ± 1.91^{Ab}
Colour b*					
Control	0.82 ± 0.99^{Aa}	0.59 ± 0.18^{Aa}	1.05 ± 0.54^{Aa}	1.00 ± 1.11^{Aa}	-0.10 ± 0.25^{Aa}
PP container	0.82 ± 0.99^{Aa}	0.76 ± 0.32^{Aa}	0.71 ± 0.25^{ABa}	0.9 ± 0.16^{Aa}	0.30 ± 0.72^{Aa}
PP film	0.82 ± 0.99^{Aa}	-0.11 ± 0.73^{Aa}	0.90 ± 0.59^{Aa}	0.81 ± 0.37^{Aa}	0.65 ± 1.50^{Aa}
PP film + vacuum	0.82 ± 0.99^{Aa}	1.12 ± 0.53^{Aab}	-0.30 ± 0.24^{Bb}	0.69 ± 0.48^{Aab}	1.65 ± 0.69^{Aa}

Note Values in Table 4.3 are means of 3 replicates (3 representative samples/replicate)
Means (n=3)±standard deviation
A – D: Means bearing the same subscript within the same column are not significantly different at 5% level ($p<0.05$)
a – b : Means bearing the same subscript within the same row are not significantly different at 5% level ($p<0.05$)

4.4 Total soluble solid and Titratable acidity ratio

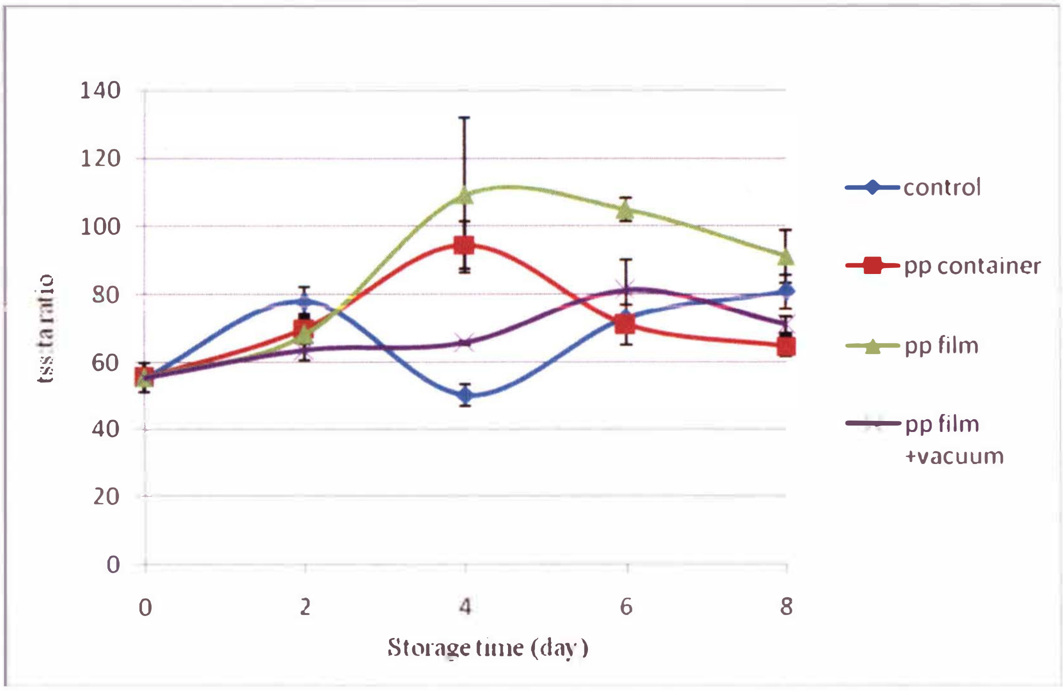


Figure 4.4: Effect of Different MAP on the TSS:TA Ratio of MAP Dragon Fruit During Storage at Low Temperature

The results in Table 4.4 showed that there was no significant different highlighted during the storage time and also among the treatments. The results on Figure 4.4 shown MAP control treatment have some inconsistently data which is decrease in day 4 and increasing the TSS:TA value in day 6 and day 8 of storage. While PP container treatments and sealed PP film treatment was increasing the ratio value in day 4 and decreasing the value after day 4. The PP film vacuum treatment showed the increasing value in day 6 and decreasing in day 8.

The TSS:TA is the value that balance up acid and sugar contents in dragon fruits that indicate the taste of the fruits either sour or sweet. Based on the results obtained, the inconsistently reading due to the different fruits from a different grade or maturity stage that cut and packed together in MAP treatments and it gives different level in sweetness or sourness.

Table 4.4: The effects of different MAP treatments of minimally processed red dragon fruit on TSS:TA at 5±1°C

Treatments	Storage time (day)				
	0	2	4	6	8
Control	55.37 ± 14.66^{Aa}	77.9 ± 14.36^{Aa}	50.23 ± 11.14^{Aa}	77.87 ± 14.19^{Aa}	80.70 ± 17.27^{Aa}
PP container	55.37 ± 14.66^{Aa}	69.2 ± 15.40^{Aa}	94.57 ± 24.24^{Aa}	71.00 ± 20.10^{Aa}	64.67 ± 10.69^{Aa}
PP film	55.37 ± 14.66^{Aa}	68.27 ± 16.54^{Aa}	1.09 ± 78.70^{Aa}	1.05 ± 11.68^{Aa}	91.00 ± 26.97^{Aa}
PP film + vacuum	55.37 ± 14.66^{Aa}	63.53 ± 10.40^{Aa}	65.67 ± 1.79^{Aa}	81.13 ± 30.7^{Aa}	70.93 ± 8.34^{Aa}

Note Values in Table 4.4 are means of 3 replicates (3 representative samples/replicate)
Means (n=3)±standard deviation
A – D: Means bearing the same subscript within the same column are not significantly different at 5% level ($p<0.05$)
a – b : Means bearing the same subscript within the same row are not significantly different at 5% level ($p<0.05$)

Minimally processed of dragon a fruit was continued respired and increase the total soluble solids due to the storage period while the acid contents will decrease. The TSS:TA can be as an indicator to a taste quality because sometime the taste seems acceptable to eat but TSS:TA will show the level of sugar (sweetness) or of acid (sourness) contents.

4.5 Anthocyanins contents

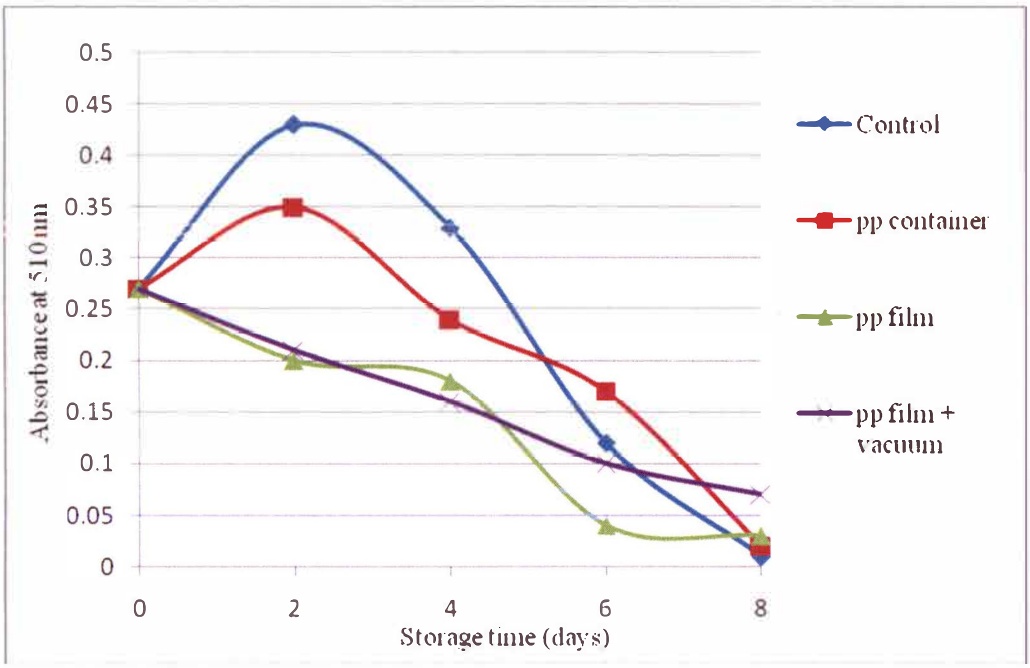


Figure 4.5: Effect of Different MAP on the Anthocyanins Contents of MAP Dragon Fruit During Storage at Low Temperature

The total absorbance of anthocyanins in Figure 4.5 showed that there is a high anthocyanin content in MAP control treatment and PP container treatment. Sealed PP film and PP film vacuum treatment showed almost the same trend, but at the end of storage, absorbance in sealed PP film treatment decrease rapidly. In the initial day showed that total absorbance of anthocyanins was 0.27 and increasing in day 2 for control treatment and PP container treatment. The other two treatments, sealed PP film and PP film vacuum showed decreasing value after initial day of storage.

The colour intensity of anthocyanins pigments is strongly dependent on pH. The difference in the absorbance at maximum wavelength for aliquots of an anthocyanins solution at pH 1.0 and pH 4.5 is directly proportional to the anthocyanins content. In the pH 1.0, anthocyanins was in the flavium cation state which is in the red colour and in pH 4.5 solution, anthocyanins was in Carbinol pseudobase (colorless). As in the pH 4.5 anthocyanins in colorless, it can be used to determine the anthocyanin contents of dragon fruits. From the results, the absorbance value can determine the total anthocyanins contents in minimally processed dragon fruits.

Anthocyanins show different responses to changes in pH, depending on their structure, also reflecting differences in stability during processing and storage. These water-soluble pigments, especially the anthocyanidins, change hue in response to pH changes. They are most stable at low pH and are destroyed in the presence of oxygen at higher pH. Anthocyanins breakdown is also pH-dependent and directly related to O_2 concentration, whereas other factors contribute to quality of anthocyanin-containing fruits and the color highly dependent on pH.

The increasing of anthocyanins absorbance in control treatment and PP container treatment during day 2 of storage due to increasing of respiration activity in the headspace of MAP treatment, as it was an early day of storage, there is enough O_2 for fruits to respire. The decreasing of the absorbance due to the polyphenoloxidase activity that associated with anthocyanins loss. As the storage period increase, the biochemical activity continue the activity even in minimally processed types.

There is also evidence that stability of anthocyanins is increase by copigementation with other polyphenolics coexisting in the same systems. Molecule that copigment with anthocyanins include flavonoids, polyphenols, alkaloids, amino acis, and organic acids. The copigmentation effects exist only in aqueous solution and sensitive to pH, temperature, and composition of solution. Copigmentaion protects anthocyanins against hydration, thus preserving their red colour.

The decreasing absorbance of anthocyanins in minimally processed dragon fruit due to the degradation process by sliced, brushed or damage in any way, they turn brown or even black. The families of phenolic compounds that found in fruits and vegetables are benzoic acids, cinnamic acids, flavonols, tannins precursor and anthocyanidins (Martinez *et al.*, 1995). Phenolics play an important role of reactions that effect colour of minimally processed fruits. The sliced or brushed can cause browing that results from enzyme-catalyzed reaction, which is usually highly undesirable and which corresponds to the oxidation of phenols catalyzed by polyphenoloxidases.

4.6 Sensory evaluation

Based on the sensory evaluation that have been done by 15 semi-trained panelist, for day 0, there is no significant different between the attributes and the MAP treatments. Generally, panelists given 4 out of 5 score for all attributes which are texture, taste, odour, colour and overall acceptability.

Based on the result in Table 4.5, it showed there was significant different for color attributes on day 2 of storage. Color attribution also highlighted that there was no significant different among the MAP treatments. The odour also highlighted that on day 2 of storage, there was significant different during day 2 and highlighted that PP film with vacuum was significant difference than other MAP treatments. For taste attribution, no significant different highlighted on the storage period. Control and PP film with vacuum showed the significantl different among the MAP treatments. Texture attributions showed that there was also no significant difference during the storage period, and among the MAP treatments there was significant different for all the treatments. Overall attributions showed there is no significant different during the storage time but have significant different for PP film treatment among the MAP treatments.

On day 0 all the attributes showed very acceptable for all MAP treatments (Figure 4.6). On day 0 all the fruits were fresh and there were low physiological injuries that might change the physical and chemical composition of minimally processed dragon fruits. The color also not gives significant difference among the treatments. The difference of acceptability minimally processed dragon fruit on day 2 due to the initiating of respiration process that changed the color, texture and also odour. The respiration process were initiated the other process such as degradation of colour and formation of aldehyde and ketones that caused the change in odor or give bad smelling.

The taste of all treatments on day 0 were very acceptable due to the lower change of TSS:TA from day 0. There was not much change in TSS:TA on day 0 to day 2. The taste of minimally processed dragon fruits still acceptable packed in PP container until day 8. This was related to the TSS:TA ratio that was increased in day 4 and decrease on day 6 and 8 as same as TSS:TA on day 0. As the fruits comes from different tree, the level of sweetness and sourness also different that influence the value of TSS:TA and the acceptability of taste among the panelist. The acceptability of sensory on day 0, day 2, day 4, day 6 and day 8 can be refere to the Figure 4.6, 4.7, 4.8, 4.9 and 4.10.

Based on the results, minimally processed of dragon fruits in PP container showed the best attributes acceptability of taste until day 8 of storage. This is due to the low chemical and physical changes and the PP container were provides good features to increase the shelf-life of minimally processed dragon fruit.

Table 4.5: The effects of different MAP treatments of minimally processed red dragon fruit on sensory evaluation stored at 5±1°C

Treatment	Storage time (day)				
	0	2	4	6	8
Color					
Control	3.67 ± 0.90^{Ab}	3.67 ± 0.90^{Ab}	2.80 ± 0.77^{Ab}	2.67 ± 0.72^{Ab}	2.80 ± 0.77^{Ab}
PP container	3.67 ± 0.90^{Ab}	3.07 ± 0.90^{Bab}	2.73 ± 0.59^{Ab}	2.87 ± 0.64^{Ab}	3.07 ± 0.70^{Aab}
PP film	3.67 ± 0.90^{Ab}	3.07 ± 0.90^{Bab}	2.67 ± 0.62^{Ab}	2.87 ± 0.52^{Ab}	2.80 ± 0.77^{Ab}
PP film + vacuum	3.67 ± 0.90^{Ab}	3.07 ± 0.90^{Bab}	2.87 ± 0.64^{Ab}	2.67 ± 0.64^{Ab}	2.53 ± 0.52^{Ab}
Odour					
Control	3.53 ± 0.92^{Aa}	3.60 ± 0.51^{Aa}	3.13 ± 0.52^{Aa}	3.33 ± 0.72^{Aa}	3.13 ± 0.52^{Aa}
PP container	3.53 ± 0.92^{Aa}	3.47 ± 0.52^{ABa}	3.27 ± 0.70^{Aa}	3.20 ± 0.56^{Aa}	3.07 ± 0.70^{Aa}
PP film	3.53 ± 0.92^{Aa}	3.07 ± 0.46^{Bab}	3.13 ± 0.64^{Aab}	3.00 ± 0.53^{Aab}	2.87 ± 0.52^{Ab}
PP film + vacuum	3.53 ± 0.92^{Aa}	3.07 ± 0.46^{Bab}	3.07 ± 0.26^{Aab}	3.07 ± 0.26^{Aab}	2.87 ± 0.35^{Ab}
Taste					
Control	3.53 ± 0.92^{Aa}	3.80 ± 0.41^{Aa}	3.07 ± 0.59^{Ab}	3.53 ± 0.74^{Aab}	3.07 ± 0.59^{Ab}
PP container	3.53 ± 0.92^{Aa}	3.73 ± 0.46^{Aa}	3.26 ± 0.70^{Aa}	3.53 ± 0.64^{Aa}	3.20 ± 0.77^{Aa}
PP film	3.53 ± 0.92^{Aa}	3.67 ± 0.49^{Aa}	3.20 ± 0.68^{Aa}	3.00 ± 0.53^{Aa}	3.21 ± 0.70^{Aa}
PP film + vacuum	3.53 ± 0.92^{Aa}	3.67 ± 0.62^{A}	3.33 ± 0.49^{Aa}	3.20 ± 0.41^{Aa}	3.27 ± 0.59^{Aa}
Texture					
Control	4.20 ± 0.68^{Aa}	3.67 ± 0.49^{Aab}	3.20 ± 0.56^{Ab}	3.27 ± 0.70^{Ab}	3.27 ± 0.59^{Ab}
PP container	4.20 ± 0.68^{Aa}	3.60 ± 0.51^{Aab}	3.13 ± 0.64^{Abc}	3.13 ± 0.64^{Abc}	2.93 ± 0.70^{Ac}
PP film	4.20 ± 0.68^{Aa}	3.47 ± 0.52^{Ab}	2.73 ± 0.46^{Ac}	2.73 ± 0.46^{Ac}	2.73 ± 0.46^{Ac}
PP film + vacuum	4.20 ± 0.68^{Aa}	3.27 ± 0.59^{Ab}	3.20 ± 0.41^{Ab}	3.20 ± 0.41^{Ab}	3.13 ± 0.64^{Ab}

Overall					
Control	3.87 ± 0.52^{Aa}	3.67 ± 0.49^{Aab}	3.13 ± 0.52^{Ab}	3.20 ± 0.68^{Ab}	3.13 ± 0.52^{Ab}
PP container	3.87 ± 0.52^{Aa}	3.53 ± 0.52^{Aab}	3.20 ± 0.68^{Ab}	3.20 ± 0.57^{Ab}	3.07 ± 0.70^{Ab}
PP film	3.87 ± 0.52^{Aa}	3.47 ± 0.52^{Aab}	3.07 ± 0.60^{Abc}	2.93 ± 0.46^{Abc}	2.87 ± 0.52^{Ac}
PP film + vacuum	3.87 ± 0.52^{Aa}	3.33 ± 0.49^{Aa}	3.13 ± 0.35^{Ab}	3.07 ± 0.26^{Ab}	2.93 ± 0.46^{Ab}

Note Values in Table 4.5 are means of 15 replicates (15 representative samples/replicate)
Means (n=15)±standard deviation
A – D: Means bearing the same subscript within the same column are not significantly different at 5% level ($p<0.05$)
a – b : Means bearing the same subscript within the same row are not significantly different at 5% level ($p<0.05$)

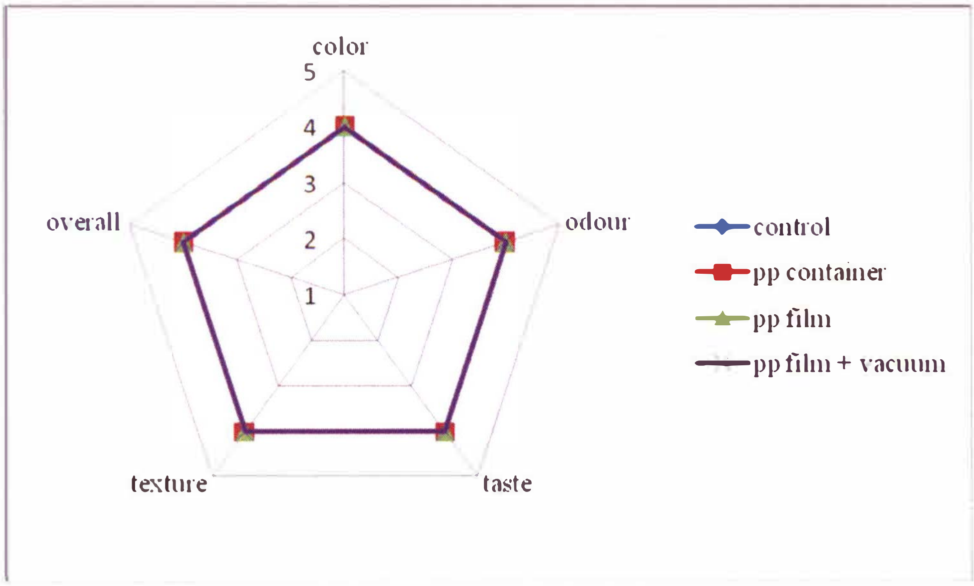


Figure 4.6:The Acceptability of Minimally Processed Dragon Fruits on Different MAP Treatments on Day 0

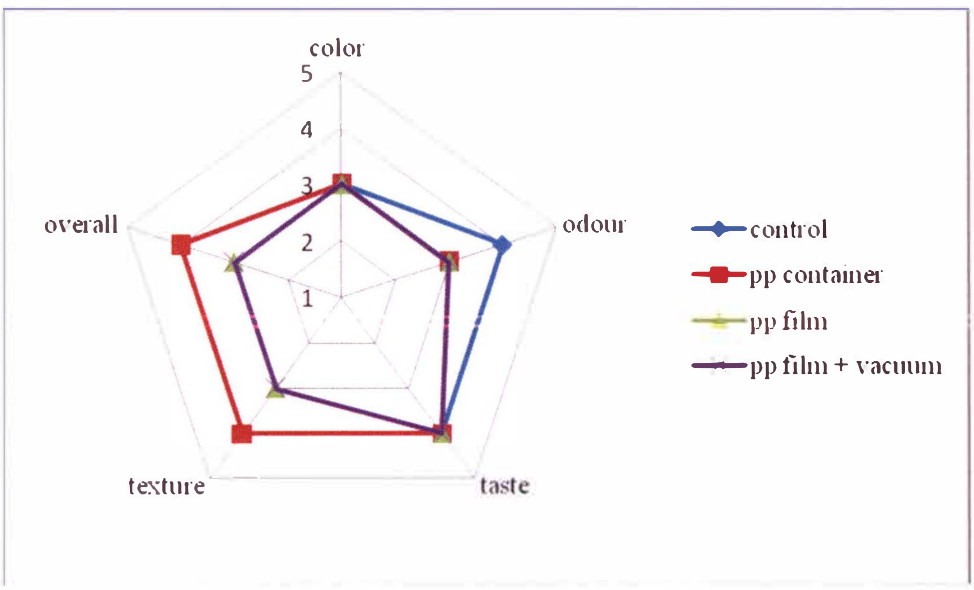


Figure 4.7: The Acceptability of Minimally Processed Dragon Fruits on Different MAP Treatments on Day 2

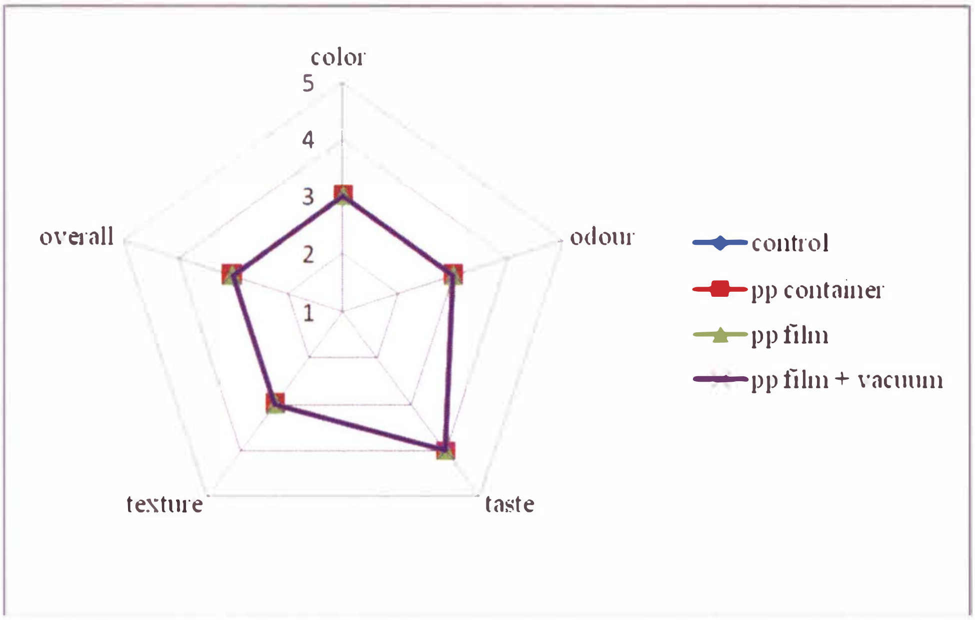


Figure4.8:The Acceptability of Minimally Processed Dragon Fruits on Different MAP Treatments on Day 4

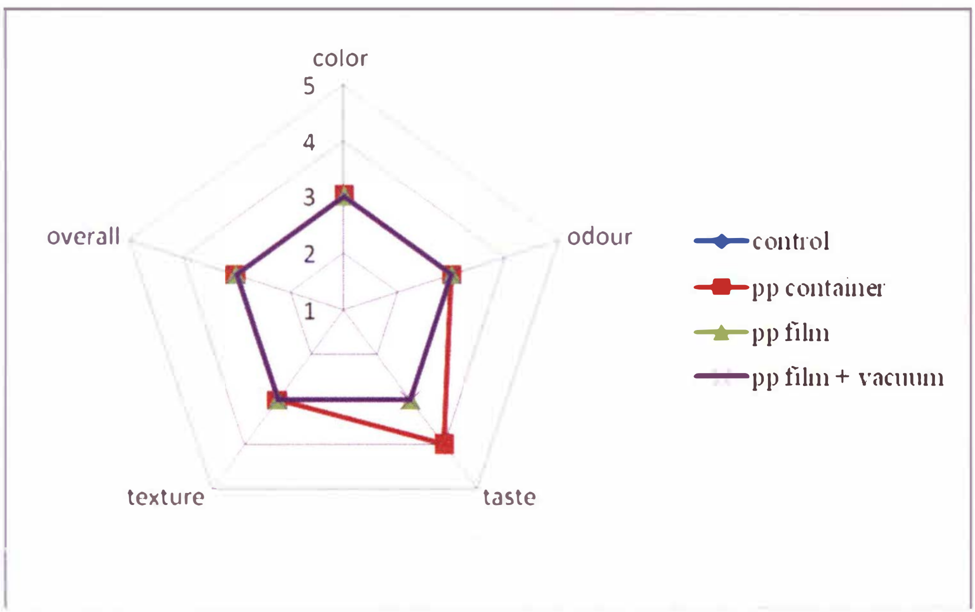


Figure4.9:The Acceptability of Minimally Processed Dragon Fruits on Different MAP Treatments on Day 6

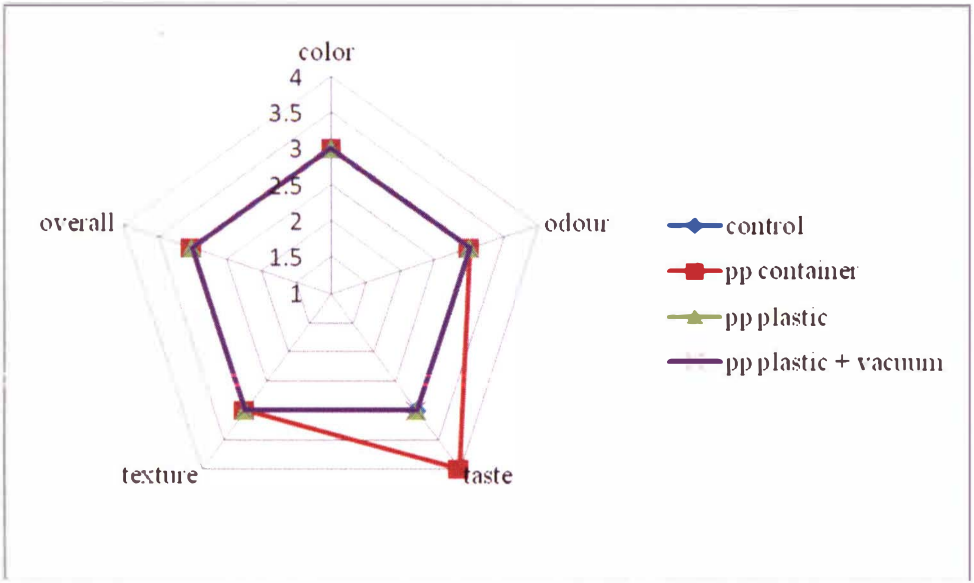


Figure 4.10:The Acceptability of Minimally Processed Dragon Fruits on Different MAP Treatments on Day 8

CHAPTER 5

CONCLUSIONS

5.1 Conclusions

In this study, the modified atmosphere packaging for minimally processed red dragon fruit which were PVC cling wrap (Control), PP container, PP film, and PP film with vacuum were used to investigate the shelf-life of minimally processed dragon fruit over the storage at 5±1°C, RH 90% for 8 days. Over the storage, the percentage weight loss, total colour change and TSS to TA ratio were increased whereas firmness, anthocyanin content and sensory acceptability were decreased for all the MAP treatments. The total color changes were increase and slowly decrease over the storage period. It was found that the percentage of weight loss in PP container increased very slowly and not as rapid as in the other MAP treatments. Texture analysis also showed that PP container could retain the firm texture better than other treatments even though it showed some decreases over the storage. As colour become the major attributes of consumers acceptability, minimally processed dragon fruits in PP container showed least total colour change, which could be an indicator that there was low metabolic and/or respiration process occurred followed by . The anthocyanin content in minimally processed dragon fruits packed in Control showed the highest content and least reduction over the storage period followed by MP dragon fruits packed in PP container, PP film with vacuum and PP film. While, based on the sensory evaluation, the minimally processed dragon fruits in PP containers showed the good acceptability even until day 8 of storage followed by

Control, PP film and lastly PP film with vaccum. Therefore, the minimally processed dragon fruits packed in PP containers had longer shelf-life and its palatability can be maintained until day 8 of storage and might probably even be longer.

5.2 Recommendations

More research should be carried out on the minimally processed red dragon fruit to increase the shelf-life during storage involving different MAP systems. Among the suggestion for future studies are determination of microbial activity on minimally processed red dragon fruits to ensure the hygiene and the safety level of microbial value suitable for consumption. The determination of gas contents in the package headspace by using gas chromatography can effectively determine the type and concentration of different gases in the package over the storage period. The research on minimally processed could also be continued using other type of packaging materials and edible coatings. In addition, some other treatments can also be applied to improve the firmness and color of dragon fruits such as calcium and anti-browning agents due to the enzymatic activity in dragon fruit after slicing or cutting.

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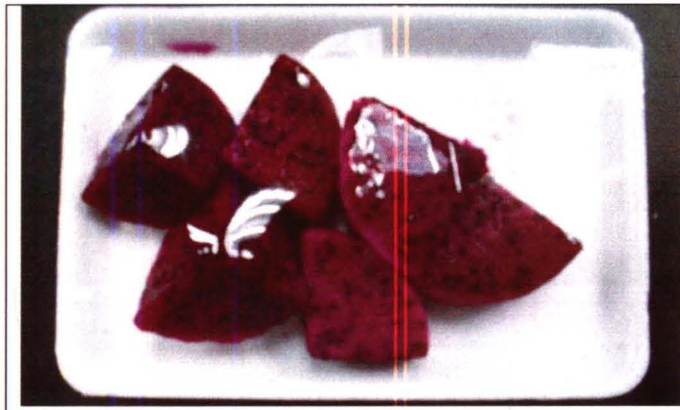
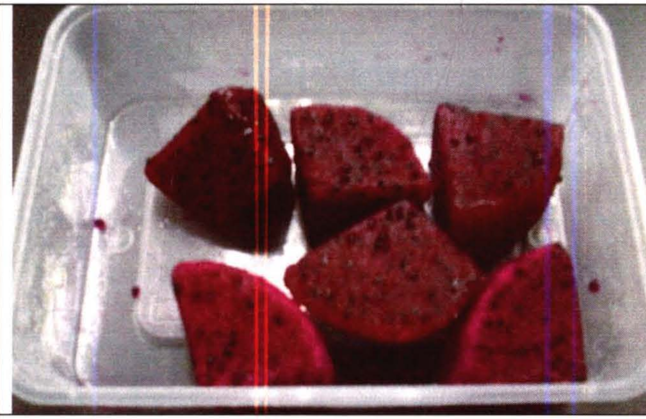
APPENDIX

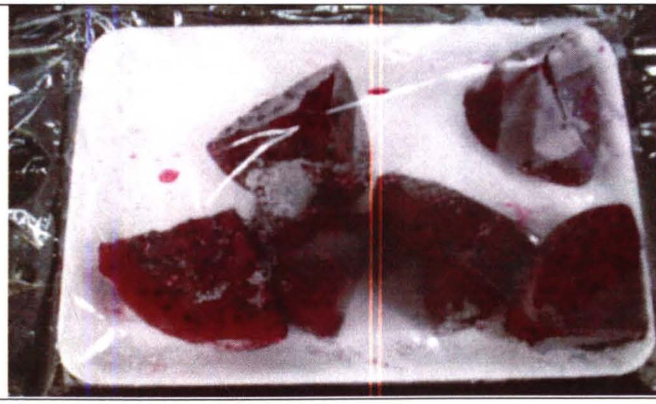
Appendix A: Photos of samples every 2 day intervals for each MAP treatment



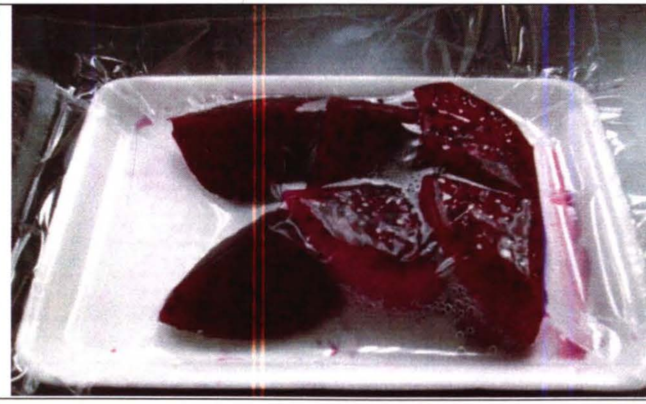
CONTROL



PP CONTAINER

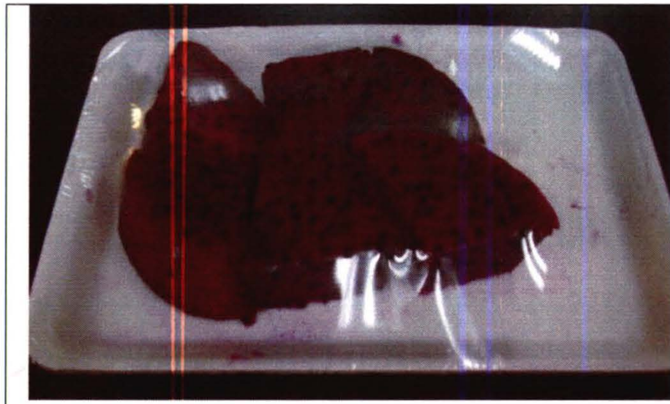


PP FILM

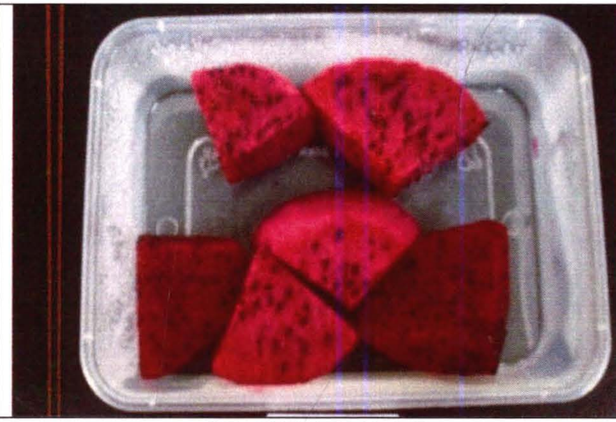


PP FILM + VACUUM

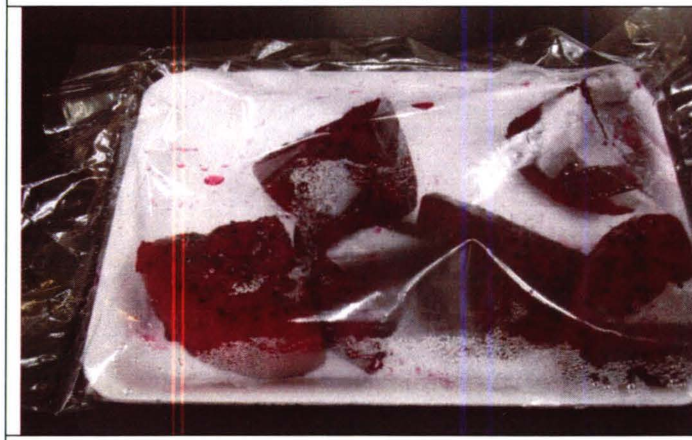
DAY 0



CONTROL



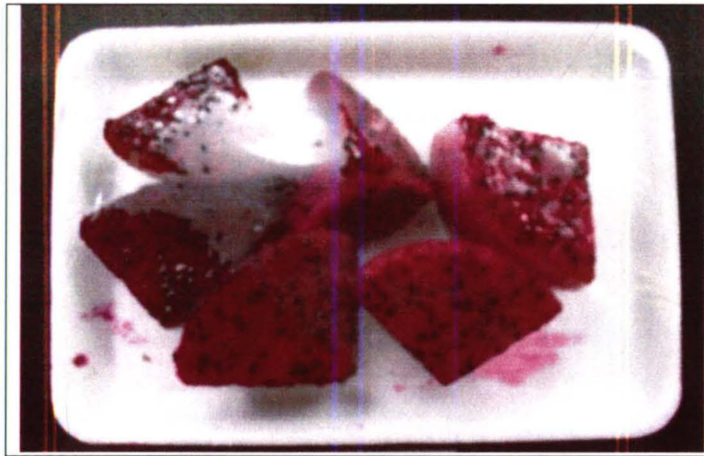
PP CONTAINER



PP FILM

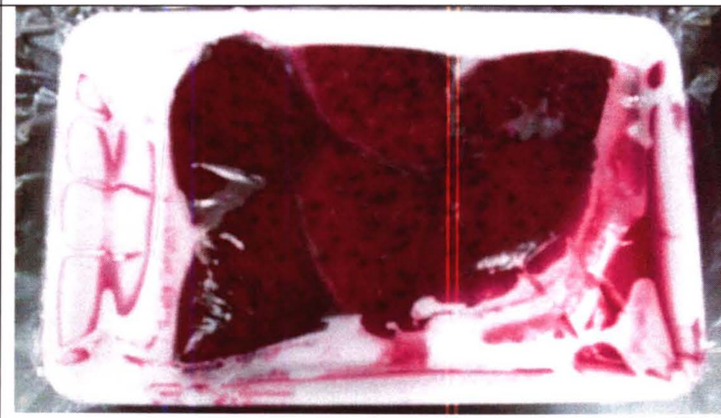
PP FILM + VACUUM

DAY 2

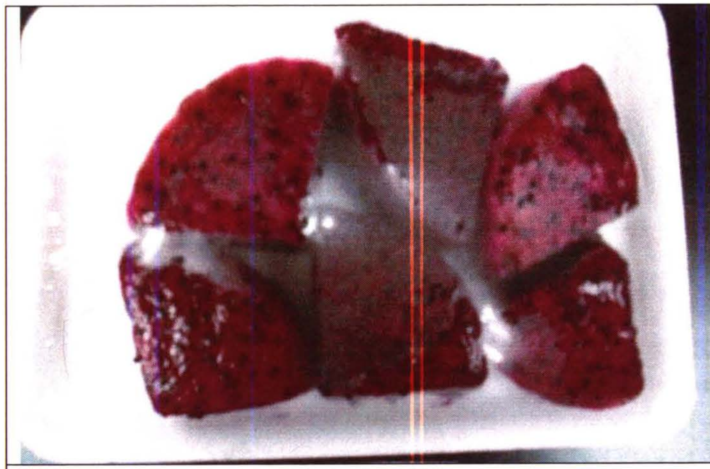

CONTROL


PP CONTAINER

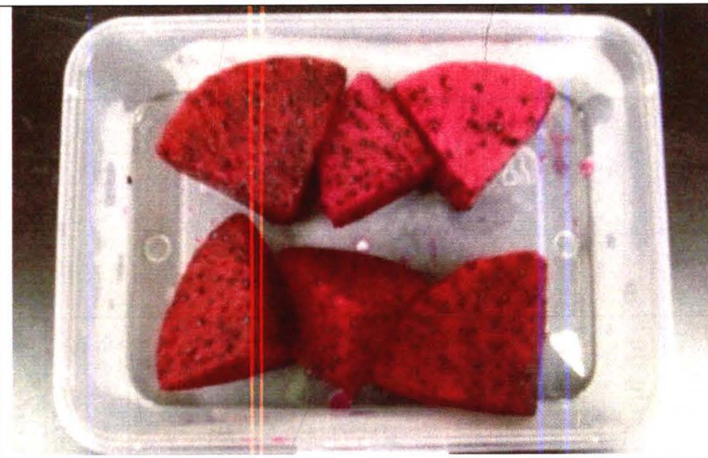

PP FILM


PP FILM + VACUUM

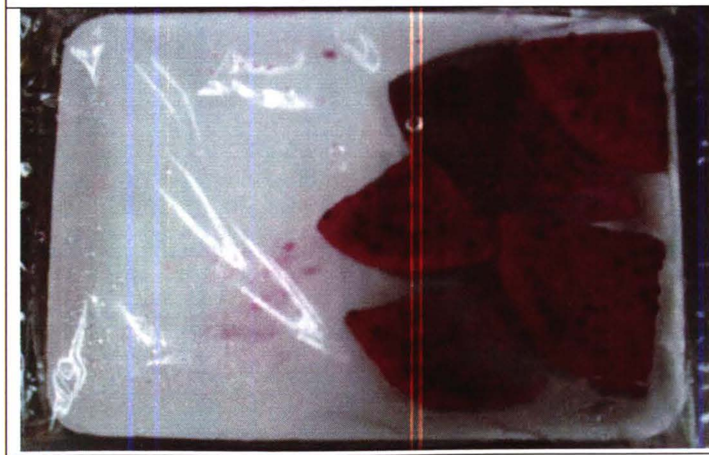
DAY 6



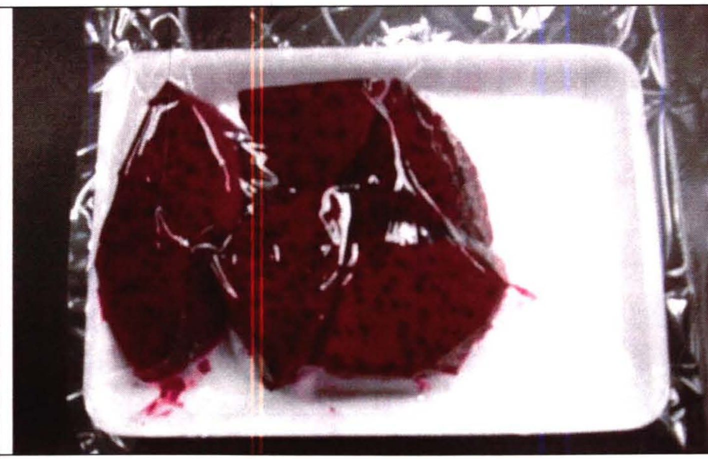
CONTROL



PP CONTAINER



PP FILM



PP FILM + VACUUM

DAY 8

Appendix B: The colour L^*, a^*, b^* of MP dragon fruit in different MAP during storage at low temperature

DAY	treatment	L^*	a^*	b^*
DAY 0	control	34.56	29.09	0.82
	pp container	34.56	29.09	0.82
	pp plastic	34.56	29.09	0.82
	pp plastic + vacuum	34.56	29.09	0.82
DAY 2	control	30.73	10.68	0.59
	pp container	32.83	13.27	0.76
	pp plastic	31.28	13.06	-0.11
	pp plastic + vacuum	33.4	13.52	1.12
DAY 4	control	34.64	16.48	1.05
	pp container	34.7	13.81	0.71
	pp plastic	33.25	16.01	0.89
	pp plastic + vacuum	33.26	14.49	-0.3
DAY 6	control	32.75	17.03	1
	pp container	33.34	15.23	0.9
	pp plastic	33.09	16.91	0.69
	pp plastic + vacuum	33.4	14.47	0.81
DAY 8	control	31.89	18.78	-0.1
	pp container	33.8	19.19	0.3
	pp plastic	33.57	22.02	0.65
	pp plastic + vacuum	32.67	20.19	1.65

Appendix C: Sensory evaluation form

Sensory Evaluation of Minimally Processed Dragon Fruit

Date:

Gender: M / F (Please circle)

You are presented with 5 samples of minimally processed dragon fruit. Please rate the degree of acceptability for all the samples giving a score of 1 to 5 for the attributes of colour, odour, taste, texture, and overall acceptability.

Scale for acceptability:

1 Very much unacceptable
2 Unacceptable
3 Neither acceptable nor unacceptable
4 Acceptable
5 Very much acceptable

1. Colour

288	499	572	880	454

2. Odour

288	499	572	880	454

3. Taste

288	499	572	880	454

4. Texture

288	499	572	880	454

5. Overall acceptability

288	499	572	880	454

Any comment?

____

____

____

THE END

Thank you very much for your kind co-operation.

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THE EFFECTS OF MODIFIED ATMOSPHERE PACKAGING ON MINIMALLY PROCESSED DRAGON FRUIT (HYLOCERUS POLRHIZUS) STORED AT LOW TEMPERATURE - NOORLISTARI BINTI MOHD SALLEH