EDIBLE COATING DEVELOPMENT FOR FRESH-CUT CANTALOUPE

A Thesis

by

MAURICIO ERNESTO MARTINON GASPAR

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2011

Major Subject: Biological and Agricultural Engineering

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Approved by:

Chair of Committee,	Rosana Moreira
Committee Members,	Stephen Talcott
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ABSTRACT

Edible Coating Development for Fresh-cut Cantaloupe.

(December 2011)

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Chair of Advisory Committee: Dr. Rosana Moreira

The consumption of fresh-cut fruits has been increasing in recent years due to their health benefits. Fresh-cut cantaloupe (*Cucumis melo* L.) represents a great snack alternative due to its low caloric content, freshness, and basic component of a healthy diet. One of the latest alternatives to reduce the decay of quality brought by minimal processing of fruits is the development of edible coatings. Acting as a barrier to moisture and gases, the coatings are expected to extend the shelf-life of fresh-cut products, thus the main objective of this research was to determine the effectiveness of an antimicrobial edible coating on the shelf-life of fresh cut cantaloupe (stored at 4^{o}C for 15 days) while maintaining its quality attributes.

The effect of different coating compositions and their concentrations on a product's chemical properties and quality attributes was studied. A set of solutions containing chitosan, beta-cyclodextrin, *trans*-cinnamaldehyde, pectin and calcium chloride were used as coating systems for the fruit using the layer-by-layer method. Quality was measured in terms of texture, color, weight loss, moisture, acidity, and pH. In addition, a consumer sensory test was carried out to support the findings from the

objective quality data. Microbiological tests were carried out to determine the effectiveness of t*rans*-cinnamaldehyde as antimicrobial agent within the coating. Uncoated fresh-cut cantaloupe samples stored at 4^{o}C served as controls.

In terms of microbiological and physicochemical quality attributes, the antimicrobial coating improved the shelf-life of fresh-cut cantaloupe (up to 12 days), compared to the controls (only 6 days). The coating composed of 2% antimicrobial, 2% chitosan and 1% pectin was the most effective in terms of consumer's acceptance ($P<0.05$) and shelf-life extension. The results indicated that different ratios between solutions present a variation for each specific quality attribute. The thicker the coating, the firmer the fruit and different thicknesses resulted in different amounts of antimicrobial compound in the coating, thus critically affecting the shelf-life of the product.

This study demonstrates the feasibility of a new generation of edible coating for fresh-cut cantaloupe, the coating consists of using a system specially designed to allow the incorporation of natural antimicrobial agents by means of the application of microencapsulation and the layer-by-layer assembly.

DEDICATION

To my parents

Thank you for all your affection and support.

I wouldn’t be the person I am today if it were not for you.

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CHAPTER I

INTRODUCTION

A rapid expansion in the sale of fresh-cut fruit and vegetables has been taking place in the recent years. This is mostly due to advantages such as freshness, low caloric content, and the ability to promote fruits and vegetables as basic components of a healthy diet (Raybaudi-Massilia et al., 2007).

As consumers become aware of this importance in their eating habits and have less time for food preparation, the production of fresh-cut fruits is increasingly more relevant from the food processor's perspective (Olivas and Barbosa-Canovas, 2005).

However, as minimal processing accelerates the end of the post-cutting life of fresh produce, further studies are needed to evaluate the effect of post-cutting treatments, including modified atmosphere packaging (MAP) and chemical dips for delaying softening and browning, and retaining the nutrients of fresh-cut fruits (Gil et al., 2006).

One of the most serious food safety problems in the United States is food-borne illness of microbial origin, where each year, about thirty-three million people are infected, and around 9,000 become fatal (Castell-Perez et al., 2004). In fact, the number of documented outbreaks of human infections associated with consumption of raw and minimally processed fruit and vegetables has increased considerably during the past decades (Lanciotti et al., 2003).

This thesis follows the style of the Journal of Food Engineering.

Pathogens, when present on the surface of whole fruits or vegetables, can be transferred to the fresh-cut produce during processing (cutting, peeling, etc.). Melons, mostly cantaloupes, are one of the groups of produce that are most frequently associated with outbreaks and contamination with foodborne pathogens (USFDA, 2003). The high rates of pathogen contamination associated with melon highlight the need for effective interventions for both whole and fresh-cut melons (Fan et al., 2008).

Edible coatings are a good alternative to extend the shelf-life of fresh-cut fruits, offering a semi-permeable barrier against moisture, gases, aroma, and flavor compounds; thus maintaining the fruit's quality properties during storage (Park, 1999). In addition, edible coatings can be used as carriers of active compounds, such as antimicrobial agents, which can be used to decrease the population of spoilage and pathogenic microorganisms (Glass and Johnson, 2004).

Many essential oils are known for having natural antimicrobial activity; therefore its addition to edible coatings would be advantageous to the product. The application of these compounds is still limited due to their impact on the organoleptic properties of foods. Hence, the objectives of the current study were as follows:

1. Develop and evaluate the effectiveness of a coating process for fresh-cut cantaloupe (*Cucumis melo* L.), using pectin, calcium chloride, and chitosan in the layer-by-layer process, with *trans*-cinnamaldehyde in beta-cyclodextrin as antimicrobial agent.
2. Determine the effect of different concentrations of antimicrobial *(trans*-cinnamaldehyde) on the extension of product shelf-life.

3. Characterize the effectiveness of the optimized coating to enhance product quality attributes (moisture content, texture, acidity, pH, sugar content, weight loss, and sensory quality) and extend shelf-life.

CHAPTER II

LITERATURE REVIEW

2.1. Fresh-cut produce

2.1.1. Cantaloupe

Melon is the 4th most important fruit in the world in terms of production (18,000,000 t), after orange, banana, and grape (Aguayo et al., 2004). The most common melon varieties used fresh-cut in the United States are Cantaloupe (*Cucumis melo* L. var reticulates Naud) and Honeydew (*Cucumis melo* L. var inodorus Naud). The United States production of melon reached 1,320,850 t in 1999, the 3rd highest in the world, only preceded by China (5,806,384 t), and Turkey (1,800,000 t), (Corporacion Colombia Internacional, 2001). The average values of the major components in cantaloupe are summarized in Table 1-1.

Table 1-1. Chemical composition of cantaloupe (USDA/ARS, 2011).

Component	Average value (g/100g cantaloupe)	Range (g/100g cantaloupe)
Protein	0.84	0.48 – 1.07
Moisture	90.15	89.1 – 91.3
Fat	0.19	0.05 – 0.37
Ash	0.65	0.56 – 0.89
Carbohydrates	8.16	6.7 – 7.9

2.1.2. Minimally processed fruits

Consumption of fruits and vegetables not only increases the intake of vitamins, minerals, and dietary fiber, but it also offers other constituents, such as carotenoids and flavonoids, that may help prevent the development of degenerative diseases and lower the risk of cancer and heart disease (Grassmann et al., 2002; Gaziano et al., 1993).

Since 1995, consumer demand for minimally processed, ready-to-eat fruits and vegetables has led to growth in the fresh-cut industry of 10% per year (Barth, 2000). The term "minimally processed fruit" refers to any type of fruit that has been physically altered from its original state (trimmed, peeled, washed, and/or cut), but remains in a fresh, "unprocessed" state. Within this context, "fresh-cut fruits" are fruits that are presented to the consumer in a state that allows for direct and immediate consumption without need for previous preparation or transformation (Olivas and Barbosa-Canovas, 2005).

The overall quality and shelf-life of fruits and vegetables are reduced by several factors including water loss, browning, texture deterioration, and microbial growth, among others. In the case of fresh-cut fruits, it is well known that these events are accelerated due to lesions of tissues inflicted by peeling, slicing, and cutting (Rojas-Grau et al., 2008).

Minimal processing alters the integrity of the fruit thus increasing tissue respiration. Watada et al. (1996) reported that the respiration rate of fresh-cut fruits is higher than that of corresponding whole fruit. This increase in respiration rate leads to

biochemical deteriorations such as enzymatic browning, off-flavor development, and texture breakdown, thus decreasing the fresh-cut fruit quality (Lee et al., 2003; Oms-Oliu et al., 2007; Raybaudi-Massilia et al., 2007).

Many factors affect the intensity of the wound response in fresh-cut tissues, including the species and cultivar, maturity stage, temperature, O_2 and CO_2 concentrations, water vapor pressure, the presence of inhibitors, and the size of the cut (Brecht, 1995; Cantwell and Suslow, 2002).

The nutritional value varies greatly among commodities and cultivars of each commodity. Preparation steps involved in fresh-cut fruit production has been described to decrease its nutritional content (McCarthy et al., 1994). In addition, some nutrients can be more delicate than others, making them more vulnerable to degradation during processing. For example, vitamin C content can be substantially affected by physical damage, extended storage duration, high temperatures, low relative humidity, and chilling injury (Nunes et al., 1998; Hussein et al., 2000).

Antioxidant constituents of fresh-cut produce are susceptible to degradation when exposed to oxygen or light, to which the interior of the fruit is exposed once cut (Klein, 1987; Bode et al., 1990). Oxidation may also occur when the fruit is exposed to acidic pH or halides, such as hypochlorite used during sanitation (Wright and Kader, 1997). The interaction of these constituents with enzymes, such as ascorbate oxidase, polyphenol oxidase, cytochrome oxidase, and peroxidase could also promote fruit degradation.

Browning due to oxidation of phenols, which is often catalyzed by the polyphenol oxidase enzyme to form colored melanins, decreases the nutrient content in fruits (Vamos-Vigyazo, 1981). Wounding also promotes the production of ethylene that leads to the oxidation of fatty acids by lipoxygenase, during which carotenoids may be degraded by co-oxidation (Watada et al., 1990).

Some detrimental myths about minimal processing were cleared in the work of Gil et al. (2006). Nutritional changes observed in whole fruits (pineapples, cantaloupes and watermelons) were similar to those found on fresh-cut fruits, and light exposure during storage had no detrimental effect on the nutrient content in fresh-cut fruits. Changes in antioxidant content were observed during 9 days at 5°C; however, these changes did not significantly affect the nutrient quality of the samples. Minimal processing's only disadvantage was that it accelerates the end of the post-cutting life, as clearly described as a reduction of the produce visual quality.

2.1.3. Sensory characteristics

In essence, the appearance of fresh-cut fruits and vegetables is the attribute most immediately obvious to the consumer. Many unrelated factors influence appearance, especially the ones related to wounds and cuts, which result in an unattractive product. This particular problem brings a great deal of attention in white-flesh fruits, like apples and pears, but is also a factor in many other fresh-cut fruit and vegetable products (Toivonen and Brummell, 2008).

The appearance and texture changes are very tightly linked to tissue deterioration (Cantwell and Suslow, 2002). Some of the problems present in processed fruits occur at individual cell level, where water loss promotes the loss of turgor of cells. This conduces to mushy textures due to the presence of "deflated" cells within the structure, thus reflecting negatively on the overall texture of fruits (Garcia and Barret, 2002). Processing of fresh-cut fruits involves wounding stress due to mechanical injury when peeling or cutting, leading to an increase in the respiration rates (Watada et al., 1996).

Since consumers usually judge the quality of fresh-cut fruit on the basis of freshness and visual quality at the time of purchase (Kader, 2002), other factors besides minimal processing that affect produce's appearance should also be considered. For instance, cantaloupe (*Cucumis melo* L.) is sensitive to chilling injury. This physiological disorder appears when melons are stored at low temperature (7–10°C). Changes in membrane structure in response to chilling temperatures are considered as the primary events of chilling injury and lead to a loss of permeability and metabolic dysfunction. Secondary reactions include ethylene production, increased respiration, or accumulation of toxic compounds such as ethanol and acetaldehyde (Valdenegro et al., 2004).

Temperatures below 7–10°C are associated with the occurrence of chilling injury in whole intact melons. However, fresh-cut produce is recommended to be held at lower temperatures (4–5°C) because of a significant reduction in the respiration rate. Lower microbial population and longer shelf-life of fresh-cut produce was reported by Bai et al. (2003) when it was stored at 5°C. Because ripe cantaloupe is commonly eaten fresh, it is

difficult to keep its quality characteristics for a long period of time once it has been processed.

Texture is one of the product quality attributes that the consumer expects not to be altered by processing or storage. Texture should be quantified and measured objectively, particularly those properties related to mechanical properties. There are two factors that influence mouth feel when eating a fruit or vegetable: firmness and juiciness. Firmness is determined largely by the physical anatomy of the tissue, particularly cell size, shape and packing, cell wall thickness and strength, the extent of cell-to-cell adhesion, and turgor status. Many of these factors are inter-related, for example, tissues with small cells tend to have a greater content of cell walls, a lower relative amount of cytoplasm and vacuole, a greater area of cell-to-cell contact, and low amounts of intercellular air spaces, making the tissue firmer and apparently less juicy (Toivonen and Brummell, 2008).

Although cell wall thickness and strength are major contributors to firmness, these are characteristic of a particular species and tissue and are determined largely by genetic factors. Unlike vegetables (stems, roots/tubers, leaves), the cells of ripening fruit flesh are generally relatively weak. Also, the cell walls of fruits undergo natural degradation during ripening, when a decline in turgor takes place, thus contributing to textural changes (Shackel et al., 1991; Harker and Sutherland, 1993). The change in firmness is partly due to an accumulation of osmotic solutes in the cell wall space (Almeida and Huber, 1999), and partly to postharvest water loss from the ripening fruit (Saladie et al., 2007). The more mature the fruit, the shorter the shelf-life of the fresh-cut

commodity. Moreover, some fruits like cantaloupe will not reach the optimal sensorial attributes if the fruit is not sufficiently mature at the time of processing (Beaulieu et al., 2004).

Factors affecting texture may change substantially either during pre- or post-harvesting, due to changes in cell size, intercellular adhesion, starch/sugar conversion, water loss, cell wall composition, and cell wall strength. Perceived juiciness is also affected by the cellular makeup of a tissue, large cells having a greater relative content of cell sap and tending to split open more easily. The nature of tissue failure by biting and chewing determines juiciness, whether cell walls split open releasing juice or whether tissue splits by cell separation along the middle lamellae, with little cell rupture (Toivonen and Brummell, 2008).

2.1.4. Microbial contamination

Consumption of fresh produce has been linked to outbreaks of foodborne illness and recalls in the United States due to contamination with human pathogens. Melons, mostly cantaloupes, are one of the groups of produce that are most frequently associated with outbreaks and contamination with foodborne pathogens (USFDA, 2003). Of these produce-related outbreaks, 25% were associated with fresh-cut fruits (Smith, 2006). Between 1990 and 2000, more than 700 cases of salmonellosis were reported in the United States and Canada (USFDA 2001).

During minimal processing, spoilage and pathogenic microorganisms can be transferred to the fruit flesh, where they can grow rapidly upon exposure to nutrients (Corbo et al., 2004). As prevention of contamination is not always possible, washing and treatment with chemical disinfectants are necessary to eliminate or at least reduce the population of pathogenic and spoilage microorganisms on the surface of fresh produce (Wei et al., 1995). The efficacy of these procedures depends on the type of fruit being treated, the produce surface characteristics, the treatment conditions, and on the type of microorganism (Roller and Seedhar, 2002).

Chlorine-based washing systems have been widely used by the majority of fresh produce manufactures to reduce microbial contamination in fresh-cut fruits and vegetables (Sapers et al., 2001). However, in recent years a concern has been raised about the potentially harmful by-products of some agents, such as when sodium hypochlorite (NaOCl) is added to water and reacts with organic compounds (Villanueva et al., 2004). It is believed that these by-products increase the risk of cancer.

Silveira et al. (2008) used different sanitizers as alternatives to chlorine to treat Galia melon (*Cucumis melo* var. catalupensis). They showed that the use of peracetic acid, hydrogen peroxide (H_2O_2), and nisin + ethylene diamino tetracetic acid can substitute chlorine in sanitizing fresh-cut melon without imparting off-flavors.

2.2. Preservation techniques

Fresh-cut fruits processing techniques are still under development because of the difficulties in preserving their fresh-like quality for prolonged periods (Soliva-Fortuny and Martin-Belloso, 2003). Interest on the part of consumers and producers has encouraged researchers to determine how fruit and vegetable antioxidant constituents can be maintained after processing (Agar et al., 1999; Chantanawarangoon and Kader, 2002).

Several techniques have been employed to minimize the deleterious effects of minimal processing in fruits and vegetables, including refrigeration, controlled atmosphere packaging, use of additives, and edible coatings (King and Bolin, 1989; Wong et al., 1994).

For many years, the most effective chemical preservatives for fresh produce were sulfites since they served as both inhibitors of enzymatic browning and as antimicrobials. However, the use of sulfur dioxide (SO_2) was subject to government regulation in several countries and sodium bisulfite has been linked to adverse reactions among certain consumer populations (Sapers, 1993). Therefore, the need for safe preservatives and preservation techniques to substitute for sulfite treatments.

The inclusion of modified atmosphere packaging brought a new concept to preservation of fresh-cut produce in the food industry. Studies demonstrated that low O_2 and/or high CO_2 atmospheres reduce respiration, decrease ethylene production, and inhibit or delay enzymatic reactions. For the particular case of fresh-cut cantaloupe and

honeydew melons, a storage atmosphere of 2–5 kPa O_2 plus 10–15 kPa CO_2 at 5°C proved to maintain its quality attributes during 10 days of storage (Bai et al., 2001; Aguayo et al., 2003).

However, some of the main visual changes of deterioration in fresh-cut melon under modified atmosphere packaging are the development of translucency, surface dehydration, and off-odor (Aguayo et al., 2004; Bai et al., 2001; Oms-Oliu et al., 2006).

2.3. Edible coatings

One of the latest alternatives to reduce the deleterious effect brought by minimal processing is the application of edible coatings. Acting as a barrier to gases, they are expected to generate a sort of modified atmosphere in each coated fruit piece, and along with relative humidity and optimum refrigeration temperature, they contribute to achieve a reasonable shelf-life in fresh-cut products (Rojas-Grau et al., 2008). The semipermeable barrier provided by edible coatings is aimed to extend the shelf-life by reducing the transfer of moisture, aroma and flavor compounds, gas exchange, respiration and oxidative reaction rates, as well as suppress physiological disorders on fresh-cut fruits (Baldwin et al., 1996; Park, 1999; Wong et al., 1994).

Not all edible coatings are adequate for any given type of fruit, and even within the same type of fruit, some edible coatings may sometimes work well in one variety and not in another. Hence, careful studies need to be conducted to determine what components are required to formulate edible coatings for specific products. In addition,

there are some requirements that must be fulfilled for the coating to be effective, including stable under high relative humidity, efficient barrier against water vapor, oxygen, and carbon dioxide, good mechanical properties, adhesion to the fruit, colorless and tasteless, physico-chemical and microbiologically stable, GRAS (generally recognized as safe), and reasonable cost (Olivas and Barbosa-Canovas 2005).

The elaboration of edible films and coatings has been possible thanks to the filmogenic capacity of natural biopolymers (Campos et al., 2011). Hydrocolloids have good aptitude to form a continuous and cohesive matrix with adequate mechanical properties (Bourtoom 2008). Such ability is related to the chemical structure of these compounds, which allows the association through hydrogen bonding of their polymeric chains.

Table 1-2 shows the most common hydrocolloids used in the manufacture of edible coatings in the last decade, presenting the main benefits and disadvantages of their use, as well as some improvements developed from previous research work.

Casting is the most common technique reported in articles to produce edible films. First, the material must be dispersed in a solvent aqueous solution, in some cases heating or stirring is required to dissolve the macromolecule (Campos et al., 2011). The addition of plasticizers to the solution provides the film with good mechanical behavior in terms of flexibility, being the most common one glycerol, because of its stability and compatibility with hydrophilic biopolymeric chains in comparison to other compounds (Fernandez-Cervera et al. 2004). Once the hydrocolloid is dispersed, other functional

ingredients, such as antimicrobials, antioxidants, flavorings, and colorants, might be added to the solution to provide the desired properties to the film.

One problem encountered in the application of edible coatings to minimally processed fruits is the adhesion of the coating material to the product; this disadvantage is due to the hydrophilic nature of the fruit's surface. A solution to this problem could be the layer-by-layer (LbL) electrodeposition technique since it can be applied on hydrogel surfaces (Ariga et al., 2010). This procedure can yield coatings with precisely controlled thickness, properties, and performance around materials such as bacterial cells, fruits, and vegetables (Caruso and Mohwald, 1999).

In this technique the material is dipped into a series of different solutions that contain oppositely charged polyelectrolytes. Between each dipping step, a washing/drying stage is necessary to remove the excess of coating material from the product's surface prior introducing it into the next dipping solution (McClements et al., 2009).

2.3.1. Texture enhancers

Processing may result in a dramatic loss of firmness in fruit tissues due to the action of pectic enzymes (Toivonen and Brummell, 2008). For this reason, texture enhancers are commonly added to edible coatings to minimize softening during storage (Rojas-Grau et al., 2008). One of the most common ones is calcium (chloride, phosphate, citric, lactate) which reduces water migration and strengthens the fruit's

Table 1-2. Hydrocolloids used in edible films elaboration. Adapted from Campos et al., (2011)	
Polysaccharides ▪ Render transparent and homogeneous edible films with moderate mechanical properties. ▪ Limited application due to their water solubility and poor water vapor permeability, which can be solved by blending with different biopolymers.	**Cellulose and derivatives** ▪ Cellulose is the structural material of plant cell walls. ▪ Cellulose derivatives films are tough, flexible, totally transparent, highly sensible to water, and resistant to fats and oils. ▪ Crosslinking treatments are commonly used to decrease its water solubility.
Seaweed extracts ▪ Alginates (brown seaweed extracts) form strong and quite brittle films with poor water resistance. Have a unique ability to react irreversibly with calcium ions to produce water insoluble polymers. ▪ Among carrageenans (red seaweed extracts), the κ-Carrageenan is the one with less negative charges per disaccharide having excellent properties to form gel and films. In comparison to λ- and ι-carrageenan, κ-carrageenan films exhibit the highest tensile strength.	**Chitosan** ▪ Major component of the shell of crustaceans such as crab, shrimp, and crawfish. High molecular weight polysaccharide that exhibits antibacterial and antifungal activity as well as film-forming properties ▪ High water vapor permeability limits their application. ▪ Its combination with fatty acids leads to a significant decrease in the tensile strength, elongation at break, and elastic modulus of the composite films.
Starches and derivatives ▪ One of its components, amylose, has excellent film-forming ability rendering strong, isotropic, odorless, tasteless, and colorless films. ▪ Film mechanical behavior could be affected by the tendency of starch systems to retrogradate, when amylose and amylopectin form a physically cross-linked network and starches-based materials become more rigid.	**Pectins** ▪ Polymers that occur widely in land plants. ▪ According to their content of methyl esters or degree of esterification (DE), they are divided into high-methoxyl and low-methoxyl. The DE has a decisive effect on pectin solubility and gelation properties. ▪ Films slow the respiration rate in fruits, but become stiff and not much flexible as pectin amount is increased.
Blends ▪ Edible films and coatings may consist of a blend of polysaccharides, protein, and/or lipids. ▪ Manufacture of biopolymer-blend films improves the permeability and mechanical properties of regular films. ▪ Polymers' association can be achieved through blending, extruding, laminating, or coating with other polymers with desirable properties.	**Gums** ▪ Exudate gums (arabic, tragacanth, karaya), seed gums (locust bean, guar), and microbial fermentation gums (xanthan, gellan). ▪ Used as coating material or as an edible film component in combination with starches. ▪ Its application as coating can be used to incorporate natural preservatives to reduce post contamination.
Proteins ▪ Its ability to form films and coatings depends on their molecular weight, conformation, electrical properties, flexibilities, and thermal stabilities. ▪ Protein-based films have better gas barrier and mechanical properties than those from polysaccharides and fat-based films, due to proteins' structure which confers it a high intermolecular binding potential. ▪ Poor water vapor resistance limits their application, but it can be improved by modifying protein's properties by chemical, physical and enzymatic methods; or by combination with hydrophobic materials or polymers. ▪ Milk proteins can provide a high nutritional added value and good taste in addition to their barrier and filmogenic properties.	

tissue by cross linking pectins in the cell wall and middle lamella, thus reinforcing cohesion among cells (Ponting et al., 1972; Rocha et al., 1998; Sams, 1999). Pre- and postharvest calcium solutions applications have been used to extend postharvest shelf-life of fruits and vegetables (Poovaiah et al., 1988). The main purpose of these texture enhancers is to improvee fruit quality during storage by inhibiting the loss of firmness of minimally processed fruits (Lee et al., 2003).

Calcium chloride has demonstrated to be the best alternative as texture enhancer among other calcium compounds; this is due to its ability to prevent softening without affecting the fruit's sensory properties. In a comparison study developed by Aguayo et al. (2007), fresh-cut 'Amarillo' melon was dipped in different calcium salts (carbonate, chloride, propionate, and lactate) at 0.5% for 1min at 60°C for 8 days. Calcium carbonate showed low solubility, little diffusion through melon tissue, which was later correlated to firmness loss. Calcium chloride, propionate, and lactate decreased the rate of softening; however calcium lactate and propionate provided a slight off-flavor and a whitish color to the fruit's flesh.

Temperature may also play an important role in calcium solutions, Lamikanra and Watson (2004) compared the effect of low-temperature and ambient treatments in fresh-cut cantaloupe. Low-temperature calcium treatment showed a reduction in the fruit's respiration rate, apparently related to the covalent crosslinking properties of calcium as indicated by the increased viscosity at 4°C, in comparison to the one at ambient temperature. In addition, the low-temperature treatment also improved ability of

calcium to reduce moisture loss during storage, while the temperature did not seem to affect the esterase activity, the lipase activity was inhibited.

2.3.2. Gelling agents

Polysaccharides like alginate and pectin are commonly used as gelling agents in the food industry. They also represent a potential coating component because of their unique colloidal properties, mostly due to their ability to form strong gels and insoluble polymers in presence of calcium (Mancini and McHugh, 2000; Rhim, 2004). The gelling mechanism involves interactions between calcium ions and carboxylic groups, forming a three-dimensional cross-linked network.

Chitosan is a unique polysaccharide, a modified carbohydrate polymer derived by deacetylation of chitin, a major component of the shells of crustaceans such as crab, shrimp, and crawfish (Baofeng et al., 2010). The antimicrobial activity of chitosan against a wide range of foodborne filamentous fungi, yeast, and bacteria has made it a potential food preservative. Due to its unique physicochemical properties, it has been successfully used as food wraps and so maintains the quality of postharvest fruits and vegetables (Devlieghere et al., 2004).

Chitosan has been approved as a food additive in Japan and Korea since 1983 and 1995, respectively. In the United States, chitosan as a food additive is expected to be in more demand upon receiving the US FDA approval for GRAS status (No et al., 2007).

Chitosan also possesses film-forming and barrier properties, thus making it a potential raw material for edible films (Balau et al., 2004). Therefore, the combination of its inherent antibacterial/antifungal properties and film forming ability make it ideal for use as biodegradable antimicrobial packaging material to improve the storability of perishable foods.

Even though polysaccharides do not act as strong moisture barriers because of their hydrophilic nature, they do behave as a good oxygen barrier due to their tight ordered network structure (Yang & Paulson, 2000). Edible coatings with pectin and alginate improved some of the quality attributes of fresh-cut 'Piel de Sapo' melon (Oms-Oliu et al., 2008). The coated fruit had increased the water vapor resistance in comparison with uncoated fresh-cut melon, less desiccation, and the coating maintained fruit firmness throughout storage at 4°C for 15 days. On the other hand, polysaccharide coatings did not provide sufficient barrier to gas diffusion and did not reduce microbiological growth.

Plasticizers like glycerol are often added to increase coating flexibility by reducing the internal hydrogen bonds between polymers chains and increasing intermolecular spacing. It generally increases 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.

2.4. Antimicrobial agents

The physical and chemical barrier provided by the epidermis, which prevents the development of microbes on the fruit surface, is removed during processing (Martin-Belloso et al., 2006). Therefore, the protective layer provided by the coating has to replace this property.

Edible coatings have a high potential to carry active ingredients such as anti-browning agents, colorants, flavors, and nutrients. Their functionality can be expanded by incorporating antimicrobial compounds that can extend product shelf-life and reduce the risk of pathogen growth on food surfaces (Pranoto et al., 2005). Direct surface application of antibacterial substances onto food by dipping, dusting, or spraying has limited benefits, because the active substances are neutralized on contact or diffuse rapidly from the surface into the product. Application of edible films and coatings containing antimicrobial agents has advantages over the direct application of antibacterial agents onto food, because edible films and coatings can be designed to slow antimicrobial diffusion from the surface of food (Dawson et al., 2002; Sebti et al., 2002). Therefore, smaller amounts of antimicrobials would be needed in edible films and coatings to achieve a target shelf life, compared with direct application of antimicrobial agents on the surface of food (Seacheol and Krochta, 2005).

These antimicrobial treatments can affect the sensory properties of fresh-cut fruits. For a commercial application, the antimicrobial treatments should impart no undesirable sensory attributes to the products. Food industries use organic acids as acidulants, flavor enhancers, and preservatives. Organic acids with antimicrobial activity

are therefore a better choice for improving the microbial safety of fruits (Eswarandam et al., 2006).

2.5. Essential oils

Essential oils, also called volatile or ethereal oils, are aromatic oily liquids obtained from plant material like flowers, seeds, leaves, herbs, wood, fruits, and roots. They can be obtained by expression, fermentation, enfleurage, or extraction. The method of steam distillation is most commonly used for commercial production of essential oils (Van de Braak and Leijten, 1999). The recent interest in alternative naturally derived antimicrobials has led to renewed scientific interest in these substances (Gutierrez et al., 2008).

Edible films and coatings are usually consumed with the coated products; that is why the addition of compounds such as antimicrobials, antioxidants, and nutraceuticals should not affect consumer acceptance (Nazer et al., 2005). During the incorporation of antimicrobial agents into edible coatings it is important to consider that they could impart undesirable sensorial modifications in foods or exceed acceptable flavor thresholds, especially when essential oils are used (Burt, 2004).

Foods generally associated with herbs, spices, or seasonings would be the least affected by this phenomenon. For instance, the use of thyme and oregano essential oils in meat and cod fillets at 0.8% v/w, imparted a herbal odor which, was found to be

acceptable and decreased gradually during storage (Tsigarida et al., 2000; Mejlholm and Dalgaard, 2002).

In general, the efficacy of many added and naturally occurring antimicrobials may be reduced by certain food components (Glass and Johnson, 2004). The greater availability of nutrients in foods compared to laboratory media may enable bacteria to repair damaged cells faster (Gill et al., 2002). It is also believed that high levels of fat and/or protein in foodstuffs protect bacteria from the action of essential oils (Pandit and Shelef, 1994; Tassou et al., 1995), while carbohydrates do not appear to affect bacteria at all (Shelef et al., 1984).

Essential oils of clove, cinnamon, bay, and thyme were tested against *Listeria monocytogenes* and *Salmonella enteritidis* in soft cheese diluted 1:10 in buffer solution. *Salmonella enteritidis* was less easily inhibited in diluted full-fat cheese than in the low-fat version, indicating the protective action of fat. In addition, the level of fat in the cheese protected the bacterial cells depending on which essential oil was used. Clove oil was more effective against *S. enteritidis* in full-fat than in lowfat cheese slurry (Smith-Palmer et al., 2001).

2.5.1. Cinnamaldehyde

Cinnamaldehyde (cinnamic aldehyde or 3-phenyl-2-propenal) is the main component in cassia oil and cinnamon bark oil, and it has also been shown to be the major antimicrobial compound in cinnamon (Gomes et al., 2011). It is considered GRAS

for food use (Code of Federal Regulation 2009), and even though it is known to be inhibitive to growth of *Escherichia coli* O157:H7, *Salmonella typhimurium* (Helander et al., 1998), mold and mycotoxin production (Beuchat, 1994), its use is often limited due to flavor considerations (Gomes et al., 2011).

Roller and Seedhar (2002) observed that the use of carvacrol and cinnamaldehyde were very effective at reducing the viable count of the natural flora on kiwi fruit, but less effective on honeydew melon, probably due to the difference in pH between fruits. The lower the pH in the fruit the more effective the essential oil becomes.

Min and Krochta (2005) indicated that the application of antimicrobial agents directly on the food surface may have limited benefits because the active substances could be neutralized in direct contact with the product.

The application of essential oils in foods is limited due to their impact on organoleptic food properties, variability of their composition, and their variable activity in foods due to interactions with food components (Gutierrez et al., 2008). Therefore, many factors must be considered in developing an antimicrobial edible coating, including the properties of the food, the type of coating, and the effectiveness of the antimicrobial agent.

CHAPTER III

MATERIALS AND METHODS

3.1. Raw material

Cantaloupes (*Cucumis melo* L.) were purchased at a local market (College Station, Texas) and stored in a refrigerator at 10°C and 95% relative humidity until testing. Total soluble solids (°Brix) were used as an indicator of ripeness in the fruit. Size uniformity and peel coloration was carefully selected before purchase. Fruits were also selected based on size and peel coloration.

3.2. Sample preparation

Cantaloupes were sanitized by immersion in chlorine solution (300 ppm); then rinsed with distilled water, and finally dried with paper towels. The fruits were then cut into 3-cm width slices with a knife, seeds removed, and then cut into cylinders (2.22-cm diameter) using a cylindrical cutter. The length of the cylinders was adjusted to 2.54-cm using a small knife and measured with a ruler. Soluble solids (°Brix) were read at this stage to determine the degree of fruit ripeness. Cantaloupes with ca. 10°Brix were considered at commercial ripeness. All utensils used during cutting and handling were also sanitized.

3.3. Solutions and antimicrobial compound preparation

3.3.1. Antimicrobial compound

The inclusion complex of *trans*-cinnamaldehyde (99+%, Sigma-Aldrich, St. Louis, MO) in beta-cyclodextrin (hydrate, Alfa Aesar Johnson Matthey, Lancashire, UK) was prepared by freeze-drying. About 2.11g of *trans*-cinnamaldehyde and 18.16g of beta-cyclodextrin were dispersed in one liter of distilled water and mixed in a laboratory stirrer for 24 hours at room temperature (23^{o}C). The suspension was filtered through a 0.45 μm nylon filter (VWR vacuum filtration systems, VWR international, West Chester, PA, USA), and the filtrate frozen at –18^{o}C and freeze-dried at -50^{o}C under 5 mtorr (9.67 x 10^{-5} psi) vacuum for 48 hours in a Labconco Freeze Dry-5 unit (Labconco, Kansas City, MO, USA). The lyophilized compound (about 17.5g) was stored in a desiccator placed inside a freezer (-20^{o}C) until further use.

3.3.2. Calcium chloride solution

Calcium chloride, $CaCl_2$, (food grade, Mallinckrodt Baker Inc., Phillipsburg, NJ) at 2% (w/w) was dissolved in sterile distilled water at room temperature.

3.3.3. Pectin solution

The solution was elaborated by adding pectin (citrus USP, Spectrum Chemical Mfg. Corp., Gardena, CA) at 0.5, 1 and 2% (w/w) in sterile distilled water previously heated at 45°C on a stirring hot plate until pectin was completely dissolved.

3.3.4. Chitosan and antimicrobial solution

Tween 20 (molecular biology grade, VWR International, West Chester, PA, USA) at 0.5% w/w, glycerin (USP multi-compendial, Mallinckrodt Baker Inc., Phillipsburg, NJ, USA) at 2% w/w and acetic acid (Glacial, Mallinckrodt Baker Inc., Paris, KY, USA) at 1% w/w was weighted and dissolved in distilled water at room temperature. Upon that, chitosan (medium molecular weight, Sigma-Aldrich, St. Louis, MO, USA) was added to the solution in three different concentrations (0.5%, 1%, and 2% w/w) while heating on a stirring hot plate at 45°C until total dissolution of the components. The antimicrobial agent (1, 2, and 3% w/w) was then added to the solution while it continued to be stirred at 45°C until pectin was completely dissolved.

3.4. Coating procedure

A four-step procedure (layer-by-layer) was developed to ensure the proper coating of the fruit pieces. The samples were dipped into each coating solution for two minutes and then the excess of coating material was allowed to drip off for 2 minutes before submerging the samples into the next solution. The order of the coating procedure was as follows: calcium chloride solution, chitosan + antimicrobial solution, pectin solution, and finally, a second dipping onto calcium chloride solution. A diagram of the coating procedure is represented in Figure 3-1.

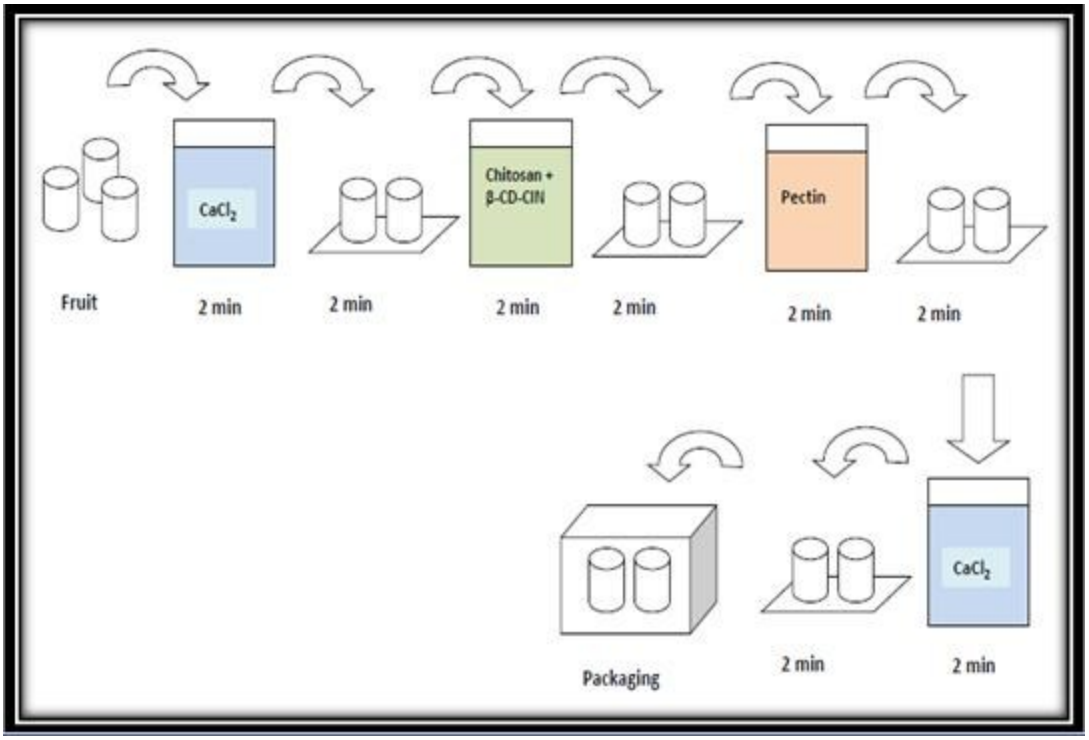


Figure 3-1. Coating procedure set-up. Adapted from Gomes (2010).

Control samples were only dipped into sterile distilled water for 2 minutes and then allowed to drip off for 2 more minutes before further analysis.

3.5. Samples packaging

Sixteen coated cylindrical samples were placed into Ziploc® containers (591 ml capacity) with lid, and stored at 4°C for 15 days (Figure 3-2). The same amount of uncoated controls were packed and stored in similar conditions.

Figure 3-2. Samples packed in Ziploc® containers for shelf-life study (4°C, 15 days).

3.6. Experimental design

Three different sets of experiments were designed to test the effect of different concentrations of the three main components in the coating - pectin (w/w), chitosan (w/w), and encapsulated *trans*-cynnamaldehyde (w/w) on the quality of fresh-cut cantaloupe. The whole experimental design had 3 factors at 3 levels and was set one factor at a time. The actual design and levels for the factors are shown in Table 3-1.

Table. 3-1. Experimental design for each set of experiments.

Set #	Experiment #	Factor 1 Chitosan (w/w)	Factor 2 Antimicrobial (w/w)	Factor 3 Pectin (w/w)
1	1	0.5%	2.0%	2.0%
	2	1.0%	2.0%	2.0%
	3	2.0%	2.0%	2.0%
	4	1.0%	0%	2.0%
2	5	0.5%	2.0%	0.5%
	6	0.5%	2.0%	1.0%
	7	0.5%	2.0%	2.0%
3	8	2.0%	0%	1.0%
	9	2.0%	1.0%	1.0%
	10	2.0%	2.0%	1.0%
	11	2.0%	3.0%	1.0%

All sets of experiments were conducted at Factor 4 – level 1 (Calcium chloride at 2% w/w).

3.7. Product quality attributes

3.7.1. Moisture content

Moisture content was determined by weight loss after drying the samples in a vacuum oven at 35°C for 10 hours (AOAC, 1990). Each sample's weight (approximately 10g) was recorded before and after drying. The samples were first chopped into cubes (0.5-cm per side) and placed in aluminum canisters prior to the drying process (Fig. 3-3). The weight of canisters was also recorded for more accurate measurements. After removing the samples from the vacuum oven the samples were placed in a dessicator to

cool down before recording the final weight. The test was performed in triplicate, and the moisture content, *MC*, in wet basis (w.b.) was calculated as follows:

$$MC(w.b.) = \frac{(M_{wet} - M_{dry})}{M_{wet}} \quad [3\text{-}1]$$

where M_{wet} (g) is weight of the wet sample and M_{dry} (g) is weight of the dry sample.

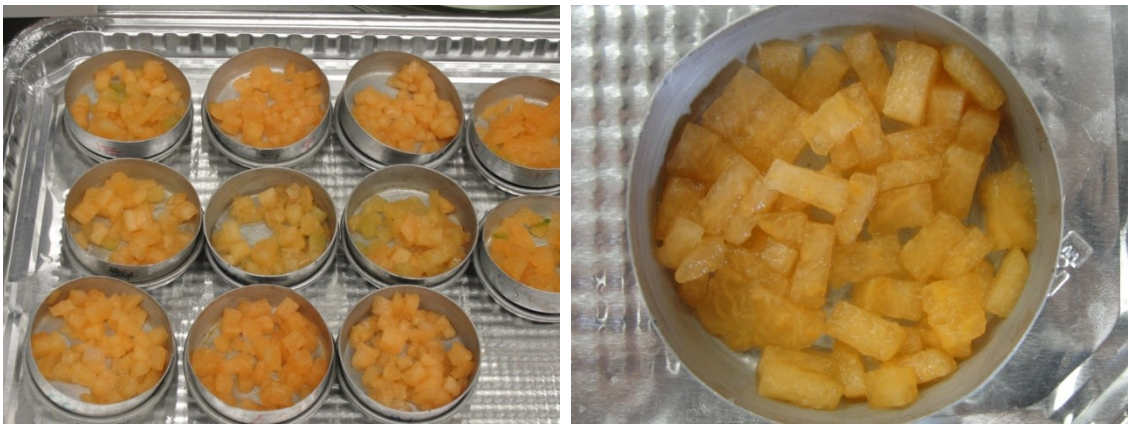


Figure 3-3. Chopped samples placed in aluminum canisters.

3.7.2. Color

Color of coated cantaloupe samples and controls was analyzed using a Labscan XE colorimeter (HunterLab, Inc., Reston, VA, USA) with the universal v.3.73 software and calibrated with a standard tile (*Y*=94.00, *x*=0.3578, *y*=0.4567). The sample was cut in half to fit in the aperture of the colorimeter (36 mm diameter), the surface side of the cylinder always facing the base. Readings of *L** (lightness), *a**(green chromaticity), and *b** (yellow chromaticity) from five samples were recorded for each of the three experiments (Table 3-1).

3.7.3. pH determination

The pH of cantaloupe flesh was measured using a digital pH meter (Cole Parmer, Ph 500 series, Model #59003-20, Singapore) previously calibrated with standard solutions, pH 4, 7, and 10. The juice of three cantaloupe cylinders (10 ml) was squeezed to avoid any solids in the sample, and a glass electrode was immersed to record the reading. The experiment was carried out at room temperature and in triplicate for each of the three experiments (Table 3-1).

3.7.4. Sugar content

A few drops from the juice utilized to measure the pH were used to calculate the soluble solids concentration of coated and uncoated cantaloupe samples, using a refractometer (ABBE ATAGO model 3T, Bellevue) and expressed in °Brix scale. The soluble solids content was determined by correlating the refraction angles and refractive index value established by the refractometer. The total concentration of five samples for each experimental design was recorded at room temperature.

3.7.5. Titratable acidity

Titratable acidity of all samples was measured following AOAC methods (AOAC, 1990) using 10g of cantaloupe juice. All tests were performed in triplicate.

3.7.6. Juice leakage (weight loss)

The percentage of juice leakage was determined by measuring the weight loss of five samples throughout the shelf-life study (three replications were carried out per experimental design). The weight of the five samples from each container was recorded initially and on the day of reading using a digital balance. The test was carried on the days 1, 4, 6, 10, and 15 of storage. Because of the risk of cross-contamination, a set of samples was prepared for every evaluation day, followed by the disposal of the samples. The percentage of juice leakage was calculated as follows:

$$\%\, Juice\ of\ fruit = \frac{(initial\ sample\ weight) - (final\ sample\ weight)}{(initial\ sample\ weight)} \quad [3\text{-}2]$$

3.7.7. Sensory evaluation

Sensory evaluation of cantaloupe samples was performed with a 35-member consumer panel (faculty, students, and staff) at Texas A&M University. Panelists were asked to evaluate five quality attributes (color, odor, texture, flavor, and overall quality) for the days 1, 5, 9, 12, and 15 of storage.

The samples were placed in plastic cups, coded with three random digits, and presented to each panelist at once. Panelists scored the samples using a nine-hedonic scale (Carr et al., 1999), where a score of 1 represents attributes most disliked and a score of 9 represents attributes most liked. Scores higher or equal to 5 were considered acceptable.

3.7.8. Microbiological analysis

Total aerobic plates, psychrotrophic, yeast, and molds counts were determined on days 1, 5, 9, 12, and 15 of storage in triplicate. Three cantaloupe pieces (ca. 30 grams) from each experimental condition were stomached inside a sterile stomacher bag. A 10 g aliquot of the blended material was transferred to another stomacher bag and mixed with 90 ml phosphate buffer and homogenized for 1 min, subsequently, a 10-fold dilutions were also made in this diluent. All counts were performed using petrifilms (3M aerobic plate count and 3M yeast and mold count plates, 3M microbiology, St. Paul, MN). All inoculated 3M aerobic plate count plates (APC) were incubated at 37^{o}C for 48 hours; for the psychrotrophic count the APC plates were incubated at 4^{o}C for 7 days, and all 3M yeast and mold count plates were incubated at 20^{o}C for 7 days at room temperature. After incubation, colonies were enumerated and results reported as logCFU/g of sample. The experiment was carried out in triplicate for each experimental condition.

3.7.9. Fruit firmness

Firmness of samples was evaluated using a Brookfield CT3 (Brookfield Engineering Laboratories, Middleboro, MA, USA); mounted with a cylindrical probe (TA4/100, 38.1 mm diameter) and a support with a flat base of 14x12.7 cm. A compression test (Fig. 3-4) was developed to measure the force (N) required to compress the sample in 50%. The test speed was set to 0.5 mm/s. Peak (maximum force) and work values (area under the curve) were determined from a force (N) vs. distance (mm) plot.

Seven replications were conducted for each experimental design. Tests were conducted at room temperature.

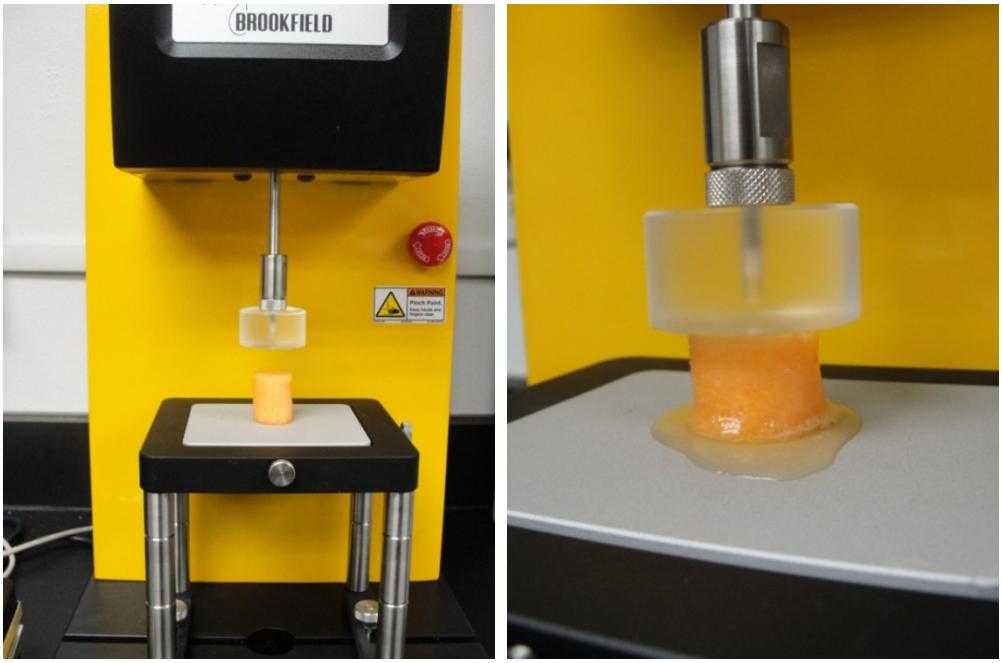


Figure 3-4. Brookfield CT3 with sample under compression test.

3.8. Coating microscopic examination

Microscopic observations were performed to compare coating's uniformity with different chitosan and pectin concentrations. The thickness of the edible film was measured based on the fluorescence properties of the fluorescein isothiocyanate isomer (Alfa Aesar Co., Heysham, Lancaster, UK) molecular dye, which produces natural fluorescence of the sample once lit at the excitation wavelength of fluorescein (494-nm). The film's thickness was examined and imaged using a Confocal Laser Scanning Microscope (CLSM, Leica TCS SP5**,** Leica Microsystems, Germany) available in the

Material and Characterization Facility at the Chemical Engineering Department of Texas A&M University. Fluorescein was added to the pectin solution at a 3 μM concentration during the coating process. Once the samples were coated, they were stored for one day at 4°C. Small pieces of the surface were excised with a cork borer (# 7 and 4 mm diameter) and was transversal cut using a stainless steel blade. Samples surfaces were inverted, placed in cover slip and then exited and evaluated in a sequential set mode with a 488-nm and 543-nm wavelength of Argon and Helium-Neon laser, respectively. Emission light (521-nm for fluorescein) from sample surfaces was collected with a small working distance (1.55 x 1.55 mm^2) with 10× magnification lens (numerical aperture = 0.3). The image layers were scanned from top to bottom and the observation planes was set in system optimized mode given 2.383 μm of distance between adjacent planes. Gain and acquire levels were adjusted through digital control to obtain optimum visualization of the film surface and one 512 × 512 pixel frame was taken at a scan speed of 400Hz. This procedure was performed by Mr. Alex F. Puerta-Gomez (2010). Research Assistant at the Biological and Agricultural Engineering Department in Texas A&M University.

3.9. Statistical analysis

Experiments were conducted at least in triplicate for each experimental design. Data analysis was performed using SPSS software (version 17.0 for Windows, 2008). Cantaloupe properties as well as differences among experiments were evaluated. Differences between variables were tested for significance by one-way ANOVA using Duncan's multiple range tests. Statistical significance was expressed at the $P<0.05$ level.

CHAPTER IV

RESULTS AND DISCUSSION

4.1. Effect of chitosan concentration on cantaloupe chemical properties

The effect of three different chitosan concentrations (0.5, 1, and 2%) in the chemical properties of coated cantaloupe samples (2% pectin, 2% antimicrobial) was evaluated. In addition, a treatment using 1% chitosan concentration without the antimicrobial was also used to test the impact of encapsulated cinnamaldehyde on the chemical properties (pH, moisture content, degree brix, and acidity), quality attributes (color and texture), and sensory attributes (flavor, odor, color and texture). Uncoated samples served as control.

4.1.1. Moisture content

Moisture content ranged between 0.90 and 0.92% (w.b.) with the coated samples having the highest values (Figure 4-1); however this difference was not significant ($P<0.05$). This small increase is probably due to the high moisture content present in the coating. Similarly, no significant differences ($P<0.05$) were observed among coated and uncoated samples through storage.

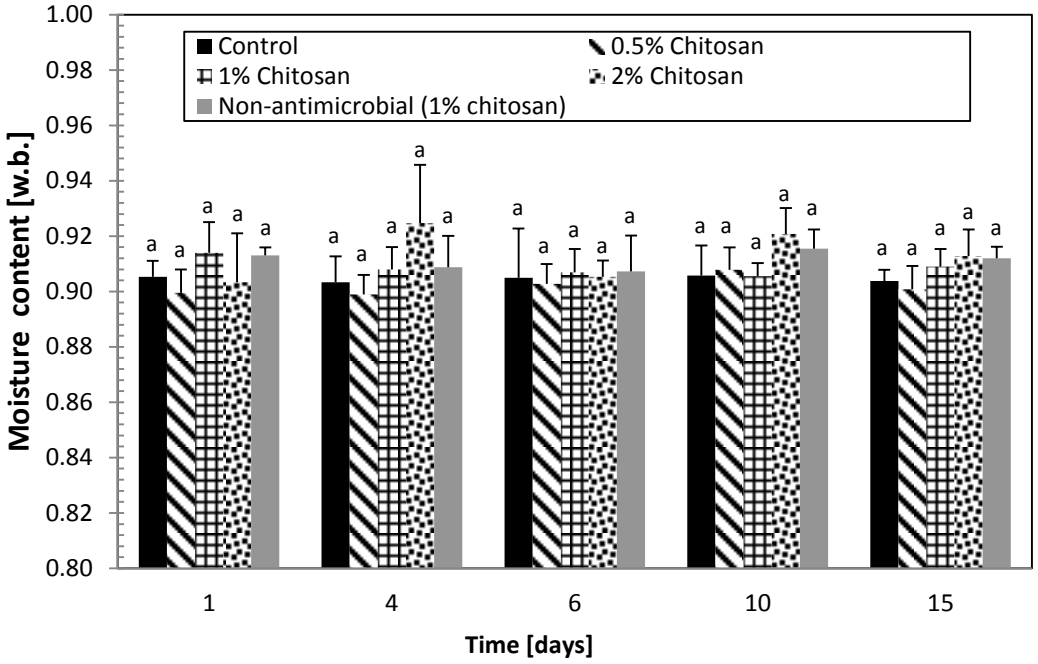


Figure 4-1. Moisture content (MC) of control (uncoated) and coated (2% antimicrobial, 2% pectin) cantaloupe samples with different chitosan concentrations stored at 4^{o}C during 15 days.

4.1.2. pH

All the samples, including the control, showed a slight decreasing trend of pH through time, as it is seen in day 15 (Table 4-1). However, there were no significant ($P<0.05$) differences among samples. The approximate pH of cantaloupe has been reported as 6.0 to 8.0 (USDA, 2007).

4.1.3. Degree Brix

All samples had total soluble solids (^{o}Brix) values between 9 and 10. No significant ($P<0.05$) differences were found among the coated and uncoated samples (Table 4-2). Thus concentration of chitosan did not affect the content of total soluble solids.

4.1.4. Acidity

Total titratable acidity (TTA) values varied slightly among all samples through time, and by the end of the day 15 all samples, including the control, had higher values (0.12 – 0.19 g citric acid/100ml) (Table 4-3). In addition, all coated samples had significantly higher TTA values than the controls for each storage interval. Higher TTA values are preferred during storage because they correlate with low pH values, thereby preventing the early growth of microorganisms in fresh-cut fruits.

Table 4-1. pH values of control (uncoated) and coated (2% antimicrobial, 2% pectin) fresh-cut cantaloupe with different chitosan concentrations during storage.

	pH				
Time (days)	**Control**	**0.5% Chitosan**	**1.0% Chitosan**	**2.0% Chitosan**	**Non-antimicrobial (1.0% chitosan)**
1	$_{w}$ 5.52 $^{a, b}$ [1] (0.07)	$_{w}$ 5.62 ^{a} (0.10)	$_{w}$ 5.67 $^{a, b}$ (0.08)	$_{w}$ 5.40 $^{a, b}$ (0.02)	$_{w}$ 5.51 $^{b, c}$ (0.13)
4	$_{w}$ 5.72 ^{b} (0.05)	$_{w}$ 5.80 $^{a, b}$ (0.08)	$_{w}$ 5.66 $^{a, b}$ (0.07)	$_{w}$ 5.62 ^{b} (0.08)	$_{w}$ 5.76 $^{c, d}$ (0.11)
6	$_{w}$ 5.43 ^{a} (0.08)	$_{w}$ 5.59 ^{a} (0.10)	$_{w}$ 5.60 $^{a, b}$ (0.02)	$_{w}$ 5.48 $^{a, b}$ (0.06)	$_{w}$ 5.65 $^{b, c}$ (0.09)
10	$_{w, x}$ 5.63 ^{b} (0.13)	$_{x}$ 5.72 $^{a, b}$ (0.11)	$_{w, x}$ 5.43 $^{a, b}$ (0.09)	$_{w, x}$ 5.44 $^{a, b}$ (0.04)	$_{w}$ 5.30 $^{a, b}$ (0.03)
15	$_{w}$ 5.25 ^{a} (0.13)	$_{x}$ 5.50 ^{a} (0.03)	$_{w}$ 5.22 ^{a} (0.05)	$_{w}$ 5.18 ^{a} (0.01)	$_{w}$ 5.06 ^{d} (0.08)

[1]Standard deviation

^{a,b}Means within a column which are not followed by a common superscript letter are significantly different ($P < 0.05$).

$_{w,x}$Means within a row, which are not followed by a common superscript letter, are significantly different ($P < 0.05$).

Table 4-2. Total soluble solids values of control (uncoated) and coated (2% antimicrobial, 2% pectin) fresh-cut cantaloupe with different chitosan concentrations during storage.

	Total Soluble Solids [^{o}Brix]				
Time (days)	**Control**	**0.5% Chitosan**	**1.0% Chitosan**	**2.0% Chitosan**	**Non-antimicrobial (1.0% chitosan)**
1	$_{w}$ 9.07 ^{a} [1] (1.01)	$_{x}$ 9.60 ^{a} (0.53)	$_{x}$ 9.80 ^{b} (0.92)	$_{w}$ 8.93 ^{a} (0.31)	$_{w}$ 8.53 ^{a} (0.46)
4	$_{w, x}$ 9.67 $^{a, b}$ (0.31)	$_{x}$ 10.00 ^{a} (0.35)	$_{x}$ 10.00 ^{b} (0.02)	$_{x}$ 9.93 ^{b} (0.12)	$_{w}$ 9.40 $^{b, c}$ (0.20)
6	$_{x}$ 9.93 ^{b} (0.99)	$_{w, x}$ 9.60 ^{a} (0.12)	$_{w}$ 9.07 ^{a} (0.13)	$_{w}$ 9.53 $^{a, b}$ (0.64)	$_{w, x}$ 9.67 ^{c} (0.31)
10	$_{x}$ 9.47 $^{a, b}$ (0.50)	$_{x}$ 9.60 ^{a} (0.40)	$_{x}$ 9.53 $^{a, b}$ (0.42)	$_{w, x}$ 9.33 ^{a} (0.42)	$_{w}$ 8.80 $^{a, b}$ (0.35)
15	$_{x}$ 9.83 ^{b} (0.29)	$_{x}$ 9.80 ^{a} (0.59)	$_{w, x}$ 9.47 $^{a, b}$ (0.31)	$_{w}$ 9.27 ^{a} (0.23)	$_{w, x}$ 9.40 $^{b, c}$ (0.53)

[1]Standard deviation

[a,b]Means within a column which are not followed by a common superscript letter are significantly different ($P < 0.05$).

[w,x]Means within a row, which are not followed by a common superscript letter, are significantly different ($P < 0.05$).

Table 4-3. Total titratable acidity values of control (uncoated) and coated (2% antimicrobial, 2% pectin) fresh-cut cantaloupe with different chitosan concentrations during storage.

	Total Titratable Acidity (g citric acid/100 ml)				
Time (days)	**Control**	**0.5% Chitosan**	**1.0% Chitosan**	**2.0% Chitosan**	**Non-antimicrobial (1.0% chitosan)**
1	$_{w}$ 0.05 ^{a} [1] (0.02)	$_{w}$ 0.09 ^{a} (0.03)	$_{w}$ 0.11 ^{a} (0.02)	$_{w}$ 0.10 ^{a} (0.01)	$_{w}$ 0.10 ^{a} (0.04)
4	$_{w}$ 0.08 $^{a, b}$ (0.02)	$_{w}$ 0.08 ^{a} (0.01)	$_{w}$ 0.09 ^{a} (0.02)	$_{w}$ 0.08 ^{a} (0.03)	$_{w}$ 0.08 ^{a} (0.03)
6	$_{w}$ 0.07 $^{a, b}$ (0.01)	$_{w}$ 0.08 ^{a} (0.01)	$_{w}$ 0.08 ^{a} (0.02)	$_{w}$ 0.08 ^{a} (0.01)	$_{w}$ 0.08 ^{a} (0.02)
10	$_{w}$ 0.11 ^{b} (0.01)	$_{w}$ 0.12 ^{a} (0.03)	$_{w}$ 0.17 ^{a} (0.02)	$_{w}$ 0.12 ^{a} (0.01)	$_{w}$ 0.18 ^{a} (0.04)
15	$_{w}$ 0.12 ^{b} (0.03)	$_{w, x}$ 0.16 ^{a} (0.04)	$_{x}$ 0.19 ^{a} (0.01)	$_{w, x}$ 0.15 ^{a} (0.01)	$_{x}$ 0.17 ^{a} (0.05)

[1]Standard deviation

[a,b]Means within a column which are not followed by a common superscript letter are significantly different ($P < 0.05$).

[w,x]Means within a row, which are not followed by a common superscript letter, are significantly different ($P < 0.05$).

4.2. Effect of chitosan concentration on cantaloupe product quality attributes

4.2.1. Color

Values for lightness (*L**) varied significantly ($P<0.05$) with a trend towards lower values through time (Table 4-4). No particular trend was found among samples coated with chitosan. Controls and samples without antimicrobial added had the lowest values compared to the other coated samples ($P<0.05$), accentuating the darkening through time. Overall, the coating with 2% antimicrobial compound showed better results in retention of fruit lightness.

The *a** values (redness-greenness) of cantaloupe samples varied slightly with storage, but without any particular trend among the coated and uncoated samples (Table 4-5). All values remained in a range between 14 to 16. The application of coating to the samples did not affect the degree of redness in comparison to the control.

The *b** values (yellowness-blueness) were used to estimate changes in the yellow color of fresh-cut cantaloupe during storage (Table 4-6). Coated samples did not show significant ($P<0.05$) changes on *b** values. However, the coated fruits had higher values (>35) in comparison to the control with exception of the first day of storage. This result indicates that coating of the fruits resulted in a better alternative to preserve yellowness in fresh-cut cantaloupe.

Table 4-4. Effect of chitosan coating at different concentrations on *L** color parameter values in uncoated (control) and coated (2% antimicrobial, 2% pectin) fresh-cut cantaloupe during storage.

	Color parameter – L^*				
Time (days)	**Control**	**0.5% Chitosan**	**1.0% Chitosan**	**2.0% Chitosan**	**Non-antimicrobial (1.0% chitosan)**
1	$_{w}$ 50.07 $^{b, c}$ [1] (2.29)	$_{w}$ 49.60 ^{a} (3.66)	$_{w}$ 51.80 $^{a, b}$ (3.94)	$_{w}$ 46.03 ^{a} (5.04)	$_{w}$ 48.97 $^{a, b}$ (4.28)
4	$_{x}$ 53.19 ^{c} (3.50)	$_{w, x}$ 54.17 $^{a, b}$ (4.36)	$_{w, x}$ 54.88 ^{b} (1.43)	$_{w}$ 49.03 ^{a} (4.56)	$_{w}$ 49.91 ^{b} (2.27)
6	$_{w, x}$ 47.97 $^{a, b}$ (8.74)	$_{x}$ 51.22 ^{a} (5.39)	$_{x}$ 49.31 ^{a} (5.70)	$_{w, x}$ 47.17 ^{a} (2.96)	$_{w}$ 42.70 ^{a} (5.51)
10	$_{w}$ 41.91 ^{a} (2.55)	$_{x}$ 48.60 ^{a} (3.72)	$_{w, x}$ 46.92 ^{a} (6.34)	$_{w, x}$ 45.83 ^{a} (4.84)	$_{w}$ 42.07 ^{a} (2.26)
15	$_{w}$ 41.01 ^{a} (1.87)	$_{x}$ 46.03 ^{a} (1.73)	$_{x}$ 48.39 ^{a} (2.40)	$_{w, x}$ 44.61 ^{a} (2.85)	$_{w}$ 40.23 ^{a} (2.35)

[1]Standard deviation

[a,b]Means within a column which are not followed by a common superscript letter are significantly different ($P < 0.05$).

[w,x]Means within a row, which are not followed by a common superscript letter, are significantly different ($P < 0.05$).

Table 4-5. Effect of chitosan coating at different concentrations on *a** color parameter values in uncoated (control) and coated (2% antimicrobial, 2% pectin) fresh-cut cantaloupe during storage.

	Color parameter – *a**				
Time (days)	**Control**	**0.5% Chitosan**	**1.0% Chitosan**	**2.0% Chitosan**	**Non-antimicrobial (1.0% chitosan)**
1	$_{w}$ 14.88 ^{a} [1] (0.64)	$_{w}$ 15.12 ^{a} (1.23)	$_{w}$ 14.21 ^{a} (0.98)	$_{w}$ 15.67 ^{a} (1.33)	$_{w}$ 14.79 ^{a} (1.17)
4	$_{w}$ 15.60 ^{a} (0.92)	$_{w, x}$ 16.56 ^{a} (0.91)	$_{w, x}$ 16.45 ^{b} (0.62)	$_{w}$ 15.09 ^{a} (0.94)	$_{x}$ 18.33 ^{b} (1.01)
6	$_{w}$ 15.04 ^{a} (0.62)	$_{w}$ 15.47 ^{a} (1.51)	$_{w}$ 15.15 $^{a, b}$ (1.34)	$_{w}$ 15.37 ^{a} (1.38)	$_{w}$ 15.53 $^{a, b}$ (1.12)
10	$_{w, x}$ 14.11 ^{a} (1.97)	$_{y}$ 15.64 ^{a} (0.94)	$_{w}$ 12.97 ^{a} (1.28)	$_{x, y}$ 14.62 ^{a} (1.33)	$_{x, y}$ 14.80 ^{a} (1.93)
15	$_{x}$ 15.77 ^{a} (0.73)	$_{w}$ 13.22 ^{a} (2.04)	$_{x}$ 15.32 $^{a, b}$ (1.42)	$_{x}$ 15.65 ^{a} (1.35)	$_{w, x}$ 14.22 ^{a} (0.68)

[1]Standard deviation

[a,b]Means within a column which are not followed by a common superscript letter are significantly different ($P < 0.05$).

[w,x]Means within a row, which are not followed by a common superscript letter, are significantly different ($P < 0.05$).

Table 4-6. Effect of chitosan coating at different concentrations on *b** color parameter values in uncoated (control) and coated (2% antimicrobial, 2% pectin) fresh-cut cantaloupe during storage.

	Color parameter – *b**				
Time (days)	**Control**	**0.5% Chitosan**	**1.0% Chitosan**	**2.0% Chitosan**	**Non-antimicrobial (1.0% chitosan)**
1	$_{x}$ 35.72 ^{a} [1] (1.28)	$_{x}$ 35.34 ^{a} (0.63)	$_{w}$ 32.96 ^{a} (0.94)	$_{w, x}$ 33.45 ^{a} (1.39)	$_{x}$ 34.97 $^{a, b}$ (1.83)
4	$_{w, x}$ 34.48 ^{a} (1.23)	$_{x}$ 35.67 ^{a} (0.78)	$_{x}$ 35.53 ^{a} (1.02)	$_{w}$ 33.74 ^{a} (0.83)	$_{y}$ 37.18 ^{b} (0.88)
6	$_{w}$ 32.88 ^{a} (0.96)	$_{w}$ 33.77 ^{a} (1.05)	$_{w}$ 32.87 ^{a} (1.21)	$_{w}$ 33.17 ^{a} (1.41)	$_{w}$ 32.73 $^{a, b}$ (1.90)
10	$_{w}$ 31.62 ^{a} (1.03)	$_{x}$ 34.44 ^{a} (0.65)	$_{w, x}$ 32.23 ^{a} (0.81)	$_{x}$ 34.55 ^{a} (1.71)	$_{w, x}$ 32.51 $^{a, b}$ (1.67)
15	$_{w}$ 31.61 ^{a} (1.21)	$_{x}$ 33.68 ^{a} (1.23)	$_{x}$ 33.77 ^{a} (0.92)	$_{x}$ 33.75 ^{a} (1.95)	$_{w}$ 31.25 ^{a} (1.06)

[1]Standard deviation

[a,b]Means within a column which are not followed by a common superscript letter are significantly different ($P < 0.05$).

[w,x]Means within a row, which are not followed by a common superscript letter, are significantly different ($P < 0.05$).

4.2.2. Texture

Figure 4-2 represents the values of maximum force required to compress the fresh-cut cantaloupe samples with different chitosan concentrations (0.5, 1, and 2%). Uncoated controls started to lose firmness after Day 4 of experiments and continued that trend during storage. All coated samples were significantly ($P<0.05$) firmer (higher force values) in comparison to the control. The 2% chitosan coating yielded fruit pieces with the highest force values (45-54 N), followed by 1% chitosan (32-43 N), then the non-antimicrobial (1% chitosan) (31-44 N), and lastly 0.5% chitosan concentration (37-41 N). All coated treatments demonstrated high effectiveness in retaining the cantaloupe original firmness even after 15 days of storage, while the uncoated controls had softer and mushy texture after the fourth day of storage.

By the last day of storage (day 15), the coated samples showed firmness values that were 4.4 to 3.1 times higher than those from the uncoated samples. The coated samples without antimicrobial also showed firmness values three times higher than the control samples.

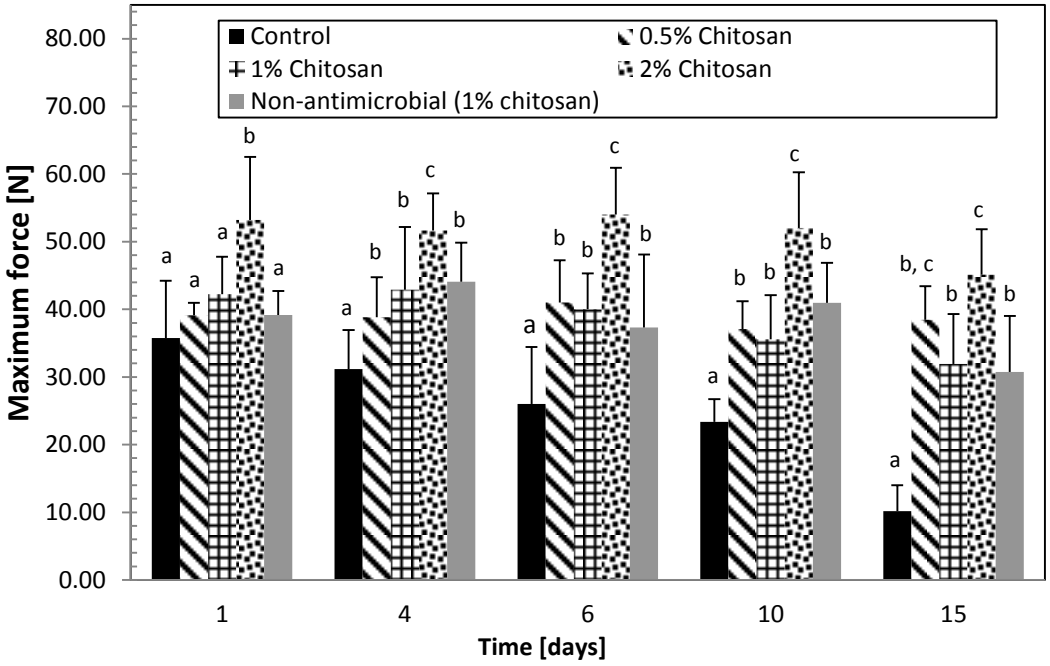


Figure 4-2. Maximum force [N] to compress control (uncoated) and coated (2% antimicrobial, 2% pectin) cantaloupe samples coated with different chitosan concentrations stored at 4^{o}C during 15 days.

4.2.3. Sensory evaluation

Sensory analysis results are presented in Figures 4-3 to 4-7. The color acceptability of all coated and uncoated samples decreased with time (Figure 4-3), and for the last two days of experiments panelists gave a slight but significant ($P<0.05$) preference to the samples coated with 0.5% chitosan. Probably, the coating helped to preserve the product color, it is worth to note that the samples with the 0.5% chitosan concentration were least noticed by the panelists (visually).

In the case of odor (Figure 4-4), consumers showed a significant ($P<0.05$) preference for the uncoated samples and the samples with non-antimicrobial coating during the first 4 days of evaluation. However, by the day 15, all samples were given scores around 4.5. This is due to the particular odor imparted by the *trans*-cinnamaldehyde nanoparticles in the coated samples. People do not associate a smell of cinnamon with fresh-cut cantaloupe. In general, all samples received scores higher than 5.0 (acceptable) until the day 13 of evaluation.

A similar trend was observed for the flavor parameter (Figure 4-5) as preference ($P<0.05$) for uncoated and non-antimicrobial coated samples was higher until the Day 9 of storage. For the last two days of evaluation, 13 and 15, all samples scored the same values in a range around 5.5 and 4.5, respectively.

Texture parameter scores (Figure 4-6) slightly changed throughout the first 13 days of storage, and no significant ($P<0.05$) differences were observed among the coated and uncoated samples; this was due to the use of fresh samples to serve as controls for every day of evaluation. All samples had scores above 6.0. However, by day 15, the

acceptability of all samples decreased drastically, as all of the treatments scores were around a 4.5 range.

Overall quality (Figure 4-7) showed a significant ($P<0.05$) preference for uncoated and non-antimicrobial samples during the first 9 days of storage. This was mostly due to the high impact in odor and flavor in the overall quality of the product. In spite of the preference for samples without antimicrobial compound, the coated samples with antimicrobial were also acceptable to the consumers and they received scores above 5.0. For the remaining days of evaluation, there were no significant ($P<0.05$) differences nor preference among the coated or uncoated samples.

Even though the uncoated samples seemed like the best choice for the first days of evaluation, the coated samples helped to retain the fruit's original attributes longer. Furthermore, a slight preference ($P<0.05$) towards coated samples was observed during the day 15 of storage.

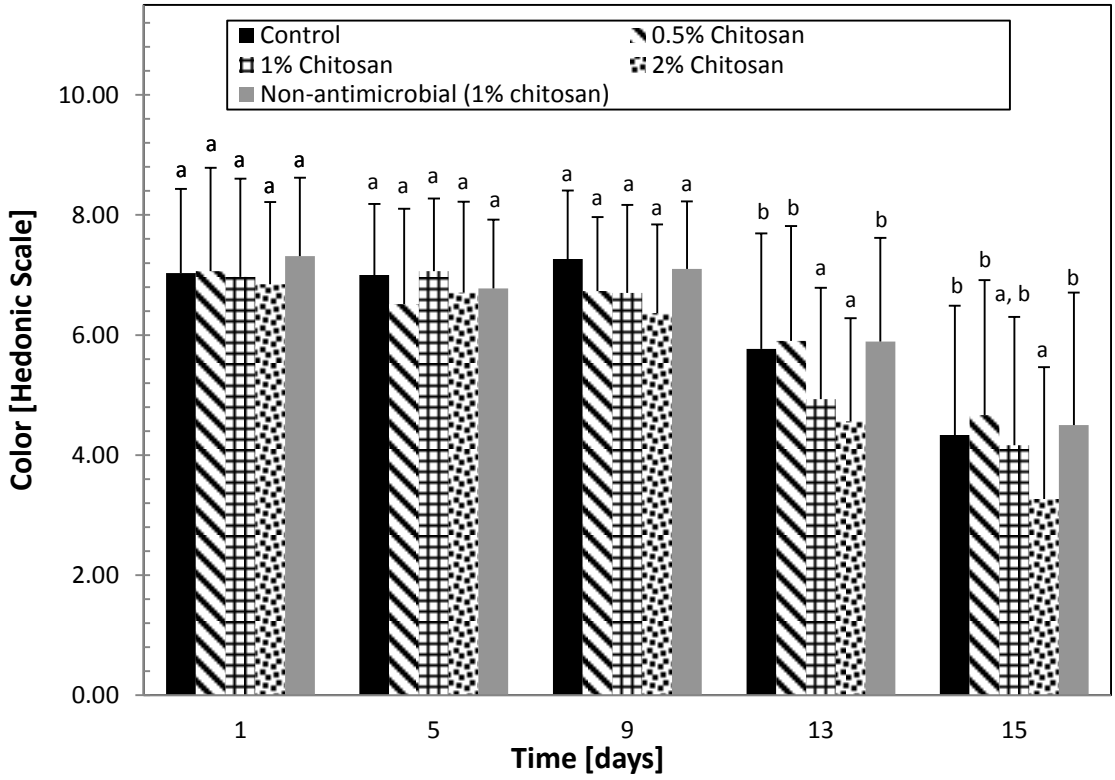


Figure 4-3. Sensory color analysis scores for control (uncoated) and coated (2% antimicrobial, 2% pectin) fresh-cut cantaloupe with different chitosan concentrations stored at 4^{o}C during 15 days. A score of 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely.

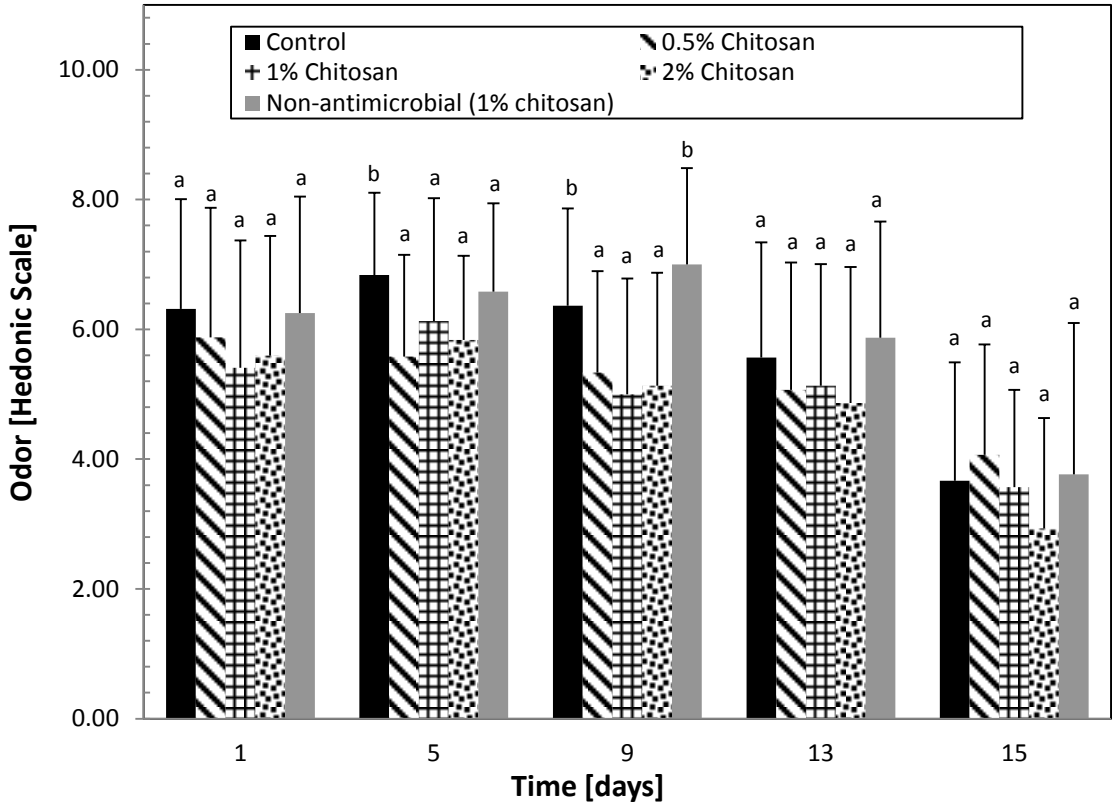


Figure 4-4. Sensory odor analysis scores for control (uncoated) and coated (2% antimicrobial, 2% pectin) fresh-cut cantaloupe with different chitosan concentrations stored at 4^{o}C during 15 days. A score of 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely.

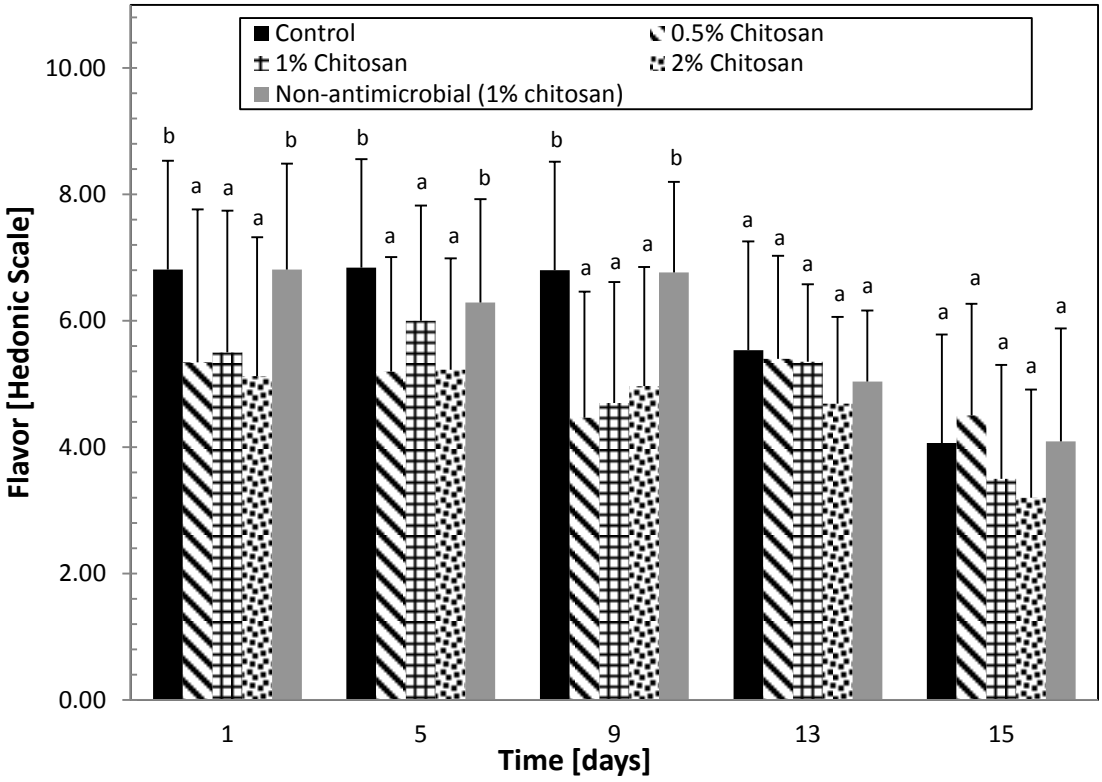


Figure 4-5. Sensory flavor analysis scores for control (uncoated) and coated (2% antimicrobial, 2% pectin) fresh-cut cantaloupe with different chitosan concentrations stored at 4^{o}C during 15 days. A score of 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely.

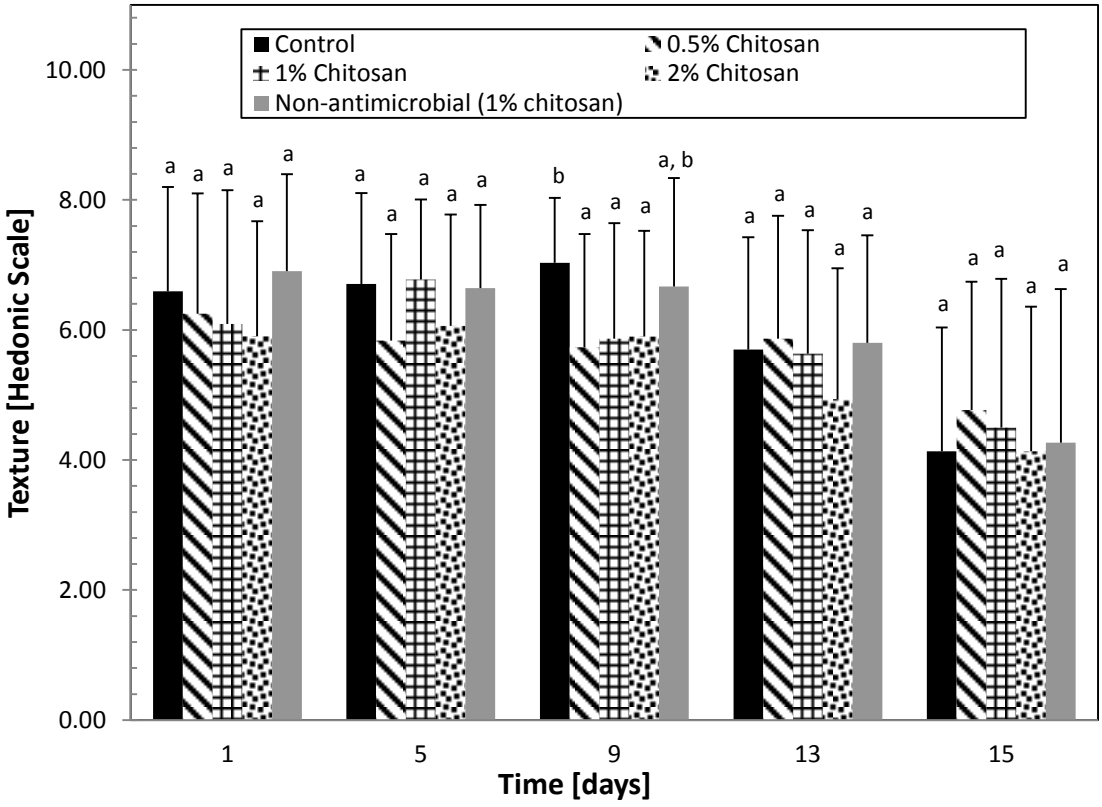


Figure 4-6. Sensory texture analysis scores for control (uncoated) and coated (2% antimicrobial, 2% pectin) fresh-cut cantaloupe with different chitosan concentrations stored at 4^{o}C during 15 days. A score of 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely.

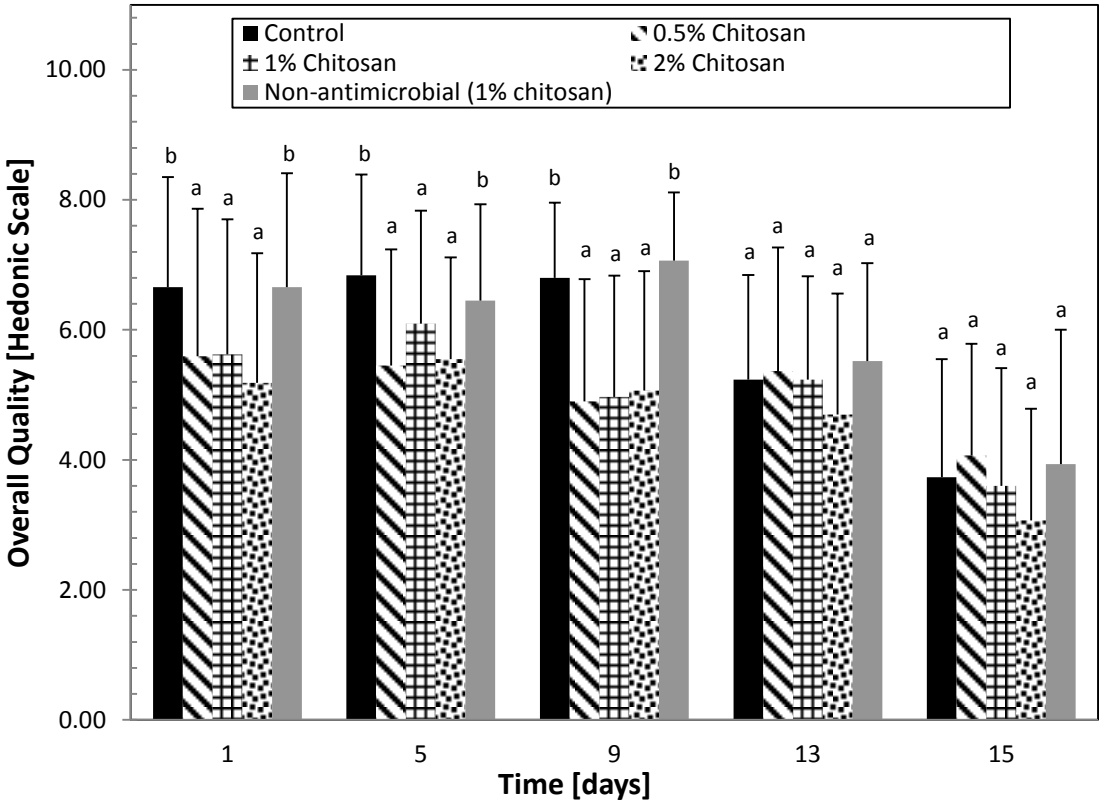


Figure 4-7. Sensory overall quality analysis scores for control (uncoated) and coated (2% antimicrobial, 2% pectin) fresh-cut cantaloupe with different chitosan concentrations stored at 4^{o}C during 15 days. A score of 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely.

4.3. Effect of pectin concentration on cantaloupe chemical properties

Results for 2% pectin concentration in the chemical properties of coated cantaloupe samples were obtained during the previous set of experiments with three different chitosan concentrations. For this second set, the effect of 0.5% and 1% pectin concentrations in the chemical properties and quality attributes of coated cantaloupe samples (2% antimicrobial, 0.5% chitosan) was evaluated. Uncoated samples served as controls.

4.3.1. Juice leakage

Juice leakage percentage increased significantly ($P<0.05$) throughout storage for the coated samples (from 1.2% to 7.1%), however the rate of juice leakage increase was always higher for the controls (from 2.8% to 8.4%) (Figure 4-8). The difference between coated and uncoated samples was highly noticeable, and by the day 15 of evaluation coated samples had 1.5% less juice leakage in comparison to the controls. The coating was effective in preventing weight loss. The concentration of pectin did not have ($P<0.05$) any effect on juice leakage.

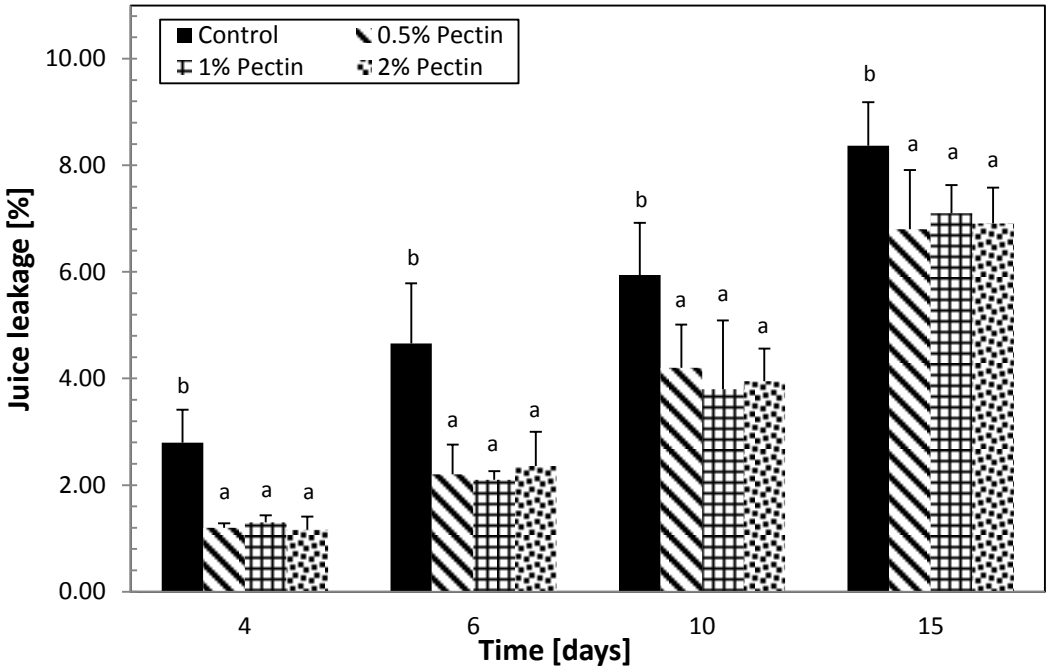


Figure 4-8. Juice leakage percentage of control (uncoated) and coated (0.5% chitosan, 2% antimicrobial) fresh-cut cantaloupe with different pectin concentrations stored at 4^{o}C during 15 days.

4.4. Effect of pectin concentration on cantaloupe product quality attributes

4.4.1. Texture

Results for texture values for different pectin concentrations in coated and uncoated fresh-cut cantaloupe samples are presented in Figure 4-9. The uncoated samples started to lose firmness after Day 4 of experiments and continued that trend during the rest of the evaluation period. All coated samples had significantly ($P<0.05$) higher firmness values in comparison to the control throughout storage. The samples coated with 0.5% pectin had slightly higher force values than the other two coatings (1% and 2% pectin), but no significant differences were found among them. By the end of storage, the difference between controls and coated samples became significant ($P<0.05$), to the point of requiring 20 N more to compress the coated samples than the controls. These results show the coating's high effectiveness in retaining the cantaloupe original firmness through storage.

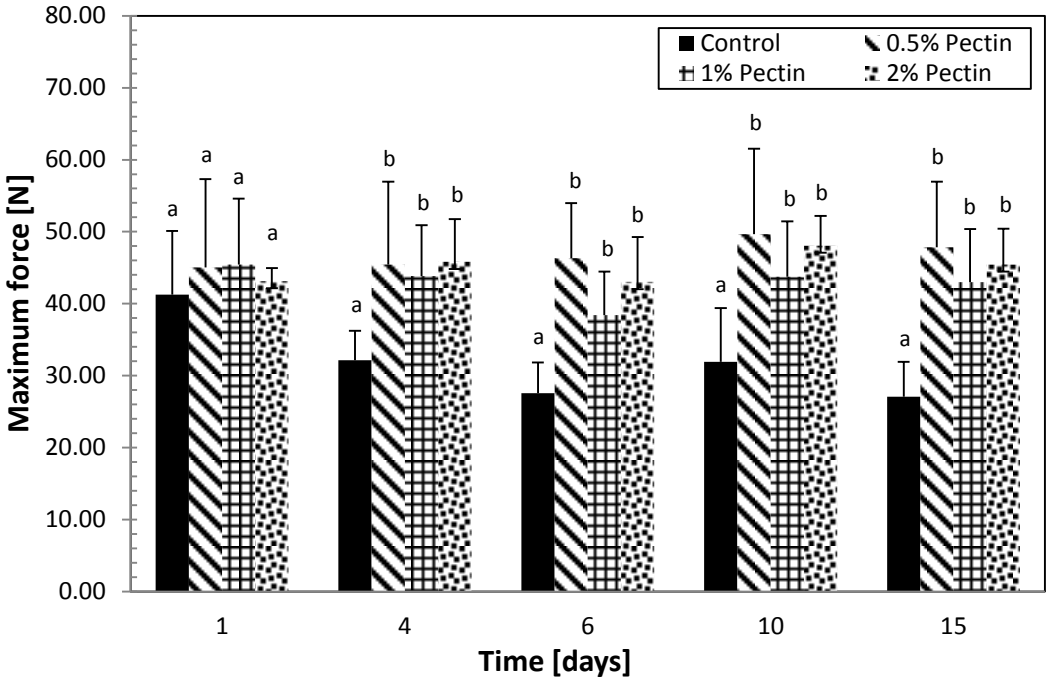


Figure 4-9. Maximum force [N] to compress control (uncoated) and coated (0.5% chitosan, 2% antimicrobial) cantaloupe samples coated with different pectin concentrations stored at 4^{o}C during 15 days.

4.4.2. Coating microscopic examination

Figures 4-10 and 4-11 present the different cross-sections of the antimicrobial edible coating, showing two different compositions in the coating system. Figure 4-10 presents the thickness for a coating with 0.5% chitosan and 0.5% pectin (2% antimicrobial) in fresh-cut cantaloupe, while Figure 4-11 shows the thickness for a coating with 2% chitosan and 2% pectin (2% antimicrobial) in fresh-cut papaya. Coating thickness, determined in the micrographs by taking measures at different points of the cross-section, was homogeneous throughout the entire surface of the fruit. The mean values for the film thickness were 87 μm (Fig. 4-10) and 300 μm (Fig. 4-11), for the samples coated with 0.5% chitosan – 0.5% pectin and 2% chitosan – 2% pectin respectively. These results indicate the importance of chitosan and pectin concentrations in the coating's thickness; where higher concentrations produce solutions with higher viscosities, and therefore higher thicknesses.

Coating thickness may be affected by the rheological properties of the polymers used on the film (Tapia et al., 2008); for instance, chitosan and pectin are very hygroscopic polymers. Another factor associated with the thickness of the coating could be the diverse gelation mechanisms of both polysaccharides.

Both samples had the same antimicrobial concentration (2%) in the coating; however, the amount of antimicrobial present in the coating would vary drastically due to the difference in thicknesses. Furthermore, it would be natural to expect a longer shelf-life for the thicker film (Figure 4-11).

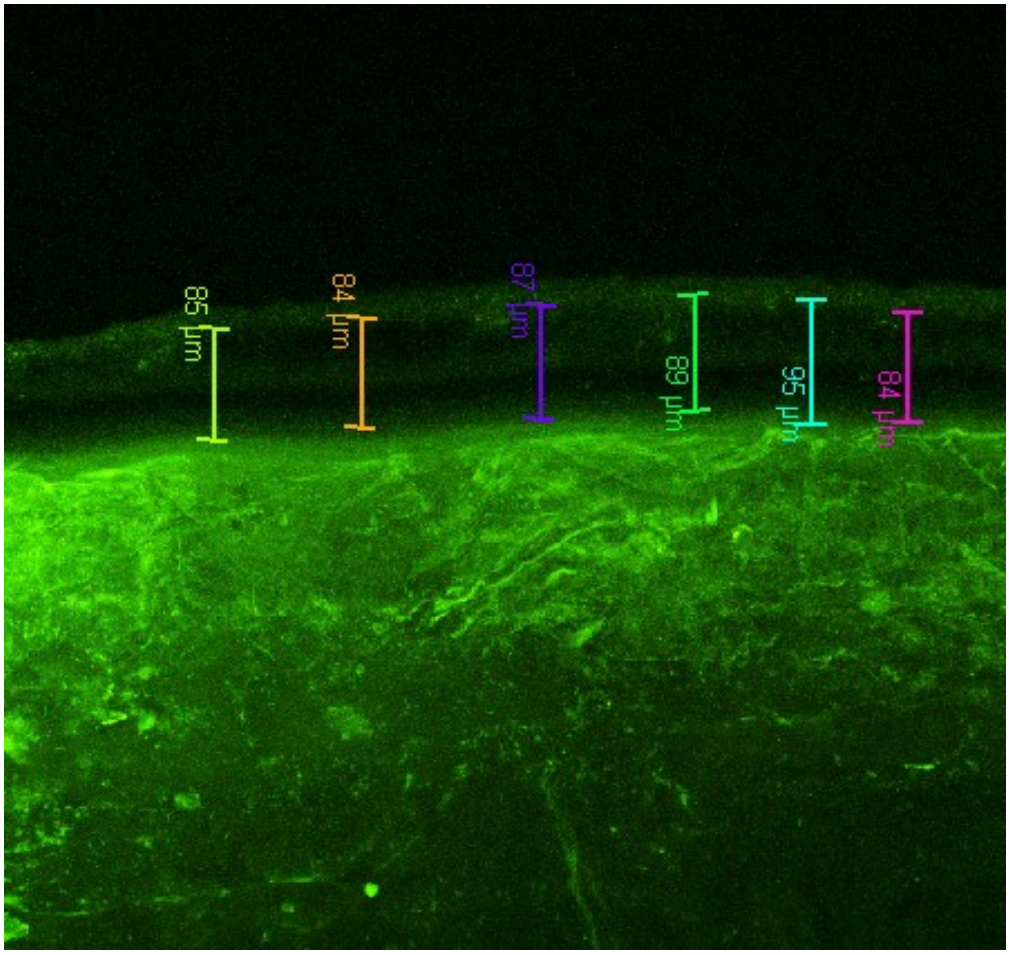


Figure 4-10. Microscopic observations of cross-section of multilayer edible coating (0.5% chitosan, 0.5% pectin, 2% antmicrobial) in fresh-cut cantaloupe. (Puerta-Gomez, A. F., 2010).

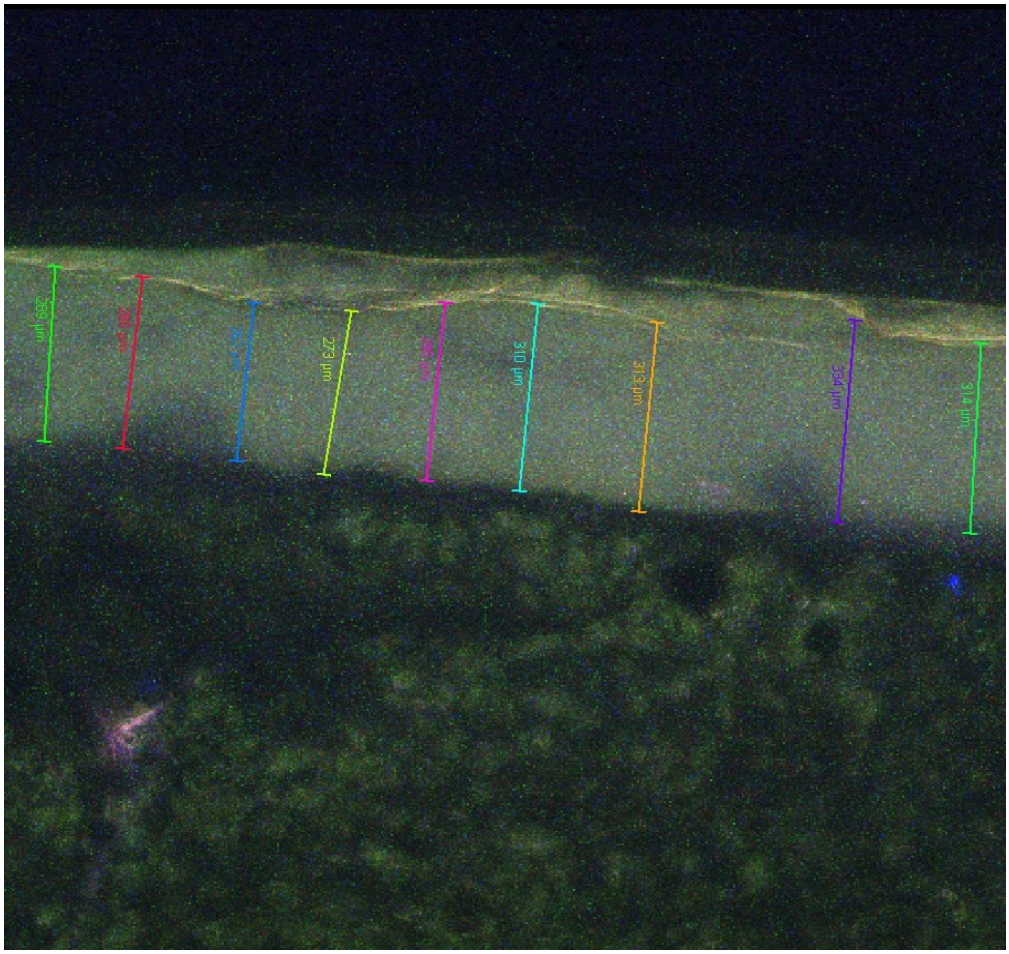


Figure 4-11. Microscopic observations of cross-section of multilayer edible coating (2% chitosan, 2% pectin, 2% antmicrobial) in fresh-cut papaya. (Puerta-Gomez, A. F., 2010).

4.4.3. Sensory evaluation

Due to the low acceptability of samples by day 15 of in the past set of experiments, the current set of tests was only scheduled for the days 1, 4, 8, 10, and 12. In addition, fresh uncoated samples served as controls for every day of evaluation, this approach also resulted in a better and more reliable analysis during all the evaluation period. Color acceptability of coated and uncoated samples remained constant throughout storage with values above 6.0 (Figure 4-12). A small preference towards the uncoated samples was observed until the day 10 of evaluation.

Similar trend was observed for the case of odor (Figure 4-13), with consumer acceptability remaining constant during the 5 days and showing values above 5.0 for the coated and uncoated samples. A significant ($P<0.05$) preference for the uncoated samples was observed throughout the whole period of evaluation. This was probably due to the particular odor imparted by cinnamaldehyde in the samples coated with antimicrobial compound.

For the flavor parameter scores (Figure 4-14), a significant ($P<0.05$) preference was found for the control samples in comparison to the coated samples as it was expected, since we were using fresh-cut cantaloupe for every evaluation day. For an instance, the coated samples observed acceptability until the day 12, since all scores received were higher than 5.0 for all the coated and uncoated samples. No significant difference among the pectin concentrations was found.

The texture parameter values (Figure 4-15) slightly changed throughout storage. This is understandable for the control, since uncoated samples within the same degree of

ripeness were fresh provided each day of evaluation, eliminating this way any possible variance within time. For the case of the uncoated samples, retention of cantaloupe's original firmness is observed during the period of evaluation without significant differences ($P<0.05$). A slight preference is shown for samples coated with 1% over 0.5% pectin, probably due to the thicker coating. All samples received scores above 5.5 throughout the evaluation period.

As it was expected, the overall quality values (Figure 4-16) showed a significant ($P<0.05$) preference for the uncoated samples compared to the coated ones during the evaluation time. This helped as a reliable reference to measure coated samples acceptability when they were compared to a real fresh-cut fruit. It is worth to mention that all coated samples received high acceptability in a range above 5.0 throughout all days of evaluation. No particular differences were observed between the pectin concentrations.

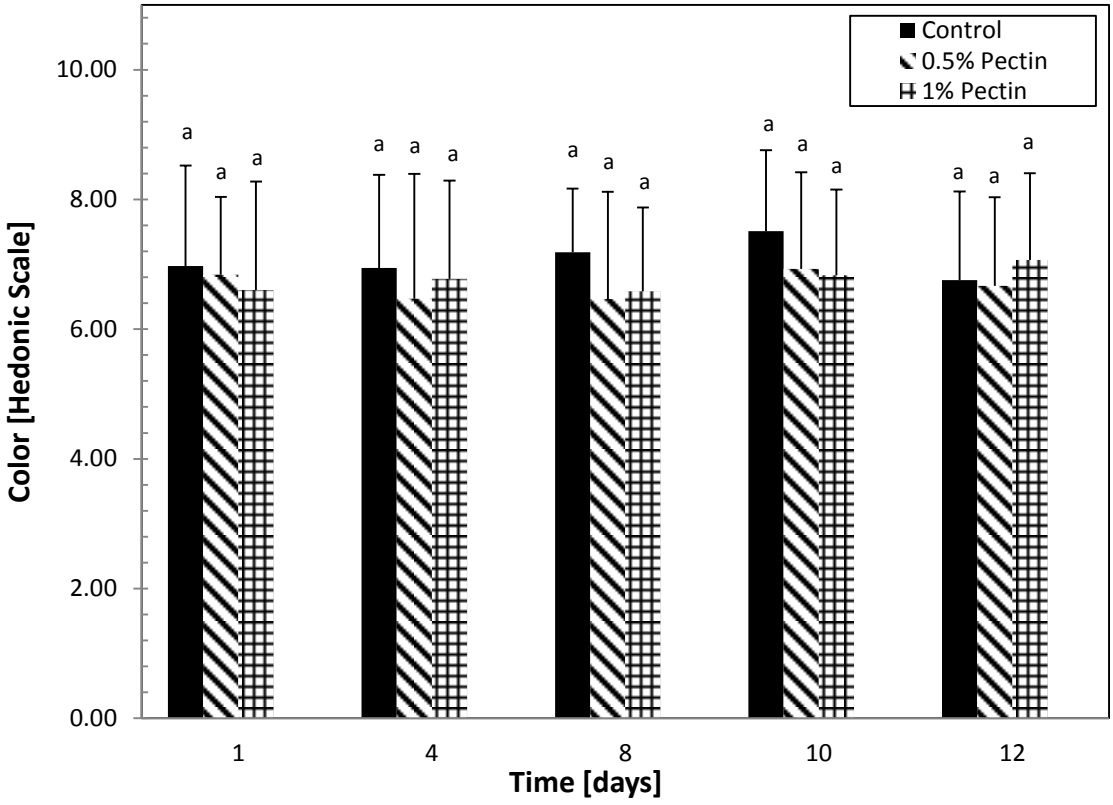


Figure 4-12. Sensory color analysis scores for control (uncoated) and coated (0.5% chitosan, 2% antimicrobial) fresh-cut cantaloupe with different pectin concentrations stored at 4^{o}C during 15 days. A score of 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely. Fresh samples were prepared for every day of evaluation to serve as controls.

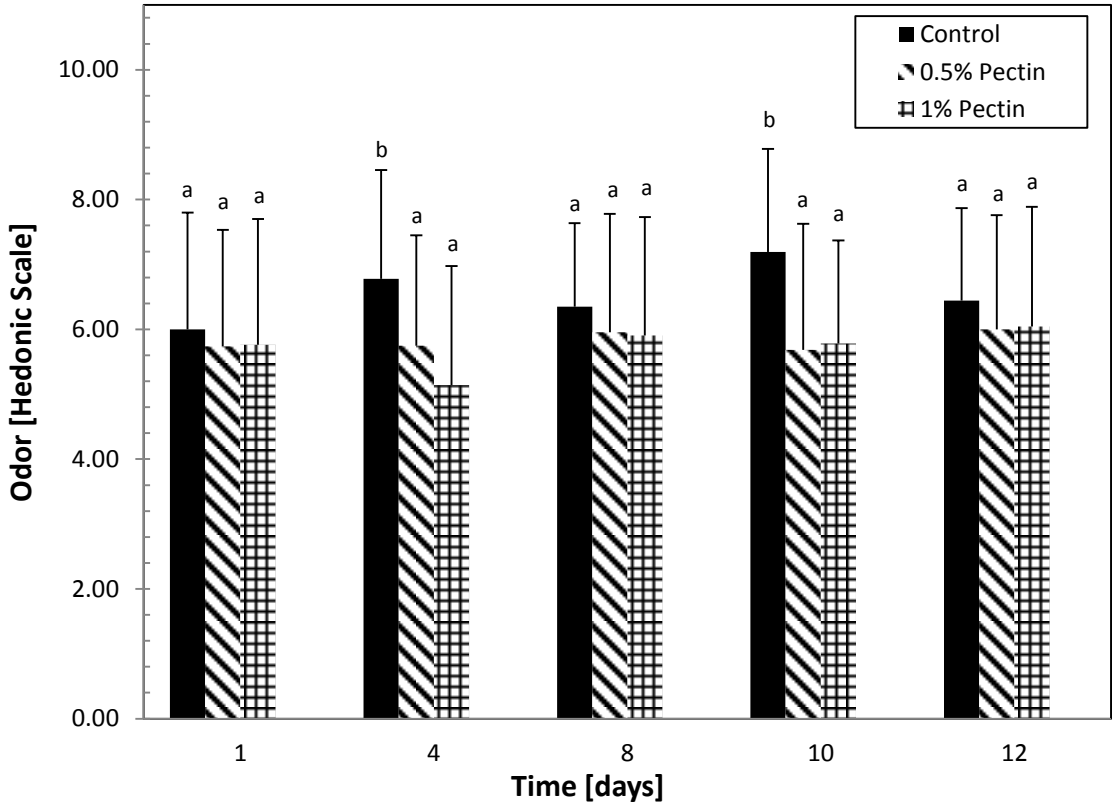


Figure 4-13. Sensory odor analysis scores for control (uncoated) and coated (0.5% chitosan, 2% antimicrobial) fresh-cut cantaloupe with different pectin concentrations stored at 4^{o}C during 15 days. A score of 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely. Fresh samples were prepared for every day of evaluation to serve as controls.

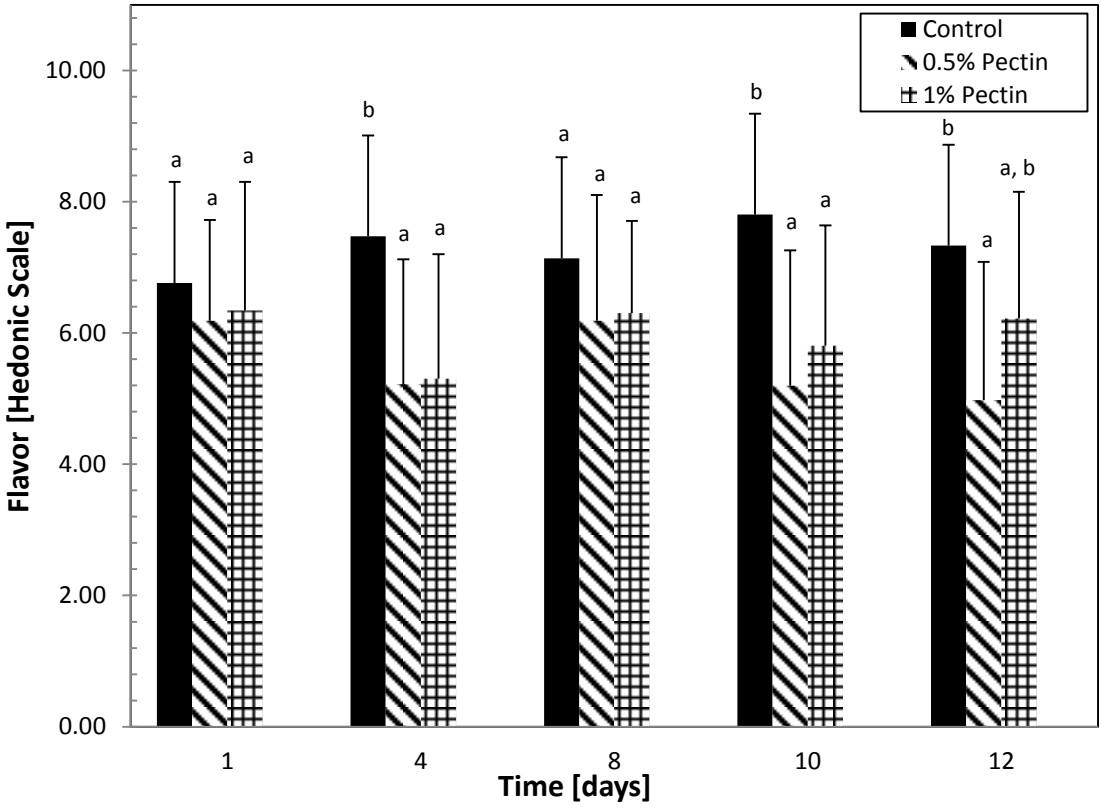


Figure 4-14. Sensory flavor analysis scores for control (uncoated) and coated (0.5% chitosan, 2% antimicrobial) fresh-cut cantaloupe with different pectin concentrations stored at 4^{o}C during 15 days. A score of 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely. Fresh samples were prepared for every day of evaluation to serve as controls.

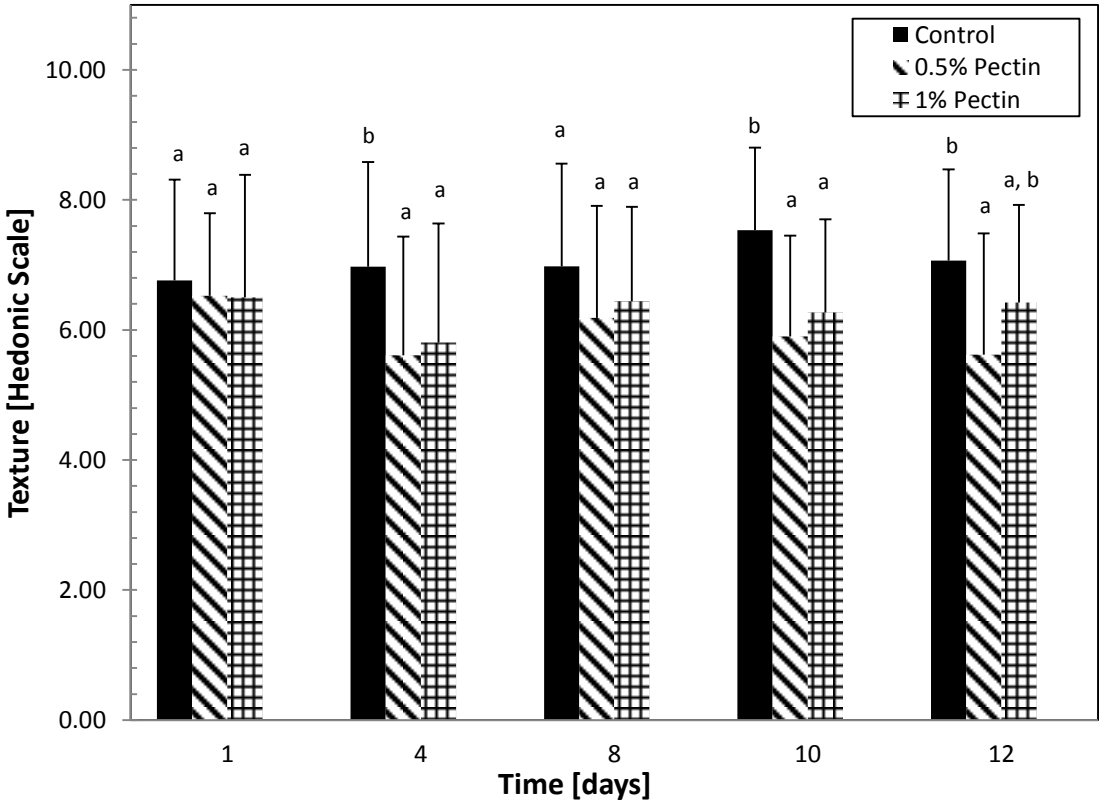


Figure 4-15. Sensory texture analysis scores for control (uncoated) and coated (0.5% chitosan, 2% antimicrobial) fresh-cut cantaloupe with different pectin concentrations stored at 4^{o}C during 15 days. A score of 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely. Fresh samples were prepared for every day of evaluation to serve as controls.

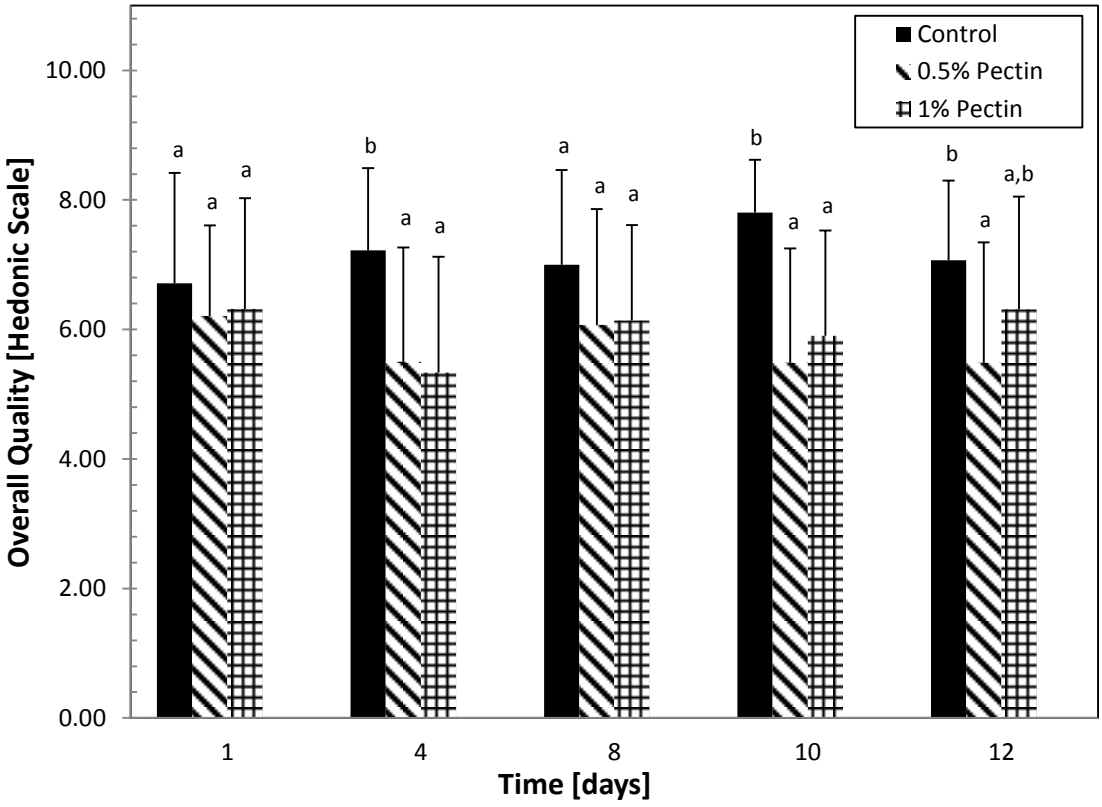


Figure 4-16. Sensory overall quality analysis scores for control (uncoated) and coated (0.5% chitosan, 2% antimicrobial) fresh-cut cantaloupe with different pectin concentrations stored at 4^{o}C during 15 days. A score of 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely. Fresh samples were prepared for every day of evaluation to serve as controls.

4.5. Effect of antimicrobial agent concentration on cantaloupe chemical properties

For the third set of experiments, the effect of three different antimicrobial compound concentrations (1, 2, and 3%) in the chemical properties and quality attributes of coated fresh-cut cantaloupe samples (1% pectin, 2% chitosan) was evaluated. Uncoated samples served as control.

4.5.1. Juice leakage

A significant increase ($P<0.05$) in juice leakage percentage was observed throughout storage for the coated and uncoated samples (Figure 4-17). Uncoated samples had the highest leakage increase during storage. A slight difference among coated samples showed that the highest concentration of antimicrobial (3%) was more effective in preventing juice leakage than the other two coatings (2% and 1%). In conclusion, any coating treatment, regardless of antimicrobial concentration, resulted in lower weight loss.

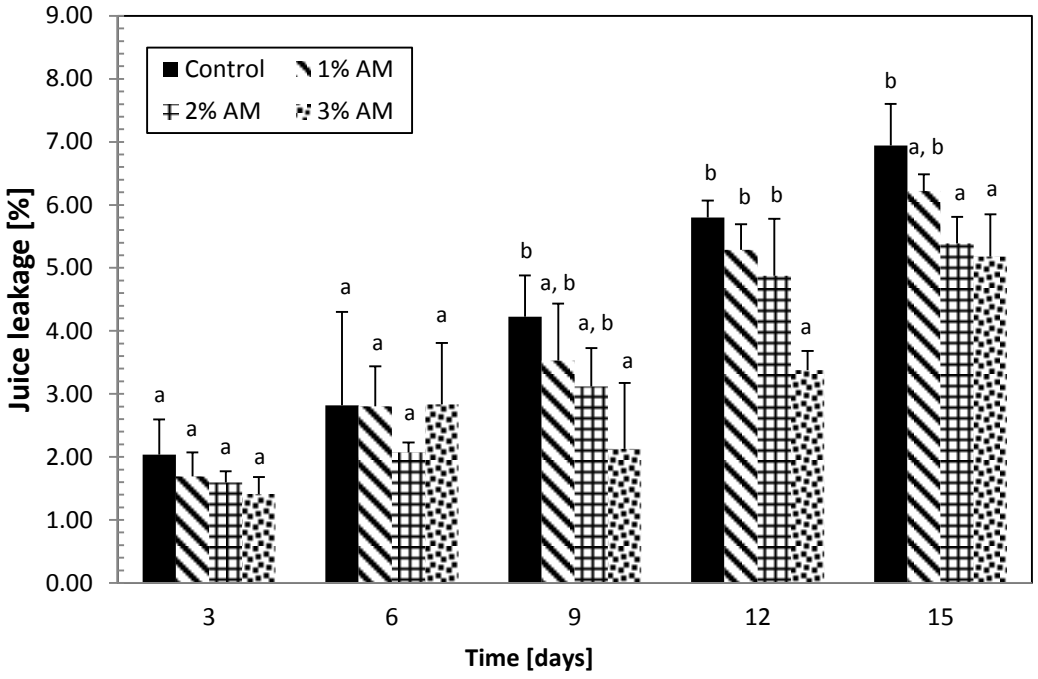


Figure 4-17. Juice leakage percentage of control (uncoated) and coated (2% chitosan, 1% pectin) fresh-cut cantaloupe with different antimicrobial (AM) concentrations stored at 4^{o}C during 15 days.

4.5.2. Microbiological analysis

Microbiological analysis results are presented in Figures 4-18 to 4-20 for aerobics, psychrophiles, and yeast & mould counts, respectively. The samples were evaluated on the days 1, 3, 6, 9, 12, and 15. Three different antimicrobial concentrations (1, 2, and 3%) were evaluated in fresh-cut cantaloupe coated samples (2% chitosan, 1% pectin), as well as one treatment with no antimicrobial compound (2% chitosan) to test for antimicrobial activity of chitosan alone.

Aerobic plate count (mesophilic microorganism) results are shown in Figure 4-18. All antimicrobial coatings demonstrated to be highly effective in the reduction of the microbial population throughout storage. As it was expected, a relationship between antimicrobial concentration and microbial population reduction was observed, with 3% concentration having the highest decrease (4 log cycles) in comparison to the control samples at the day 15 of evaluation. It was followed by 2% and 1% with 3 and 2 log cycle reductions, respectively. Chitosan treatment alone did not show significant effect in the reduction of aerobics population by itself, sometimes even presenting higher CFU/g values than the control.

Results for psychrotrophic plate count are presented in Figure 4-19. Similar to aerobic plate count, antimicrobial concentration showed the same trend in the reduction of psychrotrophiles population, with the addition of higher concentrations of antimicrobial compound demonstrated higher values in the reduction of microbial load. The highest CFU/g decrease was observed for the 3% antimicrobial coating with 3 log cycles, followed by the 2% with a 2.5 reduction, and 1% with almost 2 log cycles

reduction. Chitosan treatment alone did not present any significant ($P<0.05$) reduction in the microbial population.

For the yeast and molds plate count (Fig. 4-20), a difference throughout storage of almost 1 log cycle between control samples and chitosan treatment alone was observed, confirming this way chitosan's partial antimicrobial activity against yeasts and moulds. All the coatings with antimicrobial compound presented a higher reduction in the microbial population, with the 1% concentration showing a 1 log cycle decrease, while the 2% and 3% concentrations showing 3 log cycles reduction. No significant ($P<0.05$) differences were observed between the 2% and 3% antimicrobial concentrations.

Overall results showed that the coating with 3% antimicrobial concentration was the most effective in reducing the microbial load for aerobic, psychrotrophic and yeast & molds plate counts.

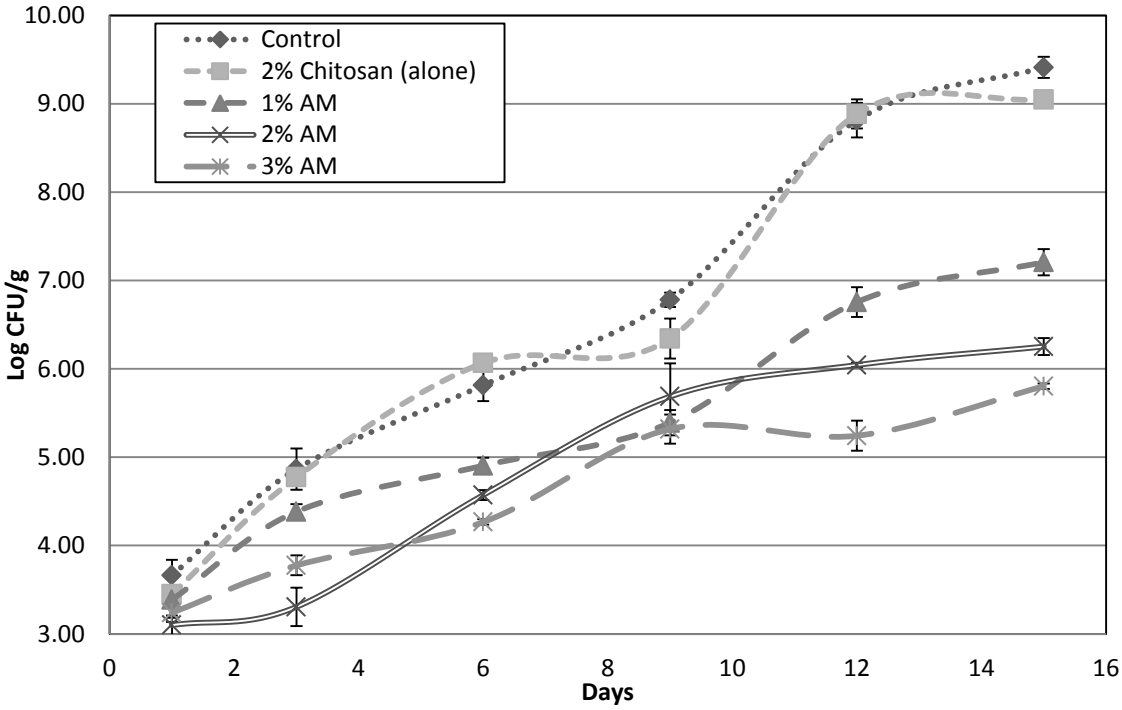


Figure 4-18. Aerobic plate count (mesophilic microorganism) of control (uncoated) and coated (2% chitosan, 1% pectin) fresh-cut cantaloupe with different antimicrobial (AM) concentrations stored at 4^{o}C during 15 days.

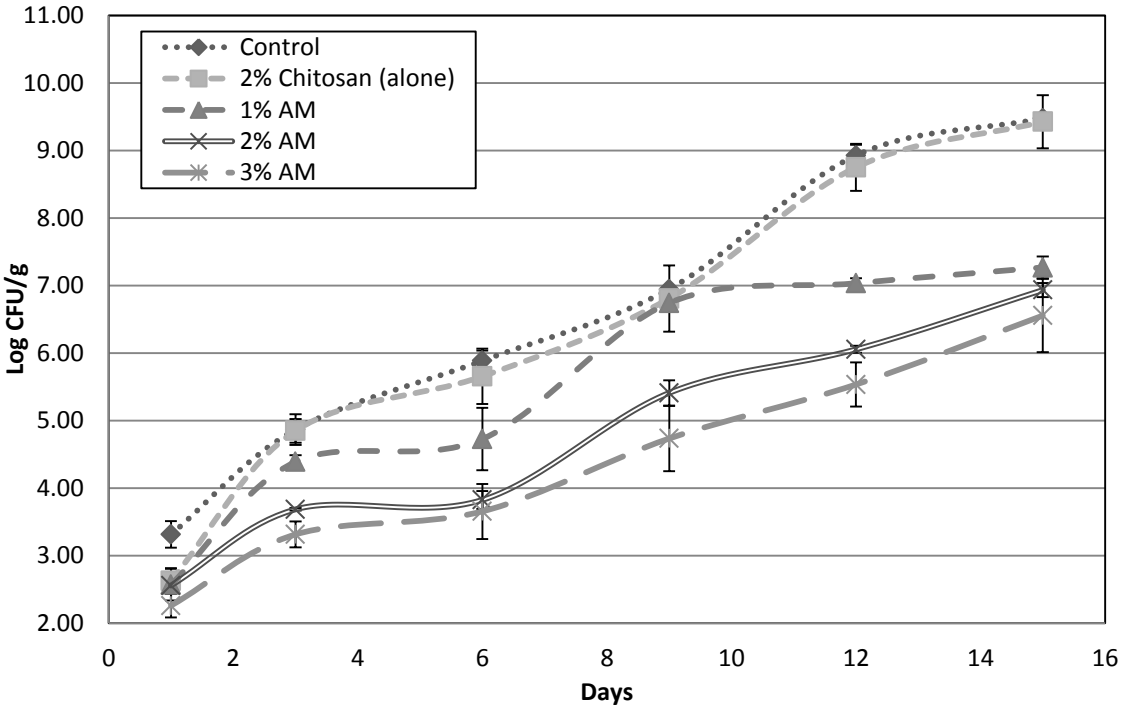


Figure 4-19. Psychrotrophic plate count of control (uncoated) and coated (2% chitosan, 1% pectin) fresh-cut cantaloupe with different antimicrobial (AM) concentrations stored at 4^{o}C during 15 days.

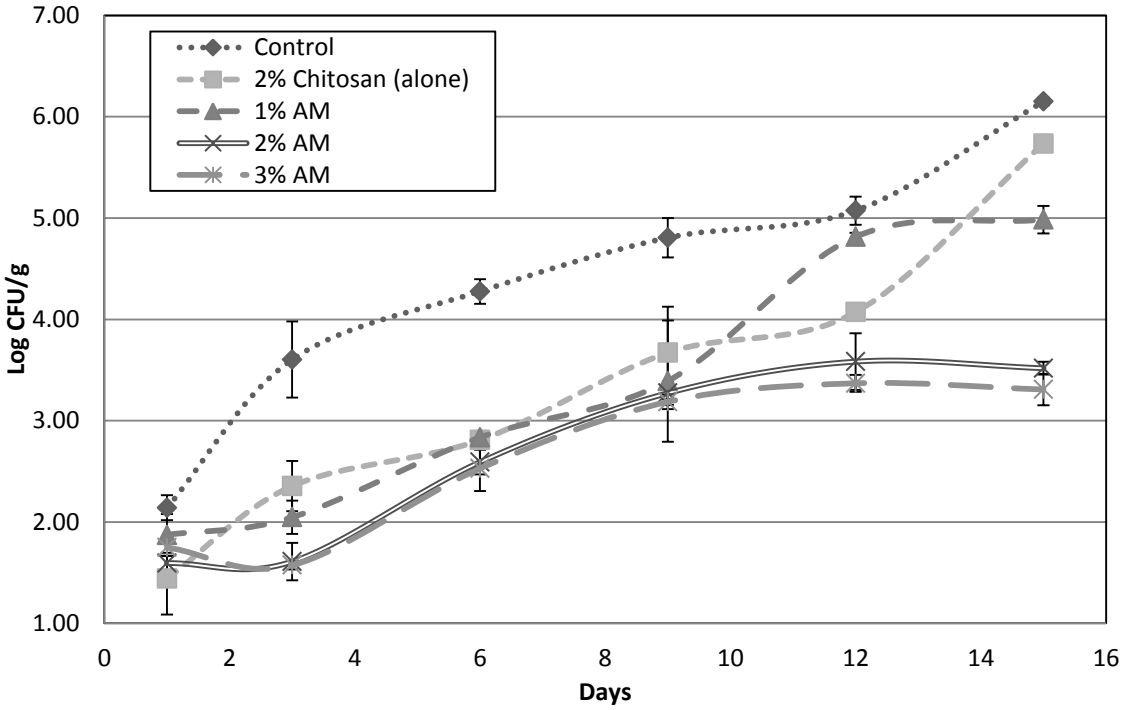
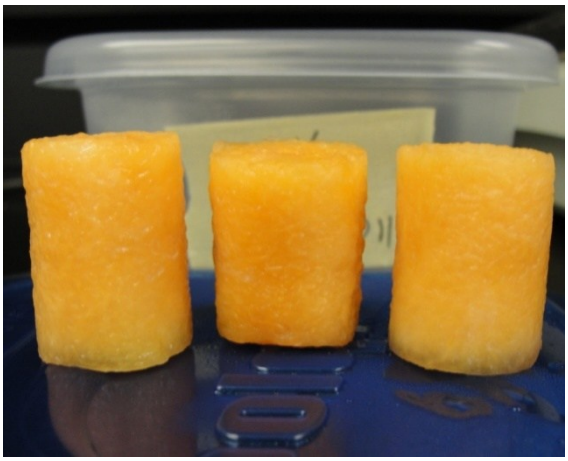


Figure 4-20. Yeast and molds plate count of control (uncoated) and coated (2% chitosan, 1% pectin) fresh-cut cantaloupe with different antimicrobial (AM) concentrations stored at 4^{o}C during 15 days.

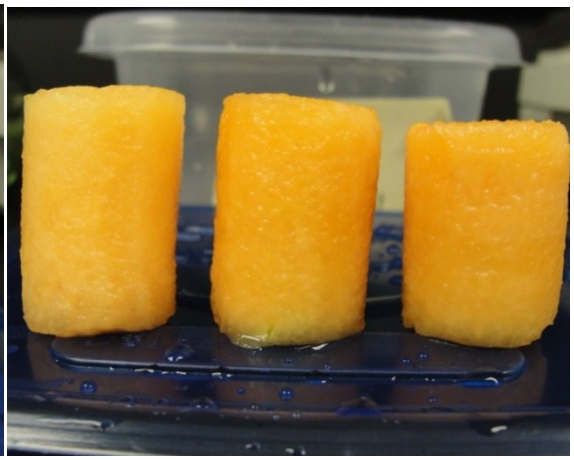
Figures 4-21 and 4-22 represent a comparison between samples coated with different antimicrobial concentrations (1, 2, and 3%) by the day 15, and uncoated controls at the days 9 and 15 of evaluation. While the samples coated with 2% and 3% antimicrobial concentrations did not show any visual evidence of microbial growth by the day 15, samples with 1% presented a few white dots on the surface of cantaloupe, presumed to be yeasts (Figure 4-22). Higher amounts of these whitish dots were shown in uncoated samples starting on day 9 of storage and became larger in size by day 15 (Figure 4-21).

Control: Day 9. Control: Day 15.

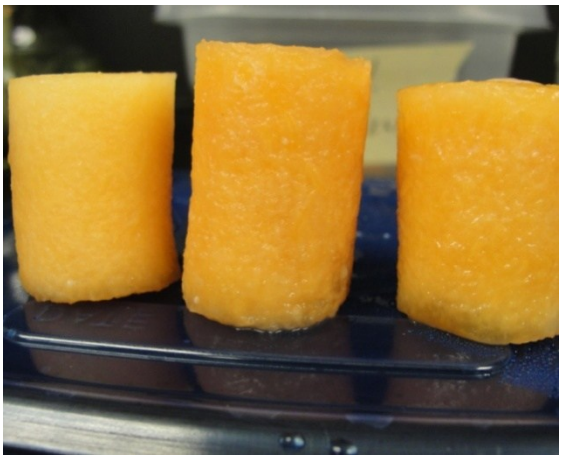
Figure 4-21. Comparison of uncoated samples from days 9 and 15 of storage.



3% Antimicrobial concentration: Day 15.



2% Antimicrobial concentration: Day 15.



1% Antimicrobial concentration: Day 15.

Figure 4-22. Comparison of coated samples with three different antimicrobial concentrations (1% pectin, 2% chitosan) on day 15.

4.6. Effect of antimicrobial agent concentration on cantaloupe sensory attributes

Fresh samples were prepared for every day of analysis to serve as controls. The current set was scheduled for the days 1, 5, 9, 13 and 15. Color acceptability for the coated and uncoated samples remained constant throughout storage with values above 6.0 (Figure 4-23). A slight preference towards the coated samples with 1% antimicrobial was observed. This trend became more obvious throughout storage, probably due to the better preservation of color by the coating; also samples with lower antimicrobial concentrations presented a clearer translucid color in the coating in comparison to the whitish color observed for 3% antimicrobial concentration.

Odor scores varied slightly for the controls and coated samples, but always showing values above 5.5 (Figure 4-24). No particular trend was observed for any of the coated samples; however preference for the 1% antimicrobial concentration was identified when it was compared to the other two coatings, probably due to a less concentrated cinnamon odor in the coating. Similarly occurred to samples with 2% antimicrobial concentration which were preferred over samples coated with 3% antimicrobial.

Flavor parameter scores showed a slight preference for samples coated with 1% antimicrobial in comparison to the other coatings (Fig. 4-25). Controls received significant ($P<0.05$) higher scores than the coated samples; these two trends are due to the consumer's preference towards the lowest concentration of *trans*-cinnamaldehyde in the fruit.

Texture values fluctuated throughout storage without preference for any of the coated samples (Fig. 4-26). All scores received up to the day 13 of evaluation were above 5.0, demonstrating consumer's acceptability. However on the day 15 a noticeable decrease was observed for all three coating treatments. Different concentrations of antimicrobial did not affect texture values. Controls scores remained constant throughout evaluation.

Overall quality values for control samples presented a significant ($P<0.05$) preference over the rest of the coated samples throughout the evaluation. Preference for 1% antimicrobial concentration among coated samples was observed until the day 13; and by day 15, all antimicrobial treatments showed low consumer's acceptability receiving scores around 4.5. Samples with 1% antimicrobial received the highest score (5.03). Overall quality results were highly affected by odor and flavor, indicating consumer's preference towards lower concentrations of *trans*-cinnamaldehyde in the coating.

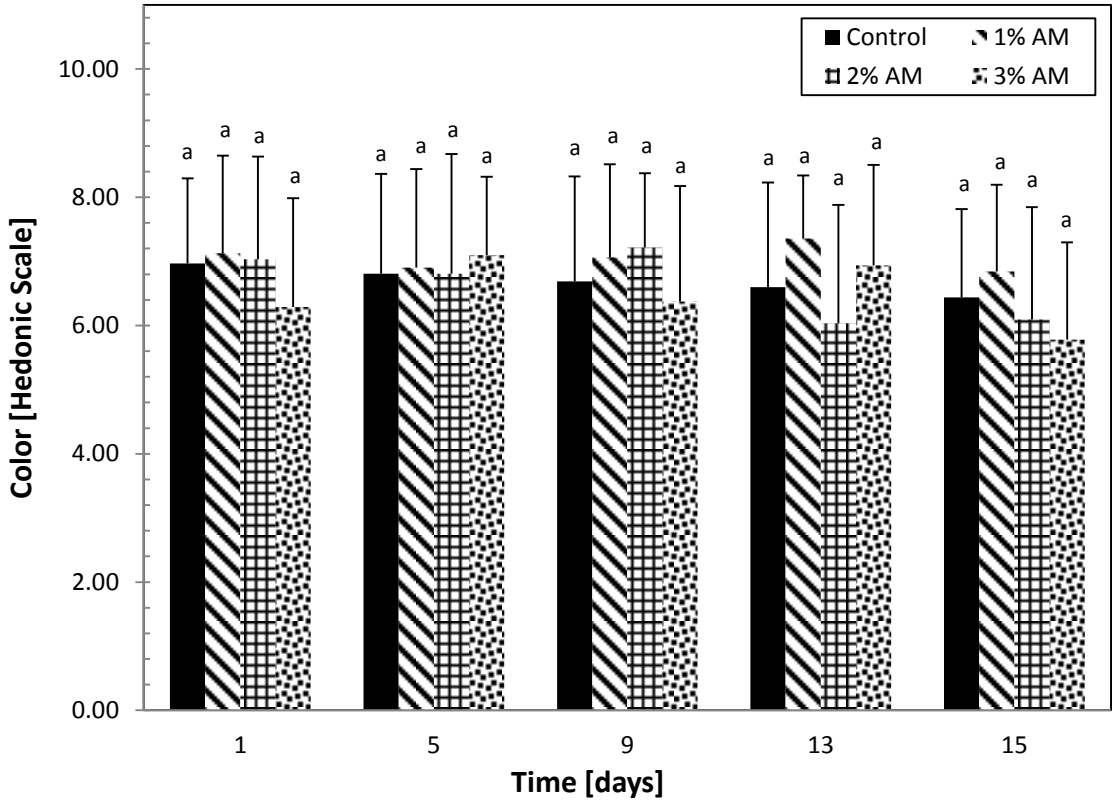


Figure 4-23. Sensory color analysis scores for control (uncoated) and coated (2% chitosan, 1% pectin) fresh-cut cantaloupe with different antimicrobial (AM) concentrations stored at 4^{o}C during 15 days. A score of 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely. Fresh samples were prepared for every day of evaluation to serve as controls.

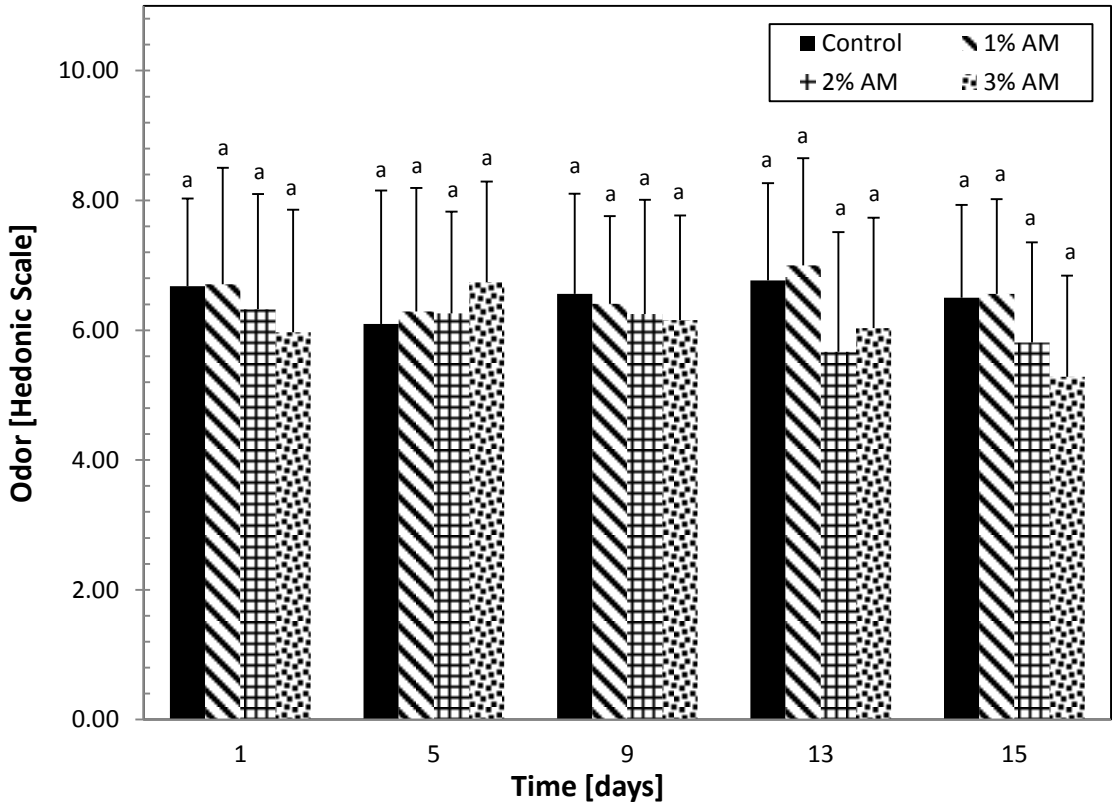


Figure 4-24. Sensory odor analysis scores for control (uncoated) and coated (2% chitosan, 1% pectin) fresh-cut cantaloupe with different antimicrobial (AM) concentrations stored at 4^{o}C during 15 days. A score of 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely. Fresh samples were prepared for every day of evaluation to serve as controls.

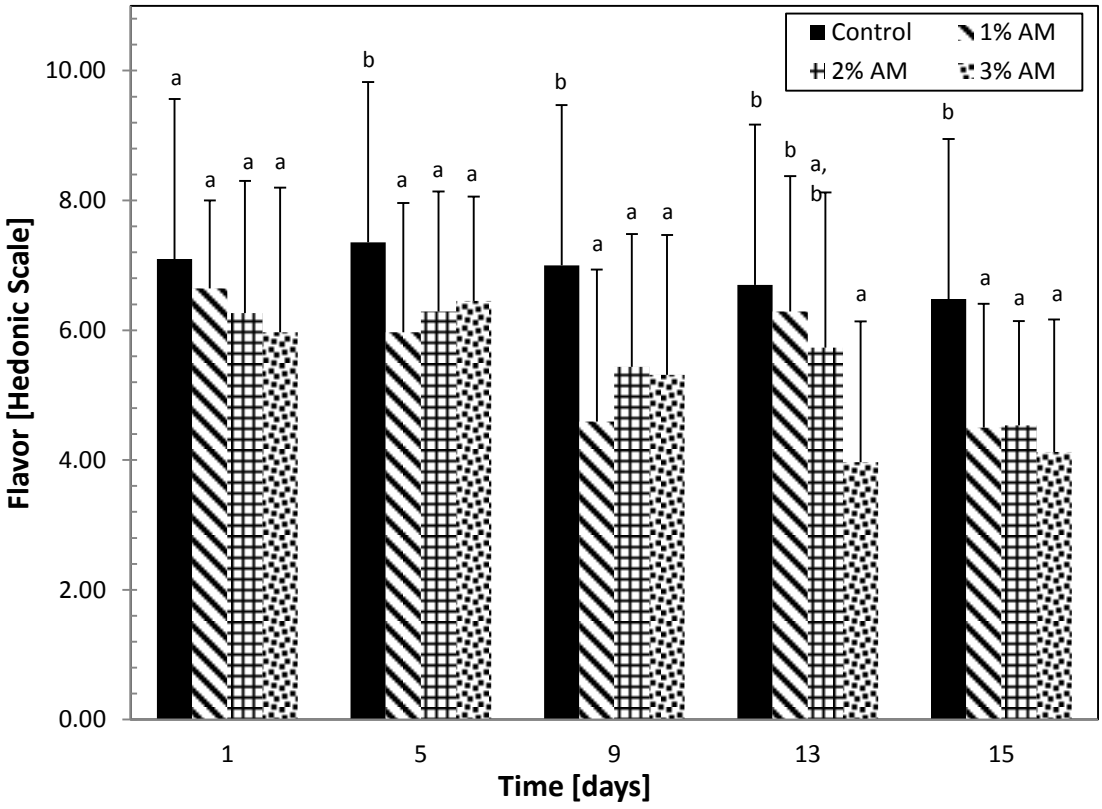


Figure 4-25. Sensory flavor analysis scores for control (uncoated) and coated (2% chitosan, 1% pectin) fresh-cut cantaloupe with different antimicrobial (AM) concentrations stored at 4^{o}C during 15 days. A score of 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely. Fresh samples were prepared for every day of evaluation to serve as controls.

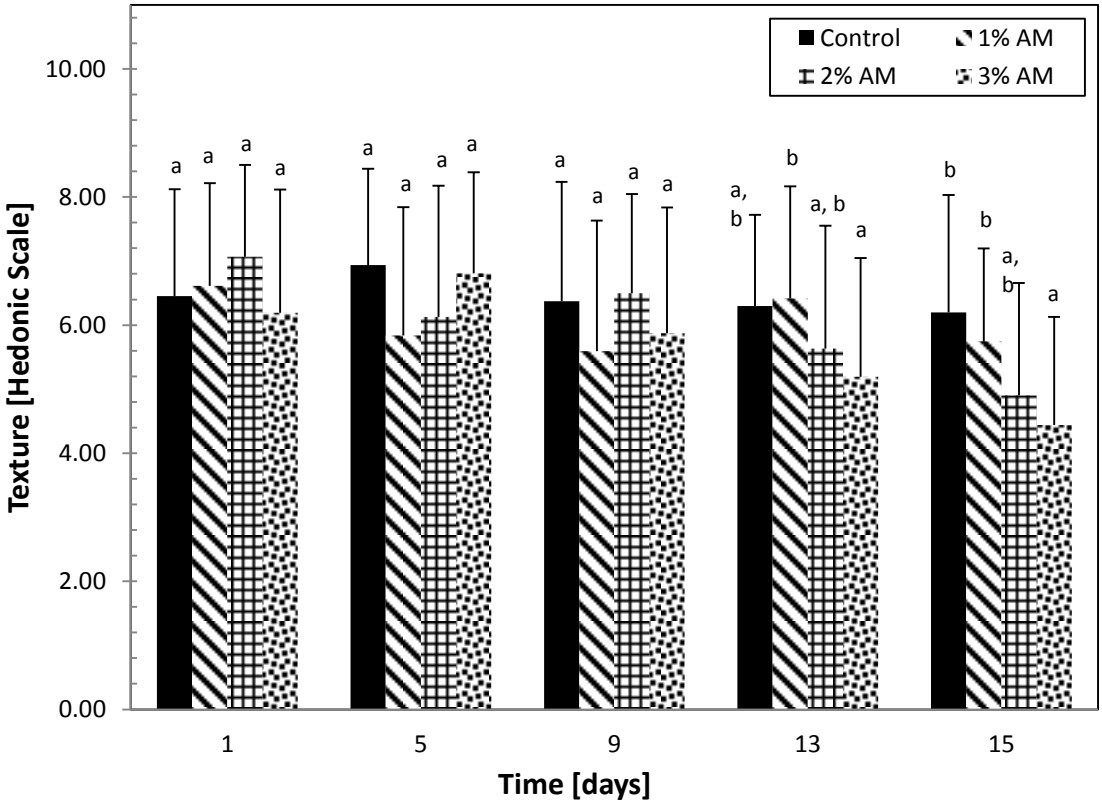


Figure 4-26. Sensory texture analysis scores for control (uncoated) and coated (2% chitosan, 1% pectin) fresh-cut cantaloupe with different antimicrobial (AM) concentrations stored at 4^{o}C during 15 days. A score of 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely. Fresh samples were prepared for every day of evaluation to serve as controls.

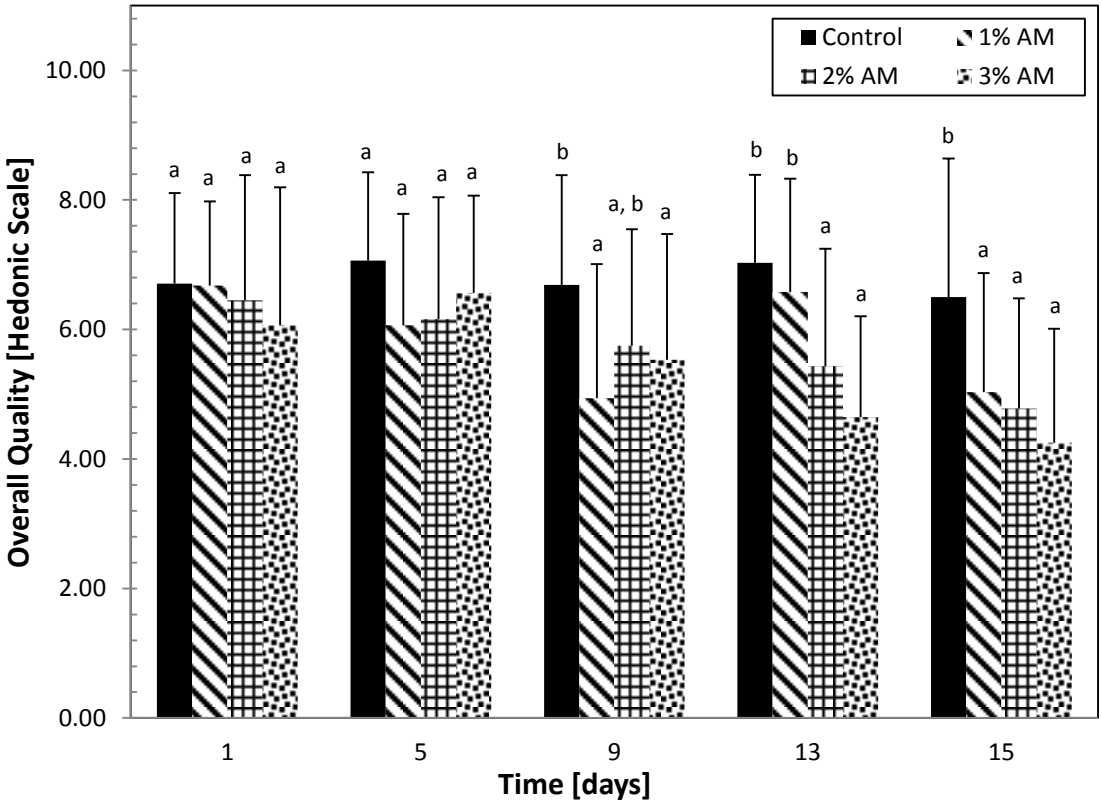


Figure 4-27. Sensory overall quality analysis scores for control (uncoated) and coated (2% chitosan, 1% pectin) fresh-cut cantaloupe with different antimicrobial (AM) concentrations stored at 4^{o}C during 15 days. A score of 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely. Fresh samples were prepared for every day of evaluation to serve as controls.

CHAPTER V

CONCLUSIONS

The effect of application of an edible coating on the quality and shelf-life of fresh-cut cantaloupe was evaluated. Coating parameters investigated included chitosan concentration (0.5, 1, and 2%), pectin concentration (0.5, 1, and 2%) and antimicrobial compound concentration (1, 2, and 3%). Cantaloupe chemical properties (acidity, ^{o}Brix, pH, juice leakage) and product quality attributes (color, moisture, firmness, sensory attributes) were evaluated in a shelf-life study at 4 ^{o}C during 15 days. In addition, microbiological analysis was carried out to determine the antimicrobial functionality of the edible coating. Moreover, different coating compositions were studied to identify the effect of each ingredient individually at different concentrations.

The main results and conclusions drawn from this work are as follows:

- Chitosan coating of fresh-cut cantaloupe samples did not affect its chemical properties. Only a few slight differences were observed for acidity, moisture, ^{o}Brix, color, and pH in comparison to the controls. However, juice leakage was considerably reduced due to the coating's effectiveness as a barrier against moisture loss.
- Cantaloupe's firmness throughout storage was highly improved by the chitosan-based coating. Differences in force values were significant after day 6 of evaluation, when uncoated samples started to lose firmness while the coated fruits kept the same texture for longer. Higher concentrations of chitosan in the

coating resulted in higher compression values, therefore providing a harder texture to the sample.

- No particular trend was found on the effect of different concentrations of pectin in the coating. Juice leakage, sensory, and texture analysis provided the same results observed for 0.5% chitosan (with no changes on pectin concentration) accordingly.
- Microbiology analysis demonstrated that higher concentrations (2 and 3%) of encapsulated *trans*-cinnamaldehyde in the coating had a stronger effect against microbial population, particularly higher against mesophilic microorganisms (aerobic plate count). Chitosan alone presented antimicrobial activity only against yeast and moulds at a very low level.
- Different concentrations of antimicrobial compound (1, 2, and 3%) in the coating did not affect juice leakage, sensory acceptability nor texture; results were similar for 2% chitosan concentration (with no cinnamaldehyde variation).
- Sensory tests showed acceptance ($P<0.05$) of the coated samples when compared to the controls throughout storage. Antimicrobial compound and chitosan concentrations affect ($P<0.05$) consumer's acceptability. Higher concentrations (3%) resulted in a product that differed from original cantaloupe characteristics, like odor, flavor, and appearance; moreover, high concentrations of chitosan (2%) made the perception of the coating more noticeable on the cantaloupe's surface.

- Pictures from microscopic observations show the importance of the concentration of gelling agents in the coating to increase or reduce the thickness of the edible film. Coating's thickness is directly proportional to the amount of antimicrobial compound present in the coating, where a higher concentration of encapsulated *trans*-cinnamaldehyde had more antimicrobial activity. It is worth to mention that very high thicknesses are not desirable either, since this will affect the product's appearance and influence acceptability among consumers by making the coating more noticeable.
- The use of edible coatings with incorporated encapsulated *trans*-cinnamaldehyde has potential as means to extend the shelf-life of fresh-cut cantaloupe, since changes in coating's composition resulted in different improvements on the product quality attributes.
- Overall, the best coating was made of 2% chitosan, 2% antimicrobial compound, and 1% pectin. This particular treatment was the best alternative to maintain cantaloupe's original quality attributes for longer, gained the best acceptability among consumers, and fulfilled the shelf-life extension requirement after 12 days in storage.
- Concentration of pectin and antimicrobial compound work at their best at 1% and 2%, respectively. While 2% chitosan proved to be highly effective in moisture and firmness retention, appearance was not entirely accepted by the consumer, as some comments about a visible coating or pieces of film were noted during the sensory test. On the other hand, differences in appearance of fruits coated with

chitosan at 1% were barely noticeable, and these samples received high scores during the sensory test; however, they were not accepted after day 9 of experiments due to a decrease in firmness and the presence of yeasts on the surface of the product. A further study involving a 1.5% chitosan concentration is recommended to find a better ratio that will improve the relationship between appearance and quality attributes.

CHAPTER VI

RECOMMENDATIONS FOR FURTHER STUDY

Recommendations for future research on fresh-cut cantaloupe edible coating include to:

- Develop a set of experiments for chitosan's concentration in a range between 1% and 2% in the coating, to find the best relationship between appearance and quality attributes in the product.
- Measure the viscosity of pectin, chitosan, and calcium chloride solutions to estimate the amount of coating in the surface area of cantaloupe pieces.
- Quantify the amount of antimicrobial present in the coating to keep the same proportion when decreasing the thickness of the coating.
- Train a panel of consumers for the sensory test to implement the variation among quality attributes.
- Develop a device that will make the dipping of cantaloupe cylinders more effective by avoiding cross contamination from excessive handling.
- Study the effect of the edible coating in the retention of carotenoids in fresh-cut cantaloupe.
- Evaluate the importance of the degree of ripeness in cantaloupe before coating and its effect on the quality attributes.
- Find another possible antimicrobial agent that would have a better affinity in organoleptic attributes with fresh-cut cantaloupe.

- Evaluate a better technique that will produce a uniform, transparent, odorless, and flavorless coating system.
- Use vacuum impregnation to incorporate the antimicrobial agent into the product and then to coat the product to prevent the loss of firmness.

REFERENCES

Agar, I.T., Massantini, R., Hess-Pierce, B., Kader, A.A., 1999. Postharvest CO_2 and ethylene production and quality maintenance of fresh-cut kiwifruit slices. Journal of Food Science 64, 433-440.

Aguayo, E., Allende, A., Artés, F., 2003. Keeping quality and safety of minimally fresh processed melon. European Food Research and Technology 216, 494– 499.

Aguayo, E., Escalona, V.H., Artés, F., 2004. Metabolic behavior and quality changes of whole and fresh processed melon. Journal of Food Science 69, S148–S155.

Aguayo, E., Escalona, V.H., Artés, F., 2007. Quality of minimally fresh processed *Cucumis melo* var. *saccharinus* as improved by controlled atmosphere. European Journal of Horticultural Science 72, 39–45.

Almeida, D.P.F., Huber, D.J., 1999. Apoplastic pH and inorganic ion levels in tomato fruit: a potential means for regulation of cell wall metabolism during ripening. Physiologia Plantarum 105, 506–512.

AOAC., 1990. Official Methods of Analysis of the Association of Official Analytical Chemists. Fifteenth edition. Washington, DC: AOAC.

Ariga, K., Ji, Q., Hill, J.P. 2010. Enzyme-encapsulated layer-by-layer assemblies: current status and challenges toward ultimate nanodevices. Adv Polym Sci 229: 51-87.

Bai, J.H., Saftner, R.A., Watada, A.E., Lee, Y.S., 2001. Modified atmosphere maintains quality of fresh-cut cantaloupe (Cucumis melo L.). Journal of Food Science 66, 1207–1211.

Bai, J.H., Saftner, R.A., Watada, A.E., 2003. Characteristics of fresh-cut honeydew (Cucumis melo L.) available to processors in winter and summer and its quality maintenance by modified atmosphere packaging. Postharvest Biology and Technology 28, 349 – 359.

Balau, L., 2004. Physico-chemical properties of chitosan films. Central European Journal of Chemistry 2, 638 – 647.

Baldwin, E.A., Nisperos, M.O., Chen, X., Hagenmaier, R.D., 1996. Improving storage life of cut apple and potato with edible coating. Postharvest Biology and Technology 9, 151-163.

Baofeng, L., Yumin, D., Xingquan, L., Xiaoying, W., Xiaohui, W., Jianhong, Y., 2010. Effect of chitosan coating on respiratory behavior and quality of stored litchi under ambient temperature, Journal of Food Engineering, doi: 10.1016/j.jfoodeng.2010.08.009.

Barth, M., 2000. Current status of the fresh-cut produce industry and future directions. IFT Annual Meeting, New Orleans, LA. Abstract 71–6.

Beaulieu J.C., Ingram, D.A., Lea, J.M., Bett-Garber, K.L., 2004. Effect of harvest maturity on the sensory characteristics of fresh-cut cantaloupe. Journal of Food Science 69, 250–258.

Beuchat, L.R., 1994. Antimicrobial properties of spices and their essential oils. In V.M. Dillon, R.G. Board, (Eds.), Natural antimicrobial systems and food preservation. p.328 Wallingford, U.K., Cab Intl.

Bode, A. M., Cunningham, L., Rose, R. C., 1990. Spontaneous decay of oxidized ascorbic acid (dehydro-L-ascorbic acid) evaluated by high-pressure liquid chromatography. Clinical Chemistry 36, 1807-1809.

Bourtoom, T., 2008. Edible films and coatings: characteristics and properties. International Food Research Journal, 15 (3), 237-248.

Brecht, J. K., 1995. Physiology of lightly processed fruits and vegetables' in lightly processed fruits and vegetables. HortScience 30,18 – 22.

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

Cagri, A., Ustunol, Z., Ryser, E.T., 2004. Antimicrobial edible films and coatings: review. Journal of Food Protection 67, No. 4, 833–848.

Campos, C.A., Gerschenson, L.N., Flores S.K., 2011. Development of edible films and coatings with antimicrobial activity: review paper. Food Bioprocess Technol 4, 849-875.

Cantwell, M.A., Suslow, T.V., 2002. Postharvest handling systems: fresh-cut fruits and vegetables. In A.A. Kader, (Ed.), Postharvest Technology of Horticultural Crops, third ed. pp. 445-463 Oakland, CA: Univ. Calif., Agric. Natural Res. Publ. 3311.

Carr, B.T., Meilgaard, M., Civille, G.V., 1999. Sensory evaluation techniques. Third ed. Washington, DC: CRC Press.

Caruso, F., Mohwald, H., 1999. Protein multilayer formation on colloids through a stepwise self-assembly technique. J. Amer. Chem. Soc., 121, 6039-6046.

Castell-Perez, E., Moreno, M., Rodriguez, O., Moreira,R.G., 2004. Electron beam irradiation treatment of cantaloupes: effects on product quality. Food Science and Technology International 10, 383 – 390.

Chantanawarangoon, S., Kader, A.A., 2002. Calcium treatments and modified atmospheres extended post-cutting life of mango cubes. Presented at the Institute of Food Technologists' Annual Meeting and Food Expo, Anaheim, CA, 2002.

Corbo, M.R., Altieri, C., D'Amato, D., Campaniello, D., Del Nobile, M.A., Sinigaglia, M., 2004. Effect of temperature on shelf life and microbial population of lightly processed cactus pear fruit. Postharvest Biology and Technology 31, 93–104.

Dawson, P.L., Carl, G.D., Acton, J.C., Han, I.Y., 2002. Effect of lauric acid and nisin-impregnated soy-based films on the growth of *Listeria monocytogenes* on turkey bologna. Poultry Science 81, 721–726.

Devlieghere, F., Vermeulen, A., Debevere, J., 2004. Chitosan: antimicrobial activity, interactions with food components and applicability as a coating on fruit and vegetables. Food Microbiology 21, 703 – 714.

Eswaranandam, S., Hettiarachchy, N.S., Meullenet, J.F., 2006. Effect of malic and lactic acid incorporated soy protein coatings on the sensory attributes of whole apple and fresh-cut cantaloupe. Journal of Food Science 71, 307–313.

Fan, X., Annous, B.A., Beaulieu, J.C., Sites, J.E., 2008. Effect of hot water surface pasteurization of whole fruit on shelf life and quality of fresh-cut cantaloupe. Journal of Food Science 73, M91 – M98.

Fernandez-Cervera, M., Karjalainen, M., Airaksinen, S., Rantanen, J., Krogars, K., Heinamaki, J., 2004. Physical stability and moisture sorption of aqueous chitosan–amylose starch films plasticized with polyols. European Journal of Pharmaceutics and Biopharmaceutics, 58, 69–76.

Garcia, E., Barret, D.M., 2002. Preservative treatments for fresh cut fruits and vegetables. In O. Lamikanra, Ed., Fresh-cut Fruits and Vegetables, pp. 267–304. Boca Raton, Florida: CRC Press.

Gaziano, J.M., Hennekens, C.H., 1993. The role of beta-carotene in the prevention of cardiovascular disease. In L.M. Canfield, N.I. Krinsky, J.A. Olson, (Eds.), Carotenoids in human health. pp. 148-155 Buffalo, NY: Academia of Science.

Gil, M.I., Aguayo, E., Kader, A.A., 2006. Quality chances and nutrient retention in fresh-cut versus whole fruits during storage. Journal of Agricultural and Food Chemistry 54, 4284 – 4296.

Gill, A.O., Delaquis, P., Russo, P., Holley, R.A., 2002. Evaluation of antilisterial action of cilantro oil on vacuum packed ham. International Journal of Food Microbiology 73, 83– 92.

Glass, K.A., Johnson E.A., 2004. Antagonistic effect of fat on the antibotulinal activity of food preservatives and fatty acids. Food Microbiology 21, 675 – 682.

Gomes, C., 2010. Personal Communication. Biological & Agricultural Engineering Department, Texas A&M University.

Gomes, C., Moreira, R.G., Castell-Perez, E., 2011. Poly (DL-lactide-co-glycolide) (PLGA) nanoparticles with entrapped *trans*-cinnamaldehyde and eugenol for antimicrobial delivery applications. Journal of Food Science 76, N16 – N24.

Grassmann, J., Hippeli, S., Elstner E.F., 2002. Plant's defence and its benefits for animals and medicine: role of phenolics and tarpenoids in avoiding oxygen stress. Plant Physiology and Biochemistry 40, 471 – 478.

Gutierrez, J., Barry-Ryan, C., Bourke, P., 2008. The antimicrobial efficacy of plant essential oil combinations and interactions with food ingredients. International Journal of Food Microbiology 124, 91-97.

Harker, F.R., Sutherland, P.W., 1993. Physiological changes associated with fruit ripening and development of mealy texture during storage of nectarines. Postharvest Biology and Technology 2, 269-277.

Helander, I.M., Alakomi, H. L., Latva-Kala, K., Mattila-Sandholm, T., Pol, I., Smid, E.J., Gorris, L.G.M., Von Wright, A., 1998. Characterization of the action of selected essential oil components on gram-negative bacteria. Journal of Agricultural and Food Chemistry 46, 3590–3595.

Hussein, A., Odumeru, J.A., Ayanbadejo, T., Faulkner, H., McNab, W. B., Hager, H., Szijarto, L., 2000. Effects of processing and packaging on vitamin C and beta-carotene content of ready-to-use (RTU) vegetables. Food Research International 33, 131-136.

Kader, A.A., 2002. Quality parameters of fresh-cut fruit and vegetable products. pp. 11-28. In O. Lamikanra (Ed.) Fresh-cut fruits and vegetables. Science, technology and market. Boca Raton, FL: CRC Press.

King, A.D., Bolin, H.R., 1989. Physiological and microbiological storage stability of minimally processed fruits and vegetables. Food Technology 43, 132-139.

Klein, B.P., 1987. Nutritional consequences of minimal processing of fruits and vegetables. Journal of Food Quality 10, 179-193.

Lamikanra, O., Watson, M.A., 2004. Effect of calcium treatment temperature on fresh-cut cantaloupe melon during storage. Journal of Food Science 69, C468–C472.

Lanciotti, R., Belleti, N., Patrignani, F., Gianotti, A., Gardini, F., Guerzoni, E., 2003. Application of hexanal, (E)-2-hexenal and hexyl acetate to improve the safety of fresh-sliced apples. J. Agric. Food Chem. 51, 2958–2963.

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

Mancini, F., McHugh, T. H., 2000. Fruit–alginate interactions in novel restructured products. Nahrung, 44, 152–157.

Martin-Belloso, O., Soliva-Fortuny, R., Oms-Oliu, G., 2006. Fresh-cut fruits. In Y.H. Hui, (Ed.), Handbook of fruits and fruit processing. pp. 129-144. Ames, IA: Blackwell publishing.

McCarthy, M.A., Matthews, R.H., 1994. Nutritional quality of fruits and vegetables subject to minimal processes. In R.C. Wiley, (Ed.), Minimally processed refrigerated fruits and vegetables. pp.313-326. Buffalo, NY: Chapman and Hall publishing.

McClements, D.J., Decker, E.A., Park, Y., 2009. Controlling lipid bioavailability through physicochemical and structural approaches. Critical Reviews in Food Science and Nutrition 49 (1), 48-67

Mejlholm, O., Dalgaard, P., 2002. Antimicrobial effect of essential oils on the seafood spoilage micro-organism Photobacterium phosphoreum in liquid media and fish products. Letters in Applied Microbiology 34, 27– 31.

Min, S., Krochta, J.M., 2005. Inhibition of Penicillium commune by edible whey protein films incorporating lactoferrin, lactoferrin hydrolysate, and lactoperoxidase systems. Journal of Food Science 70, 87-94.

Nazer, A.I., Kobilinsky, A., Tholozana, J.L., Dubois-Brissonneta, F., 2005. Combinations of food antimicrobials at low levels to inhibit the growth of *Salmonella Typhimurium*: a synergistic effect. Food Microbiology 22, 391– 398.

No, H.K., Meyers, S.P., Prinyawiwatkul, W., Xu, Z., 2007. Applications of chitosan for improvement of quality and shelf life of foods: a review. Journal of Food Science 72, R87 – R100.

Nunes, M.C.N., Brecht, J.K., Morais, A.M.M.B., Sargent, S.A., 1998. Controlling temperature and water loss to maintain ascorbic acid levels in strawberries during postharvest handling. Journal of Food Science 63, 1033-1036.

O'Connor-Shaw, R.E., Roberts, R., Ford, A.L., Nottingham, S.M., 1994. Shelf life of minimally processed honeydew, kiwifruit, papaya, pineapple and cantaloupe. Journal of Food Science 59, 1202–1206, 1215.

Olivas, G.I., Barbosa-Canovas, G.V., 2005. Edible coatings for fresh-cut fruits. Critical Reviews in Food Science and Nutrition 45, 657–670.

Oms-Oliu, G., Aguilo-Aguayo, I., Martin-Belloso, O., 2006. Inhibition of browning on fresh-cut pear wedges by natural compounds. Journal of Food Science 71, S216 – S224.

Oms-Oliu, G., Soliva-Fortuny, R., Martin-Belloso, O., 2007. Effect of ripeness on the shelf-life of fresh-cut melon preserved by modified atmosphere packaging. European Food Research and Technology 225, 301-311.

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. Food Science and Technology 41, 1862 – 1870.

Pandit, V.A., Shelef, L.A., 1994. Sensitivity of Listeria monocytogenes to rosemary (Rosmarinus officinalis L.). Food Microbiology 11, 57– 63.

Park, H.J., 1999. Development of advanced edible coatings for fruits. Trends in Food Science and Technology 10, 254-260.

Ponting, J.D., Jackson, R., Watters, G., 1972. Refrigerated apple slices: Preservative effects of ascorbic acid, calcium and sulfites. Journal of Food Science 37, 436–436.

Poovaiah, B.W., Glenn, G.M., Reddy, A.S.N., 1988. Calcium and fruit softening: physiology and biochemistry. Hortic. Rev 10, 107–152.

Pranoto, Y., Salokhe, V., Rakshit, K.S., 2005. Physical and antibacterial properties of alginate-based edible film incorporated with garlic oil. Food Research International 38, 267-272.

Puerta-Gomez, A.F., 2010. Personal Communication. Biological & Agricultural Engineering Department, Texas A&M University.

Raybaudi-Massilia, R.M., Mosqueda-Melgar, J., Sobrino-López, A., Soliva-Fortuny, R., Martin-Belloso, O., 2007. Shelf-life extension of fresh-cut Fuji apples at different ripeness stages using natural substances. Postharvest Biology and Technology 45, 265–275.

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

Rocha, A.M.C.N., Brochado, C.M., Morais, A.M.M.B., 1998. Influence of chemical treatment on quality of cut apple. Journal of Food Quality 21, 13–28.

Rojas-Grau, M.A., Tapia, M.S., Rodríguez, F.J., Carmona, A.J., Martin-Belloso, O., 2007. Alginate and gellan-based edible coatings as carriers of antibrowning agents applied on fresh-cut Fuji apples. Food Hydrocolloids 21, 118 – 127.

Rojas-Grau, M.A., Tapia, M.S., Martin-Belloso, O., 2008. Using polysaccharide-based edible coatings to maintain quality of fresh-cut Fuji apples. Food Science and Technology 41, 139-147.

Roller, S., 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.

Saladie, M., Matas, A.J., Isaacson, T., Jenks, M.A., Goodwin, S.M., Niklas, K.J., Xiaolin, R., Labavitch, J.M., Shackel, K.A., Fernie, A.R., Lytovchenko, A., O'Neill, M.A., Watkins, C.B., Rose, J.K.C., 2007. A re-evaluation of the key factors that influence tomato fruit softening and integrity. Plant Physiology 144, 1012–1028.

Sams, C.E., 1999. Preharvest factors affecting postharvest texture. Postharvest Biology and Technology 15, 249–254.

Sapers, G.M., 1993. Browning of foods – control by sulfites, antioxidants, and other means. Food Technology 47, 75 – 84.

Sapers, G.M., Miller, R.L., Pilizota, V., Mattrazzo, A.M., 2001. Antimicrobial treatments for minimally processed cantaloupe melon. Journal of Food Science 65, 529–532.

Seacheol, M., Krochta, J.M., 2005. Inhibition of penicillium commune by edible whey protein films incorporating lactoferrin, lactoferrin hydrolysate, and lactoperoxidase systems. Journal of Food Science 70, M87–M94.

Sebti, I., Ham-Pichavant, F., Coma, V., 2002. Edible bioactive fatty acid-cellulsic derivative composites used in food-packaging applications. Journal of Agricultural and Food Chemistry 50, 4290–4294.

Shackel. K.A., Greve. C., Labavitch, J.M., Ahmadi, H., 1991. Cell turgor changes associated with ripening in tomato pericarp tissue. Plant Physiology 97, 814 – 816.

Shelef, L.A., Jyothi, E.K., Bulgarelli, M.A., 1984. Growth of enteropathogenic and spoilage bacteria in sage-containing broth and foods. Journal of Food Science 49 (737–740), 809.

Silveira, A.C., Conesa, A., Aguayo, E., Artes, F., 2008. Alternative sanitizers to chlorine for use on fresh-cut "Galia" (*Cucumis melo* var. *catalupensis*) melon. Journal of Food Science 73, M405 – M411.

Smith M., (2006). Promoting produce food safety and defense. Institute of Food Technologist Annual Meeting, Abstract 026–06.

Smith-Palmer, A., Stewart, J., Fyfe, L., 2001. The potential application of plant essential oils as natural food preservatives in soft cheese. Food Microbiology 18, 463–470.

Soliva-Fortuny, R.C., Martín-Belloso, O., 2003. New advances in extending the shelf-life of fresh-cut fruits: a review. Trends in Food Science and Technology 14, 341 – 353.

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

Tassou, C., Drosinos, E.H., Nychas, G.J.E., 1995. Effects of essential oil from mint (Mentha piperita) on Salmonella enteritidis and Listeria monocytogenes in model food systems at 4 °C and 10 °C. Journal of Applied Bacteriology 78, 593– 600.

Toivonen, P.M.A., Brummell, D.A., 2008. Biochemical bases of appearance and texture changes in fresh-cut fruit and vegetables. Postharvest Biology and Technology 48, 1-14.

Tsigarida, E., Skandamis, P., Nychas, G.J.E., 2000. Behaviour of Listeria monocytogenes and autochthonous flora on meat stored under aerobic, vacuum and modified atmosphere packaging conditions with or without the presence of oregano essential oil at 5 °C. Journal of Applied Microbiology 89, 901–909.

USDA., 2007. US Food and Drug Administration Center for Food Safety and Applied Nutrition. Approximate pH of foods and food products. http://www.foodscience.caes.uga.edu/extension/documents/FDAapproximatepHoffoodslacf-phs.pdf. Accessed on August 4th, 2010.

USDA/ARS., 2011. National Nutrient Database for Standard Reference. http://www.nal.usda.gov/fnic/foodcomp. Accesed on July 29th, 2011.

USFDA, 2003. Nutrient database for standard reference. Release 15, Washington, DC: United States Department of Agriculture.

Valdenegro, M., Flores, F.B., Romojaro, F., Ramirez, M., Martinez- Madrid, M.C., 2004. Susceptibility of Spanish melon fruits to chilling injury during cold storage. In: F. Mencarelli, P. Tonutti, (Eds.), Proceedings of the Fifth International Postharvest Symposium, 6–11 June 2004, Acta Horticulturae 682. International Society for Horticultural Science, Belgium 2, 1219–1225.

Vamos-Vigyazo, L., 1981. Polyphenol oxidase and peroxidase in fruits and vegetables. Critical Reviews in Food Science and Nutrition 15, 49 – 127.

Van de Braak, S.A.A.J., Leijten, G.C.J.J., 1999. Essential oils and oleoresins: a survey in the Netherlands and other major markets in the European Union. CBI, Rotterdam. Centre for the Promotion of Imports from Developing Countries, 116.

Villanueva, C.M., Cantor, K.P., Cordier, S., Jaakkola, J.J., King, W.D., Lynch, C.F., Porru, S., Kogevinas, M., 2004. Disinfection by products and bladder cancer. A pooled analysis. Epidemiology 15,357–367.

Watada, A. E., Abe, K., Yamauchi, N., 1990. Physiological activities of partially processed fruits and vegetables. Food Technology 44, 116, 118, 120-122.

Watada, A.E., Ko, N.P., Minott, D.A., 1996. Factors affecting quality of fresh-cut horticultural products. Postharvest Biology and Technology 9, 115–125.

Wei, C.I., Huang, T.S., Kim, J.M., Lin, W.F., Tamplin, M.L., Bartz, J.A., 1995. Growth and survival of *Salmonella montevideo* on tomatoes and disinfection with chlorinated water. Journal of Food Protection 58, 829–836.

Wong, W.S., Tillin, S.J., Hudson, J.S., Pavlath, A.E., 1994. Gas exchange in cut apples with bilayer coatings. Journal of Agricultural and Food Chemistry, 42, 2278–2285.

Wright, K.P., Kader, A.A., 1997. Effect of slicing and controlled atmosphere storage on the ascorbate content and quality of strawberries and persimmons. Postharvest Biology and Technology 10, 39-48.

Yang, L., Paulson, A.T., 2000. Effects of lipids on mechanical and moisture barrier properties of edible gellan film. Food Research International 33, 571–578.

APPENDIX A

Acceptance Test: 647

Place a mark in the box which you feel best describes how you like the sample.
An honest expression of your personal feelings will help us. Thank you.

Color	☐ Like extremely	☐ Like Very much	☐ Like moderately	☐ Like slightly	☐ Neither like nor dislike	☐ Dislike slightly	☐ Dislike moderately	☐ Dislike very much	☐ Dislike extremely
Odor	☐ Like extremely	☐ Like Very much	☐ Like moderately	☐ Like slightly	☐ Neither like nor dislike	☐ Dislike slightly	☐ Dislike moderately	☐ Dislike very much	☐ Dislike extremely
Texture	☐ Like extremely	☐ Like Very much	☐ Like moderately	☐ Like slightly	☐ Neither like nor dislike	☐ Dislike slightly	☐ Dislike moderately	☐ Dislike very much	☐ Dislike extremely
Flavor	☐ Like extremely	☐ Like Very much	☐ Like moderately	☐ Like slightly	☐ Neither like nor dislike	☐ Dislike slightly	☐ Dislike moderately	☐ Dislike very much	☐ Dislike extremely
Overall Quality	☐ Like extremely	☐ Like Very much	☐ Like moderately	☐ Like slightly	☐ Neither like nor dislike	☐ Dislike slightly	☐ Dislike moderately	☐ Dislike very much	☐ Dislike extremely

Comments:

APPENDIX B

Effect of different chitosan concentrations on the moisture content (MC) of control (uncoated) and coated (2% antimicrobial, 2% pectin) cantaloupe samples stored at 4°C during 15 days.

Time (days)	Control	0.5% Chitosan	1.0% Chitosan	2.0% Chitosan	Non-antimicrobial (1.0% chitosan)
1	0.905 [a] [1] (0.006)	0.900 [a] (0.008)	0.914 [a] (0.011)	0.903[a] (0.018)	0.913 [a] (0.003)
4	0.903 [a] (0.009)	5.80 [a] (0.007)	0.908 [a] (0.008)	0.925 [a] (0.021)	0.909 [a] (0.011)
6	0.905 [a] (0.018)	0.903 [a] (0.007)	0.907 [a] (0.008)	0.905 [a] (0.006)	0.907 [a] (0.013)
10	0.906 [a] (0.011)	0.908 [a] (0.008)	0.906 [a] (0.005)	0.921 [a] (0.009)	0.915 [a] (0.007)
15	0.904 [a] (0.004)	0.901 [a] (0.008)	0.909 [a] (0.006)	0.913 [a] (0.010)	0.912 [a] (0.004)

[1]Standard deviation

[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Effect of different chitosan concentrations on the maximum force [N] required to compress control (uncoated) and coated (2% antimicrobial, 2% pectin) cantaloupe samples stored at 4°C during 15 days.

Time (days)	Control	0.5% Chitosan	1.0% Chitosan	2.0% Chitosan	Non-antimicrobial (1.0% chitosan)
1	35.75 [a] [1] (8.48)	39.13 [a] (1.81)	42.23 [a] (5.52)	53.20 [b] (9.31)	39.18 [a] (3.55)
4	31.18 [a] (5.78)	38.82 [b] (5.95)	42.90 [b] (9.29)	51.66 [c] (5.48)	44.10 [b] (5.73)
6	26.03 [a] (8.40)	41.02 [b] (6.23)	40.03 [b] (5.29)	54.00 [c] (6.92)	37.31 [b] (10.78)
10	23.34 [a] (3.39)	37.08 [b] (4.13)	35.55 [b] (6.54)	52.05 [c] (8.20)	40.95 [b] (5.92)
15	10.18 [a] (3.80)	38.44 [b, c] (4.97)	31.91 [b] (7.37)	45.13 [c] (6.69)	30.75 [b] (8.26)

[1]Standard deviation

[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Effect of different chitosan concentrations on the color sensory attribute of control (uncoated) and coated (2% antimicrobial, 2% pectin) cantaloupe samples stored at 4°C during 15 days.

Time (days)	Control	0.5% Chitosan	1.0% Chitosan	2.0% Chitosan	Non-antimicrobial (1.0% chitosan)
1	7.03 [a] [1] (1.40)	7.06 [a] (1.72)	6.97 [a] (1.64)	6.84 [a] (1.37)	7.31 [a] (1.31)
5	7.00 [a] (1.18)	6.52 [a] (1.59)	7.06 [a] (1.21)	6.71 [a] (1.51)	6.77 [a] (1.15)
9	7.27 [a] (1.14)	6.73 [a] (1.23)	6.70 [a] (1.47)	6.37 [a] (1.47)	7.10 [a] (1.12)
13	5.77 [b] (1.92)	5.90 [b] (1.92)	4.93 [a] (1.86)	4.57 [a] (1.72)	5.89 [b] (1.73)
15	4.33 [b] (2.15)	4.67 [b] (2.25)	4.17 [a, b] (2.13)	3.27 [a] (2.20)	4.50 [b] (2.21)

[1]Standard deviation

[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Effect of different chitosan concentrations on the odor sensory attribute of control (uncoated) and coated (2% antimicrobial, 2% pectin) cantaloupe samples stored at 4°C during 15 days.

Time (days)	Control	0.5% Chitosan	1.0% Chitosan	2.0% Chitosan	Non-antimicrobial (1.0% chitosan)
1	6.31 [a] [1] (1.69)	5.88 [a] (2.00)	5.41 [a] (1.97)	5.59 [a] (1.85)	6.25 [a] (1.88)
5	6.84 [b] (1.27)	5.58 [a] (1.57)	6.13 [a] (1.89)	5.84 [a] (1.29)	6.58 [a] (1.36)
9	6.37 [b] (1.50)	5.33 [a] (1.56)	5.00 [a] (1.78)	5.13 [a] (1.74)	7.00 [b] (1.49)
13	5.57 [a] (1.77)	5.07 [a] (1.96)	5.13 [a] (1.87)	4.87 [a] (2.10)	5.87 [a] (1.79)
15	3.67 [a] (1.83)	4.07 [a] (1.70)	3.57 [a] (1.50)	2.93 [a] (1.70)	3.77 [a] (2.33)

[1]Standard deviation
[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Effect of different chitosan concentrations on the texture sensory attribute of control (uncoated) and coated (2% antimicrobial, 2% pectin) cantaloupe samples stored at 4°C during 15 days.

Time (days)	Control	0.5% Chitosan	1.0% Chitosan	2.0% Chitosan	Non-antimicrobial (1.0% chitosan)
1	6.59 [a] [1] (1.60)	6.25 [a] (1.85)	6.09 [a] (2.05)	5.91 [a] (1.77)	6.91 [a] (1.49)
5	6.71 [a] (1.40)	5.84 [a] (1.63)	6.77 [a] (1.23)	6.06 [a] (1.71)	6.65 [a] (1.28)
9	7.03 [b] (1.00)	5.73 [a] (1.74)	5.87 [a] (1.78)	5.90 [a] (1.63)	6.67 [a, b] (1.67)
13	5.70 [a] (1.73)	5.87 [a] (1.89)	5.63 [a] (1.90)	4.93 [a] (2.02)	5.80 [a] (1.65)
15	4.13 [a] (1.91)	4.77 [a] (1.98)	4.50 [a] (2.29)	4.13 [a] (2.22)	4.27 [a] (2.36)

[1]Standard deviation
[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Effect of different chitosan concentrations on the flavor sensory attribute of control (uncoated) and coated (2% antimicrobial, 2% pectin) cantaloupe samples stored at 4°C during 15 days.

Time (days)	Control	0.5% Chitosan	1.0% Chitosan	2.0% Chitosan	Non-antimicrobial (1.0% chitosan)
1	6.81 [b] [1] (1.79)	5.34 [a] (2.42)	5.50 [a] (2.24)	5.13 [a] (2.20)	6.81 [b] (1.67)
5	6.84 [b] (1.90)	5.19 [a] (1.82)	6.00 [a] (1.83)	5.23 [a] (1.76)	6.29 [b] (1.64)
9	6.80 [b] (1.52)	4.47 [a] (2.00)	4.70 [a] (1.91)	4.97 [a] (1.88)	6.77 [b] (1.43)
13	5.53 [a] (1.40)	5.40 [a] (1.63)	5.35 [a] (1.23)	4.69 [a] (1.37)	5.04 [a] (1.12)
15	4.07 [a] (1.72)	4.50 [a] (1.77)	3.50 [a] (1.80)	3.20 [a] (1.71)	4.09 [a] (1.79)

[1]Standard deviation
[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Effect of different chitosan concentrations on the overall quality sensory attribute of control (uncoated) and coated (2% antimicrobial, 2% pectin) cantaloupe samples stored at 4^{o}C during 15 days.

Time (days)	Control	0.5% Chitosan	1.0% Chitosan	2.0% Chitosan	Non-antimicrobial (1.0% chitosan)
1	6.66 [b] [1] (1.70)	5.59 [a] (2.27)	5.63 [a] (2.08)	5.19 [a] (1.99)	6.66 [b] (1.75)
5	6.84 [b] (1.55)	5.45 [a] (1.79)	6.10 [a] (1.74)	5.55 [a] (1.57)	6.45 [b] (1.48)
9	6.80 [b] (1.16)	4.90 [a] (1.88)	4.97 [a] (1.87)	5.07 [a] (1.84)	7.07 [b] (1.05)
13	5.23 [a] (1.61)	5.37 [a] (1.90)	5.23 [a] (1.59)	4.70 [a] (1.86)	5.52 [a] (1.51)
15	3.73 [a] (1.82)	4.07 [a] (1.72)	3.60 [a] (1.81)	3.07 [a] (1.72)	3.93 [a] (2.07)

[1]Standard deviation

[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Effect of different pectin concentrations on the juice leakage percentage of control (uncoated) and coated (2% antimicrobial, 0.5% chitosan) cantaloupe samples stored at 4°C during 15 days.

Time (days)	Control	0.5% Pectin	1.0% Pectin	2.0% Pectin
4	2.79 [b] (0.62)	1.20 [a] (0.08)	1.30 [a] (0.13)	1.16 [a] (0.25)
6	4.65 [b] (1.13)	2.20 [a] (0.56)	2.10 [a] (0.16)	2.36 [a] (0.64)
10	5.94 [b] (0.98)	4.20 [a] (0.81)	3.80 [a] (1.29)	3.95 [a] (0.61)
15	8.37 [b] (0.82)	6.80 [a] (1.11)	7.10 [a] (0.53)	6.91 [a] (0.67)

[1]Standard deviation
[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Effect of different pectin concentrations on the maximum force [N] required to compress control (uncoated) and coated (2% antimicrobial, 0.5% chitosan) cantaloupe samples stored at 4°C during 15 days.

Time (days)	Control	0.5% Pectin	1.0% Pectin	2.0% Pectin
1	41.24 [a] [1] (8.87)	45.02 [a] (12.31)	45.45 [a] (9.15)	43.13 [a] (1.81)
4	32.14 [a] (4.08)	45.46 [b] (11.49)	43.85 [b] (7.05)	45.82 [b] (5.95)
6	27.57 [a] (4.24)	46.32 [b] (7.67)	38.43 [b] (6.05)	43.02 [b] (6.23)
10	31.90 [a] (7.50)	49.64 [b] (11.89)	43.73 [b] (7.70)	48.08 [b] (4.13)
15	27.09 [a] (4.83)	47.86 [b] (9.11)	42.97 [b] (7.39)	45.44 [b] (4.97)

[1]Standard deviation
[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Effect of different pectin concentrations on the color sensory attribute of control (uncoated) and coated (2% antimicrobial, 0.5% chitosan) cantaloupe samples stored at 4°C during 15 days.

Time (days)	Control	0.5% Pectin	1.0% Pectin
1	6.97 [a] (1.55)	6.84 [a] (1.20)	6.61 [a] (1.67)
4	6.94 [a] (1.43)	6.47 [a] (1.92)	6.78 [a] (1.51)
8	7.19 [a] (0.98)	6.47 [a] (1.65)	6.58 [a] (1.30)
10	7.51 [a] (1.25)	6.93 [a] (1.49)	6.83 [a] (1.32)
12	6.76 [a] (1.37)	6.67 [a] (1.37)	7.07 [a] (1.34)

[1]Standard deviation
[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Effect of different pectin concentrations on the odor sensory attribute of control (uncoated) and coated (2% antimicrobial, 0.5% chitosan) cantaloupe samples stored at 4^{o}C during 15 days.

Time (days)	**Control**	**0.5% Pectin**	**1.0% Pectin**
1	6.00 [a] (1.80)	5.74 [a] (1.80)	5.76 [a] (1.94)
4	6.78 [b] (1.68)	5.75 [a] (1.70)	5.14 [a] (1.84)
8	6.35 [a] (1.29)	5.95 [a] (1.83)	5.91 [a] (1.82)
10	7.20 [b] (1.58)	5.68 [a] (1.94)	5.78 [a] (1.59)
12	6.44 [a] (1.42)	6.00 [a] (1.76)	6.04 [a] (1.85)

[1]Standard deviation
[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Effect of different pectin concentrations on the texture sensory attribute of control (uncoated) and coated (2% antimicrobial, 0.5% chitosan) cantaloupe samples stored at 4°C during 15 days.

Time (days)	Control	0.5% Pectin	1.0% Pectin
1	6.76 [a] (1.55)	6.53 [a] (1.27)	6.50 [a] (1.89)
4	6.97 [b] (1.61)	5.61 [a] (1.82)	5.81 [a] (1.83)
8	6.98 [a] (1.58)	6.19 [a] (1.72)	6.44 [a] (1.45)
10	7.54 [b] (1.27)	5.90 [a] (1.55)	6.27 [a] (1.43)
12	7.07 [b] (1.40)	5.62 [a] (1.86)	6.42 [a, b] (1.50)

[1]Standard deviation
[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Effect of different pectin concentrations on the flavor sensory attribute of control (uncoated) and coated (2% antimicrobial, 0.5% chitosan) cantaloupe samples stored at 4°C during 15 days.

Time (days)	Control	0.5% Pectin	1.0% Pectin
1	6.76 [a] (1.79)	6.18 [a] (1.54)	6.34 [a] (1.96)
4	7.47 [b] (1.28)	5.22 [a] (1.90)	5.31 [a] (1.89)
8	7.14 [a] (1.58)	6.19 [a] (1.92)	6.30 [a] (1.41)
10	7.80 [b] (0.98)	5.20 [a] (2.06)	5.80 [a] (1.83)
12	7.33 [b] (1.54)	4.98 [a] (2.11)	6.22 [a, b] (1.93)

[1]Standard deviation
[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Effect of different pectin concentrations on the overall quality sensory attribute of control (uncoated) and coated (2% antimicrobial, 0.5% chitosan) cantaloupe samples stored at 4°C during 15 days.

Time (days)	Control	0.5% Pectin	1.0% Pectin
1	6.71 [a] (1.71)	6.21 [a] (1.40)	6.32 [a] (1.71)
4	7.22 [b] (1.27)	5.50 [a] (1.76)	5.33 [a] (1.79)
8	7.00 [a] (1.46)	6.07 [a] (1.79)	6.14 [a] (1.47)
10	7.80 [b] (0.81)	5.49 [a] (1.76)	5.90 [a] (1.62)
12	7.07 [b] (1.23)	5.49 [a] (1.85)	6.31 [a, b] (1.74)

[1]Standard deviation
[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Effect of different antimicrobial (AM) concentrations on the juice leakage percentage of control (uncoated) and coated (2% chitosan, 1% pectin) cantaloupe samples stored at 4°C during 15 days.

Time (days)	Control	1.0% Antimicrobial	2.0% Antimicrobial	3.0% Antimicrobial
3	2.04 [a] [1] (0.56)	1.69 [a] (0.38)	1.59 [a] (0.18)	1.41 [a] (0.27)
6	2.82 [a] (1.49)	2.80 [a] (0.64)	2.07 [a] (0.16)	2.84 [a] (0.97)
9	4.22 [b] (0.66)	3.53 [a, b] (0.91)	3.12 [a, b] (0.61)	2.13 [a] (1.05)
12	5.80 [b] (0.27)	5.29 [b] (0.40)	4.88 [b] (0.90)	3.38 [a] (0.30)
15	6.94 [b] (0.66)	6.22 [a, b] (0.26)	5.39 [a] (0.42)	5.18 [a] (0.67)

[1]Standard deviation
[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Effect of different antimicrobial (AM) concentrations on the aerobic plate count of control (uncoated) and coated (2% chitosan, 1% pectin) cantaloupe samples stored at 4°C during 15 days.

Time (days)	Control	2.0% Chitosan (No AM)	1.0% Antimicrobial	2.0% Antimicrobial	3.0% Antimicrobial
1	3.66 [a] [1] (0.18)	3.45 [a] (0.24)	3.39 [a] (0.25)	3.10 [a] (0.23)	3.24 [a] (0.06)
3	4.87 [a] (0.23)	4.77 [a] (0.08)	4.38 [a, b] (0.08)	3.31 [c] (0.22)	3.78 [b, c] (0.11)
6	5.82 [a] (0.18)	6.07 [a] (0.03)	4.91 [b] (0.09)	4.57 [b, c] (0.06)	4.27 [c] (0.03)
9	6.78 [a] (0.08)	6.34 [a] (0.23)	5.39 [b] (0.14)	5.69 [b] (0.37)	5.32 [b] (0.16)
12	8.82 [a] (0.20)	8.89 [a] (0.17)	6.76 [b] (0.17)	6.04 [b] (0.03)	5.24 [c] (0.17)
15	9.41 [a] (0.12)	9.05 [a] (0.07)	7.21 [b] (0.15)	6.25 [c] (0.10)	5.80 [c] (0.03)

[1]Standard deviation

[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Effect of different antimicrobial (AM) concentrations on the psychrotrophic plate count of control (uncoated) and coated (2% chitosan, 1% pectin) cantaloupe samples stored at 4°C during 15 days.

Time (days)	Control	2.0% Chitosan (No AM)	1.0% Antimicrobial	2.0% Antimicrobial	3.0% Antimicrobial
1	3.32 [a] [1] (0.19)	2.63 [a, b] (0.18)	2.57 [a, b] (0.23)	2.56 [a, b] (0.09)	2.26 [b] (0.17)
3	4.87 [a] (0.23)	4.85 [a] (0.18)	4.39 [a] (0.10)	3.69 [b] (0.02)	3.32 [b] (0.19)
6	5.89 [a] (0.15)	5.66 [a] (0.41)	4.73 [b] (0.46)	3.83 [c] (0.13)	3.66 [c] (0.41)
9	6.95 [a] (0.03)	6.81 [a] (0.49)	6.74 [a] (0.07)	5.41 [b] (0.19)	4.74 [c] (0.49)
12	8.93 [a] (0.16)	8.75 [a] (0.35)	7.03 [b] (0.07)	6.06 [c] (0.05)	5.54 [c] (0.33)
15	9.48 [a] (0.05)	9.43 [a] (0.39)	7.27 [b] (0.16)	6.93 [b, c] (0.10)	6.56 [c] (0.54)

[1]Standard deviation

[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Effect of different antimicrobial (AM) concentrations on the yeast and moulds plate count of control (uncoated) and coated (2% chitosan, 1% pectin) cantaloupe samples stored at 4°C during 15 days.

Time (days)	Control	2.0% Chitosan (No AM)	1.0% Antimicrobial	2.0% Antimicrobial	3.0% Antimicrobial
1	2.14 [a] [1] (0.12)	1.44 [b] (0.36)	1.87 [a, b] (0.21)	1.59 [a, b] (0.10)	1.75 [a, b] (0.08)
3	3.60 [a] (0.38)	2.35 [b] (0.25)	2.05 [b, c] (0.16)	1.61 [c] (0.19)	1.57 [c] (0.04)
6	4.28 [a] (0.12)	2.81 [b] (0.09)	2.83 [b] (0.04)	2.59 [b] (0.12)	2.53 [b] (0.22)
9	4.81 [a] (0.20)	3.67 [b] (0.45)	3.39 [b] (0.60)	3.27 [b] (0.12)	3.19 [b] (0.07)
12	5.07 [a] (0.14)	4.07 [b] (0.04)	4.82 [b] (0.04)	3.58 [b, c] (0.28)	3.37 [c] (0.08)
15	6.15 [a] (0.04)	5.74 [a] (0.04)	4.98 [b] (0.14)	3.52 [c] (0.06)	3.31 [c] (0.15)

[1]Standard deviation

[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Effect of different antimicrobial concentrations on the color sensory attribute of control (uncoated) and coated (2% chitosan, 1% pectin) cantaloupe samples stored at 4°C during 15 days.

Time (days)	Control	1.0% Antimicrobial	2.0% Antimicrobial	3.0% Antimicrobial
1	6.97 [a] [1] (1.33)	7.13 [a] (1.52)	7.03 [a] (1.60)	6.29 [a] (1.70)
5	6.81 [a] (1.56)	6.90 [a] (1.54)	6.81 [a] (1.87)	7.10 [a] (1.22)
9	6.69 [a] (1.64)	7.06 [a] (1.45)	7.22 [a] (1.16)	6.38 [a] (1.80)
13	6.60 [a] (1.63)	7.35 [a] (0.98)	6.03 [a] (1.85)	6.94 [a] (1.57)
15	6.44 [a] (1.38)	6.84 [a] (1.35)	6.09 [a] (1.75)	5.78 [a] (1.52)

[1]Standard deviation
[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Effect of different antimicrobial concentrations on the odor sensory attribute of control (uncoated) and coated (2% chitosan, 1% pectin) cantaloupe samples stored at 4°C during 15 days.

Time (days)	Control	1.0% Antimicrobial	2.0% Antimicrobial	3.0% Antimicrobial
1	6.68 [a] [1] (1.35)	6.71 [a] (1.79)	6.32 [a] (1.78)	5.97 [a] (1.89)
5	6.10 [a] (2.06)	6.29 [a] (1.90)	6.26 [a] (1.57)	6.74 [a] (1.55)
9	6.56 [a] (1.54)	6.41 [a] (1.35)	6.25 [a] (1.76)	6.16 [a] (1.61)
13	6.77 [a] (1.50)	7.00 [a] (1.65)	5.67 [a] (1.84)	6.03 [a] (1.70)
15	6.50 [a] (1.43)	6.56 [a] (1.46)	5.81 [a] (1.54)	5.28 [a] (1.56)

[1]Standard deviation
[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Effect of different antimicrobial concentrations on the texture sensory attribute of control (uncoated) and coated (2% chitosan, 1% pectin) cantaloupe samples stored at 4°C during 15 days.

Time (days)	Control	1.0% Antimicrobial	2.0% Antimicrobial	3.0% Antimicrobial
1	6.45 [a] [1] (1.67)	6.61 [a] (1.61)	7.07 [a] (1.44)	6.19 [a] (1.92)
5	6.94 [a] (1.50)	5.84 [a] (2.00)	6.13 [a] (2.05)	6.81 [a] (1.58)
9	6.38 [a, b] (1.86)	5.59 [b] (2.04)	6.50 [a, b] (1.55)	5.88 [a] (1.96)
13	6.30 [a] (1.42)	6.42 [a] (1.75)	5.63 [a] (1.92)	5.19 [a] (1.85)
15	6.20 [b] (1.83)	5.75 [b] (1.45)	4.91 [a, b] (1.75)	4.44 [a] (1.69)

[1]Standard deviation

[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Effect of different antimicrobial concentrations on the flavor sensory attribute of control (uncoated) and coated (2% chitosan, 1% pectin) cantaloupe samples stored at 4°C during 15 days.

Time (days)	Control	1.0% Antimicrobial	2.0% Antimicrobial	3.0% Antimicrobial
1	7.10 [a] [1] (1.58)	6.65 [a] (1.36)	6.27 [a] (2.03)	5.97 [a] (2.23)
5	7.35 [b] (1.52)	5.97 [a] (1.99)	6.29 [a] (1.85)	6.45 [a] (1.61)
9	7.00 [b] (1.87)	4.59 [a] (2.34)	5.44 [a] (2.05)	5.31 [a] (2.15)
13	6.70 [b] (1.59)	6.29 [b] (2.08)	5.73 [a, b] (2.39)	3.97 [a] (2.17)
15	6.48 [b] (2.47)	4.50 [a] (1.91)	4.53 [a] (1.61)	4.13 [a] (2.04)

[1]Standard deviation
[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Effect of different antimicrobial concentrations on the overall quality sensory attribute of control (uncoated) and coated (2% chitosan, 1% pectin) cantaloupe samples stored at 4^{o}C during 15 days.

Time (days)	**Control**	**1.0% Antimicrobial**	**2.0% Antimicrobial**	**3.0% Antimicrobial**
1	6.71 [a] [1] (1.40)	6.68 [a] (1.30)	6.45 [a] (1.93)	6.06 [a] (2.13)
5	7.06 [a] (1.36)	6.07 [a] (1.72)	6.16 [a] (1.88)	6.57 [a] (1.50)
9	6.69 [b] (1.69)	4.94 [a] (2.07)	5.75 [a, b] (1.80)	5.53 [a] (1.94)
13	7.03 [b] (1.36)	6.58 [b] (1.75)	5.43 [a] (1.81)	4.65 [a] (1.56)
15	6.50 [b] (2.14)	5.03 [a] (1.84)	4.78 [a] (1.70)	4.25 [a] (1.76)

[1]Standard deviation
[a,b]Means within a row, which are not followed by a common superscript letter are significantly different ($P < 0.05$).

VITA

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