# MAINTAINING THE FIRMNESS OF MINIMALLY PROCESSED WATERMELON (*Citrullus lanatus*) USING CALCIUM CHLORIDE AND CALCIUM PROPIONATE

SITI NORADILAH BINTI OMAR



FAKULTI AGROTEKNOLOGI DAN SAINS MAKANAN
UNIVERSITI MALAYSIA TERENGGANU

2010

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# MAINTAIN THE FIRMNESS OF MINIMALLY PROCESSED WATERMELON (*Citrullus lanatus)* USING CALCIUM CHLORIDE AND CALCIUM PROPIONATE

By
Siti Noradilah binti Omar

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

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

## ENDORSEMENT

The project report entitled **MAINTAIN THE FIRMNESS OF MINIMALLY PROCESSED WATERMELON (*Citrullus lanatus*) USING CALCIUM CHLORIDE AND CALCIUM PROPIONATE** by **SITI NORADILAH BINTI OMAR,** Matric No. **UK 15195** has been reviewed and corrections have been made according to the recommendations by the examiners. This report is submitted to the Department of Agrotechnology in partial fulfillment of the requirement of the degree of Bachelor of Science in Agrotechnology (Post Harvest Technology), Faculty of Agrotechnology and Food Science, University Malaysia Terengganu.

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**(WAN ZAWIAH BINTI WAN ABDULLAH)**

Supervisor

Date: 4/5/2010

## DECLARATION

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

Signature : ..................................................
Name : Siti Noradilah binti Omar
Matric No. : Uk 15195
Date : 29 April 2010

## ACKNOWLEDGEMENT

I would like to express my gratitude especially to my parents for their endless support, morally and also for their love. Besides, I would like to take this opportunity to thank my supervisor, Mrs. Wan Zawiyah binti Wan Abdullah for her guides and also her time in helping me completing this thesis. Besides, I want to thank other lecturers who are also sacrificing and contributing their time and knowledge in helping me finishing this thesis. A bunch of thanks to my friends who are helping and supporting me directly and indirectly.

# ABSTRACT

A minimally processed fruit industry is a very lucrative industry. One of the fruits used in this industry is watermelon. Minimally processed can cause fruits to loss their firmness and thus affecting their quality. The objectives of this study are to determine the suitable treatment to prevent softening in fresh cut water melon and also to study the storage stability of the fresh cut watermelon. Watermelon was cut into cubes and were dipped in calcium chloride (0.5 % w/v), calcium propionate (0.5 % w/v) and distilled water as control. The samples were then stored for 5 days in LDPE at temperature of $3 \pm 2^0$C. The physiochemical analyses evaluated on the samples are firmness, color and total soluble solids (TSS). Treatments showed no significance different in firmness, color and also TSS. The reduction in firmness was observed and it is caused by insufficient concentration of calcium treatments and also by the changes in cell wall due to ripening and maturation. The color of treated watermelon was retained by calcium treatment while TSS of watermelon was increased at the end of study.

# ABSTRAK

Industri pemprosesan buah - buahan secara minimal ialah industry yang mendatangkan keuntungan. Salah satu buah yang digunakan dalam industry ini ialah tembikai. Pemprosesan buah – buahan secara minimal menyebabkan buah kehilangan kesegahan yang akan mempengaruhi kualiti buah tersebut. Objektif kajian ini ialah untuk menentukan rawatan yang sesuai untuk menghalang pelembutan dalam tembikai yang dipotong segar dan untuk mengkaji kestabilan penyimpanan tembikai yang dipotong segar. Tembikai dipotong dalam bentuk kiub dan dicelup di dalam kalsium klorida (0.5 % w/v), kalsium propionat (0.5 % w/v) dan air suling sebagai kawalan. Sampel kemudian disimpan di dalam plastic LDPE selama 5 hari pada suhu $3 \pm 2\ ^0C$. Analisis fisiokimia dijalankan ke atas sampel ialah kesegahan, warna dan jumlah pepejal terlarut. Rawatan tidak menunjukkan perubahan yang signifikan dalam kesegahan, warna dan jumlah pepejal terlarut. Penurunan dalam kesegahan tembikai disebabkan oleh kepekatan rawatan kalsium yang tidak mencukupi dan perubahan dinding sel yang disebabkan oleh pemasakan dan kematangan buah. Warna tembikai dikekalkan dan jumlah pepejal terlarut di dalam buah meningkat di akhir kajian.

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| | |
|---|---|
| $^0C$ | Degree Celcius |
| cm | Centimeter |
| ppm | Part per million |
| mM | Milimolar |
| % | Percentage |
| $\leq$ | Less than or equal |
| kJ | Kilo Joule |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background of study

Fresh cut industry is one of the growing businesses and can bring large profits. This industry has become one of the popular commodities for the past 10 years because of its convenience (Laminkara, 2002). Besides, the commodities in the retail groceries of most developed countries also have been rising continuously during the last few years (Wiley, 1994). The United States Department of Agriculture (USDA) and Unites States Food and Drug Administration (FDA) define "fresh" and "minimally- processed" fruits and vegetables as fresh-cut (pre-cut) products that have been freshly-cut, washed, packaged and maintained with refrigeration. Fresh-cut products are in a raw state and even though processed which are physically altered from the original form, they remain in a fresh state, ready to eat or cook, without freezing, thermal processing, or treatments with additives or preservatives (Anonymous, 1998a; Anonymous, 1998b). The International Fresh-cut Produce Association defines a fresh-cut product as fruits or vegetables that have been trimmed and or peeled and or cut into 100% usable product that is bagged or pre-packaged to offer consumers high nutrition, convenience and flavor while still maintaining freshness.

Post harvest treatments that have been applied to fruit slices or pieces have targeted mainly improvement of post-processing quality rather than shelf life extension of the fresh-cut product (Guzman et al,. 1999). Although fresh-cut products have met the consumers' desire for convenience Bruhn (1995), product freshness and shelf life in particular are still important challenges for fresh-cut fruit.

Watermelon is one of the fruits that have huge potential in the fresh cut industry. In Malaysia, watermelon is cultivated mostly in East Coast area. Watermelon is being exported to Singapore, Hong Kong, Taiwan and Brunei with the estimated value of RM 60 million in the year 2000.

Watermelon *(Citrullus lanatus)* is originated from southern Africa and it is in the family of Cucurbitaceae and is an annual plant. It is globular or oblong in shape and the color of its skin varies in shades of green from pale yellowish to almost black and may be solid, striped, or marbled. Watermelon has a thin, firm outer rind, a layer of white-fleshed inner rind that may be up to about one inch thick, and an interior edible pulp containing seeds unless the variety is triploid. Pulp color of most commercial varieties is some shade of yellow or red (Sackett, 1974).

## 1.2 Problem Statement

Watermelon contains 92 percent water. Watermelon can quickly become mushy once it cut into chunks. This presents a challenge to the fresh-cut market, which demands firm, attractive fruit. There's a growing consumer demand for fresh-cut produce around the world.

Fresh-cut processing increases respiration rates and causes major tissue disruption as enzymes and substrates, normally sequestered within the vacuole, become mixed with other cytoplasmic and nucleic substrates and enzymes. Processing also increases wound-induced ethylene ($C_2H_4$), water activity and surface area per unit volume which, may accelerate water loss and enhance microbial growth since sugars also become readily available (King and Bolin, 1989; Watada et al., 1990; Watada & Qi, 1999; Wiley, 1994). These physiological changes may be accompanied by flavor loss, cut surface discoloration, color loss, decay, increased rate of vitamin loss, rapid softening, shrinkage and a shorter storage-life. Increased water activity and mixing of intracellular and intercellular enzymes and substrates may also contribute to flavor and texture changes or loss during and after processing.

Slicing the fruits result in wound of it and it will suffer from the loss of firmness of fruit tissues. Pectin exuding from bruised cells may diffuse into inner tissues (Soliva-Fortuny and Martín-Belloso, 2003). In this regard, the diffusion rates of enzymes through the tissue can be unexpectedly high (Varoquaux et al., 1990). However, softening may be also dependent on physical and chemical changes. Transformation of protopectin to water-soluble pectin, decrease in cellulose crystallinity, and thinning of cell walls King and Bolin (1989), loss of turgor, and ion movement from the cell wall Poovaiah (1986) may also cause softening. Fresh-cut fruit firmness is an important quality attribute that can be affected by cell softening enzymes present in the fruit tissue Varoquaux et al., (1990) and by decreased turgor due to water loss.

Fresh-cut watermelon is badly damaged by rough handling stress imposed during distribution (Sargent, 1998). In order to maintain the quality of watermelon, special care should be given to avoid rough handling injury of watermelon fruit during harvesting and handling. Fruits that dropped and damaged during harvesting and handling should not be marketed. This is because the injuries may developed and deteriorating the quality of the fruits.

In Malaysia, watermelon is cultivated mostly in East Coast area. Watermelon is being exported to Singapore, Hong Kong, Taiwan and Brunei with the estimated value of RM 60 million in the year 2000. Malaysia ranked 12$^{th}$ in the watermelon producer and has 3.1% of world market share. This indicates that watermelon and fresh cut watermelon has huge economic potential to Malaysia. Besides, the watermelon comprises of 47.5 % of total fresh cut in United States of America (Chryssogelos, 2006). Thus, fresh cut watermelon need to be treated carefully and correctly, in order to reduce losses and income to this industry particularly manufacturers.

## 1.3 Significance of study

Watermelon is one of the fruits that have huge potential in fresh cut industry in Malaysia and this world generally. Usually, the main problem in fresh cut produce is the loss of firmness after some times of storage. Loss of firmness is due to tissue softening and associated loss of integrity and leakage of juice from some fresh cut products can be primary cause of poor quality and unmarketability (Lamikanra, 2002). Firmness retention is an important quality parameter in fresh cut fruits and vegetables products (Agar et al., 1999; Gorny et al., 1999, Senesi and Pastine, 1996). According to Aguayo (2001), microbial spoilage and loss of firmness are the main causes of quality loss in fresh-cut melon stored in air at chilling temperatures. Watermelon is one of fruits that is accepted and cultivated worldwide which means that there will be a huge loss if this problem occurs.

## 1.4 Objectives

This study was conducted to determine the suitable treatment to prevent softening in fresh cut water melon. Besides, it is also to study the storage stability of the fresh cut watermelon.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Watermelon

### 2.1.1 Description

Watermelon (*Citrullus lanatus)* is originated from southern Africa and it is in the family of Cucurbitaceae and is an annual plant. It is globular or oblong in shape and the colour of its skin varies in shades of green from pale yellowish to almost black and may be solid, striped, or marbled. Watermelon has a thin, firm outer rind, a layer of white-fleshed inner rind that may be up to about one inch thick, and an interior edible pulp containing seeds unless the variety is triploid. Pulp color of most commercial varieties is some shade of yellow or red (Sackett, 1974). As the fruit approaches harvest maturity the surface may become a bit irregular and dull rather than glossy. The ground spot (the portion of the melon resting on the soil) changes from pale white to a creamy yellow at the proper harvest maturity. The ground spot color is easily revealed by gently rolling the fruit over to one side while still attached to the vine. As the fruit become mature, the tendril will wilt and change from a healthy green color to a partially desiccated brown color.

Watermelons generally are not pre-cooled and some are shipped in unrefrigerated trucks (Suslow, 1999). If pre-cooling is implemented, forced-air cooling would be the method of choice. In common room-cooling, good air circulation between palletized boxes is essential. Fruit that are placed in bulk fiberboard bins will cool slowly because of poor air circulation within the bin.

The optimum storage temperature for watermelon is varies depends on watermelon varieties and types, seeded or seedless, but in general none are suited to very long term storage. The ideal storage temperature is in the range of 10 to 15 °C with approximately 90% relative humidity. Fruit should be consumed within 2 to 3 weeks following harvest (Hardenburg et al., 1986).

Watermelons develop chilling injury when stored below about 10 °C for more than a few days. Lower temperatures will hasten the onset of injury. Symptoms appear as brown-staining of the rind, surface pitting, deterioration of flavor, fading of flesh color, and increased incidence of decay when returned to room temperatures (Hardenburg et al., 1986; Suslow, 1999). Conditioning fruit at 30 °C for about 4 days prior to cooling has been shown to induce some tolerance to chilling temperatures, but it does not completely alleviate the problem (Picha, 1986).

Watermelons are classified as low ethylene producers, with production rates in the range of 0.1 to 1.0 $\mu L.\ Kg^{-1}.\ h^{-1}$ at 20 °C. Although production rates are low, fruit are extremely sensitive to ethylene. Exposure to as little as 5 ppm ethylene causes softening, rind thinning, flesh color fading, and over-ripeness (Elkashif et al., 1989; Suslow, 1999). Interactions between ethylene concentration, temperature, and duration of exposure are not well defined. The recommended management protocol is to avoid any exposure to ethylene in the storage environment. The fresh-cut market for watermelon cubes and slices has grown dramatically in recent years, but most processing is done near the point of sale.

### 2.1.2 Cultivation of Watermelon

Watermelons grow and produce fruits ideally during dry, sunny periods. Excessive rainfall and high humidity reduce productivity by affecting flowering and encouraging the development of leaf diseases. Elevations up to 1000 m normally provide suitable conditions for growth although excessively high temperatures of more than 30 $^0$C may be harmful, reducing the degree of fertilization. Stable day and night temperatures promote a rapid growth rate. Watermelons need a good deal of moisture and about 8 hours of sun a day to grow and mature. The first blossoms on the watermelon vines will not set fruit. These are male or what is called pollen-bearing flowers. Only female or pitillate flowers can develop fruit. Bees are attracted most to the male flowers and will become the pollinator to watermelon plant or the pollination can be done manually using hand. Seeds in groups of 1 to 3 are sown 2 to 4 cm deep in trenches, on mounds or prepared planting holes at 1.2 to 2.0 in each way; seedlings are later thinned to 1 per holes. Seedlings may be raised in containers and transplanted when 10 to 14 cm high. Seed required per hectare is 2.5-4 kg for a density of 5000-10000 plants/hectar (Boyhan et al., 2000).

Watermelons are well adapted to soils that are well drained, high in organic matter, with a good moisture retaining capacity. The best soil type that gives optimum yield is sandy loams (Boyhan et al., 2000). However, the other types of soils still can be used to cultivate watermelon. Clayey or sandy soils that are well-drained can be managed to produce good quality of watermelon. Other than that, soil that has history of watermelon diseases should be avoided or treated before being used to cultivate watermelon. Crops are also frequently grown in low rainfall areas on soils which are relatively low in fertility. Watermelons can tolerate some degree of soil acidity. However, the pH of the soil should not be below 5.5 for good yields to be obtained. Liming at the recommended rate should be done in the planting holes or mounds, if the soil pH is below 5.5 (Boyhan et al., 2000).

Besides that, after cultivating the watermelon, mulching or covering should be applied. These practices can avoid soil erosion due to excessive water and also wind erosion. Apart from using fertilizers, organic fertilizers using organic matters can also be applied. Soil organic matter consists of plant and animal residues in various stages of decay. Organic matters can improve soil structure as well as supplying nutrients and also increases water infiltration and decreases both water and wind erosion (Boyhan et al., 2000).

### 2.1.3 Diseases of Watermelon

Just like other crops, watermelon also facing some serious diseases. One of the common diseases that infect watermelon is blossom-end rot (BER) (Figure 2.1). This disease is a physiological or non parasitic disorder caused by calcium deficiency, moisture stress or both. Prevention recommendations include adequate amounts of calcium, proper soil pH (6 to 6.5), and a uniform and sufficient supply of moisture. The incidence of BER usually is quite variable from season to season and tends to occur more readily in oblong melons. Watermelons having BER are considered unmarketable (Boyhan et al., 2000).

Figure 2.1: Blossom end rot disease of watermelon.

The other common diseases that present in watermelon are damping off. This disease is caused by bacteria *Phythium* spp., *Rhizoctonia* spp. or *Fusarium* spp. The disease usually attacked seedlings of watermelon. The amount of damping-off is usually directly related to litter from the previous crop and to environmental conditions. In some years, seedling diseases reduce stands by 50 percent; in other years, seedling diseases are rare. Good cultural practices and seed treatment are essential in preventing damping-off of young watermelon seedlings. Basically, conditions unfavorable for rapid emergence, which involves cool, wet weather, are usually most favorable for damping-off (Boyhan et al., 2000).

The other common disease in watermelon is downy mildew is caused by the fungus *Pseudoperonospora cubensis*. This fungus attacks only the leaves of watermelons. Lesions first appear on the oldest crown leaves as yellow, mottled spots with indefinite borders blending gradually into healthy portions of the leaf. Older lesions are dark brown with a slight yellow border. As the disease progresses, brown areas coalesce, causing leaves to curl inward toward midribs. Under favorable conditions for disease development, downy mildew develops rapidly, resulting in a scorched appearance over an entire field. Downey mildew is not a problem in watermelons in the last several years; however, the potential is there, and plantings should be observed frequently for signs of downy mildew (Boyhan et al., 2000), (Figure 2.2).

Figure 2.2: Downey mildew of watermelon.

The other harmful disease that infects watermelon is watermelon mosaic virus I and II are now known as papaya ring spot virus which are watermelon type (PRSV-W) and watermelon mosaic virus (WMV), respectively. There is several other viruses affect watermelon; all have similar symptoms. The most common symptom is mottling of the leaf. However, mottling may be difficult to see under certain weather conditions. Some plants are stunted with abnormal leaf shapes, shortened internodes and bushy erect growth habits of some runner tips. The first symptom on the fruits is usually a bumpy and mottled appearance of the fruit surface. This disease symptom is strongly expressed in periods of extended high temperatures. These viruses are spread by aphids, which can spread through an entire planting during the growing season (Boyhan et al., 2000), (Figure 2.3).

Figure 2.3: Mosaic virus of watermelon.

**2.3 Minimally Processed**

The definitions of fresh and minimally processed fruits and vegetables by United States Department of Agriculture (USDA) and Unites States Food and Drug Administration (FDA) as fresh-cut (pre-cut) products have been freshly-cut, washed, packaged and maintained with refrigeration. Fresh-cut products are in a raw state and even though processed (physically altered from the original form), they remain in a fresh state, ready to eat or cook, without freezing, thermal processing, or treatments with additives or preservatives (Anonymous, 1998a; Anonymous, 1998b). Minimally processed fruits are highly regarded for their variety, convenience and health benefits.

Fresh cut industry is a lucrative industry and is growing each year in every parts of the world. In Italy, fresh-cut produce sales witnessed a 38 percent increase in value in 2003 compared to the previous year (Anonymous, 2005). During that same time frame, sales jumped 123 percent in the southern part of the country, offering significant growth opportunities for those companies supplying pre-cut fruits and vegetables located there.

In 2006, overall consumption of fresh fruit in European Union (EU) was 77 million tones. Consumption of fresh vegetables amounted to 62 million tones. From 2002 to 2006, fruit consumption grew by 2.7%, though the consumption of vegetables remained stable. EU imports of fresh fruits accounted for € 19 billion in value an increase of 20% since 2002. Import volumes increased by 10% over the same period reaching 25 million tones. German, United Kingdom and Netherlands are the main importers of fresh fruits to the EU together accounting for nearly half of the EU imports by value in 2006 (Uganda Investment Authority, 2009).

## 2.4 Degradation of Minimally Processed

Once harvested, fruits are removed from their source of water, minerals and sustenance. Fruit tissues continue to respire, using available and stored sugars and organic acids and they begin to senesce rapidly. Postharvest quality loss is primarily a function of respiration, onset or progression of ripening (climacteric fruit), water loss (transpiration), and enzymatic discoloration of cut surfaces, decay (microbial), senescence and mechanical damage suffered during preparation, shipping, handling and processing (Schlimme and Rooney, 1994; Watada et al., 1996). Fruits destined for fresh-cut processors should be harvested as ripe as possible. This makes it critical that temperature-dependent events related to respiration, water loss, pathological decay and ethylene production be strictly regulated during fruit shipment or storage.

During the climacteric ripening stage of many fruits there is a dramatic increase in respiratory $CO_2$ and $C_2H_4$ production. Non-climacteric fruit, leafy vegetables, non-fruit vegetables as well as roots and tubers, do not have a surge in $C_2H_4$ production and generally have only slightly increased respiration as senescence approaches. However, if severely wounded such as in by fresh-cut processing, a significant stress-induced production of $CO_2$ and often times $C_2H_4$ occurs (Abeles et al., 1992; Brecht, 1995). Fresh-cut processing increases respiration rates and causes major tissue disruption as enzymes and substrates, normally sequestered within the vacuole, become mixed with other cytoplasmic and nucleic substrates and enzymes. These physiological changes may be accompanied by flavor loss, cut surface discoloration, color loss, decay, increased rate of vitamin loss, rapid softening, shrinkage and a shorter storage-life. Increased water activity and mixing of intracellular and intercellular enzymes and substrates may also contribute to flavor and texture changes or loss during and after processing. Therefore, proper temperature management during product preparation and refrigeration throughout distribution and marketing is essential for maintenance of quality.

Tissue softening is a very serious problem with fresh-cut fruit products that can limit shelf-life. Fresh-cut fruit firmness is an important quality attribute that can be affected by cell softening enzymes present in the fruit tissue (Varoquaux et al., 1990) and by decreased turgor due to water loss. For example, there was 26 to 49 % firmness loss in four varieties of fresh-cut cantaloupe processed from ¾ to full-slip maturity fruit when stored in air at 4 °C. Unwrapped watermelon slices lost 47% of their firmness after 4 days at 5 °C (Abbey et al., 1988) and firmness decreased in stored cantaloupe cubes (12 days in air at 5 °C) by more than 25% (Cantwell and Portela, 1998).

## 2.5 Treatments on the Minimally Processed

### 2.5.1 Anti browning Treatment

Minimally processed products will be browning due to enzyme polyphenol oxidase (PPO) that oxidized phenolic compound. The browning will cause poor appearance to the products and several treatments have been proven to prevent discoloration.

Teixeira et al., (2006) reported that cultivars of fruits can affect the browning process in star fruits. Addition of catechol, however, led to rapid browning, and indication that lack of substrate was possibly responsible for the lack of browning on the cut surface of the cultivars under evaluation.

Sulphite is one of the chemical that used in preventing browning, traditionally (Ahvenainen, 1996). However, sulphite is harmful to human health as it causes asthma and United State Food and Drug Administration (FDA) has partly restricted the use of sulphites in the spring of 1990 and there is increasing interest in substitutes for sulphites since.

Application of ascorbic acid (AA) combined with citric acid (CA), alone or when used together with potassium sorbate particularly in potato and apple indicates these treatments can be an alternative to the sulphite especially when hand peeling is applied. Potatoes were heated for 5 -20 min in a solution containing 1% AA and 2% CA at 45 to 55°C cooled and then dipped for 5 min in a browning inhibitor solution containing 4% AA, 1% CA and 1% sodium acid pyrophosphate. The combined treatment inhibited potato discoloration for 14 day at 4°C, compared with 3 to 6 day with the browning inhibitor treatment alone. The study conducted by Liu et al., (2006) showed that combination of AA and CA is the most effective in controlling browning of litchi. CA and AA are found to protect membrane damage by eliminating the reactive oxygen species in oxidation of phenolic compounds. The application of AA and CA helps in maintaining membrane integrity and inhibited peel browning of harvested litchi fruits.

### 2.5.2 Modified Atmosphere Packaging and Control Atmosphere

One of the important aspects in minimally processed fruits and vegetables is packaging. The most studied packaging method for prepared raw fruit and vegetables are modified-atmosphere packaging (MAP) (Ahvenainen, 1996). Kader et al., (1989), Powrie and Sakura (1991) have presented excellent overviews on the principles and modelling of the MAP of fruit and vegetables, as well as some aspects of the packaging of minimally processed fruit and vegetables.

Modified atmosphere packaging can be created passively by using properly permeable packaging materials, or actively by using a specified gas mixture together with permeable packaging materials. Both principles are aiming in creating an optimal gas balance inside the package, where the respiration activity of a product is as low as possible, but the levels of oxygen and carbon dioxide are not detrimental to the product. In general, the aim is to have a gas composition of 2 to 5% $CO_2$ and 2 to 5% $O_2$, and the rest is nitrogen (Kader et al., 1989).

Different commodities have different amounts of internal air space (potatoes 1 to 2%, tomatoes 15 to 20%, and apples 25 to 30%). A limited amount of air space leads to increase in resistance to gas diffusion. The evaluation of these gases ($O_2$, $CO_2$ and $C_2H_4$) by three varieties of apricots stored at 10 $^0$C under four plastic films of different permeability has been studied (Pretel et al., 1993). Respiration rate of mushroom under air has been studied with apparent activation energy of 43.4 kJ/mol between 10 $^0$C to 20 $^0$C (Varoquaux et al., 1999). One of the primary effects of MAP is a lower rate of respiration, which reduces the rate of substrate depletion. Ethylene ($C_2H_4$) is a natural plant hormone and plays a central role in the initiation of ripening, and is physiologically active in trace amounts (0.1 ppm). $C_2H_4$ production is reduced by about half at $O_2$ levels of around 2.5%. This low $O_2$ retards produce ripening by inhibiting both the production and action of $C_2H_4$.

Firmness can sometimes be maintained by controlled atmosphere (CA) storage. Firmness loss averaged 2.2 lb (10 N) in honeydew cylinders after 12 days of storage in air at 5 °C while CA storage (air + 15% $CO_2$) reduced the loss significantly in one of four cultivars tested (Portela and Cantwell, 1998). CA treatments (2% $O_2$ + 10% $CO_2$ at 5 °C) and 4 % $O_2$ + 10% $CO_2$ at 10 °C) were more beneficial than air storage in maintaining honeydew cube quality for up to 6 days at 5 °C (Qi et al., 1999).

### 2.5.3 Calcium Treatment

Calcium is essential for living organisms, particularly in cell physiology, where movement of the calcium ion $Ca^{2+}$ into and out of the cytoplasm functions as a signal for many cellular processes. The role of calcium in plants is quite similar to that in people; it is essential for good growth and structure. Insufficient calcium levels lead to deterioration of the cell membrane; the cells become leaky resulting in the loss of cell compounds and eventually death of the cell and plant tissue.

Calcium ions interact with pectic polymers to form a cross-linked polymer network that increases mechanical strength, thus delaying senescence and controlling physiological disorders in fruits and vegetables ( Poovaiah, 1986). In pome fruits, dips in calcium chloride ($CaCl_2$) solutions are widespread and their effects on texture preservation have been demonstrated in a wide scope of conditions. Treatments reported in literature range from 0.1 to 1% $CaCl_2$ dips (Rosen & Kader, 1989; Soliva-Fortuny et al., 2002 and Soliva-Fortuny et al.,2003). Some works have been developed in apple slices to improve the efficiency of the dipping treatments.

Monsalve-Gonzalez et al., (1993) and Ponting et al., (1972) reported slight or null influence of the solution acidity on the preservation of texture. Optimal concentration of calcium chloride treatments in minimally processed melon was found at 2.5% (Luna-Guzman et al., 1999). In kiwifruit slices, Agar et al., (1999) could not observe significant differences between 1 and 2% $CaCl_2$ treatments. On the other hand, the use of alternative calcium salts such as propionate, lactate or tartarate was proposed by Buta et al., (1999) who investigated the possible advantages of substituting the commonly used $CaCl_2$. No improvement was reported, except for calcium propionate, which extended the shelf life of fresh-cut apples due to a reduction of physiological breakdown and a decrease in microbial growth.

Aguayo et al., (2008) found that dipping in hot calcium solution (60 $^0$C, 1min) as $CaCl_2$ (0.5%), or weak organic acid salts like calcium propionate (0.9%) or lactate (1.4%), was very effective in reducing microbial growth and maintaining firmness in minimally processed melon. These treatments increased the bound calcium concentration by 50% and decreased softening of melon pieces.

Fresh-cut cantaloupe shelf life may be extended by using modified atmospheres (Nguyen-the and Carlin, 1994) or calcium chloride dips alone or in combination with heat treatments (Luna-Guzma´n et al., 1999). Calcium chloride is commonly used industrially as a firming agent for canned tomatoes and cucumber pickles. Other products in which texture is improved or maintained by calcium chloride dips include whole apples (Sams et al., 1993), whole hot peppers (Mohammed et al., 1991), whole and sliced strawberries (Rosen and Kader, 1989; Garcı´a et al., 1996) and diced tomatoes (Floros et al., 1992).

Flesh firmness of fresh-cut fruit products can be maintained by application or treatment with calcium compounds. Dipping fresh-cut products in solutions of 0.5 to 1.0% calcium chloride is very effective in maintaining product firmness (Ponting et al., 1971; Ponting et al., 1972). However, calcium chloride may leave bitter off flavors on some products. Firmness of slices from 12 untreated apple cultivars stored at 2 °C (decreased steadily for 7 days and more rapidly thereafter) (Kim et al., 1993). However, mild heat treatment of whole apples before processing retained firmness during storage in some fresh-cut apple cultivars (Kim et al., 1994).

# CHAPTER 3

# MATERIAL AND METHODS

## 3.1 Material

Fresh watermelons were purchased from market at Gong Badak, Kuala Terengganu, Terengganu.

## 3.2 Methods

The watermelon was initially washed with distilled water to eliminate surface contamination. Then, they were cut into cubes. The watermelon cubes were then dipped in distilled water as control, calcium propionate (0.5 % w/v) and calcium chloride (0.5 % w/v) for five minutes. There were three replicates for each treatment. The samples were then stored in low density polyethylene (LDPE) bag without sealing at $3 \pm 2\ ^{o}C$ for 5 days. Samples were evaluated for several physiochemical parameters after 5 days of storage time.

### 3.3 Physiochemical assessment

The physiochemical assessments evaluated include the firmness, total soluble solid, and color.

#### 3.3.1 Firmness

The firmness of the fresh cut watermelon was determined using TA-XT Plus texture analyzer (Stable Micro Systems Ltd, Surrey, England). The probe used was a needle probe (P/2N).

#### 3.3.2 Colour Assessment

Color of the samples was recorded using chromameter Minolta CR-400 (Minolta Corp., Ramsey, NJ, USA). L*, chromacity value a*, and chromacity value b* readings were recorded at two opposite sides of each cubes and results were expressed as lightness (L*), a* value as the color of green (-) to red (+) while b* value which represents blue (+) to yellow (-).

#### 3.3.3 Total Soluble Solid

The total soluble solid of the samples were determining using a handheld refractometer (Model ATC-1, Atago Co., Ltd., Tokyo, Japan) and the total soluble solids was expressed in ° Brix.

### 3.4 Statistical Analysis

The data were subjected to the analysis of variance (ANOVA) using SPSS version 16 (IBM Company, Chicago, Illinois, USA). Treatment were further separated using Tukey Test for least significant different at ($P \leq 0.05$).

(Varoquaux et al., 1990). However, softening may be also dependent on physical and chemical changes. Transformation of protopectin to water-soluble pectin, decrease in cellulose crystallinity, and thinning of cell walls King and Bolin (1989), diffusion of sugar to the intercellular spaces Bolin and Huxsol (1989), loss of turgor, and ion movement from the cell wall Poovaiah (1986) may also cause softening. Fresh-cut fruit firmness is an important quality attribute that can be affected by cell softening enzymes present in the fruit tissue Varoquaux et al., (1990) and by decreased turgor due to water loss.

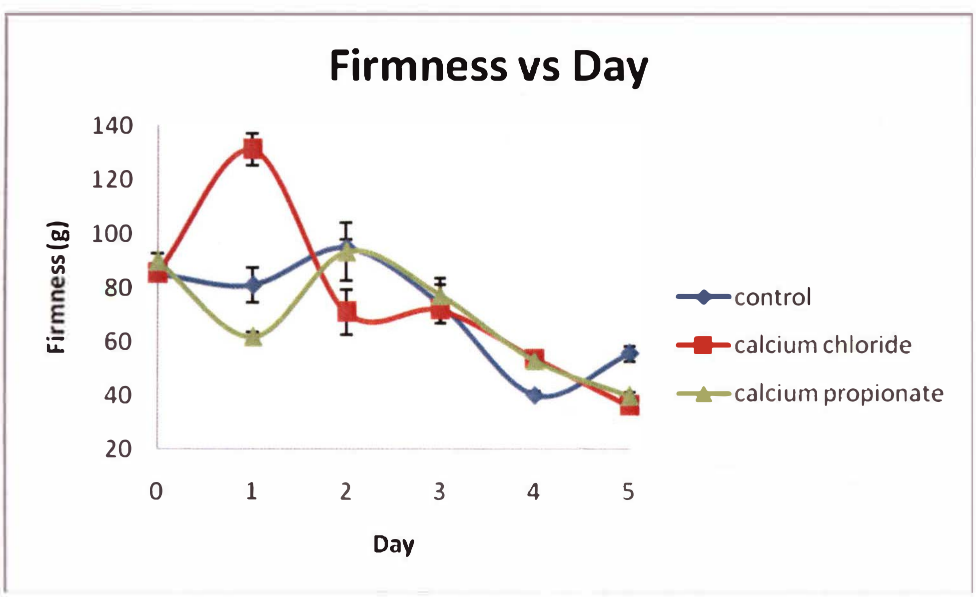


Figure 4.1: The effects of different treatments on firmness of watermelon. Vertical bars represent standard deviation. When vertical bars are not visible, standard deviation is smaller than the symbol.

## 4.2 Color

The lightness of watermelon was decreasing as the L* value was decreasing throughout the study. At the end of study (Day 5), the lightness of watermelon samples treated in control and calcium propionate were increased but the calcium chloride treated sample was decreasing.

The highest L* value was showed on Day 2 for all treatments while the lowest L* value was on Day 3 in all treatments (Figure 4.2). A* which indicates the color of green (-) to red (+) showed a decrease in all treatments. However, the samples treated with calcium chloride and calcium propionate have an increasing a* value starting on Day 4 while samples treated in control showed a decrease in a* value starting on Day 4 (Figure 4.3). Meanwhile, the b* value which represents blue (+) to yellow (-) showed an increase in samples of calcium chloride and calcium propionate treated samples while the samples in control showed a decrease value of b* in Day 5. The highest value of b* was observed on Day 4 in the sample treated with distilled water (Figure 4.4). Lightness, a* and b* value of minimally processed watermelon was not significantly affected with the application of calcium treatment (Appendix B, C and D).

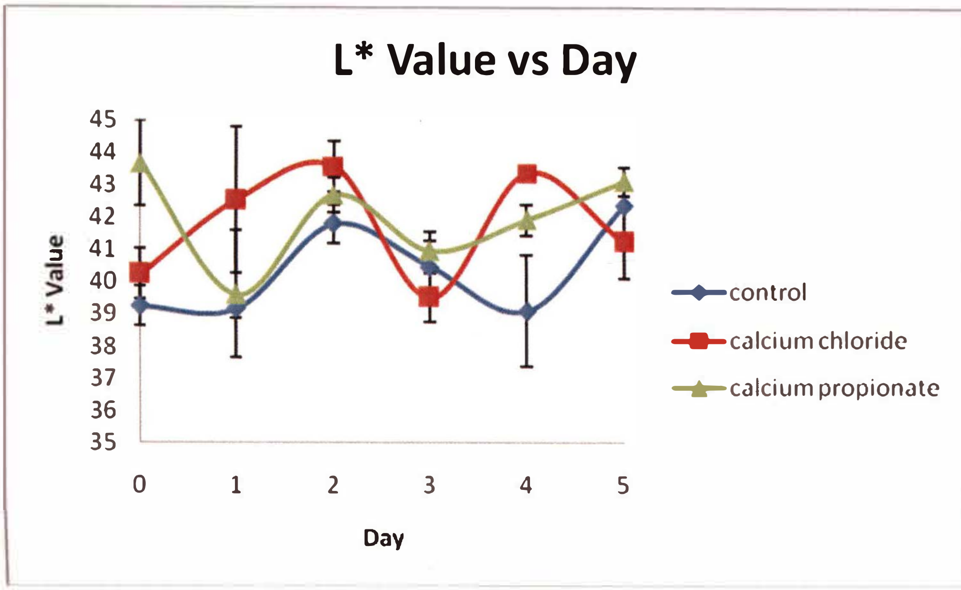


Figure 4.2: The effects of different treatments on the L* value of the watermelon. Vertical bars represent standard deviation. When vertical bars are not visible, standard deviation is smaller than the symbol.

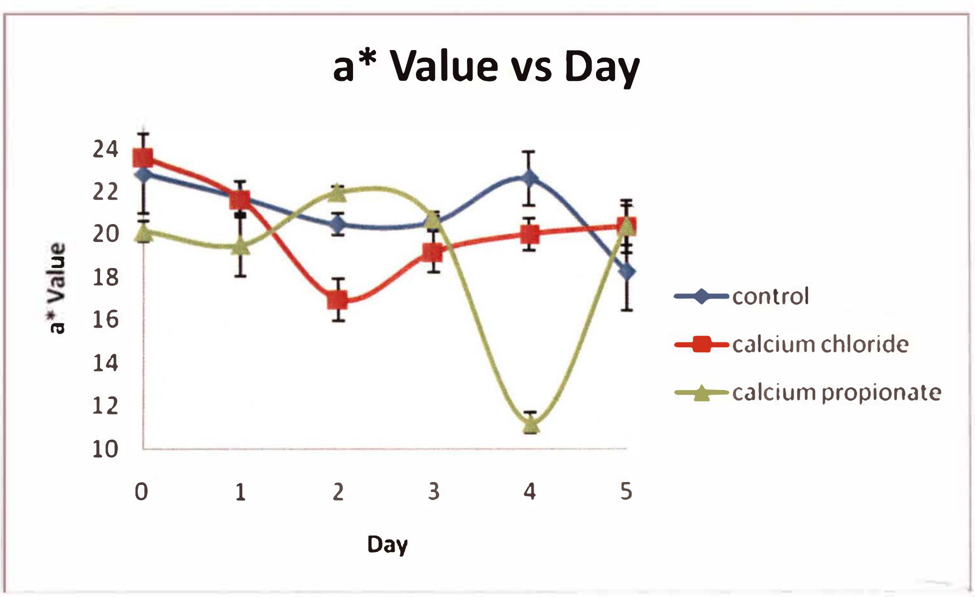


Figure 4.3: Effect ofdifferent treatments on the a* value of watermelon. Vertical bars represent standard deviation. When vertical bars are not visible, standard deviation is smaller than the symbol.

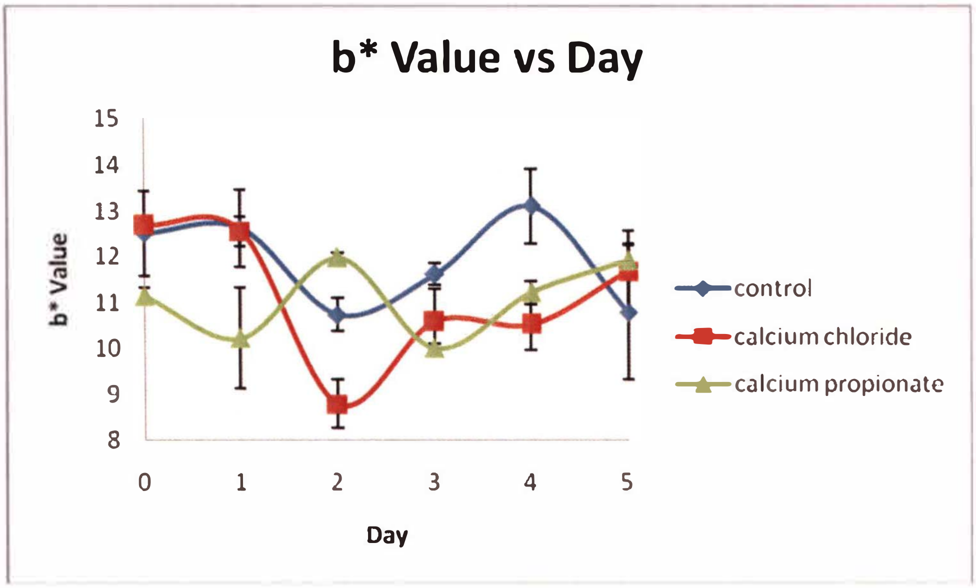


Figure 4.4: Effect of different treatments on the b* value of watermelon. Vertical bars represent standard deviation. When vertical bars are not visible, standard deviation is smaller than the symbol.

The insignificant difference in L*a* b* value of minimally processed watermelon indicates that the treatments of calcium chloride ($CaCl_2$) and calcium propionate $Ca(C_2H_5COO)_2$ do not have any effects on the color changes and the treatments retain the color of watermelon. A reduction in chromacity b* value, L* indicates redder fruit color while increase in a* value increase red color.

As reported earlier by Machado et al (2008), calcium treatment in fresh cut muskmelon cantaloupe did not showed any physical damage due to processing on surface darkness or loss of flesh yellow color during storage at 10°C for 18 days. Color changes in harvested, fully red, ripe strawberries occur progressively during storage. Fruit darkens, skin color becomes less chromatic and surface browning develops (Herna´ndez-Mun˜oz et al., 2008). Less red skin and darkening due to oxidative browning reactions have been found to be more marked in ripe strawberries that suffer greater moisture loss during storage (Nunes et al., 1995).

### 4.3 Total Soluble Solid (TSS)

Total soluble solid (TSS) of all treated samples were decreasing on Day 1 before showing and increase on Day 2, 3 and 4 except for samples treated with distilled water that had decreasing pattern on Day 2 and 3. On Day 5, all samples in all treatments showed an increase in TSS (Figure 4.5). There is no significant difference (P≤0.05) in TSS observed in all treatments (Appendix E).

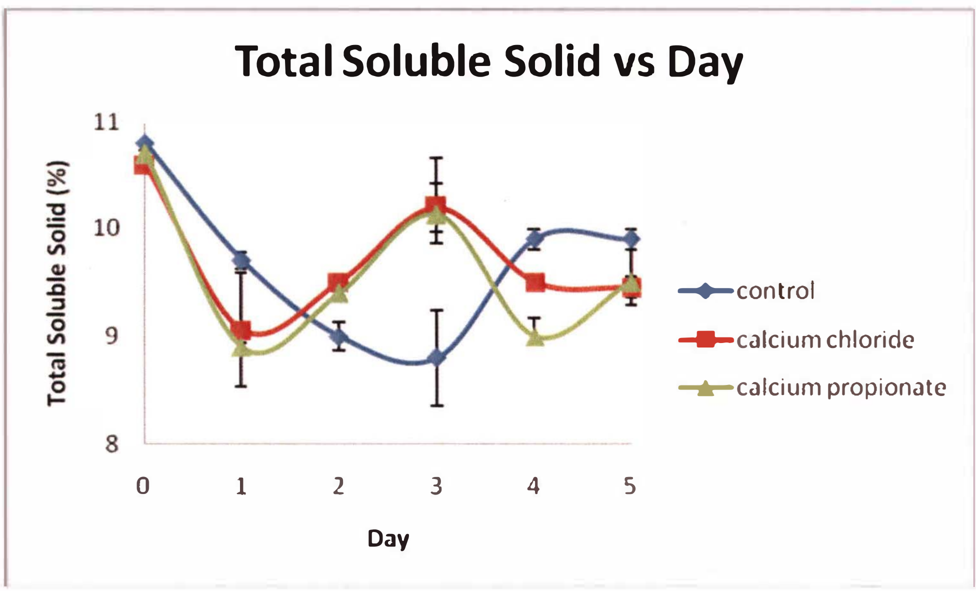


Figure 4.5: Effect of different treatments on the total soluble solids of watermelon. Vertical bars represent standard deviation. When vertical bars are not visible, standard deviation is smaller than the symbol.

Herna´ndez-Mun˜oz et al., (2008) explained that sugars are the first substrates used during respiration in their study of papaya. The increase of total soluble solid (TSS) in strawberry is caused by the ripening and decreases in mature fruit due to respiration. A plausible explanation for the observed increment in TSS is the considerable loss of water suffered by strawberries during storage. Indeed, the greater changes in TSS occurred in those strawberries which suffered the greatest water loss.

The solubilization of the cell wall polyuronides and hemicelluloses in mature strawberry might also contribute to the increase in TSS

# CHAPTER 5

# CONCLUSION

## 5.1 Conclusion

In conclusion, calcium treatments, $CaCl_2$ and calcium propionate ($Ca(C_2H_5COO)_2$) retain fruit color of watermelon stored for five days at 3 to 5 $^0$C. In addition, the application of both calcium treatments decreased the fruits firmness and enhanced total soluble solids of stored-sliced-watermelon.

The calcium treatment that is more suitable in this study for the fresh cut watermelon is calcium propionate ($Ca(C_2H_5COO)_2$). This is because calcium propionate ($Ca(C_2H_5COO)_2$) shows the gradual decrease in firmness of minimally processed watermelon compared to calcium chloride treatment where the firmness is decreased quite tremendously. However, both treatments retain the color and the total soluble solids of the watermelon.

## 5.2 Recommendation

The present investigation contributes to the development of basic information on how calcium treatments can influence fruit quality of minimally processed of watermelon particularly on fruit color, firmness and total soluble solids. This finding open up further research to determine the effectiveness of calcium treatment at higher concentration higher than 0.5 % w/v in order to maintain fruit firmness and other quality attributes.

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## APPENDIX A

Firmness of watermelon during storage at 3 $^{0}$C to 5 $^{0}$C for determination optimum treatment

| Treatment | Day 0 | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 |
|---|---|---|---|---|---|---|
| Control | 85.3367 ± 9.16704 [a] | 81.4700 ± 20.01478[a] | 94.7267± 9.98701 [a] | 74.1800 ± 21.96501 [a] | 40.3433 ± 4.24266 [a] | 55.6270± 9.48080 [b] |
| Calcium chloride | 90.8400 ± 6.26357[a] | 131.0267 ± 18.08309[b] | 71.0733 ± 26.21295 [a] | 71.9130 ± 15.07927 [a] | 54.0150 ± 9.07784 [a] | 36.2283± 2.85876 [a] |
| Calcium propionate | 85.3800 ± 7.83087[a] | 90.4967 ± 4.70523 [a] | 93.4213 ±33.73682 [a] | 77.4980 ± 19.17907 [a] | 53.1720 ±8.50404 [a] | 40.1300± 3.20832[a] |

Each data point represents the mean of three replicates ± SE. [a]Different letters in the same column denote a significant difference by the Tukey HSD test (P≤0.05).

## APPENDIX B

Brix of watermelon during storage at 3 $^{0}$C to 5 $^{0}$C for determination optimum treatment

| Treatment | Day 0 | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 |
|---|---|---|---|---|---|---|
| Control | 10.7000 ± 0.10000 [a] | 9.7333 ± 0.23094 [a] | 9.0000 ± 0.40000 [a] | 8.8000 ± 1.40000 [a] | 9.8667 ± 0.30551 [a] | 9.9333 ± 0.30551 [a] |
| Calcium chloride | 10.7000 ± 0.10000 [a] | 9.0667 ± 1.67730 [a] | 9.5333 ± 0.11547 [a] | 10.2000 ± 0.72111 [a] | 9.5333 ± 0.11547 [a] | 9.4667 ± 0.30551 [a] |
| Calcium propionate | 10.7000 ± 0.10000 [a] | 8.9333 ± 0.11547 [a] | 9.4000 ± 0.20000 [a] | 10.1333 ± 1.67730 [a] | 9.0000 ± 0.52915 [a] | 9.5000 ± 1.32288 [a] |

Each data point represents the mean of three replicates ± SE. [a]Different letters in the same column denote a significant difference by the Tukey HSD test (P≤0.05).

# APPENDIX C

L* value of watermelon during storage at 3 $^{0}$C to 5 $^{0}$C for determination optimum treatment

| Treatment | Day 0 | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 |
|---|---|---|---|---|---|---|
| Control | 39.8633 ± 1.91051 $^{a}$ | 39.1100 ± 0.91000 $^{a}$ | 41.7967 ± 1.85646 $^{a}$ | 40.4867 ± 2.55163 $^{a}$ | 39.1167 ± 5.44757 $^{a}$ | 42.3733 ± 3.66657 $^{a}$ |
| Calcium chloride | 40.5267 ± 2.43422 $^{a}$ | 42.4933 ± 7.09032 $^{a}$ | 39.5267 ± 2.42223 $^{a}$ | 39.5267 ± 2.38475 $^{a}$ | 43.3867 ± 0.15631 $^{a}$ | 44.5933 ± 3.57336 $^{a}$ |
| Calcium propionate | 42.7900 ± 4.17321 $^{a}$ | 39.6067 ± 6.23344 $^{a}$ | 40.7400 ± 1.67661 $^{a}$ | 40.7400 ± 1.83033 $^{a}$ | 41.9133 ± 1.54001 $^{a}$ | 43.1233 ± 1.40115 $^{a}$ |

Each data point represents the mean of three replicates ± SE. $^{a}$Different letters in the same column denote a significant difference by the Tukey HSD test ($P \leq 0.05$).

# APPENDIX D

a* value of watermelon during storage at 3 $^{0}$C to 5 $^{0}$C for determination optimum treatment

| Treatment | Day 0 | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 |
|---|---|---|---|---|---|---|
| Control | 12.3833 ± 2.90397 $^{a}$ | 12.6233 ± 2.63766 $^{a}$ | 10.7500 ± 1.13265 $^{a}$ | 11.6333 ± 0.72968 $^{a}$ | 13.1033 ± 2.57189 $^{a}$ | 10.8400 ± 4.61403 $^{a}$ |
| Calcium chloride | 12.5000± 0.34117 $^{a}$ | 12.5567 ± 1.02295 $^{a}$ | 8.7967 ± 1.63467 $^{b}$ | 10.6000 ± 2.27165 $^{a}$ | 10.7033 ± 1.77647 $^{a}$ | 11.7000 ± 2.69568 $^{a}$ |
| Calcium propionate | 11.4700 ± 0.56400 $^{a}$ | 10.2267 ± 3.49763 $^{a}$ | 11.9733 ± 0.36529 $^{a}$ | 12.0867 ± 0.35726 $^{a}$ | 10.5800 ± 0.76295 $^{a}$ | 11.9267 ± 1.15764 $^{a}$ |

Each data point represents the mean of three replicates ± SE. $^{a}$Different letters in the same column denote a significant difference by the Tukey HSD test ($P \leq 0.05$).

# APPENDIX E

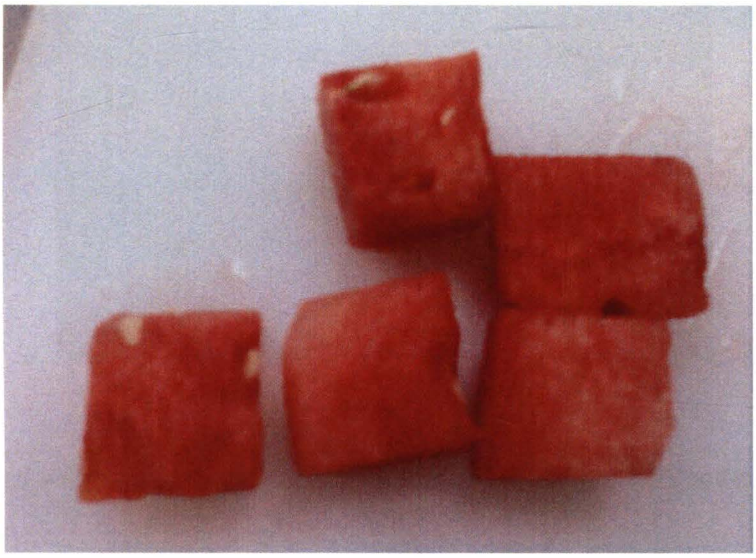
b* value of watermelon during storage at 3 $^{0}$C to 5 $^{0}$C for determination optimum treatment

| Treatment | Day 0 | Day 1 | 2 day | 3 day | 4 day | 5 day |
|---|---|---|---|---|---|---|
| Control | $12.3833 \pm 2.90397^{a}$ | $12.6233 \pm 2.63766^{a}$ | $10.7500 \pm 1.13265^{a,b}$ | $11.6333 \pm 0.72968^{a}$ | $13.1033 \pm 2.57189^{a}$ | $10.8400 \pm 4.61403^{a}$ |
| Calcium chloride | $12.5000 \pm 0.34117^{a}$ | $12.5567 \pm 1.02295^{a}$ | $8.7967 \pm 1.63467^{a}$ | $10.6000 \pm 2.27165^{a}$ | $10.7033 \pm 1.77647^{a}$ | $11.7000 \pm 2.69568^{a}$ |
| Calcium propionate | $114700 \pm 0.56400^{a}$ | $10.2267 \pm 3.49763^{a}$ | $11.9733 \pm 0.36529^{b}$ | $12.0867 \pm 0.35726^{a}$ | $10.5800 \pm 0.76295^{a}$ | $11.9267 \pm 1.15764^{a}$ |

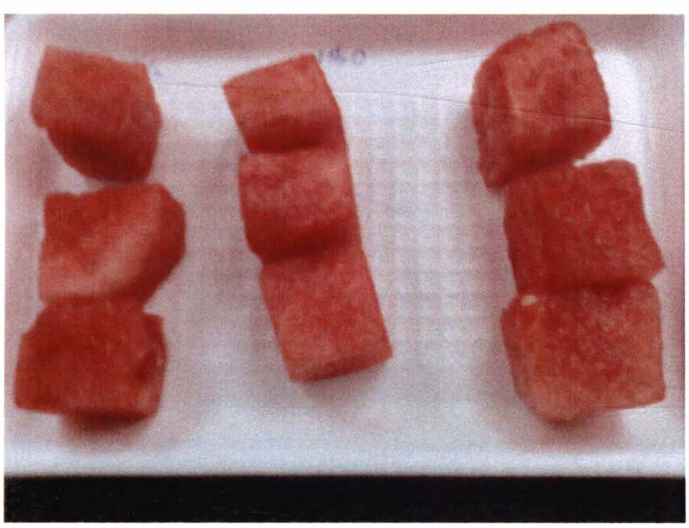
Each data point represents the mean of three replicates ± SE. [a]Different letters in the same column denote a significant difference by the Tukey HSD test ($P \leq 0.05$).

APPENDIX F

Watermelon cubes at Day 0, 3 and 5

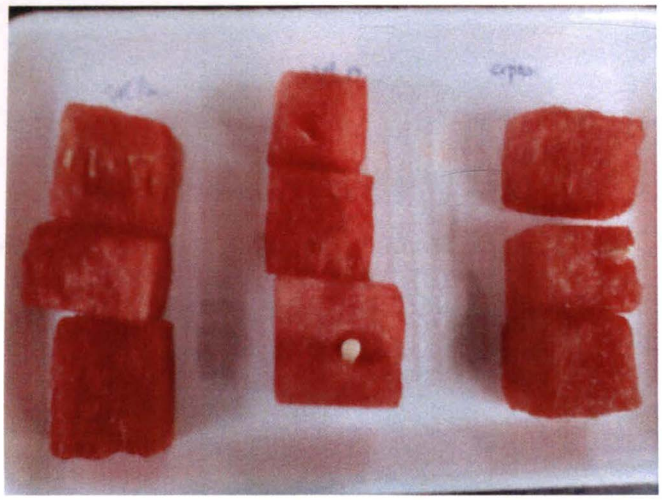


Day 0



Day 3

Watermelon treated with $CaCl_2$ (left), distilled water as control (center) and calcium propionate (right).



Day 5

Watermelon treated with $CaCl_2$ (left), distilled water as control (center) and calcium propionate (right).

CURRICULUM VITAE

Name : Siti Noradilah binti Omar

Permanent Address : Kampung Bemban, Mukim Gelong,
06000, Jitra,
Kedah.

Telephone Number : 013-3085564

E-mail : snowy_poison@yahoo.com

Date of Birth : 27 January 1988

Place of Birth : Kedah

Nationality : Malaysia

Race : Malay

Gender : Female

Religion : Islam

Educational Background :

2007 – 2010 Universiti Malaysia Terengganu

2006 – 2007 Kolej Matrikulasi Kedah

2001 – 2005 Sekolah Menengah Sains Pokok Sena, Alor Setar, Kedah

1995 – 2000 Sekolah Kebangsaan Gelong, Jitra, Kedah

Awards : Dean List Semester December 2007/2008

MAINTAIN THE FIRMNESS OF MINIMALLY PROCESSED WATERMELON (CITRULLUS LANATUS) USING CALCIUM CHLORIDE AND CALCIUM PROPIONAT - SITI NORADILAH OMAR