EXTENDING THE SHELF LIFE OF MINIMALLY PROCESSED MUSKMELON (*Cucumis melo*) USING HYDROCOLLOIDS AS EDIBLE COATINGS

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EXTENDING THE SHELF LIFE OF MINIMALLY PROCCESSED MUSKMELON *(Cucumis melo)* USING HYDROCOLLOIDS AS EDIBLE COATINGS

By
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ENDORSEMENT

The project report entitled '**Extending the shelf life of minimally processed muskmelon (*Cucumis melo*) using hydrocolloids as edible coating'**, by **Nurul Atiqah bt Ramli**, Matric No **UK15221** has been reviewed and corrections have been made according to the recommendations by examiners. This report is submitted to the Department of Agrotechnology in partial fulfillment of the requirement of the degree of B. Sc. Agrotechnolgy (Post Harvest Technology), Faculty of Agrotechnology and Food Science, Universiti Malaysia Terengganu.

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DECLARATION

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ABSTRACT

The storage stability of minimally processed Muskmelon (*Cucumis melo* variety *Glamour*) treated with hydrocolloids as edible coatings were investigated. Muskmelons were selected base on uniformity of size, colour, shape and absences of damage and fungal infection. The muskmelons were sliced longitudinally into 12 wedges with 3 cm thick in the middle and treated with selected edible coatings of chitosan (1%), carrageenan (1%), pectin (2%) with calcium chloride (2%) and untreated fruits served as control. Physico-chemical changes, microbiological quality and sensory acceptability of minimally processed muskmelons were evaluated throughout 8 days of storage day at 5±1 ° C. Edible coating treatments of chitosan (1%), carrageenan (1%) and pectin (2%) with calcium chloride (2%) reduced the percentage of weight loss of minimally processed muskmelon. Treatment of carrageenan (1%) showed the highest of colour changes where it affects the overall acceptability in the sensory evaluation as well as the increasing microbial counted that exceeded the limit for safe consumption. There were no significant different showed on total soluble solid of minimally processed muskmelon for each treatment of hydrocolloids and control throughout day 8. Texture analysis of minimally processed muskmelon treated with chitosan (1%) did not affect the texture acceptability in sensory evaluation. Microbial analysis showed that chitosan (1%) was found to be the best treatment in retaining the quality of minimally processed muskmelon and the level was safe for consumption until day 8. The results of this study demonstrated that chitosan (1%) effectively prolong the quality and extends the shelf life of minimally processed muskmelon followed by pectin (2%) with calcium chloride (2%), control and carrageenan (1%) stored at low temperature.

ABSTRAK

Kestabilan penyimpanan proses minima tembikai wangi (*Cucumis melo* varieti *Glamour*) yang disalut dengan larutan hidrokolloid sebagai penyalut yang boleh dimakan dijalankan. Buah tembikai wangi dipilih berdasarkan keseragaman saiz, warna, bentuk dan tiada kerosakan serta jangkitan kulat. Tembikai wangi dipotong memanjang menjadi 12 potongan baji dengan 3 cm tebal di tengah dan disalut dengan penyalut kitosan (1%), karagenan (1%), pektin (2%) bersama kalsium klorida (2%) serta buah tanpa penyalut dijadikan sebagai kawalan. Perubahan fiziko-kimia, kualiti mikrobiologi dan penilaian deria terhadap proses minima tembikai wangi dinilai dalam tempoh 8 hari pada suhu simpanan 5±1 ° C. Proses minima tembikai wangi yang disalut dengan kitosan (1%), karagenan (1%) dan pektin (2%) bersama kalsium klorida (2%) mengurangkan peratus kehilangan berat. Salutan karagenan (1%) menunjukkan perubahan warna yang tertinggi di mana ia memberi kesan terhadap penerimaan keseluruhan dalam penilaian deria disamping peningkatan bilangan mikroorganisma yang melebihi tahap selamat untuk dimakan. Tiada perubahan ketara ditunjukkan terhadap jumlah keseluruhan pepejal terlarut dalam proses minima tembikai wangi antara setiap larutan hidrokolloid dan kawalan. Analisis tekstur salutan kitosan (1%) pada proses minima tembikai wangi tidak mempengaruhi penerimaan tekstur dalam penilaian deria. Analisis mikrob menunjukkan bahawa kitosan (1%) telah dikenalpasti sebagai salutan terbaik dalam mengekalkan kualiti proses minima tembikai wangi dan ditahap yang masih selamat untuk dimakan sehingga hari yang ke 8. Keputusan kajian ini menunjukkan bahawa kitosan (1%) secara efektifnya dapat mengekalkan kualiti dan memanjangkan jangka hayat proses minima tembikai wangi diikuti dengan salutan pektin (2%) bersama kalsium klorida (2%) control dan karagenan (1%) pada penyimpanan suhu rendah.

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LIST OF ABBREVIATIONS

%	-	Percentage
°C	-	Degree celcius
cm	-	Centimeter
mm	-	Millimeter
min	-	Minute
L	-	Liter
g	-	Gram
s	-	Second
w/v	-	Weight per volume
ANOVA	-	Analysis of variance
$CaCl_2$	-	Calcium chloride
CRD	-	Complete randomized design
ClO_2	-	Chlorine dioxide
EO	-	Essential oil
MP	-	Minimally Processed
MPFV	-	Minimally Processed Of Fruits and Vegetables
NA	-	Nutrient Agar
NaOH	-	Sodium Oxide
PDA	-	Potatoes Dextrose Agar
SPSS	-	Statistical program for social science
TSS	-	Total Soluble Solid
VRBA	-	Violet Red Bile Agar

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Muskmelon (*Cucumis melo* L.) is a commercially important crop in many countries. It is cultivated in all the temperate regions of the world due to its good adaptation to soil and climate. Fruits are consumed in the summer period and are popular because the pulp of the fruit is very refreshing and sweet, with a pleasant aroma (Villanueva *et al.*, 2004). Muskmelon (*Cucumis melo*) is widely known as Cantaloupe. It is net-like (or reticulated) skin covering. In Australia and New Zealand, it is called rockmelon due to the rock-like appearance of the skin of the fruit. It is called a *spanspek* or sweet melon in South Africa, where it is harvested during the summer months of October through February (Wikipedia, 2009). The fruit is round with firm, orange, moderately sweet flesh and a thin reticulated light-brown rind. It can be eaten fresh.

Minimally processed fruits and vegetables (MPFV) are any fresh fruit or vegetables that have been physically altered from the intact whole fresh fruit, but remain in a fresh state (Gomez-Lopez *et al.,* 2008). Regardless of the commodity, it has been trimmed, peeled, washed, and cut into a 100% usable product that is subsequently bagged or pre-packaged (IFPA, 2009). Marketing of fresh-cut, packaged, and ready-to-eat products has increased rapidly due to increased in consumer demand for fresh, convenient foods (Olivas *et al.,* 2007). Consumers

usually judge the quality of the fresh-cut fruit based on the appearance and freshness at the time.

There are several methods to extend the shelf life of MPFV. One of them is by applying edible coatings. Edible coatings may be defined as a thin layer of material which covers the surface of the food and can be eaten as part of the whole product (Vargas *et al.,* 2008). Edible films and coatings offer some advantages such as edibility, biocompatibility, and aesthetic appearance, barrier properties, being non-toxic, non-polluting and having low cost (Han, 2000; Kester and Fennema, 1986; Krochta, *et al.,* 1994). In this study, different types of edible coating were used such as chitosan (1%), carrageenan (1%), and pectin (2%) with calcium chloride (2%).

1.1 Problem Statement

MPFV containing living tissue that has undergone minor changes from its fresh state where the most important enzyme of the fruits and vegetable (polyphenol oxidase) will cause the browning. MPFV have a short shelf life due to their metabolism and the action of spoilage microorganisms. As the result of peeling, grating and shredding, produce will change from relatively stable commodity with a shelf-life of several weeks to a perishable one that has only a very short shelf-life at chilled temperature. During peeling and grating operation, many cells are broken and intracellular products such as oxidizing enzymes are released. MP produce deteriorates owing to physiological ageing, biochemical changes and microbial spoilage, which may result in degradation of the colour, texture and flavour (Varoquaux and Wiley, 1994; Kabir, 1994).

1.2 Significant of study

Fresh-cut or minimally processed of fruits are more perishable than their corresponding whole uncut commodities due to wounding during preparation (Brecht, 1995). The physical and chemical barrier provided the epidermis, which prevents the development of microbes on the fruit surface, is removed during processing (Martín-Belloso *et al,* 2006). The application of edible coatings is one of the most innovative methods to extend the commercial shelf-life of fruits and acting as a barrier against gas transport and having a similar effect on the storage under controlled or modified atmosphere (Park, 1999).

1.4 Objectives

The general objective of this study is to determine the storage stability of minimally processed Muskmelon (*Cucumis melo* variety *Glamour*) treated with a few selected hydrocolloids as edible coatings. Therefore, the specific objectives will be to determine the pysico-chemical changes, microbial counts and sensory acceptability using different hydrocolloid coatings during storage at low temperature (5 ± 1°C; Relative Humidity 90-95%).

CHAPTER 2

LITERATURE REVIEW

2.1 Muskmelon (*Cucumis melo* var "*Glamour*")

Muskmelon (*Cucumis melo*) is widely known as Cantaloupe. There many type of the cantaloupe such as Petti cantaloupe, 'Damsha', Melon varieties and Romana. Muskmelon is a round or oblong melon, having a juicy, often aromatic, sweet, yellow, white, or green, edible flesh and has been developed into many cultivated varieties. It is a variety of melon of the gourd family, having a hard scaly or warty rind and grows in Europe, Asia and United State (Wikipedia, 2009). It has a reticulated rind and pale-orange flesh (Figure 2.1). Muskmelon has a lot of benefit especially to human health. Its juice is very much effective in conditions such as lack of appetite, weight loss, urinary tract infections, constipation, acidity, and ulcer.

Muskmelon reduces heat in the body for good extent, relieves tiredness, enhances appetite and is an effective laxative. It is a good source of Vitamins A, B, and C. Muskmelons are rich in potassium, a nutrient that may help control blood pressure, regulate heartbeat, and possibly prevent strokes. Muskmelons are also abundant in vitamin C, and they are rich in beta-carotene. Researchers believe that beta-carotene and vitamin C are capable of preventing heart disease, cancer, and other chronic conditions (Ayushveda, 2009).

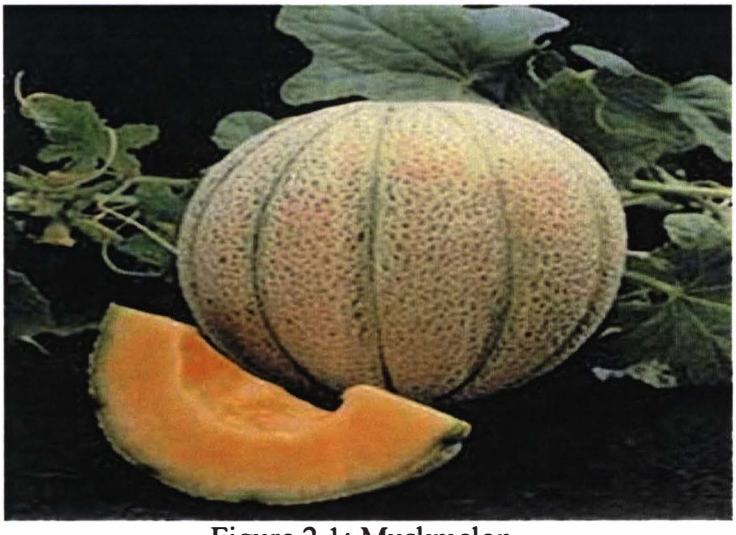

Figure 2.1: Muskmelon

2.2 Minimally processing in Malaysia

Malaysia rich with tropical fruits and some of them are very suitable for minimally processing such as jackfruit, durian and pineapple. According to research done by Latifah (2009), chili, mustard, cabbage, onion, garlic and long bean are some vegetable that suitable for minimally processing. Minimally processed fruits and vegetables (MPFV) are any fresh fruit or vegetables that have been physically altered from its original form, but remain in a fresh state. Minimal processing of raw fruits and vegetables to keeping the produce fresh without losing its nutritional quality and ensuring a product shelf-life sufficient to make distribution feasible within a region of consumption. Preparations of MPFV are differ according to different species of fruits and vegetables. Usually, MPFV has been washed, precondition, trimmed, peeled, and cut into 100% usable product that is subsequently bagged or pre-packaged as they can be eaten fresh (Figure 2.2).

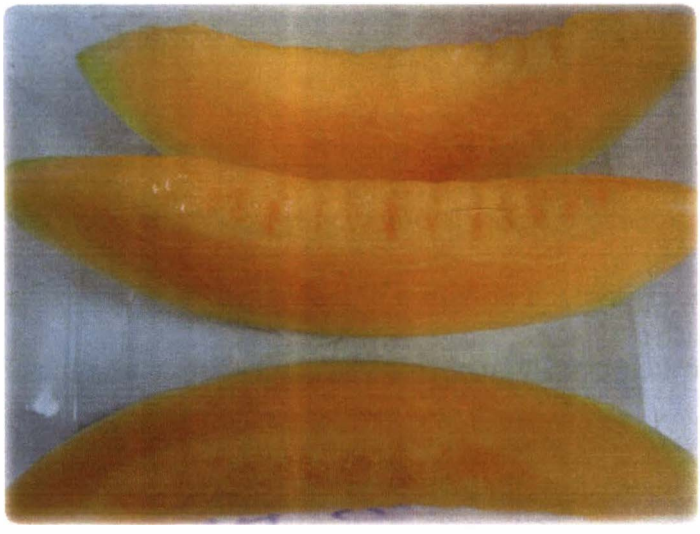

Figure 2.2: Minimally processed muskmelon

Productions of the MPFV are becoming an important task in food industry because of their convenience as ready-to-eat products as well as for the health benefits associated with consumption. MPFV will deteriorate fasten then whole fruits or vegetables and they cannot be storage for long period. This situation will cause financial loss to sellers and consumers. The suitable preparation and proper storage condition can prolong the shelf-life of MPFV. Minimally processed fruits such as jackfruit, durian and mangoesteen can be stored at; 2°C for 3 weeks, 10°C for 7 days and only 2 days at 25°C. The shelf-life of minimally processed pineapple, *Salaca edulis,* melon and mixed fruits can be extend for 2 weeks at 2°C, 7 days at 10°C and 2 days at 25°C (Latifah, 2009).

2.3 Potential Degradation of Minimally Processed of Fruits and Vegetables

The specific qualities required in fruits and vegetables will depend on the selection of appropriate cultivars. The quality of an individual product is also affected by its specific pre-harvest factor. The position of a fruit on the tree will determine its nutrient and water status and its exposure to environmental factors such as sunlight or pests and diseases. All these factors may ultimately influence post-harvest shelf-life (Hofman and Smith, 1994; Sharples, 1984).

For most fresh produce, shelf-life is best defined as the period within which the product retains acceptable quality for sale to the processor or consumer. It is necessary, therefore, to identify what 'acceptable quality' means before it can be decided at what point the product no longer satisfies those expectations. Providing the quality standards have been met, the factors which limit storage and shelf-life fall into the following categories: appearance, texture and flavour/aroma. With respect to the processing industry, each company will have its own carefully defined quality criteria based on the nature of the processing undertaken. These criteria will be agreed in advance with the supplier (Aked, 2002).

2.3.1 Appearance and colour

Appearance is the key factor for consumers in making purchases of fresh produce. As the multiple retail sectors have come to dominate food retailing in many countries, consumers have come to expect fresh produce to have near perfect visual appearance. Displays of fruits and vegetables are characterized by uniformity of size, shape and colour. Vital components of visual quality include colour and colour

uniformity, glossiness, and absence of defects in shape or skin finish and freedom from disease. The importance of appearance in the processing industry will depend on which part of the produce is used in the product and whether the appearance can readily be enhanced during processing, for example by the use of natural colouring additives (Aked, 2002).

In most products, the peel will be removed from the produce, so purely surface blemishes will be of little consequence. Internal flesh colour is usually more important than peel colour. Size and shape may be highly important where processing is automated rather than manual. However, for some products these attributes are less important, for example for juice extraction. Many fruits and vegetables undergo colour changes as part of the ripening process. Unripe fruit is usually green (the so-called 'ground colour') and in many types of fruit, the green colour becomes lighter during ripening and maturation owing to breakdown of chlorophyll, for example in apples, grapes and papaya. This may reveal underlying yellow or red pigments (Tucker, 1993).

Peel and pulp often undergo different colour changes, as in apples and bananas. In some cases, fruit colour is a strong indicator of eating quality and shelf-life, for example, tomatoes and bananas, whereas in others it is not. Many pre-harvest factors can affect fruit colour independently of other ripeness characteristics. So, for example, the peel of oranges grown in tropical regions may remain green despite having attained acceptable eating quality. Yellowing of green vegetables such as broccoli and spinach will reduce their quality as may browning of cut tissues, for example butt-ends of Brussels sprouts. Other aspects of appearance which reduce quality include the loss of freshness, like the wilting of leafy crops, loss of surface gloss or skin wrinkling and the development of external and internal defects caused

either by natural senescence, physiological disorders or the growth of disease organisms (Aked, 2002).

2.3.2 Texture

Eating quality includes a complex of textural properties which are not readily defined or measured. Crisp firm tissues are generally desired in vegetable crops. However, the development of tough fibres during storage in stem crops such as asparagus is not at all acceptable. Some aspects of texture can be judged visually as described above, for example, where produce has begun to wilt or shrivel. Although some degree of softening is required for optimal quality in fruit, over softening is undesirable and is a sign of senescence or internal decay. The maintenance of textural quality is often critical in certain types of processing, for example in canning and freezing (Aked, 2002).

The metabolic events responsible for the textural changes in fruits are believed to involve loss in turgor pressure, degradation and other physiological changes in the composition of membranes, modifications in the symplast/apoplast relations, degradation of starch, and modifications in the cell wall structure and dynamics. Although the relative contribution of each event in fruit ripening is not clear, and probably depends on the species, changes in cell wall composition, especially cell wall mechanical strength and cell-to-cell adhesion, have been considered to be the most important factors (Fischer and Bennett, 1991; Hadfield and Bennett, 1998).

In the most consensual model, the plant cell wall is composed by xyloglucan molecules in which short lengths are hydrogen bonded to restricted areas of cellulose, forming a tether that reinforces the primary cell wall. This xyloglucan-cellulose

framework is embedded in an amorphous pectin matrix composed of polyuronides together with a domain of other less abundant components, including phenolic compounds, structural proteins, enzymes and receptor-interacting molecules (Bootten, *et al.,* 2004; Cosgrove, 2001).

The complexities in structure of these individual components of the cell wall and the different ways by which they are linked together have been extensively reviewed (Brummell, 2006; Carpita and Gibeaut, 1993; O'Neill *et al.,* 2004; Vicente, *et al.,* 2006; Vincken *et al.,* 2003; Willats *et al.,* 2001; Zykwinska *et al.,* 2005). This knowledge is fundamental to understand the significance of the enzyme driven action in the polysaccharide backbones or side groups during fruit softening. Biochemical studies indicate that the structural changes and rearrangements of the cell wall structure during ripening occur mutually in pectin, hemicelluloses and cellulose (Huber, 1983; Seymour *et al.,* 1990) as the result, at least in part, from the activity of members of cell wall-modifying enzymes and proteins from the same families that promote tissue growth and extension (Fischer and Bennett, 1991).

2.3.4 Flavour and aroma

Flavour is a complex of taste and aromatic components. Total flavour can rarely be assessed by the consumer prior to purchase but it is critical in the repeat purchase of a particular product or product cultivar. Key taste components in fresh produce are sweetness, acidity, astringency and bitterness. Sweetness of some fruits may increase dramatically during ripening owing to starch to sugar conversions, for example in apples, bananas, mangoes and pears. At the same time, astringent factors (tannins) will disappear (Tucker, 1993).

Sugar levels of fruits are often measured to determine whether produce has reached the required ripeness for marketing. Sugar levels do not usually fall significantly during storage. However, maintaining the sugar to acid balance can be important to the fruit flavour balance, for example, in citrus species and grapes. Acid levels generally decrease during storage. If the acid/sugar ratio falls too low, the product can become bland and lose acceptable eating quality. This will also be of importance in processed products in which extra sugars or acids are not added. Bitter components can develop in various fruits and vegetables under certain storage conditions or when infected with certain pathogens (Aked, 2002).

Aroma can be determined to some extent before purchase by the consumer but it tends to be important as a positive factor only in highly aromatic products such as certain cultivars of melons or mangoes. With the emphasis on visual quality which has dominated retailing, it has been claimed that flavour and aroma have been lost from many fresh products as breeding has concentrated on cultivars which will survive the rigours of post-harvest handling without loss of visual and textural quality. (Aked, 2002).

Refrigeration also tends to limit the development of aroma volatiles in ripening fruits. The aroma profile can change dramatically during the post-harvest life of fresh produce, particularly in climacteric fruits in which the dominant volatile may be quite different in the unripe fruit, the ripe fruit and the over-ripe or senescing fruit (Morton and Macleod, 1990). An unexpected or unpleasant aroma may make a product unmarketable even if all other quality factors are quite acceptable. Therefore aroma can be an important factor in the storage and shelf-life of fresh produce (Aked, 2002).

2.4 Treatment in minimally processed fruits and vegetables

There are several treatment applied to minimally processed fruits and vegetables (MPFV) such as anti-browning, anti-microbial, anti-oxidant, modified packaging, modified atmosphere and edible coatings. For this study, edible coating will be applied as treatment for muskmelon.

2.4.1 Edible coatings

Edible coatings have long been used to retain quality and extend shelf life of some fresh fruits and vegetables, such as citric fruits, apples, and cucumbers (Baldwin *et al.,* 1996; Li and Barth 1998). Fruits or vegetables are usually coated by dipping in or spraying with a range of edible materials, so that a semi-permeable membrane is formed on the surface for suppressing respiration, controlling moisture loss, and providing other functions (Ukai *et al.,* 1976; Thompson, 2003).

A variety of edible materials, including lipids, polysaccharides, and proteins, alone or in combinations, have been formulated to produce edible coatings (Ukai *et al.,* 1976; Kester and Fennema, 1986). Lipid-based coatings made of acetylated monoglycerides (AM), waxes (beeswax, carnauba, candelilla, paraffin, and rice bran), and surfactants were the first successful ones on whole fruits and vegetables (Paredes-Lopez *et al.,* 1974; Lawrence and Iyengar 1983; Warth, 1986), used for reducing surface abrasion during handling and serving as moisture barrier (Hardenburg, 1967). Colloidal suspensions of oils or waxes dispersed in water were typical early fruit-coating formulations.

2.4.1.1 Purpose of edible coating

Appropriately, formulated edible coatings can be utilized for most foods to meet challenges associated with stable quality, market safety, nutritional value, and economic production cost. With regard to the fresh produce industry, the potential benefits of using edible coatings (Lin and Zhao, 2007); it is provide moisture barrier on the surface of produce for helping alleviate the problem of moisture loss. Moisture loss during postharvest storage of fresh produce leads to weight loss and changes in texture, flavor, and appearance. Edible coatings also provide sufficient gas barrier for controlling gas exchange between the fresh produce and its surrounding atmosphere, this would slow down respiration and delay deterioration. The gas-barrier function could in turn retard the enzymatic oxidation and protect the fresh produce from browning discoloration and texture softening during storage.

Besides that, restrict the exchange of volatile compounds between the fresh produce and its surrounding environment through providing gas barriers, which prevents the loss of natural volatile flavor compounds and color components from fresh produce and the acquisition of foreign odours. It protect from physical damage of produce caused by mechanical impact, pressure, vibrations, and other mechanical factors. It act as carriers of other functional ingredients, such as antimicrobial and antioxidant agents, nutraceuticals, colour and flavour ingredients for reducing microbial loads, delaying oxidation and discoloration, and improving quality (Rooney 2005).

The basic composition of edible coating for fresh-cut fruits may include hydrocolloids and lipids. These hydrocolloids (proteins and carbohydrates) tend to form hydrophilic networks, usually being a good barrier to oxygen and carbon

dioxide, but a poor barrier to water. Some polysaccharides that have been successfully used to coat fresh-cut fruits include carrageenan, maltodextrin, methylcellulose, carboxymethyl cellulose, pectin, alginate, chitosan, starch, and microcrystalline cellulose (Debeaufort *et al.,* 1998; Olivas *et al.,* 2003; Wong *et al.,* 1994). Therefore in this study, different type of edible coating will be used such as chitosan (1%), carrageenan (1%), and pectin (2%) with calcium chloride (2%).

2.4.1.2 Chitosan

Chitosan is a biodegradable cationic polysaccharide with antimicrobial activity (Cuero, 1999; Jung and Kim, 1999; No *et al.,* 2001; Tharanathan and Kittur, 2003; Zheng and Zhu, 2003) and excellent film forming ability (Domard and Domard, 2001; Li *et al.,* 1992). This makes it particularly suitable for the formulation of edible coatings, which have proved to be effective at extending the shelf-life of fruits and vegetables (Durango *et al.,* 2006; Han *et al.,* 2004; Vargas *et al.,* 2006). Chitosan films have a selective permeability to gases (CO_2 and O_2) and good mechanical properties. However, the fact that they are highly permeable to water vapour limits their uses (Butler *et al.,* 1996; Caner *et al.,* 1998), which is an important drawback since an effective control of moisture transfer is a desirable property for most foods.

The functional properties of chitosan-based films can be improved by combining them with other hydrocolloids (Park *et al.,* 2002; Xu *et al.,* 2004). In this sense, Hoagland and Parris (1996) developed chitosan/pectin laminated films by interacting cationic groups of chitosan with the anionic groups of pectin. Xu *et al.,* (2004) observed a decrease in water vapour transmission rates (WVTRs) by combining chitosan with two thermally gelatinized cornstarches. Chitosan, a linear

polymer of 2-amino-2-deoxy-β- D-glucan, is a deacetylated form of chitin, a naturally occurring cationic biopolymer (BeMiller 1965; Davis *et al.,* 1988; Tharanathan and Kittur., 2003). It occurs as the shell component of crustaceans (crab and shrimp), as the skeletal substance of invertebrates, and as the cell wall constituent of fungi and insects (Anonymous, 1991). Applications of chitosan include flocculating agent, clarifier, thickener, gas-selective membrane, coating material, promoter of plant disease resistance, wound-healing factor agent, and antimicrobial agent (Brine *et al.,* 1991; Goosen 1997).

Chitosan has been one of the most promising coating materials for fresh produce because of its excellent film-forming property, broad antimicrobial activity, and compatibility with other substances, such as vitamins, minerals, and antimicrobial agents (Li *et al.,* 1992; Shahidi *et al.,* 1999; Park and Zhao 2004; Durango *et al.,* 2006; Chien *et al.,* 2007; Ribeiro *et al.,* 2007). Chitosan-based coatings have shown effectiveness in delaying ripening and decreasing respiration rates of fruits and vegetables (Krochta *et al.,* 1997; Vargas *et al.,* 2006), and reducing weight loss, colour wilting, and fungal infection in bell peppers and cucumbers (El Ghaouth and *et al.,* 1991). A commercial fruit coating, Nutri-Save (Nova Chem, Halifax, Canada), was developed to serve as both film former and natural preservative and to create a modified atmosphere for whole apples and pears to reduce respiration rate and desiccation of these commodities (Elson *et al.,* 1985).

Another very attractive function of chitosan is its broad anti-fungal property (Allan and Hadwiger, 1979; Stossel and Leuba, 1984; Hirano and Nagao, 1989), by inducing a plant-defense enzyme, chitinase, in plant tissues, which degrades fungal cell walls (Hirano and Nagao, 1989). The fungistatic property of chitosan coating, which inhibits spore germination, germ tube elongation, and growth of pathogens

(*Botrytis cinerea* and *Rhizopus stolonifer*) has been reported by several researchers. Zhang and Quantick (1998) demonstrated the anti-fungal effects of chitosan coating on fresh strawberries and raspberries during cold storage. Iverson and Ager, (2003) invented a chitosan-based antifungal coating mixed with an edible wax emulsion and/or a preservative such as sodium benzoate, and/or an adhesion additive such as zinc acetate, and/or a wetting agent to have a molecular weight sufficient to form a composition having a solid content of about 15% or higher.

Han *et al.,* (2004) reported chitosan coatings for extending shelf life of fresh strawberries and red raspberries by decreasing weight loss and delaying changes in colour, titratable acidity, and pH during cold storage, and reducing the drip loss and improving the texture quality of frozen-thawed strawberries. Park *et al.,* (2005) demonstrated the anti-fungal function of chitosan coatings on fresh strawberries through a microbial challenge study and showed the excellent compatibility of chitosan with other anti-fungal agents.

Vargas *et al.,* (2006) evaluated high molecular weight chitosan combined with oleic acid for preserving the quality of strawberries and found that the addition of oleic acid not only enhances chitosan antimicrobial activity but also improves water vapor resistance of coated samples. Chien *et al.,* (2007) also reported on the effectiveness of chitosan coating for prolonging quality and extending shelf life of sliced mango fruit. In addition, chitosan-based coatings can carry high concentrations of vitamins and minerals for increasing the content of these nutrients in the fresh and frozen fruits without altering its anti-fungal and moisture-barrier functionality (Han *et al.,* 2004).

2.4.1.3 Carrageenan

Carrageenan, extracted from several red seaweeds, mainly *Chondrus crispus* (Whistler and Daniel 1985) and a complex mixture of several polysaccharides, is another potential coating material for fruits and vegetables. Carrageenan-based coatings have been applied to fresh fruits and vegetables such as fresh apples for reducing moisture loss, oxidation, or disintegration of the apples (Bryan, 1972; Lee *et al.,* 2003). In combination with anti-browning agents such as ascorbic acid, carrageenan-based coatings resulted in positive sensory results and reduction of microbial levels on minimally processed apple slices (Lee *et al.,* 2003). By acting as a sacrificial moisture layer, carrageenan coating was able to protect moisture loss of grapefruits (Bryan, 1972).

In addition, κ-carrageenan films can effectively carry food-grade antimicrobials such as lysozyme, nisin, grape fruit seed extract, and EDTA for a wide range of applications as a food package material (Choi *et al.* 2001). Lee *at al.,* (2003) reported that apple slices coated with carrageenan containing ascorbic acid, citric acid, and oxalic acid extended shelf-life by 2 weeks when packaged in trays at 3°C. Garcia *et al.,* (2001) reduced microbial growth below 6 $\log_{10}$CFU/g at the maximum storage time assayed (28 days) and extended storage life of fresh strawberries using a starch-based coating containing potassium sorbate and citric acid. However, in the last years there has been a considerable pressure by consumers to reduce or eliminate chemically synthesized additives in foods.

2.4.1.4 Pectin and Calcium chloride

Calcium chloride has been widely used as preservative and firming agent in the fruits and vegetables industry for whole and fresh-cut commodities. Chardonnet *et al.*, (2003) and Sams *et al.,* (1993) studied the effect of calcium chloride on fruit firmness and decay after the harvest of whole apples. Saftner *et al.,* (2003) work was also focused on the firming effect of calcium chloride treatment on fresh-cut honeydew. Luna-Guzman and Barrett (2000) compared the effect of calcium chloride and calcium lactate dips in fresh-cut cantaloupe firmness, microbial load, respiration and sensorial evaluation. Other authors (Garcia *et al.,* 1996; Main *et al.,* 1986; Morris *et al.,* 1985; Rosen and Kader, 1989 and Suutarinen *et al.,* 1998) used calcium chloride as firming agent for processed strawberries.

Wills and Mahendra (1989) examined the effect of calcium chloride on fresh-cut peaches from a quality point of view, meanwhile Conway and Sams (1984) evaluated the safety of strawberries treated with calcium chloride. Other fruits and vegetables, in which the effect of calcium chloride was studied, showing significant improvement in the quality of the final product, are grapefruit (Baker, 1993), hot peppers (Mohammed *et al.,* 1991) and diced tomatoes (Floros *et al.,* 1992). The use of calcium chloride is associated with bitterness and off-flavours (Bolin and Huxsoll, 1989 and Ohlsson, 1994), mainly due to the residual chlorine remaining on the surface of the product.

Alginate, derived from a marine brown algae (Phaeophyceae), gellan, secreted by the bacterium *Sphingomonas elodea* (formerly referred to as *Pseudomonas elodea*) and pectin, extracted from apple waste or from the peel of citrus fruits are common polysaccharides used as gelling agents in food industry. These polysaccharides are of

interest as a potential coating component because of their unique colloidal properties. Alginate, gellan or low methoxyl pectin gel forming properties are mainly due to their capacity to form strong gels or insoluble polymers in the presence of multivalent metal cations like calcium (Mancini and McHugh, 2000; Rhim, 2004; Yang and Paulson, 2000).

The gelling mechanism involves interactions between calcium ions and carboxylic groups, forming a three-dimensional cross-linked network. That interaction is produced by mixing the components and casting them as films, or by pouring the cation solution onto a previously cast and dried film Polysaccharide-based coatings are expected to be a good/oxygen barrier due to their tightly packed, ordered hydrogen bonded network structure although they do not behave well as moisture barriers because of their hydrophilic nature (Yang and Paulson, 2000). In addition, plasticizers like glycerol, added to increase coating flexibility by reducing the internal hydrogen bonds between polymers chains and increasing intermolecular spacing, generally increase film permeability to oxygen and moisture transmission (Rojas-Grau¨ *et al.,* 2007).

Therefore, lipid incorporation, in small quantities, may be necessary to improve water vapor barrier properties of hydrophilic nature coatings. The addition of sunflower oil with essential fatty acids was shown to improve the barrier properties of alginate and gellan-based edible coatings for fresh-cut 'Fuji' apples (Rojas-Grau¨ *et al.,* 2007). The addition of a lipid to coating formulations for fresh-cut apples, based on apple pure´e and pectin, also remarkably diminished the gas permeation through the edible matrix (McHugh and Senesi, 2000). In the present work, the objective was to compare the effectiveness of alginate, gellan or pectin based coatings in preserving quality of fresh-cut 'Piel de Sapo' melon. Effects of the coatings on gas exchange,

antioxidant properties, sensory and microbial quality were evaluated for 15 days at 4°C.

2.4.2 Potential active ingredients to be carried by edible coatings

Fresh-cut fruits are more perishable than their corresponding whole uncut commodities due to wounding during preparation (Brecht, 1995). The physical and chemical barrier provided by the epidermis, which prevents the development of microbes on the fruit surface, is removed during processing (Martı´n-Belloso *et al.*, 2006). Dipping of aqueous solutions containing antimicrobials is the most practical way to extend the microbial stability of fresh-cut fruits. However, application of antimicrobial agents directly on the food surface may have limited benefits because the active substances are rapidly neutralized or diffuse from the surface into the food product, thus limiting the effect of the antimicrobial compound (Min and Krochta, 2005). In this sense, antimicrobial edible films and coatings may provide increased inhibitory effects against spoilage and pathogenic bacteria by maintaining effective concentrations of the active compounds on the food surfaces (Gennadios *et al.*, 1997).

There are several categories of antimicrobials that can be potentially incorporated into edible films and coatings, including organic acids (acetic, benzoic, lactic, propionic, sorbic), fatty acid esters (glyceryl monolaurate), polypeptides (lysozyme, peroxidase, lactoferrin, nisin), plant essential oils (EOs) (cinnamon, oregano, lemongrass), nitrites and sulphites, among others (Franssen and Krochta, 2003). While their actual mechanisms of action are not well understood, the antibacterial effectiveness of organic acids is thought to stem from the fact that

protonated acids are membrane soluble, and can enter the cytoplasm by simple diffusion (Ricke, 2003). Lee *et al.,* (2003) reported that apple slices coated with carrageenan containing ascorbic acid, citric acid, and oxalic acid extended shelf-life by 2 weeks when packaged in trays at 3°C.

Garcia *et al.,* (2001) reduced microbial growth below 6 $\log_{10}$CFU/g at the maximum storage time assayed (28 days) and extended storage life of fresh strawberries using a starch-based coating containing potassium sorbate and citric acid. However, in the last years there has been a considerable pressure by consumers to reduce or eliminate chemically synthesized additives in foods. Essential oils outstand as an alternative to chemical preservatives and their use in foods meets the demands of consumers for natural products, as reviewed by Burt (2004).

The activity of EOs and their active constituents have been widely studied against many microorganisms, including several pathogens (Delaquis *et al.,* 2002; Karatzas *et al.,* 2000; Va´zquez, *et al.,* 2001), although their mechanism of action has not been studied in great detail (Lambert *et al.,* 2001). In this sense, Burt (2004) reported that hydrophobicity is an important characteristic of EOs, which makes them able to pass through cell membranes and enter mitochondria, disturbing the internal structures and rendering the membranes more permeable.

CHAPTER 3

MATERIAL AND METHODOLOGY

3.1 Sample preparation

Muskmelons *(Cucumis melo)* variety glomour were purchased at commercial maturity and selected based on uniformity of size, colour, shape and absences of damage and fungal infection. Whole fruits were washed with water. The skin, seed and core area were removed. The Muskmelon was sliced longitudinally into 12 wedges with 3 cm thick in the middle part using a sanitized knife and cutting board. The slices were washed with 500 mg/L chlorine dioxide solution before dipping into anti-browning agent solution; citric acid (0.5 M) for 2 min. They were then air-dried for 10 minutes, they were dipped in three coating treatments of chitosan (1%, w/v), carrageenan (2%, w/v) and pectin (2%, w/v) with calcium chloride (2%, w/v) and fruits without any coating treatment were serving as control. The coated samples were air-dried for 10 minutes at 25$\pm$1°C. The sliced fruits were placed in PP container of 30 cm x 20 cm x 10 cm in size with lid with three slices per container.

3.1 Experimental activities

The experimental works are summarized in Figure 3.1 below.

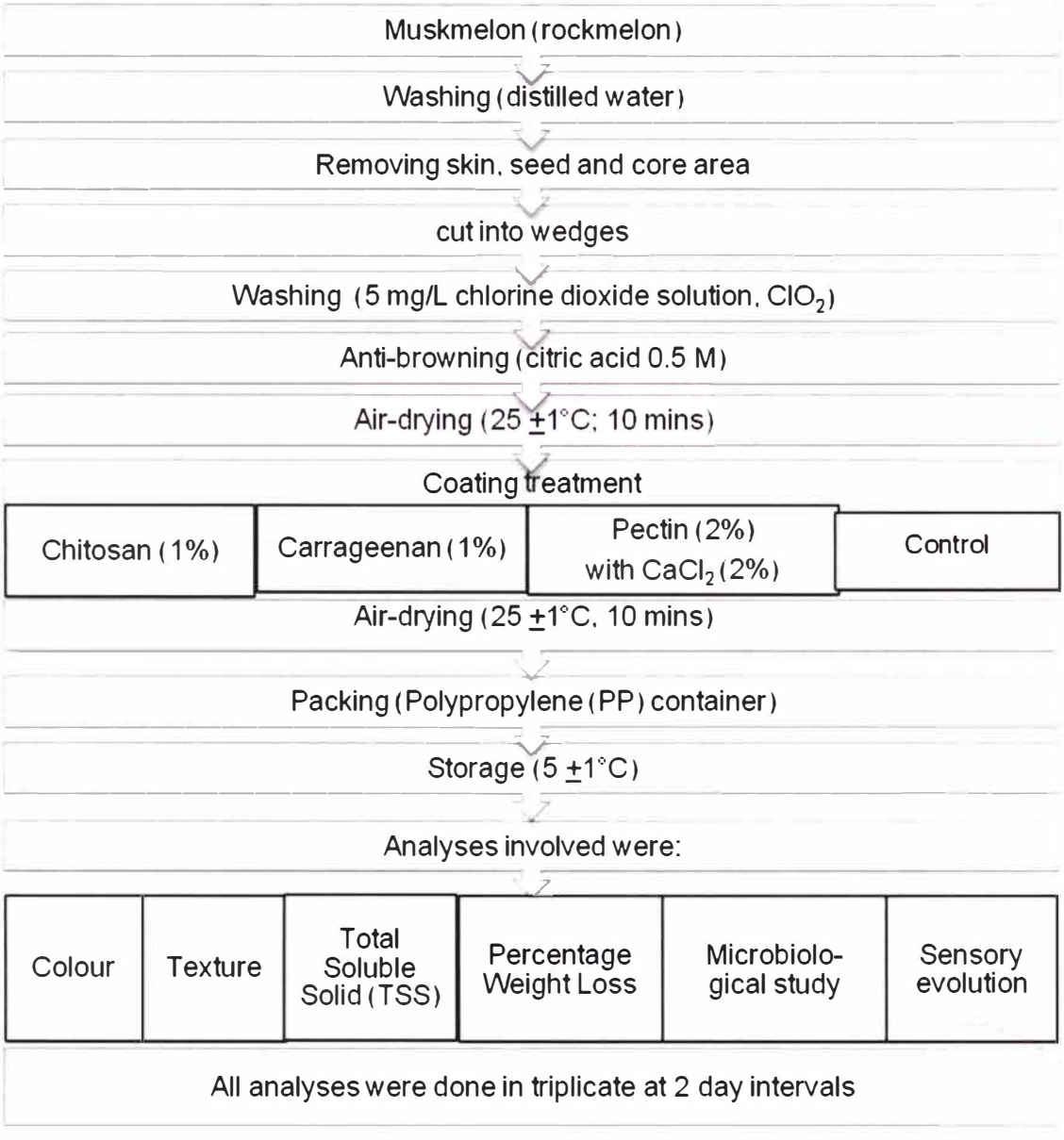

Figure 3.1: Flow diagram of the experimental activities.

3.3 Coating treatments

The hydrocolloid coating solutions were prepared on the same day just prior to use.

3.3.1 Chitosan (1%)

The 1% chitosan was prepared according to Jiang and Li (2001). One gram of chitosan was dispersed in 90 ml of distilled water to which 5 ml of glacial acetic acid was added to dissolve the chitosan. The solution pH was then adjusted to pH 5.0 with NaOH (1 M), and the solution was made up to 1.0 L with distilled water.

3.3.2 Carrageenan (1%)

Carrageenan coating was prepared according to Lee *et al.*, (2003). 0.5 g carrageenan was dissolved in 100 ml distilled water. The solution was heated at 70°C and stirred vigorously with magnetic stirrer bar for 40 min. The solution was then cooled down to room temperature prior to pH adjustment of 5.6 using citric acid (1 M).

3.3.3 Pectin (2%) with calcium chloride (2%)

Pectin solution was prepared by dissolving 2g pectin powders in 100 ml of distilled water and heated at 70°C with stirring until the solution became clear. Glycerol was added as plasticizer at 1.5 g per 100 ml pectin solution. The solutions were then emulsified with cooking oil at 0.025 g per 100 ml solution. The mixture

was dispersed using blender at the high speed for 15 minutes. For the cross linking of carbohydrate polymers, 2% (w/v) of calcium chloride was added (Oms-Oliu *et al.*, 2008).

3.4 Storage Quality Analyses

3.4.1 Colour

The muskmelon pulp colour was analyzed using a Konica Minolta chromameter. L*, a*, and b* values was recorded from three slices of sample. The hue angle and chroma were calculated from the L* (lightness), a* (red-green) and b* (yellow-blue) values obtained (Oms-Oliu *et al.*, 2008).

3.4.2 Texture analysis

Firmness of coated and uncoated minimally processed (MP) Muskmelon was determined with a Stable Micro Systems, TA.XT plus texture analyzer. The P2N needle probe was used. The parameters of the test were as follows:

Pre-test speed : 1.0 mm/s

Test speed : 0.5 mm/s

Post-test speed : 7.0 mm/s

Distance : 5.0 mm

Trigger force : 5 g (auto)

Samples were carefully positioned so that the needle penetrated at the geometric center of the slices. Triplicate samples were measured for each coating treatment in order to obtain representative results. (Harker *et al.*, 2003). The firmness was denominated by the maximum positive peak of the texture profile curve.

3.4.4 Total soluble solid (TSS)

Total soluble solid content (mainly sugars) in MP muskmelon of four different coating treatments with triplicate were determined using hand-held refractometer, (Atago; MODEL REF 103). The prism was first cleaned well with distilled water and wiped dry. The fruits were cut into small pieces and put in muslin cloth and then squeeze to get the juice. One to two drop of juice is enough to put on the refrectometer prism. The readings (°Brix) were recorded. The refractometer prism was rinsed well before measuring the next sample.

3.4.4 Weight Loss analysis

All the treatments were weighed individually using a top-pan balance and the weight were recorded. Each of the treatment was weighed every 2 days until day 8. Then, the percentage weight loss was calculated as below and the result was tabulated. The graph of percentage weight loss vs. time was plotted for every treatment. (Wills *et al.*, 1981; Ibrahim, R., 2009).

$$\text{Percentage of weight loss} = \frac{\text{Initial weight of MP Muskmelon} - \text{Final weight of MP Muskmelon}}{\text{Initial weight of MP Muskmelon}} \times 100$$

3.4.5 Microbiological Study

MP Muskmelon was weighed approximately 10 grams into sterile stomacher bag. Saline water was added (90 ml) and homogenized for half minutes and 30 second at normal speed in a Stomacher. A serial dilution was made with 9 ml saline water until 10^{-5} dilution. One milliliter from dilution 10^{-3}, 10^{-4} and 10^{-5} were analyzed on three different media using pour-plate method. The media and the incubation conditions are as follows:-

i. Nutrient Agar (Oxoid) incubated at 37±1 °C for 24 hours for Aerobic Mesophilic Bacteria count or Total Bacteria count (TBC).
ii. Violet Red Bile Agar (Oxoid) incubated at 37±1 °C for 24 h for Coliforms or Total Coliforms (TC)
iii. Potato Dextrose Agar (PDA) acidified with tartaric acid (1.2ml for 1000ml PDA), incubated at 25±1°C for 5-7 days for yeasts and moulds (YM).

Finally, the colony from unit (CFU) of the microbes grown on each plate was counted. The whole steps of microbiological study were illustrated in Figure 3.2 (Nur Aida, *et al.*, 2008).

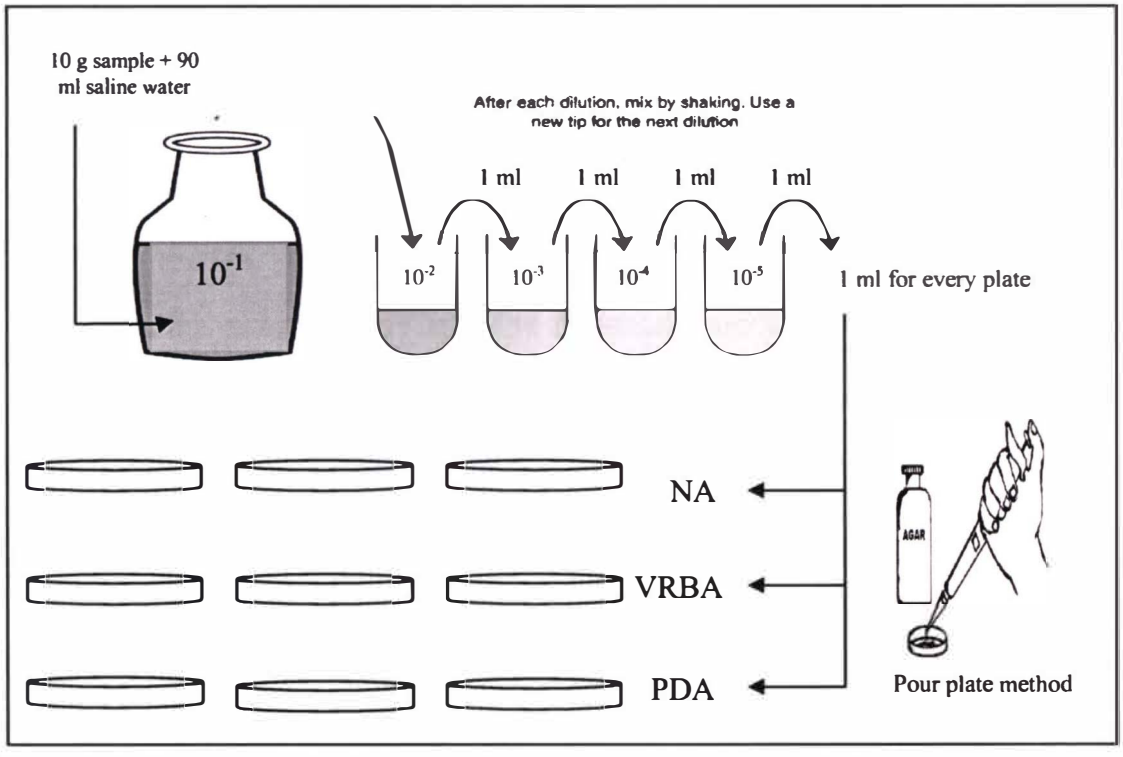

Figure 3.2: The schematic diagram of the whole steps of microbiology study

3.4.6 Sensory Evaluation

The sensory quality of each triplicate MP muskmelon was evaluated for the attributes of appearance, taste, flavor and overall acceptability. Samples were presented in random order to 15 semi-trained panelists. Each attribute was rated on a 5 point hedonic scale as follows:

5- Very much acceptable

4- Acceptable

3- Neither acceptable nor acceptable

2- Unacceptable

1- Very much unacceptable

3.5 Statistical Analysis

The data collected from all the analyses were analyzed using one-way analysis of variance (ANOVA), and the significant differences ($p<0.05$) between treatments were determined using Tukey Test. The statistical programme used was Statistical Program for Social Science (SPSS) version 16.0. The Table 3.1 below details out the replications of whole analysis.

Treatment / Parameter	Control	Chitosaan 1%	Carrageenan 1%	Pectin 2% with $CaCl_2$ 2%
Colour	$3X^3$	$3X^3$	$3X^3$	$3X^3$
Texture analysis	$3X^3$	$3X^3$	$3X^3$	$3X^3$
Total Soluble Solid (TSS)	3X	3X	3X	3X
Weight loss	3Y	3Y	3Y	3Y
Microbial Analysis	3X	3X	3X	3X
Sensory evaluation	3Y	3Y	3Y	3Y

Table 3.1: Statistical analysis analyses replications

X : One slice/one replicate

X^3 : Three readings/slice

Y : One PP container

All data were analyzed using one-way ANOVA for significant differences treatment at $P<0.05$. This experiment was use complete randomized design (CRD) as experimental design.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Colour changes

Figure 4.1 and Table 4.1 was the measurement of colour of MP muskmelon. Colour is the basis for sorting many products into commercial grade, but concentration of pigment might provide a better quality index (Lancaster *et al.*, 1997). Pulp colour of the fruit is one of the most significant parameter that indicates the condition of the fruit. The hue angle and chroma for MP muskmelon calculated from the L* (lightness), a* (red-green) and b* (yellow-blue) values according to procedures detailed in (Oms-Oliu *et al.*, 2008).

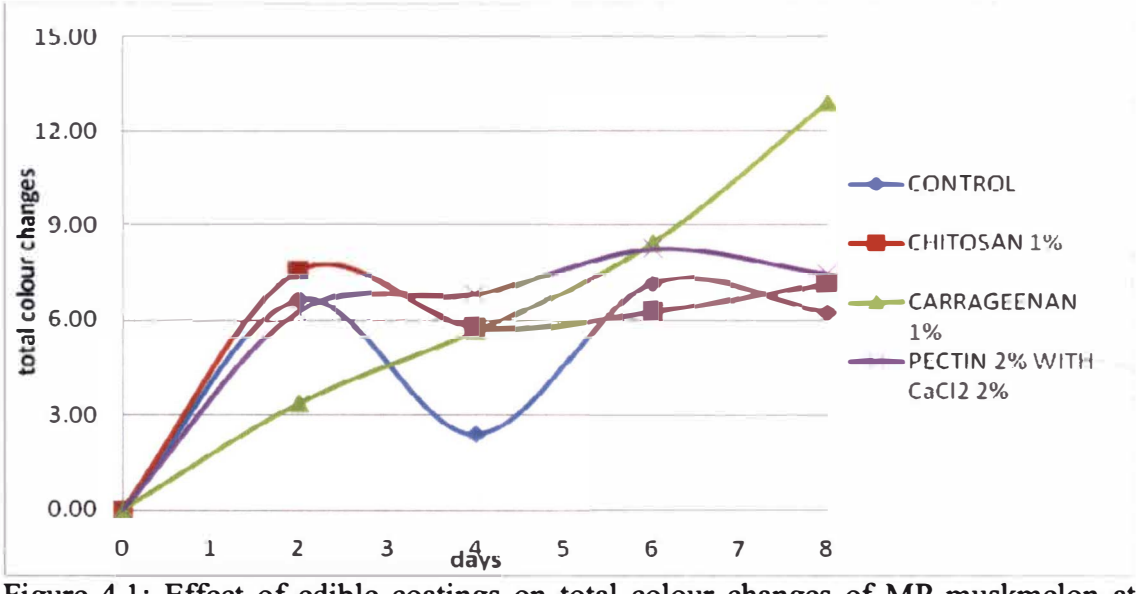

Figure 4.1: Effect of edible coatings on total colour changes of MP muskmelon at chilled storage.

Total colour changes of MP muskmelon revealed an increased pattern throughout storage day (Figure 4.1). Total colour changes of MP muskmelon treated

with carrageenan (1%) was higher compared to others. There were no significant different for L value on day 2 (Table 4.1) but pectin (2%) with $CaCl_2$ (2%) showed higher of L value compared to chitosan (1%). On day 4, control revealed significantly higher L value compared to other treatments but significantly no vary on day 6 for each treatment. Treatment with carrageenan (1%) showed significantly lower of L value on day 8 compared to others. The L value decreased with increasing in storage day due to change the fresh orange colour of MP muskmelon to dull orange. The appearance was bruised and water soaked. However, for a* values for all treatments remained unchanged over the storage period (Table 4) due to no changes of red or green colour.

The b* value did not vary significantly from day 0 to day 4 for all treatments. For day 6, carrageenan (1%) showed significantly lower of b* value than control and chitosan (1%). On day 8, carrageenan showed significantly lower of b* than chitosan (1%), pectin (2%) with $CaCl_2$ (2%). The b* value of cantaloupe increased slightly from the under-ripe to the ripe then decreased from ripe to overripe stages. It showed the decreasing of b* value on day 8 for carrageenan (1%) due to changes of maturity stage of the fruits.

The Cantaloupe colour observations were reasonable since I-carotene (orange in colour) is subject to increase during the development and ripening of melons (Lester and Dunlap 1985).Therefore a* and hue angle values appeared to provide a good indication of maturity. Han *et al.,* (2004) reported chitosan coatings for extending shelf life of fresh strawberries and red raspberries by decreasing weight loss and delaying changes in colour, titratable acidity, and pH during cold storage, and reducing the drip loss and improving the texture quality of frozen-thawed strawberries.

Table 4.1: Effect of edible coatings on colour (L*, a* and b* value) of MP muskmelon during chilled storage

	Colour (L*, a* and b* value)				
	Day 0	Day 2	Day 4	Day 6	Day 8
L* value					
Control 1%	62.84 ± 3.08^{Aab}	57.67 ± 0.22^{ABbc}	63.27 ± 0.25^{Aa}	57.13 ± 2.76^{Ac}	59.56 ± 1.58^{Aabc}
Chitosan 1%	62.10 ± 2.01^{Aa}	55.48 ± 1.14^{Bb}	57.70 ± 0.74^{Bb}	56.96 ± 1.15^{Ab}	56.90 ± 0.85^{Ab}
Carrageenan 1%	60.29 ± 2.63^{Aa}	57.09 ± 0.75^{ABab}	55.66 ± 2.24^{Babc}	53.91 ± 1.47^{Abc}	49.76 ± 3.10^{Bc}
Pectin 2% with $CaCl_2$ 2%	64.75 ± 0.83^{Aa}	59.45 ± 1.37^{Ab}	58.69 ± 3.21^{Bb}	57.11 ± 0.61^{Ab}	57.69 ± 0.27^{Ab}
a* value					
Control 1%	10.32 ± 0.97^{Aa}	8.80 ± 0.19^{Aa}	9.55 ± 0.74^{Aa}	11.33 ± 4.59^{Aa}	7.59 ± 0.24^{Aa}
Chitosan 1%	10.78 ± 0.39^{Aa}	9.07 ± 0.71^{Ab}	8.95 ± 0.66^{Ab}	8.58 ± 0.33^{Ab}	7.59 ± 0.67^{Ab}
Carrageenan 1%	9.39 ± 0.64^{Ab}	9.07 ± 0.44^{Aab}	7.84 ± 0.76^{Aab}	7.12 ± 1.06^{Ab}	8.53 ± 0.77^{Aab}
Pectin 2% with $CaCl_2$ 2%	9.61 ± 0.78^{Ab}	9.10 ± 0.10^{Aab}	8.58 ± 0.80^{Aab}	8.53 ± 0.77^{Aab}	8.16 ± 0.09^{Ab}
b* value					
Control 1%	29.32 ± 1.78^{Aa}	25.50 ± 1.36^{Aab}	27.11 ± 2.28^{Aab}	25.17 ± 1.65^{Aab}	24.81 ± 0.44^{Ab}
Chitosan 1%	30.00 ± 1.29^{Aa}	26.83 ± 1.67^{Aab}	26.76 ± 1.46^{Aab}	27.22 ± 0.74^{Aab}	26.24 ± 0.58^{Ab}
Carrageenan 1%	25.97 ± 2.27^{Aa}	25.05 ± 1.49^{Aab}	23.22 ± 1.87^{Aab}	20.95 ± 1.73^{Bab}	19.46 ± 2.45^{Bb}
Pectin 2% with $CaCl_2$ 2%	27.46 ± 0.66^{Aa}	24.24 ± 1.22^{Aab}	23.08 ± 1.70^{Ab}	24.54 ± 1.21^{ABab}	25.57 ± 1.42^{Aab}

Note: Values in Table 4.1 are mean of 3 replicates (3 representative samples/replicate)
Mean (n=3) $\pm$ standard deviation
(A-B) mean bearing the same superscript within the same column are not significantly different at 5% level ($p<0.05$)
(a-c) mean bearing the same superscript within the same row are not significantly different at 5% level ($p<0.05$)

4.2 Texture analysis

Figure 4.2 showed the changes of texture of MP muskmelon treated with four difference edible coatings during chilled storage. The trend of the firmness generally decreases throughout the storage day. On day 0, carrageenan (1%) showed significantly higher than control but no significant different between other edible coatings treatments. On day 2 until day 6, there were no significant different for each treatments. The evaluation of texture revealed significantly lower for edible coating treatments on day 8 for chitosan (1%) and carrageenan (1%) compared to control. For texture analysis, control showed higher value in the firmness on day 0 until day 8 compared to other treatments but no significant different was observed throughout the storage (Table 4.2). It showed MP muskmelon treated with edible coatings affects the firmness of the sample on day 0.

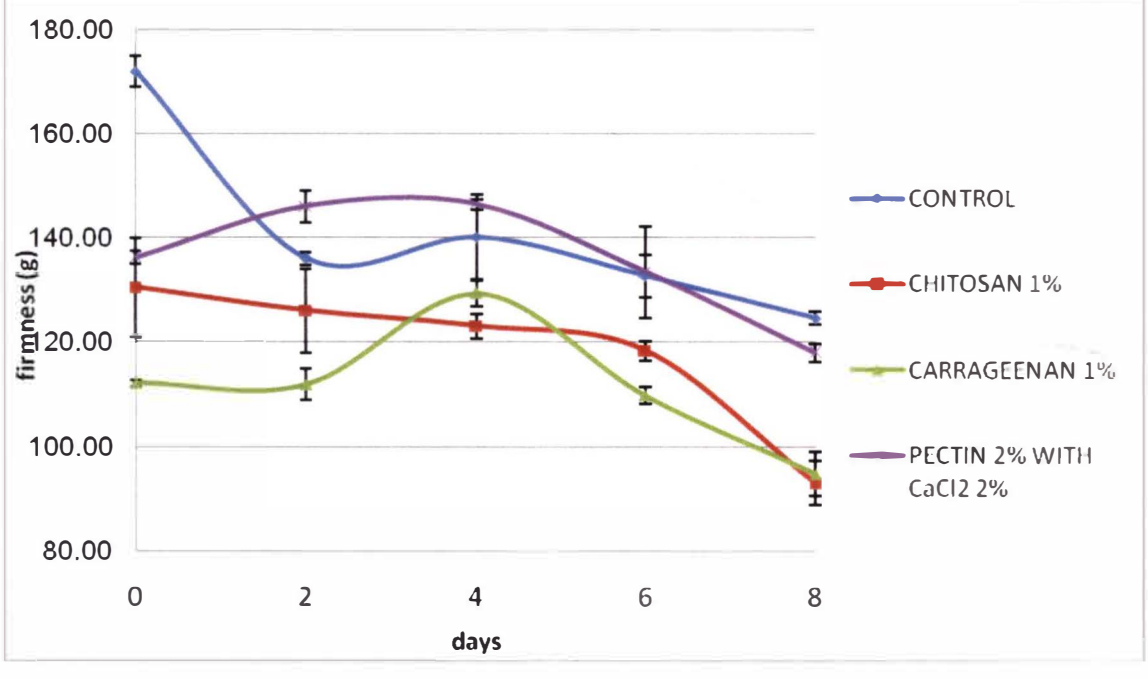

Figure 4.2: Effect of edible coatings on texture MP muskmelon at chilled storage

Textural changes that lead to softening of fruits are accompanied by loss of neutral sugars, solubilisation and depolymerisation of the polysaccharides of the cell wall and rearrangements of their associations, as the result of the combined action of several cell wall-modifying enzymes, acting in both pectic and hemicellulosic fractions (Luis and Cristina, 2008).

The metabolic events responsible for the textural changes in fruits are believed to involve loss in turgor pressure, degradation and other physiological changes in the composition of membranes, modifications in the symplast/apoplast relations, degradation of starch, and modifications in the cell wall structure and dynamics. Although the relative contribution of each event in fruit ripening is not clear, and probably depends on the species, changes in cell wall composition, especially cell wall mechanical strength and cell-to-cell adhesion, have been considered to be the most important factors (Fischer and Bennett, 1991; Hadfield and Bennett, 1998).

In the most consensual model, the plant cell wall is composed by xyloglucan molecules in which short lengths are hydrogen bonded to restricted areas of cellulose, forming a tether that reinforces the primary cell wall. This xyloglucan-cellulose framework is embedded in an amorphous pectin matrix composed of polyuronides together with a domain of other less abundant components, including phenolic compounds, structural proteins, enzymes and receptor-interacting molecules (Bootten, *et al.,* 2004; Cosgrove, 2001). The complexities in structure of these individual components of the cell wall and the different ways by which they are linked together have been extensively reviewed (Brummell, 2006; Carpita and Gibeaut, 1993; O'Neill *et al.,* 2004; Vicente *et al.,* 2006; Vincken *et al.,* 2003; Willats *et al.,* 2001; Zykwinska *et al.*, 2005).

This knowledge is fundamental to understand the significance of the enzyme driven action in the polysaccharide backbones or side groups during fruit softening. Biochemical studies indicate that the structural changes and rearrangements of the cell wall structure during ripening occur mutually in pectins, hemicelluloses and cellulose (Huber, 1983; Seymour *et al.,* 1990) as the result, at least in part, from the activity of members of cell wall-modifying enzymes and proteins from the same families that promote tissue growth and extension (Fischer and Bennett, 1991). The disassembly of the cell wall structural network probably involves the concerted and synergistic action of several different enzymatic activities, where one family of cell wall-modifying enzymes may mediate the activity of another, resulting in ordered cell wall modifications (Rose and Bennett, 1999).

The developmental of rational and effective approaches to improve texture and shelf-life depends on understanding the biological basis of fruit ripening. Different fruits differ markedly in their botanical origin, polysaccharide and protein composition, cell wall structure, enzymatic metabolism, growing and ripening pattern, or softening behaviour. These differences that reflect pulp firmness, rate of softening and overall texture are now recognized not only between different species but also between different cultivars, varieties and selections from the same species (Luis and Cristina, 2008). Firmness was inversely related to drip loss in both Cantaloupe and Honey Dew melons as maturity increased. (Simandjuntak *et al.,* 1996). With increased maturity, firmness decreased and drip loss increased as rhamnose, fucose, arabinose, mannose and galactose also decreased. This suggests that both pectin and hemicellulose were solubilised from the muskmelon cell wall polysaccharide as softening occurred. Prior to solubilisation, polysaccharide degradation into smaller molecules may have occurred. It is likely that these molecules were discarded during

the isolation and purification of cell wall polysaccaride, causing a decreasing in total sugars as maturity increased. (Simandjuntak *et al.*, 1996).

Therefore, texture analysis of control showed significantly higher in the firmness on day 0 compared to MP muskmelon treated with carrageenan (1%) and chitosan (1%) but no significant different was observed throughout the storage. However, the texture of chitosan (1%) was accepted in sensory analysis (Figure 4.9).

Table 4.2: Effect of edible coatings on texture of MP muskmelon during chilled storage

Treatment	Texture (F/g)				
	Day 0	Day 2	Day 4	Day 6	Day 8
Control 1%	171.92 ± 33.27^{Aa}	136.00 ± 4.47^{Aa}	140.01 ± 28.22^{Aa}	182.67 ± 14.14^{Aa}	124.52 ± 4.53^{Aa}
Chitosan 1%	130.35 ± 0.04^{ABa}	125.92 ± 27.82^{Aa}	123.02 ± 8.11^{Aa}	118.29 ± 6.62^{Aa}	93.08 ± 14.40^{Ba}
Carrageenan 1%	112.15 ± 2.27^{Bab}	111.90 ± 10.23^{Aab}	129.23 ± 8.80^{Aa}	109.82 ± 5.43^{Aab}	94.89 ± 14.73^{Bb}
Pectin 2% with $CaCl_2$ 2%	136.15 ± 4.01^{ABa}	146.00 ± 10.35^{Aa}	146.34 ± 3.29^{Aa}	133.35 ± 30.63^{Aa}	117.94 ± 5.88^{ABa}

Note: Values in Table 4.2 are mean of 3 replicates (3 representative samples/replicate)
Mean (n=3) ± standard deviation
(A-B) mean bearing the same superscript within the same column are not significantly different at 5% level ($p<0.05$)
(a-b) mean bearing the same superscript within the same row are not significantly different at 5% level ($p<0.05$)

4.3 TSS (°Brix)

Figure 4.3 showed the effects of edible coatings on TSS of MP muskmelon during storage days. From this figure the trend is decreasing throughout period from day 0 until day 8. TSS value for chitosan (1%) increased after day 4 but decreased back on day 6. After day 6, all treatments except chitosan (1%) were slightly increase in TSS value and decrease again after day 8. (Some variability in the cut fruits might influence the reading values at day 4).

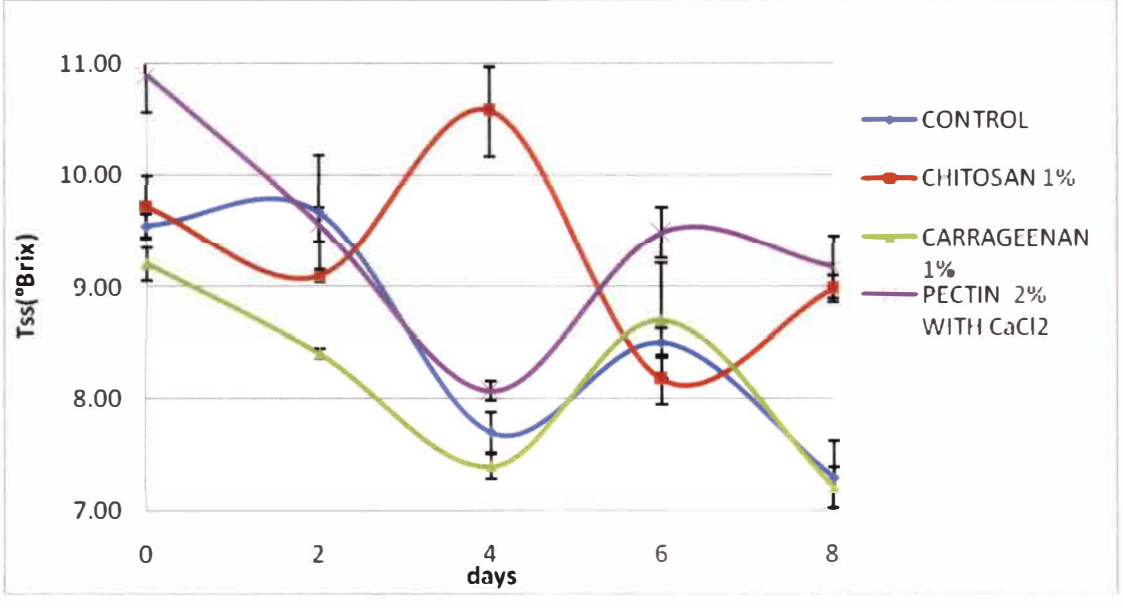

Figure 4.3: Effect of edible coatings on TSS value of MP muskmelon during chilled storage

According to the Table 4.3, during the first day of storage no significant different was observed among all the treatments. On day 4, TSS of chitosan (1%) showed significantly high value during storage compared to carragenan (1%). For day 6 and day 8, there was no significant different found within the treatment throughout the storage days. Pectin (2%) with $CaCl_2$ (2%) showed higher value as the storage day increases.

Table 4.3: Effect of edible coatings on TSS (°Brix) of MP muskmelon during chilled storage

Treatment	TSS (°Brix)				
	Day 0	Day 2	Day 4	Day 6	Day 8
Control 1%	9.55 ± 0.39^{Aa}	9.67 ± 1.76^{Aa}	7.73 ± 0.61^{Ba}	8.53 ± 0.43^{Aa}	7.30 ± 1.15^{Aa}
Chitosan 1%	9.72 ± 0.92^{Aa}	9.10 ± 0.17^{Aa}	10.06 ± 1.40^{Aa}	8.17 ± 0.75^{Aa}	8.98 ± 0.40^{Aa}
Carrageenan 1%	9.21 ± 0.51^{Aa}	8.40 ± 0.17^{Aa}	7.43 ± 0.38^{Ba}	8.68 ± 1.79^{Aa}	7.21 ± 0.63^{Aa}
Pectin 2% with $CaCl_2$ 2%	10.89 ± 0.94^{Aa}	9.56 ± 0.51^{Aab}	8.07 ± 0.31^{ABa}	9.49 ± 0.75^{Aab}	9.18 ± 0.96^{Aab}

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

The increased of TSS value for each treatment was related to the hydrolysis of starch to simple sugar. Soluble solids content, pH, total sugars, protein and carbohydrate content increase from the unripe to ripe stage and decline at overripe stage.

Above observation indicated that, higher significant in TSS value at day 4 for chitosan (1%), due to the MP muskmelon increase glucose and fructose content was high while control and carrageenan 1% indicated lower significant due to the rapid changing stage of ripe to overripe. For the next two last day treatment, MP muskmelon was no significant different among the treatments due to changing it stage from ripe to overripe as the sucrose content increased and the concentrations of the two monosaccharides decreased.

Sucrose content increase continuously throughout fruit development, whereas glucose and fructose contents increase from the unripe to ripe stage, then decrease from ripe to overripe stage. The percentage contributions of the sugars changed during ripening. Sugars are a basic parameter in evaluating fruit market quality attributes. Genetic and environmental factors may affect the qualitative and quantitative composition of the sugar fraction by altering the activity of the enzymes involved in synthesis and breakdown processes (Lingle and Dunlap, 1987). In the early growth stages the glucose and fructose content was high and the sugars were present in similar amounts. As ripening progressed the sucrose content increased and the concentrations of the other two monosaccharides decreased.

Sucrose may be formed by the above mentioned monosaccharides as well as by the breakdown of the different carbohydrates present in other organs of the plant. Hubbard *et al.,* (1989) recorded the presence of stachyose in leaves and partial breakdown of this substance, with synthesis of sucrose, in the fruit pedicel. Schaffer *et*

al., (1987) reported the presence of the saccharose galactosides raffinose and stachyose, which may be transported to the fruit, though sucrose is the sugar finally accumulated by the fruit. Rapid increase in total sugar during the ripening was attributed to increases in sucrose (Villanueva *et al.*, 2004). Almost half of the final concentration of sugar in cantaloupe was achieved in the last week before or at the time of abscission (McCollum *et al.*, 1989).

4.4 Percentage of weight loss

The percentage weight loss showed an increasing trend throughout the storage period (Figure 4.4) for all treatments. Percentage of weight loss in control was significantly higher compared with other treatments on day 6 and day 8. However, treatment with chitosan (1%), carragenan (1%) and pectin (2%) with $CaCl_2$ (2%) showed no significant different among each others on day 6 and day 8.

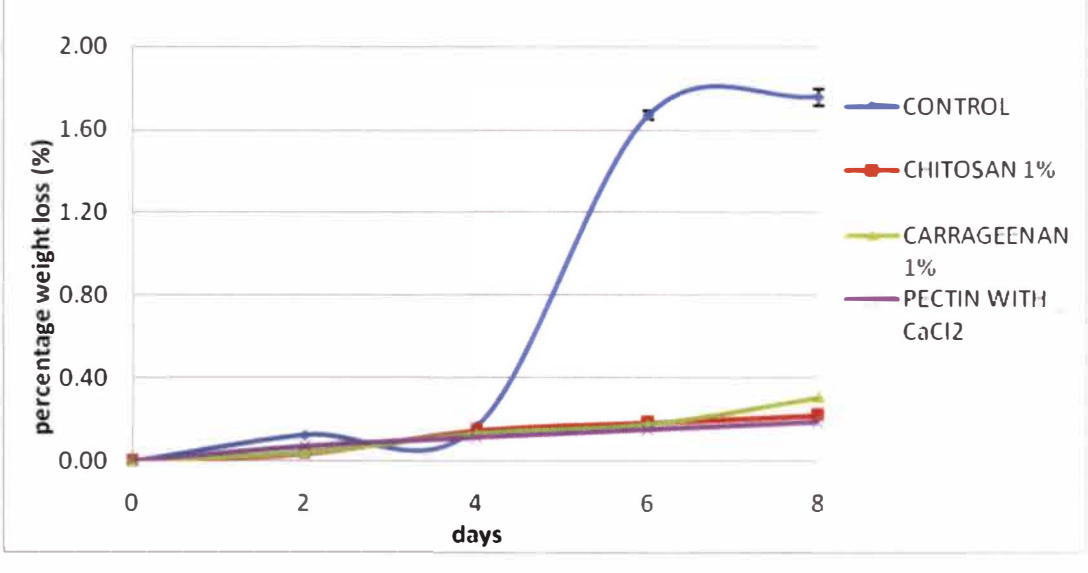

Figure 4.4: Effect of edible coatings on percentage weight loss of MP muskmelon at chilled storage

The water barrier of a biopolymer was impaired in the higher relative humidity environment or with higher moisture content of the food (Garcia *et al.,* 2004). A poor water vapour barrier property allows movement of water vapour across the film, thus, preventing the water condensation that can be potential source of microbial spoilage in horticultural commodities (Park *et al.,* 1994). From the result, the rate of weight loss for control was significantly higher than edible coatings treatment. Therefore the rate of moisture loss was increases due to the increasing of weight loss. Relative humidity (RH) plays an important role of transpiration. According to Mir and Beaudry (2004), plant tissues tend to lose moisture when RH is below 99-99.5%. The refrigerator used in the research was around 75% RH and this could be the reason of high weight loss of control and dip (Bico *et al.*, 2009). Edible coating treatments reduce the percentage weight loss of the sample.

Table 4.4: Effect of edible coatings on percentage weight loss of MP muskmelon during chilled storage

Treatment	Percentage of Weight Loss (%)				
	Day 0	Day 2	Day 4	Day 6	Day 8
Control 1%	0.00 ± 0.00^{Ab}	0.13 ± 0.01^{Ab}	0.17 ± 0.02^{Ab}	1.67 ± 0.07^{Aa}	1.76 ± 0.13^{Aa}
Chitosan 1%	0.00 ± 0.00^{Ac}	0.04 ± 0.02^{Cb}	0.15 ± 0.03^{ABb}	0.19 ± 0.01^{Ba}	0.22 ± 0.03^{Ba}
Carrageenan 1%	0.00 ± 0.00^{Ad}	0.04 ± 0.01^{Cd}	0.13 ± 0.03^{ABc}	0.18 ± 0.02^{Bb}	0.31 ± 0.01^{Ba}
Pectin 2% with $CaCl_2$ 2%	0.00 ± 0.00^{Ae}	0.08 ± 0.01^{Bd}	0.11 ± 0.01^{Bc}	0.15 ± 0.01^{Bb}	0.19 ± 0.01^{Ba}

Note: Value in Table 4.4 are mean of 3 replicates (3 representative samples/replicate)
Mean (n=3) ± standard deviation
(A-B) mean bearing the same superscript within the same column are not significantly different at 5% level ($p<0.05$)
(a-e) mean bearing the same superscript within the same row are not significantly different at 5% level ($p<0.05$)

4.5 Microbiological study

Microbial safety is one of the most important factors to be considered for preservation of minimally processed food (Wiley, 1994). There were three types of media used (NA, VRBA and PDA) for microbial growth of total bacteria count (TBC), total coliforms (TC), and yeast and moulds (YM) respectively in the different MP muskmelon treated with different edible coatings.

Growth of microbial in NA, VRBA and PDA agar showed increased pattern throughout the storage period. Figure 4.5 showed the count of total bacteria on NA of MP muskmelon treated with different edible coatings. There were significantly high of total bacterial counts in control compared to others edible coating treatments on day 0 followed by treatments of carrageenan (1%) and pectin (2%) with $CaCl_2$ (2%) (Table 4.5). Treatment with chitosan (1%), was significantly lower than other treatments which was about 3.4_log_{10}CFU/g on day 0. It was proved, that aerobic mesophilic bacteria was growth rapidly in control but the growth where lesser in edible coating treatments.

However MP muskmelon without edible coatings (control) safe to be consumed as it did not exceeded 7 Log_{10}CFU/g. Growth of bacteria was increased in control and edible coating treatments throughout the storage. There was significantly low bacterial growth in MP muskmelon treated with chitosan (1%) compared to other treatments. The treatment chitosan (1%) only showed 5.56 Log_{10}CFU/g of bacterial growth while other edible coating treatments and control recorded count of exceeding 7 Log_{10}CFU/g.

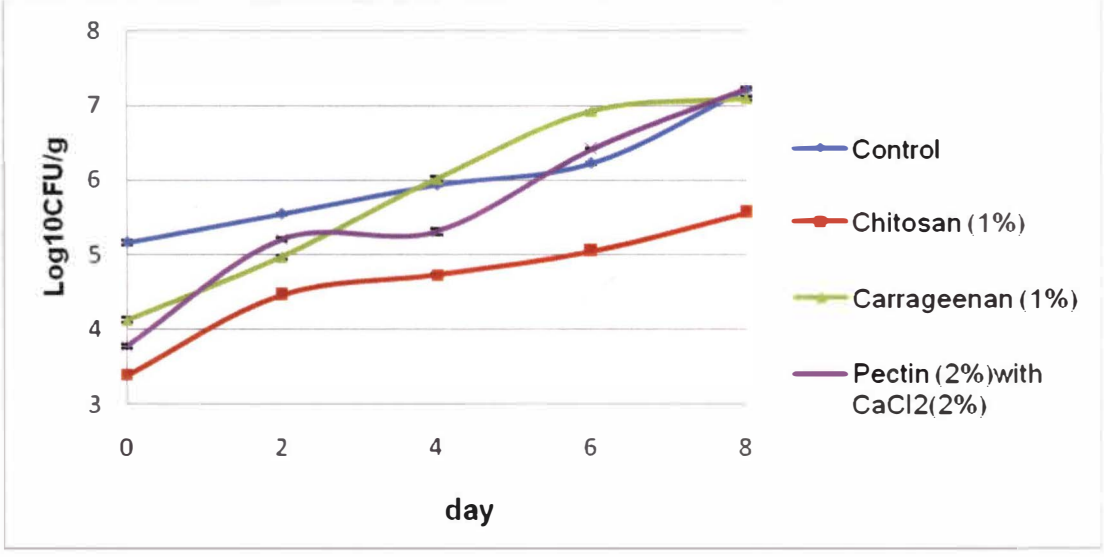

Figure 4.5: Effect of edible coatings on the TBC growth in MP muskmelon

Figure 4.6 revealed a significantly high difference in coliform counts in treatment pectin (2%) with $CaCl_2$ (2%), while no coliform counted in the VRBA plate for control, chitosan (1%) and carrageenan (1%) on day 0. Total number of coliforms contained in all MP muskmelon samples was increased over the storage day. On day 6, there was significantly higher of total coliform counts in control compared with the other edible coating treatments. The total coliform counts were exceeding detection limit of 6 $Log_{10}CFU/g$ (Table 4.5).

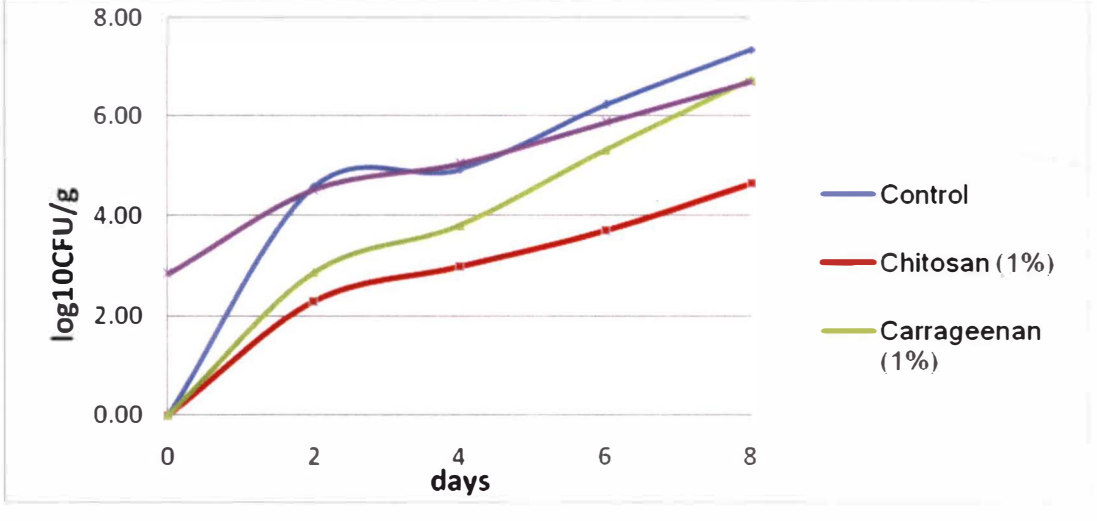

Figure 4.6: Effect of edible coatings on TC growth in MP muskmelon

The samples treated with other edible coatings were still safe to be consumed on day 6. Samples of MP muskmelons treated with chitosan (1%) remained below detection limit of about 3.72 Log_{10}CFU/g for day 6 and 4.66 Log_{10}CFU/g for day 8 which showed that MP muskmelons were safe to be consumed. On the 8th day storage at 5±1°C, control presented the highest microbial counts followed by carrageenan (1%) and pectin (2%) with $CaCl_2$ (2%) that was recorded to exceed the detection limit and unsafe to be consumed.

Figure 4.7 showed the counts in the MP muskmelon during storage. Yeasts and moulds (YM) level were accepted for all treatments on day 0 but the total YM was significantly higher in treatment of pectin (2%) with $CaCl_2$ (2%) compared to the other treatments (Table 4.5). Although the visual appearance did not changes on day 2 until day 6 for pectin (2%) with $CaCl_2$ (2%) but it showed increasing number of the total YM which exceeded the detection limit of 5 Log_{10}CFU/g.

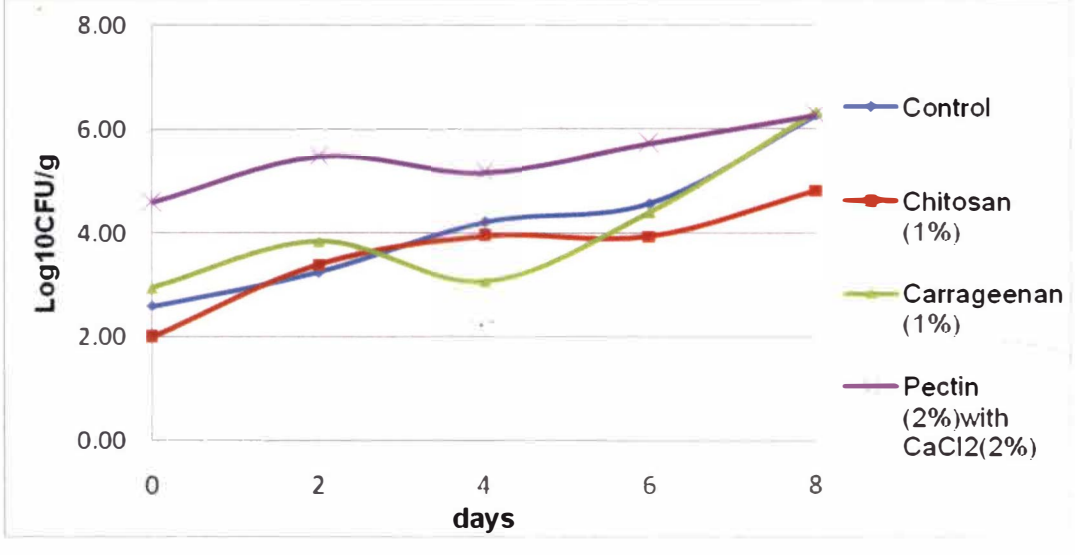

Figure 4.7: Effect of edible coatings on total YM growth in MP muskmelon

Exceeding the microbiological limit does not always result in the occurrence of visual defects as both microbiological and physiological activity play a role in spoilage of this product (Ragaert *et al.*, 2004). The other treatments showed the values of total YM were still can be acceptable and safe to be consumed until day 6. The pattern for counts total was same with TBC and TC in all the treatments. The totals YM were significantly high in the treatments such as control, carrageenan (1%) and pectin (2%) with $CaCl_2$ (2%) while MP muskmelons treated with edible coating of chitosan (1%) showed significantly low count compared to the treatments on day 8.

For microbiological study, three types of microorganisms should be observed and the microbial counts of each in MP muskmelon should not exceed the critical limit. Each of the TBC, TC and total YM in MP muskmelons measured would indicate the safety level for consumption. According to table 4.5, MP muskmelons treated with chitosan (1%) were safe to be consumed until day 8. Even the value of total coliforms and total bacterial of MP muskmelons treated with pectin (2%) with $CaCl_2$ (2%) was still below the detection limit until day 6, but the value of total YM were exceeded detection limit and can only be consumed safely before day 2.

For MP muskmelon with edible coating treatments of carrageenan (1%) it was safe to be consumed until day 6 while control samples were only safe for consumption until day 4. Therefore, from the microbial study the treatment of chitosan (1%) was found to be the best treatment which can retain the quality of MP muskmelon and safe for consumption until day 8.

Table 4.5: Effect of edible coatings on microbial count (NA, VRBA and PDA) of MP muskmelon during chilled storage

	Microbial count (NA, VRBA and PDA)/(Log_{10}CFU/g)				
	Day 0	Day 2	Day 4	Day 6	Day 8
Nutrient Agar (NA)					
Control 1%	5.16 ± 0.10^{Ad}	5.07 ± 0.06^{Bd}	5.93 ± 0.08^{Ac}	6.23 ± 0.05^{Cb}	7.22 ± 0.07^{Aa}
Chitosan 1%	3.40 ± 0.06^{De}	4.46 ± 0.02^{Cd}	4.25 ± 0.05^{Cc}	5.04 ± 0.04^{Db}	5.56 ± 0.07^{Ba}
Carrageenan 1%	4.12 ± 0.12^{Bd}	4.96 ± 0.76^{Bc}	6.01 ± 0.12^{Ab}	6.93 ± 0.03^{Aa}	7.09 ± 0.08^{Aa}
Pectin 2% with $CaCl_2$ 2%	3.77 ± 0.12^{Cd}	5.21 ± 0.03^{Ac}	5.31 ± 0.06^{Bc}	6.42 ± 0.03^{Bb}	7.23 ± 0.35^{Aa}
Violet Red Bile Agar (VRBA)					
Control 1%	0.00 ± 0.00^{Be}	4.59 ± 0.02^{Ad}	4.93 ± 0.01^{Bc}	6.23 ± 0.01^{Ab}	7.34 ± 0.02^{Aa}
Chitosan 1%	0.00 ± 0.00^{Be}	2.29 ± 0.11^{Cd}	3.00 ± 0.02^{Dc}	3.72 ± 0.02^{Db}	4.66 ± 0.01^{Da}
Carrageenan 1%	0.00 ± 0.00^{Be}	2.87 ± 0.08^{Bd}	3.81 ± 0.06^{Cc}	5.32 ± 0.02^{Cb}	6.74 ± 0.01^{Ba}
Pectin 2% with $CaCl_2$ 2%	2.84 ± 0.04^{Ae}	4.51 ± 0.01^{Ad}	5.05 ± 0.04^{Ac}	5.87 ± 0.08^{Bb}	6.69 ± 0.12^{Ca}
Potatoes Dextrose Agar (PDA)					
Control 1%	2.59 ± 0.06^{BCe}	3.25 ± 0.05^{Cd}	4.18 ± 0.06^{Bc}	4.56 ± 0.19^{Bb}	6.26 ± 0.07^{Aa}
Chitosan 1%	2.25 ± 0.36^{Cd}	3.39 ± 0.09^{Cc}	3.95 ± 0.05^{Cb}	3.94 ± 0.04^{Cb}	4.84 ± 0.03^{Ba}
Carrageenan 1%	3.28 ± 0.62^{Bcd}	3.84 ± 0.06^{Bbc}	3.08 ± 0.04^{Dd}	4.42 ± 0.03^{Bb}	6.34 ± 0.02^{Aa}
Pectin 2% with $CaCl_2$ 2%	4.60 ± 0.76^{Ae}	5.49 ± 0.12^{Ac}	5.18 ± 0.01^{Ad}	5.74 ± 0.01^{Ab}	6.27 ± 0.00^{Aa}

Note: Values in Table 4.5 are mean of 3 replicates (3 representative samples/replicate)
Mean (n=3) $\pm$ standard deviation
(A-D) mean bearing the same superscript within the same column are not significantly different at 5% level ($p<0.05$)
(a-e) mean bearing the same superscript within the same row are not significantly different at 5% level ($p<0.05$)

4.6 Sensory Evaluation

The sensory quality of each triplicate of MP muskmelon was evaluated for the attributes of appearance, texture, odour, colour, taste and the overall acceptability. Samples were presented in random order to 15 semi-trained panelists. Fresh samples were used as a standard for the measurement the acceptability level to the treated samples. For the attribute of appearance, texture, odour and colour, there were no significant different among the treatments until day 6 (Table 4.6).

Figure 4.8 revealed the sensory evaluation on the attribute of the appearance MP muskmelon treated with different coatings treatments from day 0 until day 8. The appearance can still be accepted until day 8 for chitosan (1%) and pectin (2%) with $CaCl_2$ (2%) where they showed significantly higher score than carrageenan (1%) and control. MP muskmelon for both control and carrageenan (1%) were not accepted in the term of their appearance on day 8 because there were signs of fatigue tissues.

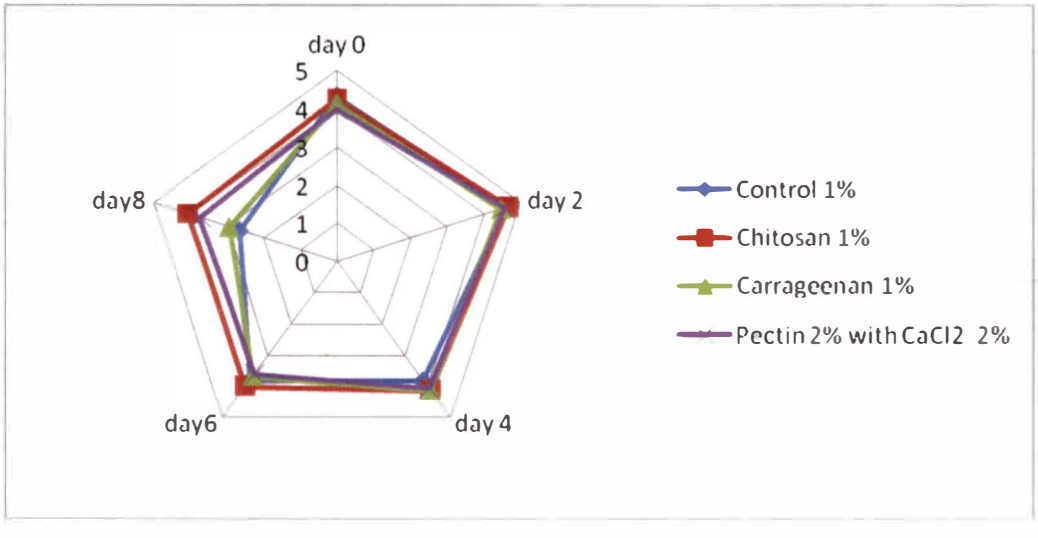

Figure 4.8: Sensory evaluation on the attribute of appearance of MP muskmelon treated with different edible coating treatments.

For the texture of MP muskmelon on day 8, there were significantly higher in chitosan (1%) and pectin (2%) with $CaCl_2$ (2%) but significantly lower for samples treated with carrageenan (1%) and control (Table 4.6). The texture for chitosan (1%) and pectin (2%) with $CaCl_2$ (2%) was accepted due to their firm and turgidity and no sense of softness. Although the values in the (Table 4.2; Figure 4.2) texture analysis, chitosan (1%) showed lower firmness but it scored higher in the acceptability (Figure 4.9).

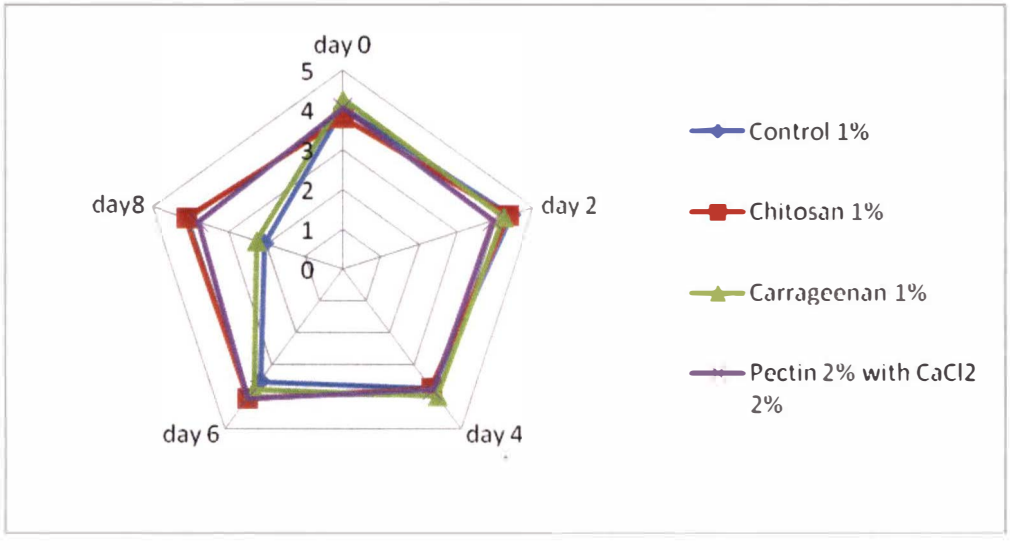

Figure 4.9: Sensory evaluation on the attribute of texture of MP muskmelon treated with different edible coating treatments.

The sensory attribute of odour showed no significant different on day 0 until day 6 as mention earlier. However, on day 8, odour acceptability was decreased for control (Figure 4.10) where it significantly lower compared to the MP muskmelon treated with edible coatings as they were off-odour. The odour of MP muskmelon treated with chitosan (1%) was very acceptable because the odour was almost similar to the fresh sample even after 8 days of storage.

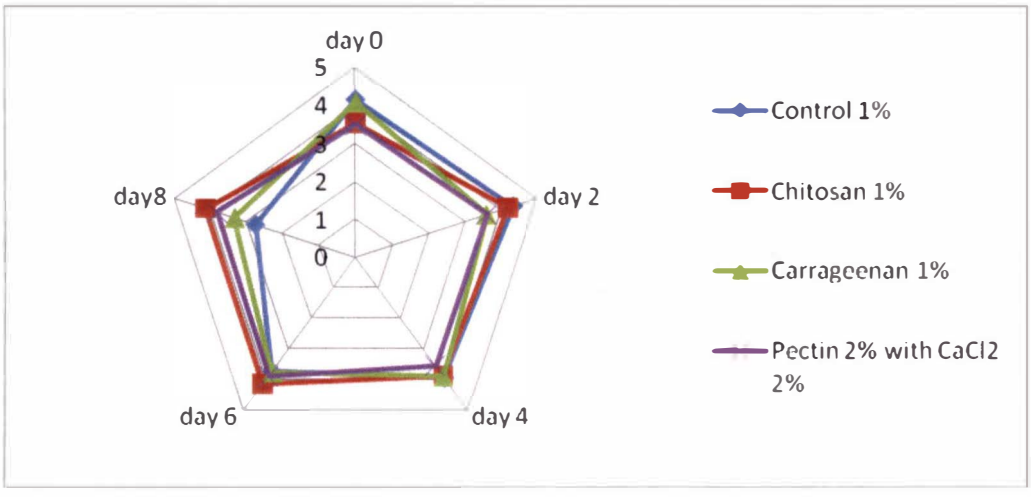

Figure 4.10: Sensory evaluation on the attribute of odour of MP muskmelon treated with different edible coating treatments

For the attribute of colour, the acceptability of all the treatments were significantly no difference from day 0 until day 6 but on day 8 there were significantly high acceptability in the samples treated with chitosan (1%) compared to control (Table 4.6). However, the colour attribute for control and other treatments can still be accepted on day 8. The colour changes for both treatments increase throughout the storage day as obtained in the colour analysis (Figure 4.1) but for colour acceptability it can still be accepted.

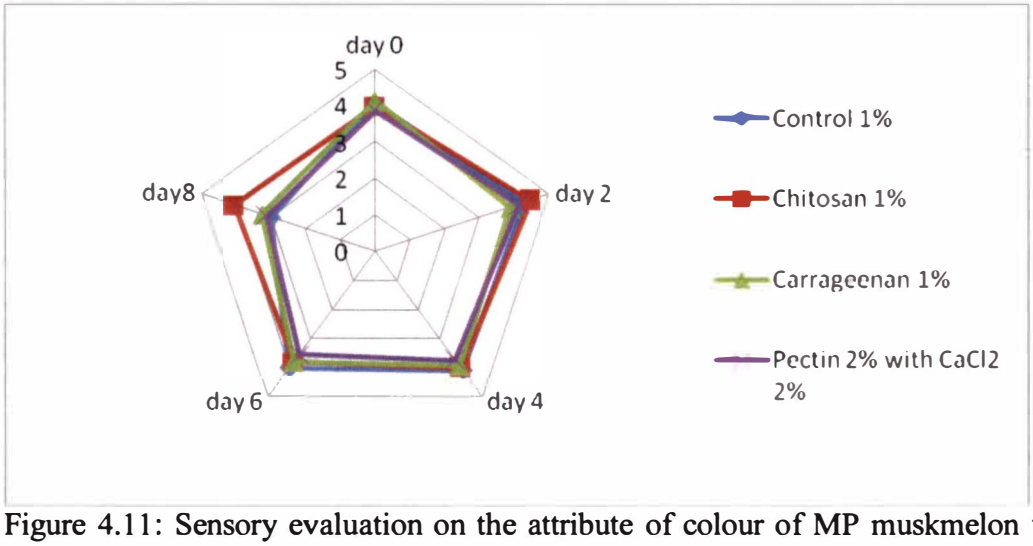

Figure 4.11: Sensory evaluation on the attribute of colour of MP muskmelon treated with different edible coating treatments

Figure 4.12 and Table 4.6 was showed the taste acceptability for MP muskmelon treated with different edible coatings and control. On day 0 there was no significant different among the treatments but there was significantly high in control for the attribute of taste acceptability on day 2 compared to MP muskmelon treated with chitosan (1%) and carrageenan (1%). The taste acceptability of MP muskmelon was decreasing. However on day 4 and day 6 there were no significant different obtained. On day 8 there were significantly low in control and carrageenan (1%) compared to other treatments because the sample had already discarded due to the exceeded limit of microbial detection. The sample treated with chitosan (1%) was accepted until day 8.

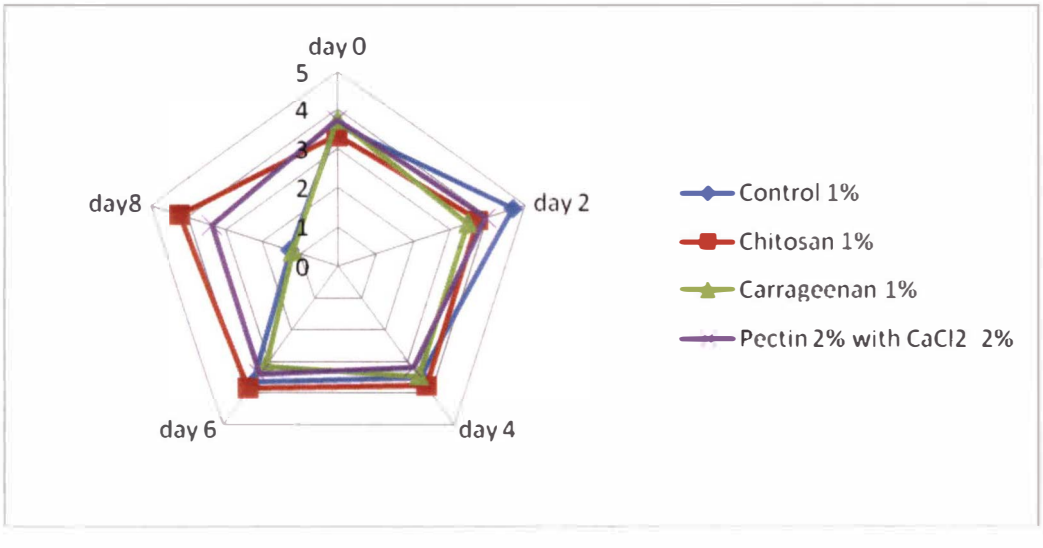

Figure 4.12: Sensory evaluation on the attribute of taste of MP muskmelon treated with different edible coating treatments

For the overall acceptability, all treatments were accepted on day 0 until day 6 and there was no significant different of overall acceptability on day 2 for all treatments. For day 8, treatment with carrageenan (1%) and control were not accepted due to the off-flovour and off-taste but chitosan (1%) and pectin (2%) with $CaCl_2$ (2%) were accepted until end of storage day (Table 4.6 and Figure 4.13).

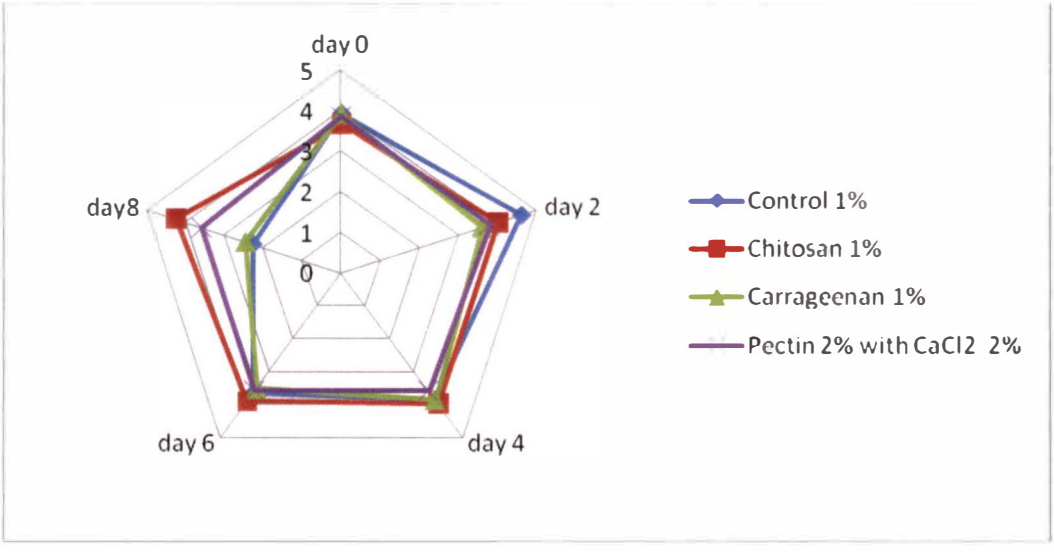

Figure 4.13: Sensory evaluation on the attribute of overall acceptability of MP muskmelon treated with different edible coating treatments

Table 4.6: Sensory evaluation of MP muskmelon treated with different edible coatings treatments

Sensory attributes/ Treatments	Acceptability Score				
	Day 0	Day 2	Day 4	Day 6	Day 8
Appearance					
Control 1%	4.33 ± 0.72^{Aa}	4.60 ± 0.63^{Aa}	3.80 ± 0.77^{Aa}	3.80 ± 0.77^{Aa}	2.66 ± 1.06^{Cb}
Chitosan 1%	4.27 ± 0.80^{Aa}	4.67 ± 0.49^{Aa}	4.13 ± 0.83^{Aa}	4.00 ± 0.65^{Aa}	4.07 ± 0.59^{Aa}
Carrageenan 1%	4.13 ± 0.83^{Aab}	4.46 ± 0.64^{Aa}	4.13 ± 0.64^{Aab}	3.67 ± 0.81^{Abc}	2.93 ± 0.88^{BCc}
Pectin 2% with $CaCl_2$ 2%	4.00 ± 0.87^{Aab}	4.57 ± 0.56^{Aa}	4.07 ± 0.46^{Aab}	3.60 ± 0.99^{Abc}	3.73 ± 0.70^{ABc}
Texture					
Control 1%	4.07 ± 0.80^{Aab}	4.40 ± 0.63^{Aa}	3.73 ± 0.80^{Aab}	3.53 ± 0.92^{Ab}	2.07 ± 0.88^{Bc}
Chitosan 1%	3.80 ± 0.94^{Aa}	4.33 ± 0.62^{Aa}	3.73 ± 0.60^{Aa}	4.07 ± 0.70^{Aa}	4.13 ± 0.52^{Aa}
Carrageenan 1%	4.27 ± 0.89^{Aa}	4.20 ± 0.86^{Aa}	4.00 ± 0.53^{Aa}	3.80 ± 0.68^{Aa}	2.27 ± 0.88^{Bb}
Pectin 2% with $CaCl_2$ 2%	4.07 ± 0.68^{Aa}	3.93 ± 0.88^{Aa}	3.80 ± 0.68^{Aa}	4.07 ± 0.77^{Aa}	3.80 ± 0.68^{Aa}
Odour					
Control 1%	4.13 ± 0.83^{Aa}	4.33 ± 0.90^{Aa}	3.93 ± 0.80^{Aa}	3.73 ± 1.03^{Aa}	2.73 ± 0.68^{Cb}
Chitosan 1%	3.53 ± 1.06^{Aa}	4.20 ± 0.68^{Aa}	3.87 ± 0.52^{Aa}	4.13 ± 0.64^{Aa}	4.13 ± 0.52^{Aa}
Carrageenan 1%	4.07 ± 0.70^{Aa}	3.60 ± 0.83^{Aab}	3.87 ± 0.64^{Aab}	3.73 ± 0.46^{Aab}	3.33 ± 0.72^{BCb}
Pectin 2% with $CaCl_2$ 2%	3.47 ± 0.92^{Aa}	3.60 ± 0.83^{Aa}	3.53 ± 0.74^{Aa}	3.87 ± 0.52^{Aa}	3.80 ± 0.77^{ABa}

Colour					
Control 1%	4.07±0.88^{Aa}	4.27±0.59^{Aa}	4.07±0.59^{Aa}	4.00±0.85^{Aa}	3.00±1.25^{Bb}
Chitosan 1%	4.00±0.85^{Aa}	4.47±0.52^{Aa}	4.00±0.53^{Aa}	3.80±0.77^{Aa}	4.07±0.80^{Aa}
Carrageenan 1%	4.13±0.83^{Aa}	3.87±0.83^{Aab}	3.93±0.46^{Aab}	3.80±0.77^{Aab}	3.27±1.16^{ABb}
Pectin 2% with $CaCl_2$ 2%	3.87±1.06^{Aab}	4.13±0.74^{Aa}	3.73±0.59^{Aab}	3.53±0.92^{Aab}	3.13±0.83^{ABb}
Taste					
Control 1%	3.60±1.12^{Ab}	4.67±0.62^{Aa}	3.53±0.63^{Ab}	3.67±1.05^{Ab}	1.27±0.46^{Cc}
Chitosan 1%	3.33±1.11^{Aa}	3.73±1.10^{Ba}	3.80±1.06^{Aa}	3.87±1.13^{Aa}	4.20±0.68^{Aa}
Carrageenan 1%	3.73±1.00^{Aa}	3.47±1.07^{Ba}	3.47±0.83^{Aa}	3.13±0.74^{Aa}	1.20±0.41^{Cb}
Pectin 2% with $CaCl_2$ 2%	3.73±1.10^{Aa}	3.93±1.10^{ABa}	3.20±0.68^{Aa}	3.40±1.00^{Aa}	3.33±0.72^{Ba}
Overall					
Control 1%	3.93±0.80^{Aab}	4.60±0.63^{Aa}	3.87±0.64^{Ab}	3.67±0.72^{Ab}	2.27±0.70^{Cc}
Chitosan 1%	3.67±0.49^{Ab}	4.00±0.65^{ABab}	4.00±0.53^{Aab}	3.93±0.70^{Aab}	4.27±0.46^{Aa}
Carrageenan 1%	3.93±0.80^{Aa}	3.60±1.12^{Ba}	3.87±0.64^{Aa}	3.53±0.74^{Aa}	2.47±0.83^{Cb}
Pectin 2% with $CaCl_2$ 2%	3.87±0.99^{Aa}	3.80±0.77^{Ba}	3.60±0.63^{Aa}	3.60±0.63^{Aa}	3.60±0.63^{Ba}

Note: Values in Table 4.6 are mean of 3 replicates (3 representative samples/replicate)
Mean (n=15) ± standard deviation
(A-D) mean bearing the same superscript within the same column are not significantly different at 5% level ($p<0.05$)
(a-e) mean bearing the same superscript within the same row are not significantly different at 5% level ($p<0.05$)

CHAPTER 5

CONCLUSION

5.1 Conclusion

Marketing of fresh-cut and ready-to-eat products has increased rapidly due to increased in consumer demand for fresh convenient foods. The storage stability of minimally processed Muskmelon (*Cucumis melo* variety *Glamour*) treated with hydrocolloids as edible coatings were investigated. The pysico-chemical changes, microbial counts and sensory acceptability using different hydrocolloid coatings during storage at low temperature (5±1°C; Relative Humidity 90-95%) were evaluated. The total colour changes, percentage of weight loss and microbial counts were increased whereas TSS, texture and sensory acceptability were decrease over the storage period. All the edible coating treatment showed significantly lower of percentage weight loss then control.

Total colour changes of MP muskmelon treated with carrageenan (1%) was higher compared to others. For texture analysis, control showed higher in the firmness on day 0 until day 8 compared to other treatments but no significant different was observed throughout the storage. Among all treatments, there were no significant different in the TSS value on day 8. Microbial analysis showed chitosan (1%) showed the best treatment in retaining the quality of minimally processed muskmelon whereas carrageenan (1%) had the highest counts and only safe to be consumed before day 2. The sensory attribute

of the overall acceptability showed that control and carrageenan (1%) were not accepted after day 6. Therefore, the results of this study also demonstrated that chitosan (1%) effectively prolong the quality and extends the shelf life of minimally processed muskmelon.

5.2 Recommendation

Edible coating treatment is one of the methods to prolong the shelf life of MP muskmelons. The investigation of the microbial counts of minimally processed samples must always be checked to ensure the safety of the product. Therefore, the sanitize place, autoclave equipments, proper storage handling, aseptic methods of handling and storage are needed to obtain the best result for the experiment.

Edible coating treatment can also be coupled with other treatments such as anti-browning and modified atmosphere packaging to better prolong the shelf-life of MP products. A similar study could also be carried out to investigate the effectiveness of edible coatings on different fruits such as watermelon, honey dew, pineapple etc.

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APPENDICES

MP muskmelons were skinned and cut in hygienic procedures

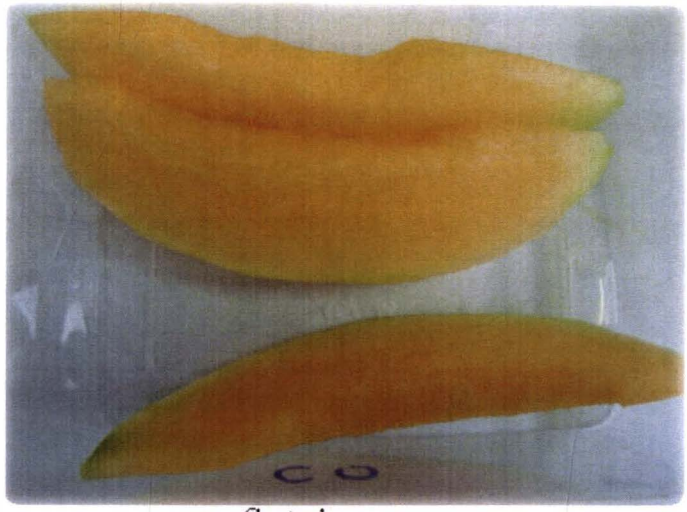
MP muskmelons were dipped in chlorine dioxide (ClO_2)

MP muskmelons were air-dried and treated with edible coatings

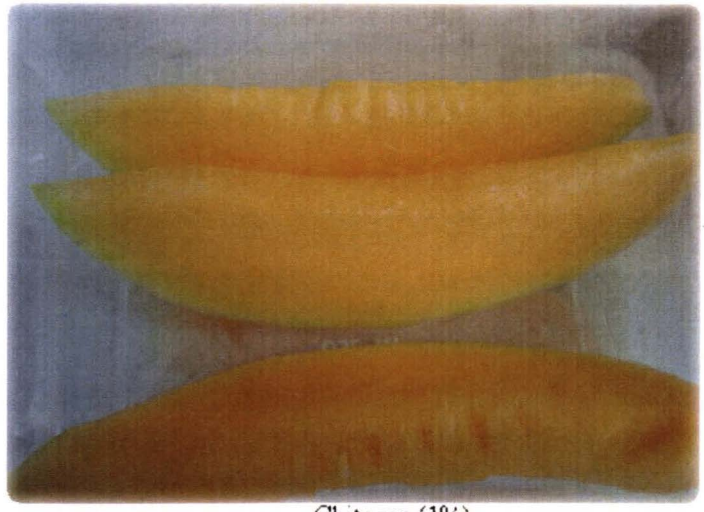
MP muskmelons ready to be packed in PP containers

Appendix A Preparations of MP muskmelons

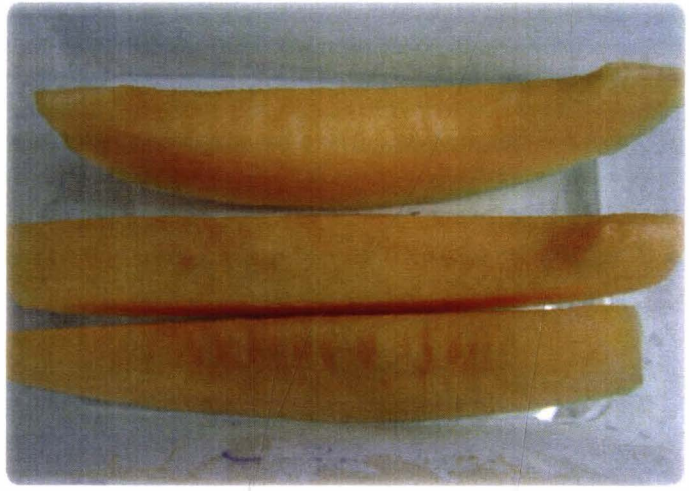
DAY 0



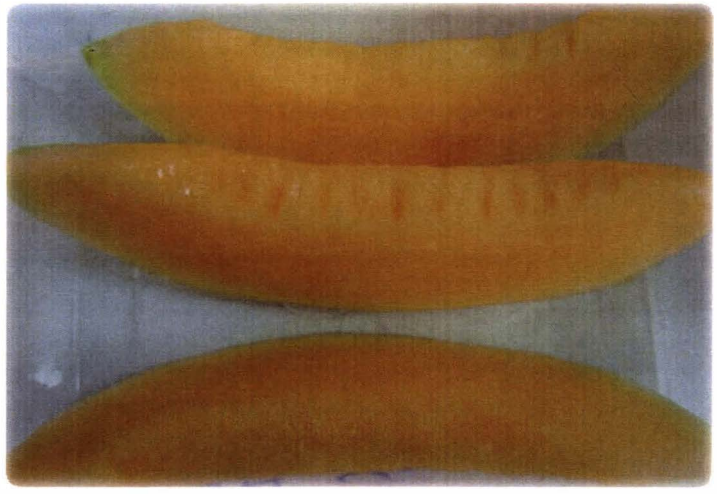
Control



Chitosan (1%)



Carrageenan (1%)

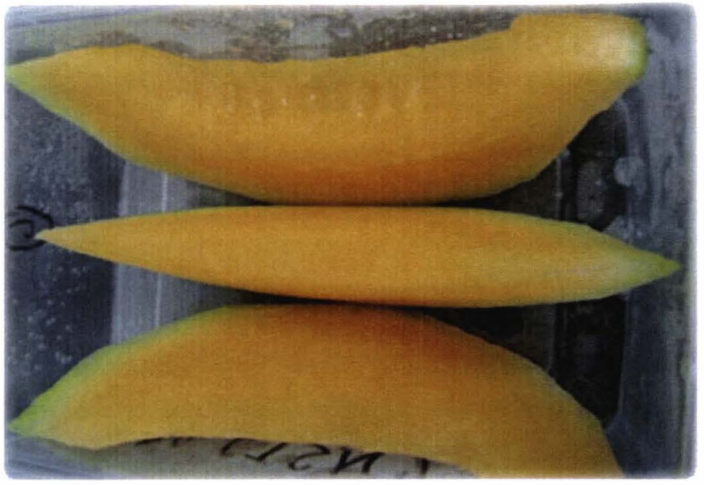


Pectin (2%) with calcium chloride (2%)

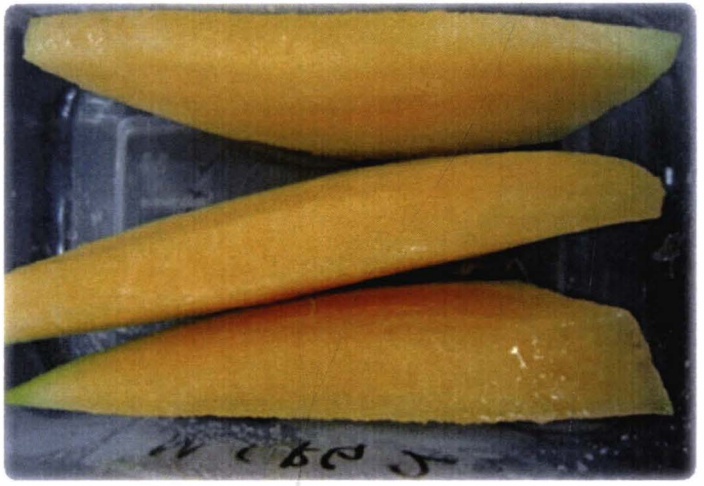
Appendix E Observations of muskmelons treated with different edible coatings on day 0

DAY 2

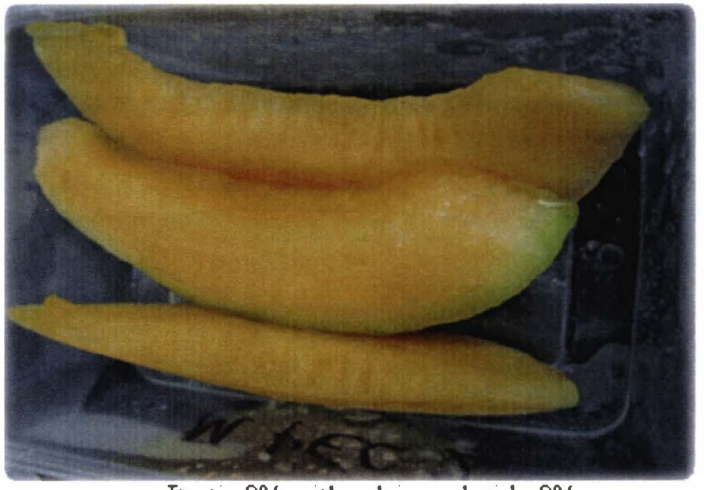
Control



Chitosan 1%

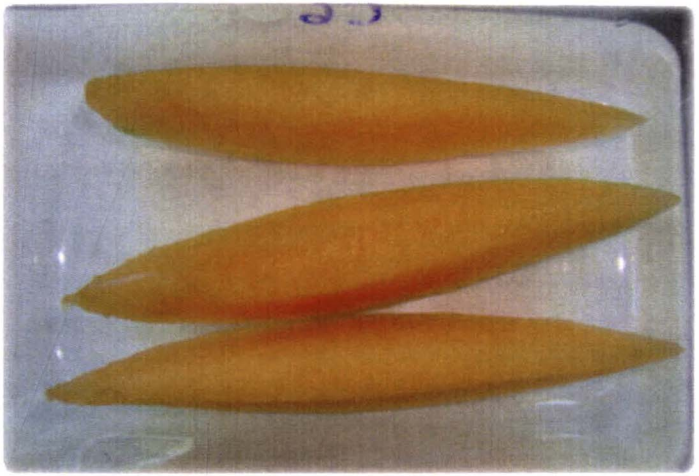


Carrageenan 1%

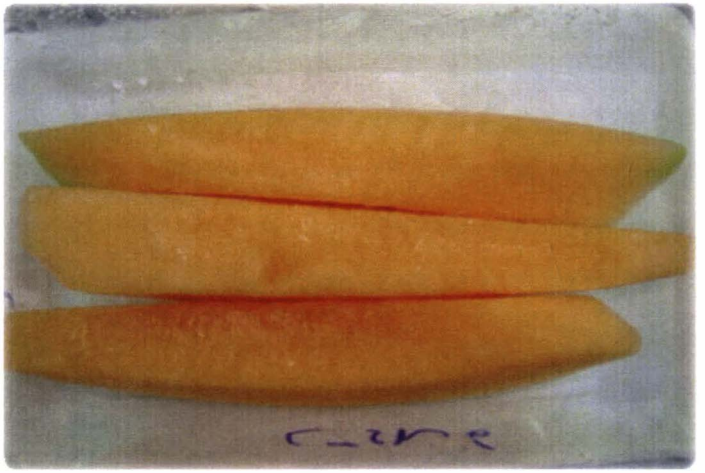


Pectin 2% with calcium cloride 2%

Appendix C Observations of MP muskmelons treated with different edible coatings on day 2

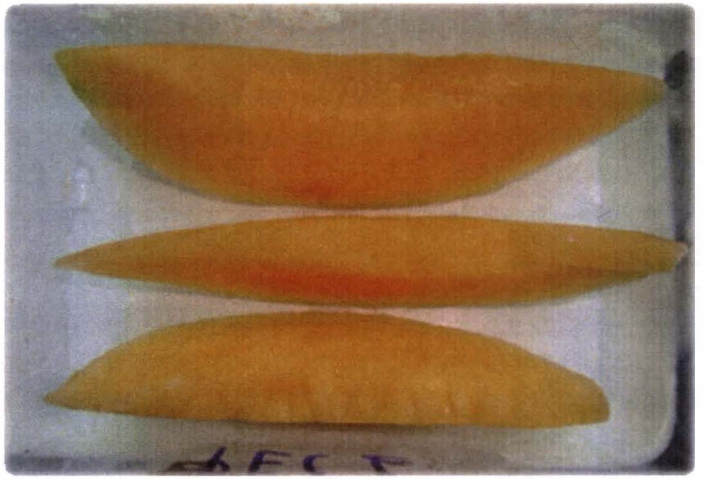


Control



Chitosan 1%

Carrageenan 1%



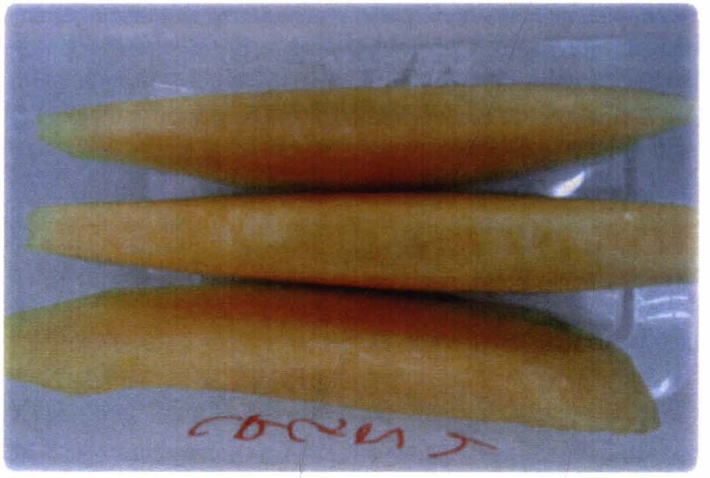
Pectin 2% with calcium clorride 2%

Appendix D Observations of MF muskmelons treated with different edible coatings on day 4

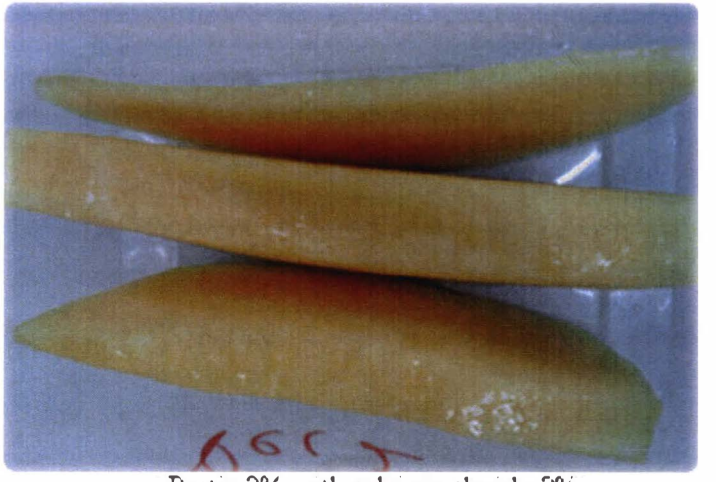
DAY 6

Control

Chitosan 1%



Carrageenan 1%

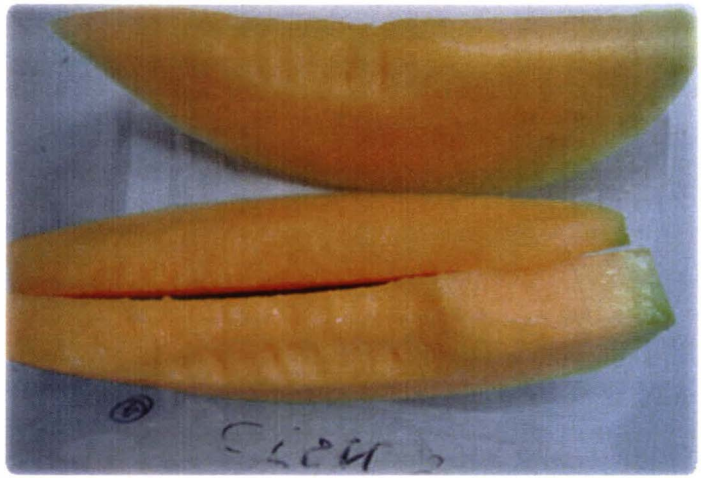


Pectin 2% with calcium cloride 2%

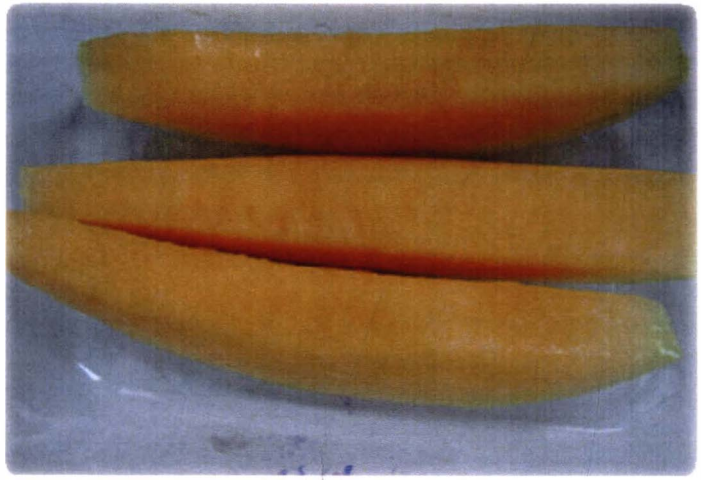
Appendix E Observations of MP muskmelons treated with different edible coatings on day 6

DAY 8

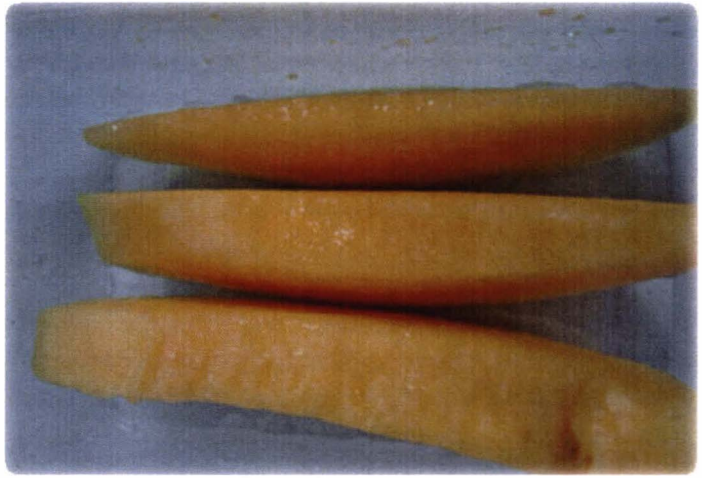
Control



Chitosan 1%



Carrageenan 1%



Pectin 2% with calcium cloride 2%

Appendix F Observations of MP muskmelons treated with different edible coatings on day 8

CURRICULUM VITAE

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Date of Birth	: 20th October 1988
Place of Birth	: Muadzam Shah, Pahang
Nationality	: Malaysian
Gender	: Female
Marital Status	: Single
Health	: Good
Race	: Malay
Religion	: Islam
Height/ Weight	: 157cm/48kg
Hobbies/Interest	: Reading, Drawing and Gardening /Agriculture
Hobbies	: Gardening, Drawing and jogging
Personality	: Outgoing and pleasant, fast learning, patient, well manage, Hardworking, Honest, Trustworthy and independence.

Education background:

2007-2010	: Bachelor in Science of Agrotechnology (Post Harvest Technology) at Universiti Malaysia Terengganu (UMT)
2006-2007	: Perak Matriculation Collage, Perak
2001-2005	: Sekolah Menengah Kebangsaan Chanis (SMK CHANIS), Muadzam Shah, Pahang (SPM & PMR)

EXTENDING THE SHELF LIFE OF MINIMALLY PROCESSED MUSKMELON (CUCUMIS MELO) USING HYDROCOLLOIDS AS EDIBLE COATINGS - NURUL ATIQAH BINTI RAMLI