EFFECT OF [illegible] COMBINED WITH CINNAMIC ACID COATING ON POSTHARVEST QUALITY OF MANGO FRUIT (*Mangifera indica* L.) VARIETY CHOKANAN STORED UNDER AMBIENT TEMPERATURE

TEY HUAN YOON

FACULTY OF AGROTECHNOLOGY AND FOOD SCIENCE
UNIVERSITI MALAYSIA TERENGGANU
2010

EFFECTS OF SODIUM ALGINATE COMBINED WITH CINNAMIC ACID COATING ON POST-HARVEST LIFE OF MANGO (*MANGIFERA INDICA L.*) VAR. CHOKANAN STORED UNDER AMBIENT TEMPERATURE

By
Tey Huan Yoon

Research Report submitted in partial fulfillment of
the requirements of the degree of
Bachelor of Science in Agrotechnology (Post Harvest Technology)

DEPARTMENT OF AGROTECHNOLOGY
FACULTY OF AGROTECHNOLOGY AND FOOD SCIENCE
UNIVERSITI MALAYSIA TERENGGANU
2010

ENDORSEMENT

The project report entitled **EFFECTS OF SODIUM ALGINATE COMBINED WITH CINNAMIC ACID COATING ON POST-HARVEST LIFE OF MANGO (*Mangifera indica L.*) VAR. CHOKANAN STORED UNDER AMBIENT TEMPERATURE**

by **TEY HUAN YOON** , Matric No. **UK 15187**

has been reviewed and corrections have been made according to the recommendations by examiners. This report is submitted to the Department AGROTECHNOLOGY in partial fulfillment of the requirement of the degree of BACHELOR OF SCIENCE IN AGROTECHNOLOGY (POST HARVEST TECHNOLOGY) , Faculty of Agrotechnology and Food Science, University Malaysia Terengganu.

....

DR. ADZEMI MAT ARSHAD

Date:

DR. ADZEMI MAT ARSHAD
Ketua
Jabatan Agroteknologi
Fakulti Agroteknologi dan Sains Makanan
Universiti Malaysia Terengganu
21030 Kuala Terengganu

....

DR. CHUAH TSE SENG

Date:

DECLARATION

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

Signature : ____________________

Name : TEY HUAN YOON

Matric No.: UK 15187

Date : 22 APRIL 2010

ACKNOWLEDGEMENT

First of all, I wish to convey my deepest appreciation and sincere thanks to my supervisor Dr. Adzemi Mat Arshad, for his supervision, assistance, and guidance on my final year project that enable this project to run smoothly. Dr. Adzemi also gives me a lot of opinions which enable me to improve and complete my whole final year project. I am very much indebted to him. I wish to express my heartfelt gratitude to my second supervisor, Dr. Chuah Tse Seng for his suggestion, advice, guidance and comments during all phase of the study. I want to extent my gratitude to all technical staff and lab assistants of Post-harvest Technology of University Malaysia Terengganu for their cooperation and practical assistance. I also want to express my appreciation to my coursemates for their precious support, opinion and advice. Last but not least, my appreciation goes to those who have contributed to this project.

ABSTRACT

This study was conducted to examine the effects of sodium alginate (2% or 4%) combined with cinnamic acid (4mM or 6mM) on shelf life of mango fruits (*Mangifera indica* L.) stored at 25°C for fifteen days. The effectiveness of the treatments in extending shelf life was measured by determining the post-harvest quality and post-harvest disease of mango fruits. Coated mango fruits had a greater quality and visual acceptability as compared to that of uncoated mango fruits. Mangoes coated with a combination of 4% sodium alginate and 6mM cinnamic acid delayed the external colour change, retaining fruit firmness and reduced total soluble solid change throughout the storage while mangoes coated with a combination of 2% sodium alginate and 6mM cinnamic acid had a strong barrier effect against the pathogenic microorganisms and fungi decay besides delaying ripening and reducing weight loss of mango fruits without impeding the development of sweetness of mango fruits. The results of this study suggests that mangoes coated with a combination of 2% sodium alginate and 6mM cinnamic acid is the most effective treatment in maintaining post-harvest quality and prolonging the shelf life of mangoes.

ABSTRAK

Kajian ini dijalankan untuk mengkaji kesan kombinasi rawatan natrium alginat (2%, 4%) dan asid cinamik (4mM, 6mM) ke atas jangka hayat buah mangga (*Mangifera indica* L.) yang disimpan pada suhu 25°C selama lima belas hari. Keberkesanan rawatan-rawatan ini dalam memanjangkan hayat buah mangga telah dinilai dengan menentukan ciri-ciri kualiti dan penyakit lepas tuai buah. Manga yang dirawat mempunyai kualiti dan ciri visual yang lebih baik berbanding dengan mangga yang tidak dirawat. Buah mangga yang dirawat dengan kombinasi 4% natrium alginat dan 6mM asid cinamik dapat melewatkan perubahan warna buah, menggurangkan kandungan pepejal terlarut dan mengekalkan kesegahan buah manakala buah mangga yang dirawat dengan kombinasi 2% natrium alginate dan 6mM asid cinamik dapat menghalang serangan daripada penyakit di samping melambatkan proses permasakan dan mengurangkan kehilangan berat buah tanpa menjejaskan perkembangan kemanisan buah mangga. Hasil kajian mencadangkan bahawa buah mangga yang dirawat dengan kombinasi 2% natirum alginat dan 6mM asid cinamik ialah kombinasi yang terbaik untuk mengekalkan kualiti dan memanjangkan tempoh buah mangga.

TABLE OF CONTENTS

CHAPTER 4 RESULTS AND DISCUSSION

CHAPTER 5 CONCLUSION

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS/ ABBREVIATIONS

<	-	Less than
>	-	More than
g	-	Gram
%	-	Percentage
^{o}C	-	Degree Celsius
mM	-	Milimolar
w/v	-	Weight per volume
v/v	-	Volume per volume
s	-	Second
min	-	Minute
SA	-	Sodium alginate
CINN	-	Cinnamic acid
RH	-	Relative humidity
TSS	-	Total soluble solid

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of study

Mango (*Mangifera indica* L.), a member of the family Anacardiaceae, genus *Mangifera* is one of the most celebrated tropical fruits. According to FAO statistics in the year 2000, at least 87 countries produced mango totaling slightly over 25 million tonnes. The shelf life of mango varies among the varieties with 4 to 8 days at room temperature while 2 to 3 weeks in cold storage at 13°C (Carrillo-Lopez et al., 2000). There are various factors affecting the biosynthesis of aroma volatiles in mango. These include cultivar, growing conditions, fruit maturity at harvest, fruit senescence, fruit parts, storage and fruit-ripening temperature, controlled atmosphere storage and other postharvest treatments (Khuyen et al., 2008).

" Green packaging" such as edible packaging is replacing the non-degradable films in food packaging that cause "white pollution" to the environment since edible packaging is biodegradable, not harmful to environment because they are obtained from both animal and vegetable agricultural products, thus reducing packaging waste (Petersen et al., 1999). Edible films and coatings are thin layers of edible material which can be eaten by the consumers and applied on or even within foods by wrapping, brushing, immersing or spraying to form a barrier against the transmission of gases in order to form a lower oxygen and carbon dioxide permeabilities, vapours and solutes while giving a mechanical protection (Donhowe et al., 1994). Therefore, edible coating is an ideal alternative to fully use in fruit product by replacing the plastic film.

Alginate is derived from marine brown algae *Phaeophyceae* (Mancini and McHugh, 2000). The polymer is a well-established industrial product obtained commercially by harvesting brown seaweeds. The capacity of alginate, gellan or low methoxyl pectin is forming a strong gels or insoluble polymers (Mancini and McHugh, 2000). Alginate is of interest as a potential biopolymer film or coating component because of its unique colloidal properties, which include thickening, stabilizing, suspending, film forming, gel producing, and emulsion stabilizing. It is a hydrophilic colloidal carbohydrate extracted with dilute alkali from various species of brown seaweeds (Phaeophyceae).

Cinnamic acid and cinnamic acid derivatives provide a natural protection or barrier against infections by pathogenic microorganisms in plants and fruits (Mazza and Miniati, 1993; Davidson, 1997). Besides, cinnamic acid has low toxicity in rats and rabbits, implying its safety for animals and human beings (Hoskins 1984). It is also known that it exerts some favorable effects on plant growth (Strobel 2001). Commercial cinnamic acid, a phenylacrylic acid structure compound, is used by converting it to its esters such as methyl, ethyl, and benzyl cinnamate. Cinnamic acid and its derivatives including esters and carboxylic functional derivatives are used as important components in flavours, perfumes, synthetic indigo and pharmaceuticals.

1.2 Problem Statement

Mango ripens rapidly after harvest around 3 to 9 days. This has restricted the long distance transportation of mango (Gomez-Lim, 1997). It is estimated that about 20–25% of the harvested fruits and vegetables are decayed by pathogens during post-harvest handling in the developed countries (El-Ghaouth et al., 2004; Droby, 2006; Zhu, 2006; Singh and Sharma, 2007). Many pathogens including *Botrytis cinerea* (grey mold rot), *Fusarium solani* (fruit rot) and *Phytophthora capsici* (fruit rot) cause severe pre- and post-harvest damage to agriculture. To minimize the economic losses caused by these fungi, various fungicides are used over this fruit on a massive scale. For example, carbendazim for dipping mangoes are very highly toxic to fish and also linked with cancer while dimethoate is very toxic to animals.

Common postharvest treatments on mangoes are less efficient. For instance, Noomhorm and Tiasuwan, (1995) and Bender et al. (2000) reported that controlled atmosphere is cost prohibitive although controlled storage has been shown to extend the shelf life of mango while Gonzalez-Aquilar et al. (1997) stated that modified atmosphere can slow down the ripening process but it causes off flavour of mango. It is rather difficult to implement this method because of complicated interactions between the product and the packaging material. On the other hand, Baldwin et al. (1999) stated coatings on mango are less studied and developed in the past few years. Although coating method can efficiently prolong shelf life of fruit and vegetables but not all coating materials are suitable to food products. For instance, carnauba wax is efficient in weight loss reduction and organoleptic quality but it is less efficient in maintaining external and internal textures of mango fruit.

1.3 Significance of Study

Mango is highly appreciated in many of the European, Middle Eastern and Far-Eastern Countries, thus opening tremendous opportunities for its exports as well as the fetch premium prices in the world markets. However, due to rapid ripening of mango after harvest within 6 days under ambient temperature, ripe mango fruit undergoes numerous physicochemical, biochemical and microbiological changes during storage which is susceptible to many diseases (Salunkhe and Kadam, 1998). These changes and diseases are accompanied by economical post-harvest repercussions because of weight losses as well as occurrence of decay due to fungal plant pathogens (Valverde et al., 2005). The current market demand is focusing on the quality of agricultural produce under a safety and environment friendly production practices. This situation can be seen through the FAO/WHO Codex Alimentarus Commission standards for pesticide residues act as reference points for sanitary and phytosanitary (SPS) measures in the year 2004 (Hussain et al., 2002). On the other hand, the world food shortage and continually increasing demand for high quality nutritious foods have paved the way for improved methods of storage for fresh fruits and vegetables of both domestic and export trades. Therefore, alternative approaches need to be developed for delaying ripening and reducing post-harvest decay of mango fruits (Zhu et al., 2008). Fruit coating is one of the options available to prolong the shelf life and quality of mango fruits with a convenient and relatively inexpensive method by replacing the fungicides used in post-harvest treatment that is able to cause hazard to environment, plant as well as human health. To improve the physical and functional properties of coating materials used in mango fruits, alginate is combined with cinnamic acid to reduce weight loss of mango fruit and increase barrier against the invasion of fungal pathogen, and subsequently extend the edible period of mango.

1.4 Objective

The objective of this project was to determine suitable concentration of alginate combined with cinnamic acid to extend shell life of mango under ambient temperature.

CHAPTER 2

LITERATURE REVIEW

2.1 Mango (*Mangifera indica L.*)

Mango (*Mangifera indica L.*), is one of the most popular tropical fruits. Maturity stage of mango depends on the basis of external colour and growth. Mango is a well adapted fruit with a good annual crop may be 200 to 300 fruits per tree and it is a one of the major fruit crop cultivated in Malaysia with several important commercial varieties of mango. Mangoes are generally harvested at a physiological mature stage and ripened for optimum fruit equality. The flesh ranged from pale-yellow to deep-orange. It is essentially peach-like but much more fibrous and it is extremely juicy with a flavor range from very sweet to subacid to tart. Mango contains a high nutrition value with 62.1 to 63.7 calories energy per 100g of ripe mango flesh. Mango contains protein from 0.36 to 0.40g, carbohydrate from 16.20 to 17.18g, calcium from 6.1 to 12.8mg and vitamin A (carotene) from 0.135 to 1.872mg (Duckworth, 1979, Amin and Hanif, 2002) with a minimum and maximum level of food constituents derived from various analyses made in Cuba, Central America, Africa and India. Mango is nearly round, oval, ovoid- oblong or kidney- shaped. They range from 6.25 to 25 cm in length and from a 1.8 to 2.26 kg in weight. (Morton, 1987). The development physiology of mango fruit entails changes in size, weight, and several major enzymes.

Mango is a climacteric fruit, and its period of ontogeny is characterized by a series of biochemical changes initiated by the autocatalytic production of ethylene and increase in respiration (Rhodes, 1980). Apart from a respiratory peak observed during development of mango with several patterns of respiration in mango: (a) a preclimacteric phase lasting 3 days with slow release of CO_2, (b) a climacteric peak rise extending up to 6 days with sudden sprut in CO_2 production, (c) a climacteric peak occurring between 6 and 10 days with softening of the fruit, and (d) a postclimacteric phase lasting from 10 to 14 days with a decrease in CO_2 production resulting in edible ripeness of fruit followed by senescence (Krishnamurthy and Subramanyam, 1970). Visual assessment by using the score from 1 to 5. 1 - 100% green, 2 - 75% green, 3 - 50 green/yellow, 4 - 75% yellow, and 5 - 100% yellow. Besides, the export quality mangoes can be categorised into three grades according to the fruit weight viz., Category-I (200-250 g), Category-II (251-300 g) and Category-III (300-350 g) (FAO, 2004).

Mango variety Chokanan originates from Thailand and is also locally called “Mangga madu” or “Honey mango”. Chokanan is the most popular mango grown in Malaysia. It is an oval-shaped mango, weighing 250-350g. The fruit is of average size with an attractive yellow skin when ripe and it is very sweet and aromatic as long as it is harvested at proper maturity. It is also a favourite for eating as a green mango because it is not sour when mature green (Nor et al., 2008). Plenty mango products are daily produced, including canned mango slices, jams, juices, squashes, nectars, pulp, beverages, pickle, raw mango slices and others. It is well known for the nutritional value, delicious taste and aromatic (Rome, 1990).

2.2 Post harvest treatment

The sensitivity of mango fruit to disease and low temperature, and perishability due to ripening or softening of the fruit, limits its potential in terms of storage, packaging and transport (Mitra and Baldwin, 1997). Moreover, packaging, storage and delivery induce the oxidation reactions and contamination by pathogenic microorganisms as the main factors reducing the shelf life of mango (Lee et al., 2004). Therefore, the post-harvest treatment is very important to prolong the shelf life of fruit without any deterioration of quality post- harvest treatment is usually for export purpose, but not for local marketing due to cost and market demand. For exports, the stem of the fruits is cut approximately at a length of 1 cm from the fruit with the help of sharp scissors. Then, the fruits are kept upside down for two hours so that the latex flows out from the fruit completely. Utmost care should be taken while cutting the stem of the fruit so that latex drop does not fall on the fruit. Wooden boxes are commonly used for packaging and transportation of mango fruits. However, the developed corrugated fibreboard boxes of 5 kg and 10 kg capacity for packing and shipping of mango fruits successfully as an alternative to traditional nailed wooden boxes prevent them from getting bruised and spoiled during storage and transportation (FAO, 2004).

Sap injury is regarded as the most serious problem to external fruit quality of mango because the sap exudes out when the stem (pedicel) of a mango fruit is broken then it is spreading over the fruit peel thus causes serious skin damage symptomizing as brownish black streaks or blotches over the skin (Campbell, 1992 and Loveys et al., 1992). Apart from the skin damages, the fruit peel colour development also seems to be interfered by the sticking of sap. The sap also attracts soil particles and micro organisms towards it due to its sugary and sticky nature (Campbell, 1992). Ultimately, the fruit quality is affected negatively, degrading the cosmetic appeal of fruit, reducing consumer acceptance and storage life and resulting in high economic losses. Muhammad et al. (2008) reported that desapping of mango fruits with lime and mango wash can induce better returns to the stakeholders by controlling sap injury and improving the cosmetic look of mango fruits.

The primary importance of post-harvest treatment is to reduce the respiration, water loss as well as the growth of pathogens with a maximum shelf life under an excellent condition. The first edible film from fruits was produced by McHugh et al. (2000). It was produced from apple puree and different amounts of fatty acid, alcohol, bee wax and vegetable oil. It acted as an appropriate barrier against oxygen loss especially in relatively low or medium humidity plus to reduce browning reaction, loss of moisture and maintained the flavor of sliced apple. It can be used for coating of walnut, almond and bakery products. Peng and Jiang (2003) reported that the chitosan coating has been proven in delaying the activity of polyphenoxidase and peroxidase, associated with discolouration then delay the colour change and browning appearance of litchi, longan fruit as well as Chinese water chestnut. Besides, application of aloe vera gel coating has been reported to extend shelf life by delaying postharvest loss of quality such as colour change, fruit softening an reduced physiological weight loss in table grapes (Serrano et al., 2006).

2.3 Antimicrobial

Colletotrichum gloeosporiodes is the most common anthracnose disease in mango which infects immature fruit early in the season. Then it enters a long latent phase until the fruit start to ripen stage caused the latency break and the fungus ramifies through the peel and pulp tissues causing black disease lesions. Therefore control of disease using a suitable and healthy method is needed (Zainuri et al., 2003). Fungicide application can bring neurotoxin therefore it highly restricted in many countries (Bil Noad, 2004). The residues of some these pesticides can remain on foods and pose a significant hazard to human health when applied improperly (Hussain et al., 2002).

There is a series of problems against the effective use of these chemicals in areas where the fungi have developed resistance. The higher concentrations of these chemicals were used in order to overcome this obstacle, but this increases the risk of high-level toxic residues in the products. Not all the treatment is able to effectively control the situation. For instance, Hot water treatment is an effective non-chemical method and equally effective in moderating the transfer of microorganisms from the fruit surface to the flesh for controlling post-harvest pests and diseases with suitable combinations of temperatures and exposure times to prevent quality loss (Lurie, 1998). However, washing and sanitizing the surface may not be practical due to their delicate structures causing the accelerated fruit ripening and deterioration by removing natural skin cuticle and thereby causing rapid water loss (Campos and Yahia, 1991). Therefore, other means of microbial control are needed to ensure maximum shelf-life and safety. Thus, there has been a growing interest on the research of the possible use of plant extracts, which can be relatively less damaging for pest and disease control in agriculture.

In the past few years, due to concerns regarding the safety of synthetic antimicrobial agents there has been an increase in naturally developed substances, which has resulted in a huge increase in the use of naturally derived compounds as potential antifungal agents (Negi et al., 2005). In 1991, a major transnational research project on Natural Anti-microbial Systems was initiated with the objective of identifying and assessing natural antimicrobial systems as novel means of extending the safety and quality of food. Many plant extracts have been reported to have activity against a wide range of fungi (Kumar and Tripathi, 1991; Doubrava et al., 1998), and those with fungitoxic properties may include volatile constituents. When two or more substances are present in the extracts, the fungitoxic potential may be enhanced. There are two basic approaches that use microbial antagonists for controlling the post-harvest diseases of fruits and vegetables: (1) use of microorganisms which already exist on the produce itself, which can be promoted and managed, or (2) those that can be artificially introduced against postharvest pathogens. The antimicrobial activity of some essential oils including oregano oil, lemongrass oil and vanillin is assigned to a number of small terpenoid and phenolic compounds, which also in pure form have been shown to exhibit antibacterial or antifungal activity (Burt, 2004) and (Friedman et al., 2004).

Saks and Barkai-Golan (1995) and Jasso de Rodrı ´guez, (2005) reported that the antifungal activity of aloe vera pulp has been documented, including several postharvest fruit pathogens, such as *Penicillium digitatum*, *Penicillium expansum*, *Botrytis cinerea*, and *Alternaria alternate* by suppressing pathogen germination and mycelia growth. Besides, leaf and seed extracts of huamuchil (*Pithecellobium dulce*) had fungicidal effects on sporulation and mycelial growth of *Botrytis cinerea*, *Penicillium digitatum* and *Rhizopus stolonifer* of strawberry fruit (Bautista-Baños et al., 2003)

2.4 Edible coating

Coatings act as barriers to moisture and oxygen during processing, handling, and storage without retard food deterioration due to their natural biocide activity or the incorporation of antimicrobial compounds (Cha and Chinnan, 2004). The performance of different types of edible coatings is dependent on their composition. The application of various edible coatings has been reported to affect fruit appearance, ripening, and quality in different mango cultivars. The outcomes of edible coatings on fruit ripening and quality are a function of various factors such as coating type, formulation concentration, fruit nature, cultivar, fruit maturity, storage conditions, and thickness of the coating layer. A good coating formulations should have several characteristics (Ben-Yehoshua, 1987) which is non-toxic to humans, good permeability properties, stability in formulation, strong adherence to the fruit throughout the entire storage life, high gloss and economical. Coatings offer some resistance to gas exchange to avoid respiration that occurs during storage which can speed up the ripening process. It also may create a modified atmosphere when applied to fruit and vegetables by slowing down the respiration, metabolism and retards ethylene production without affecting flavour of fruit and vegetables (Baldwin et al., 1999).

Application of an edible coating on the fruit surface imparts a glossy appearance and better colour, and prevents microbial spoilage, which is vitally important to perishable fruits (Salvador et al., 2003). There are different kinds of films which are used such as protein, polysaccharide, lipid, and composed films. The first edible film from fruits was produced by McHugh et al. (1994) which extracted from apple puree and various amounts of fatty acid, alcohol, bee wax and vegetable oil that are able to form a barrier against the oxygen loss, reduce browning reaction, loss of moisture and maintained the flavour of sliced apple. Also, contamination of product by microorganism could be controlled by pectin film which is used for coating of dried fig, raisin and some kind of candy. Park et al. (1994) reported that coating tomatoes with a corn-zein film reduced the respiration rate and result in a delay of the ripening of tomatoes and maintain firmness, and retard the ripening of tomatoes from the pink stage to the red stage. The storage life of tomatoes could be prolonged by about 6 days.

Cellulose derivatives of methylcellulose, hydroxypropyl methylcellulose, and hydroxypropyl cellulose, have excellent film-forming characteristics to coat mature-green tomatoes. The retardation of the rate of firmness loss could reduce the economic loss that would result from spoilage by mechanical injury during transportation of fruits and vegetables. The formulation of edible coatings includes vegetable oils, cellulose gums, emulsifiers, surfactants and fatty acids. The edible coatings successfully delay ripening in some climacteric fruits such as tomatoes, papayas, guavas and bananas (Nisperos-Carriedo et al., 1991). However, Kittur et al. (2001) reported that the starch and cellulose-based coating are more effective than waxol in shelf life extension and maintain the quality of mango by significantly reducing the respiration rate that will hasten the development of ripening but their effect on weight loss is insignificant.

Besides, chitosan has been reported to maintain the quality of fruits and vegetables, reducing respiration rates, ethylene production, and transpiration (El Ghaouth et al., 1992, Li and Yu, 2000), Han et al. (2004) used chitosan-based edible coatings to extend or prolong the shelf life and enhance the nutritional value of strawberries and raspberries. Pro-longTM or SemperfreshTM, is a commercial coating formulated with sucrose esters of fatty acids, mono- and di-glycerides, and the sodium salt of carboxymethylcellulose has been applied successfully to retard ripening on mangoes (Dhalla & Hanson, 1988).

2.4.1 Alginate coating

Alginate obtained from marine algae is acid polysaccharides that can be used to form stable films by crosslinking with calcium ions under controlled conditions (Wong et al., 1996). In molecular terms, it is a family of unbranched binary copolymers of (1→4)-linked β-D -mannuronic acid and α-L -guluronic acid residues of widely varying composition and sequential structure (King et *al*., 1983; Moe et al., 1995). Poor water barrier properties can be expected due to hydrophilic nature of alginate. Mango and other fruit puree films without adding glycerol as a plasticizer showed higher elastic modulus (EM), lower tensile strength (TS) and elongation (%E) than those films made of fruit starch and plasticized with glycerol. However the coating performance is different depending on the concentration of added plasticizer such as glycerol and antioxidant as calcium chloride (Kester and Fennema, 1986). The addition of plasticizers may help to increase flexibility of the coatings, decreasing brittleness and reduce internal hydrogen bonds between polymer chains also increasing intermolecular spaces (Sothornvit and Krochta, 2000). The water resistance increased with the increase in tensile length and decrease in water vapour permeability of the films. These properties could be utilized or exercised as natural water-insoluble film in food and non- food applications (Rhim, 2003). Alginate could be recommended for commercial purposes due to the high economic cost of low methoxyl pectins for industrial applications (Oms-Oliu, et al., 2008).

Besides, alginate coating with sunflower oil, as lipid to improve water vapour barrier properties which is more effective than alginate coating by increasing the water vapour resistance to prevent water loss and carry antibrowning agents through the changes of colour external part of fresh-cut fruits (Tapia et al., 2008). Alginate also obviously reduced microbial decay, decreased weight loss, maintained the firmness of the strawberries, improve the storage, properties of the strawberries quality with combination of *Cryptococcus laurentii* (Wang, 2009). Alginate coatings can improved firmness of the fresh-cut of papaya by restricting the amount of respiratory rate and ethylene production of the coated papayas (Tapia et al., 2008). Alginate-apple puree edible coatings were successfully formulated with the addition of essential oils such as lemongrass, oregano oil as well as vanillin by maintaining the firmness and colour of fruit besides inhibiting the growth *Listeria inoculation* effectively (Rojas-Grau, 2007).

2.4.2 Cinnamic acid coating

Cinnamic acid is a phenolic component of several spices, including cinnamon and generally regarded as safe for use in foods and is already used as a component in several food flavourings. It is important natural substrates of polyphenol oxidase in fruits and vegetables. The extraction from cinnamon has fungistatic and fungicidal activity against the anthracnose and crown rot pathogens by spraying them on Embul banana prior to storage, controlled crown rot and prolonged shelf-life (Ranasinghe et al., 2003).

Likewise, it has an excellent potential as a green pesticide that can control various crop pests without any harmful effects on the environment and human health through its hybridization with layered double hydroxides (Man et al., 2010). Also, cinnamon extracts with other two plant materials such as piper and garlic extracts can inhibit conidial germination and mycelia growth of the causal pathogens of banana crown rot caused by *Colletotrichum musae*, *Fusarium* spp. and *Lasiodiplodia theobromae* (Jitareerat, 2007). Cinnamic acid as the deaminated product of phenylalanine in plant tissue, as well as its derivatives is abundant molecules that incorporated the complex lignin polymer into hemicellulose and cellulose in the cell wall of plants (De Vries *et al*., 1997). Cinnamic acid is used for the antibacterial activity on fruits such as kiwifruit and honey drew melon. Cinnamic acid is tested on both kiwifruit and honey drew melon that contains natural floral content by dipping 1 mM cinnamic acid solution in two temperatures tested respectively. There is no extension of lag phase growth while it has extension of lag phase growth for honey drew melon. Nevertheless, both have positive respond or reaction for the reduction population of natural floral although cinnamic acid is more effective in reducing the variable count of the natural flora on kiwifruit compared to honey drew melon (Roller and Seedhar, 2002). Cinnamic acid is applied on the meat and fish products. The Japanese have been reported to use cinnamic acid as an antimicrobial agent in fish paste (Shimada et al., 1991).

Cinnamic acid dissolved in ethanol was tested as a dip or spray at a variety of concentrations on a range of whole fruit and fruit slices, stored under ambient and refrigeration temperatures. It was found that cinnamic acid was very effective in prolonging the shelf-life of several important fruit products. For instance, the shelf-life of fresh tomato slices stored at 4°C was extended from 42 to 70 days whilst slices stored at 25°C had their shelf-life doubled from 21 to 42 days (Roller, 1995). Besides, the lipophilicity as well as the ionization constant of substituted cinnamic acids was found to influence the standard of inhibition of *Listeria monocytogenes* growth. The higher lipophilicity the higher the antimicrobial activity observed (Ramos-Nino et al. 1996).

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

3.1.1 Collection of samples

Mangoes were purchased from Federal Agricultural Marketing Authority (FAMA) in Terengganu, and Bidor, Perak in a covered truck. A total of 400 Chokanan mangoes were selected based on uniformity of size and equal maturity stage (Index 3), free from damage, pest, disease and fungal infections.

3.2 Methods

3.2.1 Edible coating formulations

Alginic acid (sodium salt) and cinnamic acid were purchased from Sigma – Aldrich Germany. Sodium alginate solutions were prepared by dissolving 2% or 4% (w/v) in distilled water and heated at 70°C and stirred until clear appearance. Glycerol was dissolved at 2% (w/v) as a plasticizer. After that, 4 or 6mM cinnamic acid were added into the alginate solution stirred and distilled water was added until 1 litre in the solution.

This experiment of study is comprised five treatments with three replications. There are three fruits for each of replications. These coating formulations resulted in set of treatments: (a) Control (untreated mango); (b) 2.0% sodium alginate and 4mM cinnamic acid; (c) 4.0% sodium alginate and 4mM cinnamic acid; (d) 2.0% sodium alginate and 6mM cinnamic acid; (e) 4.0% sodium alginate and 6mM cinnamic acid. Table 3.1 indicates the distribution of fruits based on treatments.

Table 3.1: Distribution of fruits based on treatments

	Treatment				
Day	**Control**	**2% SA+ 4mM CINN**	**4% SA+ 4mM CINN**	**2% SA+ 6mM CINN**	**4% SA+ 6mM CINN**
0	6				
3rd	9	9	9	9	9
6th	9	9	9	9	9
9th	9	9	9	9	9
12th	9	9	9	9	9
15th	9	9	9	9	9
Total	51	45	45	45	45

Total of fruits (samples) for analysis observation = 231

Total of fruits (samples) for microbial and weight loss observation = 150

Total of fruits used = 381

* Treatment: Control, Sodium alginate (SA) and Cinnamic acid (CINN)

3.2.2 Coating application

Before treatments, fruits with uniform size, colour, free of physical damage and fungal infection were washed several times in running water and sterilized superficially by dipping in 2% sodium hypochlorite (R&M Chemicals) for 2 minutes. Then, they were washed twice in distilled water, and dried between sterilized filter papers and air-dried. After that, mangoes were dipped individually in coating solution for two minutes, subsequently dipped off for one minute. Then, 2% calcium chloride (R&M Chemical) in distilled water was added and dripped off for one minute. The fruits were dried at an open area for ten minutes and placed on trays under ambient temperature. Table 3.2 shows a total of five coating treatments including control.

Table 3.2: Experimental design of coating treatments

Treatments	**Coating solution**
T0 (Control)	Dipped with distilled water only
T1	2.0% sodium alginate + 4 mM Cinnamic acid
T2	4.0% sodium alginate + 4 mM Cinnamic acid
T3	2.0% sodium alginate + 6 mM Cinnamic acid
T4	4.0% sodium alginate + 6 mM Cinnamic acid

3.2.3 Fruit analysis

Two major fruits analyses which are physical and chemical analysis were taken to determine the change of mango after being coated with different combinations of coating materials. Fruits were stored at ambient temperature around 26°C to 29°C and evaluated every 3 days for firmness, skin colour, total soluble solids, and weight loss of mango for two weeks.

3.2.3.1 Colour

Skin colour of fruit was measured using a Minolta Chromameter (model CR-400X Minolta Camera Co. Ltd., Japan). The instrument was calibrated against a standard white colour plate (Y= 93.9, X= 0.313, y= 0.321). Four measurements were taken for external colour around the equator of the fruit. L* represenst lightness and a* represents greenness (-) to redness (+) while b* represents blueness (-) to yellowness (+). The standard calculation hue [Arc tan (b/a)], positive signed results are generated for the first quadrant [+a, +b] only. The other quadrants should be handled so that a 360° representation is accommodated and results are expressed as positive signed numbers. Second quadrant [-a, +b] and third quadrant [−a, −b] calculations should be: hue = 180+Arc tan(b/a). Fourth quadrant [+a, −b] calculations should be: hue = 360+ Arc tan(b/a) (Mcellan, et al., 2007).

3.2.3.2 Firmness

Firmness is measured as the maximum penetration force (g) when reached the tissue breakage and determined with a needle probe P/2N. The penetration depth was 5mm and the cross-head speed was 20mm/min using TA-TX2 Texture Analyzer (Texture Technologies Corp., USA). The penetration force (g) required to penetration through mango longitudinally to get the firmness value of mango fruit.

3.2.3.3 Total soluble solids (TSS)

TSS was determined using a portable refractometer (Hand Refractometer Model 103, 0-32% Brix) and the results were expressed as percentage. The blended fruit samples of mango were squeezed and twisted manually to obtain the drops of mango juice. Few drops were taken on prism of refractometer and readings were recorded. The purpose of TSS analysis is to determine the sugar content in mango.

3.2.3.4 Weight loss

Mango weight was weighed using a top pan balance. Initial mango weight was measured before coating mango. The weight loss of mangoes was determined by calculating the difference between initial and final weight for each samples after storage. The calculation can be written as follows:

$$\text{Percentage of weight loss (\%)} = \frac{\text{(initial weight} - \text{final weight)}}{\text{Initial weight}} \times 100\%$$

3.2.3.5 Visual quality

The visual quality of mango was visually inspected during the final day of the storage (14^{th} days). The visual qualities of samples were evaluated by subjective method using a rating scale of 5 points (Rattananpanone et al., 2001). The parameters for evaluation of the quality of samples are shown below

Table 3.3: Evaluation of visual appearance

Score	Visual appearance
1	Inedible
3	Poor
5	Fair
7	Good
9	Excellent

(Gonzalez-Aguilar et al., 2001)

Table 3.4: Evaluation of defects (disease of severity)

Score	Disease of severity
0	No injury
1	Very mild (injury area < $1cm^2$)
2	Mild (injury area >1< $2cm^2$)
3	Moderate (injury area >2< $4cm^2$)
4	Severe (injury area > $4cm^2$)

(Maqbool et al., 2007)

3.2.3.6 Disease of incidence

Disease of severity includes microbial spoilage, fungal decay, softening, discolouration, and pitting. Mango fruits showing mycelia growth and development on surface are considered decayed. Results are expressed as the percentage of fruits infected or disease of incidence using a formula below:

$$\text{Disease of incidence} = \frac{\text{Number of infected fruits}}{\text{Total of fruits}} \times 100\%$$

3.2.4.7 Statistical analysis

Complete randomized design was used in this study. Data including weight loss, firmness, skin colour and total soluble solids were analyzed using Analysis of Variance (ANOVA), Tukey HSD was used to compare the mean among the treatments. Differences are regarded as significant when the p- values are less than 0.05 (P<0.05). Square root transformation was performed on data total soluble solids content on Day 3.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Effect of sodium alginate and cinnamic acid on hue angle

Colour is a very important determinant of quality and consumer acceptability, especially with respect to mangoes (Aked, 2000). Hue angle (H^o) is calculated to measure the degree of colour of the outer skin of the mango fruits. Hue angle tends to decrease throughout the storage period, indicating a shift in the colour of the fruit from greenish yellow to orange- yellow (Jacobi et al., 1995).

Figure 4.1 shows that there was significant difference in hue angle value ($P< 0.05$) among the all treated mangoes starting sixth day of storage between treated mangoes and untreated mangoes. The mangoes coated with a combination of 4% sodium alginate plus 4mM cinnamic acid and 4% sodium alginate plus 6mM cinnamic acid obtained significantly higher value of hue angle as compared to that of untreated mangoes starting third until twelfth day of storage (Appendix A). The hue angle values decreased as the mango fruits ripened with increase in maturity (Batu, 2003).

It is found that not much of variation seen in decrease of hue angle between mango fruits coated with sodium alginate combined cinnamic acid solutions irrespective of any concentrations. It is because high concentration of sodium alginate with glycerol as plasticizer will increase the water vapour barrier and decrease gas vapour permeabilities and slow down colour change due to low respiration rate than low concentration of sodium alginate. The combined treatment of 4% sodium alginate plus 4mM cinnamic acid and 4% sodium alginate plus 6mM cinnamic acid were the best treatment in delaying the fruit ripening with slightly colour change throughout the storage period.

Chlorophyll degradation and the subsequent prominence of carotenoids, the major colour pigment in ripe fruits bring the yellow colour development. Yellowness of the fruit was accompanied by a progressive sweetness of the fruit pulp due to formation of sugars resulting from starch (Aina, 1990). Jacobi et al. (1995) stated a decrease in the Hue angle of hot air treated 'Kensington' mango after 10-12 days within 12 days of storage at ambient temperature.

Hydroxypropyl methlcellulose (HPMC) coating has low oxygen and carbon dioxide permeablities that can prevent oxygen enter into the tissue decrease ethylene synthesis and reduce the respiration rate which would in turn delay ripening as evidenced by slower changes in colour (Zhuang and Huang, 2003). This finding agrees with the observed by Hoa et al. (2002). On the other hand, the films dried much faster than the control film and resulted in slightly translucent, milk white-tinted and stiff films after soaking calcium chloride solution and it may change the colour on mango surface. Rhim (2004) reported that it did not showed any significant difference compared with control films.

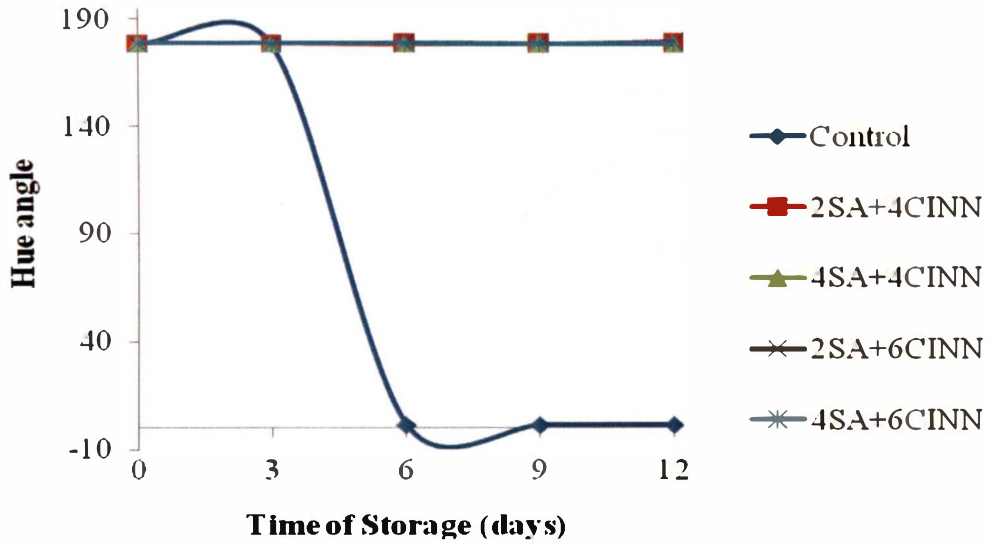

Figure 4.1: Hue angle changes of mango fruits after coated with combination of sodium alginate (SA) and cinnamic acid (CINN) stored at ambient temperature for 12 days.

4.2 Effect of sodium alginate and cinnamic acid on fruit firmness

Loss of firmness is one of the main factors limiting quality and the postharvest shelf-life of fruit and vegetables. Texture is a critical quality attribute in the consumer acceptability of fresh fruit and vegetables while mango is one of the finest fresh fruits in the world that rapidly loss of firmness during the storage time resulting a short edible period and highly susceptible to microorganisms invasion. The soft texture of fruit and vegetables because of many factors such as the loss in cell turgor pressure, vascular air and the degradation of cell wall constituents and polysaccharides (Sothornvit and Rodsamran, 2008). Turgor pressure altered after harvest and decreased transpiration plus respiration eventually water loss and fruit softening by enzymatic dehydration of the pectin holding adjacent cells together as mango fruits begin to senesce and proceed to an overripe stage (Whitaker, 1996). The retardation of the rate of firmness loss can reduce the economic loss that would result from spoilage by mechanical injury during transportation of mangoes (Zhuang and Huang, 2003).

Figure 4.2 shows the changes in flesh firmness of untreated and treated mango fruits throughout the storage period. All the fruits had the similar initial flesh firmness value ($P<0.05$) but the firmness decreased gradually for both uncoated and coated fruits throughout the storage period. Mango fruits treated with a combination of 4% sodium alginate plus 4mM cinnamic acid and 2% sodium alginate plus 6mM cinnamic acid (Appendix B) exhibited higher firmness value as compared to that of control on third day of storage. However, both combination treatments were unable to maintain the firmness of mangoes on sixth day of storage while mangoes coated with a combination of 4% sodium alginate and 6mM cinnamic acid had higher firmness value than untreated mangoes. All treated mangoes showed higher firmness value as compared to the control starting twelfth day of storage.

The mangoes coated with a combination of 4% sodium alginate and 4mM cinnamic acid exhibited a higher firmness value than other treated mangoes on third day of storage. However, it is found that no significant difference among all treated mangoes on sixth day of storage. Mangoes coated with a combination of 4% sodium alginate and 6mM cinnamic acid gave a higher firmness value than combination of 2% sodium alginate and 6mM cinnamic acid from ninth until twelfth day of storage but there was no significant difference in firmness value for all treated mangoes at the end of storage. The combination of 4% sodium alginate and 6mM cinnamic acid was the best treatment to delay the decrease in flesh firmness values of fruit. In general, all treated and untreated mangoes are significantly different in flesh firmness as storage time increases with treated mangoes having higher value of firmness than that of control. Coatings are effective in conferring a physical barrier to moisture loss and therefore retarding dehydration and fruit shriveling. The results of this study suggests that the coating of sodium alginate added with cinnamic acid can delay the decrease of flesh firmness thereby maintaining the flesh firmness of mango fruits at edible level for fifteen day when being stored under ambient temperature.

The changes in fruit firmness during ripening results from both alteration in cell wall structure and the degradation of starch. As the ripening progresses, bound carbohydrate fractions, especially pectic substances and hemicelluloses are rapidly depolymerized by hydrolases (Priyasethu et al., 1996). Strawberries soften during ripening, mainly through degradation of the middle lamella of the cell wall of cortical parenchyma cells (Perkins-Veazie, 1995). The use of calcium chloride to cross-link the polymer matrix could also represent a beneficial effect for the coated fruit by delaying softening. Firming and resistance to softening resulting from addition of calcium have been attributed to the stabilization of membrane systems and the formation of calcium pectates, which increase rigidity of the middle lamella and cell wall (Jackman and Stanley, 1995). Mangoes treated with polysaccharide-based coatings have been shown to have higher firmness values than those treated with 'Waxol' which is a commercial product and untreated control fruit, with retardation of colour development (Kittur et al., 2001)

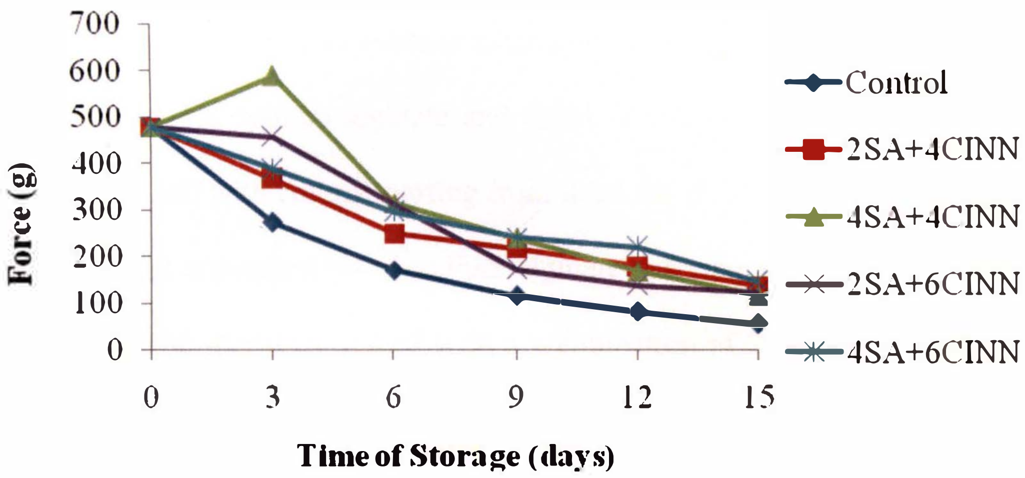

Figure 4.2: Firmness changes of mango fruits after coated with combination of sodium alginate (SA) and cinnamic acid (CINN) stored at ambient temperature for 15 days.

4.3 Effect of sodium alginate and cinnamic acid on total soluble solid content

Ueda et al. (2000) reported that the mango dry matter mainly consists of carbohydrates, 60% of which are sugars and acids, the main compounds contributing to fruit sweetness and acidity (Malundo et al., 2001). Fruit flesh taste is highly dependent on the balance between organic acids and soluble sugars, which are predominantly represented in mango by citric and malic acids, and sucrose, fructose and glucose, respectively (Medlicott and Thompson, 1985). Total soluble is measured in terms of brix value. The value increase with increase of the total soluble solid (TSS) in the mango as the storage period increased.

Figure 4.3 shows that all treated mango fruits obtained a lower increase in TSS than untreated mangoes starting ninth day of storage. Mangoes treated with a combination of 4% sodium alginate and 6mM cinnamic acid exhibited significant different ($P<0.05$) with control starting from third day of storage (Appendix C). The addition of high concentration of sodium alginate and cinnamic acid can slow down TSS change. The mangoes treated with a combination of 2% sodium alginate plus 6mM cinnamic acid and 4% sodium alginate plus 4mM cinnamic acid showed a higher TSS content than other treated mangoes on ninth day of storage and there was no significant difference between all treated mangoes on day 12 of storage. This implies that combination of 2% sodium alginate plus 6mM cinnamic acid and 4% sodium alginate plus 4mM cinnamic acid did not change or inhibit the development of sweetness in flesh fruit when apply coating. The small increase in the soluble solids observed may be explained by the effect of calcium chloride on sugar metabolism, as has been found in apples and tomatoes (Klein and Lurie, 1991).

Throughout storage, it is also found that sodium alginate (2% and 4%) and cinnamic acid (4mM and 6mM) treatments showed not much difference in increase of TSS content. However, both highest concentration of sodium alginate and cinnamic acid was easiest to slow down TSS change as compared to control throughout the storage due to the high concentration of treatment enhance its effectiveness on suppression of starch convert into sucrose and glucose as sweetness of mango fruits. Therefore, the combination of 4% sodium alginate and 6mM cinnamic acid was the best treatment in delaying the soluble solid change. The reducing sugar content and TSS of polysaccharide-based coated fruits were lower than control because of higher enzyme activity. Imran et al. (2005) reported that 2% calcium chloride was able to minimize the increase in total soluble solid of apples which formed a thin layer on the surface of fruits that delayed degradation process and reduced evaporation from the fruits. However, the increase of total soluble solids was probably because of polysaccharides and concentrated juices content of a result of dehydration (Imran et al., 2005). More rapid conversion of starch to sugar as the storage period increased. An extended storage resulted in control fruits turning black with a collapsed structure due to overripening and fungal infection.

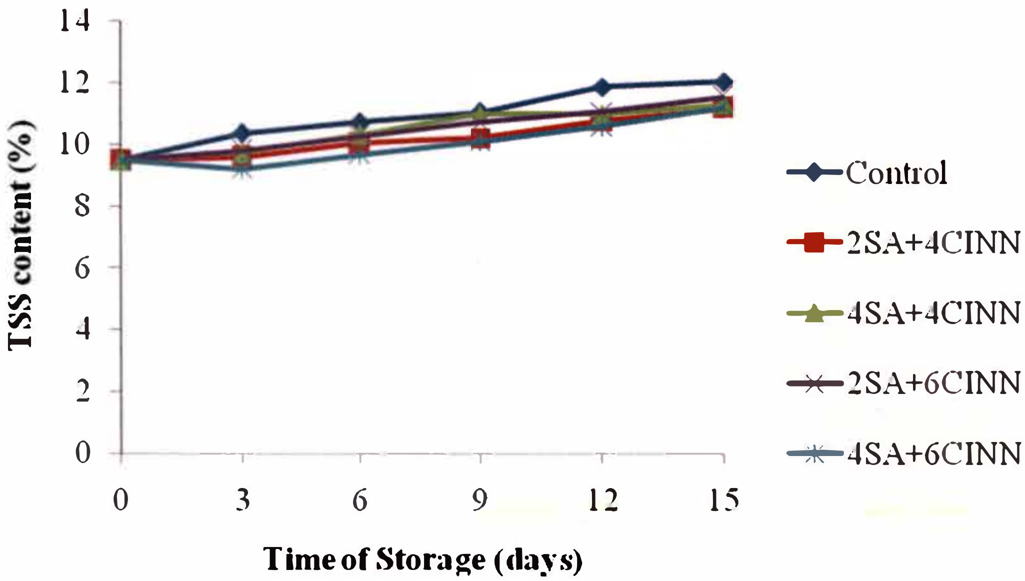

Figure 4.3: TSS changes of mango fruits after coated with combination of sodium alginate (SA) and cinnamic acid (CINN) stored at ambient temperature for 15 days.

4.4 Effect of sodium alginate and cinnamic acid on weight loss

The exocarp of mango is a very thin cellular layer easily injured during transportation after harvest. Moisture loss in fruits normally controlled by epidermal layer of the skin which together with stomata and guard cells controls the gas exchange properties of the fruit (Ben, 1987). Transpiration can lead to water loss eventually wilting and shrivelling which both reduce market value and consumer acceptability (Ball, 1997).

Changes in the weight loss of mango fruits are shown in Figure 4.4. During the course of ripening at ambient temperature, the weight loss increased in all treated and untreated mangoes. The untreated mangoes showed a significantly higher weight loss ($P<0.05$) as compared to treated mangoes (Appendix D). However, there was no significant difference between all treated mangoes after fifteenth day of storage. Alginate with glycerol as plasticizer to the coating gave good results in terms of reducing the moisture loss in apple and strawberry (Zapata et al., 2008).

Throughout storage, it is found that not much of variation seen decrease of weight loss between mango fruits coated with sodium alginate combined cinnamic acid solution irrespective of any concentration. On other hand, moderate concentration of sodium alginate and cinnamic acid edible coating for mangoes can provide an additional protective layer and thereby reduce quality degradations and quantity losses by modification of the internal atmosphere of mangoes.

The reason for the reduction in weight loss may be due to the blockage of lenticels and/or stomates (Dhalla and Hanson 1988) as evidenced by the reduction in respiration and gas exchange (Hagenmaier and Baker, 1993). Alginate posses good film- forming properties to reduce weight loss and natural microfloral counts in carrots and maintain the quality and prolong shelf life of fresh cut apples (Zapata et al., 2008). Nussinovitch and Hershko (1996) showed that alginate coatings served as a barrier to moisture loss in garlic. The coating helps reduce weight loss further because it forms a film on the top of the skin acting as additional barrier to moisture loss.The most beneficial characteristic in coatings formulated with carnauba

(TFC150 and TFC210) is their ability to act as a water barrier. They reduced weight loss in 'cat Hoa loc' mangoes after one week at ambient temperature. (Baldwin et al., 1999) and (Hoa et al., 2002). Besides, chitosan forms a semipermeable film that regulates the gas exchange and reduces transpiration loses hence water loses occurred (Kittur et al., 2001).

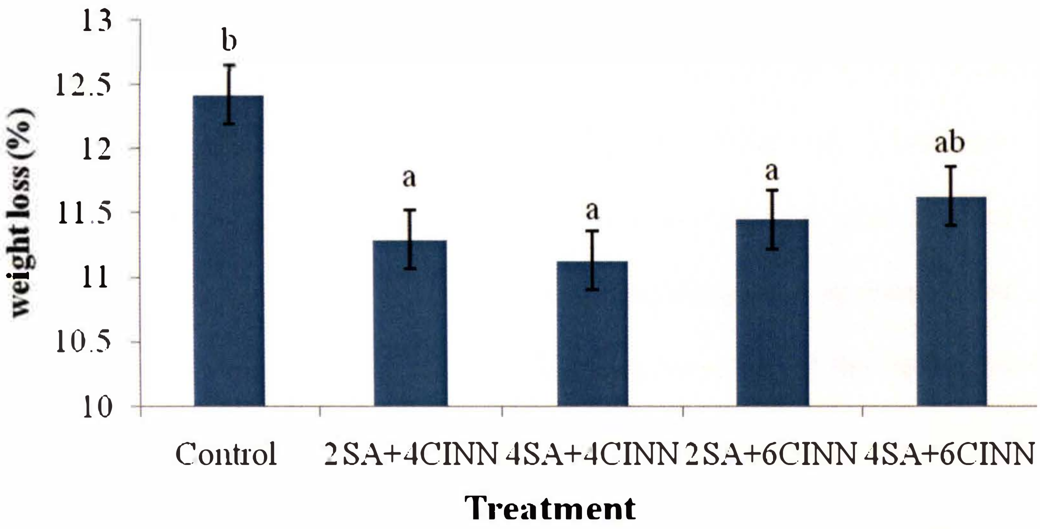

Figure 4.4: Weight loss of mango fruits after coated with combination of sodium alginate (SA) and cinnamic acid (CINN) stored at ambient temperature after 15 days.

4.5 Effect of sodium alginate and cinnamic acid on visual appearance

Consumers will evaluate the appearance of mango before quality inspection therefore they prefer mangoes with clean, shinny and bright coloured without any blemishes, damaged or diseases. The lower score indicates the more poor appearance of mango fruits.

Figure 4.5 shows that the mean score for visual appearance began to reduce and the untreated mangoes exhibited significantly lower scores ($P<0.05$) as compared to all treated mangoes on third day of storage. However, only mangoes treated with a combination of 2% sodium alginate and 6mM cinnamic acid gave significant difference as compared to that of control starting from sixth day until twelfth day of storage (Appendix E). Black spot was observed on the surface of untreated mango fruits on the third day of storage, indicating the presence of *Colletotrichum gloeosporiodes* thus reducing the score of appearance. The combination of 2% sodium alginate and 6mM cinnamic acid gave a better score compared to other treatments and control in maintaining good appearance but there was no significant difference in visual appearance score for all the treated mangoes starting from sixth day of storage.

Mangoes treated with a combination of 2% sodium alginate and 6mM cinnamnic acid was the most effective treatment to preserve the shinny and bright appearance of mangoes compared to other treatments. This might be due to the addition of glycerol as plasticizer in higher concentration of sodium alginate reduce the tensile strength and elongation thus the coating film is not wrap the mangoes completely and easier peel off during inspection for visual appearance of fruits throughout the storage. Fruit treated 4mM cinnamic acid obtained a poorer appearance score than fruits treated with 6mM cinnamic acid because high concentration of cinnamic acid gave effect on the glossiness and transparency of the coating, thus prolonging the shelf life of mango fruits as well.

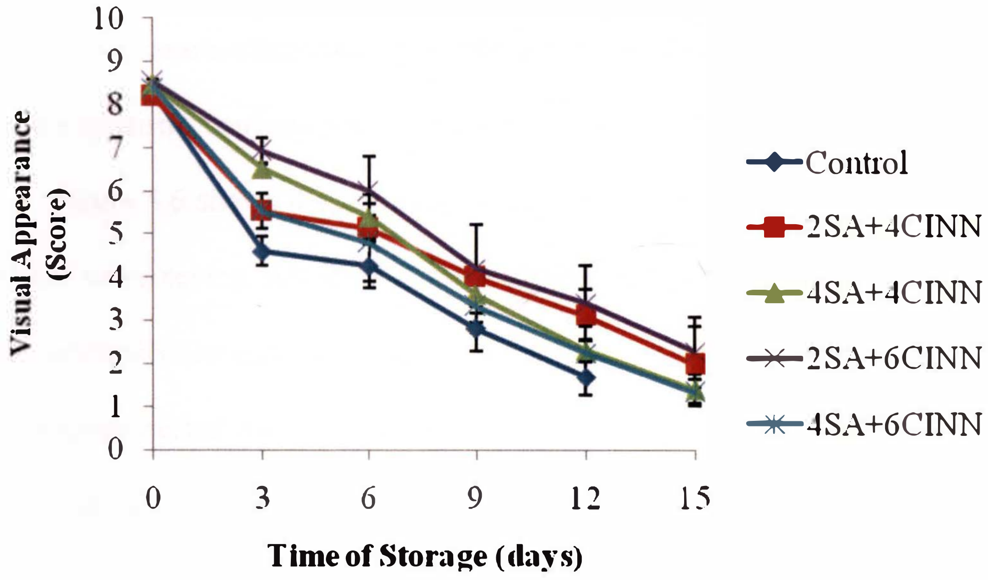

Figure 4.5: Visual appearance of mango after coated with combination of sodium alginate (SA) and cinnamic acid (CINN) stored at ambient temperature for 15 days.

Score:

1	Inedible
3	Poor
5	Fair
7	Good
9	Excellent

4.6 Effect of sodium alginate and cinnamic acid on disease of severity

A range of visual score is used to reflect degree of defect such as discolouration, decay, pitting, softening, microbe growth of mango. The pests and the possible intrinsic defects in the produce itself may cause the waste and spoilage of fresh fruits during storage, transportation and marketing. Cinnamic acid contains antifungal and antibacterial principles that can be used to prevent food spoilage due to microorganisms contamination (Fabio et al., 2003).

Figure 4.6 shows the scores for fruit defects, higher the score means mango fruits are more severe. All fruits had the similar initial score but the score became higher gradually for untreated and treated mangoes throughout the storage period. The mangoes treated with a combination of 4% sodium alginate and 4mM cinnamic acid showed a lower score as compared to that of untreated mangoes starting from day 3 until day 9 of storage (Appendix F). This combination was unable to protect those mangoes from the invasion of pathogens thereby causing decay after ninth day of storage. Interestingly only the mangoes treated with a combination of 2% sodium alginate and 6mM cinnamic acid gave a lower defect score compared to control throughout storage period. There was no significant difference among the all treated mangoes on third and sixth day of storage but the mangoes coated with a combination of 4% sodium alginate and 6mM cinnamic acid had significantly higher defect score ($P<0.05$) starting from ninth day of storage as compared to mangoes treated with a combination of 2% sodium alginate and 6mM cinnamic acid (Appendix F).

This implies that the combination of 2% sodium alginate and 6mM cinnamic acid is better in preventing occurrence of defect and spoilage. Most of the fruits showed symptoms of tissue softening, mould growth, presence of anthracnose and stem scar, and subsequently resulting spoilage on day 12 while the untreated mangoes were terminated on twelfth day of storage because the mango fruits were highly infected by disease.

Addition of cinnamic acid gives the additional protection onto mango fruits from pathogen invasion in this study. Cinnamic acid in a high concentration of sodium alginate may not significantly build up a barrier against pathogen while the addition of cinnamic acid is much effect on the lower concentration of sodium alginate due to loosen intermolecular space in the sodium alginate solution (2%). Mineral imbalance and unflavourable environment factors for instance inappropriate storage temperature and humidity condition hasten the physiological disorders, thus changing the edible quality of mangoes Thangavelu et al. (2004) reported that an extract from *Solanum torvum* effectively controlled anthracnose disease and increased the shelf-life of bananas. These results also support Ranasinghe et al. (2003) who showed that cinnamon oil sprays on Embul bananas can induce disease resistance to crown rot without any detrimental effect on the physico-chemical properties.

In addition, coatings applied on fresh-cut fruit create an internal modified atmosphere that may change the growth rate of spoilage and pathogenic microorganisms (Olivas and Barbosa-Cánovas, 2005). Furthermore, cinnmic aicd was used as antimicrobial natural compounds in prevention of pre-harvest as well as postharvest fungal infection in walnut (Smits and Brul, 2005) besides inhibiting enzymatic browning in apples when added into sodium chloride solution (Lu et al., 2007).

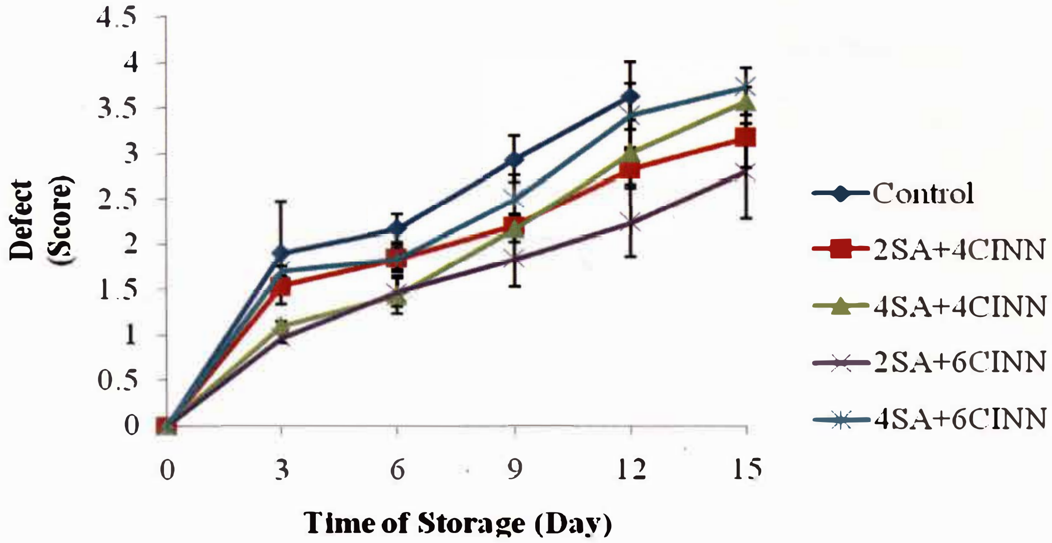

Figure 4.5: Disease severity changes after coated with combination of sodium alginate (SA) and cinnamic acid (CINN) stored at ambient temperature for 15 days.

Score:

0	No injury
1	Very mild (injury area < $1cm^2$)
2	Mild (injury area > 1<$2cm^2$)
3	Moderate (injury area >2< $4cm^2$)
4	Severe (injury area > $4cm^2$)

4.7 Effect of sodium alginate and cinnamic acid on disease of incidence

Figure 4.7 showed that no significant difference between all treated and untreated mangoes on third day of storage and the mango treated with a combination of 2% sodium alginate and 4mM cinnamic acid exhibited lower percentage of disease incidence as compared to that of control on ninth day of storage (Appendix G).

The mango fruits coated with a combination of 2% sodium alginate plus 4mM cinnamic acid, 4% sodium alginate plus 4mM cinnamic acid and 2% sodium alginate plus 6mM cinnamic acid showed a significant difference in percentage of fungal decay ($P<0.05$) as compared to that of uncoated mangoes starting from third day until ninth day of storage and started increased the percentage of fungal decay on day 12 and only mangoes coated with a combination of 2% sodium alginate and 6mM cinnamic acid gave a significantly different on day 12 of storage.

There was no sign of fungal decay detected by visual inspection of fruits treated with 2% sodium alginate plus 4mM cinnamic acid and 2% sodium alginate plus 6mM cinnamic acid from the beginning until third and sixth day of storage, respectively. The coated fruits were infected gradually as the storage time increased. The mango fruits treated with a combination of 2% sodium alginate and 6mM cinnamic acid gave a lower percentage of fungal decay as compared to that of untreated mangoes throughout the storage period. However, there was no significant difference among all treated mangoes on fifteenth day of storage. This indicates that a combination of 2% sodium alginate and 6mM cinnamic acid was the best treatment to extent its antifungal and antibacterial properties.

The concentration of cinnamic acid in the coating solution affects the fungal decay of mango fruits. Mango fruits coated with 6mM cinnamic acid were better than fruits coated with 4mM cinnamic acid solution where it had no sign of disease until ninth day of storage when 2% sodium alginate was used for coating (Appendix G). This implies that a higher concentration of cinnamic acid had a better on control of disease. Cinnamic acid showed strong anti-bacterial activities that complete inhibition the bacterial growth, while vanillyl acetone and gallic acid showed less activity (Brul and Coote, 1999). Bown (1995) also reported that the cinnamic acid contain anti-fungal and anti-bacteria properties that could be used as a medicine to prevent the human affecting disease infection or disorders.

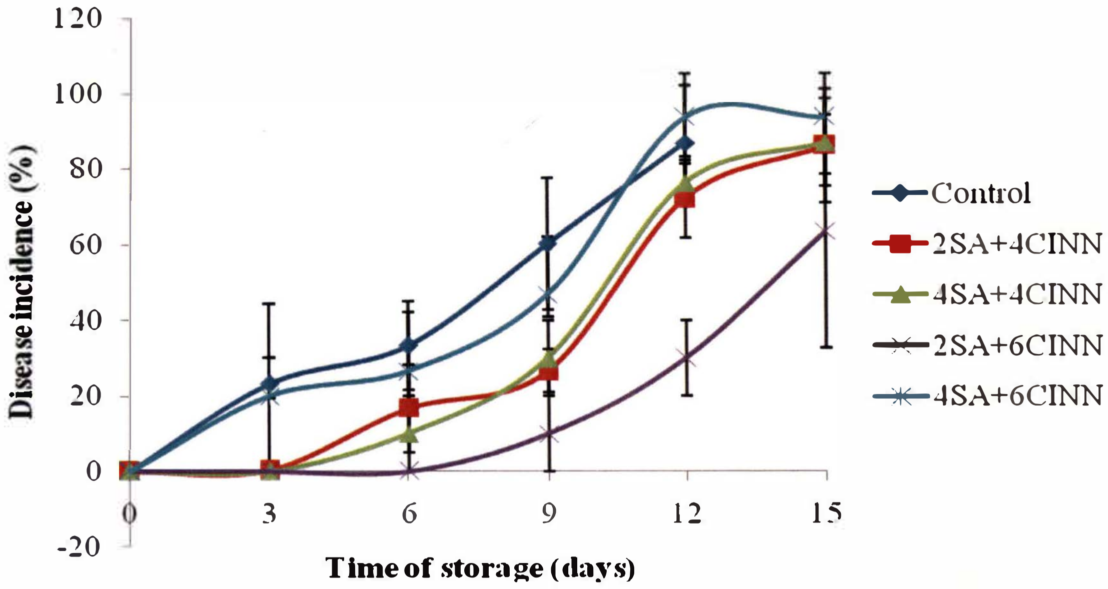

Figure 4.7: Disease incidence changes after coated with combination of sodium alginate (SA) and cinnamic acid (CINN) stored at ambient temperature for 15 days.

CHAPTER 5

CONCLUSION

5.1 Conclusion

In summary, mango fruits coated with a combination of sodium alginate and cinnamic acid is suitable to extend the shelf life of mango fruits stored under ambient temperature without unflavourable changes in external and internal quality for fifteen day of storage. Sodium alginate is a major structural polysaccharide derived from marine brown algae that could be considered for edible film and coating while cinnamic acid is a phenolic compound that is able to prolong the shelf life of fruits and vegetables by providing a natural protection against infections by pathogenic microorganisms. This study has revealed that a combination of 4% sodium alginate and 6mM cinnamic acid is effective in retarding colour changes, retaining fruit firmness and delaying total soluble solid content in mango fruits whereas a combination of 2% sodium alginate and 6mM exhibits strong inhibitory effects against invasion of microorganisms and fungi decay in mango fruits. It is because a higher concentration of sodium alginate will increase the viscosity and thickness thereby decreasing intermolecular space in the film and inhibiting cinnamic acid to fill in the intermolecular space while a lower concentration of sodium alginate has lower viscosity and thickness of sodium alginate allowing cinnamic acid to fill and replace the intermolecular space of sodium alginate. This study suggests that mango fruits coated with a combination of 2% sodium alginate and 6mM cinnamic acid is the most effective treatment in maintaining post-harvest quality and prolonging the shelf life of mango fruits because this combination can delay ripening reduce weight loss and protect fruits from disease infection without impeding the development of sweetness of mango fruits.

5.2 Suggestion for further study

A combination of sodium alginate and cinnamic acid coating on mangoes has a potential to extend the shelf life and quality of mangoes by controlling the amount of pathogenic microorganisms under the ambient temperature. For further study, the application of sodium alginate and cinnamic acid solutions should be tested and exerted to the other horticulture crops such as guava, muskmelon and others at different maturity stage and the storage conditions. An optimum concentration of both solutions should be able to give as well as maintain all the quality assessment of mango fruit. Besides, sodium alginate and cinnamic acid have a great potential for novel uses in food industry because both compounds are natural, biodegradable and harmless to human being and environment.

REFERENCES

Aina, O. J. 1990. Physico-chemical Changes in African Mango (lrvingia gabonensis) during Normal Storage Ripening. *Food Chemistry*. 36:205-212.

Aked, J. 2000. Fruits and vegetables, In: Kilcast, D. And Subramaniam, P., (Eds) the stability and shelf life of food. *New York: Woodhead Publishing Limited*. P 249- 278.

Amin. M. and M. Hanif. 2002. Cultivation of mango in Dera Ismail Khan. Agri. Research institute. Ratta, D. I. Khan. Pp. 1-18.

Baldwin E. A., Burns J.K., Kazokas W., Brecht J.K., Hagenmaier R. D., Bender R.J., Pesis E. 1999. Effect of two edible coatings with different permeability characteristics on mango (Mangifera indica L.) ripening during storage. *Postharvest Biology and Technology*. 17:215-226.

Ball, J. A. 1997. Evaluation of two lipid-based edible coatings for their ability to preserve postharvest quality of green ball peppers. M. Sc. Thesis, Blacksburg, Virgina. p.89.

Batu, A. 2003. Temperature effect on fruit quality of mature green tomatoes during controlled atmosphere storage. *International Journal Food Science and Nutrition*. 54(3):201- 208.

Bautista-Baños, S., García-Domínguez, E., Barrera-Necha, L.L., Reyes-Chilpa, R.and Wilson, C.L. 2003. Seasonal evaluation of the postharvest fungicidal activity of powders and extracts of huamuchil (*Pithecellobium dulce*): action against *Botrytris cinerea*, *Penicillium digitatum* and *Rhizopus stolonifer* of strawberry fruit. *Postharvest Biology Technology*.
29:81–92.

Bender, R. J., Brecht, J. K., Baldwin, E. A. and Malundo, T. M. M. 2000. Aroma volatiles of mature-green and tree ripe 'Tommy Atkins" mangoes after controlled atmosphere vs air storage. *HortScience*. 35:684-686.

Ben-Yehoshua S. 1987. Transpiration, water stress and gas exchange. In: Weichmann J, ed. Postharvest Physiology of Vegetables. Marcel Dekker, New York. p.113-170.

Bil, N. 2004. Blight diseases in mangoes. New south wales department of primary industries. 1: 1-3.

Brown, M. H. and Booth, I. R. 1991. Acidulants and low pH. In: Russell, N. J. and Gould, G. W. (Eds) *Food Preservatives*. Blackie, Glasgow. p. 22-43.

Burt, S. 2004. Essential oils: their antibacterial properties and potential applications in foods-a review. *International Journal of Food Microbiol*ogy 94:223–253.

Brul, S. and Coote, P. 1999. Preservative agents in foods: mode of action and microbial resistance mechanisms. *International Journal of Food Microbiology*. 50:1-17.

Campbell, J. 1992. A guide to mangoes in Florida. Miami. *Fairchild Tropical Garden*. p. 227.

Campos, J. P. And Yahia, E. M. 1991. Hot water quarantine treatment effect on the ripening and senescence of mango. *HortScience*. 26:696 (Abstract).

Carillo-Lopez, A., Ramirez-Bustamante, F., Valdez-Torres, J. B., Rojas-Villegas, R. and Yahia, E. M. 2000. Ripening and quality changes in mango fruit as affected by coating with edible film. *Journal of Food Quality*. 23(5):479-486.

Dhalla, R. and Hanson, S. W. 1988. Effect of permeability coatings on the storage life of fruits.II.Pro-long treatments of mangoes (Mangiferz indict L.cv. Julie). *Int. J. Food Science Technology*. 23:107-12.

Davidson, P.M., 1997. Chemical preservatives and natural antimicrobial compounds. In: Doyle, M.P., Beuchat, L.R., Montvil e, T.J. (Eds.), Food Microbiology: Fundamentals and Froniers, ASM Press, Washington D.C, p. 520–556.

De Vries, R.P., Michelsen, B., Poulsen, C.H., Kroon, P. A., Van Den Heuvel, R. H. H., Faulds, C.B., Williamson, G., Van Den Hombergh, J. P. T. W. and Visser, J. 1997. The *faeA* genes from *Aspergillus tubingensis* encode ferulic acid esterases involved in degradation of complex cell wall polysaccharides. *Applied and Environmental Microbiology*. 63:4638–4644.

Donhowe, G. and Fennema, O. R., 1994. Edible films and coatings: characteristics, formation definitions and testing methods. *In:* Krochta J. M., Baldwin E. A. and Nisperos- Carriedo M. O. (eds), Edible coatings and films to improve food quality. Technomic Publishing Co. Inc, Lancaster, PA, p. 1-24.

Doubrava, N.S., Dean, R.A., and Kuc, J., 1998. Induction of systemic resistance to anthracnose caused by *Coletotrichum legenarium* in cucumber by oxalate and extract from spinach and rhubarb leaves. *Physiology Molecular and Plant Pathology*. 33:69–79.

Droby, S., 2006. Improving quality and safety of fresh fruit and vegetables after harvest by the use of biocontrol agents and natural materials. *Acta Horticulturae*. 709:45–51.

Duckworth. R. B., 1979. Fruit and Vegetables: The Composition of fruit and vegetable. Pergamon Press, Oxford New York. Appendix-1

El-Ghaouth, A., Wilson, C.L. and Wisniewski, M.E., 2004. Biologically based alternatives to synthetic fungicides for the postharvest diseases of fruit and vegetables. In: Naqvi, S.A.M.H. (Ed.), Diseases of Fruit and Vegetables, vol. 2. Kluwer Academic Publishers, The Netherlands. p.511–535.

Fabio, A., Corona, A., Forte, E. and Quaglio, P. 2003. Inhibitory activity of species and essential oils on psychrotrophic bacteria. *Microbiology*. 26(1):115-120.

FAO, *Food and Agriculture Production year Book*, FAO, Rome, 1990.

FAOSTAT. 2004. *FAO Statistical Database – Agriculture*; http://apps. fao.org (accessed November, 2004).

Friedman, M., Henika, P.R., Levin, C.E. and Mandrell, R.E. 2004. Antibacterial activities of plant essential oils and their components against *Escherichia coli* O157:H7 and *Salmonella enterica* in apple juice. *Journal Agricultural and Food Chemistry*. 52: 6042–6048.

Gomer-Lim, M. A. 1997. Postharvest physiology. In *the Mango: Botany, Production and Uses* (R. E. Litz, ed.) P. 425-446, CAB International, New York.

Gonzalez-Aguilar, G. A., Zacarias, L., Mulas, M. and Lafuente, M. T. 1997. Temperature and duration of water dips influence chilling injury, decay and polyamine content in Fortune mandarins. *Postharvest Biology And Technology*. 12:61-69.

Hagenmaier, R.D. and Baker, R.A. 1993. Reduction in gas exchange of citrus fruit by wax coatings. *Journal Agricultural Food Chemistry*. 41:283-287.

Han, C., Zha, Y., Leonard, S. W., Traber, M. G. 2004. Edible coatings to improve storability and enhance nutritional value of fresh and frozen strawberries (*Fragaria ananassa*) and raspberries (*Rubus ideaus*). *Postharvest Biology and Technology*. 33: 67-78.

Herianus, J. D., L. Z. Singh, and S. C. Tan. 2003. Aroma volatiles production during fruit ripening of "Kesington pried" mango. *Postharvest Biology And Technology*. 27:323-336.

Hoa, M.N., Ducamp, M. Lebrun and Baldwin, E. 2002. Effect of different coating treatments on the quality of mango fruit. *Journal of Food Quality*. 25:471–486.

Hoskins JA. 1984. The occurrence, metabolism and toxicity of cinnamic acid and related compounds. *Journal Application Toxicology*. 4:283–292.

Hussain S., Masud T. and Ahad K. 2002. Determination of pesticides residues in selected varieties of mango. *Pakistan Journal of Nutrition*. 1:41-42.

Imran, H., Tariq, M. and Habib, A. R. 2005. Effect of coating and wrapping material on the shelf life of apple (Malus domestic acv. Borkh). *Journal of Food Safety.* 5:24-34.

Jackman, R.L. and Stanley, D.W. 1995. Perspectives in the textural evaluation of plant foods, *Trends in Food Science and Technology*. 6:187–194.

Jacobi, K. K., Wong, L. S. and Giles, J. E. 1995. Effect of fruit maturity on quality and physiology of high humidity and hot air-treated 'Kensington' mango (*Mangifera indica* L.). *Postharvest Technology.* 5:149-159.

Jasso de Rodrı ´guez, D.; Herna ´ndez-Castillo, D.; Rodrı ´guez-Garcı ´a, R.; Angulo-Sa ´nchez, J. L. 2005. Antifungal activity in vitro of aloe vera pulp and liquid fraction against plant pathogenic fungi. *Ind. Crop Production.* 21:81-87.

Jiang, Y.M, and Li, Y.B. 2001. Effects of chitosan coating on storage life and quality of longan fruit. *Food Chemstry.* 73:139- 143.

Jitareerat, P., Win' N. K. K., Kanlayanarat, S. and Sangchote, S. 2007. Effects of cinnamon extract, chitosan coating, hot water treatment and their combinations on crown rot disease and quality of banana fruit. *Postharvest Biology and Technology*. 45(3):333-340.

Kalra, S. K., and D. K. Tandon. 1983. Ripening behaviour of Dashehari mango in relation to harvest period. *Journal of the American Society and Horticulture Science*. 19:263.

Kester, J. J., and Fennema, O. R. 1986. Edible films and coatings: A review. *Food Technology*.40:47–59.

Khuyen T.T, Dang, Zora Singh and Ewald E. Swinny. 2008. Edible coatings influence fruit ripening, quality, and aroma biosynthesis in mango fruit. *Agricultural and Food Chemistry*. 56: 1361–1370.

King, A.H., 1983. Brown seaweed extracts (Alginates). *Food Hydrocolloids* 2. pp. 115–188.

Kittur, F.S., Saroja, N., Habibunnisa and Tharanathan, R.N. 2001. Polysaccharide-based composite coating formulations for shelf-life extension of fresh banana and mango. *European Food Research and Technology.* 213:306–311.

Klein, J. D. and Lurie, S. 1991. Pre-storage heat treatment as a means of improving poststorage quality of apples. *Journal of the American Society and Horticulture Science*. 115:265-269.

Krishnamurthy, S., and Subramanyam, H. 1970. Effect of malic hydrazide and 2,4,5-trichlorophenoxy propionic acid on ripening and quality of mango fruit. *Journal of the American Society and Horticulture Science*. 95:333.

Kumar, A. and Tripathi, S.C., 1991. Evaluation of the leaf juice of some higherplants for their toxicity against soil borne pathogens. *Plant Soil.* 132:297–301.

Lee, J.Y., Park, H.J., Lee, C.Y. and Choi, W.Y. 2003. Extending shelf-life of minimally processed apples with edible coatings and antibrowning agents, Lebensmittel-Wissenschaft und-Technologie. 36:323–329.

Li, H. and Yu, T. 2000. Effect of chitosan on incidence of brown rot, quality and physiological attributes of postharvest peach fruit. *Journal of the Science and Food Agricultural.* 81:269- 274.

Loveys, B.R., Robinson, S.P., Brophy, J.J. and Chacko, E.K. 1992. Mango Sapburn: Components of fruit sap and their role in causing skin damage. *Australia Journal of Plant Physiology*. 19:449-457.

Lu, S., Luo, Y., Turner, E. and Feng, H. 2007. Efficacy of sodium chlorite as an inhibitor of enzymatic browning in apple slices. *Food Chemistry.* 104(2):824- 829.

Lurie, S., 1998. Postharvest heat treatments. *Postharvest Biology and Technology.* 14:257–269.

Malundo, T. M. M., Shewfelt, R. L., Ware, G. O., Baldwin, E. A. 2001. Sugars and acids influence flavor properties of mango (*Mangifera indica*). *Journal of the American Society and Horticulture Science*. 126:115-121.

Man, P., Chang, L., Young, J. S., Sang, R. W., Dongill, S., Jyung, C. 2010. Hybridization of the natural antibiotic, cinnamic acid, with layered double hydroxides (LDH) as green pesticide. *Environmental Science and Pollution Research.* 17:203–209.

Mancini, F., and McHugh, T. H. 2000. Fruit- alginate interactions in novel restructured products. *Nahrung,* 44:152-157.

Maqbool, M., Malik, A.U. and. Jabbar. A 2007. Sap dynamics and its management in commercial mango cultivars of Pakistan. *Pakistan Journal Botani.* 39:1565-1574.

Mazza, G., Miniati, E., 1993. Grapes. In: Anthocyanins in Fruits, Vegetables and Grains, CRC Press, pp. 149–200.

McHugh, T. H. and J. M. Krochta, 1994. Milk-protein-based edible films and coatings. *Food Technology*. 48 (1):97-103.

McHugh, T.H., Senesi, E., 2000. Apple wraps: a novel method to improve the quality and extend the shelf-life of fresh-cut apples. *Journal of Food Science*. 65:480–485.

Mclellan, M. R., Lind, L. R. and Kime, R. W. 2007. Hue angle determinations and stastica; analysis for multiquadrant hunter L, a, b data. *Journal of Food Quality*. 18 (3):235-240.

Medlicott, A. P., Thompson, A. K. 1985. Analysis of sugars and organic acids in ripening mango fruits (*Mangifera indica* L. var Keitt) by high performance liquid chromatography. *Journal of the Science and Food Agriculture*. 36:561-566.

Mitra, S.K., Baldwin, E.A., 1997. Mango. In: Mitra, S.K. (Ed.), Postharvest Physiology and Storage of Tropical and Subtropical Fruit. CAB International, New York, NY, pp. 85–122.

Moe, S. T., Draget, K. L. Skjak-Braek, G. and Smidsrod, O., 1995. Alginates. In: Stephen, A. M., Editor. 1995. *Food polysaccharides and their applications*, Marcel Dekker, New York, pp. 245-286.

Morton, J. 1987. Mango. p. 221–239. In: Fruits of warm climates. Julia F. Morton, Miami, FL.

Muhammad, A., Aman, U.M., Muhammad, S.M, Islam-Ud-Din, Muhammad, S. K. and Saeed, A. 2008. Mango fruit desapping in relation to time of harvesting. *Pakistan Journal Botani*., 40(4):1587-1593.

Negi, P.S.; Chauhan, A.S.; Sadia, G.A.; Rohinishree, Y.S.; Ramteke, R.S. 2005. Antioxidant and antibacterial activities of various seabuckthorn (Hippophae rhamnoides L.) seed extracts. *Food Chemistry*. 92:119-124.

Nisperos-Carriedo, M. O. Baldwin , E. A. and Shaw P. E. 1991. Development of an edible coating for extending postharvest life of selected fruits and vegetables. *Proc. Fla. State Horticulture Society*. 104:122-125.

Noomhorm, A. and Tiasuwan, N. 1995. Controlled atmosphere storage of mango fruit. *Mangifera indica* L., cv. Rad. *Journal of Food Processing and Preservation* 19:271-281.

Nor, H. M. S., Tengku Ab. M. T. M. and Johari, S. 2008. Breeding horticultural crops @MARDI. p. 133- 154.

Nussinovitch, A. and Hershko, V. 1996. Gellan and alginate vegetable coating. Carbohydrate Polymers. 30:185- 192.

Olivas and Barbosa-Cánovas, G.V. 2005. Edible coating for fresh-cut fruits, *Crit. Revision of Food Science*. 45:657–670.

Oms-Oliu, G., Soliva-Fortuny, R., Martin-Belloso, O. 2008. Using polysaccharide-based edible coatings to enhance quality and antioxidant properties of fresh-cut melon. *LWT-Food Science and Technology*.
41:1862-1870.

Park, H. J., Chinnan, M. S. and Shewfelt, R. L. 1992. Coating tomatoes with edible films. Prediction of internal oxygen concentration and effect on storage life and quality. Paper 848, Ann. Mtg., Inst. Food Technol., New Orleans, LA.

Park, H. J., Chinnan, M. S. and Shewfelt, R. L. 1994. Edible coating effects on storage life quality of tomatoes. *Journal of Food Science*. 59:568-570.

Peng, L. L. and Jiang, Y. M. 2003. Effects of chitosan coating on shelf life and quality of fresh-cut Chinese water chestnut. *Lebensmittel – Wissenschaft unad Technologie*. 36:359- 364.

Perkins-Veazie, P., 1995. Growth and ripening of strawberry fruit. *Horticulture. Revision.* 17: 267–297.

Petersen, K., Nielsen, P.V., Bertelsen, G., Lawther, M., Olsen, M., Nilssonk, N.H. and Mortenseny, G. 1999. Potential of biobased materials for food packaging. *Trends in Food Science and Technology*. 10: 52–68

Priyasethu, K. M., Prabha, T. N. and Tharanathan, R. N. 1996. *Phytochemistry.* 42:961-966

Ramos-Nino, M.E., Clifford, M.N., Adams, M.R., 1996. Quantitative structure activity relationship for the effect of benzoic acids, cinnamic acids and benzaldehydes on Listeria monocytogenes. *Journal of Application and Microbiology*. 80:303–310.

Ranasinghe, L., Jayawardena, B. and Abeywickrama, K. 2003. Use of waste generated from cinnamon bark oil (*Cinnamomum zeylanicum* Blume) extraction as a post harvest treatment for Embul banana. *Journal of Food Agriculture and Environment.* 1:340–344.

Rhim. J. W. 2003. Physical and mechanical propertities of water resistant sodium alginate films. 37:323-330.

Rhim, J.W., 2004. Physical and mechanical properties of water resistant sodium alginate films. *Lebensmittel-Wissenschaft und-Technologie*. 37(3):323-330.

Rhodes, M. J. C. 1980. The maturation and ripening of fruit, *Senescence in Plants* (K. V. Thimann, ed.), CRC Press, Boca Raton, FL.

Rojas-Grau, M. A., Tapia, M. S., Rodriguez, F. J., Carmona, A. J. and Martin-Belloso, O. 2007. Alginate and gellan-based edible coatings as carriers of antibrowning agents applied on fresh-cut Fuji apples. 21: 118-217.

Roller, S. and Seedhar, P., 2002. Carvacrol and cinnamic acid inhibit microbial growth in fresh-cut melon and kiwifruit at 4 °C and 8 °C. *Letters in Applied Microbiology* 35:390–394.

Roller, S. 1995. The quest for natural antimicrobials as novel means of food preservation: status report on a European research. *International Biodeterioration & Biodegradation*. P 333-345

Saks, Y. and Barkai-Golan, R. 1995. Aloe Vera gel against plant pathogenic fungi. *Postharvest Biology and Technology*. 6:159-165.

Salunkhe, D. K. and Kadam, S. S. 1995. Mango. *Handbook of Fruit Science and Technology: Production, Composition, Storage, and Processing.* P.150-151. CRC Press, Boca Raton, London, New York.

Salunkhe, D. K. and Kadam, S. S. 1998. Postharvest Biotechnology of Fruits. 1:77-94. Florida:CRC Press.

Salvador, M. L., Jaime, P. and Oria, R. 2003. Use of edible coatings to reduce water loss and maintain quality of Reinette apple. *Acta Horticulture*. 60:701-705.

Senesi, E. and T.H. Mchugh, 2000. Apple wraps: A novel method to improve the quality and extend the shelf life of fresh-cut apples. *Journal of Food Science*. 65(3):480-485.

Serrano, M., Valverde, J. M., Guillen, F., Castillo, S., Martinez-Romero, D. Valero, D. 2006. Use of Aloe Vera gel coating preserves the functional properties of table grapes. *J. Agric. Food Chem*. 54:3882–3886.

Shimada, K., Kimura, E., Yasui, Y., Tanaka, H., Matsushita, S., Nagakmura, M. and Kawahisa, M. 1991. Styrene formation by the decomposition of Pichia carsonii of trans- cinnamic acid added to a ground fish product. *Application of Environment and Microbiology*. 58: 1577-1582.

Singh, D., Sharma, R.R., 2007. Postharvest diseases of fruit and vegetables and their management. In: Prasad, D. (Ed.), Sustainable Pest Management. Daya Publishing House, New Delhi, India.

Smith, G. J. and Brul, S. 2005. Stress tolerance in fungi to kill spoilage yeast. *Current Opinion in Biotechnology*. 16:225- 230.

Sothornvit, R., and Krochta, J. M. 2000. Plasticizer effect on oxygen permeability of B-lactoglobulin films. *Journal of Agricultural and Food Chemistry*. 48:6298–6302.

Sothornvit, R. and Rodsamran, P. 2008. Effect of a mango film on quality of whole and minimally processed mangoes. 47(3):407-415.

Strobel, B. W. 2001. Influence of vegetation on low-molecular-weight carboxylic acids in soil solution—a review. Geoderma. 99:169–198.

Tapia, M. S., Rojas-Grau, M. A., Carmona, A., Rodriguez, F. J., Soliva-Fortuny, R., Martin-Belloso, O. 2008. Use of alginate- and gellan-based coatings for improving barrier, texture and nutritional properties of fresh-cut papaya. *Food Hydrocolloids*. 22:1493-1503.

Thangavelu, R., Sundararaju, P.and Sathiamoorthy, S. 2004. Management of anthracnose disease of banana caused by *Colletotrichum musae* using plant extracts. *Journal of Horticulture and Science Biotechnology*. 79:664–668.

Ueda, M., Sasaki, K., Utsunomiya, N., Inaba, K. and Shimabayashi, Y. 2000. Changes in physical and chemical properties during maturation of mango fruit (*Mangifera indica* L. 'Irwin') cultured in a plastic greenhouse. *Food Science and Technology Research*. 6:299-305.

Valverde, J. M., *et al*., 2005. Novel edible coating based on aloe vera gel to maintain table grape quality and safety. *Journal of Agriculture and Food Chemistry*. 53:7807-7813.

Wang , D. F., Fan, Y., Xu, Y., Zhang, L., Sun, J. P., Sun, L.P. and Zhang, B. 2009. Effect of alginate coating combined with yeast antagonist on strawberry (*Fragaria* × *ananassa*) preservation quality. *Postharvest Biology and Technology*. 53: 84-90.

Whitaker, J. R. 1996. Enzymes. In: Fennema O.R. and Dekker, M., (Eds) *Food Chemistry*. 3rd ed. New York. p. 431- 530.

Wong, D. W. S., Gregorski, K. S., Hudson, J. S., and Pavlath, A. E. 1996. Calcium alginate films: Thermal properties and permeability to sorbate and ascorbate. *Journal of Food Science*. 61:337–341.

Zainuri, Irving, D. E., Dann, E. K., Coates. L.M. and Wearing, A.H. 2003. Activating mango fruit defence to anthracnose disease. *Plant Pathology Plant Physiology*. P 149 – 150.

Zapata, P. J., Guillen, F., Romero, D.M., Castillo, S., Valero, D. and Serrano, M. 2008. Use of alginate or zein as edible coatings to delay post harvest ripening process and to maintain tomato (*Solanum lysopersicon* Mill) quality. *Journal of the Science of Food and Agricultural*. 88:1287- 1293.

Zhu, S.J., 2006. Non-chemical approaches to decay control in postharvest fruit. In: Noureddine, B., Norio, S. (Eds.), Advances in Postharvest Technologies for Horticultural Crops. Research Signpost, Trivandrum, India. pp. 297–313.

Zhu *et al*., 2008. Effects of chitosan coating on postharvest quality of mango (*Mangifera indica* L. Cv. Tainong) fruits. *Journal of Food Processing and Preservation*. 32:770- 784.

Zhuang, R. Y. and Huang, Y. W. 2003. Influence of hydroxypropyl methlcellulose edible coating on fresh- keeping and storability of tomato. *Journal of Zhejiang University*. 4:109-113.

APPENDIX A

Table: Mean hue values of mangoes during storage at ambient temperature

	Hue Angle				
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**
Control	178.80 ± 0^{a}	178.52 ± 0.07^{a}	1.5 ± 0.03^{a}	1.45 ± 0.02^{a}	1.45 ± 0.03^{a}
2% SA + 4mM CINN	178.80 ± 0^{a}	178.75 ± 0.15^{ab}	178.59 ± 0.11^{b}	178.54 ± 0.09^{b}	178.52 ± 0.11^{b}
4%SA + 4mM CINN	178.80 ± 0^{a}	178.83 ± 0.09^{b}	178.73 ± 0.05^{b}	178.66 ± 0.07^{b}	178.58 ± 0.04^{b}
2% SA + 6mM CINN	178.80 ± 0^{a}	178.77 ± 0.06^{ab}	178.68 ± 0.04^{b}	178.57 ± 0.13^{b}	179.24 ± 1.34^{b}
4%SA + 6mM CINN	178.80 ± 0^{a}	178.85 ± 0.13^{b}	178.70 ± 0.04^{b}	178.61 ± 0.04^{b}	178.5 ± 0.05^{b}

Means within the same columns with different letters are significantly different ($P<0.05$).

APPENDIX B

Table: Mean firmness of mangoes during storage at ambient temperature

	Firmness (Force, g)					
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**	**Day 15**
Control	478.71 ± 0^{a}	273.17 ± 26.96^{a}	203.41 ± 2.65^{a}	125.73 ± 14.64^{a}	82.47 ± 10.79^{a}	56.72 ± 13.17^{a}
2% SA + 4mM CINN	478.71 ± 0^{a}	366.36 ± 28.84^{ab}	249.80 ± 22.62^{ab}	217.93 ± 3.6^{bc}	179.28 ± 12.13^{bc}	137.58 ± 21.42^{b}
4%SA + 4mM CINN	478.71 ± 0^{a}	589.53 ± 49.14^{c}	314.5 ± 76.90^{ab}	240.29 ± 37.87^{c}	168.78 ± 15.24^{b}	116.71 ± 15.02^{b}
2% SA + 6mM CINN	478.71 ± 0^{a}	456.6 ± 49.37^{b}	313.68 ± 39.00^{ab}	172.04 ± 11.54^{ab}	138.68 ± 18.07^{b}	124.22 ± 20.1^{b}
4%SA + 6mM CINN	478.71 ± 0^{a}	387.31 ± 59.28^{ab}	325.99 ± 25.19^{b}	241.44 ± 21.06^{c}	220.14 ± 31.18^{c}	147.21 ± 18.39^{b}

Means within the same columns with different letters are significantly different ($P<0.05$).

APPENDIX C

Table: Mean Total soluble solid (TSS) of mangoes during storage at ambient temperature

	TSS Content (Brix, %)					
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**	**Day 15**
Control	9.47 ± 0^{a}	10.34 ± 0.35^{b}	10.71 ± 0.34^{b}	11.03 ± 0.09^{c}	11.87 ± 0.2^{b}	12.03 ± 0.2^{b}
2% SA + 4mM CINN	9.47 ± 0^{a}	9.59 ± 0.06^{ab}	10.02 ± 0.54^{ab}	10.09 ± 0.12^{a}	10.37 ± 0.02^{a}	10.88 ± 0.22^{a}
4%SA + 4mM CINN	9.47 ± 0^{a}	9.72 ± 0.52^{ab}	10.30 ± 0.30^{ab}	10.33 ± 0.19^{ab}	10.71 ± 0.10^{a}	11.21 ± 0.37^{a}
2% SA + 6mM CINN	9.47 ± 0^{a}	9.79 ± 0.4^{ab}	10.26 ± 0.04^{ab}	10.52 ± 0.14^{b}	10.81 ± 0.08^{a}	11.4 ± 0.2^{ab}
4%SA + 6mM CINN	9.47 ± 0^{a}	9.19 ± 0.13^{a}	9.61 ± 0.31^{a}	10.07 ± 0.18^{a}	10.59 ± 0.38^{a}	11.2 ± 0.22^{a}

Means within the same columns with different letters are significantly different ($P<0.05$)

APPENDIX D

Table: Mean loss of weight of mangoes after 15 days of storage at ambient temperature

Treatment	Weight Loss (%)
Control	12.42 ± 0.33^{b}
2% SA + 4mM CINN	11.29 ± 0.24^{a}
4% SA + 4mM CINN	11.13 ± 0.4^{a}
2% SA + 6mM CINN	11.45 ± 0.31^{a}
4% SA + 6mM CINN	11.63 ± 0.23^{ab}

Means within the same columns with different letters are significantly different ($P<0.05$).

APPENDIX E

Table: Mean scores for visual appearance of mangoes during storage at ambient temperature

	Visual Appearance (Score)					
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**	**Day 15**
Control	8.5 ± 0.12^{a}	4.6 ± 0.35^{a}	4.3 ± 0.50^{a}	2.8 ± 0.53^{a}	1.7 ± 0.43^{a}	
2% SA + 4mM CINN	8.5 ± 0.12^{a}	5.5 ± 0.12^{b}	5.1 ± 0.31^{ab}	4.4 ± 0^{ab}	3.1 ± 0.59^{ab}	2 ± 0.88^{a}
4%SA + 4mM CINN	8.9 ± 0.12^{ab}	6.5 ± 0.12^{c}	5.4 ± 0.53^{ab}	3.9 ± 0.64^{ab}	2.3 ± 0.26^{ab}	1.4 ± 0.35^{a}
2% SA + 6mM CINN	9 ± 0^{b}	6.9 ± 0.31^{c}	6 ± 0.80^{b}	4.7 ± 1.03^{b}	3.4 ± 0.87^{b}	2.3 ± 0.81^{a}
4%SA + 6mM CINN	8.6 ± 0.23^{a}	5.5 ± 0.42^{b}	5.1 ± 0.90^{ab}	4.1 ± 0.61^{ab}	2.2 ± 0.60^{ab}	1.3 ± 0.31^{a}

Means within the same columns with different letters are significantly different ($P<0.05$).

APPENDIX F

Table: Mean scores for disease of severity of mangoes during storage at ambient temperature

	Disease of Severity (Score)					
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**	**Day 15**
Control	0±0	$1.9{\pm}0.57^{b}$	$2.2{\pm}0.15^{b}$	$2.9{\pm}0.25^{c}$	$3.6{\pm}0.37^{b}$	
2% SA + 4mM CINN	0±0	$1.2{\pm}0.06^{ab}$	$1.8{\pm}0.12^{ab}$	$2.2{\pm}0.1^{ab}$	$2.8{\pm}0.21^{ab}$	$3.2{\pm}0.32^{ab}$
4%SA + 4mM CINN	0±0	$0.9{\pm}0.06^{a}$	$1.4{\pm}0.21^{a}$	$2.2{\pm}0.15^{ab}$	$3.0{\pm}0.35^{ab}$	$3.6{\pm}0.15^{ab}$
2% SA + 6mM CINN	0±0	$0.9{\pm}0.06^{a}$	$1.5{\pm}0.15^{a}$	$1.8{\pm}0.31^{a}$	$2.2{\pm}0.38^{a}$	$2.8{\pm}0.52^{a}$
4%SA + 6mM CINN	0±0	$1.4{\pm}0.6^{ab}$	$1.8{\pm}0.15^{ab}$	$2.5{\pm}0.26^{bc}$	$3.4{\pm}0.36^{b}$	$3.7{\pm}0.20^{b}$

Means within the same columns with different letters are significantly different ($P<0.05$).

APPENDIX G

Table: Mean percentages for disease of incidence of mangoes during storage at ambient temperature

	Disease of Incident (%)					
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**	**Day 15**
Control	0±0	23.33 ± 5.77^{b}	33.33 ± 5.77^{d}	60 ± 10^{c}	86.67 ± 5.77^{bc}	
2% SA + 4mM CINN	0±0	3.33 ± 5.77^{a}	16.67 ± 5.77^{bc}	26.67 ± 5.77^{b}	71.85 ± 10.26^{b}	85.83 ± 15.07^{ab}
4%SA + 4mM CINN	0±0	0 ± 0^{a}	10 ± 0^{ab}	30 ± 0^{bc}	75.93 ± 5.25^{bc}	86.67 ± 11.55^{ab}
2% SA + 6mM CINN	0±0	0 ± 0^{a}	0 ± 0^{a}	10 ± 0^{a}	30 ± 10^{a}	63.33 ± 5.77^{a}
4%SA + 6mM CINN	0±0	20 ± 10^{b}	26.67 ± 5.77^{cd}	46.67 ± 5.77^{c}	93.33 ± 5.77^{c}	93.33 ± 5.77^{b}

Means within the same columns with different letters are significantly different ($P<0.05$).

CURRICULUM VITAE

Name	:Tey Huan Yoon
Permanent addres	: 448, Jalan Pee Kang Hai, Bukit Siput, 85020 Segamat, Johor.
Telephone Number	: 07-9434461 (H) / 017-7630163 (Hp)
E-mail	: yoonyoon228@hotmail.com
Date of Birth	: 28 February 1987
Place of Birth	: Melaka
Nationality	: Malaysia
Race	: Chinese
Gender	: Female
Religion	: Buddha

Educational Background :

2007 – 2010	University Malaysia Terengganu (UMT)
2004 – 2006	Sekolah Tinggi Segamat (STS)
2003 – 2004	Sekolah Menengah Seg Hwa (SMSH)
2000 – 2002	Sekolah Menengah Kebangsaan Paduka Tuan (SMKPT)
1994 – 1999	Sekolah Jenis Kebangsaan Bukit Siput (SJKBS)

Award : Dean's list

EFFECT OF SODIUM ALGINATE COMBINED WITH CINNAMIC ACID COATING ON POSTHARVEST QUALITY OF MANGO FRUIT (MANIFERA INDICA L.) VARIETY CHOKANAN STORED UNDER AMBIENT TEMPERATURE - TEY HUAN YOON