EFFECTS OF DIFFERENT [illegible] ON THE QUALITY RETENTION OF [illegible] CUT GUAVAS

(*Psidium guajava* L.)

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Effects of different packaging films on the quality retention of fresh-cut guavas (Psidium guajava L.) / Sew Su Yin.

EFFECTS OF DIFFERENT PACKAGING FILMS ON THE QUALITY RETENTION OF FRESH-CUT GUAVAS (*Psidum guajava* L.)

By
Sew Su Yin

This research report is submitted in partial fulfilment of the requirements for the degree of
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ENDORSEMENT

This project report entitled **Effects of Different Packaging Films on the Quality Retention of Fresh-Cut Guavas (*Psidium guajava* L.)** by **Sew Su Yin**, Matric No. **UK 15543** has been reviewed and corrections have been made according to the recommendations by the examiners. This report is submitted to the Department of Agrotechnology in partial fulfilment of the requirements for the degree of Bachelor of Science in 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 quotations and summaries which have been duly acknowledged.

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ABSTRACT

Effects of different packaging films on the quality retention of fresh-cut guavas were studied. Whole guavas (*Psidium guajava* var. Kampuchea) were sliced into uniform boat-shaped sizes of approximately L 90 mm X W 40 mm X T 20 mm and dipped into 1% ascorbic acid to prevent browning of the fruits. The sliced fruits were placed on polystyrene trays and packed in three different types of packaging films namely polypropylene (PP) film, low density polyethylene (LDPE) film and polyvinyl chloride (PVC) stretch film with unpacked samples served as control. Samples were stored at 5±1°C with relative humidity 90% for 15 days. Physico-chemical and sensory qualities of the samples were analyzed at three days interval during storage. The data showed that the guava slices packed in LDPE and PP films had significantly lower percentage weight loss than the control and PVC-packed guava slices. Total soluble solids and firmness of the guava slices packed in plastic films were found to be decreasing during storage. Total colour change increased during storage but there were no significant effects in all packed and unpacked guavas. Sensory analysis conducted showed that the guava slices packed in plastic films had good sensory qualities for up to 12 days of storage whereas control was found to be unacceptable after 3 days. PP-packed guava slices with minimum weight loss showed acceptance score of 3.0 and above in all attributes until day 15. Therefore, it was suggested that PP should be used in replaced of the conventional packaging of fresh-cut guavas using PVC for better quality retention.

ABSTRAK

Satu kajian telah dijalankan untuk menguji kesan penggunaan pembungkus filem yang berlainan ke atas kualiti potongan segar jambu. Buah jambu (*Psidium guajava* var. Kampuchea) dipotong dalam bentuk bot dengan saiz yang sekata yang lebih kurang panjangnya 90 mm X lebar 40 mm X tebal 20 mm. Potongan buah juga dicelup dalam 1% larutan askorbik asid untuk mengelakkan pemerangan berlaku ke atas buah. Potongan buah yang dicelup disusun ke atas dulang polistirena dan dibungkus dengan filem plastik yang berlainan iaitu filem polipropilena (PP), filem polietilena berketumpatan rendah (LDPE) dan filem boleh regang polivinil klorida (PVC). Potongan buah yang tidak dibungkus dijadikan sebagai kawalan. Semua sampel disimpan pada suhu 5±1°C dengan kelembapan relatif 90% selama 15 hari. Penilaian deria dan fisikokimia dijalankan pada sampel setiap tiga hari sepanjang penyimpanan. Data yang diperolehi menunjukkan bahawa potongan buah yang dibungkus dengan filem LDPE dan PP mempunyai kehilangan berat minima yang ketara jika dibandingkan dengan kawalan dan potongan buah yang dibungkus dengan PVC. Jumlah pepejal terlarut and ketegaran buah yang dibungkus dengan filem plastik didapati semakin menurun sepanjang penyimpanan. Tiada sebarang perbezaan yang ketara antara sampel-sampel pada perubahan warna kulit dan isi. Penilaian deria yang dijalankan menunjukkan bahawa potongan buah yang dibungkus dengan filem plastik mendapat skor yang memuaskan sehingga hari ke-12 manakala potongan buah kawalan sehingga hari ke-3 sahaja. Potongan segar jambu yang dibungkus dengan filem PP menunjukkan skor yang memuaskan dalam semua atribut sepanjang penyimpanan dengan kehilangan berat yang paling minima. Maka, filem PP adalah dicadangkan untuk menggantikan pembungkusan konvensional yang menggunakan PVC sebagai pembungkus potongan segar jambu memandangkan PP mempunyai kesesuaian yang lebih tinggi dan ekonomis.

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MAP	Modified Atmosphere Packaging
RH	Relative Humidity
LDPE	Low Density Polyethylene
PP	Polypropylene
PVC	Polyvinyl Chloride
L	Length
W	Width
T	Thickness
L*	Lightness
a*	Greenness (-) to Redness (+)
b*	Blueness (-) to Yellowness (+)
L_0	Initial L*
L_1	Final L*
a_0	Initial a*
a_1	Final a*
b_0	Initial b*
b_1	Final b*
mgL^{-1}	Milligram per Litre
g	Gram
kg	Kilogram
µm	Micrometer
mm	Milllimeter
cm	Centimeter
cm^3	Centimeter Cube
m^2	Meter Square
atm	Atmospheric Pressure
T_g	Glass transition temperature (°C)
T_m	Melting temperature (°C)
T_h	Heat distortion temperature, at 455 kPa (°C)
FT	Tensile strength
WVTR	Water vapour transmission rate at 37.8°C and 90% RH (g $\mu m/m^2$ day)
P_{CO2}	Permeability at 25°C for CO_2 (cm^3 $\mu m/m^2$-h-atm)
P_{O2}	Permeability at 25°C for O_2 (cm^3 $\mu m/m^2$-h-atm)
°Brix	Degree of Brix
°C	Degree Celcius
%	Percentage
±	Plus Minus
<	Less Than
>	More Than

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Guava (*Psidium guajava L.*) being a member of the dicotelydon family Myrtaceae (Adsule and Kadam, 1995) is renowned commercially for its high nutritional value of excellent source of Vitamin A and C. The fruit was believed to be originated from the warm areas of tropical America, extending from Peru to Mexico. Being one of the main producers of guava in the world besides India and Brazil, Malaysia as a subtropical country has a wide distribution of guava cultivation with several leading commercial varieties throughout the Peninsula i.e. Gu4, Gu5, Gu7, Hongkong Pink, Jambu biji, Taiwan, Laknaw and Vietnamese (Yusof, 1990; Lim and Khoo, 1990). The fruit is also popular among the locals as "jambu batu" (Lim and Khoo, 1990) for its distinctive aroma and flavour.

Since it is a non-seasonal fruit, guava which shows climacteric behaviour (Adsule and Kadam, 1995) is available all year round in Malaysia. Hence, processing and preservation of guavas in the form of a variety of products such as pulp, puree, juices, dried slices, jam and canned products have been carried out and well distributed into the markets. However, guavas are still preferred to be consumed fresh by the consumers. Thus, this has brought to the gaining popularity of minimally processing of guavas.

Minimally processing which are normally carried out on fruits and vegetables is defined as partially preparation of the produce so that no additional preparation is necessary for their use. It includes processes such as trimming, peeling, washing and cutting into 100% useable products of any fruit or vegetable or combination of both which will then be packed to remain its fresh state (IFPA, 2004).

Minimally processed products or ready-to-eat products are normally made available to the restaurants, fast food outlets and retail markets. It is found that fresh cut fruits have benefited from the demand for convenience. Retail sales of fresh cut items have grown from under $100 million in 1990 to $15 billion in 2006 with a high contribution from the foodservice operators in the United States of America (Baeza, 2007).

Packaging is mandatory for distribution of minimally processed products. Fresh-cut guavas or other minimally processed products will be typically presented in convenient packs for the consumers such as sealed polymeric film bags, rigid plastic trays and sealed across the top with polymeric films on overwrapped trays (Schlimme and Rooney, 1994; Lamikanra et al., 2005b). A few types of commonly used polymeric films in packaging of minimally processed fruits and vegetables are polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET) and polyvinyl chloride (PVC). However, suitable polymeric films should be applied in packaging respiratory products to prolong the shelf life and maintain the freshness of fruits and vegetables until they are presented to the consumers.

1.2 Problem Statement

Due to the hectic lifestyle of the majority consumers today, fresh-cut fruits appeared as an increasing popularity of ready-to-eat products in the market as well as a response of a consumer trend toward fresh-like high quality products. Albeit these minimally processed products present, as distinguishing features of simplicity in use and convenience, they generally perish more quickly than the original raw material. This is due to tissue damage caused by minimally processing operations such as peeling, cutting, and seed removal. Hence, this results in rapid deterioration of the product's quality and consequently shortens its respective shelf life as raw material (Ahvenainen, 1996).

Rosen and Kader (1989) have compared the quality of whole fruits to sliced fruits in a study done with strawberry and pears. The major consequences of both sliced commodities are the elevation of CO_2 and ethylene which induces ripening, thus contributes to the loss of firmness in fruits and enzymatic browning is observed in sliced pears. Besides that, fresh-cut products lack a natural barrier which directly exposes the tissues to the outside surrounding, thus increases the water evaporation rate and causes moisture loss from the products and attracts microbial attack on the expose tissues.

Fresh-cut guavas which will be distributed either to local or foreign markets must have preservative measures to prolong its shelf life and eating quality. However, it is still a challenge for the processors to achieve microbiologically safe products with sensorial and nutritional fresh-like values despite the amount of research already spent on this topic (Bett et al., 2001 and Baeza, 2007).

1.3 Significance of Study

Guava is nutritious and rich in flavour. However, fresh-cut fruit products are complicated by the nature of fruits in which softening and other ripening processes continue after harvest (Kader, 2002 and Lamikanra, 2002). Hence, the shelf life of fresh-cut guava fruit is limited.

Packaging technology is indispensable for most fresh cut products to be able to achieve a balance between the O_2 demand of the product for respiration and the permeability of the film to O_2 and CO_2. Modified atmosphere packaging (MAP) applies the principle of placing the product in a sealed package such as polymeric film and establishing different environment conditions inside the package (Baeza, 2007). In general, film wrapping will reduce weight loss, colour development and chilling injury; and maintain firmness and internal quality even under optimum storage conditions (Risse, 1989).

However, selection of polymeric film with suitable film permeability for packing of fresh-cut products is critical to prevent any unfavourable condition within the film which might cause adverse effects on the products. Commonly used polymeric films in food packaging such as polyethylene (PE), polypropylene (PP) and polyvinyl chloride (PVC) has different permeability rates to CO_2, O_2 and water vapour. Hence, this study is to determine the shelf life of fresh-cut guavas packed in different types of plastic films.

1.4 Objective

This study was to evaluate the effect of packaging films on the quality retention of fresh-cut guavas at 5±1°C and also to decide the most suitable packaging film for storing fresh-cut guavas.

CHAPTER 2

LITERATURE REVIEW

2.1 Guava (*Psidium guajava* L.)

Guava is a berry with a persistent calyx which is borne directly on the trunk or branches of the tree. It is normally round in shape but it could be in ovate or pear shaped in some cultivars. Fully matured fruit have an average of 4–10 cm in length, 4–8 cm in diameter and 50–500 g in weight which varies according to different cultivars (Adsule and Kadam, 1995).

Guava has been cultivated in Malaysia for a long time (Allen, 1967). Commercial production began in the mid 1980s and the fruit is now mainly grown in Perak, Johor, Selangor and Pahang. Guava is grown for both the domestic and export markets. The main importers of Malaysian guava are Singapore, Brunei, Hong Kong and Saudi Arabia. Guava production had contributed to the export value in 2003 of about RM3 billion (Abdul, 2008).

One of the seeded fresh varieties which were used in this study is the Kampuchea. The fruit weighs 400–600 g on the average with white, thick and crunchy sweet flesh. The total soluble solids vary from 6.5–7.0 °Brix, with 0.5 acidity and high ascorbic acid (Vitamin C) content of 55 mg/100 g (Abdul, 2008).

Guava which is well known for its relatively high ascorbic acid content as some cultivars could reach about 200–300 mg/100 g, which are three to six times the amount of vitamin C in a single orange (Holland et al., 1998; Uddin et al., 2002). Besides that, the fruit is also rich in antioxidants which help reduce ageing and the incidence of degenerative diseases such as arthritis, arteriosclerosis, cancer, heart disease, inflammation and brain dysfunction. (Lim et al., 2006)

The suitable maturity stage for fresh cut guavas is at its commercial maturity stage. This is the stage whereby the fruits are acceptable to the consumers. The commercial maturity stage for the Vietnamese or Kampuchea cultivar is Index 3 which is light green in colour with a considerable hard, crunchy texture and low level of astringency due to the presence of tannins (Yusof et al., 1988). Lim and Khoo (1990) have classified and grade the fruit according weight, length and diameter which is shown as follows:

Table 2.1: Grading of guavas (Source: Lim and Khoo, 1990)

Aspects	Very Big	Big	Medium	Small
Weight (g)	400–1000	250–399	150–399	<150
Length (cm)	10–13	8–10	6–8	<6
Diameter (cm)	8–10	7–8	6–7	<6

Harvesting of fruits that are immature green is normally avoided as they will fail to develop into quality ripe fruit. Proper storage of harvested guavas before processing with the optimum temperature 5°C with 85–95% relative humidity should be carried out to prevent the development of diseases and disorders such as antracnose and rots caused by *Phytophora criticola*, *Mucor hiematis*, *Carticium rolfsii* and others (Adsule and Kadam, 1995).

2.2 Minimally Processing of Fruits

2.2.1 Post Harvest Losses of Minimally Processed Fruits

The application of minimally processing to tropical fruits can represent an interesting world market (Pereira et al., 2004). However, as a result of peeling, grating and shredding, produce will change from a relatively stable product with a shelf life of several weeks or months to a perishable one that has only a very short shelf life, even as short as 1–3 days at chill temperatures (Ahvenainen, 1996). Minimally processed produce deteriorates because of physiological ageing, biochemical changes and microbial spoilage, which may result in degradation of the colour, texture and flavour of the produce (Kabir, 1994). During peeling and grating operations, many cells are ruptured, and intracellular products such as oxidizing enzymes are liberated.

The most important enzyme that causes discolouration of the fresh-cut products is polyphenol oxidase (PPO). It causes oxidative browning at the cut surface where when the cells are broken, substrates and the oxidizing agents come into contact (Alzamora et al., 2000). Hence, the enzyme converts phenolic compounds in fruits and vegetables into dark coloured pigments in the presence of O_2 (Baeza, 2007). Another important enzyme is lipooxidase, which catalyzes peroxidation reactions, causing the formation of numerous bad-smelling aldehydes and ketones (Kabir, 1994).

Apart from that, increasing ethylene production following minimally processing could contribute to biosynthesis of enzymes involved in fruit maturation. It may be partially responsible for bringing about physiological changes in sliced fruit, such as softening. In addition, the respiration activity of minimally processed produce will increase 1.2–7.0 fold, or even more, depending on the produce, cutting grade and temperature (Kabir, 1994; Ahvenainen, 1996). If packaging conditions are anaerobic, this leads to anaerobic respiration and thus the formation of ethanol, ketones and aldehydes, giving the fresh-cut produce off odour and off flavour (Powrie and Skura, 1991).

Agar et al. (1999) determined that peeling and slicing kiwifruit caused an increased in CO_2 and C_2H_4 production rates within two to six hours at 20°C. And the C_2H_4 and CO_2 production rates of peel were about two to four times higher than those of unpeeled slices. Peeled fruit and slices had double the C_2H_4 and CO_2 production of whole fruit, which was unchanged during six hours at 20°C or three days at 2°C. Respiration and C_2H_4 production rates increased with temperature.

Gorny et al. (2000) compared the respiration and ethylene production of different cultivars of whole and sliced pears (4 cultivars) held at 10°C and 90-95% relative humidity. The difference between whole and sliced pears was evident for Bosc, Anjou and Red Anjou pear slices that had 3%, 65% and 232% greater respiration rates than whole fruits.

Aguayo et al. (2004) studied whole and fresh cut melons and found that wounding by cutting caused an increase in carbon dioxide and ethylene production. The increase was more pronounced at 5°C than at 0°C.

Plant tissues are in equilibrium with an atmosphere at the same temperature and relative humidity. However, when the fruits are cut or peeled the tissues are exposed and this increases the water evaporation rate. The rate of water loss between intact and wounded plant surfaces varies according to the commodity (Watada and Qi, 1999).

Agar et al. (1999) working with kiwifruits found that mass loss was highest in peeled slices and lowest in intact whole fruit stored for three days at 20°C. Fresh-cut slices had more water loss since they do not have the protective epidermal cells and surface area/mass rate was increased.

Microorganisms such as mesophilic bacteria, lactic acid bacteria, coliforms, yeasts and molds have been found to be actively growing in packaged fresh cut fruits and vegetables. Increases in microbial populations are related to increased respiration rates with time in storage and the factor that damaged tissue and broken cells provide nutrients and a protected environment for growth of most types of microflora (Lamikanra, 2002).

The natural fruit barriers such as the peel, rind and skin prevent microorganisms from entering fruits. However, breaks in these barriers caused by punctures or damage during handlings or the cutting can allow pathogens such as *Escherichia coli 0157:H7* to enter and potentially grow. Fatemi et al. (2006) studied the ability of *Escherichia coli 0157:H7* to penetrate and grown within punctures of fresh cut Golden Delicious apples. The fresh cut surfaces permitted up to 2.8 mm penetration and the population increased 3 logs after 48 hours. These findings showed the importance to control the temperature of the fruit and rapid speed of processing as well as the use of sanitizing treatments.

Furthermore, processing which is to maintain the shelf-life might affect the nutrient content of the minimally processed produce. These nutrient losses could be due to removal of parts such as peeling, inadequate handling and inevitable handling such as blanching whereby the heat destroys the heat labile nutrients (Lamikanra et al, 2005a).

Therefore, fresh-cuts fruit produce requires new preservation techniques capable of keeping the safety and quality of commodity long enough to make distribution feasible and achievable.

2.2.2 Basis of Minimally Processing

Minimal processing of raw fruits and vegetables is in objective to keep the freshness of the product, yet supplying it in a convenient form without losing its nutritional quality. The shelf life of these products should be long enough to make their distribution feasible (Soliva-Fortuny et al., 2004).

Barta et al. (2006) described these products are usually processed by appropriate unit operations which is shown as follows:-

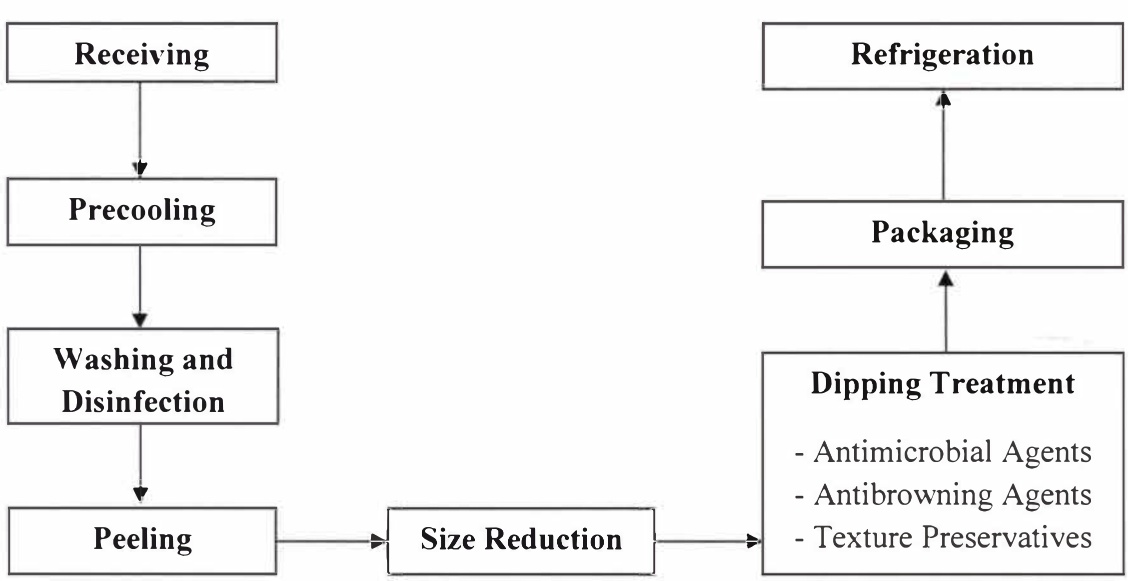

Figure 2.1: Basic process flow chart for fresh-cut fruits (Barta et al., 2006)

2.2.2.1 Sorting, Precooling and Sanitizing of Fruits

Sorting of fruits is important to discard those that are disease infected by fungi and pesticides such as spots on the skin surface. Precooling of the produce is essential as well to remove field heat and preparing the fruits for cold storage (Lim and Khoo, 1990).

Besides that, vegetables and fruits could be contaminated with pathogenic microorganism during harvesting through faecal material, human handling, harvesting equipment, processing, transportation, and distribution. Washing is generally used to reduce the microbial load and remove debris and cellular fluid (Sothornvit and Kiatchanapaibul, 2009).

Sanitizers are chemicals that are used during washing to reduce microbial loads on the surfaces of whole and cut produce since fresh produce can be a vehicle of viruses, parasites, spoilage bacteria, moulds and yeast, as well as occasional pathogenic bacteria. Chlorine is an effective sanitizer for surfaces that may come in contact with fruits and vegetables during harvesting and handling, as well as processing equipment. Chlorinated water is widely used to sanitize whole fruits and vegetables and fresh cut produce (Alzamora et al., 2000). The use of chlorination as commonly used for fresh-cut salad sanitation, may not be desirable for all fresh cut fruits.

Washing or dipping after cutting may cause negative consequences, such as the washing away of desirable flavour and increased water activity (Lamikanra, 2002). Chlorine is commonly used at 200 ppm (free chlorine or concentration of hypochlorous acid) and at a pH below 8.0, with a contact time of 1–2 minutes. Temperature of chlorinated water should ideally be at least 10°C higher than fruits or vegetables to achieve a positive temperature differential and minimize uptake of wash water through tissues (Baeza, 2007). Apples of Golden Delicious cultivar were sanitised for 2 minutes in chlorinated water (0.2 mg free chlorine L^{-1}), rinsed with tap water and gently dried by hand (Soliva-Fortuny et al., 2004).

2.2.2.2 Cutting of Fruits

All the utensils and knives must be pre-sterilized by dipping in 50 g/kg H_2O_2 solution to prevent contamination during preparation of fruits as suggested by Shah and Nath (2008).

Even though minimally processing permits the use of fruit which may not be visually acceptable for fresh market, it is generally recognized that raw product quality for fresh-cut should be high to insure a good quality fresh cut product (Baeza, 2007). A study to compare fresh cut melons from good quality areas with melons that showed externally ground spots and melons with sunburn areas determined that common external defects can impact the quality of fresh-cut melon pieces. Using pulp from beneath sunburned areas should be avoided, and pieces from ground spot areas showed softer pieces than undamaged area (Cantwell and Portela, S., 1998).

An example in fruits is the study by Cantwell and Portela (2001). They found that cutting cantaloupe melon pieces with a sharp borer resulted in longer shelf life at 5°C than cutting with a blunt borer. The reduction of mechanical injury will result in keeping better quality attributes of fresh cut by minimizing the number of injured cells whereas a blunt cutting instrument can induce injury to cells many layers removed from the actual cut because of the mechanical shock imparted to the tissue.

2.2.2.3 Ascorbic Acid as Antibrowning Treatment

Ascorbic acid is a moderately strong reducing compound, which is acidic in nature, forms neutral salts with bases and is highly water-soluble. L-ascorbic acid (vitamin C) and its various neutral salts and other derivatives have been widely used as an antibrowning agent for use on fruits and vegetables and in fruit juices, for the prevention of browning and other oxidative (Lamikanra, 2002).

Ascorbic acid reduces polyphenoloxidase browning by reducing o-quinones back to phenolic compounds before they form brown pigments and act on the enzyme polyphenol oxidase by linking irreversibly the copper of the enzyme (Lamikanra, 2002). However, ascorbic acid is consumed in the process, providing only temporary protection unless used at higher concentrations.

Gil et al. (1998) determined that 2% ascorbic acid was effective in reducing the browning of fresh cut Fuji apple slices but in combination with low oxygen atmospheres storage.

Besides that, ascorbic acid treatment also adds nutritional value to the fresh-cut products. Cocci et al. (2006) studied the effect of antioxidant dipping treatment (1% ascorbic acid and 1% citric acid for 3 minutes) and modified atmosphere in fresh cut apples. As a result of the antibrowning treatment, the ascorbic acid treated samples had about 20–fold ascorbic acid higher than non treated samples at the beginning of storage and remained higher until the sixth day of refrigeration; total pholyphenols were also higher for treated samples compared to those not treated. Results showed that the treatment used served the antibrowning purpose and in addition compensated the losses of the nutritional properties.

2.3 Plastic Packaging of Minimally Processed Fruits

The principal roles of food packaging are to contain food in a cost-effective way that satisfies industry requirements, consumer desires and maintains food safety such as protecting the food products from outside influences and damage (Coles, 2003).

Modified atmosphere packaging (MAP) is defined as the enclosure of food products in a barrier film in which gaseous environment has been changed or modified to slow respiration rates, reduce microbiological growth and retard enzymatic spoilage with the intent of extending shelf life. MAP of commodity refers to the technique of sealing actively respiring produce in polymeric film packages to modify the O_2 and CO_2 levels within the package atmosphere. It is often desirable to generate an atmosphere low in O_2 and/or high in CO_2 to influence the metabolism of the product being packaged and the activity of decay-causing organisms to increase storability and/or shelf life (Mangaraj et al., 2009).

Plastic packaging is a type of MAP and generally, the most suitable polymeric films would be a CO_2 to O_2 ratio of 3 over 1 such as PVC and LDPE for adequate distribution and marketing time (Smith et al., 2003). Guava packed with PVC, LDPE or PET and stored for 2 and 3 weeks at 5°C and 8°C hindered the development of peel colour and the loss of firmness (Pereira et al., 2004).

2.3.1 Types of Plastic Films

2.3.1.1 Low-Density Polyethylene (LDPE)

$$nCH_2 = CH_2 \rightarrow [CH_2 - CH_2]-_n$$

Figure 2.2: Formula structure of low density polyethylene (LDPE)

Low-Density Polyethylene (LDPE) is the simplest and the most inexpensive plastics made by addition polymerization of ethylene. It is the most extensively used packaging film for fresh produce. LDPE seals at lower and over a wider temperature range, and has better hot tack, all of which result, to a great extent, from its long-chain branching. LDPE is a good barrier to water vapour, but a poor barrier to oxygen, carbon dioxide and many odour and flavour compounds (Table 2.4.1.1). As LDPE is relatively transparent, it is predominantly used in film applications and in applications where heat sealing is necessary. LDPE is generally the cheapest plastic film, on a per-unit mass basis (Mangaraj et al., 2009).

Packaging citrus fruits in polyethylene films maintained high RH inside the package and hence resulted in reduction of shrinkage (Smith et al., 1987). Combrink et al. (2004) reported that non-perforated polyethylene bags maintained guava fruit quality better than perforated bags. Most workers have used polyethylene and PVC films (Geesan et al.; 1985; Saguy and Mannheirn, 1975) to extend tomato shelf life up to 21 days. Banana is greatly benefited from MAP using LDPE films due to reduced C_2H_4 sensitivity associated with high CO_2 and low O_2 (Aradya et al., 1993; Banks, 1985; Bhande, 2007).

Table 2.2: Major plastic films used and its properties (Source: Mangaraj et al., 2009)

Property	LDPE	PP	PVC
T_g (°C)	-120	-10	75-105
T_m (°C)	105-115	160-175	212
T_h (°C)	40-44	107-121	57-82
Density (g/cm^3)	0.92-0.94	0.89-0.91	1.35-1.41
FT (Mpa)	8-31	31-43	10-55
Elongation (%)	100-965	500-650	14-450
WVTR	375 - 500	100-300	750-15700
P_{O2}	6666 - 8750	2083-3916	154-10000
P_{CO2}	41662 - 54687	11706-22008	939-61000
P_{CO2}/P_{O2}	6.25	5.62	6.10

T_g (°C) : Glass transition temperature
T_m (°C) : Melting temperature
T_h (°C) : Heat distortion temperature, at 455 kPa
FT (Mpa): Tensile strength
WVTR : Water vapour transmission rate at 37.8°C and 90% RH (g µm/m^2 day)
P_{CO2} and P_{O2}: Permeability at 25°C for O_2 and CO_2, respectively (cm^3 µm/m^2-h-atm)

2.3.1.2 Polypropylene (PP)

Polypropylene (PP) is a linear addition polymer of propylene; resins used in packaging are predominantly isotactic. PP has the lowest density of the commodity plastics, 0.89–0.91 g/cm^3 (Table 2.4.1.1). Harder and more transparent than polyethylene, PP has good resistance to chemicals and is effective at baring water vapour. It's a theromoplastic which has high melting point (Table 2.2), thus makes it suitable for application where thermal resistance is required. In many applications, biaxially oriented film (BOPP) is preferred. BOPP film is explicitly used in MAP of food commodity (Mangaraj et al., 2009).

$$\mathbf{nCH_2 = CHCH_3 \rightarrow [CH_2 - CHCH_3]\text{-}_n}$$

Figure 2.3: Formula structure of polypropylene (PP)

2.3.1.3 Polyvinyl Chloride (PVC)

$$\mathbf{nCH_2 = CHCl \rightarrow [CH_2 - CHCl]\text{-}_n}$$

Figure 2.4: Formula structure of polyvinyl chloride (PVC)

Polyvinyl Chloride (PVC) is formed by combining PVC resin, produced by addition polymerization of vinyl chloride, with plasticizers and other additives to produce a flexible film. In general, the films are quite soft and flexible, easy to heat seal, and have excellent self-cling, toughness, medium strength, excellent resistance to chemical, resilience and clarity. Permeability is relatively high (Mangaraj et al., 2009).

2.4 Storage Temperature for Minimally Processed Fruits

According to Kader (2002), fresh cut products require low temperatures to reduce respiration rates, retard microbial growth and retard deterioration processes such as softening and browning. In general, fresh cut product should be stored at 0°C to 5°C to maintain quality. For chilling-sensitive fruits, in general, low temperatures retard the rate of deterioration of the fresh cut products more than they induce chilling injury.

CHAPTER 3

MATERIALS AND METHODS

3.1 Collection of Materials

The white flesh guava (*Psidium guajava* var. Kampuchea) fruits were obtained from Federal Agricultural Marketing Authority (FAMA) branch in Chendering, Terengganu. 90 fruits (approx. 35 kg) at commercial maturity with uniformity in size and shape (L 95–135 mm X W 85–110 mm), light green in colour and free from defects were selected for the study. The fruits were transported to Post-Harvest Technology Laboratory at Universiti Malaysia Terengganu.

Three types of plastic films which were obtained from the local plastic manufacturer in Kuala Terengganu were used: polyvinyl chloride (PVC) stretch film with a thickness of 0.048 mm; 18 low density polyethylene (LDPE) (L 242 mm X W 177 mm X T 0.049 mm) films; 18 polypropylene (PP) (L 244 mm X W 177 mm X T 0.048 mm) films and 72 polystyrene trays (L 130 mm X W 196 mm). Laboratory grade ascorbic acid used was purchased from a local supplier in Kuala Terengganu.

3.2 Methods

3.2.1 Fruit Preparation

Processing of fruits was carried out in an air-conditioned room under hygienic conditions. All surfaces that were used for the processing of fruits, utensils such as knives, spoons, containers and plastics films (LDPE, PP and polystyrene trays) were washed and disinfected with sodium hypochlorite solution (200 mgL^{-1}) (Teixeira et al., 2008).

The fruits were initially sorted and washed with tap water to remove any dirt upon arrival at the laboratory. Next, the fruits were cut longitudinally into slices and the seeds were removed (approx. L 90 mm X W 40 mm X T 20 mm). Immediately after cutting and the removal of seeds, the slices were immersed into 2% sodium hypochlorite solution for 3 minutes. The sanitized slices were then immersed into 1% ascorbic acid solution for another 3 minutes and drained for 1 minute before placing onto polystyrene trays randomly with 5 slices each tray.

The filled trays were immediately either wrapped with PVC stretch film or placed into LDPE and PP films and heat sealed. As the size of the LDPE and PP films were larger than the polystyrene trays, 3 sides of each film were heat sealed into the size of the polystyrene tray. The experimental design was laid out in a complete randomized design. Each treatment as shown in Table 3.2.1 represented a different packaging film used. The slices which were displayed on the polystyrene tray without wrapping or packing with any packaging films were used as the control. Distribution of guava slices among the treatments was illustrated and shown in Figure 3.1. The samples were kept in the cold room at 5±1°C for 15 days.

Table 3.1: Packaging films used for packaging of guava slices

Treatment	Packaging Materials used for Packaging of Guava Slices
T_0 (Control)	Without Packing (Control)
T_1	Low Density Polyethylene (LDPE) Film
T_2	Polyvinyl Chloride (PVC) Stretch Film
T_3	Polypropylene (PP) Film

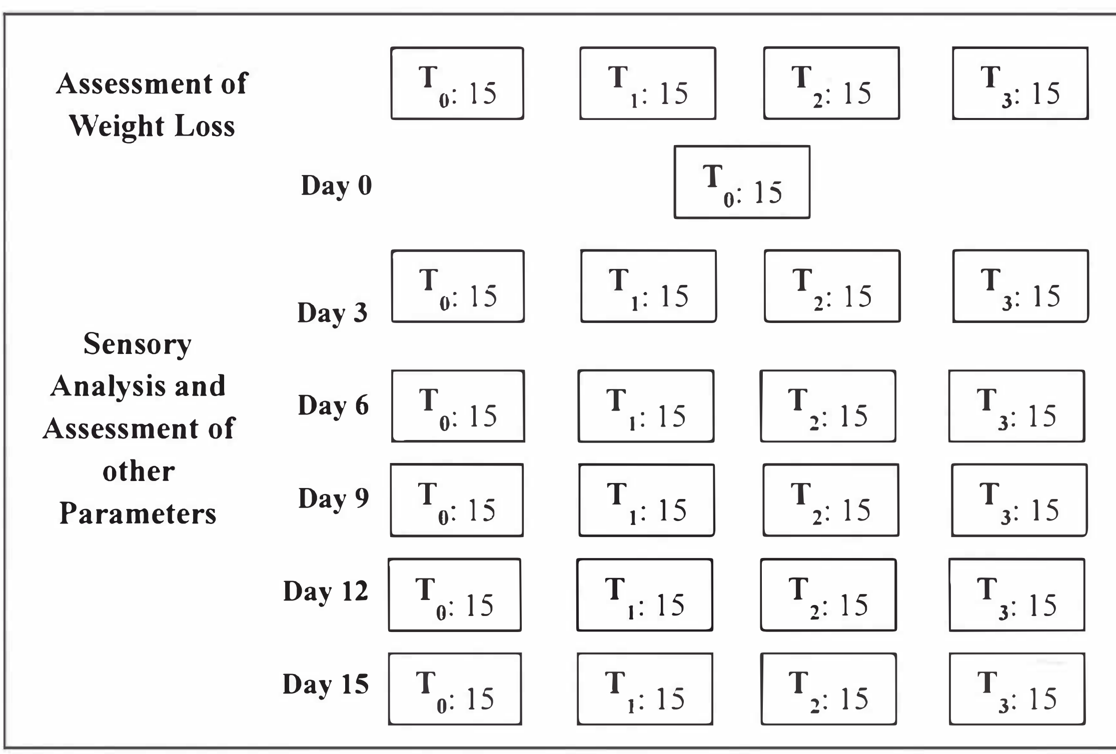

Figure 3.1: Distribution of guava slices among all treatments. A total of 105 slices with each treatment consisted of three replicates. Each replicate represented a tray of five guava slices which were arranged randomly.

3.2.2 Physicochemical Analysis

Physicochemical analysis was conducted at every three days interval (at day 0, 3, 6, 9, 12 and 15). Each treatment consisted of three replicates at each withdrawal; a replicate consisted of a single polystyrene tray with 5 guava slices (Diagram 3.2.1). However, only three slices from each replicate were used for the physico-chemical analysis whereas the remaining two slices were used for sensory analysis.

3.2.2.1 Percentage of Weight Loss

The same samples were used throughout the 15 days of storage. Each replicate including the polystyrene tray with the plastic material or without (control) was weighed by using a top pan balance at the beginning of the experiment (Initial Weight) and thereafter at every 3 days interval (Final Weight). Weight loss of the fruits was expressed as the percentage loss of initial weight according to the formula shown:-

$$\% \text{ Weight Loss} = \frac{\text{Initial Weight} - \text{Final Weight}}{\text{Initial Weight}} \text{ X } 100\%$$

3.2.2.2 Fruit Firmness

Slice firmness was determined by measuring the force (g) required for a 5 mm cylindrical probe (P5), attached to TA-XTplus Texture Analyzer (Texture Technologies Corp, USA), to penetrate the cut surface (midpoint between endocarp and skin) to a depth of 10 mm at test speed of 0.5 mms^{-1}, in accordance with Wu and

Abbott (2002) and Teixeira et al. (2008). Each measurement was conducted at the midpoint between the two ends of each slice.

3.2.2.3 Total Soluble Solids (TSS)

TSS analysis was used to determine the changes of sugar content within 3 days interval of observation. Each replicate was homogenized separately and the homogenate was filtered through a muslin cloth to obtain clear juice. The total soluble solids (TSS) of every filtered homogenate were determined by using handheld refractometer (Atago, Japan). Three readings per replicate were taken which were expressed as degree (°) of Brix.

3.2.2.4 Colour Evaluation

Colour measurements on the skin and the flesh were performed with a Minolta Chroma Meter (Model CR 200 Trimulus Colour Analyzer, Minolta Camera Co. Ltd., Japan) using the CIELAB colour parameters, L* [lightness], a* [greenness (-) to redness (+)], and b* [blueness (-) to yellowness (+)]. A standard white tile will be employed to calibrate the equipment. The colour of the fruits was recorded immediately after removal from the cold storage. Readings for the skin and flesh were taken at three different points on each slice and mean values of each slice was expressed as total colour change according to the formula provided below.:-

$$\text{Total Colour Change} = [(a_1 - a_0)^2 + (b_1 - b_0)^2 + (L_1 - L_0)^2]^{½}$$

3.2.3 Sensory Analysis

Sensory analysis was carried out by acceptance tests in 3 days interval along storage time to evaluate quality attributes such as colour, odour, texture, taste and overall acceptability. The samples of each treatment were presented monadically in completely randomized blocks, using transparent Low Density Polyethylene (LDPE) bags labeled with random alphanumeric codes. 15 untrained panelists who were students from Universiti Malaysia Terengganu and also guava consumers evaluated the samples. Scores were given in a 5-point hedonic scale where 1 = extremely unacceptable, 2 = unacceptable, 3 = neither acceptable nor unacceptable, 4 = acceptable and 5 = extremely acceptable. An average score of 2.5 was considered the limit of acceptability (Meilgaard et al., 1988).

3.3 Data Analysis

The experiment was laid out in a Completely Randomized Design (CRD). The data obtained was subjected to one-way analysis of variance (ANOVA) and the differences of means among treatments were determined for significance at $p<0.05$ using Tukey multiple comparision test. The statistical procedures were performed with MINITAB® Release 14.12.0.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Effects on Physico-Chemical Qualities of Fresh-Cut Guavas

4.1.1 Percentage of Weight Loss

Figure 4.1 indicated that weight loss of plastic-packed and non-packed guava slices increased throughout storage at 5°C. The non-packed guavas slices which were the control showed significantly ($p<0.05$) much higher weight loss throughout storage compared to the plastic-packed (Appendix A).

Weight loss which was often associated with water loss usually leads to undesirable quality changes (Kays, 1991). Minimally processing of fruits such as cutting reduces or eliminates the fruits' resistance (i.e. outer periderm or cuticle) towards transpirational movement of water vapour (Ben-Yehoshua, 1987). Unlike the packed guava slices whereby the plastic materials served as protective barriers from transpiration, the control was directly exposed to the outer atmosphere with a larger surface area to volume ratio, hence resulted in highest weight loss. The effects of dehydration are noticeable visually when weight loss exceeded 5% on day 3 and on day 9, the guava slices acquired a dehydrated, desiccated and shrivelled appearance. Augustin and Azizah (1988) also showed similar result on the study of intact guava which the skin of the fruit appeared to be tougher after stored at 5°C

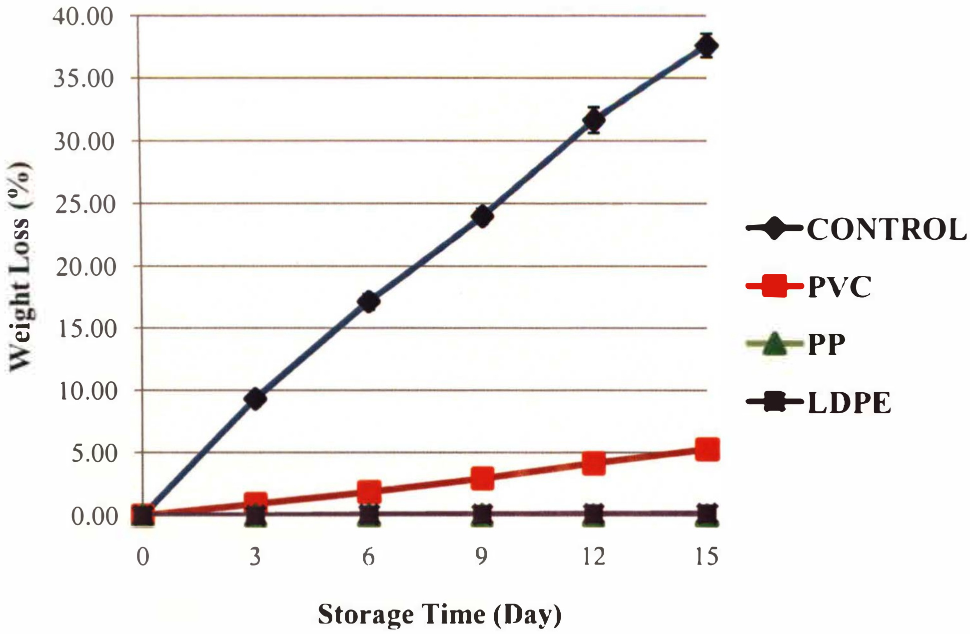

Figure 4.1: Effects of different packaging films on percentage of weight loss of fresh-cut guavas stored at 5±1°C for 15 days

PVC-packed guava slices had higher weight loss than LDPE- and PP-packed guavas with 5.27% being the highest on day 15 (Appendix A). The difference between PVC-packed with the LDPE- and PP-packed was significant ($p<0.05$) on the ninth day of storage. This result indicated that PVC film was less efficient in maintaining product moisture compared to the other two plastic films due to its relatively higher water vapour permeability (Mangaraj et. al, 2009). Hence, PVC facilitated the water vapour transmission from the guavas slices to the outer atmosphere which caused higher weight loss but at a much slower rate than control.

On the other hand, guava slices packed in LDPE and PP films did not suffer much from weight loss although increment of weight loss which was ranged between 0.02% and 0.16% was observed as storage period increased. The guava slices packed in PP films showed lower weight loss than those packed in LDPE films indicated that PP film had slightly slower water vapour transmission rate than LDPE material

(Mangaraj et. al, 2009). However, the difference between the two materials was insignificant (p>0.05).

4.1.2 Fruit Firmness

As expected, regardless of packed or unpacked guava slices with plastic films, firmness of the fruits decreased significantly (p<0.05) with increased storage period (Appendix B). This phenomenon was mainly attributed to the action of polygalacturonase and pectin esterase on the solubilization of pectic substrates which also occurred at low temperatures along with the presence of water, thus caused the cell tissues to soften and loses firmness (Lakshminarayana, 1980; Fayyaz et al., 1995).

Siddiqui and Bangerth (1996), studied on the structural changes in cell walls of apple during storage, reported that low temperature storage could cause a loss of rigidity in fruits due to the dissolution of the middle lamella and subsequent cell separation. Besides that, respiration of the guava slices also contributed to cell wall degradation which was attributed to the increasing activities of the cell wall hydrolytic enzymes (Kojima et al., 2004).

On day 3, there was an increased in firmness for the unpacked and packed guava slices. It was a result of the abrupt increase in proportion of cell wall constituents such as hemicelluloses, cellulose and lignin which might be due to loss of moisture (Marcelin et al., 1993; Jain, 2003). However, Figure 4.2 showed that the PP- and PVC-packed guava slices had higher increased in firmness. It was hypothesized that the sudden change in temperature and relative humidity upon storage was the cause of this physiological behaviour found in the guava slices.

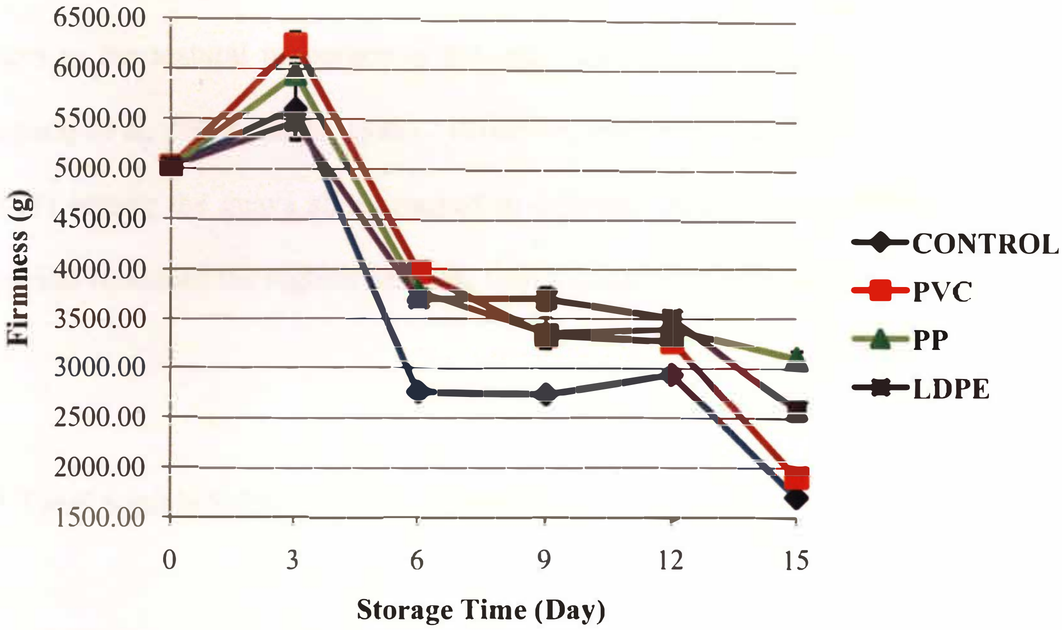

Figure 4.2: Effects of different packaging films on firmness of fresh-cut guavas stored at 5±1°C for 15 days

Apart from that, a sharp and significant ($p<0.05$) decreased in firmness between day 3 and day 6 for all unpacked and packed guava slices was observed (Figure 4.2). The steep decline in firmness was due to the loss of turgidity in fruits which was largely contributed by the transpiration process (Kojima et al., 2004).

Throughout the storage period, the unpacked guava slices (control) significantly ($p<0.05$) suffered the most losses in fruit firmness (Appendix B). The softening in fruits which caused the fruits to lose its crunchiness and juiciness occurred was due to the absence of a modified atmosphere which caused the cells to be directly exposed to the outer atmosphere. Hence, this fastened the respiration rate and weight loss through transpiration and softening of the fruits was induced (Rodrigues et al., 2006).

The guava slices packed with plastic films showed better retention in firmness compared to control. The three packaging films served as a gas barrier to reduce respiration and ethylene activities which was found to be closely correlated with changes in the textural properties of the cell wall during development and ripening (Mangaraj et al, 2009; Kader, 1986). However, there were no significant differences (p>0.05) among the guava slices packed in different plastic films until day 15 with PP-packed remained the highest firmness than the others (Appendix B).

4.1.3 Total Soluble Solids (TSS)

In Figure 4.3, the control displayed a trend line of an increase in total soluble solids throughout the storage period whereas the packed guava slices showed the opposite. The phenomenon observed in control might be due to high percentage of water being loss through transpiration and evaporation to the atmosphere which caused the soluble solids in the cells to become concentrated. From day 0 to day 6, there was a slight decline in the °Brix value of control indicated that the low percentage of water loss did not affect the total soluble solids concentration in control. The effect of water loss was only prominent on day 9 onwards when the high loss of water (23.98%) was sufficient to cause a rise in proportion of the total soluble solids in the cells (Figure 4.3).

The packed guava slices showed a decline in total soluble solids throughout the whole storage period. A similar effect was observed by Durigan et al. (2005) with guava halves wrapped in PVC film or kept in a PET container with lid and stored at 5°C for 12 days. Moreover, a study by Gaspar et al. (1997) also described that plastic wrapped guavas had lower total soluble solids content than the unwrapped when stored at 8°C for two to three weeks. According to Kays (1991) and Seymour et al.

(1993), the reduction in total soluble solids content was due to senescence of the fruits. Since percentage of weight loss of plastic-packed guava slices was much lower compared to control, hence the decrease in total soluble solids became obvious.

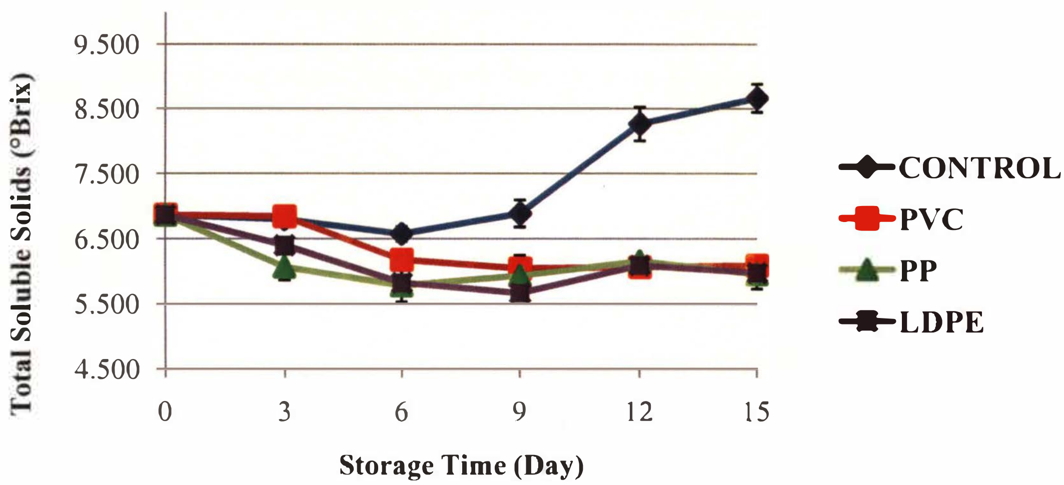

Figure 4.3: Effects of different packaging films on total soluble solids of fresh-cut guavas stored at 5±1°C for 15 days

Despite there was a significant difference ($p<0.05$) between the control and the plastic-packed guavas, it was not shown until day 12 onwards (Appendix C). Figure 4.3 showed that the guava slices packed in LDPE and PP bag had lower total soluble solids than PVC-packed. However, the difference was insignificant ($p>0.05$).

Besides that, the total soluble solids in PVC- and PP-packed guava slices showed no significant difference ($p>0.05$) between the storage period albeit the gradual decline of total soluble solids. Thus, this indicated that these two films had better retention in total soluble solids than control and LDPE-packed guava slices.

4.1.4 Total Colour Change

The guava slices initially had white flesh with light green skin. Figure 4.4(a) showed that the total colour change on skin for all packed or unpacked guava slices increased along with storage time. The flesh of the fruits also showed the same result with increasing total colour change over storage time (Figure 4.4(b)).

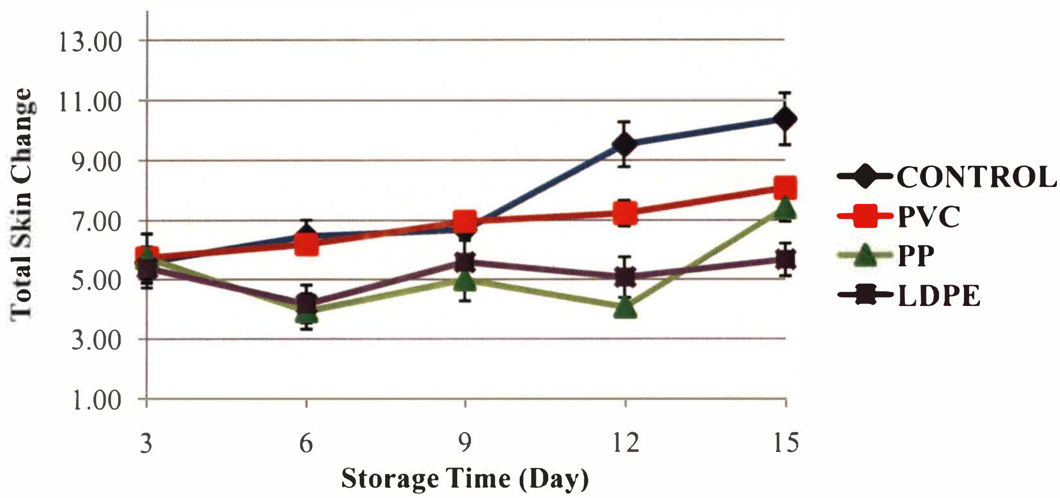

Figure 4.4(a): Effects of different packaging films on total colour change of skin of fresh-cut guavas stored at 5±1°C for 15 days

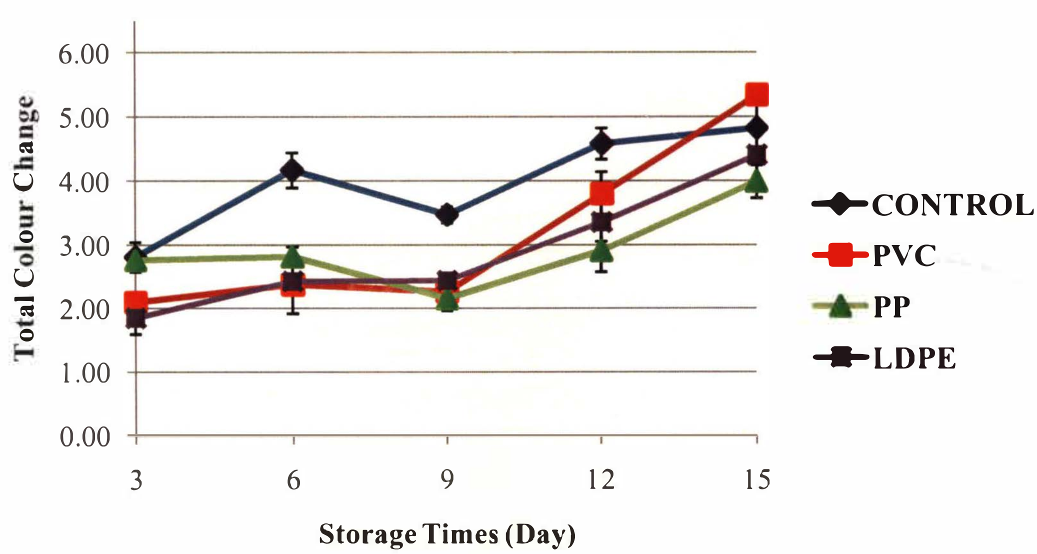

Figure 4.4(b): Effects of different packaging films on total colour change of flesh of fresh-cut guavas stored at 5±1°C for 15 days

Although statistical analysis did not show significant results (p>0.05) among the guava slices, Figure 4.4(a) and 4.4(b) showed that plastic packed guava slices had lower value of total colour change compared to control. The degradation of chlorophyll due to the increase in the activities of chlorophyll degrading enzymes such as chlorophyllase, chlorophyll oxidase and peroxidise during respiration was one of the major contribution to the total colour change on the skin of the guava slices (Jain et al., 2003).

Apart from that, discolouration such as browning on the skin and flesh was due to rapid activity of polyphenol oxidase (PPO) within the cells which was enhanced by cutting and disruption of compartmentation of cells. Ascorbic acid was used to control browning of the cells by reducing o-quinone back to phenolics compound before they form brown pigments. However, its effect was minimal and temporary, as it was being consumed as well through the process (Baeza, 2007). Therefore, browning of the fruits increased with storage time as ascorbic acid degraded and lost its ability as an antibrowning agent.

In Figure 4.4(a), PVC-packed guava slices showed higher total colour change on skin throughout the 15 days and on flesh since day 9 onwards. Gaspar et al. (1997) reported that LDPE-packed guavas had a two days delay on loss of skin colour and fruits firmness compared to PVC-packed guavas. On day 12, there was a significant difference (p<0.05) among the samples (Appendix D–1) which showed that the PP-packed guavas slices had the least total colour change on skin. This was an indication that PP was able to provide the least changes in skin colour for up to 12 days.

4.2 Effect on Sensory Quality of Fresh-Cut Guavas

The sensory qualities for the plastic packed and the unpacked guava slices showed a decline throughout the 15 days of storage. It was also observed that the plastic packed guava slices showed good sensory characteristics than the control for up to 12 days with an average score of 3.0 and above.

The control only showed satisfying sensory characteristics until day 3. Although there was no significant difference ($p>0.05$) on the total colour change of skin and flesh among the plastic packed and unpacked, however, the colour score of the control was significantly lower ($p<0.05$) since day 3 onwards through visual inspection (Appendix E–1). On day 6, the odour, texture, taste and overall acceptability were scored below 2.5 which was the limited acceptability level, in accordance to Meilgaard et al. (1988) (Appendix E–2; Appendix E–3; Appendix E–4; Appendix E–5). Hence, the sensory analysis for control was terminated after day 6. The poor scores was a result of the absence of a modified atmosphere which exposed the guava slices directly to the atmosphere and caused rapid deterioration processes such as toughness, off flavour and off odour apart from excessive water loss which caused poorer appearance.

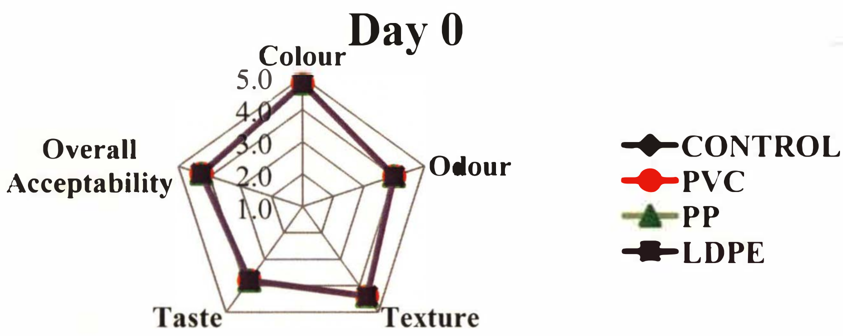

Figure 4.5(a): Effects of different packaging films on the sensory characteristic of fresh-cut guavas at day 0

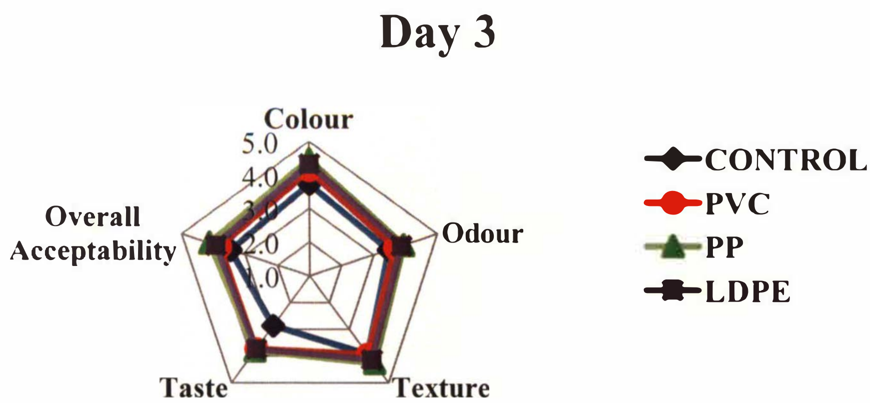

Figure 4.5(b): Effects of different packaging films on the sensory characteristics of fresh-cut guava at day 3

Pinheiro et al. (2009) reported that the peroxidase was responsible for the degradation of fresh cut products including skin and flesh darkening, the destructuring of the cellular membranes, which reduced their selective permeability and even promoting chain reactions that lead to free radical formation which could cause damage to the organelles and membranes. All of these were able to alter the sensory characteristics of the product. Therefore, a high rate of enzymatic activity implied a high deterioration potential of the sensory characteristics of the fruit, reducing their shelf life.

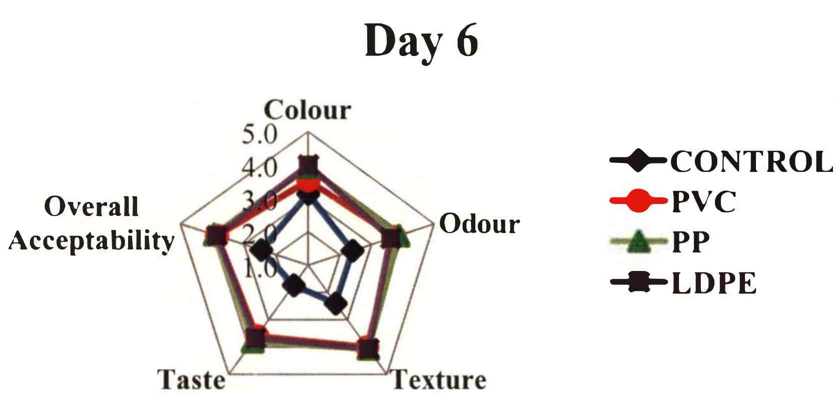

Figure 4.5(c): Effects of different packaging films on the sensory characteristics of fresh-cut guavas at day 6

Day 9

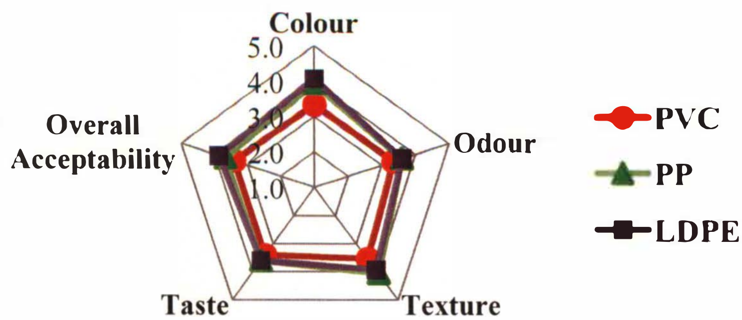

Figure 4.5(d): Effects of different packaging films on the sensory characteristics of fresh-cut Guavas at day 9

For colour score, all of the packed guavas showed significant changes ($p<0.05$) throughout storage period although there was no significant difference ($p>0.05$) among the packed guava slices of different packaging materials used (Appendix E–1). On day 15, PP-packed guava slices showed a significant difference ($p<0.05$) with a higher colour score compared to the other two plastic packed which showed scores below 2.5 (Figure 4.5(f)). This was supported by the total colour change which showed PP-packed guava slices had lower total colour change on the skin and flesh compared to LDPE- and PVC packed even though there was no significant difference ($p>0.05$).

Day 12

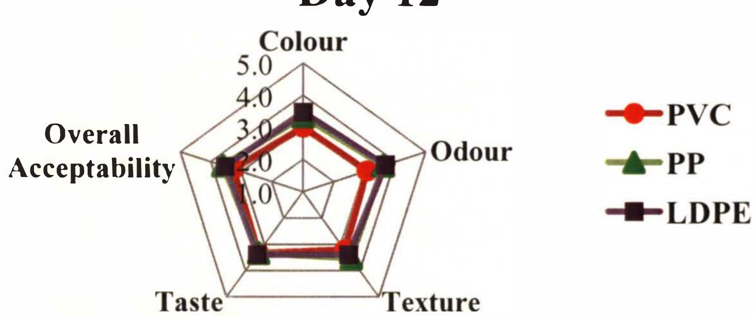

Figure 4.5(e): Effects of different packaging films on the sensory characteristics of fresh-cut guavas at day 12

There was no significant difference ($p>0.05$) among the plastic packed guava slices on the other attributes tested such as odour and texture (Appendix E–2 and Appendix E–3). Both of the attributes that asserted in the guavas slices of different packaging films were found above the acceptability level of 2.5. However, the score for taste found on day 15 was significantly lower ($p<0.05$) in PVC-packed guava slices which might be due to its gas barrier properties that enhanced the anaerobic activities in cells and caused the development of off flavour (Figure 4.5(f)).

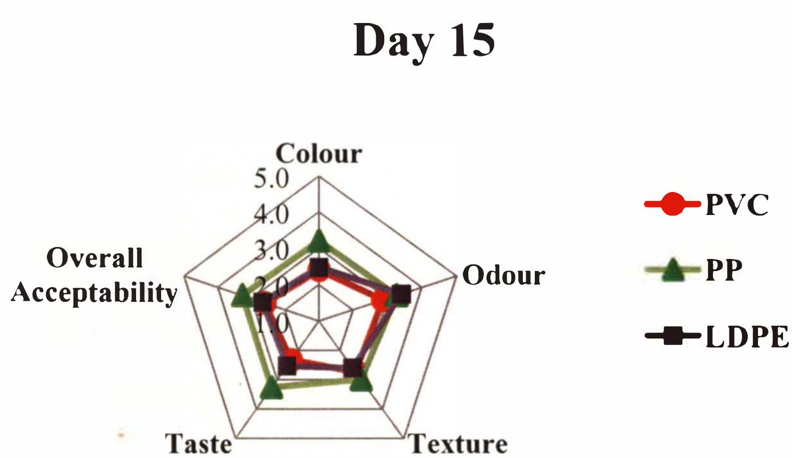

Figure 4.5(f): Effect of different packaging materials on the sensory characteristics of guava slices at day 15

The overall acceptability of the guava slices did not differ much among the guava slices packed with different packaging films. However, it is shown that PP-packed guava slices had a significantly ($p<0.05$) slower decline in the overall acceptability score compared to the other two plastic packed guava slices (Appendix E–5). Hence, this indicated that the guava slices packed in PP bag had better quality retention until day 15 in terms of colour, odour, taste and texture which gained acceptability by the consumers (Figure 4.5(f)).

CHAPTER 5

CONCLUSION

5.1 Conclusion

The guava slices packed in plastic materials showed better retention in quality compared to control throughout the 15 days of storage. Weight loss was significantly minimal in plastic packed guava slices compared to control. Besides that, the plastic packed guava slices also showed higher firmness retention after day 3. Therefore, the results presented indicated the importance of packaging material used for fresh-cut guavas storage in maintaining its physico-chemical and sensory qualities.

Even though PP, LDPE and PVC showed satisfactory results in the quality retention of fresh-cut guavas, the materials were still unable to inhibit the ongoing metabolic processes in fruit cells that caused senescence. Thus, total soluble solids content was found to be gradually decreasing with time and browning on the flesh and skin was observed despite the fruits were stored under modified atmosphere condition.

Each material had its own properties that suits packaging of certain types of food. Through this study, it was found that PVC which was the most recently used packaging material in packaging of minimally processed fruits was not able to prevent weight loss as efficiently as LDPE and PP due to its poor water vapour barrier properties. Besides that, sensory analysis carried out indicated that guava slices wrapped with PVC stretch film received poor results on colour and taste which was also a result of its properties with poor gas permeability.

On the other hand, there was no significant difference ($p>0.05$) LDPE and PP in the packaging of fresh cut guavas although guava slices packed in PP bag had higher sensory score and lower total colour change. This might be due to the thickness of LDPE which was 0.001mm thicker than PP, thus exerted the same effect as PP. However, PP had higher clarity than LDPE that could facilitate in food displaying. Besides that, the material is also economical and affordable. Hence, PP was found to be the most suitable packaging material for fresh-cut guavas packaging. It should be in consideration as well to replace the frequent use of PVC and LDPE in many food packaging industries.

5.1 Suggestions for Further Study

In this study, the major problem occurred was the rapid browning on the skin of the guava slices. This may be due to that the ascorbic acid concentration used was not sufficient to retain the skin from browning throughout the 15 days. Hence, it was suggested that a higher concentration of ascorbic acid instead of 1% or a combination with another effective antibrowning agent such as citric acid should be studied on the effect of the quality of fresh-cut guavas.

Previous studies indicated that by providing a modified atmosphere with lower oxygen and/or higher carbon dioxide was desirable in extending the shelf life of fresh produces. Teixeira et al. (2008) studied on the response of minimally processed carambola to chemical treatments and low-oxygen atmospheres. It was found that the quality of the carambola was significantly improved by combining both treatments. Hence, it was suggested that a study on the manipulation of the oxygen content in the packed fresh-cut guavas, incorporating with different concentrations of ascorbic acid as dipping treatment should be conducted. It is to determine whether the combination of treatments is helpful in prolonging the shelf life of fresh-cut guavas.

Apart from that, the thickness of the packaging materials would affect the gas permeability and water vapour permeability of the films. Thicker polyethylene (PE) films which were 0.03 mm and 0.05 mm showed to enhance tissue lignification, resulting in higher internal browning of loquat compared to thinner PE film (0.02 mm) (Ding et al., 2002). Hence, another suggestion for future study would be to determine the best PP film thickness which could better retain the quality of fresh-cut guavas.

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APPENDIX A

Effects of different packaging films on the percentage weight loss of fresh-cut guavas stored at 5±1°C for 15 days

Treatment	Weight Loss (%)				
	Day 3	Day 6	Day 9	Day 12	Day 15
Control	9.310 ± 1.964^{Ad}	17.130 ± 2.186^{Ac}	23.977 ± 2.053^{Ab}	31.623 ± 3.552^{Aa}	37.597 ± 3.271^{Aa}
PVC	0.927 ± 0.050^{Be}	1.883 ± 0.270^{Bd}	2.960 ± 0.226^{Bc}	4.167 ± 0.162^{Bb}	5.270 ± 0.485^{Ba}
PP	0.000 ± 0.000^{Ba}	0.020 ± 0.035^{Ba}	0.020 ± 0.035^{Ca}	0.030 ± 0.030^{Ca}	0.030 ± 0.030^{Ca}
LDPE	0.000 ± 0.000^{Ba}	0.090 ± 0.090^{Ba}	0.103 ± 0.111^{Ca}	0.147 ± 0.090^{BCa}	0.157 ± 0.081^{Ca}

Note: Values are means of 3 replicates with 1 reading per replicate (n=3) ± standard deviation. Capital letters (ABCDE) show significant difference ($p<0.05$) between treatments. Lower case letters (abcde) show significant difference ($p<0.05$) between storage duration.

APPENDIX B

Effects of different packaging films on the firmness of fresh-cut guavas stored at 5±1°C for 15 days

Treatment	Firmness (Force, g)					
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Control	5036.5 ± 279.6^{Aa}	5611.7 ± 1104.5^{Aa}	2757.1 ± 189.7^{Bbc}	2734.1 ± 150.4^{Abc}	2940.0 ± 194.0^{Ab}	1705.3 ± 149.8^{Bc}
PVC	5036.5 ± 279.6^{Ab}	6251.6 ± 442.2^{Aa}	3968.1 ± 273.6^{Ac}	3332.0 ± 290.3^{Ac}	3269.6 ± 192.6^{Ad}	1906.1 ± 280.9^{Be}
PP	5036.5 ± 279.6^{Ab}	5956.0 ± 352.3^{Aa}	3768.4 ± 410.7^{Ac}	3351.9 ± 531.3^{Ac}	3392.7 ± 332.0^{Ac}	3093.6 ± 270.6^{Ac}
LDPE	5036.5 ± 279.6^{Aa}	5473.3 ± 555.8^{Aa}	3701.0 ± 280.3^{Ab}	3699.9 ± 393.3^{Ab}	3498.3 ± 288.2^{Ab}	2576.0 ± 336.1^{ABc}

Note: Values are means of 3 replicates with 3 readings per replicate (n=9) ± standard deviation. Capital letters (AB) show significant difference ($p<0.05$) between treatments. Lower case letters (abcde) show significant difference ($p<0.05$) between storage duration.

APPENDIX C

Effects of different packaging films on the total soluble solids of fresh cut guavas stored at 5±1°C for 15 day

Treatment	Total Soluble Solids (°Brix)					
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Control	6.867 ± 0.334^{Ab}	6.800 ± 0.133^{Ab}	6.578 ± 0.391^{Ab}	6.889 ± 0.713^{Ab}	8.267 ± 0.902^{Aab}	8.666 ± 0.757^{Aa}
PVC	6.867 ± 0.334^{Aa}	6.844 ± 0.269^{Aa}	6.178 ± 0.214^{Aa}	6.045 ± 0.713^{Aa}	6.067 ± 0.467^{Ba}	6.089 ± 0.192^{Ba}
PP	6.867 ± 0.334^{Aa}	6.067 ± 0.696^{Aa}	5.778 ± 0.844^{Aa}	5.933 ± 0.306^{Aa}	6.156 ± 0.204^{Ba}	5.956 ± 0.102^{Ba}
LDPE	6.867 ± 0.334^{Aa}	6.400 ± 0.267^{Aa}	5.822 ± 0.367^{Aab}	5.667 ± 0.000^{Ab}	6.089 ± 0.234^{Bab}	5.978 ± 0.857^{Bab}

Note: Values are means of 3 replicates with 3 readings per replicate (n=9) ± standard deviation. Capital letters (AB) show significant difference ($p<0.05$) between treatments. Lower case letters (ab) show significant difference ($p<0.05$) between storage duration.

APPENDIX D–1

Effects of different packaging films on the total colour change of skin of fresh cut guavas stored at 5±1°C for 15 days

Treatment	Total Colour Change (Skin)				
	Day 3	Day 6	Day 9	Day 12	Day 15
Control	5.562 ± 1.878^{Aa}	6.463 ± 1.898^{Aa}	6.676 ± 1.253^{Aa}	9.528 ± 2.571^{Aa}	10.375 ± 2.998^{Aa}
PVC	5.727 ± 2.820^{Aa}	6.181 ± 0.323^{Aa}	6.958 ± 0.696^{Aa}	7.232 ± 1.508^{ABa}	8.081 ± 1.065^{Aa}
PP	5.717 ± 2.913^{Aa}	3.926 ± 2.061^{Aa}	4.991 ± 2.475^{Aa}	4.067 ± 0.097^{Ba}	7.420 ± 1.612^{Aa}
LDPE	5.380 ± 2.273^{Aa}	4.175 ± 2.211^{Aa}	5.573 ± 2.882^{Aa}	5.070 ± 2.360^{ABa}	5.663 ± 1.907^{Aa}

Note: Values are means of 3 replicates with 9 readings per replicate (n=27) ± standard deviation. Capital letters (AB) show significant difference ($p<0.05$) between treatments. Lower case letter (a) shows no significant difference ($p>0.05$) between storage duration.

APPENDIX D–2

Effects of different packaging films on the total colour change of flesh of fresh-cut guavas stored at 5±1°C for 15 days

Treatment	Total Colour Change (Flesh)				
	Day 3	Day 6	Day 9	Day 12	Day 15
Control	2.807 ± 0.822^{Aa}	4.165 ± 0.943^{Aa}	3.470 ± 0.446^{Aa}	4.579 ± 0.842^{Aa}	4.822 ± 1.292^{Aa}
PVC	2.094 ± 0.448^{Ab}	2.372 ± 1.572^{Ab}	2.258 ± 1.024^{Ab}	3.800 ± 1.181^{Aab}	5.337 ± 0.363^{Aa}
PP	2.756 ± 0.458^{Aa}	2.810 ± 0.557^{Aa}	2.150 ± 0.490^{Aa}	2.908 ± 1.160^{Aa}	3.989 ± 0.891^{Aa}
LDPE	1.846 ± 0.866^{Ab}	2.423 ± 0.432^{Ab}	2.433 ± 0.317^{Ab}	3.357 ± 1.052^{Aab}	4.403 ± 0.286^{Aa}

Note: Values are means of 3 replicates with 9 readings per replicate (n=27) ± standard deviation. Capital letter (A) shows no significant difference ($p>0.05$) between treatments. Lower case letters (ab) show significant difference ($p<0.05$) between storage duration.

APPENDIX E–1

Effect of different packaging films on the sensory quality (colour) of fresh-cut guavas stored at 5±1°C for 15 days

Treatment	Sensory Acceptance Score (1–5) of Colour					
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Control	4.800 ± 0.414^{Aa}	3.733 ± 0.799^{Bb}	3.133 ± 0.743^{Bb}	-	-	-
PVC	4.800 ± 0.414^{Aa}	4.133 ± 0.516^{ABb}	3.533 ± 0.516^{ABbc}	3.333 ± 0.900^{Ac}	3.000 ± 0.756^{Acd}	2.400 ± 0.737^{Bd}
PP	4.800 ± 0.414^{Aa}	4.467 ± 0.516^{Aab}	3.933 ± 0.594^{Ab}	3.933 ± 0.884^{Ab}	3.333 ± 0.724^{Abc}	3.200 ± 0.561^{Ac}
LDPE	4.800 ± 0.414^{Aa}	4.333 ± 0.488^{Aab}	4.000 ± 0.756^{Abc}	4.067 ± 0.594^{Ab}	3.467 ± 0.743^{Ac}	2.467 ± 0.743^{Bd}

Note: Values are means of 15 panellists (n=15) ± standard deviation. Capital letters (AB) show significant difference ($p<0.05$) between treatments. Lower case letters (abcd) show significant difference ($p<0.05$) between storage duration. Score 2.5 is the limited acceptability level.

APPENDIX E–2

Effect of different packaging films on the sensory quality (odour) of fresh-cut guavas stored at 5±1°C for 15 days

Treatment	Sensory Acceptance Score (1–5) of Odour					
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Control	4.000 ± 0.655^{Aa}	3.467 ± 0.990^{Aa}	2.400 ± 0.910^{Bb}	-	-	-
PVC	4.000 ± 0.655^{Aa}	3.667 ± 0.817^{Aab}	3.733 ± 0.594^{Aab}	3.333 ± 0.900^{Aab}	3.067 ± 0.704^{Ab}	2.867 ± 0.916^{Ab}
PP	4.000 ± 0.655^{Aa}	3.933 ± 0.594^{Aa}	3.867 ± 0.516^{Aab}	3.600 ± 0.633^{Aab}	3.600 ± 0.633^{Aab}	3.267 ± 0.800^{Ab}
LDPE	4.000 ± 0.655^{Aa}	3.867 ± 0.834^{Aa}	3.600 ± 0.986^{Aa}	3.600 ± 0.737^{Aa}	3.667 ± 0.900^{Aa}	3.400 ± 0.633^{Aa}

Note: Values are means of 15 panellists (n=15) ± standard deviation. Capital letters (AB) show significant difference ($p<0.05$) between treatments. Lower case letters (ab) show significant difference ($p<0.05$) between storage duration. Score 2.5 is the limited acceptability level.

APPENDIX E–3

Effect of different packaging films on the sensory quality (texture) of fresh-cut guavas stored at 5±1°C for 15 days

Treatment	Sensory Acceptance Score (1–5) of Texture					
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Control	4.400 ± 0.633^{Aa}	3.933 ± 0.884^{Aa}	2.400 ± 0.910^{Bb}	-	-	-
PVC	4.400 ± 0.633^{Aa}	3.933 ± 0.704^{Aab}	4.000 ± 0.845^{Aab}	3.533 ± 1.061^{Aab}	3.200 ± 0.862^{Ab}	2.733 ± 1.100^{Ab}
PP	4.400 ± 0.633^{Aa}	4.267 ± 0.594^{Aab}	4.067 ± 0.704^{Aab}	4.067 ± 0.799^{Aab}	3.533 ± 0.834^{Ab}	3.000 ± 1.069^{Ab}
LDPE	4.400 ± 0.633^{Aa}	4.133 ± 0.640^{Aa}	4.067 ± 0.799^{Aab}	3.933 ± 0.799^{Aab}	3.400 ± 0.828^{Ab}	2.600 ± 0.737^{Ac}

Note: Values are means of 15 panellists (n=15) ± standard deviation. Capital letters (AB) show significant difference ($p<0.05$) between treatments. Lower case letters (abc) show significant difference ($p<0.05$) between storage duration. Score 2.5 is the limited acceptability level.

APPENDIX E–4

Effect of different packaging films on the sensory quality of minimally-processed guavas stored at 5±1°C for 15 days

Treatment	Sensory Acceptance Score (1–5) of Taste					
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Control	3.800 ± 0.676^{Aa}	2.867 ± 0.743^{Bb}	1.733 ± 0.799^{Bc}	-	-	-
PVC	3.800 ± 0.676^{Aa}	3.733 ± 0.704^{Aa}	3.600 ± 0.737^{Aa}	3.400 ± 1.056^{Aa}	3.333 ± 0.976^{Aa}	2.333 ± 0.900^{Bb}
PP	3.800 ± 0.676^{Aa}	3.800 ± 0.676^{Aa}	3.800 ± 0.561^{Aa}	3.600 ± 0.737^{Aa}	3.333 ± 0.724^{Aa}	3.267 ± 0.704^{Aa}
LDPE	3.800 ± 0.676^{Aa}	3.733 ± 0.961^{Aa}	3.667 ± 0.976^{Aa}	3.600 ± 0.737^{Aa}	3.400 ± 0.828^{Aab}	2.533 ± 0.916^{ABb}

Note: Values are means of 15 panellists (n=15) ± standard deviation. Capital letters (AB) show significant difference ($p<0.05$) between treatments. Lower case letters (abc) show significant difference ($p<0.05$) between storage duration. Score 2.5 is the limited acceptability level.

APPENDIX E–5

Effect of different packaging films on the sensory quality (overall acceptability) of fresh-cut guavas stored at 5±1°C for 15 days

Treatment	Sensory Acceptance Score (1–5) of Overall Acceptability					
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Control	4.267 ± 0.458^{Aa}	3.467 ± 0.743^{Bb}	2.467 ± 0.516^{Bc}	-	-	-
PVC	4.267 ± 0.458^{Aa}	3.800 ± 0.676^{ABa}	3.800 ± 0.676^{Aa}	3.400 ± 0.828^{Ab}	3.267 ± 0.884^{Abc}	2.600 ± 0.910^{Ac}
PP	4.267 ± 0.458^{Aa}	4.133 ± 0.516^{Aab}	3.933 ± 0.594^{Aab}	3.667 ± 0.617^{Aab}	3.600 ± 0.507^{Ab}	3.267 ± 0.800^{Ab}
LDPE	4.267 ± 0.458^{Aa}	3.933 ± 0.594^{ABab}	3.867 ± 0.640^{Aab}	3.867 ± 0.516^{Aab}	3.533 ± 0.834^{Ab}	2.667 ± 0.724^{Ac}

Note: Values are means of 15 panellists (n=15) ± standard deviation. Capital letters (AB) show significant difference ($p<0.05$) between treatments. Lower case letters (abc) show significant difference ($p<0.05$) between storage duration. Score 2.5 is the limited acceptability level.

APPENDIX F

SENSORY EVALUATION OF FRESH-CUT GUAVAS

Date : _______________

Time : _______________

Name : _______________

SCORE:

1 – Extremely unacceptable
2 – Unacceptable
3 – Neither unacceptable or acceptable
4 – Acceptable
5 – Extremely acceptable

INSTRUCTION: There are 4 samples to be tested. Try each sample and evaluate the sample according to the attributes below.

(A) ColourR143	QC831	LL551	KF640

(B) Aroma

MR143	QC831	LL551	KF640

(C) Texture

MR143	QC831	LL551	KF640

(D) Taste

MR143	QC831	LL551	KF640

(E) Overall Acceptability

MR143	QC831	LL551	KF640

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Race : Chinese

Gender : Female

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