UNIVERSITI PUTRA MALAYSIA

EFFECT OF VARIOUS ACTIVE PACKAGING SYSTEM ON QUALITY AND MICROBIAL STABILITY OF FRESH-CUT CANTALOUPE (Cucumis melo L. var. Reticulates cv. Glamour)

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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EFFECT OF VARIOUS ACTIVE PACKAGING SYSTEM ON QUALITY AND MICROBIAL STABILITY OF FRESH-CUT CANTALOUPE (*CUCUMIS MELO* L. VAR. RETICULATES CV. GLAMOUR)

By

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July 2015

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A study was conducted to determine the effect of initial packaging atmosphere by using different packaging system on the quality and microbial stability of fresh-cut Cantaloupe and to investigate the effect of different absorbers. Fresh-cut Cantaloupe was stored in two types of containers; specifically a rigid container and semirigid container. Each of containers was sealed under different conditions. These were Polypropylene (PP) film and Low-Density Polyethylene (LDPE) films. Between the two types of film, Low-Density Polyethylene (LDPE) film material was shown to have better quality of both containers, being the rigid and semirigid containers. It was found that the physico-chemical properties (firmness, colour, total soluble solid, titratable acidity) of fresh-cut Cantaloupe were maintained over 18 days of storage. Meanwhile, for pH value, there are no significant effects in the storage time for all type of packages. Microbial analysis (total plate count and yeast and mould) were found to increase over storage, but LDPE materials were found to have lower TPC compared to the other package. The packages did not exhibit any effects on the YM counts during the 18 days of storage. For the oxygen, carbon dioxide, respiration rate and ethylene production, the LDPE film materials could maintain the quality of about 11 days with acceptable level of oxygen (above 2%) and a moderate level of carbon dioxide (2%-12%). LDPE shows the lowest value of respiration rate and ethylene production in the rigid and semirigid container. The effects of absorbers were investigated after the selection of the seal package materials for rigid and semirigid containers. Two types of absorbers were used namely, oxygen absorber and ethylene absorber. There were four different conditions created in this experiment. The first container does not contain absorber. The second container contained an oxygen absorber. The third container contained ethylene absorber, and finally, the samples included both types of absorbers, being oxygen and ethylene absorbers. It was found that the physico-chemical of fresh-cut Cantaloupe (firmness, colour, total soluble solid, titratable acidity) was maintained over 18 days of storage for all types of conditions in an active packaging system. The microbial analysis (total plate count (TPC) and yeast and mould (YM)) were increased throughout the storage time and the storage can last until day 11 for microbial spoilage. It was found that all types of absorbers able to reduce the oxygen concentration of fresh-cut Cantaloupe but too little of oxygen may cause

anaerobic metabolism and production of off flavors and odors. The results showed that the absorbers had reduced the oxygen level of oxygen tremendously (below than 2%). The percentage of carbon dioxide had shown the same amount for both containers (2%-12% of CO_2). For respiration rate and ethylene production, the ethylene-oxygen absorbers had shown the lowest value for fresh-cut Cantaloupe for both containers. Therefore, the fresh-cut Cantaloupe packaged with LDPE film was found to maintain the quality and microbial stability up to 11 days of postharvest storage for rigid and semirigid container at 2±1°C. The fresh-cut Cantaloupe packaged with LDPE film can be consumed until day 11. However, the package associated with oxygen and ethylene absorbers can be only being consumed up to day 7.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
Sebagai Memenuhi Keperluan untuk Ijazah Sarjana Sains

KESAN KEPELBAGAIAN SISTEM PEMBUNGKUSAN AKTIF KE ATAS KUALITI DAN KESTABILAN MIKROB BAGI TEMBIKAI SEGAR POTONG (*CUCUMIS MELO* L. VAR. RETICULATES CV. GLAMOUR)

Oleh

SYAHIDAH BINTI KAMARUDDIN

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Satu kajian telah dijalankan untuk menentukan kesan atmosfera awal pembungkusan dengan menggunakan sistem pembungkusan yang berbeza terhadap kualiti dan kestabilan mikrob daripada buah tembikai segar potong dan untuk mengkaji kesan penyerap yang berbeza. Tembikai segar potong disimpan di dalam dua jenis bekas khususnya bekas tegar dan separa tegar. Dalam eksperimen yang pertama, setiap bekas telah dimeterai pada keadaan yang berbeza. Ini adalah filem polietilena(PP) dan filem berkepadatan rendah polietilena (LDPE). Antara kedua-dua jenis filem ini, bahan filem daripada berkepadatan rendah polietilena (LDPE) telah menunjukkan kualiti yang lebih baik bagi kedua-dua bekas yang tegar dan separa tegar. Ia telah mendapati bahawa sifat-sifat kimia fisiko (ketegasan, warna, jumlah kandungan pepejal larut,keasidan) tembikai segar potong dapat kekal selama 18 hari tempoh penyimpanan. Sementara itu, nilai pH, didapati tiada kesan yang ketara dalam masa penyimpanan bagi semua jenis pakej. Kestabilan mikrob iaitu kiraan jumlah plat (TPC) dan yis dan kulat(YM) telah meningkat sewaktu tempoh penyimpanan. Walau bagaimanapun, filem daripada berkepadatan rendah polietilena (LDPE) mempunyai TPC yang lebih rendah berbanding dengan pembungkusan yang lain. Semua jenis pembungkusan tidak memberikan apa-apa kesan untuk kiraan YM sepanjang tempoh 18 hari penyimpanan. Bagi oksigen, karbon dioksida, kadar respirasi dan pengeluaran etilena, filem daripada bahan berkepadatan rendah polietilena (LDPE) dapat mengekalkan kualiti kira-kira 11 hari dengan tahap oksigen (lebih 2%) dan tahap sederhana karbon dioksida (2%-12%). Filem daripada bahan berkepadatan rendah polietilena (LDPE) menunjukkan nilai terendah bagi kadar respirasi dan pengeluaran etilena bagi bekas yang tegar dan separa tegar. Kesan penyerap yang berbeza dikaji selepas pemilihan bahan bahan pembungkusan filem bagi bekas yang tegar dan separa tegar. Dua jenis penyerap yang digunakan iaitu serapan oksigen dan serapan etilena. Terdapat empat keadaan yang berbeza di dalam eksperimen ini. Bekas pertama tidak mengandungi penyerap. Bekas kedua mengandungi penyerap oksigen. Bekas ketiga mengandungi penyerap etilena dan yang terakhir, sampel kajian

mengandungi kedua-dua jenis penyerap iaitu penyerap oksigen dan penyerap etilena. Ia menunjukkan bahawa sifat-sifat kimia-fisiko (ketegasan, warna, jumlah kandungan pepejal larut,keasidan) dapat dikekalkan selama 18 hari tempoh penyimpanan bagi semua jenis keadaan dalam sistem pembungkusan yang aktif. Kestabilan mikrob (kiraan jumlah plat (TPC) dan yis dan kulat (YM)) telah meningkat sepanjang tempoh penyimpanan dan simpanan boleh dilanjutkan sehingga hari yang ke 11 bagi kerosakan mikrob. Semua jenis penyerap boleh mengurangkan kepekatan oksigen tembikai segar potong tetapi jika terlalu sedikit tahap oksigen, ia boleh menyebabkan metabolisme anaerobik dan kerosakan pada rasa dan bau. Hasil kajian menunjukkan bahawa serapan amat mengurangkan tahap oksigen (di bawah paras 1%). Peratusan karbon dioksida menunjukkan jumlah yang sama untuk kedua-dua bekas iaitu (2 % - 12 %). Untuk kadar respirasi dan pengeluaran etilena, serapan oksigen-etilena menunjukkan nilai yang terendah bagi tembikai segar potong untuk kedua dua bekas. Oleh itu, tembikai segar potong yang dibungkus dengan LDPE didapati dapat mengekalkan kualiti dan kestabilan mikrob sehingga hari ke 11 penyimpanan lepas tuai untuk bekas tegar dan separa tegar pada 2±1°C. Tembikai segar potong yang dibungkus dengan filem LDPE hanya boleh dimakan sehingga 11 hari. Manakala, bungkusan yang mengandungi penyerap oksigen dan etilena hanya boleh dimakan sehingga 7 hari sahaja.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

a*	Greenness
ANOVA	One way analysis of variance
AP	Active Packaging
b*	Yellowness
C*	Chromaticity
C_2H_4	Ethylene
$CaCl_2$	Calcium chloride
Ca-Lactate	Calcium Lactate
CFU	Colony-Forming Unit
CO_2	Carbon Dioxide
COO	Sample volume in ml
CRD	Completely Randomized Design.
cv	Cultivar
DMRT	Duncan's Multiple Range Test
DRBC	Dichloran Rose Bengal Chloramphenicol agar
EP1	Volume in ml NaOH up to endpoint (pH=8.5)
FDA	Food and Drug Administration
FID	Flame Ionization Detector
GC	Gas Chromatography
h°	Hue angle
H_2O_2	Hydrogen Peroxide
HDPE	High-Density polyethylene
$KMnO_4$	Potassium permanganate

L*	Lightness
LDPE	Low-Density Polyethylene
LLDPE	Linear Low-Density Polyethylene
MA	Modified Atmosphere
MAP	Modified Atmosphere Packaging
MGC	Mitsubishi Gas Chemical
NaOCl	Sodium Hypochlorite
NaOH	Sodium Hydroxide
O_2	Oxygen
OTR	Oxygen Transmission Rate
PCA	Plate Count Agar
PE	Polyethylene
PET	Polyethylene Terephthalate
PP	Polypropylene
PPM	Part Per Million
PPO	Polyphenol Oxidases
PS	Polystyrene
PVC	Polyvinyl Chloride
R	Rigid
RH	Relative humidity
SR	Semirigid
SAS	Statistical Analysis Software
SSC	Soluble Solid Content
TA	Titratable Acidity

TA	Texture Analyzer
TPC	Total Plate Count
TSS	Total Soluble Solid
USDA	United State Department of Agriculture
YM	Yeast and Mould

CHAPTER 1

INTRODUCTION

Consumers of late have developed particular demands on the freshness, health, convenience and safety of their food (James and Ngarmsark, 2010). Fresh-cut products, also recognised as minimally processed products, are highly delicate or perishable foods (Watada et al., 1996). These foods have been peeled, trimmed and cut into a ready-to-eat form (IFPA, 2000) and are in high demand for retail and food services because of their convenience, quality, safety and reduced waste (Watada et al., 1996; Luna-Guzm´an, 1997; Robert et al., 2003; Olivas and Barbosa-Canovas, 2005). Changes in lifestyles have increased the demand for ready-to-eat food such as fresh processed fruits and vegetables (Benedetti et al., 2008). Within this context, the fruits are presented in a condition that is suitable for direct and instant consumption without the need to process it for consumption (Olivas and Barbosa-Canovas, 2005). When selecting the fruits, consumers gauge its appearance and avoid fruits that are bruised or damaged. Food packaging is one of the chief factors that affect the quality of fresh-cut fruit products. Packaging considerations are vital to food products as it will protect the food from the external environments, provide information about the food contained within the package and afford convenience to consumer food handling and food storage.

There have been many innovations in food packaging due to current consumer demands in advanced technology in terms of food packaging. Usually, for fresh-cut fruits, the treatments that have been used to extend the shelf life of food include using shock, ozone, chemical treatments sterilisers, ultraviolet radiation and heat. However these methods are not suitable for food packaging even though these technologies are popularly used in the United States and Europe. These methods can cause low consumer acceptability, reduce the freshness, and lessen the nutritional quality (Erturk and Picha, 2008; González -Aguilar et al., 2008). Another food packaging method that is commonly used to preserve the food is known as Modified Atmosphere Packaging (MAP). MAP of fresh-cut fruits and vegetables refer to the technique of sealing actively respiring produce in plastic film packages to modify the O_2 and CO_2 levels within the package atmosphere (Mir and Beaudry, 2004). MAP is effective in maintaining quality because of its effects on the modification of gas composition in the package headspace (Schlimme and Rooney, 1994; Jacxsens et al., 2002; Kim et al., 2003).The levels of O_2 and CO_2 within a package depend on the interaction between commodity respiration and the permeability properties of the packaging film or microperforations (Beaudry et al., 1992; Kader et al., 1997). There are two approaches for creating film barriers. The first approach employs continuous films that control the movement of O_2 and CO_2 into or out of the package. The second approach uses perforated films with small holes or microperforations as the primary of gas exchange. Both of the films show different permeability to O_2 and CO_2.

Cantaloupe is categorized as a climacteric fruit where it exhibits higher respiration and ethylene production rates, a quicker rate of softening and shorter shelf-life than the non-climacteric fruits. When O_2 levels are lowered, the respiration of the produce begins to decrease and generally continues to do so with lowering O_2 levels down to a level where anaerobic respiration takes place (Barrett et al., 2004). Microperforated films are not suitable for fresh-cut Cantaloupe because perforated packages are for produce that has a high O_2 demand (Mir and Beaudry, 2004). Perforated packaging is more suitable for vegetables that have a high demand for O_2 (Gonzalez et al., 2008). Packaging films provide a wide range of different materials such as polypropylene (PP), polyethylene terephthalate (PET), polyethylene (PE) and polyvinyl chloride (PVC). Polypropylene is used largely in MAP, in two forms: continuous and perforated film (Mattoss et al., 2012). The selection of the plastic film packaging material strives to achieve equilibrium between the oxygen demand of the product (oxygen consumption by respiration) (Cantwell and Suslow, 1999). An important aspect in the application of modified atmosphere packaging is the selection of packaging materials (Barrett et al., 2004).

In general, there are three types of formats that are most commonly used in fresh-cut produce modified atmosphere packaging, namely rigid packaging, semirigid packaging and active packaging. Rigid packaging offers high impact strength, high stiffness, and high barrier properties, often exceeding industry standards for quality and durability (Anon, 2005). In rigid packaging, there are a number of designs commonly used in fresh-cut produce applications. The most common rigid container and tray includes clamshell, snap-on lid, sealable and easy-peel lidding film. These methods are utilized to close or seal the tray or container. Frequently these styles of rigid packages are referred to as natural aspiration packages, meaning that the final atmosphere in the package can vary according to how tight the lid is attached or "snapped" onto the container (Toivonen et al., 2009). For semi-rigid packaging, the materials are those which are neither rigid nor flexible in nature. There are four main groups of semi-rigid packages, namely paperboard packages, flexible pouches, plastic cups and trays (George, 2001).

Active packaging refers to the incorporation of certain additives into packaging film or within packaging containers (rigid and semirigid) with the aim of maintaining product shelf life (Day, 1989). Common examples of an active packaging include absorbent packaging (Toivonen et al., 2009). Absorbent packaging describes ability of packages to absorb liquids or gases produced by fresh-cut produce (Ozdemir and Floros, 2004). Active packaging with oxygen absorbers dynamically decreases the oxygen concentration in the package headspace, even down to 0.01%, thus slow down the oxidation processes, colour changes, yeast and mould growth, that are occurring in foods (Smith et al., 1990; Andersen and Rasmussen 1992). Accumulation of gases such as ethylene, the ripening hormone, can significantly reduce shelf life. These trends have initiated a huge amount of research in the field of active and intelligent packaging to provide the market with packaging technologies designed to keep produce fresh, since it is impossible to attain the optimum quality characteristics with passive plastic package for such highly deteriorative and metabolically active produce (Ozdemir and Floros, 2004).The active packaging technologies that have been developed for fruits and vegetables are oxygen absorbers, carbon dioxide emitters, moisture absorbers, ethylene absorbers, antimicrobial agent releasers, and others (Han and Floros, 2007). Oxygen absorber is an active element used in the packaging system to absorb residual oxygen that remains after the package is sealed that originated from the product respiration and the package permeability (Mehyar and Han, 2010). Controlling the oxygen concentration provides benefits in protecting the produce against the quality deterioration associated with oxygen, such as off-flavor formation, color change, nutritional value reduction, and safety losses (Sanjeev and Ramesh, 2006). Meanwhile, ethylene causes the increase in fruit respiration rate and textural and color changes in climacteric fruits (Toivonen and Brummell, 2008). Ethylene absorber acts to remove the exogenous ethylene from the atmosphere surrounding the produce by oxidizing it to ethylene glycol, which later decomposes to carbon dioxide and water (Martinez-Romero and Bail´en, 2007). Carbon dioxide reduces the fruit respiration rate and blocks the synthesis of endogenous ethylene (Mehyar and Han, 2010). Several studies have been published on the use of oxygen absorbers, ethylene absorbers and their beneficial effects with fruit and vegetables. Bolin and Huxsoll (1989) showed that oxygen scavengers improve firmness of peaches. Charles et al. (2005) observed that oxygen absorbers did not modify the gas equilibrium composition and improved the quality of fresh endives, and Tarr and Clingeleffer (2005) have reported that oxygen absorbers minimize color changes of dried vine fruit.

1.1 Problem Statements

Consumers generally purchase fresh-cut produce for convenience, freshness, nutrition, safety and the eating experience. Many soft fresh-cut fruit items need to be packaged in rigid and semirigid containers, possibly lidded with a plastic film that permits development of a modified atmosphere (Cantwell and Suslow, 1999). Initial atmospheric modification within a modified atmosphere package is a consequence of the respiratory O_2 uptake and CO_2 development of the packaged produce and the rate of gas transfer across the package (Al-Ati and Hotchkiss, 2002). Excessive levels of O_2 in a package may allow for cut surface discoloration to occur, while too little O_2 may cause anaerobic metabolism and production of off flavors and odors (Beaulieu and Gorny, 2001). Anaerobic conditions enable lactic acid bacteria to cause spoilage, such as souring of the product, gas production and slime formation (James and Ngarmsak, 2010). The purpose of an enclosed system is to provide a barrier to microorganisms and to prevent oxygen from degrading the food. Packaging film with the right permeability can create desirable modified atmosphere of fresh fruit and vegetables (Zhang and Chen, 1996). Senesi et al., (2000) found that after 7 days at refrigeration temperature, the environment within the package had become anaerobic and high in CO_2, stressing the importance of careful selection of a MAP film and initial gas atmosphere. The type of packaging, for example, flexible, rigid and semirigid plays a very important role for the fresh-cut Cantaloupe to retain the quality of the products. Flexible packages were commonly used in previous MAP studies. However, only a few studies used rigid and semirigid containers, and among those were trays overwrapped with films. Little information on quality changes of fresh-cut fruits in rigid and semirigid structures with different sealed packaging films are available in literature.

Incorporating oxygen and ethylene-absorbing materials in the container of the packaging material could prove to be more efficient (Huff, 2009). Packaging materials for fresh-cut fruits should have higher permeability to gases and ethylene, or contain gas absorbers to cope with high respiration and ethylene production (Mehyar and Han, 2010). However, there is no report on the effects of active packaging using ethylene and oxygen absorber combined with modified atmosphere on the quality and shelf life of fresh-cut Cantaloupe.

1.2 Scope and Limitations of the study

This study was conducted to determine the effects of different packaging systems on the quality and microbial stability of fresh-cut Cantaloupe. Fresh-cut cantaloupe was stored in two types of containers; specifically a rigid container and semirigid container. The container holds 350ml and polypropylene (PP) was used for both containers. Each container utilized different sealants, being polypropylene (PP) film and low-density polyethylene (LDPE) film. Between the two films, only the PP film or LDPE film was used to study the effects of different absorbers for the fresh-cut Cantaloupe. Two types of absorbers were used, namely oxygen absorber and ethylene absorber. There were four different conditions created in this experiment for comparison. In this study, Statistical Analysis System (SAS) 9.3 system was used for statistical analysis.

1.3 Outline of the thesis

This study is focused on the quality and microbial stability of fresh-cut Cantaloupe through the utilization of various active packaging systems used in this study. Chapter 2 introduces the attributes of Cantaloupe, its benefits in medication, the postharvest storage of Cantaloupe fruits, the processing of fresh-cut Cantaloupe, calcium treatments employed for fresh-cut fruits, the usage of rigid and semirigid containers, effects of the packaging materials, the usage and effects of modified atmosphere packaging (MAP) and active packaging on its quality. Chapter 2 also provides a literature review of published works from related research. The purpose of this chapter is to convey the information and ideas that have been established on the topic, solutions and methods as well as discussions. The research methodology was described in Chapter 3. The descriptions include materials, methods, procedures, equipments, and statistical analysis used for the entire experiment conducted. Chapter 4 discusses the results of analysis and discussions on the experiment conducted. The physico-chemical, microbial stability, gas measurement, respiration rate and ethylene production were discussed and evaluated. Lastly, chapter 5 summarises the main findings obtained in this research. The recommendations included are also suggested for future research.

1.4 Objectives

This research has two main objectives as listed below;

1) To determine the effects of initial packaging atmosphere by using different packaging systems on the quality and microbial stability of fresh-cut Cantaloupe.
2) To investigate the effects of different absorbers.

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