DISSERTATION

POST-HARVEST TREATMENT EFFECTS ON QUALITY AND SAFETY CHARACTERISTICS OF MELONS AND TOMATOES

Submitted by

Heather LeAnne Troxell

Department of Food Science and Human Nutrition

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY HEATHER LEANNE TROXELL ENTITLED POST-HARVEST TREATMENT EFFECTS ON QUALITY AND SAFETY CHARACTERISTICS OF MELONS AND TOMATOES BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

Committee on Graduate Work

Dr. Marisa Bunning

Dr. Lawrence Goodridge

Dr. Cecil Stushnoff

Dr. Dawn Thilmany

Advisor: Dr. Patricia Kendall

Department Head: Dr. Christopher Melby

•ABSTRACT OF DISSERTATION•

Post-Harvest Treatment Effects on Quality and Safety Characteristics of Melons and Tomatoes

Production, processing, and transport of high quality, safe, and healthful produce presents a constant challenge. Calcium chloride ($CaCl_2$) dips have been shown to help maintain fruit quality after harvest by delaying senescence, reducing postharvest decay, and controlling many physiological disorders in fruit. There is little research available, however, assessing the effects of $CaCl_2$ on sensory, nutritional, and microbial qualities of fresh, whole produce, including melons and tomatoes. This research project evaluated the impact of post-harvest storage temperature and use of a $CaCl_2$ dip on selected organoleptic, nutritional, and microbiological qualities of organic and conventional Colorado-grown melons and tomatoes over time. Melons (cultivars 'Haogen' and 'Arava') were grown on conventional and certified organic plats and tomatoes (cultivar 'Early Girl') were grown on certified organic plots during summer 2007 with controlled pre-harvest, harvest, and post-harvest conditions. All produce was picked at peak maturity and either dipped in a $CaCl_2$ solution or not treated, then stored at $10^{\circ}\pm1^{\circ}$ or $21^{\circ}\pm1^{\circ}$ C. A variety of sensory, nutritional, and microbial tests were conducted on the fruit after storage for 1, 5, and 10 days. Storage temperature significantly impacted many of the fruit characteristics evaluated. Melons stored at 10° C had less microbial growth and higher sensory scores compared to the melons stored at 21° C. For tomatoes, many of the sensory and nutritional

qualities were higher when stored at 21° C, even at 10 days storage. Use of a $CaCl_2$ dip treatment positively influenced ($p<0.05$) sensory scores for melons (appearance, texture, and overall acceptability) and tomatoes (flavor and overall acceptability). Overall, $CaCl_2$ did not affect the fruits' antioxidant contents. When storing organic melons at 21° C, the $CaCl_2$-dipped melons had lower ($p<0.05$) Enterobacteriaceae bacterial counts compared to non-dipped melons. Based on this study, a $CaCl_2$ treatment shows promise for increasing some safety and sensory characteristics of fresh melons and tomatoes, especially for produce stored at room temperature (21° C). Additional research should be conducted to further explore the potential of $CaCl_2$ to lessen post-harvest expenses and losses while maximizing the sensory, nutritional, and safety characteristics of fruit.

Heather LeAnne Troxell
Department of Food Science and Human Nutrition
Colorado State University
Fort Collins, CO 80523
Fall 2008

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•CHAPTER I•

Introduction

Tomatoes (*Solanum lycopersicum* L.) are widely consumed, ranking second to potatoes among vegetable and melon per capita use in the United States (Lucier and Dettman 2008b). They are a good source of vitamin C, folate, and potassium as well as many phytochemicals (Beecher 1998; Leonardi, et al. 2000; Djuric and Powell 2001; Willcox, et al. 2003). Melons (*Cucumis melo* L.) are also popular in the United States, reaching a record high total consumption of 8.5 billion pounds in 2007 (Lucier and Dettman 2008a), and they also contain many healthful compounds, including carotenoids, phenolics, vitamin A, and vitamin C (Lester 1997; Vinson, et al. 2001).

Awareness regarding the important role fruits and vegetables have in a healthful diet is increasing (Goldman 2003; Bazzano 2006), as is the number of farmers' markets in the United States. According to the United States Department of Agriculture (USDA), the number of U.S. farmers' markets more than doubled from 1,755 in 1994 to 4,385 in 2006 (USDA-AMS 2006). Also, based on the results of a national survey conducted in 2006, 3 out of 4 respondents had shopped at a farmers' market within the last year (Keeling-Bond, et al. 2006).

Organic foods are also one of the fastest growing food categories with sales increasing nearly 20% each year since 1990 (Winter and Davis 2006). Studies

assessing consumer perceptions of organic produce have often found people think organic produce is safer, more nutritious, and better tasting than conventionally grown produce (Torjusen, et al. 2001; Magnusson, et al. 2003; Shepherd, et al. 2005; Yiridoe, et al. 2005). However, research comparing such attributes have produced inconsistent or inconclusive results, most likely due to unparallel growing conditions, cultivar choices, and other uncontrolled variables (Harker 2004; Lester 2006). More well-controlled studies are needed to better understand the role organic and conventional growing methods have on produce safety and quality attributes as well as the impact of production method on post-harvest storage (Bourn and Prescott 2002).

The increased popularity and demand for high quality, fresh produce, along with the growing interest in local and organic production (Keeling-Bond, et al. 2006), provides small-scale growers with a unique opportunity. Smaller scale farmers often grow specialty melon cultivars and often harvest tomatoes at peak maturity to sell directly to consumers. Most post-harvest storage handling recommendations have focused on enhancing the quality of common commercial melon cultivars (Salunkhe and Kadam 1998; Thompson 2003) or tomatoes harvested in unripe stages (Kader, et al. 1978; Chomchalow, et al. 2002). To our knowledge little post-harvest research has focused on enhancing the quality of specialty produce harvested ripe.

Melons and ripe tomatoes are highly perishable (Kader 1992), and thus could benefit from a post-harvest treatment to increase their shelf-life. One post-harvest treatment showing positive results on fruit such as strawberries, lemons, melons, and peaches has been calcium chloride ($CaCl_2$) dips (Garcia, et al. 1996; Tsantili, et al. 2002; Manganaris, et al. 2007; Martin-Diana, et al. 2007). Calcium plays an important role in maintaining the cell wall structure in fruit by interacting with pectic acid to form calcium pectate, which has a firming effect on plant cell walls (Poovaiah 1986). Concentrations of $CaCl_2$ used in previous studies have ranged from 0.045 M-0.27 M, with recommendations falling in the 0.06-0.09 M range (Garcia, et al. 1996; Tsantili, et al. 2002; Manganaris, et al. 2007; Martin-Diana, et al. 2007), depending on the fruit being studied and whether the fruit was treated whole or fresh-cut.

Foodborne illness outbreaks associated with fresh produce have increased in the United States during the last thirty years (Sivapalasingam, et al. 2004; Doyle and Erickson 2008). Fresh fruits and vegetables are especially vulnerable to causing foodborne outbreaks due to the fact that they are often eaten raw or minimally processed and each step, from planting through post-harvest handling, may contribute to the microbial load (Johnston, et al. 2005). Therefore, it is also important to consider the impact post-harvest handling methods have on produce safety.

The objective of this research project was to evaluate the impact of a post-harvest $CaCl_2$ dip on selected nutritional, organoleptic, and microbiological qualities of organic and conventional Colorado-grown tomatoes and melons harvested at the ripe stage and stored at two temperatures for up to 10 days.

•CHAPTER II•

Review of Literature

Produce Consumption

Despite myriad health benefits of eating fruits and vegetables, most American's produce consumption is still lacking. Even the well-known, national 5-a-Day For Better Health Program implemented in 1991, did not significantly increase Americans' consumption of fruits and vegetables (Stables, et al. 2002; Serdula, et al. 2004; Casagrande, et al. 2007). And now the recommendations are even higher—the 2005 Dietary Guidelines for Americans recommends that an average adult diet (based on 2,000 kcal) should include two cups of fruit and 2 ½ cups of vegetables a day (DHHS/USDA 2005). Estimates show only 1-17% of Americans over the age of 3 are meeting these current recommendations (Guenther, et al. 2006).

Price, preparation time, high-spoilage rates, and poor flavor qualities have all been shown to be common barriers to adequate produce consumption (Knee 2002; Cassady, et al. 2007; Yeh, et al. 2008). The increased occurrence of foodborne outbreaks associated with fresh produce has also been implicated as a reason consumers may question the advice to increase the amount of fruit and vegetables in their diets (Delea 2001).

Therefore, it is critical that the produce industry provide consumers with high quality, nutritious, and safe fruit and vegetable products to assist consumers in the challenges of eating a healthy diet. Since melons and tomatoes are both popular fruits and widely grown in Colorado, they will be the focus for this research project.

Melons

Melons (*Cucumis melo* L.) are a popular fruit in the United States, reaching a record high total consumption of 8.5 billion pounds in 2007 (Lucier and Dettman 2008a). Melons are primarily consumed fresh and often classified into two groups based on the type of rind they have—*reticulatus* (netted or rough-skinned) and *inodorus* (smooth-skinned) (Seymour, et al. 1993). Fruit color varies, depending on cultivar, but commonly includes shades of green, yellow, orange, pink, and white (Nunez-Palenius, et al. 2008). Melons possess many healthful compounds, including carotenoids, phenolics, vitamin A, and vitamin C (Lester 1997; Vinson, et al. 2001).

Tomatoes

Tomatoes (*Solanum lycopersicum* L.) are widely consumed, ranking second to potatoes among vegetable and melon per capita use in the United States (Lucier and Dettman 2008b). Often considered a vegetable, tomatoes are botanically classified as a fruit. Anatomically speaking, fruit is derived from a plant's ovary and contains seeds, but many less sweet fruit, including tomatoes, eggplant,

peppers, and cucumbers, are commonly grouped in the vegetable category due to their culinary uses (McGee 1984). Extremely popular world-wide, ripe, red tomatoes can be consumed fresh, or further processed into pastes, sauces, soups, ketchup, and other food products (Salunkhe and Kadam 1998). They are a good source of vitamin C, folate, and potassium as well as many phytochemicals (Beecher 1998; Leonardi, et al. 2000; Djuric and Powell 2001; Willcox, et al. 2003).

Post-Harvest Challenges

High quality produce is important, but has little significance if the quality is not maintained up to the point of consumption. Many factors can influence produce quality during the storage time that occurs between harvest and consumption. High metabolic activity, even after harvest, makes fruit highly perishable, shortens shelf-life, and challenges transport and storage processes (Seymour, et al. 1993).

One common method for increasing the post-harvest quality of many fruits and vegetables is to store the produce at refrigeration temperatures after harvest. However, some warm season crops such as melons and tomatoes are susceptible to chilling injury, which is a physiological disorder caused by exposure to low, but above freezing temperatures (Morris 1982). The exact time and temperature conditions that cause chilling injury vary by crop, cultivar, maturity, and other variables. Common symptoms include surface lesions, water-soaked and/or

tissue breakdown, internal discoloration, failure to ripen properly, increased susceptibility to decay, and compositional changes which often influence flavor and aroma (Morris 1982).

Ripe tomatoes can experience chilling injury symptoms when stored at temperatures less than 7-10° C (45-50° F) (Lamikanra, et al. 2005). Adverse effects on the flavor of chilled tomatoes have been shown to occur before visual symptoms are apparent (Kader, et al. 1978). Maul et al. (2000) found ripe tomatoes stored at 5°, 10°, or 12.5° C had lower scores in ripe aroma, sweetness, and tomato flavor than those stored at 20° C. Storing tomatoes at chilling temperatures has also been shown to lower volatile scores (Stern, et al. 1994) and lycopene content (Toor and Savage 2006) compared to samples stored at warmer temperatures.

In melons, one study found similar texture, flavor, off-flavor, sweetness, and overall acceptability scores among melons stored for 7 days at refrigerated temperatures (5° and 12.5° C) and freshly harvested melons. However, vein track browning was found in the refrigerated melons, which can negatively influence sale at the retail level (Cohen and Hicks 1986). Most melon post-harvest storage temperature research has been done on fresh-cut melons, and since the physiology of cut melons has been shown to be distinctly different than that of whole fruit (Lamikanra, et al. 2003), more research on whole melons is needed.

Post-harvest expenses often exceed production costs (Chakraverty 2003); therefore, many producers look to cut costs in this area. It is critical that any modifications to post-harvest handling be designed to maintain produce safety as well as quality.

Calcium Chloride

Calcium plays a critical role in maintaining cell wall structure in fruit by interacting with pectic acid to form calcium pectate, which has a firming effect on the cell wall; thus calcium deficiency during the growing process has been shown to cause a variety of physiological disorders in produce (Poovaiah 1986). Because of the importance of calcium in maintaining the cell wall of fruit, researchers have investigated the use of post-harvest calcium treatments on increasing the quality and shelf-life of produce after harvest (Table 2.1).

Calcium chloride ($CaCl_2$) dips were found to increase post-harvest quality and/or shelf-life in many of the studies listed in Table 2.1 (Conway, et al. 1991; Beavers, et al. 1994; Garcia, et al. 1996; Picchioni, et al. 1996; Picchioni, et al. 1998; Lester and Grusak 1999; Luna-Guzman and Barrett 2000; Lester and Grusak 2001; Tsantili, et al. 2002; Saftner, et al. 2003; Serrano, et al. 2004; Manganaris, et al. 2007). Other benefits of using $CaCl_2$ are that it is allowable for organic food production (7CFR205), relatively inexpensive, and is easily accessible for use by smaller-scale farmers (Dow-Chemical 2007). Concentrations of $CaCl_2$ used in

previous studies have ranged from 0.045 M-0.27 M, with recommendations falling in the 0.06-0.09 M range (Garcia, et al. 1996; Tsantili, et al. 2002; Manganaris, et al. 2007; Martin-Diana, et al. 2007), depending on the fruit being studied and whether the fruit is treated whole or fresh-cut.

For example, strawberries dipped in a $CaCl_2$ solution had a longer shelf-life and less rotten fruit than untreated strawberries, with 1% $CaCl_2$ (approximately 0.09 M) being the most effective concentration (Garcia, et al. 1996). Research on lemons conducted by Tsantili et al. (2002) found a 0.09 M $CaCl_2$ dip slowed firmness loss and peel color changes during storage without affecting the juice's ascorbic acid content, soluble solids content, or titratable acidity. Another study done using peaches determined a 62.5 mM $CaCl_2$ solution (0.0625 M) increased tissue firmness and made the peaches less susceptible to chilling injury symptoms (Manganaris, et al. 2007). The optimal $CaCl_2$ concentration found to slow senescence without any negative side effects in a study using whole honeydew melons was 0.08 M (Lester and Grusak 2001).

There is some controversy concerning the sensory effects of $CaCl_2$. In a study where fresh-cut cantaloupe cubes were dipped in various calcium treatments, $CaCl_2$-treated melons were found to have higher bitterness scores and lower melon flavor scores compared to other treatments evaluated (Luna-Guzman and Barrett 2000). Yet another study found stored whole melons dipped in $CaCl_2$ and stored for 14 and 22 days (at 10° C for 11 or 19 days and 21° C for last three days

to simulate retail conditions) were rated as high for consumer preference as the freshly harvested untreated melons (Lester and Grusak 2001). Further research is needed to determine sensory effects on whole produce, including melons and tomatoes.

Published research is lacking regarding $CaCl_2$'s effect on produce food safety. Research by Chikthimmah et al. (2005) found that using $CaCl_2$ in mushroom irrigation water during crop production resulted in lower levels of microbial growth during storage compared to mushrooms grown without $CaCl_2$ added to the irrigation water. Additional research would be beneficial to determine if using $CaCl_2$ as a post-harvest treatment influences bacterial counts as well as other unstudied impacts of such a treatment on fresh produce, such as the effect on antioxidant levels.

Small-Scale and Alternative Farm Production

Locally Grown Food

The increased popularity of and demand for high quality, fresh produce, along with the "green" movement's interest in local food and organic production (Keeling-Bond, et al. 2006), provides small-scale growers with a unique opportunity. According to the United States Department of Agriculture (USDA), the number of U.S. farmers' markets more than doubled from 1,755 in 1994 to 4,385 in 2006 (USDA-AMS 2006). Based on the results of a national survey in

2006, 3 out of 4 respondents had shopped at a farmers' market within the last year (Keeling-Bond, et al. 2006).

Most current post-harvest research has been conducted using large-scale production and post-harvest handling methods. Small-scale handling needs may be different than large-scale. For example, most post-harvest storage handling recommendations have focused on enhancing the quality of common commercial melon cultivars (Salunkhe and Kadam 1998; Thompson 2003). Little research exists on specialty cultivars often grown by smaller scale farmers (Miccolis and Saltveit 1995). Optimal post-harvest handling methods vary from cultivar to cultivar (Miccolis and Saltveit 1995), and therefore, more research is needed to determine the most beneficial post-harvest conditions for specialty varieties. While much research has focused on enhancing the quality of tomatoes harvested in unripe stages (Kader, et al. 1978; Chomchalow, et al. 2002), little focus has been placed on how post-harvest handling methods affect tomatoes harvested at the ripe, red stage, as is common in direct marketing.

The stage of maturity when tomatoes are harvested appears to affect tomato qualities such as flavor, color, and antioxidant content, though there are mixed results on how the level of maturity affects antioxidant levels. In a study by Arias et al. (2000b), higher overall likeably sensory scores were given to vine-ripened tomatoes than to post-harvest ripened tomatoes. Vine-ripened tomatoes have also been found to have significantly higher ascorbic acid (Wold, et al. 2004;

Kumar, et al. 2007), β-carotene (Arias, et al. 2000b; Raffo, et al. 2002), lycopene (Thompson, et al. 2000; Raffo, et al. 2002), and a deeper red color (Arias, et al. 2000b) compared to post-harvest ripened tomatoes. However, there is also evidence that degree of maturity at harvest may not effect the ascorbic acid content of tomatoes after ripening (Arias, et al. 2000b; Raffo, et al. 2002). Or post-harvest ripened tomatoes could have higher antioxidant levels than vine-ripened tomatoes (Giovanelli, et al. 1999). More research is needed to address the optimal post-harvest methods for small-scale farmers, as they are more likely to harvest produce at peak maturity, and since they may have less time and distance between harvest and consumption.

Organic Food

Organic foods are one of the fastest growing food categories with sales increasing nearly 20% each year since 1990 (Winter and Davis 2006). Due to different requirements as well as allowable fertilizers, pest control methods, and processing aids, organically grown produce food safety strategies may not be the same as those designed for conventionally grown produce (USDA-AMS 2000; Plotto and Narciso 2006).

The popularity of organic foods can be attributed to a variety of reasons, and studies have shown that consumers often perceive organically grown produce to taste better, be more nutritious, and be safer (with regards to pesticides) than

conventionally grown produce (Torjusen, et al. 2001; Magnusson, et al. 2003; Zehnder, et al. 2003; Shepherd, et al. 2005; Yiridoe, et al. 2005).

While consumers perceive these differences between organic and conventional produce, the results of studies conducted to examine the impact of growing method on nutritional, sensory, and safety characteristics have largely been inconclusive and inconsistent.

In a literature review of nutritional differences conducted by Magkos and colleagues (2003), a slight trend toward higher ascorbic acid content in organic leafy vegetables and potatoes and a trend toward slightly lower (but higher quality) protein levels in some organic crops compared to conventional counterparts was found. In another review article, organically grown produce was found to have significantly more vitamin C, iron, magnesium, and phosphorus, as well as significantly lower nitrate levels compared to conventionally grown produce (Worthington 2001). Yet, both reviews noted that few studies comparing nutritional values were adequately controlled, which limited the overall conclusions.

The literature reviews mentioned above also looked at sensory comparisons of organic and conventional produce. Neither production method is clearly preferred and the same challenges comparing research studies as described above limits most sensory results as well (Woese, et al. 1997; Bourn and Prescott 2002;

Yiridoe, et al. 2005). However, a recent study by Zhao and colleagues (2007) compared sensory attributes of organic and conventional produce in a more controlled research design. No significant differences in overall sensory qualities were found based on growing method. The authors did find, however, that conventionally grown tomatoes had a stronger flavor than did organically grown ones. Additional well-controlled research is needed to adequately evaluate sensory qualities of produce grown using different production methods.

There has been some concern among public health experts that organically grown produce may be at higher risk for microbial contamination due to increased manure use (compared to using chemical fertilizers in conventional farming) (Stephenson 1997a; Stephenson 1997b). However, several reviews have found no clear significant microbial safety differences attributed to growing methods (Woese, et al. 1997; Bourn and Prescott 2002; Yiridoe, et al. 2005; Magkos, et al. 2006).

One of the most comprehensive studies comparing microbiological safety differences of organic and conventional produce was done by Mukherjee and others (2004). The research team evaluated 467 organic samples and 129 conventional samples taken from a variety of produce grown on Minnesota farms. *Salmonella* was isolated from one organic lettuce sample and one green pepper sample, and generic *E. coli* was found in lettuce samples from both organic (9.7%) and conventional (1.6%) sources. These differences, however,

were not substantial enough to conclude that one method was safer than another, especially since the majority of the organic farms used in the study were not certified organic and may not have been following the organic manure fertilization requirements.

Current organic vs. conventional research has primarily focused on nutritional, sensory, and safety differences, while the impact of production method on post-harvest storage remains unknown (Bourn and Prescott 2002). Also, due to different requirements and allowable processing aids, organically grown produce post-harvest strategies may not be the same as for conventionally grown produce (Plotto and Narciso 2006).

Produce and Food Safety

Foodborne illness outbreaks associated with fresh produce have increased in the United States during the last thirty years (Sivapalasingam, et al. 2004; Doyle and Erickson 2008). Fresh fruits and vegetables are especially vulnerable to causing foodborne outbreaks due to the fact that they are often eaten raw or minimally processed, which presents a unique set of challenges to maintaining food safety (Brody 1998). Each step, from planting through post-harvest handling, may contribute to the microbial load of fresh fruits and vegetables (Johnston, et al. 2005).

Many hypotheses for the increased prevalence of produce-borne illness exist. Some of the most widely accepted explanations include overall increased fruit and vegetable consumption, increasing population of immunocompromised individuals, increased surveillance and detection methods for food pathogens, global food distribution methods, and changing ecology of microorganisms (De Roever 1998; Bender, et al. 1999; Doyle and Erickson 2008). More sophisticated methods for detecting foodborne pathogens allow for better tracking and identification of outbreak sources. Such methods may more accurately depict the levels of foodborne illness than was possible in the past (Angulo, et al. 1998).

Fresh fruits and vegetables also have natural microflora, metabolic activity, unique surfaces, and tissue nutrient composition—all conditions that will support, and even encourage, pathogen growth (Beuchat 2002). Many pre-harvest and post-harvest factors have been implicated in foodborne illness outbreaks of fresh produce. The main sources of contamination include contact with animals, poor employee hygiene, and contaminated water (Beuchat and Ryu 1997; Beuchat 2006).

Animal waste from animals on the farm or on nearby farms, or even from wild animals, has been shown to play a possible role in contaminating fresh produce. Livestock animals can serve as non-symptomatic carriers of human pathogens including *E. coli* O157:H7, *Salmonella* spp., *Campylobacter* spp., and *Cryptosporidium*, and such organisms are often found in their waste (Kirby, et al.

2003). If animal manure containing these pathogenic organisms comes into contact with crops directly or through contaminated water, the organisms may cause human illness (Pell 1997). In the final investigation summary of the fall 2006, *E. coli* O157:H7 outbreak associated with spinach, the Food and Drug Administration (FDA) described a probable source of the contamination coming from wild pig or cattle feces (FDA 2007; *FDA and Fresh Spinach Safety* 2008).

When using manure as fertilizer, proper treatment, storage, and application processes are important (Bicudo and Goyal 2003). In a study done by Hutchison and colleagues (2004), it was found that spreading and mixing manure into soil increased the length of time pathogens remain viable. Keeping the manure on the soil surface was shown to increase the risk for disease spread by insects or rainfall. Also of concern with using manure, it has been shown that antibiotic residues fed to animals can remain present in manure and be absorbed by crops growing in the soil where the manure was added (Kumar, et al. 2005).

Another factor in maintaining produce food safety is proper employee hygiene. While little research has been published evaluating farm worker hygiene practices, the practices of other food handler groups are discouraging. For example, in a study conducted by Clayton et al. (2002) in Wales, 95% of food workers surveyed received food hygiene training, yet 63% of these respondents admitted to not always following the food safety procedures. A study focused on consumer food safety found practices related to clean hands, utensils, and

preparation surfaces were inadequate (Kendall, et al. 2004). Another consumer study reported nearly all subjects cross-contaminated ready-to-eat foods with raw meat, poultry, seafood, eggs, and/or unwashed vegetables during food preparation as well as lacked proper handwashing techniques (Anderson, et al. 2004). Observational research of cheese vendors selling product at farmer's markets indicated that nearly half did not follow proper refrigeration procedures and 88% did not follow adequate handwashing methods (Teng, et al. 2004).

Many foodborne pathogens can be transmitted through water and contaminated water has also been linked to several foodborne outbreaks in fresh produce (Kirby 2004; Steele and Odumeru 2004). Contaminated irrigation water was implicated in an iceberg lettuce hepatitis A outbreak (Rosenblum, et al. 1990) and a mesclun lettuce greens outbreak of *E. coli* O157:H7 (Hilborn, et al. 1999). Wash water used during post-harvest processing to clean and sanitize fresh produce can also carry foodborne pathogens. For example, cases of *Salmonella* outbreaks in fresh melon have been linked to contaminated water during processing and this is especially a concern as the flesh can then become contaminated during cutting if the rind is damaged (Gagliardi, et al. 2003).

The Microbiological Data Program (MDP) has been conducting microbiological testing of fresh fruit and vegetables since 2001 (MDP 2002-2006). This is a non-regulatory data gathering program through the United States Department of Agriculture designed to collect baseline data on foodborne pathogens and

indicator organisms on fresh produce. Data is collected from terminal markets and wholesale distribution centers in 11 states across the country on a year-round basis (Table 2.2 and 2.3).

Without inoculating produce, it would be very difficult to determine the effect of a post-harvest treatment on specific pathogens due to the extremely low levels of organisms present on fresh produce, as indicated in Table 2.2 and Table 2.3. Therefore, this study will look at the post-harvest effects on aerobic bacterial counts and Enterobacteriaceae bacterial counts. Aerobic counts will indicate the effect on bacteria that grow in oxygenated conditions, which include spoilage as well as pathogenic organisms present on the produce. Evaluating Enterobacteriaceae bacteria levels will provide trends on how the post-harvest conditions affect bacteria in this gram-negative family, which include many of the common food pathogens, such as *Shigella* spp., *Salmonella* spp., and Enterohemorrhagic *E. coli* (Varnam and Evans 1991).

Sensory Quality

In addition to keeping fresh produce safe, it is also important to maintain sensory qualities of produce after harvest.

Quality with regard to food products is difficult to define and combines many factors. Often consumers consider a plethora of criteria—including price,

nutrition, taste, convenience, brand, packaging, and others—when making food choices (Jacoby and Olson 1985; Rao and Monroe 1989).

Several views of quality exist, and perhaps the best way to describe the goal of quality is "to meet the expectations of the consumer" (Fenwick 1996). That is more difficult than it sounds because in order to meet the expectations of the consumer, there needs to be an understanding of who the consumer is and what the consumer expects out of a certain food product. This is especially a challenge with horticultural products, as they are often not associated with a specific brand. Therefore, consumers cannot assume repeat purchases will be the same as before, and many of the quality criteria used in the industry are not what consumers use to make purchase choices (Lockshin and Rhodus 1991).

Agricultural crops have a large amount of variability that can be difficult to control. Growing conditions, cultivar choices, weather, pest pressure, water input, time since harvest, post-harvest handling, and many other variables may influence the final quality of fresh produce (Multon 1996).

After produce is harvested, there is a short window of time during which the food is consumable. The primary post-harvest goal is to minimize quality loss (Fenwick 1996). More emphasis should be placed on better understanding consumer perceptions for making produce purchases, including post-harvest

handling modifications to assure they will be acceptable to consumers (Lockshin and Rhodus 1991).

While objective quality characteristics such as Brix, pH, weight change, and quantitative color measurements are important to determine changes during post-harvest storage, food acceptance is primarily a subjective measurement of consumers' perceptions of produce quality. Quality in food products is closely tied to the sensory attributes of the food (Jacoby and Olson 1985). There is also strong evidence that sensory characteristics are the most influential factors in consumer food choices (Pollard, et al. 2002). The primary attributes that factor into consumers' food preferences include appearance, flavor, and texture (Solms, et al. 1981; MacFie and Thomson 1994; Meiselman and MacFie 1996; Drewnowski 1997).

Appearance

Appearance of a food product refers to the visual impression the food has for the consumer, which may include the color, shape, surface texture, size of the food, translucency, and gloss (Solms, et al. 1981; Hutchings 1999).

Since consumers cannot taste everything prior to purchase, they must rely on the appearance to make many food purchase decisions (Richardson-Harman, et al. 1998; Hutchings 1999). Therefore, appearance is the quality that receives the most emphasis (by consumers and industry), even to the point of sacrificing

flavor and texture (Knee 2002). As a result, grocery stores are often accused of carrying produce that may look good, but be lacking in flavor and other sensory qualities (Hutchings 1999).

One of the most significant characteristics of appearance is the food's color. Color has been found to greatly affect consumers' perception of quality (Clydesdale 1993). If the color is viewed as unacceptable, a consumer most likely will choose not to eat the food, and therefore, the other sensory characteristics would be insignificant (Francis 1995).

A food's color has also been shown to impact flavor expectations of the food, thus affecting the flavor and quality perceptions by consumers (Scott and Batra 2003). In research done with inappropriately colored fruit-flavored solutions, the participants still associated the flavor with the usual color it matches (Garber Jr, et al. 2000; Zampini, et al. 2007). Another study found the color of fruit-flavored beverages affected the sweetness score of the solution as well as a consumer's perception of the ability of the beverage to quench their thirst (Clydesdale, et al. 1992). These studies indicate that visual cues may override other sensory cues when eating food products.

Flavor

Flavor is a complex phenomenon—made up of interaction between taste, smell, touch, temperature, sight, sound, and pain (Delwiche 2004). Taste (or gustation)

is the sensation most often associated with the flavor of food, and it is the result of the response a particular food gives to receptors located in the oral cavity. Although a broad spectrum of flavors exist, four primary taste qualities (sweet, sour, salty, and bitter) are typically considered to make up all flavors (Meiselman and MacFie 1996).

While appearance of a food may be more important in purchase decisions, the taste of a food is critical for consumer acceptance of the food and repeat food purchases (MacFie and Thomson 1994). Maintenance of fruit flavor quality after harvest is a real challenge, as most fruit is harvested at peak maturity and therefore at its peak flavor (Knee 2002).

Texture

Consumer texture perception has been less studied than appearance and flavor, though it clearly plays an important role in sensory quality (Szczesniak 1991; MacFie and Thomson 1994). The role of texture in food quality is often taken for granted by consumers unless it is obviously different than expected. Therefore, consumers need to be specifically probed about texture in sensory tests (Szczesniak 2002).

The importance and specific nature of texture varies by type of food, but includes characteristics such as springiness, chewiness, cohesiveness, denseness,

hardness, moisture release, juciness, and crispness (Lamikanra 2002). For fresh produce, firmness is often associated with freshness, and maintaining a fruit's peak firmness is a primary post-harvest goal (Knee 2002).

Measurement of food preferences

Since the sensory experience is a multi-faceted combination of a consumer's perception, it can be difficult to measure. Food preference tests are typically done using untrained panelists of the target population to determine how a typical consumer views the food product, in contrast to using a trained panel when the objective of the test is analytical, such as specific discrimination or descriptive measurements (Lawless and Claassen 1993; Lawless and Heymann 1999; Chambers, et al. 2004).

The hedonic dimension of food consumption is at the core of food acceptance. The term hedonic refers to "having to do with pleasure," and food acceptance is based on one's pleasure (or lack of pleasure) associated by a given food (Meiselman and MacFie 1996). Therefore, hedonic scales are often used to measure food preference. One such common measurement technique to evaluate like-dislike judgments of a food product is with balanced category scales (Lawless and Heymann 1999). An example of a 9-point hedonic scale would include choices such as: highly acceptable, acceptable, moderately acceptable, slightly acceptable, neither acceptable nor unacceptable, slightly unacceptable, moderately unacceptable, unacceptable, and highly unacceptable.

Nutritional Characteristics

Fresh produce has many nutritional benefits, including vitamins, minerals, phytochemicals, and fiber (Watson 2001), and ideally post-harvest handling methods will maximize such benefits. This research project will specifically determine post-harvest effects on selected antioxidants and calcium content of tomatoes and melons.

Antioxidants

While "antioxidant" has become a popular nutritional buzzword and the focus of a great deal of research, there is not a universally accepted definition of what antioxidants include (Becker, et al. 2004). A commonly used rule-of-thumb presented by Gutteridge and Halliwell (1994) describes antioxidants as substances that protect a target molecule by one of the following mechanisms:

1. Scavenging oxygenated-derived species, either by using protein catalysts (enzymes) or by direct chemical reaction (in which case the antioxidant will be consumed as the reaction proceeds)
2. Minimizing the formation of oxygen-derived species
3. Binding metal ions needed to convert poorly reactive species (such as $O_2^{\bullet -}$ and H_2O_2) into harmful ones (such as $OH^{\bullet}$)
4. Repairing damage to the target
5. Destroying badly damaged target molecules and replacing them with new ones

Many antioxidants have been identified and while the chemical structures and specific mechanisms vary widely, they all function to inactivate free radicals (Yanishlieva, et al. 2001). Antioxidants include vitamins such as vitamin C and E, as well as a variety of phytochemicals (Figure 2.1). Phytochemicals are nonnutritive compounds present in plants that have been linked to reducing chronic disease, though many are not well understood (Shahidi and Ho 2007).

The relationship between antioxidants and health continues to become more and more important. Antioxidant compounds of fruits and vegetables have been shown to play an important role in preventing chronic diseases such as a heart disease, obesity, diabetes, osteoporosis, and a variety of cancers (Ames, et al. 1993; Buring and Hennekens 1997; Prior and Cao 2000; Shahidi and Ho 2007).

Due to the complexity of foods and the different mechanisms involved in antioxidant activity, there is not a single assay for measuring total antioxidant levels (Huang, et al. 2005; Prior, et al. 2005; MacDonald-Wicks, et al. 2006). Therefore, it is difficult to compare antioxidant results from different research groups and results from different tests (Huang, et al. 2005; Sun and Tanumihardjo 2007). In order to best estimate the antioxidant levels of a given food, multiple tests should be used.

Several common analytical methods for determining antioxidant levels in food are based on an electron transfer reaction. Electron transfer assays work by using a molecular probe as an oxidant, which when added to an antioxidant removes an electron (Figure 2.2), causing the probe to change color. By measuring the amount of color change on a spectrophotometer and comparing to a standard curve, the antioxidant capacity of the food being tested can be determined (Huang, et al. 2005; MacDonald-Wicks, et al. 2006).

The antioxidant tests used in this project are described in additional detail below. They include three electron transfer assays (Folin-Ciocalteu, $ABTS^{\bullet+}$, and $DPPH^{+}$) and vitamin C content analysis using high performance liquid chromatography (HPLC).

Folin-Ciocalteu assay for total phenolics

This assay is based on a color reaction of phenolic compounds extracted from plant tissues with a reagent available commercially as Folin-Ciocalteu. Absorbance is measured at 76nm and total phenolic content is estimated by derivation from a standard curve based upon gallic acid. Results are expressed in gallic acid equivalents (GAE). Sequence, time, and reaction temperature are held constant, and data are adjusted for interference from vitamin C (Spanos and Wrolstad 1990). The assay has been derived from the Phytochemicals and Health Group, Crop and Research, Lincoln, NZ and modified in our lab for high-

throughput application using a 96 well Spectramax 640 microplate spectrophotometer (Rivera, et al. 2006).

2,2' azinobis (3-ethlbezothazoline-6-sulfonic acid) diammonium salt ($ABTS^{\bullet+}$) assay to estimate antioxidant capacity

This assay is based upon measuring the capacity of an extract to scavenge and detoxify the $ABTS^{\bullet+}$ radical and is considered an estimate of hydroxyl scavenging activity (Miller and Rice-Evans 1997). Quantification is based upon the decolorization of the blue-green $ABTS^{\bullet+}$ radical under time and temperature sensitive conditions at 734 nm. The assay is performed on aqueous acetone extracts of fruits or vegetables. The $ABTS^{\bullet+}$ radical is prepared by oxidizing 2,2' azinobis (3-ethlbenzothiazoline-6-sulfonic acid), adding to prepared test material, and comparing absorbance values to a standard curve of Trolox (water soluable analog of vitamin E) (Nenadis, et al. 2004). The assay has been modified in our lab for high-throughput using a 96 well Spectramax 640 microplate spectrophotometer (Rivera, et al. 2006).

2,2-diphenyl-1-picryhydrazl ($DPPH^{+}$) assay to estimate antioxidant capacity

The $DPPH^{+}$ radical is a relatively stable organic nitrogen free radical with chromophoric properties (Buijnsters, et al. 2001). After adding a $DPPH^{+}$-methanol solution to the prepared test material, the color change is measured at 515 nm. The amount of decolorization is correlated with a Trolox standard curve to determine the antioxidant capacity of the food being tested (Brandwilliams, et

al. 1995; Lu and Foo 2000). In our lab, this assay has been adapted for use with a microplate reader enabling high-throughput analyses.

Ascorbic Acid Analysis

Since humans cannot synthesize ascorbic acid (also known as vitamin C) we must consume adequate levels of this nutrient in our diets. Vitamin C serves many functions in the human body including roles in collagen and connective tissue formation, neurotransmitter synthesis and metabolism, iron absorption regulation, and various antioxidant scavenging capacities (Shils 1999).

Although first associated with deficiency-related diseases such as scurvy, the antioxidant functions of vitamin C are becoming better understood. Fresh fruits and vegetables are a major source of dietary vitamin C, yet the levels are easily influenced by growing, treatment, and storage conditions (Davey, et al. 2000). Therefore, it is especially important to ensure post-harvest handling methods minimize vitamin losses.

Freeze-dried tissues are extracted in 5% w/v aqueous solution of metaphosphoric acid containing 1% w/v dithiothreitol (DTT), then centrifuged and filtered through a 0.45 mm nylon syringe filter (Dale, et al. 2003). DTT is added to reduce any dehydroascorbic acid present in the sample to ascorbic acid, thus determining total ascorbate content with this test (Washko, et al. 1992). Extracts are then injected into a high performance liquid chromatography (HPLC) Inertsil

4° C column run with a phosphoric acid/methanol gradient with absorbance read at 254 nm (Rivera, et al. 2006).

Calcium content

Calcium is an important mineral and still under-consumed by many Americans (Briefel and Johnson 2004). Though often associated with its role in bones and teeth, calcium also serves important functions in cellular messaging and as a cofactor for extracellular enzymes and proteins (Shils 1999).

Several studies have found using a $CaCl_2$ dip treatment on fresh fruit increases the calcium content of the fruit (Garcia, et al. 1996; Tsantili, et al. 2002; Manganaris, et al. 2007). The calcium levels vary depending on the type of fruit and the $CaCl_2$ concentration used, but the use of a $CaCl_2$ post-harvest dip could possibly increase the calcium consumed by the public.

Calcium content can be evaluated on freeze-dried samples using inductively coupled plasma-atomic emission spectroscopy (Miller and Kotuby-Amacher 1994).

Research Objectives

This research project was designed to address many of the current challenges facing the produce industry with regards to producing safe, high quality, and nutritious fruit, focusing specifically on smaller-scale production and post-harvest methods for melons and tomatoes.

Since hundreds of melon and tomato cultivars exist, this project will focus on two Galia-type specialty melons grown in Colorado, 'Arava' and 'Haogen,' and one common tomato cultivar, 'Early Girl.' 'Arava' melons (Figure 2.3) have a netted skin that is a grey-green color while growing and turns light yellow when ripe. 'Haogen' melons (Figure 2.4) have a smooth, thin, delicate skin which is dark green while immature and turns a golden yellow upon ripening. Both melons have light green flesh and require approximately 80-90 days to maturity. 'Early Girl' (Figure 2.5) tomatoes are medium, globe shaped tomatoes primarily consumed fresh and require approximately 65 days to maturity.

The objectives of this study were to:

- Determine the effects of a post-harvest $CaCl_2$ dip and storage temperature on the aerobic and Enterobacteriaceae counts of conventionally and organically-grown 'Arava' melons over 10 days storage.

- Determine the effects of a post-harvest $CaCl_2$ dip and storage temperature on selected objective and subjective sensory qualities of conventionally and organically-grown 'Haogen' melons over 10 days storage.

- Determine the effects of a post-harvest $CaCl_2$ dip and storage temperature on calcium and selected antioxidant levels of conventionally and organically-grown 'Haogen' melons over 10 days storage.

- Determine the effects of a post-harvest $CaCl_2$ dip and storage temperature on selected objective and subjected sensory qualities of organically-grown 'Early Girl' tomatoes over 10 days storage.

- Determine the effects of a post-harvest $CaCl_2$ dip and storage temperature on calcium and selected antioxidant levels of organically-grown 'Early Girl' tomatoes over 10 days storage.

Hypotheses tested in this project were:

- $CaCl_2$ dip: A post-harvest $CaCl_2$ dip will not impact safety, sensory, and nutritional qualities of conventionally and organically-grown melons and tomatoes compared to non-dipped fruit over time.

- Storage temperature: A higher storage temperature will positively affect sensory and nutritional qualities, yet negatively impact microbial growth of melons over storage time.

- Storage temperature: A higher storage temperature will positively affect sensory and nutritional qualities of tomatoes over storage time.

- Storage time: Increased storage time will negatively impact safety, sensory, and nutritional characteristics of melons and tomatoes regardless of post-harvest $CaCl_2$ dip or storage temperature.

- Growing method: Growing method (conventional verses organic) will not impact safety, sensory, or nutritional qualities of melons regardless of post-harvest treatment or storage temperature.

Figure 2.1. Classification of dietary phytochemicals [adapted from (Shahidi and Ho 2007)].

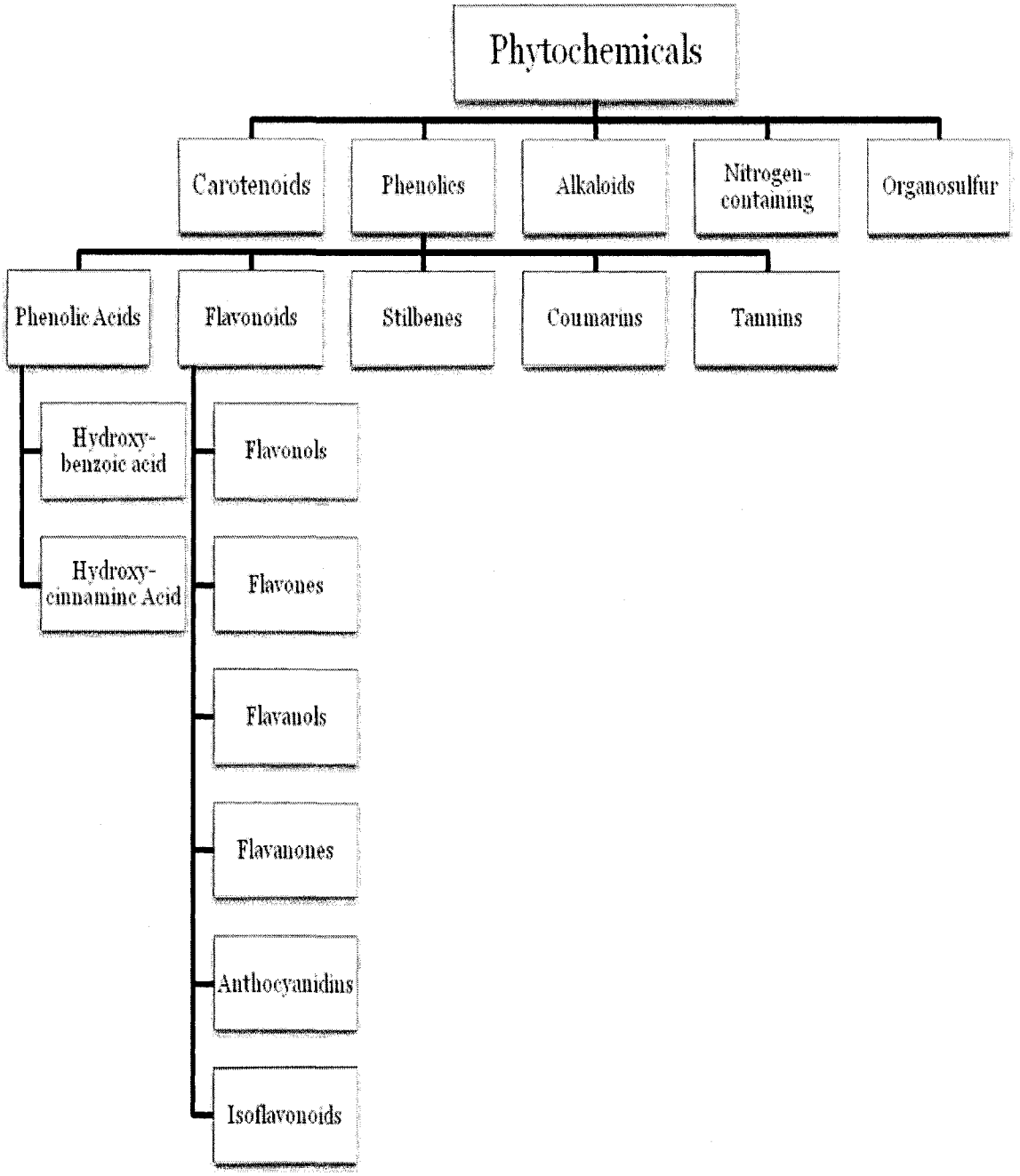

Figure 2.2. Reaction mechanism of electron transfer assays [adapted from (Huang, et al. 2005; MacDonald-Wicks, et al. 2006)].

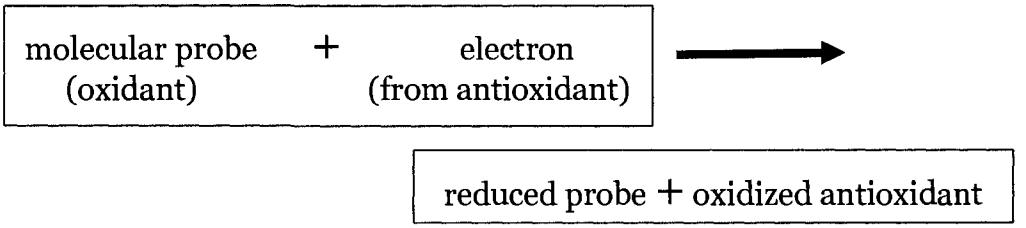

Figure 2.3. 'Arava' melons growing in the field.

Photo courtesy of Marisa Bunning

Figure 2.4. 'Haogen' melons growing in the field.

Photo courtesy Marisa Bunning

Figure 2.5. 'Early Girl' tomatoes growing in the field.

Photo courtesy of Marisa Bunning

Table 2.1. Review of literature using post-harvest calcium treatments on fresh produce

Citation	Fruit: what measured	Pre-treatment	Calcium source/conc/time	Storage temp/time	Significant Results
(Beavers, et al. 1994)	Apples: Firmness, Ca content, injury	None	CaCl2, Ca EDTA chelate, Stopit CaCl2 solution 0, 0.73, 1.46, 2.91, 5.82% pressurized infiltration for 6 min	0° ± 1° C for 18 wks	-Fruit injury with Ca EDTA solution -Year and cultivar variations in Ca content -CaCl2 and Stopit maintained fruit firmness and increased Ca concentration of the apple
(Conway, et al. 1991)	Apples: 3 fungal pathogens	None	CaCl2 (0, 2, 4, 8%) pressure infiltrated for 2 min Inoculated with respective pathogens	0° C for six months 20° C overnight before inoculation Stored at 20° C for 7 d before determining area of decay	-As the Ca content of the apples increased, severity of the decay decreased -Broad spectrum calcium induced resistance seen in both cultivars
(Garcia, et al. 1996)	Strawberries: Ca content, post-harvest decay, firmness, SSC	None	CaCl2 1%, 2%, 4% Used solutions at 25° C and 45° C 15 min	1° C for 1 day 18° C for 3 days samples taken at harvest, 1d, 2d, 3d, 4d	-1% CaCl2 at 45° C had highest Ca content -1% CaCl2 (both temps, but 45° C slightly better) most effective at reducing postharvest decay -Treatments did not affect sensory qualities (but authors did not describe how this was tested) -1% CaCl2 at 45° C highest firmness
(Lester and Grusak 1999)	Honeydew and netted muskmelon: tissue mineral content, quality, shelf-life	None	Ca AA chelate (.08 M) Mg AA chelate (.08 M) Ca+Mg chelate Dips adjusted to pH 7 20 min	4° C for muskmelon 10° C for honeydew For 7 and 21 days Plus 3 days at 21 C	-Ca chelate delayed fruit senescence in the honeydew variety (increased shelf-life 2.4 fold) -Muskmelon (netted melon) results were highly variable
(Lester and Grusak 2001)	Honeydew melon: Ca Content, quality, sensory	Washed with 0.53% bleach and rinsed in tap water (temp 23-26° C)	Amino acid chelate Ca EDTA chelate Ca CaCl2 Adjusted with potassium carbonate to reach pH 8.0-8.3 20 min at 24°± 2° C Conc levels: .08, .16, .24	10° ± 1° C 11 and 19 d plus 3 d at 21°± 1°C	-Amino acid chelate lengthened shelf-life best -Trts had no negative sensory effect

Citation	Fruit: what measured	Pre-treatment	Calcium source/conc/time	Storage temp/time	Significant Results
(Luna-Guzman and Barrett 2000)	Fresh-cut cantaloupe melon: Firmness, microbiological, sensory, respiration, ethylene	None	2.5% Calcium chloride 2.5% Calcium lactate Dipped for 1 minute Dip 25° and 60° C For sensory test used 1% and 2.5% calcium dips	5° C for 0, 4, 8, 12 days Sensory tests used within 6 hours of treatment	-Calcium dips increased firmness compared to control -Calcium chloride significantly more bitter than calcium lactate samples or control -No significant differences observed in the physiological behavior of calcium treated samples compared to the control samples
(Manganaris, et al. 2007)	Peaches: tissue/peel Ca levels, incidence of browning/chilling injury	None	Calcium chloride Calcium lactate Calcium propionate All 62.5 and 187.5 mM All 5 min immersion	-1 day -5 day @ 20° C -2wks@5°C + 1d@20°C -2wks@5°C + 5d@20°C -4wks@5°C + 1d@20°C -4wks@5°C + 5d@20°C	-Calcium chloride 62.5 mM overall recommendation
(Picchioni, et al. 1998)	Apples: Shelf-life/firmness, Ca content, membrane lipid concentrations	None	CaCl2 (0, 2, 4%) pressure infiltrated for 3 min	Overnight 20° C (1st measurement) 0° C for six months (2nd measurement) 7 d 20° C (3rd measurement)	-Ca infiltration improves firmness retention and delays loss of membrane phospholipids, free sterols, and sterol conjugates
(Picchioni, et al. 1996)	Shredded carrots: Shelf-life/firmness, Ca content, membrane lipid	None	CaCl2 (0, 1%) immersed for 2 min	10° C for 0, 4, 10 d	-Ca preserved membrane integrity of carrot shreds not only by delaying senescence-related membrane changes, but also by apparently augmenting membrane restructuring processes

Citation	Fruit: what measured	Pre-treatment	Calcium source/conc/time	Storage temp/time	Significant Results
(Saftner, et al. 2003)	Fresh-cut honeydew: Respiration rates, firmness, translucency, microbiological, sensory, color, Ca	19 mM hypochlorous acid (ClO) washed 5 min	Dipped for 30 seconds 1.9 mM ClO solution with 40 mM Ca -CaCl2 (.6%) -Ca propionate (.7%) -Ca AA chelate (1.5%) -Just ClO -Untreated control	Stored 10° C for 0, 2, 4, 5, 7 d	-Sanitary dips containing low concentrations of Ca increased shelf-life by maintaining surface color and firmness as well as inhibiting respiration and ethylene production rates, microbial growth, and the development of tissue translucency.
(Serrano, et al. 2004)	Plums: Physiological changes induced by mechanical damage	None	CaCl2 at 1 mM (plus Tween and pressure) for 8 min (also looked at heat trt)	20° C 4h, 4d, 7d, 11d, 14d	-Calcium (and also the heat trt) induced a significant resistance to mechanical damage in plums
(Tsantili, et al. 2002)	Lemons: Color, firmness, respiration, pH, ascorbic acid conc, soluble solids, titratable acidity	Washed with water, treated with imazalil and thiabendazole	CaCl2, 15° C Yr 1: 0, .045, .09, .18, .27, .36 M for 25 min Yr 2: 0, .09, .18, .27 M For 10, 15, 20, 25 min	Yr 1: 12° C, Yr 2: 11° C Some tests day 0, 27, 40 Some tests day 0, 14, 28, 45, 56	-Promising method to improve quality of lemons. Slows firmness loss and peel color changes without affecting juice characteristics. -Optimal CaCl2 concentration from this study was 0.09 M.

Table 2.2. Summary of MDP samples tested for *Salmonella*[#] [adapted from (MDP 2002-2006)].

Commodity	2002	2003	2004	2005	2006*
Celery	0/2,175	0/2,190	0/1,113	n/a	n/a
Cantaloupe	0/1,077	0/2,184	3/2,233	8/2,304	5/1,533
Lettuce	3/4,357	2/4,397	3/3,340	22/2,298	5/1,530
Tomato	0/2,706	1/2,194	7/2,237	5/2,304	1/1,535
Parsley	n/a	n/a	0/588	3/1,118	n/a
Cilantro	n/a	n/a	3/572	0/1,122	n/a
Green Onions	n/a	n/a	1/1,128	9/2,294	4/1,536
Alfalfa Sprouts	n/a	n/a	n/a	0/72	7/1,512

[#]Results given as: number of positive samples/number of total samples tested
*2006 results taken during Jan-Jun only

Table 2.3. Summary of MDP samples tested for virulent *E. coli*# [adapted from (MDP 2002-2006)].

Commodity	2002	2003	2004	2005	2006*
Celery	3/2,175	3/2,190	1/1,113	n/a	n/a
Cantaloupe	2/1,077	7/2,184	2/2,233	8/2,304	3/1,533
Lettuce	57/4,357	32/4,397	19/3,340	8/2,298	8/1,530
Tomato	3/2,706	2/2,194	1/2,237	3/2,304	1/1,535
Parsley	n/a	n/a	10/588	10/1,118	n/a
Cilantro	n/a	n/a	8/572	8/1,122	n/a
Green Onions	n/a	n/a	2/1,128	9/2,294	8/1,536
Alfalfa Sprouts	n/a	n/a	n/a	2/72	9/1,512

#Results given as: number of positive samples/number of total samples tested
*2006 results taken during Jan-Jun only

•CHAPTER III•

Effects of a Post-Harvest $CaCl_2$ Dip and Storage Temperature on Aerobic and Enterobacteriaceae Counts of Organically and Conventionally Grown Melons

ABSTRACT

Melons (*Cucumis melo* L.), a popular fruit in the United States, have been associated with many foodborne illness outbreaks. While calcium chloride ($CaCl_2$) dips have been shown to reduce post-harvest decay and increase the shelf-life of fruit, the antimicrobial effect is unknown. This study evaluated the impact of a 0.08 M $CaCl_2$ post-harvest treatment and storage temperature on total aerobic and Enterobacteriaceae bacterial counts present on organically and conventionally grown melons (cultivar 'Arava') stored for 10 days. Storage temperature significantly impacted microbial growth, as higher levels of aerobic and Enterobacteriaceae bacteria grew on melons stored at 21° C compared to 10° C. After 10 days of storage at 21° C, non-dipped organic melons had significantly more aerobic bacterial growth than non-dipped conventional melons. However, at day 10, organic melons treated with $CaCl_2$ and stored at 21° C had significantly lower Enterobacteriaceae levels than non-dipped melons stored at the same temperature. Enterobacteriaceae growth on conventional melons was not decreased by using the $CaCl_2$ treatment. Based on the results of this study, storing whole Arava melons at cooler temperatures is best to slow bacterial growth and a $CaCl_2$ dip decreased aerobic and Enterobacteriaceae counts on organic melons, which may increase the safety of the fruit.

INTRODUCTION

Foodborne illness outbreaks associated with fresh produce have increased in the United States during the last thirty years (Sivapalasingam, et al. 2004; Doyle and Erickson 2008). Fresh fruits and vegetables are especially vulnerable to causing foodborne outbreaks due to the fact that they are often eaten raw or minimally processed and each step, from planting through post-harvest handling, may contribute to the microbial load (Johnston, et al. 2005).

Melons (*Cucumis melo* L.) are a popular fruit in the United States that have been tied to numerous foodborne illness outbreaks. While it is difficult to confirm exactly how many outbreaks have been associated with contaminated melons, a review article by Bowen et al. (2006) found at least 28 documented outbreaks associated with cantaloupes and muskmelons between 1984 and 2003, indicating a strong need to increase the safety of fresh melons. This review found contamination has been linked to *Salmonella enterica*, *Campylobacter jejuni*, *Escherichia coli* O157:H7, and norovirus, and both domestic and imported melons have been implicated in past outbreaks.

There is some concern among public health experts that organic production methods increase the risk for microbial contamination due to increased manure use, compared to using chemical fertilizers in conventional farming (Stephenson 1997a; Stephenson 1997b). Because organic foods are one of the fastest growing

food categories with sales increasing nearly 20% each year since 1990 (Winter and Davis 2006), this is an important concern to address.

Studies assessing consumer perceptions of organic produce have often found that consumers think organic produce is safer, more nutritious, and better tasting than conventionally grown produce (Torjusen, et al. 2001; Magnusson, et al. 2003; Shepherd, et al. 2005; Yiridoe, et al. 2005). However, research comparing such attributes have produced inconsistent or inconclusive results, most likely due to unparallel growing conditions, cultivar choices, and other uncontrolled variables (Harker 2004; Lester 2006). Well-controlled studies are needed to better understand the role of organic and conventional growing methods on the microbial growth on fresh produce.

Calcium plays an important role in maintaining cell wall structure in fruit by interacting with pectic acid to form calcium pectate, which has a firming effect on cell walls; thus, calcium deficiency during the growing process has been shown to cause a variety of physiological disorders in produce (Poovaiah 1986). Because of the role calcium has for maintaining the cell wall of fruit, researchers have investigated the use of post-harvest calcium treatments to increase the quality and shelf-life of fruit after harvest (Martin-Diana, et al. 2007). One such calcium treatment showing positive results on fruits such as strawberries, lemons, and peaches has been calcium chloride ($CaCl_2$) dips (Garcia, et al. 1996; Tsantili, et al. 2002; Manganaris, et al. 2007; Martin-Diana, et al. 2007). Concentrations of

$CaCl_2$ used in the above studies have ranged from 0.045 M-0.27 M, with the recommended concentrations falling into the 0.06-0.09 M range depending on the fruit being studied and whether the fruit was treated whole or fresh-cut. The optimal $CaCl_2$ concentration found to slow senescence without any negative side effects in a study using whole honeydew melons was 0.08 M (Lester and Grusak 2001).

To our knowledge, the microbial effects of using $CaCl_2$ as a post-harvest treatment have not been studied. Research by Chikthimmah et al. (2005) did find, however, that using $CaCl_2$ in mushroom irrigation water during crop production resulted in lower levels of microbial growth during storage compared to mushrooms grown without $CaCl_2$ added to the irrigation water, indicating the potential of such a treatment after harvest to impact microbial levels.

The United States Department of Agriculture (USDA) has monitored for the presence of several foodborne pathogens on cantaloupe as well as alfalfa sprouts, pre-cut bagged lettuce, spinach, and tomatoes since 2002 as part of the Microbiological Data Program (MDP). Out of the thousands of samples tested for this program between 2002-2006, only 0.17% of cantaloupe samples tested were found to be positive for *Salmonella* spp. and 0.24% for virulent *E. coli* (MDP 2003-2007; McCallum 2007). Though this shows pathogens can be found on cantaloupe, due to the very low rates of contamination, it would be difficult to

determine post-harvest treatment effects on specific foodborne pathogens without inoculating the produce.

This study was designed to assess selected post-harvest effects on aerobic and Enterobacteriaceae microflora commonly found on fresh produce. Testing for aerobic bacteria present on melons in this study provides an indicator of the post-harvest treatment impact on all bacteria that grow in oxygenated conditions, which include spoilage as well as pathogenic organisms. Evaluating Enterobacteriaceae bacteria levels provides information on how the post-harvest conditions affect bacteria in this gram-negative family, which includes several common food pathogens, such as *Salmonella* spp., *Shigella* spp., and Enterohemorrhagic *Escherichia coli* (Varnam and Evans 1991).

Current melon handling recommendations state cool temperature storage is not necessary to maintain the safety of whole melons (Fleming and Pool 2005). However, a study evaluating the effect of temperature on inoculated whole cantaloupe melons, found significantly more microbial growth occurred at 19° C than 4° C (Annous, et al. 2004). Most whole melon storage temperature recommendations are based on preventing chilling injury among commonly grown cultivars (Salunkhe and Kadam 1998; Thompson 2003). There is a lack of research available on optimal storage conditions for specialty melon cultivars such as 'Arava.'

This project evaluated the impact of storage temperature and a $CaCl_2$ dip treatment on total aerobic and Enterobacteriaceae bacteria concentrations present on organically and conventionally grown 'Arava' melons stored for up to 10 days.

METHODS AND MATERIALS

Plant Material

Melons (cultivar 'Arava') (Johnny's Selected Seeds, Winslow, ME) were grown at the Colorado State University Horticulture Field Research Center (HFRC) in Fort Collins, CO during the summer of 2007. 'Arava' melons have a netted rind that is a grey-green color while growing and turns light yellow when ripe. Fruit flesh of this Galia-type melon is light green and the melons require approximately 80-90 days to reach maturity.

Organic and conventional melons were grown simultaneously on plots 50 meters apart. Soil at the HFRC is classified as Nunn clay with a pH of 7.8 and the organic plots have been USDA certified organic since 2001.

Plants were started in the Colorado State University Plant Environmental Research Center's greenhouses in 3-inch peat pots using Sunshine Organic Basic planting media (Sun Gro Horticulture, Bellvue, WA) with 20% vermicompost (local source). After four weeks, the melons were transplanted to the field,

spaced evenly in black plastic mulched beds (rows 24 inches apart and beds 50 inches apart).

Prior to planting, soil tests were conducted on the organic and conventional plots. The certified organic plots contained 2.0-2.4% higher levels of organic matter derived from green manure plough-down of legume and cereal cover crops and from thoroughly composted chicken manure. Otherwise, nutrient content of nitrogen, phosphorus, and potassium was made approximately equivalent at the beginning of the growing season from either organic or conventional fertilizers. 'Evergreen' poultry compost (A1 Organics, Eaton, CO) was applied to the organic plot with a Millcreek spreader and rototilled into the soil. To match nutrient levels in the organic fertilizer, urea (45-0-0) and triple superphospate (0-20.1-0) were applied to the conventional plot using a broadcast spreader.

Crops were irrigated using drip irrigation with municipal water. Irrigation levels were determined using 'Watermark' granular matrix sensors (Irrometer Company, Riverside, CA). Irrigation levels were monitored to ensure the melons were watered adequately.

During the growing season, pest management practices were used to minimize cucumber beetle (*Acalymma vittatum*) pressure on the melons. Synthetic insecticide Permethrin (Loveland Products Inc., Greeley, CO) was applied to the

conventional plots while naturally derived pyrethrum (MGK Co., Golden Valley, MN) was used on the organic plots.

Once the 'Arava' melons reached peak maturity (as indicated by light yellow rind and nearly full slip off the vine), they were harvested manually early in the morning, then transported at ambient temperature to the laboratory for processing within 30 minutes.

Treatments

Organically and conventionally grown melons (17 ± 1-cm diameter) were randomly assigned into $CaCl_2$ dip and no dip treatment groups (see Figure 3.1) (total n=144). Any visible soil was brushed off melons using paper towels. Half of all organically and conventionally grown melons were dipped in a 0.08 M $CaCl_2$ solution (8.8 g $CaCl_2$ per L of water) and half were left untreated. The $CaCl_2$ concentration was chosen based on favorable results to increase shelf-life of fruit in other studies (Garcia, et al. 1996; Lester and Grusak 2001; Tsantili, et al. 2002; Manganaris, et al. 2007) as well as preliminary research conducted in our lab.

For the dip, food grade $CaCl_2$ (DOW Chemical Company, Midland, MI) was mixed with water (21° ± 1° C) in 68 L plastic tubs (Sterile, Townsend, MA) until dissolved. Dipped melons were completely immersed in the $CaCl_2$ solution for 20 minutes, then removed and allowed to air dry on paper towels for 1 hour.

Melons were then individually wrapped loosely in tissue paper labeled with sample ID information and placed in new 30.5x38.1x25.4-cm cardboard boxes (Weyerhaeuser, Federal Way, WA), keeping treatment groups separate. Melons were stored at 21° ± 1° C (relative humidity 30 ± 5%) or 10° ± 1° C (relative humidity 70 ± 5%). At days 1, 5, and 10 total aerobic and Enterobacteriaceae counts were determined, with six melons evaluated individually per treatment group as test replications.

Microbial Analysis

The following microbial testing procedures are based on methods used by USDA's Microbiological Data Program (MDP 2003-2007; McCallum 2007) and modified for our lab.

One whole melon and 300 mL Universal Pre-Enrichment Broth (UPEB) solution [UPEB (Difco, Sparks, MD) and 0.1% Tween 80 (Fisher Scientific, Fair Lawn, NJ)] were placed in a 38.1x50.8-cm sterile bag (VWR, West Chester, PA) and sealed with a twist tie. The bagged melons were shaken for 20 up and down strokes and 20 side to side strokes to assure the UPEB solution adequately "washed" all surfaces of the melon, then stored with the melon remaining in the bag at 5°C for 18-24 hours. A 5 mL sample was taken from the bagged UPEB solution and transferred to a sterile Falcon tube (BD Falcon™, Franklin Lakes, NJ). Six, 10-fold serial dilutions were made using buffered peptone water (Difco,

Sparks, MD). From each dilution, 1 mL samples were plated on aerobic and *Enterobacteriaceae* Petrifilm™ (3M, St. Paul, MN) according to manufacturer's instructions. All Petrifilm™ samples were incubated overnight (37°C). Colonies for each sample were counted on plates that contained 25-250 colonies and expressed as CFU/mL.

Data Analysis

Results were transformed into log scale and analyzed using SAS Proc Mixed (Version 9.1, Cary, NC). A factorial analysis of variance was performed with differences between means assessed using a significance of $p<0.05$ with the Tukey-Kramer adjustment for multiple comparisons. Fixed effects included time, temperature, dip, and growing method; replication was included as a random effect.

RESULTS

Aerobic Counts

The mean aerobic bacterial counts are presented in Figure 3.2 and Table 3.1. Aerobic counts ranged from 4.56-8.28 log CFU/mL. Organic non-dipped melons stored at 21° C experienced the most aerobic bacterial growth during storage, increasing 1.28 log CFU/mL from day 1 to day 10.

Overall, storage temperature, dip, and growing method significantly affected aerobic bacterial levels (Table 3.2). Melons stored at 10° C had lower bacterial

growth ($p<0.0001$) than those stored at 21° C (Figure 3.3). Also, overall aerobic counts were lower ($p<0.01$) on $CaCl_2$ dipped melons compared to non-dipped melons (Figure 3.4). The main effect of growing method also impacted the presence of aerobic bacteria ($p<0.05$), with organic melons overall having higher aerobic counts than conventional melons (Figure 3.5).

A significant ($p=0.0130$) time x method x dip interaction shows that across temperature, organically grown melons had higher aerobic counts on day 10 than did conventionally grown melons (Figure 3.6). This figure also shows that at day 1, significantly lower ($p<0.05$) aerobic counts were found on the $CaCl_2$-dipped organic melons than the non-dipped organic melons regardless of temperature.

Another three-way interaction, time x temperature x dip, also was significant ($p=0.02$) showing that regardless of growing method, on day 10, non-dipped melons stored at 21° C had significantly higher aerobic counts than non-dipped melons stored at 10° C (Figure 3.7). In comparison, the temperature effect at 10 days was not seen in the $CaCl_2$-dipped melons. Also contributing to this interaction was that at day 1, $CaCl_2$-dipped melons stored at 10° C had lower counts ($p<0.05$) than non-dipped melons at 10° C as well as lower counts ($p<0.05$) than $CaCl_2$-dipped melons stored at 21° C.

After 10 days storage at 21° C, organic melons had significantly higher levels ($p<0.05$) of aerobic bacterial growth than conventional melons (Figure 3.8). Day

1 and day 5 differences were not significant, indicating organic 'Arava' melons may have higher levels of microorganisms than conventionally grown melons only after being stored at room temperature for several days. Yet, this is a concern because farmers as well as consumers may store melons at room temperature before the fruit is consumed.

Enterobacteriaceae Counts

The Enterobacteriaceae bacterial counts ranged from 4.19-7.15 log CFU/mL (Figure 3.9 and Table 3.3), and were significantly affected overall by temperature and dip treatment (Table 3.2). Like the aerobic counts, melons stored at 10° C had lower ($p<0.0001$) bacterial counts than those stored at 21° C (Figure 3.3). Also, melons dipped in $CaCl_2$ had lower ($p<0.001$) overall Enterobacteriaceae counts compared to non-dipped melons (Figure 3.4).

A significant ($p=0.0199$) time x temperature x dip x method interaction was experienced due to the organic $CaCl_2$ dipped melons having significantly lower Enterobacteriaceae counts on day 10 compared to organic non-dipped melons when stored at 21° C but not 10° C (Figure 3.10, Table 3.3). This is especially important as the non-dipped, day 10 organic melons stored at 21° C experienced the most bacterial growth with 7.15 log CFU/mL, while the $CaCl_2$-dipped organic melons were reduced to 4.82 log CFU/mL. The conventional melons were not significantly affected by the $CaCl_2$ treatment.

DISCUSSION

The effect of storage temperature on microbial growth seen in this study is consistent with the results from other studies showing lower bacterial growth at lower temperatures for inoculated whole melons (Annous, et al. 2004), as well as for fresh-cut produce (Zagory 1999; Francis and O'Beirne 2001). Storing melons at cooler temperatures may be an effective solution for limiting post-harvest microbial growth. Yet, many melons are susceptible to chilling injury when storage temperatures are decreased, and the specific temperature causing chilling injury symptoms varies greatly by cultivar (Miccolis and Saltveit 1995). Most storage recommendations have been based on commonly-grown commercial cantaloupe or honeydew cultivars (Salunkhe and Kadam 1998; Thompson 2003). Further research should be done to determine the effect of storage temperature on quality and sensory characteristics of specialty cultivars such as 'Arava'.

The $CaCl_2$ dip in this study appears to be a promising option for decreasing the bacterial growth in whole 'Arava' melons, especially when the melons are grown organically and stored at room temperature. Since Enterobacteriaceae bacteria includes many common foodborne pathogens such as *Shigella* spp., *Salmonella* spp. and Enterohemorrhagic *E. coli* (Varnam and Evans 1991), $CaCl_2$ may potentially increase the safety of organic melons stored for longer lengths of time. $CaCl_2$ is approved as a processing aid for organic food production (CFR 2008), is relatively inexpensive, and easily accessible (Dow-Chemical 2007), making it a feasible solution for farmers.

Organic melons had higher levels of aerobic bacteria in this study compared to the conventional melons, most of which was due to significantly higher counts in non-dipped organic melons on day 10 stored at 21° C. Enterobacteriaceae counts were not significantly different between the two growing methods. Other studies comparing organic and conventional produce safety have used produce from different farms (Magkos, et al. 2006), which would greatly confound the results. Based on this research, especially after storing melons at room temperature for 10 days, it appears that growing method may impact the general microflora of Arava melons. Additional well-controlled research is needed to determine the growing method effect on other produce as well as specific microorganisms.

Overall, time was not a significant factor impacting microbial growth in this study. This is encouraging as melons are often stored by farmers or consumers for many days before being eaten. However, other variables, such as temperature and growing method may eventually allow microbial levels to significantly increase over time, as seen with the significant interactions in this study for both aerobic and Enterobacteriaceae counts and the highest levels of bacterial growth found on day 10 in organic melons stored at 21° C.

The sensory impact of using a $CaCl_2$ treatment should also be addressed. Research on whole melons dipped in a 0.08 M $CaCl_2$ solution indicate there may be no negative sensory effects (Lester and Grusak 2001), yet another study found

higher bitterness and lower melon flavor scores for fresh cut melons dipped in 1% and 2.5% $CaCl_2$ solutions (approximately 0.09 and 0.23 M, respectively) compared to the control and other treatments (Luna-Guzman and Barrett 2000). Since the later study used fresh cut melons the results may not be the same for whole melons, as the physiology of cut melons has been shown to be distinctly different than that of whole fruit (Lamikanra, et al. 2003). Further assessment of the value of dipping whole melons in $CaCl_2$ as well as sensory effects of $CaCl_2$ on different melon cultivars is important to assure consumer acceptance.

CONCLUSIONS

Based on the results of this study, storing melons at 21° C for 10 days may pose a greater microbial risk for melons grown using organic compared to conventional production methods. This risk may be minimized through the use of a $CaCl_2$ dip at harvest. Regardless of growing method, storing whole 'Arava' melons at cooler temperatures is an effective method for slowing bacteria growth. Additional research should be conducted to explore the potential for a $CaCl_2$ dip to decrease specific foodborne pathogens on melons and other produce as well as treatment and storage effects on sensory and quality characteristics.

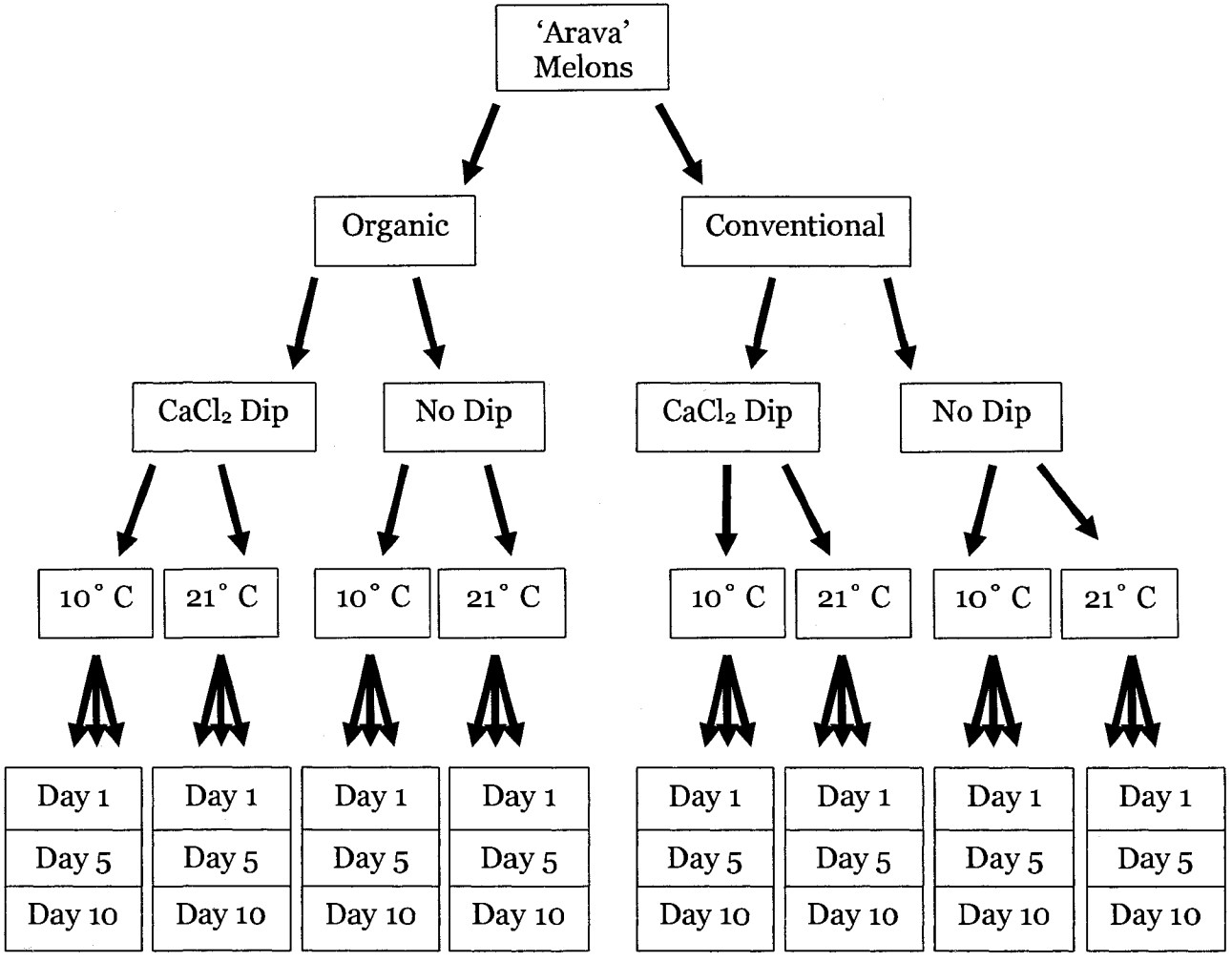

Figure 3.1. Research Design. Six replications tested for each of the 24 treatment combinations (total n=144).

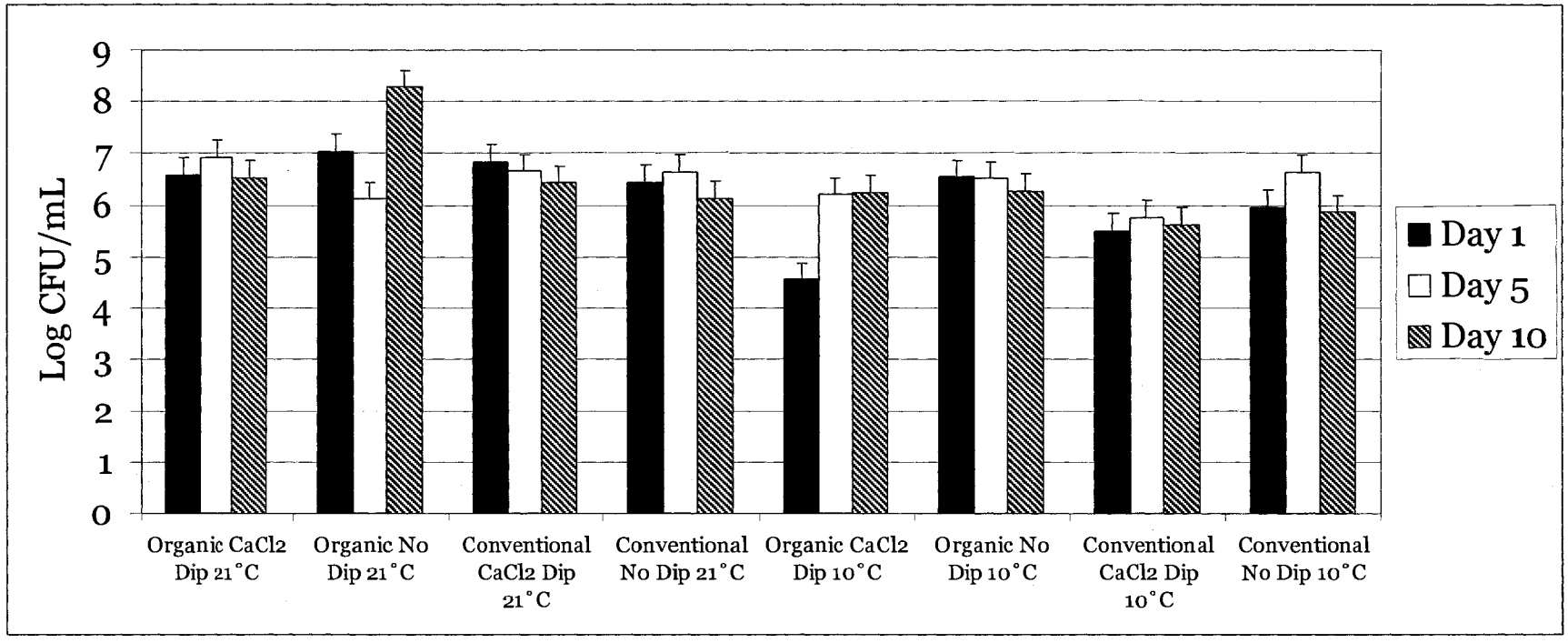

Figure 3.2. Mean aerobic bacterial counts (log CFU/mL). Each bar represents the average of six melons. Error bars indicate the standard error.

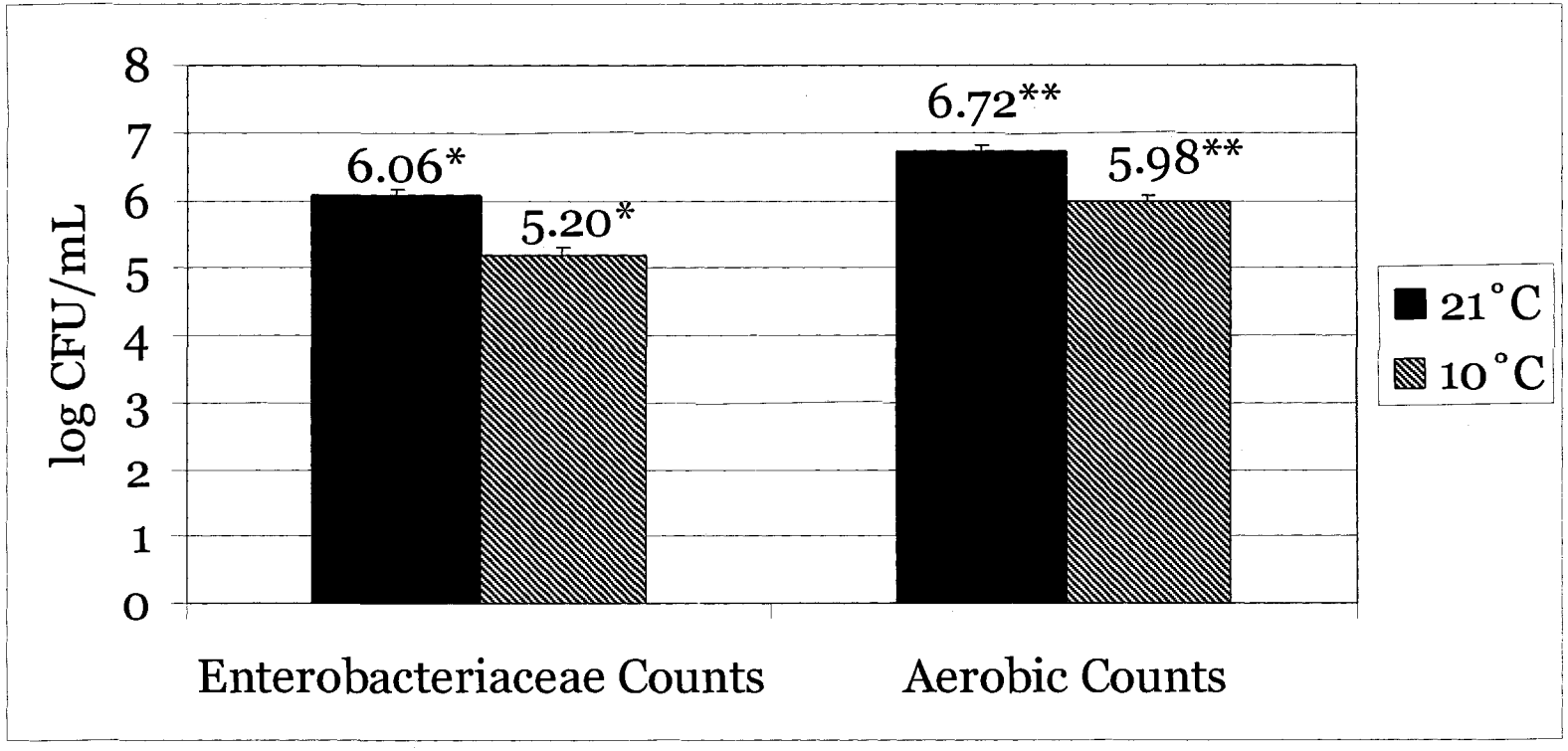

Figure 3.3. Effect of storage temperature on Enterobacteriaceae and aerobic bacterial counts (log CFU/mL). Organically and conventionally grown 'Arava' melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored at 21° C or 10° C for 1, 5, and 10 days. Each bar represents the mean bacterial counts of all melons stored at each temperature (n=72 for each temperature). Error bars indicate the standard error. Data labels marked by the same symbol (*, **) are significantly different ($p<0.0001$).

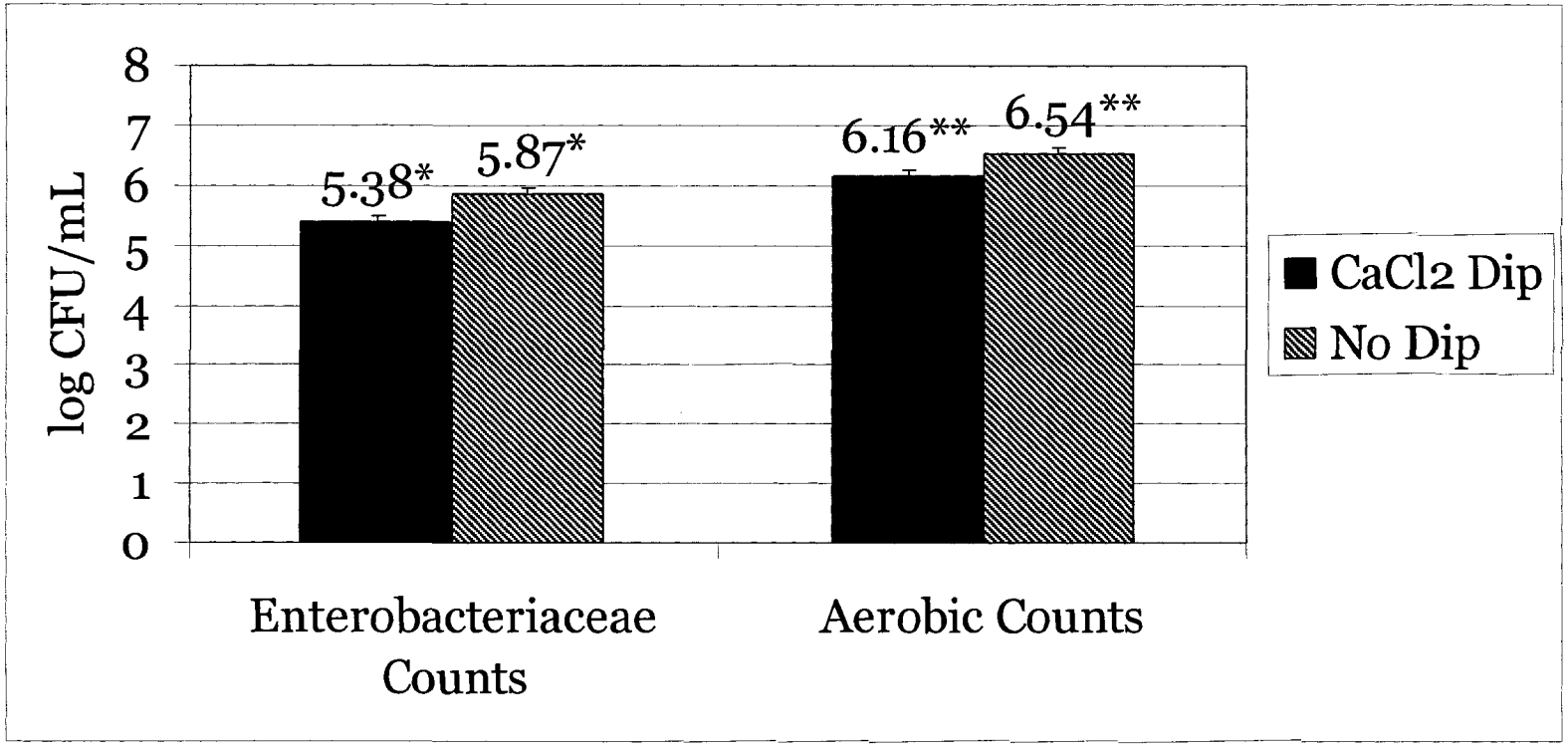

Figure 3.4. Effect of dip treatment on Enterobacteriaceae and aerobic bacterial counts (log CFU/mL). Organically and conventionally grown 'Arava' melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored at 21° C or 10° C for 1, 5, and 10 days. Each bar represents the mean bacterial counts of all melons for each dip treatment (n=72 for each dip treatment). Error bars indicate the standard error. Data labels marked by the same symbol (*, **) are significantly different (*$p<0.001$, **$p<0.01$).

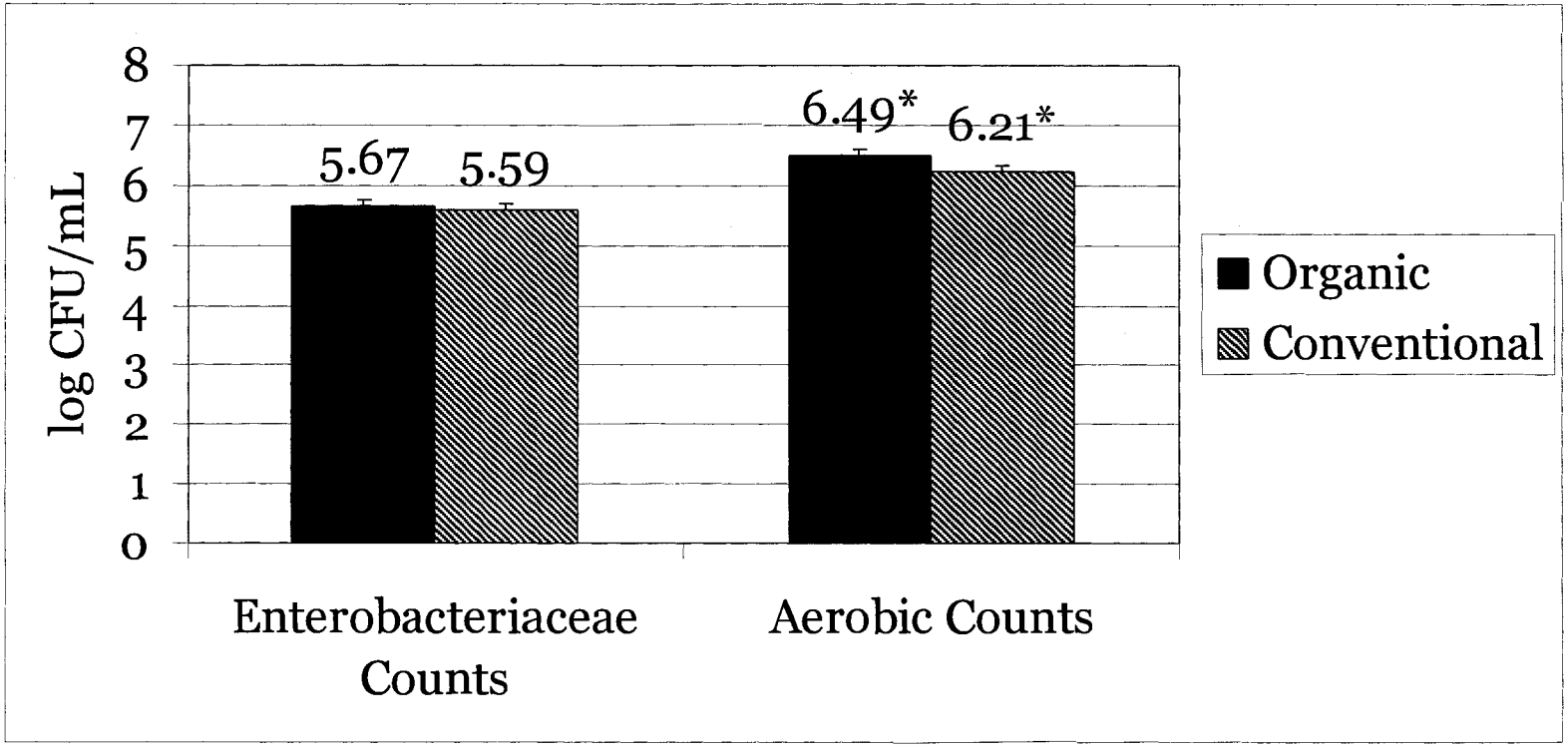

Figure 3.5. Effect of growing method on Enterobacteriaceae and aerobic bacterial counts (log CFU/mL). Organically and conventionally grown 'Arava' melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored at 21° C or 10° C for 1, 5, and 10 days. Each bar represents the mean bacterial counts of all melons grown by each method (n=72 for each growing method). Error bars indicate the standard error. Data labels marked by the same symbol (*) are significantly different ($p<0.05$).

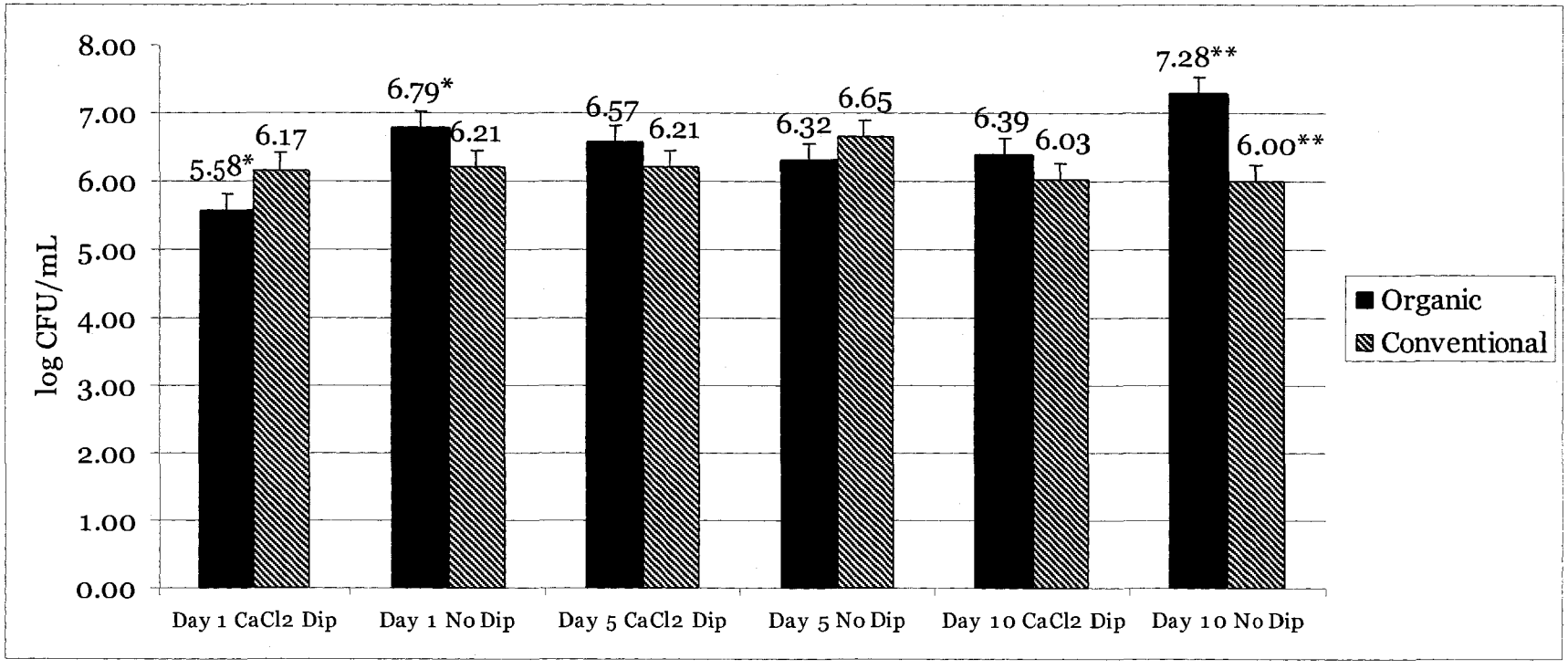

Figure 3.6. Aerobic bacterial counts (log CFU/mL) of organically and conventionally grown 'Arava' melons either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1, 5, and 10 days. Each bar represents the mean bacterial counts of melons stored at 21° C and 10° C (n=12 per bar). Error bars indicate the standard error. Data labels marked by an asterisk (*) are significantly different ($p<0.05$) between dip treatments for the same day and growing method and data labels marked by a double asterisk (**) are significantly different ($p<0.05$) between growing methods for the same day and dip treatment.

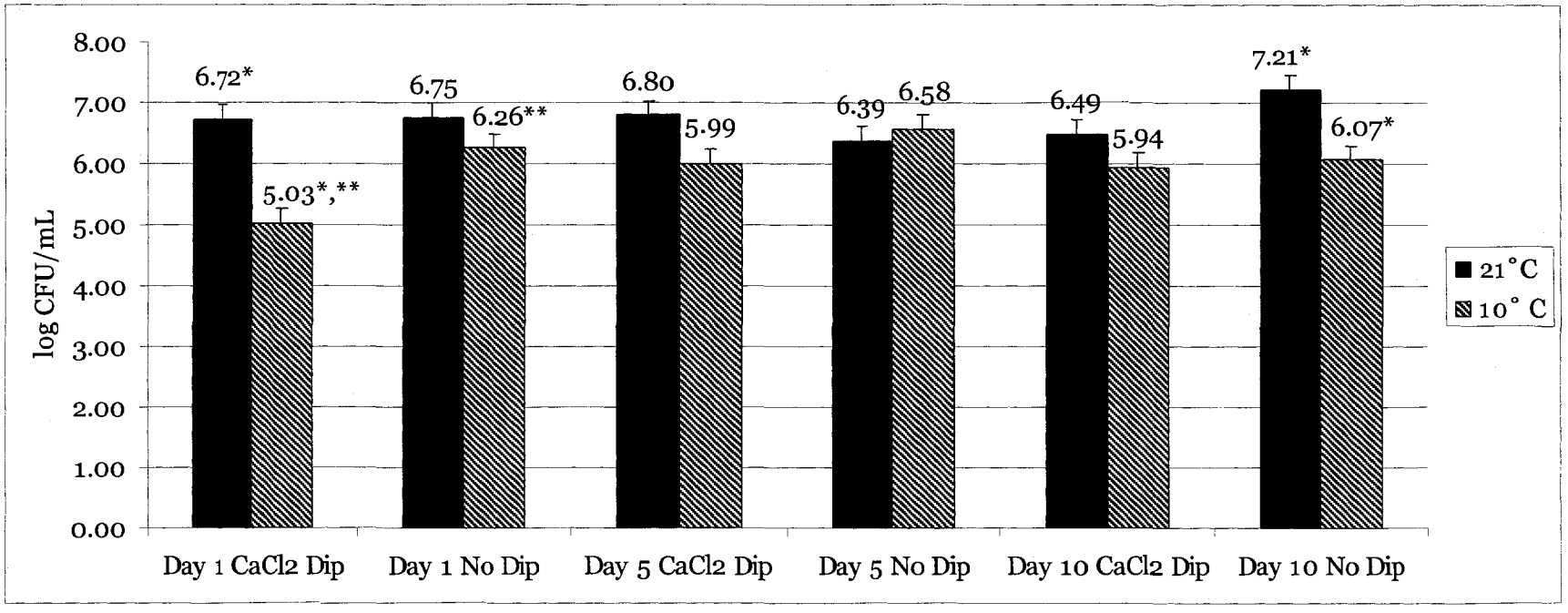

Figure 3.7. Aerobic bacterial counts (log CFU/mL) of $CaCl_2$-dipped and undipped 'Arava' melons stored at 10° C and 21° C for 1, 5, and 10 days. Each bar represents the mean bacterial counts of organic and conventional melons (n=12 per bar). Error bars indicate the standard error. Data labels marked by an asterisk (*) are significantly different ($p<0.05$) between storage temperature for the same day and dip treatment and data labels marked by a double asterisk (**) are significantly different ($p<0.05$) between dip treatments for the same day and storage temperature.

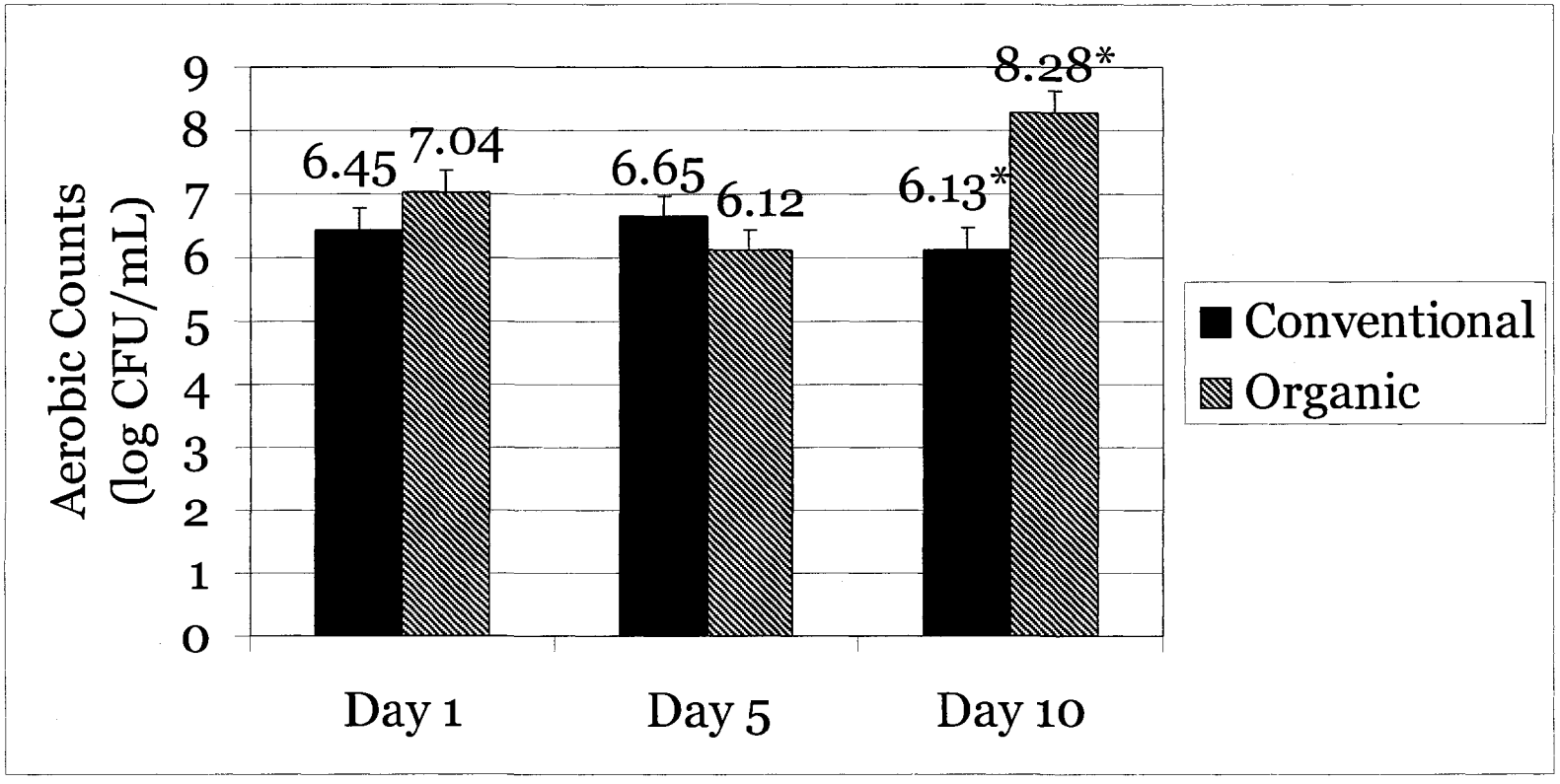

Figure 3.8. Effect of growing method on aerobic bacterial counts (log CFU/mL) of untreated 'Arava' melons stored at 21° C for 1, 5, and 10 days. Each bar represents the mean bacterial counts of six melons. Error bars indicate the standard error. Data labels marked by the same symbol (*) are significantly different ($p<0.05$).

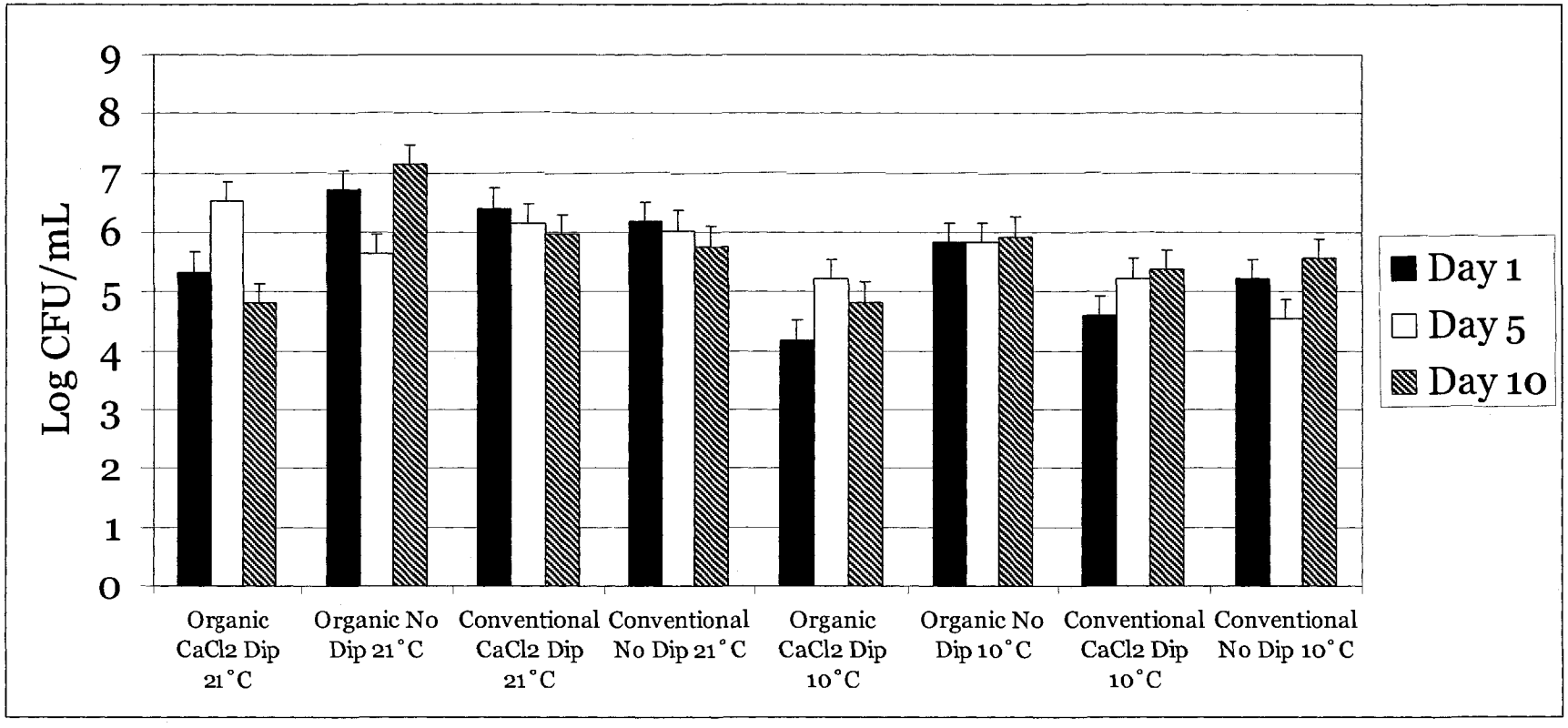

Figure 3.9. Mean Enterobacteriaceae bacterial counts (log CFU/mL). Each bar represents the average of six melons. Error bars indicate the standard error.

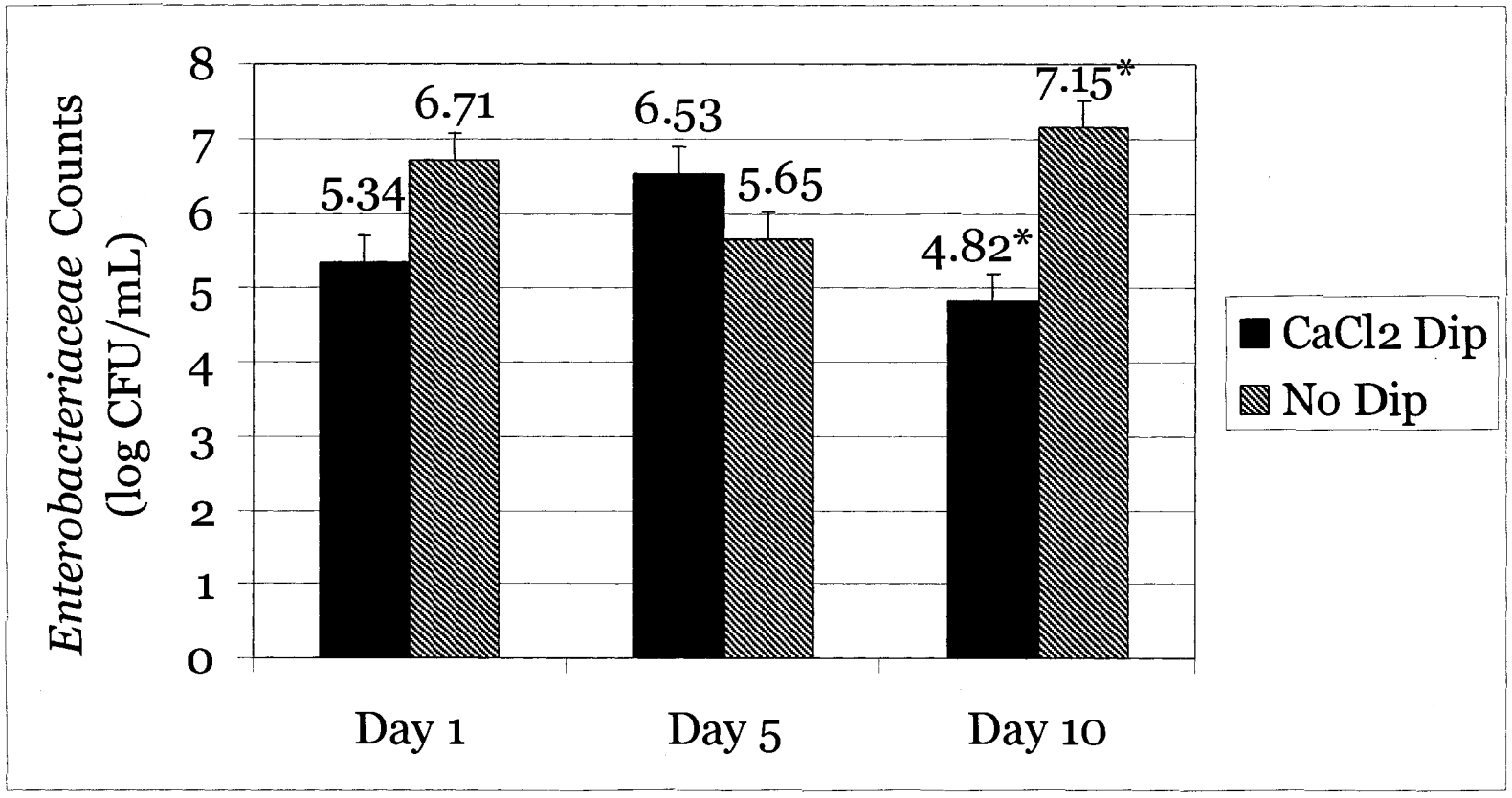

Figure 3.10. Effect of a $CaCl_2$ dip on Enterobacteriaceae bacterial counts (log CFU/mL) of organic 'Arava' melons stored at 21° C. Melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1, 5, and 10 days. Each bar represents the mean bacterial counts of six melons. Error bars indicate the standard error. Data labels marked by the same symbol (*) are significantly different ($p<0.05$).

Table 3.1. Mean aerobic bacterial counts (log CFU/mL)[1]

		21° C Storage			10° C Storage		
		Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
Organic	$CaCl_2$ Dip[2]	6.60^{Y} ±0.33	6.94 ±0.33	6.54 ±0.37	$4.56^{A,Z}$ ±0.37	6.21 ±0.33	6.25 ±0.33
	No Dip	7.04^{ab} ±0.33	6.12^{a} ±0.33	$8.28^{b,Y,y}$ ±0.33	6.55^{B} ±0.33	6.52 ±0.33	6.28^{Z} ±0.33
Conventional	$CaCl_2$ Dip[2]	6.84 ±0.33	6.66 ±0.33	6.44 ±0.37	5.51 ±0.37	5.77 ±0.33	5.63 ±0.33
	No Dip	6.45 ±0.33	6.65 ±0.33	6.13^{z} ±0.33	5.97 ±0.33	6.65 ±0.33	5.87 ±0.33

[1] Means represent six replications (±SE) of log colony forming units (CFU/mL).
[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.

A,B: Treatment effect—means for same day, temperature, and method with different superscripts are significantly different ($p<0.05$).
a,b: Day effect—means for same treatment, temperature, and method with different superscripts are significantly different ($p<0.05$).
Y,Z: Temperature effect—means for same treatment, day, and method with different superscripts are significantly different ($p<0.05$).
y,z: Growing Method effect—means for same treatment, day, and temperature with different superscripts are significantly different ($p<0.05$).

Table 3.2. Analysis of variance on the effects of time, storage temperature, dip treatment, and growing method on the aerobic and Enterobacteriaceae bacterial counts of Arava melons

Effect	Aerobic	Enterobacteriaceae
Time	0.2575^{NS}	0.7802^{NS}
Temp	$<0.0001^{***}$	$<0.0001^{***}$
Time* Temp	0.0660^{NS}	0.1212^{NS}
Dip	0.0072^{**}	0.0006^{***}
Time*Dip	0.2827^{NS}	0.0008^{***}
Temp*Dip	0.0537^{NS}	0.4527^{NS}
Time*Temp*Dip	0.0193^{*}	0.2728^{NS}
Method	0.0487^{*}	0.5609^{NS}
Time*Method	0.0245^{*}	0.4543^{NS}
Temp*Method	0.4141^{NS}	0.3134^{NS}
Time*Temp*Method	0.3932^{NS}	0.4310^{NS}
Dip*Method	0.0934^{NS}	$<0.0001^{***}$
Time*Dip*Method	0.0130^{*}	0.0838^{NS}
Temp*Dip*Method	0.4394^{NS}	0.9446^{NS}
Time*Temp*Dip*Method	0.0725^{NS}	0.0199^{*}

Expressed as p values for statistical significance.
$^{NS, *, **, ***}$Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table 3.3. Mean Enterobacteriaceae bacterial counts (log CFU/mL)[1]

		21° C Storage			10° C Storage		
		Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
Organic	$CaCl_2$ Dip[2]	5.34 ±0.33	6.53 ±0.33	4.82[A] ±0.36	4.19 ±0.36	5.21 ±0.33	4.83 ±0.33
	No Dip	6.71 ±0.33	5.65 ±0.33	7.15[B] ±0.33	5.84 ±0.33	5.84 ±0.33	5.93 ±0.33
Conventional	$CaCl_2$ Dip[2]	6.41 ±0.33	6.16 ±0.33	5.97 ±0.36	4.60 ±0.36	5.23 ±0.33	5.38 ±0.33
	No Dip	6.19 ±0.33	6.04 ±0.33	5.77 ±0.33	5.22 ±0.33	4.55 ±0.33	5.56 ±0.33

[1] Means represent six replications (±SE) of log colony forming units (CFU/mL).
[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.

A,B: Treatment effect—means for same day, temperature, and method with different superscripts are significantly different ($p<0.05$).

•CHAPTER IV•

Effects of a Post-Harvest $CaCl_2$ Dip and Storage Temperature on Selected Quality Characteristics of Conventionally and Organically Grown 'Haogen' Melons

ABSTRACT

Melon (*Cucumis melo* L.) consumption in the United States is increasing and so is the interest in local and organic produce. A variety of factors influence produce quality during the storage time from harvest to consumption. Published research is lacking on the best post-harvest handling methods for specialty melons, especially those grown by smaller-scale farmers who often sell directly to consumers. This study evaluated the impact of a 20-minute 0.08 M $CaCl_2$ post-harvest dip treatment as well as storage temperature on selected sensory and nutritional qualities of organically and conventionally grown 'Haogen' melons stored up to ten days. Use of a $CaCl_2$ dip positively impacted sensory scores of the melons. Melons stored at 10° C had a longer shelf-life as well as higher sensory scores, higher $DPPH^+$ test results, and less weight loss during storage than melons stored at 21° C. However, significant fruit color changes were observed at 10° C, with lighter and less green flesh than melons stored at 21° C. By day 10, time negatively impacted many qualities, including sensory scores, percent weight loss, and melon color, as well as total phenolic and $DPPH^+$ antioxidant test results. Growing method significantly affected many of the sensory and nutritional tests, though results were mixed. Tailoring post-harvest

handling methods to specialty melons such as 'Haogen' can help growers maintain the shelf-life as long as possible while maximizing sensory and nutritional qualities of unique, though often more delicate, melon cultivars.

INTRODUCTION

Melons (*Cucumis melo* L.) are a popular fruit in the United States, reaching a record total consumption of 8.5 billion pounds in 2007 (Lucier and Dettman 2008a). Melons are primarily consumed fresh and contain moderate levels of carotenoids, phenolics, vitamin A, and vitamin C (Lester 1997; Vinson, et al. 2001).

Awareness for the important role fruits and vegetables have in a healthy diet is increasing (Goldman 2003; Bazzano 2006), as is the number of farmers' markets in the United States. According to the United States Department of Agriculture (USDA), the number of U.S. farmers' markets more than doubled from 1,755 in 1994 to 4,385 in 2006 (USDA-AMS 2006). Also, based on the results of a national survey conducted in 2006, 3 out of 4 respondents had shopped at a farmers' market within the last year (Keeling-Bond, et al. 2006).

Organic foods are also one of the fastest growing food categories with sales increasing nearly 20% each year since 1990 (Winter and Davis 2006). Studies assessing consumer perceptions of organic produce have often found people think organic produce is safer, more nutritious, and better tasting than

conventionally grown produce (Torjusen, et al. 2001; Magnusson, et al. 2003; Shepherd, et al. 2005; Yiridoe, et al. 2005). However, research comparing such attributes have produced inconsistent or inconclusive results, most likely due to unparallel growing conditions, cultivar choices, and other uncontrolled variables (Harker 2004; Lester 2006). More well-controlled studies are needed to better understand the role of organic and conventional growing methods on produce quality attributes as well as the impact of production method on post-harvest storage (Bourn and Prescott 2002).

This increased popularity of and demand for high quality, fresh produce, along with the growing interest in locally produced food and organic production (Keeling-Bond, et al. 2006), provides small-scale growers with a unique opportunity. The opportunity, however, can only be realized if small-scale growers can get their crops in the hands of retailers and consumers while the produce is at peak quality.

Most post-harvest storage handling recommendations have focused on enhancing the quality of common commercial melon cultivars (Salunkhe and Kadam 1998; Thompson 2003). To our knowledge little research exists on post-harvest recommendations for the specialty cultivars often grown by smaller scale farmers (Miccolis and Saltveit 1995). Optimal post-harvest handling methods vary from cultivar to cultivar (Miccolis and Saltveit 1995), and therefore, more

research is needed to determine the most beneficial post-harvest conditions for specialty varieties, such as 'Haogen.'

While refrigeration of melons is not required to maintain fruit safety and quality, many producers refrigerate melons to lengthen the shelf-life (Fleming and Pool 2005). Therefore, this research project will look at the impact on selected sensory and nutritional qualities of storing 'Haogen' melons at ambient temperature (21° C) and a commonly recommended refrigeration temperature for melons susceptible to chilling injury (10° C) (Salunkhe and Kadam 1998; Thompson 2003; Fleming and Pool 2005).

Because melons are highly perishable (Kader 1992), they could benefit from a post-harvest treatment that increases their shelf-life. One post-harvest treatment showing positive results on fruit such as melons, strawberries, lemons, and peaches has been calcium chloride ($CaCl_2$) dips (Garcia, et al. 1996; Lester and Grusak 2001; Tsantili, et al. 2002; Manganaris, et al. 2007; Martin-Diana, et al. 2007). Calcium plays an important role in maintaining the cell wall structure in fruit by interacting with pectic acid to form calcium pectate, which has a firming effect on plant cell walls (Poovaiah 1986). Concentrations of $CaCl_2$ used in previous studies have ranged from 0.045 M-0.27 M, with recommendations falling in the 0.06-0.09 M range depending on the fruit being studied and whether the fruit is treated whole or fresh-cut. The optimal $CaCl_2$ concentration

found to slow senescence without any negative side effects in a study using whole honeydew melons was 0.08 M (Lester and Grusak 2001).

Based on favorable $CaCl_2$ concentrations used in other studies and preliminary research conducted in our lab, we chose to evaluate the impact of a 20-minute 0.08 M $CaCl_2$ post-harvest dip treatment as well as storage temperature on selected sensory and nutritional qualities of organically and conventionally grown 'Haogen' melons stored up to ten days.

METHODS AND MATERIALS

Plant Material

Melons (cultivar 'Haogen') (Seeds of Change, Santa Fe, NM) were grown at Colorado State University's Horticulture Field Research Center (HFRC) in Fort Collins, CO during the summer of 2007. 'Haogen' melons have a smooth, thin, delicate skin which is dark green while immature, turning golden yellow upon ripening. Fruit flesh of this Galia-type melon is light green and the melons require approximately 80-90 days to reach maturity.

Organic and conventional melons were grown simultaneously on plots 50 meters apart. Soil at the HFRC is classified as Nunn clay with a pH of 7.8 and the organic plots have been USDA certified organic since 2001.

Plants were started in Colorado State University Plant Environmental Research Center's greenhouses in 3-inch peat pots using Sunshine Organic Basic planting media (Sun Gro Horticulture, Bellvue, WA) with 20% vermicompost (local source). After four weeks, the melons were transplanted to the field, spaced evenly in black plastic mulched beds (rows 24 inches apart and beds 50 inches apart).

Prior to planting, soil tests were conducted on the organic and conventional plots. The certified organic plots contained 2.0-2.4% higher levels of organic matter derived from green manure plough-down of legume and cereal cover crops and from thoroughly composted chicken manure. Otherwise, nutrient content of nitrogen, phosphorus, and potassium was made approximately equivalent at the beginning of the growing season from either organic or conventional fertilizers. 'Evergreen' poultry compost (A1 Organics, Eaton, CO) was applied to the organic plot with a Millcreek spreader and rototilled into the soil. To match nutrient levels in the organic fertilizer, urea (45-0-0) and triple superphospate (0-20.1-0) were applied to the conventional plot using a broadcast spreader.

Crops were irrigated using drip irrigation with municipal water. Irrigation levels were determined using 'Watermark' granular matrix sensors (Irrometer Company, Riverside, CA). Irrigation levels were monitored to ensure the melons were watered adequately in order to prevent water stress.

During the growing season, pest management practices were used to minimize cucumber beetle (*Acalymma vittatum*) pressure on the melons. Synthetic insecticide Permethrin (Loveland Products Inc., Greeley, CO) was applied to the conventional plots while naturally derived pyrethrum (MGK Co., Golden Valley, MN) was used on the organic plots.

Once the 'Haogen' melons reached peak maturity (as indicated by golden yellow rind and full slip off the vine), they were harvested manually early in the morning. Melons were transported at ambient temperature to the laboratory for processing within 30 minutes.

Treatments

Organically and conventionally grown melons (13 ± 1-cm diameter) were randomly assigned into $CaCl_2$ dip and no dip treatment groups (Figure 4.1). Seventy-two melons were used for the sensory taste tastes and 72 melons were used for the objective quality measurements and chemical analyses (total harvested melons=144). Any visible soil was brushed off melons using paper towels. Half of each organically and conventionally grown group of melons was dipped in a 0.08 M $CaCl_2$ solution (8.8 grams $CaCl_2$ per liter of water) and half were left untreated. To make the dip, food grade $CaCl_2$ (DOW Chemical Company, Midland, MI) was mixed with water (21° ± 1° C) in 68 L plastic tubs (Sterile, Townsend, MA) until dissolved. Dipped melons were completely

immersed for 20 minutes, then removed and allowed to air dry at ambient temperature on paper towels for 1 hour.

Melons were then individually wrapped in loose tissue paper labeled with the sample ID information and placed in new 30.5x38.1x25.4-cm cardboard boxes (Weyerhaeuser, Federal Way, WA), keeping treatment groups separate. Melons were stored at 21° ± 1° C (relative humidity 30 ± 5%) or 10° ± 1° C (relative humidity 70 ± 5%). On days 1, 5, and 10, melons were randomly selected for sensory evaluations as well as for objective quality measurements and chemical analyses.

By day 10, many of the melons stored at 21° C were past an acceptable shelf-life. The $CaCl_2$-dipped organic and conventional melons as well as the non-dipped conventional melons were not suitable for inclusion in the sensory evaluation. For the objective quality measurements and chemical analyses, the conventionally grown melons dipped in $CaCl_2$ were too spoiled to be tested.

Sensory Evaluation

The protocol for the melon sensory evaluations was reviewed and approved by the Colorado State University Human Research Committee before beginning this project. Forty untrained consumer panelists were recruited from CSU faculty, staff, and students for each sensory evaluation session.

On days 1, 5, and 10, the stored melons being tested were washed under running tap water (21° ± 1° C) for approximately 30 seconds. The washed melons were sliced into wedges, and the fruit was cut off the rind into uniform pieces, approximately 3-cm cubed. Samples were coded with a three-digit number and given to panelists in a random order. Distilled water and unsalted crackers were given to panelists to cleanse their palate between samples. Four to six samples were tested in each session and panelists were asked to rate the appearance, flavor, texture, and overall acceptability of the samples using a 9-point hedonic scale, with 9=highly acceptable and 1=highly unacceptable (Figure 4.2).

Objective Quality Measurements

Percent Weight Loss

The weight of all melons was recorded at harvest. On the day of testing, melons were weighed again and the percent weight loss was calculated as [(initial weight-final weight)/initial weight] x 100. Measurements were taken in grams on three melons per treatment group.

Color

Color values were determined for all treatments on days 1, 5, and 10. A cube cut from the center of a melon wedge (approximately 5-cm) was placed in the chamber of a HunterLab ColorFlex spectrocolorimeter (Hunter Associates Laboratory, Inc., Reston, VA). L* (100=white, 0=black), a* (positive=red,

negative=green), and b* (positive=yellow, negative=blue) values were read three times, averaged for each of the three sample replications per treatment group.

Soluble Solids Content

The soluble solids content (SSC) of each melon sample was measured using an AR200 Reichert Digital, Temperature-Compensated Refractometer (Reichert Analytical Instruments, Depew, NY). An eyedropper was used to transfer melon juice from a cut melon to the sample well. Samples from three melons were measured per treatment group and results expressed as °Brix.

Chemical Analyses

Sample Preparation

Melons were cut in half and the seeds were removed. The melon halves were cut into wedges, and then the fruit was cut off the rind. The rindless wedges were cut in half to create two short wedges. Thin slices were randomly cut off several of the short wedges. For each replication, 35-40 g of these thin slices were freeze-dried using a Genesis Freeze Drier (Virtis, Inc., Gardiner, NY).

Lyophilized samples were then weighed to determine dry matter content and ground in preparation for extraction. The dried samples were ground into a powder using a mortar and pestle and sieved with a No. 20 Tyler sieve (WS Tyler Inc., Mentor, OH).

Samples were extracted by placing 5 mL of 80% acetone (Fisher Chemicals, Fair Lawn, NJ) and 500 mg dried powder from each replicate in 15 mL centrifuge tubes. The tubes were vortexed until thoroughly mixed then rotated in the dark (4° C) for 15 minutes. Samples were then centrifuged (4° C; 4,000 rpm) for 15 minutes. One mL of supernatant was transferred to an Eppendorf tube and vacufuged at 45° C to dryness (approximately 2-3 hours). Samples were stored at -20° C until analytical tests were completed.

Total Phenolic Content

Total phenolic content was measured using a microplate-based Folin-Ciocalteu assay adapted from Singleton and Rossi (1965), Spanos and Wrolstad (1990), and Rivera et al. (2006). Vacufuged extractions were reconstituted with 1.0 mL 80% acetone, then 100 µL of this solution was diluted with 900 µL nanopure water. In triplicate, 35 µL of the diluted sample was pipetted into microplate wells. Using a multichannel pipette, 150 µL of 0.2 M Folin-Ciocalteu reagent (Sigma-Aldrich, Inc., St. Louis, MO) was added to all wells. The plate was shaken for 30 seconds and held for 5 minutes at room temperature. Then 115 µL 7.5% (w/v) Na_2CO_3 (Fisher Chemicals) was added to all wells, shaken for 30 seconds, and held for 5 minutes at room temperature. The microplate was incubated at 45° C for 30 minutes, and then cooled to room temperature for 1 hour before reading at 765 nm in a Spectra Max Plus (Molecular Devices, Sunnyvale, CA) spectrophotometer using Softmax Pro software (Molecular Devices). Total phenolic content was calculated by comparing to a gallic acid (Sigma Chemical Co., St. Louis, MO)

standard curve and expressed as milligrams per 100 gram of melon fresh weight (mg GAE/100 g FW).

ABTS$^{\bullet+}$ Trolox Equivalent Antioxidant Capacity

The 2,2' azinobis (3-ethlbezothazoline-6-sulfonic acid) diammonium salt (ABTS$^{\bullet+}$) assay was used to estimate antioxidant capacity. This assay is based upon measuring the capacity of an extract to scavenge and detoxify the ABTS$^{\bullet+}$ radical and is considered an estimate of hydroxyl scavenging activity (Miller and Rice-Evans 1997). The protocol used was based on the microplate method described by Rivera et al. (2006), as modified from Miller and Rice-Evans (1997).

The ABTS$^{\bullet+}$ solution was prepared by mixing 40 mg ABTS$^{\bullet+}$ (Calbiochem, EMD Biosciences, La Jolla, CA), 15 mL distilled water, and 2.0 ± 0.5 g MnO_2 (Sigma-Aldrich). After 20 minutes, the MnO_2 was removed using double filtration, first with a vacuum filtration and second with a 0.2 μm syringe filter. The absorbance value of the ABTS$^{\bullet+}$ solution was read at 734 nm in the Spectra Max Plus (Molecular Devices, Sunnyvale, CA) spectrophotometer using Softmax Pro software (Molecular Devices) and adjusted to 0.70 absorbance units (AU) by adding 5.0 mL phosphate buffer solution. Once the ABTS$^{\bullet+}$ solution was adjusted, it was held at 30° C and used within 4 hours.

Vacufuged samples were reconstituted with 1 mL 80% acetone (Fisher Chemical). Twenty-five μL of each reconstituted sample was mixed with 250 μL of the

$ABTS^{\bullet+}$ solution, and after 60 seconds, the absorbance value was read. $ABTS^{\bullet+}$ antioxidant capacity was reported as Trolox equivalent antioxidant capacity (TEAC) per gram of sample on a fresh weight basis (TEAC/g FW) and was calculated by comparing to a Trolox (Calbiochem) standard curve. Analyses were run in triplicate at 3 dilutions for a total of 9 assays per sample.

$DPPH^+$ Trolox Equivalent Antioxidant Capacity

The 2,2-diphenyl-1-picryhydrazl ($DPPH^+$) assay was also used to estimate antioxidant capacity was measured using the method of Lu and Foo (2000) with some modifications. Vacufuged samples were reconstituted with 1.0 mL of 5.0 mM Phosphate buffer solution. A 0.1 mM $DPPH^+$ solution was made by mixing 7.89 mg DPPH with 100% methanol. Absorbance was read in the Spectra Max Plus (Molecular Devices, Sunnyvale, CA) spectrophotometer using Softmax Pro software (Molecular Devices) at 515 nm and adjusted to 0.95 AU.

Fifteen µL of the reconstituted samples were mixed with 285 µL of the $DPPH^+$ solution, held for three minutes at 25° C, then read at 515 nm. The results were compared to a Trolox (Calbiochem) standard curve and expressed as TEAC/100 g FW.

Ascorbic Acid Content

Ascorbic acid (vitamin C) content was determined using a high-performance liquid chromatography (HPLC) method as described by Rivera et al. (2006) and modified from Dale and others (2003). Freeze-dried samples were extracted with a 5% w/v aqueous solution of metaphosphoric acid containing 1% w/v dithiothreitol (DTT) (Promega Corp., Madison, WI), and then allowed to rotate for 15 minutes at 4° C. The samples were then centrifuged for 5 minutes at 4,000 rpm and 4° C before the supernatant was filtered through a 0.45 mm nylon syringe filter. The extraction process was repeated and the supernatant from both extractions was placed in an amber HPLC vial.

Ascorbic acid standards were made by mixing 100 mg DTT (Pormega Corp.), 10 mg ascorbic acid (Sigma-Aldrich), and 10 mL 100% methanol before diluting to five concentrations for the standard curve. All analyses were run in duplicate and were analyzed by HPLC chromatography (Hewlett Packard Model 1050 Series, Palo Alto, CA) using Chem Station for LC Rev A 09.01 software (Agilent Technologies, Palo Alto, CA). Samples were injected onto an Inertsil C4 column (Agilent Technologies) run with a phosphoric acid/methanol gradient and absorbance read at 254 nm.

Calcium Content

Freeze-dried melon samples (1 g ground powder each) were sent to the Soil-Water-Plant Testing Laboratory at Colorado State University to determine the

calcium content. Calcium content was tested using inductively coupled plasma-atomic emission spectroscopy (Miller and Kotuby-Amacher 1994). Three replications of the dipped and non-dipped melons grown organically and conventionally and stored for 1 day at 21° C were tested to determine if the dip affected the calcium content of the melons.

Data Analysis

Results were analyzed using SAS Proc Mixed (Version 9.1, Cary, NC). A factorial analysis of variance was performed with differences between means assessed using a significance of $p<0.05$ with the Tukey-Kramer adjustment for multiple comparisons. Fixed effects included time, temperature, growing method, and dip; replication (or panelist for sensory tests) was included as a random effect.

RESULTS

Sensory Evaluation

Overall, dip, storage temperature, time, and growing method each significantly impacted at least half of the sensory qualities tested (Table 4.1). Melons dipped in $CaCl_2$ were favored overall, with appearance, texture, and overall acceptability scores significantly higher than non-dipped melons (Figure 4.3).

Time affected all sensory attributes, with appearance, texture, and overall acceptability receiving highest scores on day 1 and lowest scores on day 10 (Figure 4.4). Flavor received its highest scores on day 5. It is important to note

that 75% of the melons stored at 21° C were inedible by day 10 and unable to be tested; therefore the day 10 sensory scores would have been even lower if the results could have been included.

Storage temperature was also significant overall for appearance, texture, and overall acceptability, with 10° C melons receiving higher scores than 21° C melons (Figure 4.5). Organically grown melons had overall higher scores than conventional melons, with appearance and texture scores significantly higher (Figure 4.6).

In addition to the significant main effects, appearance scores (Figure 4.7, Table 4.2) experienced dip-method and time-dip-method interactions which were due to a significantly lower mean score on day 10 for the non-dipped conventional melons stored at 10° C compared to the same melons dipped in $CaCl_2$ or grown organically.

Flavor scores (Figure 4.8, Table 4.3) experienced many significant interactions and differences between means, yet no clear trends are identifiable. Day 5 organic melons dipped in $CaCl_2$ and stored at 10° C received the highest flavor score (8.10), which was significantly higher than the same melons tested at day 1 or day 10, as well as for the day 5 dipped organic melons stored at 21° C. All organic melons stored at 21° C and dipped organic melons stored at 10° C received significantly higher scores on day 5 compared to day 1, while the scores

for conventional non-dipped melons stored at 10° C decreased significantly from day 1 to day 5.

Significant texture score interactions (Table 4.1) can be explained by comparing the significant effect of growing method for all day 5 and day 10 non-dipped melons evaluated at both temperatures, with organic melons receiving higher scores (Figure 4.9, Table 4.4). Dipped melons did not experience the same trend.

Overall acceptability scores ranged from 8.06 to 6.06, with organic $CaCl_2$-dipped melons stored at 10° C for 5 days being most preferred and conventional non-dipped melons stored at 10° C for 5 days being less preferred (Figure 4.10, Table 4.5).

Objective Quality Measurements

Percent Weight Loss

The percent weight loss was significantly affected by time and storage temperature (Table 4.1). Overall, more weight was lost as time increased ($p<0.0001$) and melons stored at 21° C had more weight loss than those stored at 10° C ($p<0.0001$). A time-temperature interaction was also significant, as more weight was lost over time at the higher temperature than for the lower temperature. For melons stored at 21 C, the $CaCl_2$-dipped organic melons and the non-dipped conventional melons had significant ($p<0.05$) weight loss from day 1 to day 10 (Figure 4.11, Table 4.6).

Color

Color a* values (Figure 4.12, Table 4.7) were significantly impacted overall by time ($p<0.0001$) and dip ($p=0.0008$), as well as several interactions (Table 4.1). Day 10 scores were higher overall than day 1 scores and individually time was a significant factor for all melons except for organic $CaCl_2$-dipped melons at 21° C (unable to make conventional comparison on day 10 at 21° C due to unavailable data). Non-dipped melons tended to have higher color a* values compared to $CaCl_2$-dipped melons, indicating the dip may help preserve the green fruit color. The effect of the dip was especially pronounced by day 10 at 21° C as seen with the significant difference between -6.16 and -2.91 for the organic melons. The dipped organic melons stored at 21° C for 10 days also had significantly higher a* values than the same melons stored at 10° C.

All color b* main effects and interactions were significant (Table 4.1) indicating post-harvest conditions greatly impact the yellow and blue hues present in the green flesh of 'Haogen' melons. Overall organic melons had higher scores (more yellow) than conventional melons (less yellow) ($p<0.0001$). Melons stored at 10° C experienced lower b* values over time ($p<0.05$) (Figure 4.13, Table 4.8). For melons stored at 21° C, the b* values of $CaCl_2$-dipped melons increased over time, while for the non-dipped melons the values decreased ($p<0.05$) or did not change over time.

Overall, color L* values (Figure 4.14, Table 4.9) were significantly impacted by time ($p<0.0001$) and storage temperature ($p<0.0001$) (Table 4.1). Color L* values went up over time, indicating the fruit became lighter. Melons stored at 10° C also had overall higher color L* values than 21° C melons. However, significant time x temperature interactions were seen in that melons stored at 21° C experienced relatively little change, while the color L* value of 10° C melons significantly increased over time.

Soluble Solids Content

Overall, the conventional melons had higher ($p<0.05$) soluble solids content (SSC) than the organic melons (10.8 compared to 9.4 °Brix) (Table 4.1). However, on an individual comparison basis, conventional SSC values were only higher ($p<0.05$) than organic values for day 1 non-dipped melons stored at 10° C (Figure 4.15, Table 4.10). SSC values were quite variable causing significant interactions but no identifiable trends.

Chemical Analyses

Antioxidant Assays

Overall, growing method had a significant impact on all four antioxidant assays (Figure 4.16, Table 4.1), though the trends were not consistent. Conventional melons had higher scores for the total phenolic ($p=0.0146$), $ABTS^{\cdot+}$ ($p=0.0002$), and ascorbic acid tests ($p=0.0012$), while organic melons scored higher on the $DPPH^{+}$ test ($p=0.0007$).

Time also significantly affected total phenolic ($p=0.0248$), $ABTS^{\bullet+}$ ($p=0.0008$), and $DPPH^{+}$ ($p=0.0088$) scores, but not ascorbic acid content (Figure 4.17). In general, day 5 values were highest for total phenolic content and $DPPH^{+}$ tests and day 10 values were highest for the $ABTS^{\bullet+}$ test.

The $DPPH^{+}$ test was the only test which was significantly impacted by storage temperature ($p<0.0086$), with melons stored at 10° C having a higher antioxidant capacity than those stored at 21° C (Figure 4.18). However, due to the 10° C organic $CaCl_2$-dipped melons having 1126.88 µmole TEAC/100 g FW on day 1 and dropping to 475.70 µmole TEAC/100 g FW by day 10 (Figure 4.19, Table 4.11), time-method ($p<0.0001$) and temperature-method ($p=0.0003$) interactions were also significant.

When comparing individual means, the only significant difference for the $ABTS^{\bullet+}$ test results was seen between day 5 and 10 for conventional non-dipped melons stored at 10° C (Figure 4.20, Table 4.12). No differences were significant for individual total phenolic means (Figure 4.21, Table 4.13) or ascorbic acid means (Figure 4.22, Table 4.21), indicating these results were not impacted by time, by storage temperature, by use of a $CaCl_2$ dip, or by production method.

Calcium Content

The calcium content was affected overall by dip ($p<0.0212$) and growing method ($p<0.0267$) (Table 4.1), though individual comparisons were not significant (Figure 4.22, Table 4.15). Organic melons had higher calcium levels than conventional melons and non-dipped melons had higher calcium levels than those dipped in $CaCl_2$.

DISCUSSION

Based on the results of this study, use of a $CaCl_2$ dip appears to have a beneficial impact on sensory scores of 'Haogen' melons. Other research on whole melons dipped in a 0.08 M $CaCl_2$ solution indicate positive sensory results (Lester and Grusak 2001). After 14 and 22 days storage (10° C for 11 or 19 days and 21° C for last three days to simulate retail conditions), Lester and Grusak found melons dipped in 0.08 M $CaCl_2$ received the same scores as freshly harvested melons (7.6 on a 1-10 scale, with 10 being most liked). Scores of all other treatments used were lower than the freshly harvested melons (ranging from 5.0-6.8). In contrast, Luna-Guzman and Barrett (2000) found higher bitterness and lower melon flavor scores for fresh cut melons dipped in 1% and 2.5% $CaCl_2$ solutions (approximately 0.09 and 0.23 M, respectively) compared to the control and other treatments. Since the later study used fresh cut melons the results may not be the same for whole melons, as the physiology of cut melons has been shown to be distinctly different than that of whole fruit (Lamikanra, et al. 2003). Further assessment of the value of dipping whole melons in $CaCl_2$ as well as sensory

effects of $CaCl_2$ on different melon cultivars is important to ensure consumer acceptance.

The results in this study are consistent with other melon research in which post-harvest storage variables, such as temperature and time, have been shown to have no significant impact on SSC (Cohen and Hicks 1986; Miccolis and Saltveit 1995). SSC in melons has been shown to vary greatly by cultivar (Miccolis and Saltveit 1995), yet little is known about the effect of growing method on SSC in melons. The results of this study indicate that overall, conventional 'Haogen' melons contained higher SSC than organic melons, though this did not carry over into the sensory scores, as organic melons were preferred over conventional.

The most significant color changes occurred in melons stored at 10° C, especially as time increased. This is perhaps an indication of chilling injury in the melons since the color test results indicate melons stored at the lower temperature had a lighter flesh color and contained less green and yellow hues. Watersoaked tissues are a common chilling injury symptom (Morris 1982), and the color changes observed in this study could indicate such symptoms. Melon fruit color varies widely, depending on cultivar, with flesh colors including green, orange, pink, yellow, and white (Nunez-Palenius, et al. 2008). Therefore it is impossible to compare color changes from one cultivar to another. Further research would be necessary to determine whether the color changes in light green fleshed 'Haogen'

melons during storage were in fact caused by physiological chilling injury changes.

Due to the complexity of foods and the different mechanisms involved in antioxidant activity, there is not a single assay for measuring total antioxidant levels (Huang, et al. 2005; Prior, et al. 2005; MacDonald-Wicks, et al. 2006). Therefore, it is difficult to compare antioxidant results from different research groups and results from different tests. In order to best estimate a food's antioxidant levels, the use of multiple tests is recommended (Huang, et al. 2005; Sun and Tanumihardjo 2007). The antioxidant assessments from this study indicate some antioxidants may be affected by post-harvest conditions and others may not.

Like many of the other qualities, antioxidants present in melons have been found to vary significantly by cultivar (Hodges and Lester 2006; Lester and Hodges 2008). A review article by Lee and Kader (2000) indicates storage temperature is the most important factor to maintain ascorbic acid levels in produce after harvest, with most fruits and vegetables losing ascorbic acid as storage temperatures increase. Similarly, a study using orange-fleshed honeydew melon varieties found higher ascorbic acid levels in melons stored up to 24 days at 5° C compared to those stored at 10° C (Lester and Hodges 2008). While this study did not find significant changes in ascorbic acid levels over time or between temperatures, this could be due to 'Haogen' melons having a shorter shelf-life.

Post-harvest effects on other antioxidants have not been well-studied in melons (Hodges and Lester 2006). Lester and Hodges (2008) found that storage temperature and duration had little impact on antioxidant capacity (tested using a Trolox equivalent assay) of orange honeydew melons stored up to 24 days at 5° and 10° C. Storage temperature also had little impact in this study except for the $DPPH^+$ assay, where overall 10° C melons had higher levels than 21° C melons. Time had more effect on the antioxidant assay results, though some went up and some went down. In another study, Hodges and Lester (2006) found total phenolic content increased over time in three melon cultivars tested on days 0, 10, and 17 (stored at 10° C for 7 or 14 days and three days at 21° C). Additional research is needed to better understand antioxidant changes in melons, including specialty cultivars, during storage and to determine the best post-harvest conditions to optimize such levels at consumption.

The use of a $CaCl_2$ dip appears to decrease the calcium content in whole melons. This is consistent with results from a study conducted by Lester and Grusak (2001) where whole honeydew melons dipped in $CaCl_2$ also experienced decreased calcium levels compared to the control. The authors' explanation of this outcome was that $CaCl_2$ does not allow for the diffusion of calcium through the epidermis and into the hypodermal-mesocarp tissue of the melon. However, other fruit with different external characteristics dipped in such a treatment, including strawberries (Garcia, et al. 1996) and peaches (Manganaris, et al. 2007)

have shown increased flesh calcium levels. Since fresh melons are not an important source of calcium (Lester 1997), the effect of using a $CaCl_2$ on fruit calcium levels is not of much concern.

Sensory and nutritional differences between organically and conventionally grown produce have been the topic of much debate (Worthington 2001; Bourn and Prescott 2002; Yiridoe, et al. 2005; Lester 2006). This study found many significant differences between growing methods, yet both production methods were favored for different tests. For example, overall, organically grown 'Haogen' melons received higher sensory scores, calcium content, and $DPPH^+$ assay results than conventionally grown melons. Yet, conventional melons had higher SSC as well as $ABTS^{\bullet+}$, total phenolic, and ascorbic acid assay results. Additional research with well-controlled comparisons, as used in this project, is warranted to determine whether one production method produces overall higher quality fruit and vegetables.

In determining the best practices for maximizing sensory and nutritional qualities of melons and other produce, it is also critical to consider the impact such methods would have on microbial growth. Lower storage temperatures have been associated with lower bacteria growth on fresh produce, including both spoilage organisms and pathogenic organisms (Hao and Brackett 1993; Zagory 1999; Francis and O'Beirne 2001). Therefore, that may be another reason to encourage lower storage temperatures for whole melons. Also, little is known

about the microbial impacts of using a post-harvest $CaCl_2$ dip treatment. Use of a pre-harvest $CaCl_2$ treatment was found to decrease bacteria growth on fresh mushrooms in a study by Chikthimmah et al. (2005), which may indicate potential for reducing bacteria growth when applied post-harvest as well.

CONCLUSIONS

In this study, the effect of $CaCl_2$, storage temperature, time, and growing method, as well as their complex interactions impacted many post-harvest qualities of 'Haogen' melons. Using a post-harvest $CaCl_2$ dip appears to positively impact sensory scores of 'Haogen' melons, with little overall effect on the other tests conducted. Storage temperature greatly impacted many sensory and antioxidant qualities, with 10° C stored melons receiving higher scores for appearance, texture, and overall acceptability, as well as higher TEAC values for the $DPPH^+$ test and less weight loss than melons stored at 21° C. Melons stored at 10° C also had a longer shelf-life, as 75% of the melons stored at 21° C were inedible by day 10. However, fruit color may be adversely affected at the lower temperature when stored for extended periods of time. By day 10, time negatively impacted many qualities, including sensory scores, percent weight loss, and melon color, as well as total phenolic and $DPPH^+$ antioxidant tests. Growing method significantly affected many of the sensory and nutritional tests, though results were mixed. Organic melons had higher overall appearance and texture scores as well as $DPPH^+$ results and calcium content, yet conventional melons had higher results for $ABTS^{\bullet+}$, total phenolic, ascorbic acid, and SSC tests. More research is

needed to better understand these effects to tailor post-harvest methods that can optimize sensory and nutritional qualities of 'Haogen' and other specialty melons with limited shelf-life.

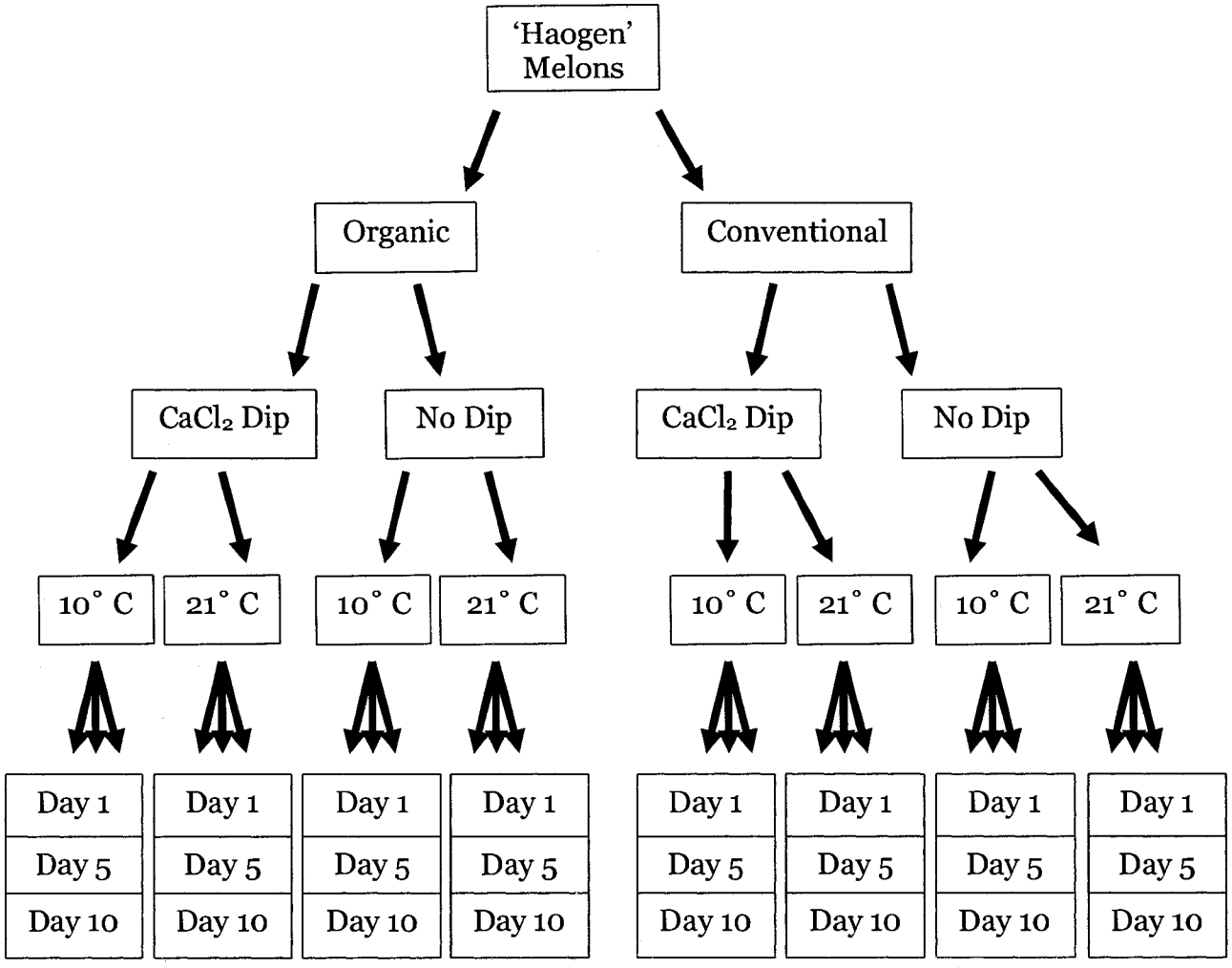

Figure 4.1. Research Design.

Figure 4.2. Sensory scorecard used to rate appearance, flavor, texture, and overall acceptability of 'Haogen' melons.

Panelist #_____

SCORE SHEET FOR FRESH PRODUCE

Sample 127	Highly Acceptable	Acceptable	Moderately Acceptable	Slightly Acceptable	Neither Acceptable nor Unacceptable	Slightly Unacceptable	Moderately Unacceptable	Unacceptable	Highly Unacceptable
Appearance	❑	❑	❑	❑	❑	❑	❑	❑	❑
Flavor	❑	❑	❑	❑	❑	❑	❑	❑	❑
Texture	❑	❑	❑	❑	❑	❑	❑	❑	❑
Bitterness	❑	❑	❑	❑	❑	❑	❑	❑	❑
Overall Acceptability	❑	❑	❑	❑	❑	❑	❑	❑	❑

Comments: _____

Sample 443	Highly Acceptable	Acceptable	Moderately Acceptable	Slightly Acceptable	Neither Acceptable nor Unacceptable	Slightly Unacceptable	Moderately Unacceptable	Unacceptable	Highly Unacceptable
Appearance	❑	❑	❑	❑	❑	❑	❑	❑	❑
Flavor	❑	❑	❑	❑	❑	❑	❑	❑	❑
Texture	❑	❑	❑	❑	❑	❑	❑	❑	❑
Bitterness	❑	❑	❑	❑	❑	❑	❑	❑	❑
Overall Acceptability	❑	❑	❑	❑	❑	❑	❑	❑	❑

Comments: _____

Sample 916	Highly Acceptable	Acceptable	Moderately Acceptable	Slightly Acceptable	Neither Acceptable nor Unacceptable	Slightly Unacceptable	Moderately Unacceptable	Unacceptable	Highly Unacceptable
Appearance	❑	❑	❑	❑	❑	❑	❑	❑	❑
Flavor	❑	❑	❑	❑	❑	❑	❑	❑	❑
Texture	❑	❑	❑	❑	❑	❑	❑	❑	❑
Bitterness	❑	❑	❑	❑	❑	❑	❑	❑	❑
Overall Acceptability	❑	❑	❑	❑	❑	❑	❑	❑	❑

Comments: _____

(PLEASE TURN OVER)

Sample 603	Highly Acceptable	Acceptable	Moderately Acceptable	Slightly Acceptable	Neither Acceptable nor Unacceptable	Slightly Unacceptable	Moderately Unacceptable	Unacceptable	Highly Unacceptable
Appearance	❑	❑	❑	❑	❑	❑	❑	❑	❑
Flavor	❑	❑	❑	❑	❑	❑	❑	❑	❑
Texture	❑	❑	❑	❑	❑	❑	❑	❑	❑
Bitterness	❑	❑	❑	❑	❑	❑	❑	❑	❑
Overall Acceptability	❑	❑	❑	❑	❑	❑	❑	❑	❑

Comments: _____

_____

Sample 819	Highly Acceptable	Acceptable	Moderately Acceptable	Slightly Acceptable	Neither Acceptable nor Unacceptable	Slightly Unacceptable	Moderately Unacceptable	Unacceptable	Highly Unacceptable
Appearance	❑	❑	❑	❑	❑	❑	❑	❑	❑
Flavor	❑	❑	❑	❑	❑	❑	❑	❑	❑
Texture	❑	❑	❑	❑	❑	❑	❑	❑	❑
Bitterness	❑	❑	❑	❑	❑	❑	❑	❑	❑
Overall Acceptability	❑	❑	❑	❑	❑	❑	❑	❑	❑

Comments: _____

_____

Sample 535	Highly Acceptable	Acceptable	Moderately Acceptable	Slightly Acceptable	Neither Acceptable nor Unacceptable	Slightly Unacceptable	Moderately Unacceptable	Unacceptable	Highly Unacceptable
Appearance	❑	❑	❑	❑	❑	❑	❑	❑	❑
Flavor	❑	❑	❑	❑	❑	❑	❑	❑	❑
Texture	❑	❑	❑	❑	❑	❑	❑	❑	❑
Bitterness	❑	❑	❑	❑	❑	❑	❑	❑	❑
Overall Acceptability	❑	❑	❑	❑	❑	❑	❑	❑	❑

Comments: _____

_____

Please write in the sample number in the space provided by ranking the samples in order of your preference (1=liked most; 6=liked least):

1)_____ 2)_____ 3)_____ 4)_____ 5)_____ 6)_____

THANK YOU FOR YOUR PARTICIPATION!

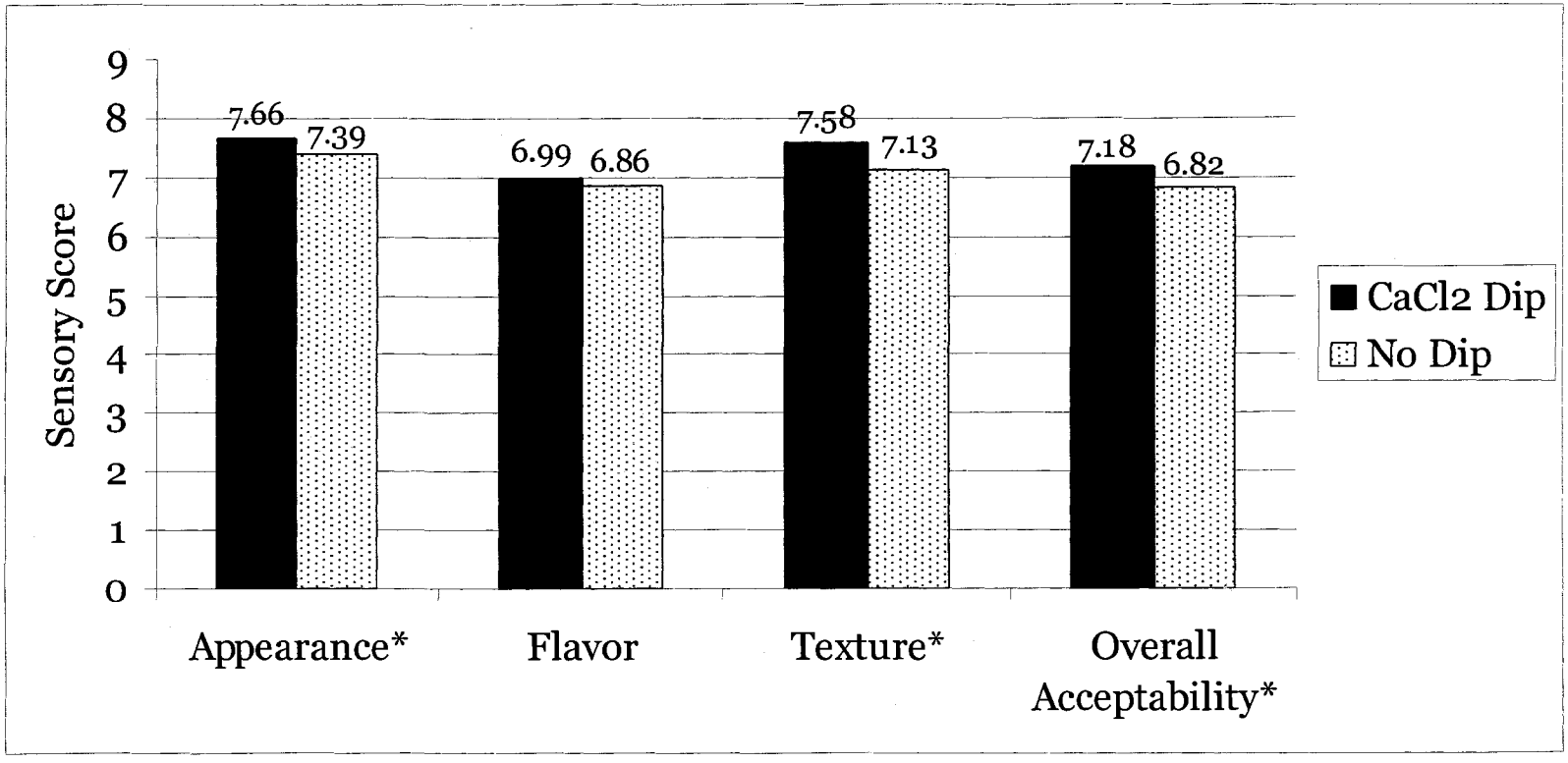

Figure 4.3. Effect of $CaCl_2$ dip on melon sensory scores. Organic and conventionally grown melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each bar represents the mean sensory score of all dipped or non-dipped melons, regardless of day, growing method, and storage temperature (n=480 for each bar). Sensory tests marked by an asterisk (*) are significantly different ($p<0.05$) between dip treatments. Sensory scale: 9=highly acceptable, 1=highly unacceptable.

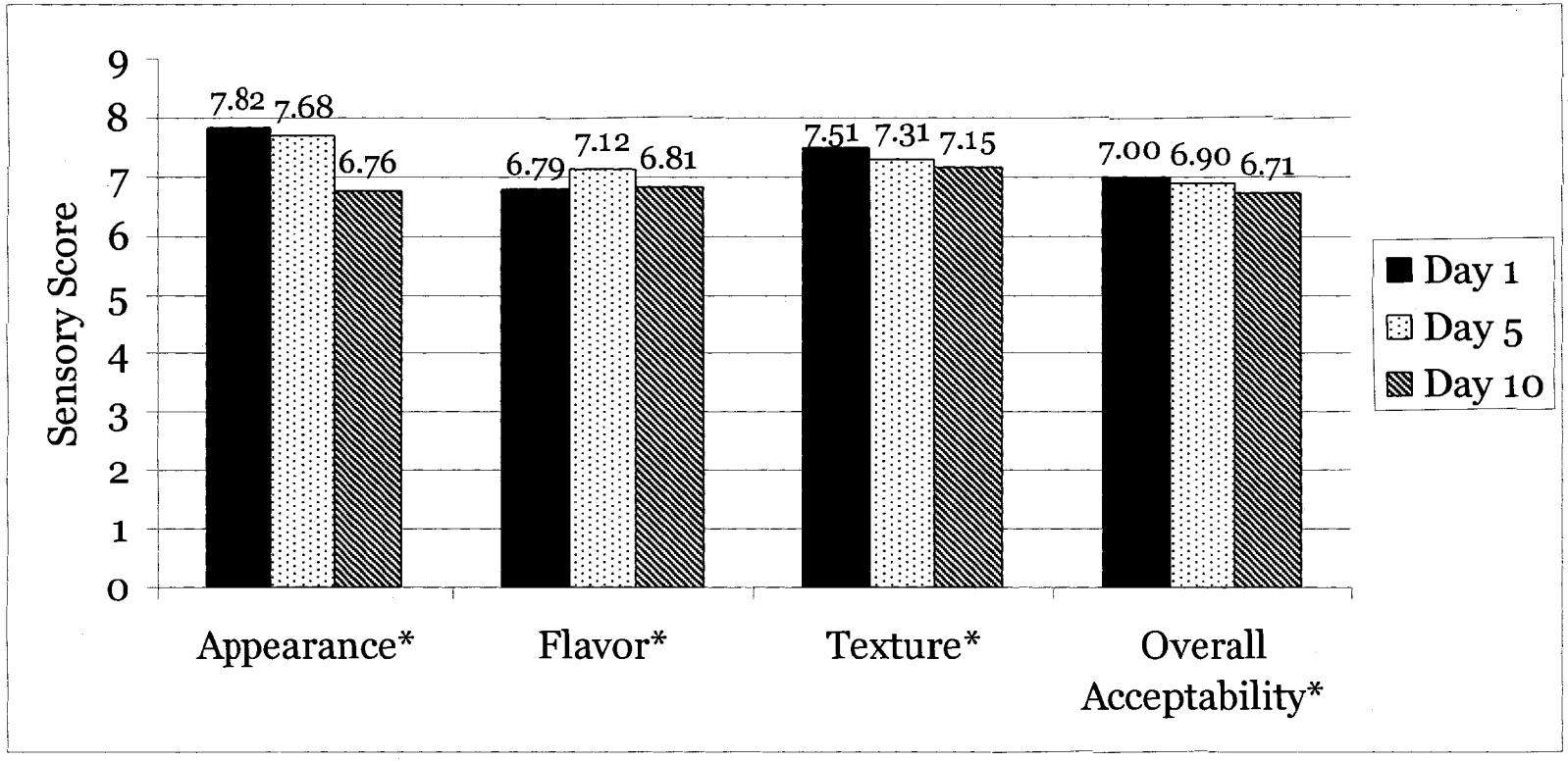

Figure 4.4. Effect of time on melon sensory scores. Organic and conventionally grown melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each bar represents the mean sensory score of all day 1, 5, or 10 melons, regardless of storage temperature, growing method, and dip treatment (n=320 for each bar). Sensory tests marked by an asterisk (*) are significantly different ($p<0.05$) between days. Sensory scale: 9=highly acceptable, 1=highly unacceptable.

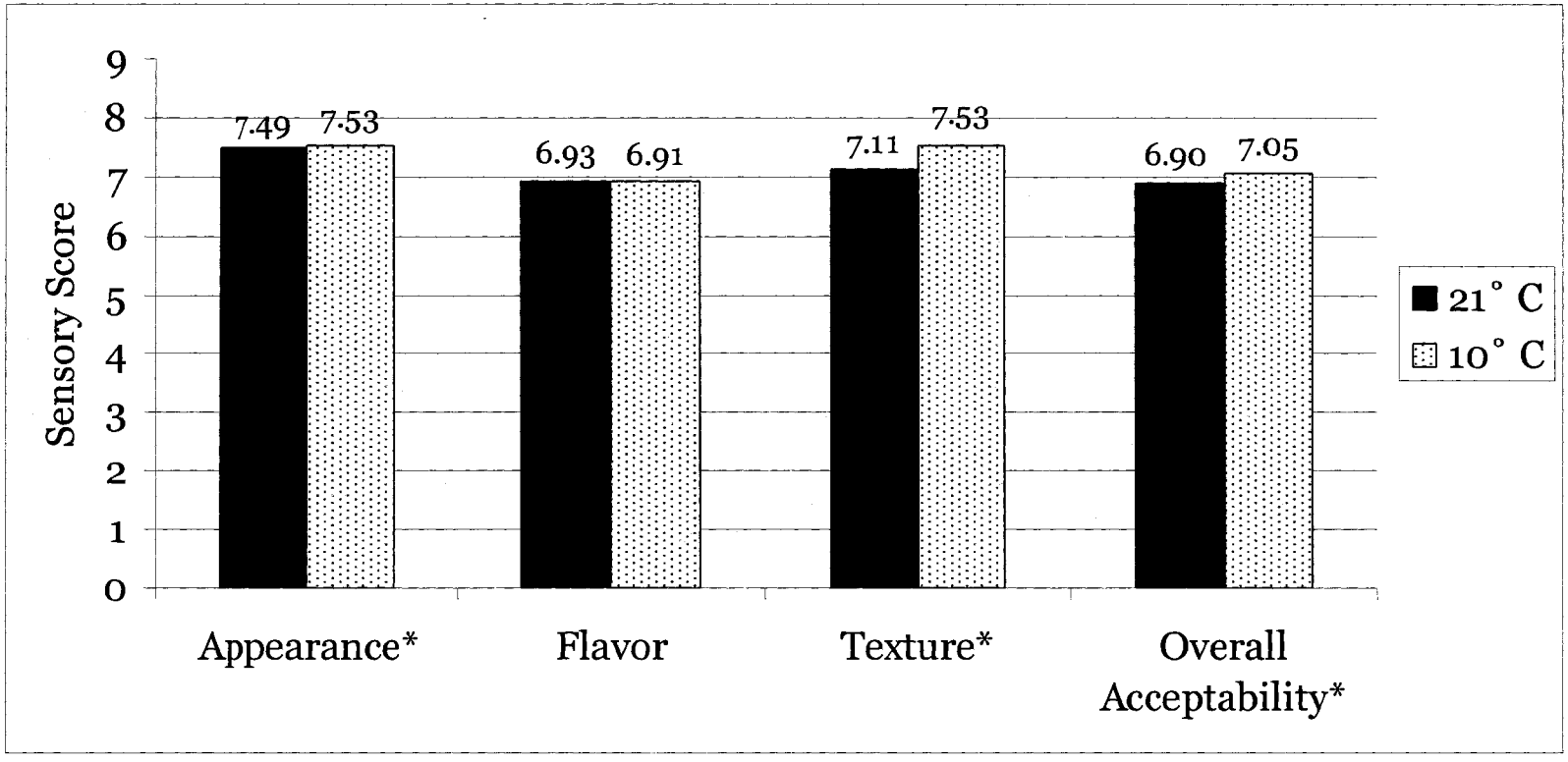

Figure 4.5. Effect of storage temperature on melon sensory scores. Organic and conventionally grown melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each bar represents the mean sensory score of all melons stored at that temperature, regardless of day, growing method, and dip treatment (n=480 for each bar). Sensory tests marked by an asterisk (*) are significantly different ($p<0.05$) between temperatures. Sensory scale: 9=highly acceptable, 1=highly unacceptable.

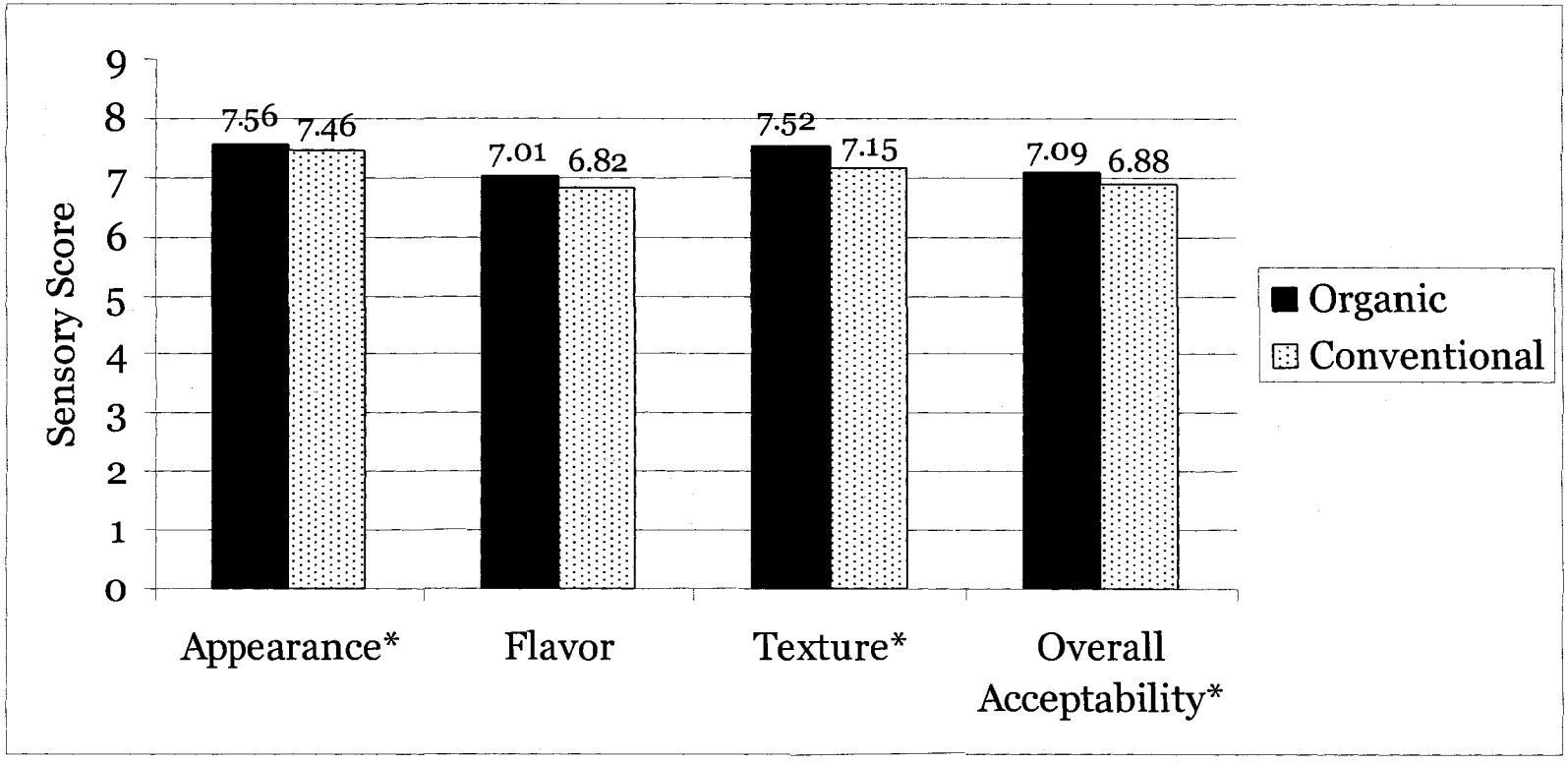

Figure 4.6. Effect of growing method on melon sensory scores. Organic and conventionally grown melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each bar represents the mean sensory score of all organic or conventional melons, regardless of day, storage temperature, and dip treatment(n=480 for each bar). Sensory tests marked by an asterisk (*) are significantly different ($p<0.05$) between growing methods. Sensory scale: 9=highly acceptable, 1=highly unacceptable.

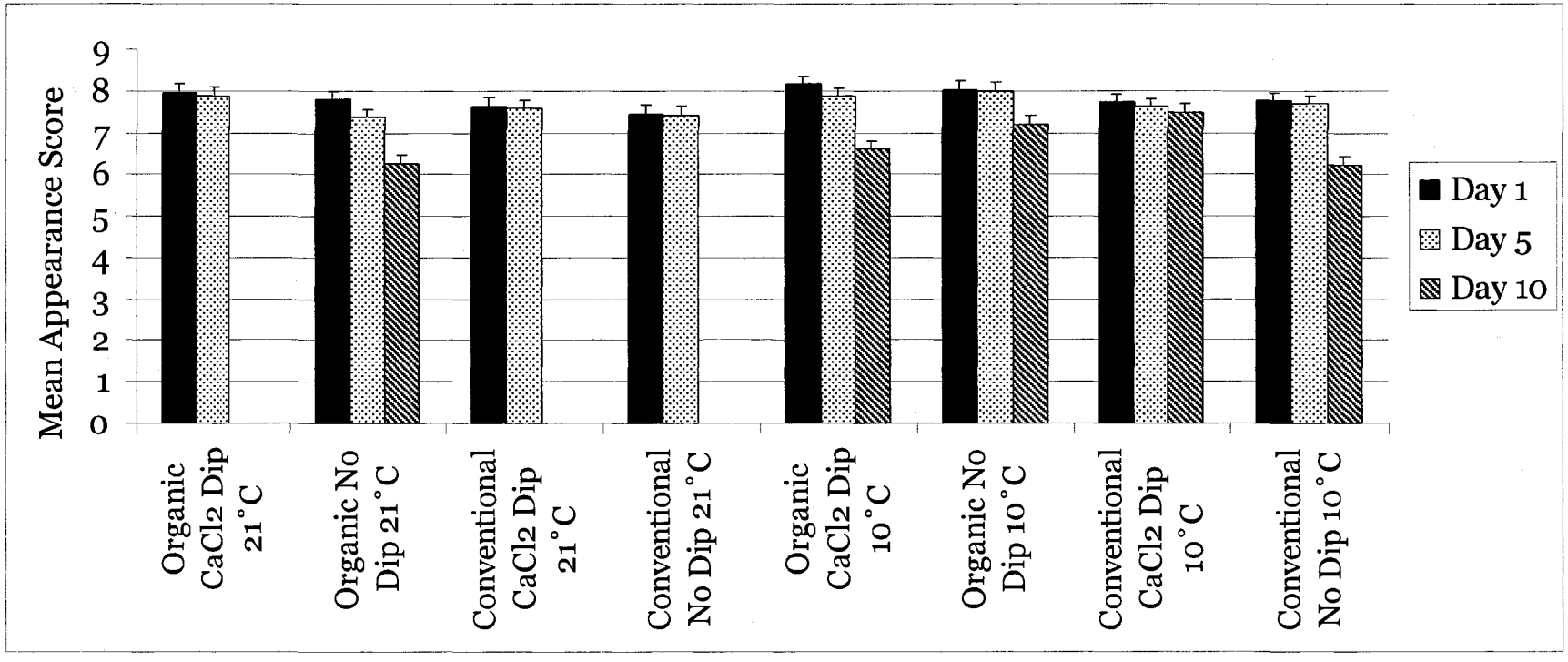

Figure 4.7. Mean appearance scores. Organic and conventionally grown melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each bar represents the average scores of 40 taste panelists. Error bars indicate the standard error. Sensory scale: 9=highly acceptable, 1=highly unacceptable.

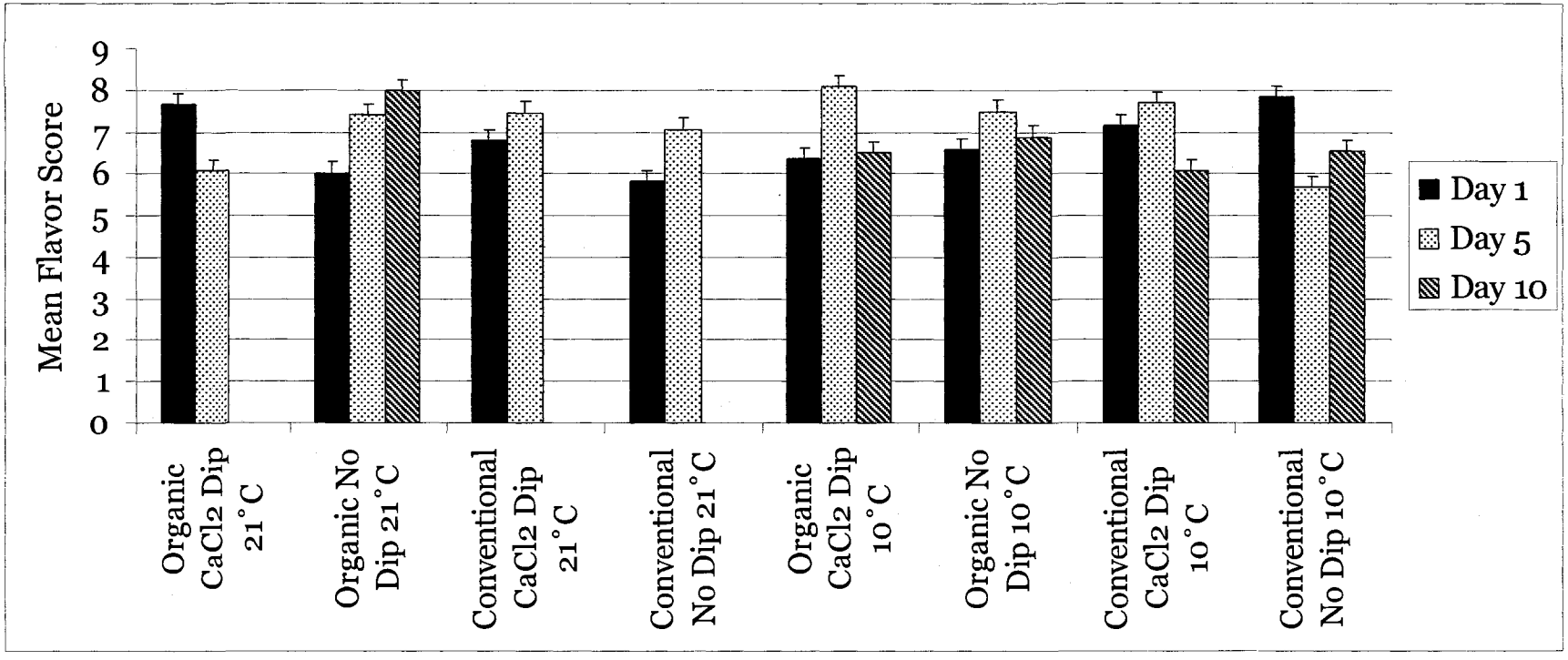

Figure 4.8. Mean flavor scores. Organic and conventionally grown melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each bar represents the average scores of 40 taste panelists. Error bars indicate the standard error. Sensory scale: 9=highly acceptable, 1=highly unacceptable.

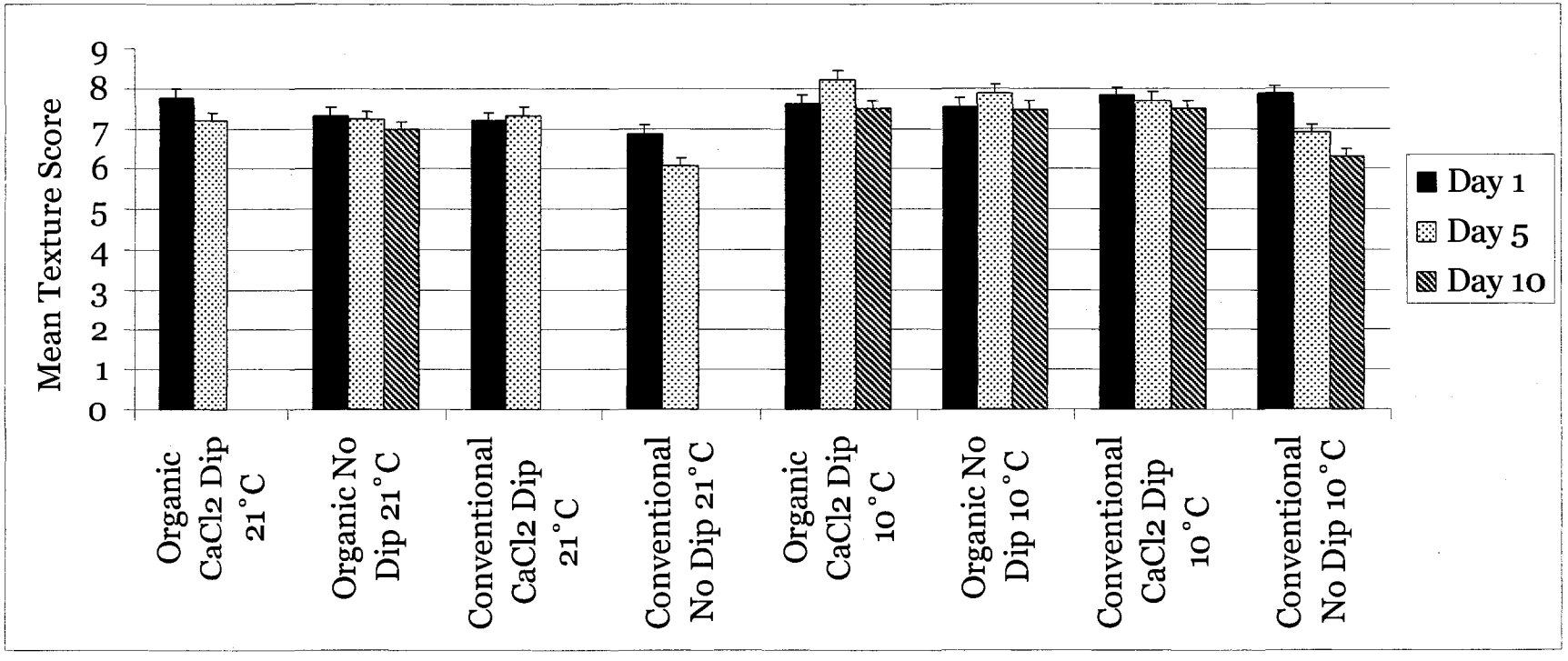

Figure 4.9. Mean texture scores. Organic and conventionally grown melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each bar represents the average scores of 40 taste panelists. Error bars indicate the standard error. Sensory scale: 9=highly acceptable, 1=highly unacceptable.

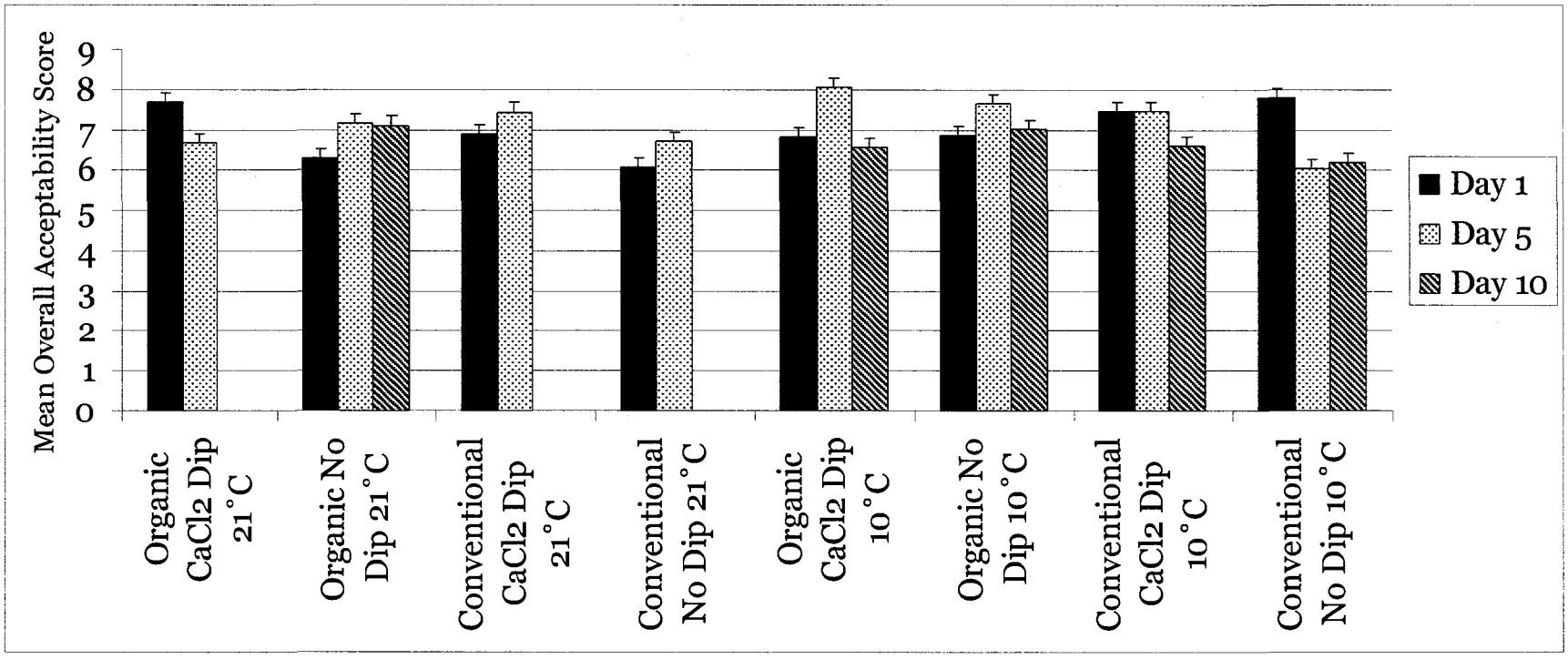

Figure 4.10. Mean overall acceptability scores. Organic and conventionally grown melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each bar represents the average scores of 40 taste panelists. Error bars indicate the standard error. Sensory scale: 9=highly acceptable, 1=highly unacceptable.

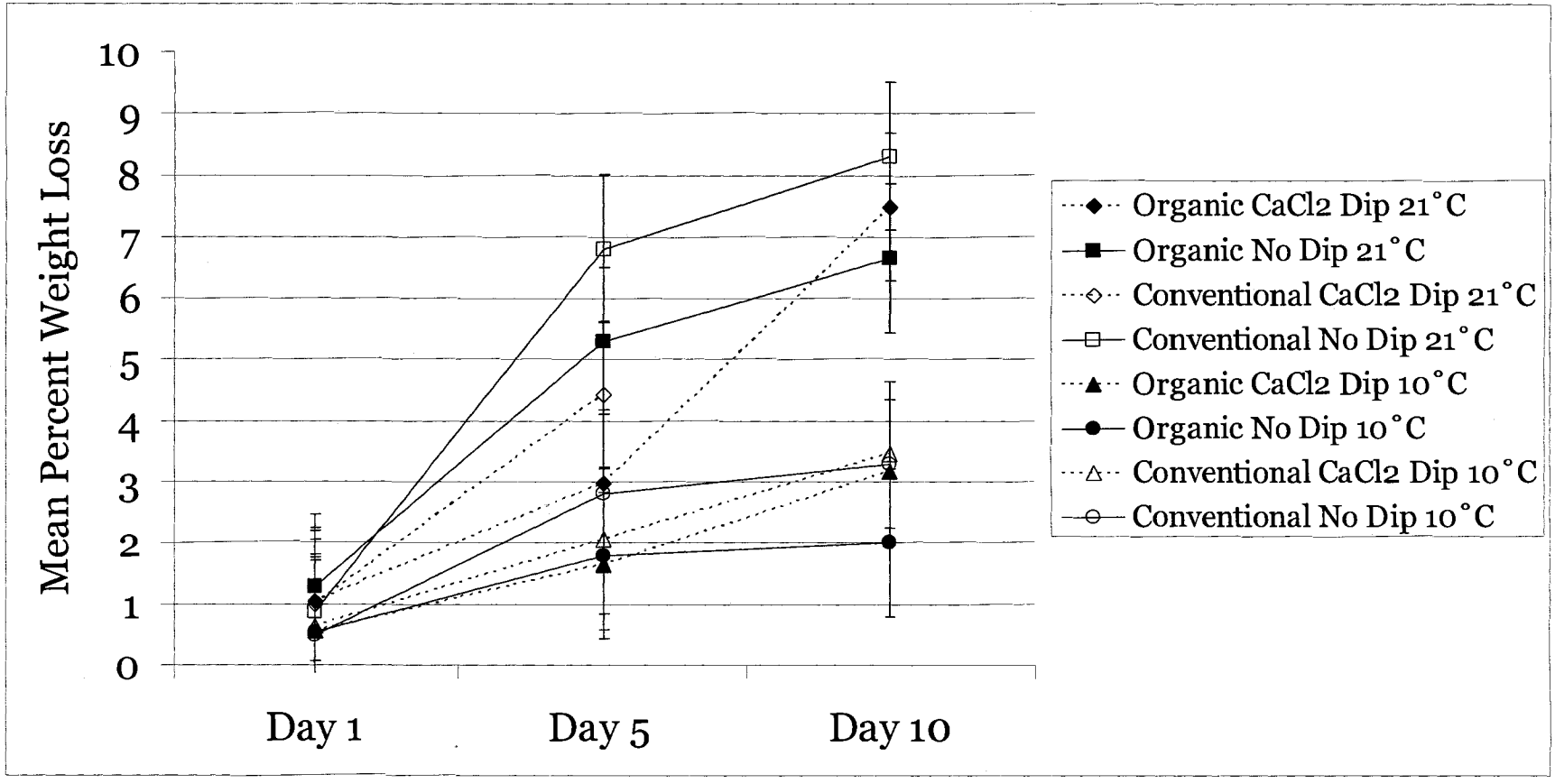

Figure 4.11. Mean percent weight loss. Organic and conventionally grown melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each data point represents the average percent weight loss of 3 melons. Error bars indicate the standard error.

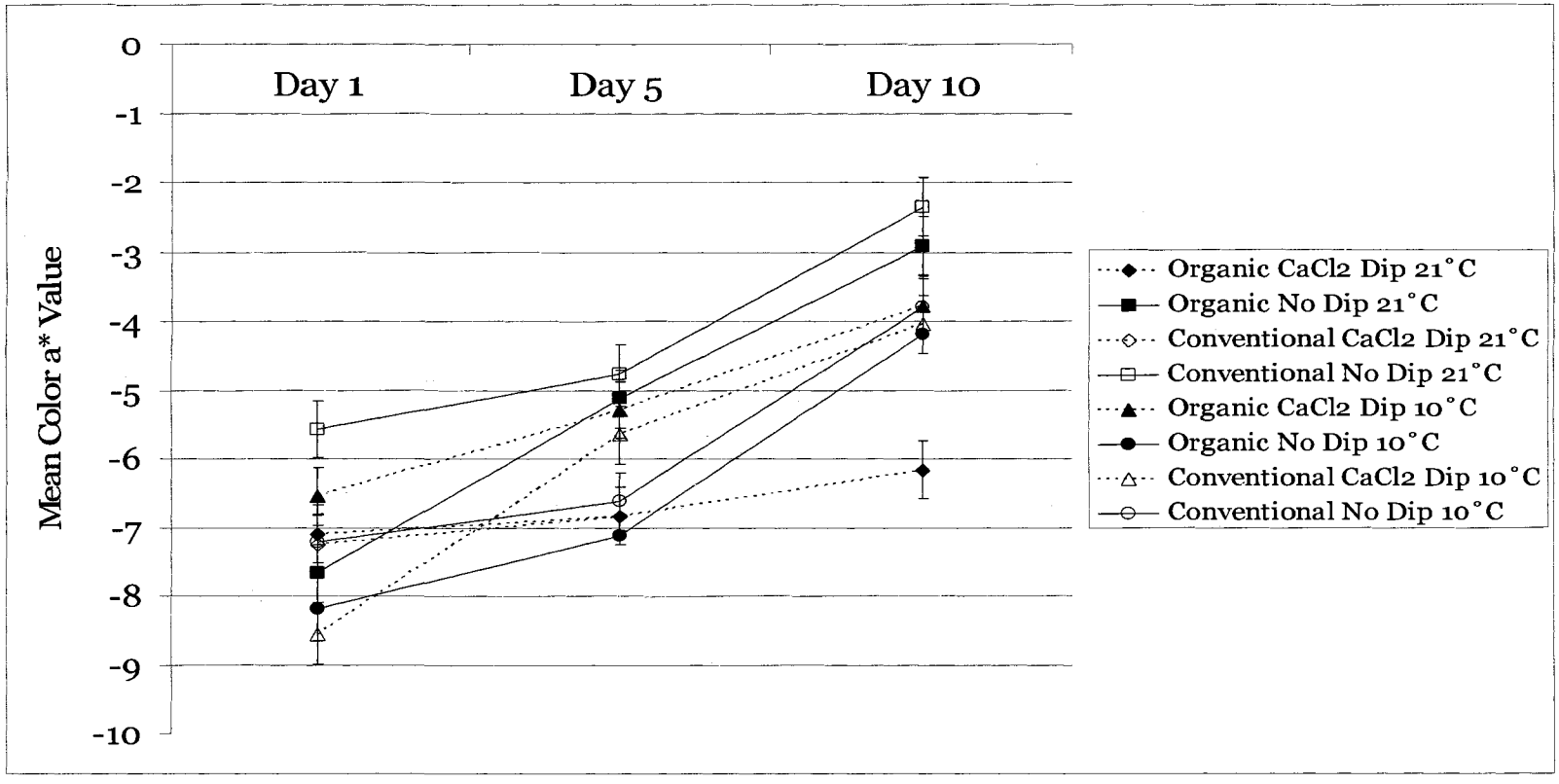

Figure 4.12. Mean color a* values. Organic and conventionally grown melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each data point represents the average of 3 melons tested 3 times each. Error bars indicate the standard error.

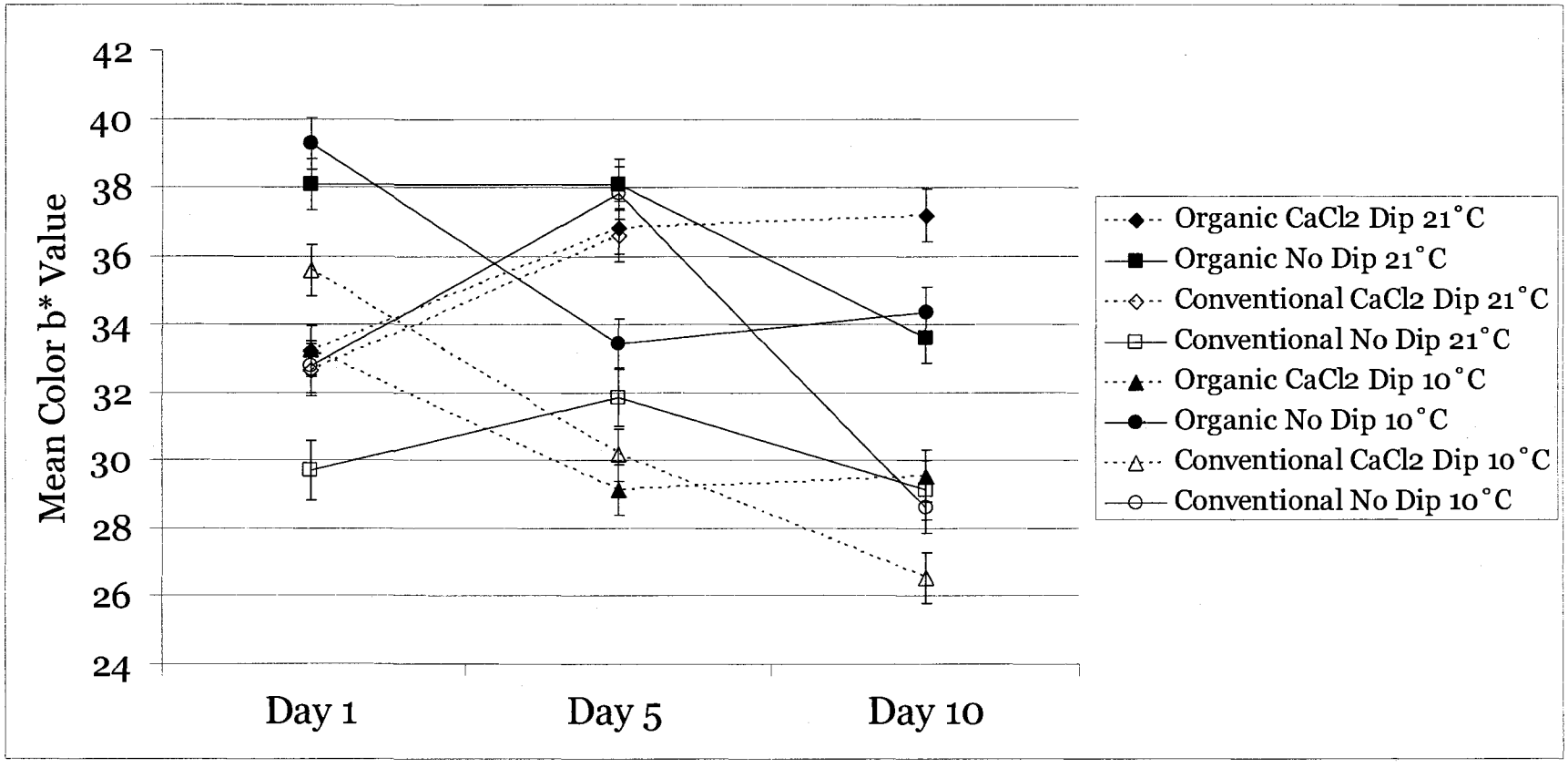

Figure 4.13. Mean color b* values. Organic and conventionally grown melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each data point represents the average of 3 melons tested 3 times each. Error bars indicate the standard error.

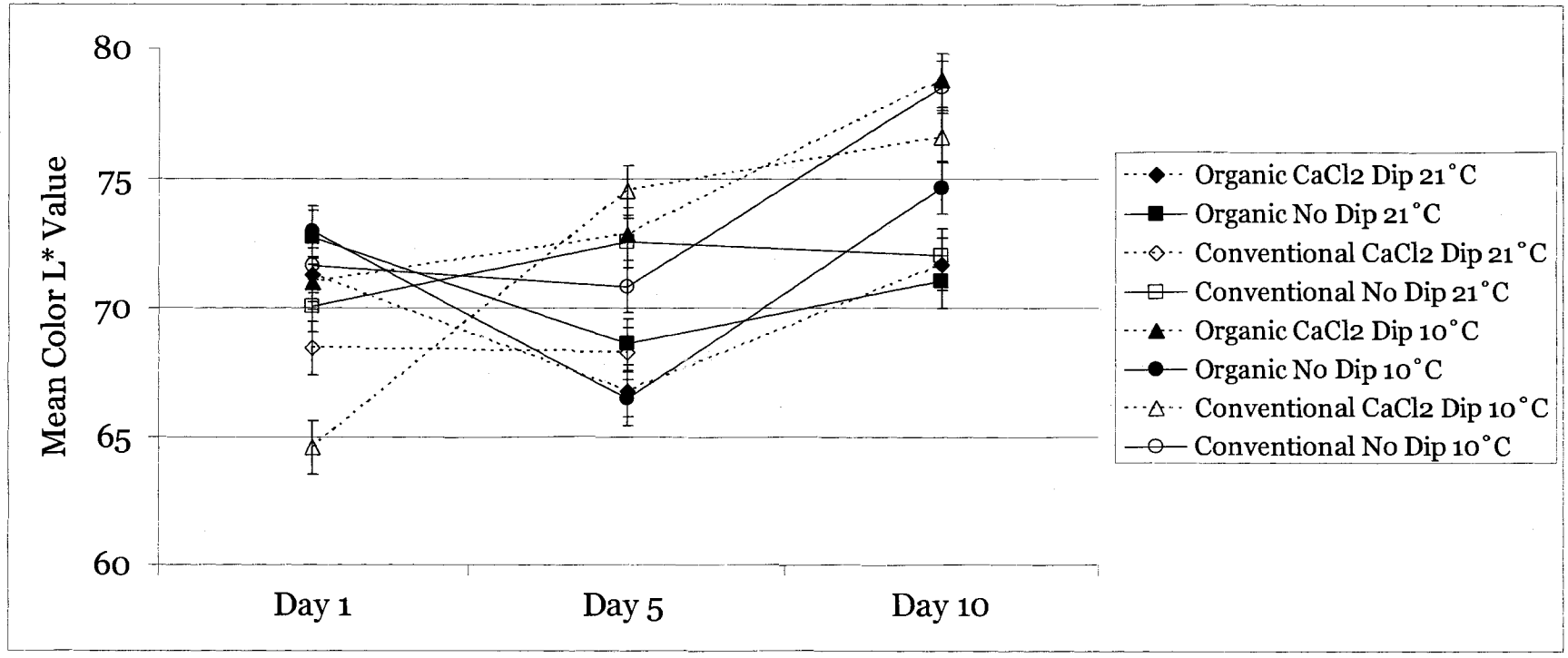

Figure 4.14. Mean color L* values. Organic and conventionally grown melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each data point represents the average of 3 melons tested 3 times each. Error bars indicate the standard error.

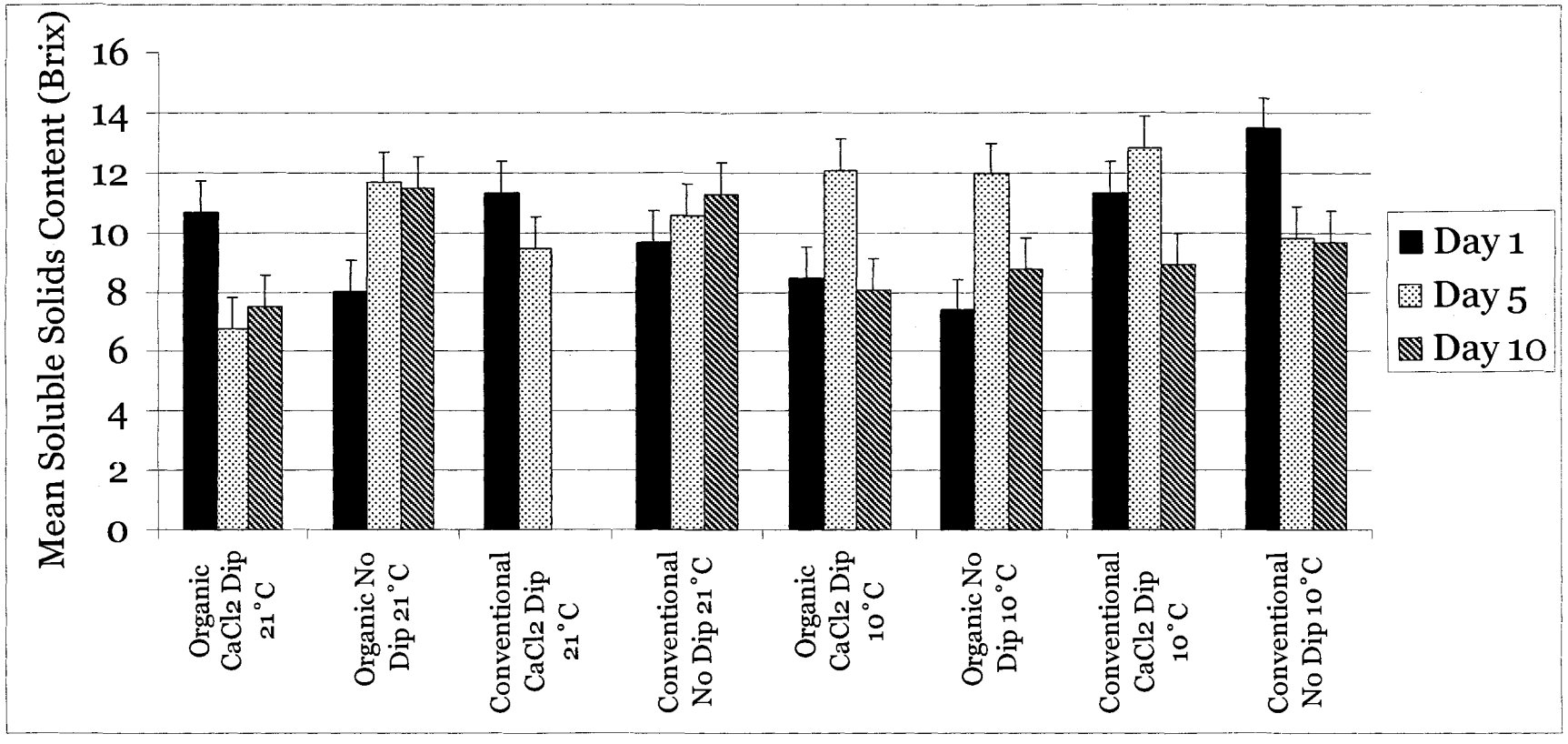

Figure 4.15. Mean soluble solids content. Organic and conventionally grown melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each data point represents the average soluble solids content of 3 melons. Error bars indicate the standard error.

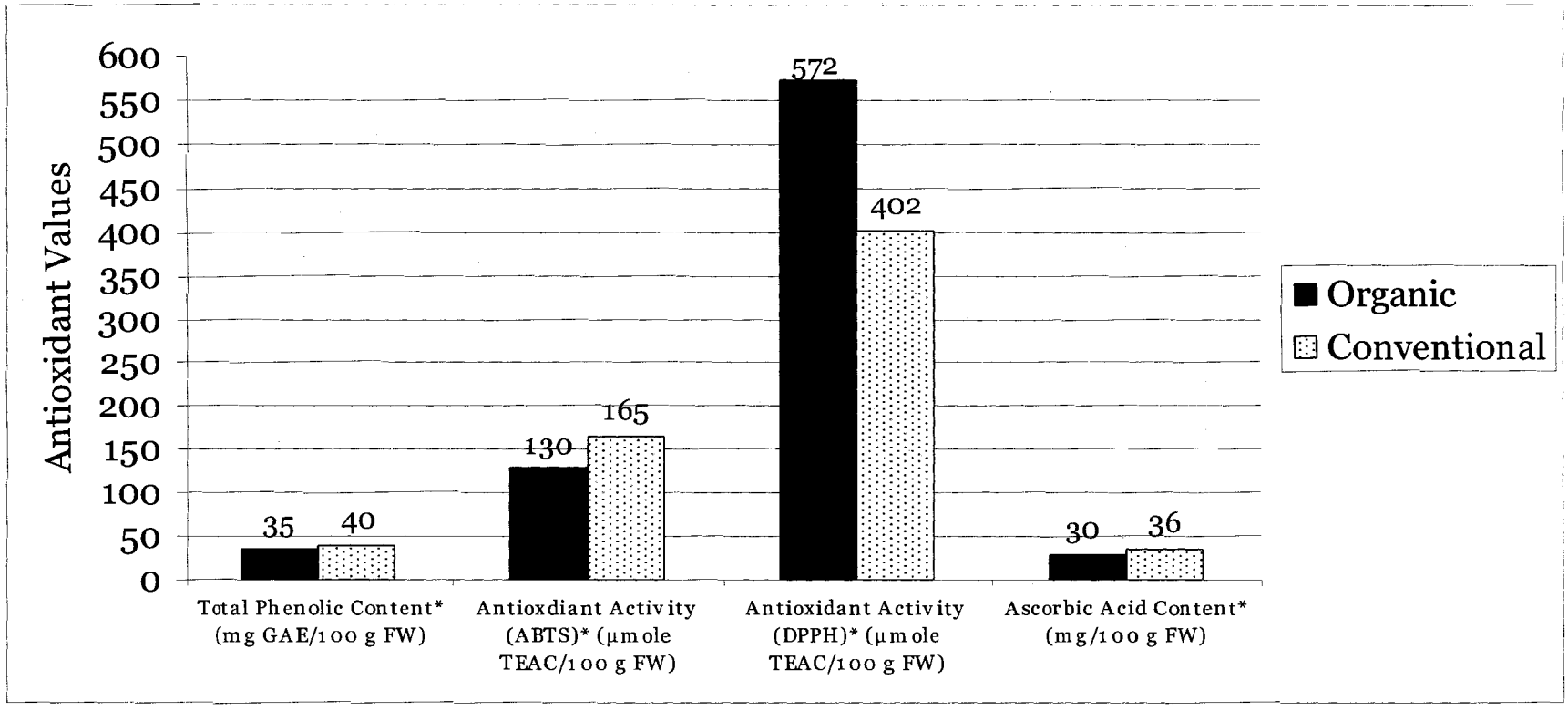

Figure 4.16. Effect of growing method on melon antioxidant tests. Organic and conventionally grown melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each bar represents the mean antioxidant test results of all organic or conventional melons, regardless of day, storage temperature, and dip treatment. Antioxidant tests marked with an asterisk (*) are significantly different ($p<0.05$) between growing methods.

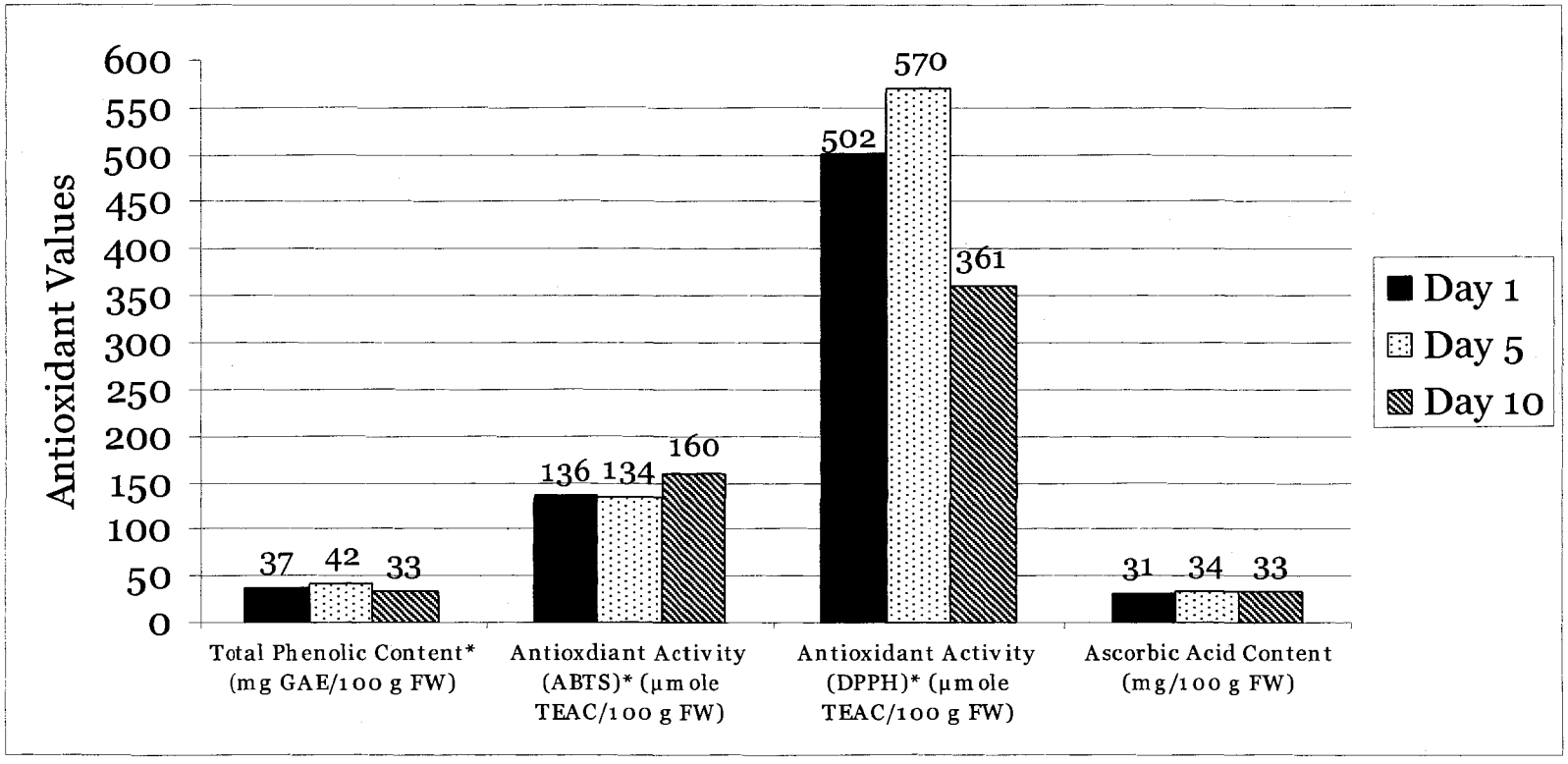

Figure 4.17. Effect of time on melon antioxidant tests. Organic and conventionally grown melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each bar represents the mean antioxidant test results of all day 1, 5, or 10 melons, regardless of storage temperature, growing method, and dip treatment. Antioxidant tests marked with an asterisk (*) are significantly different ($p<0.05$) between days.

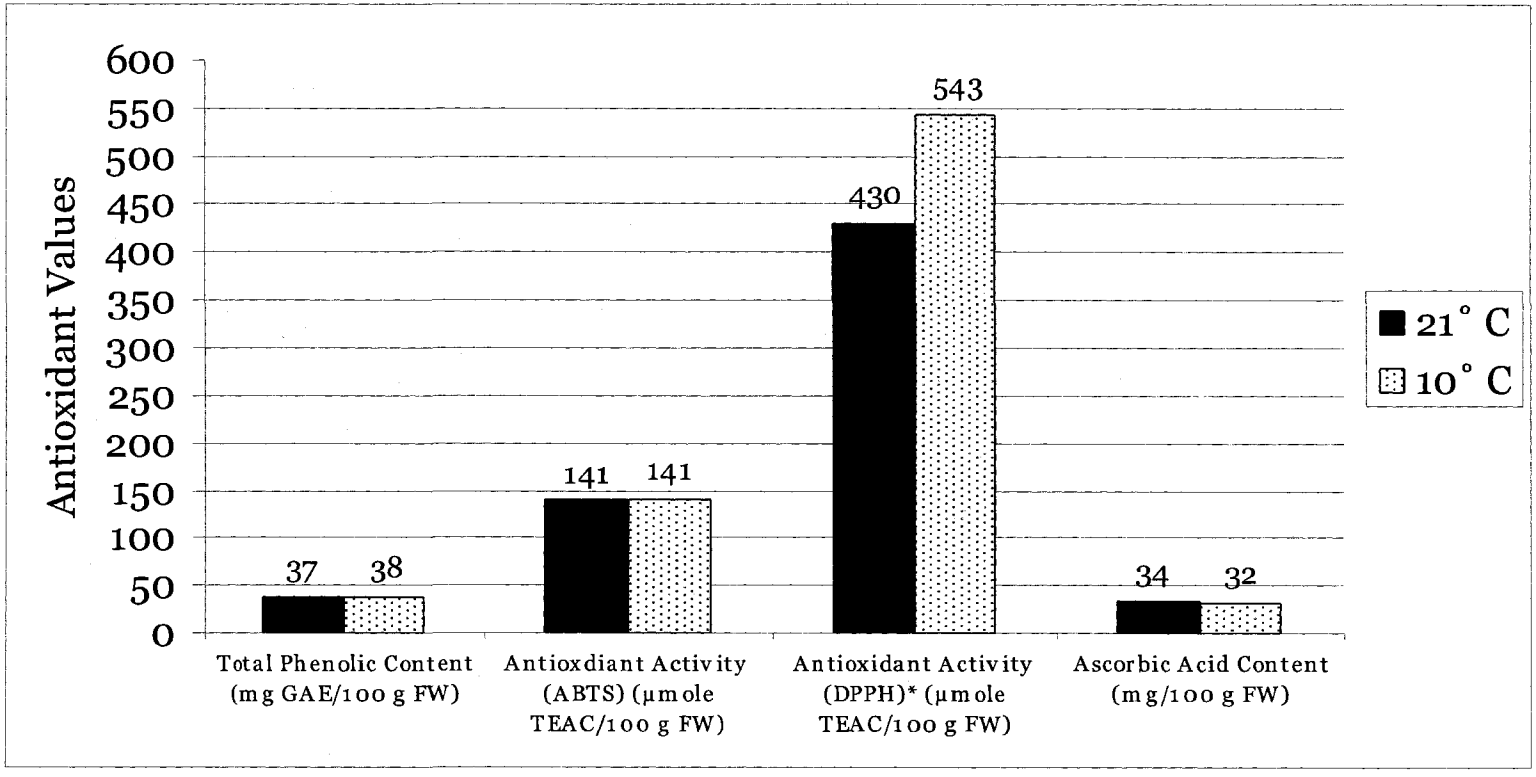

Figure 4.18. Effect of storage temperature on melon antioxidant tests. Organic and conventionally grown melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each bar represents the mean antioxidant test results of all melons stored at each temperature, regardless of day, growing method, and dip treatment. Antioxidant test marked with an asterisk (*) is significantly different ($p<0.05$) between temperatures.

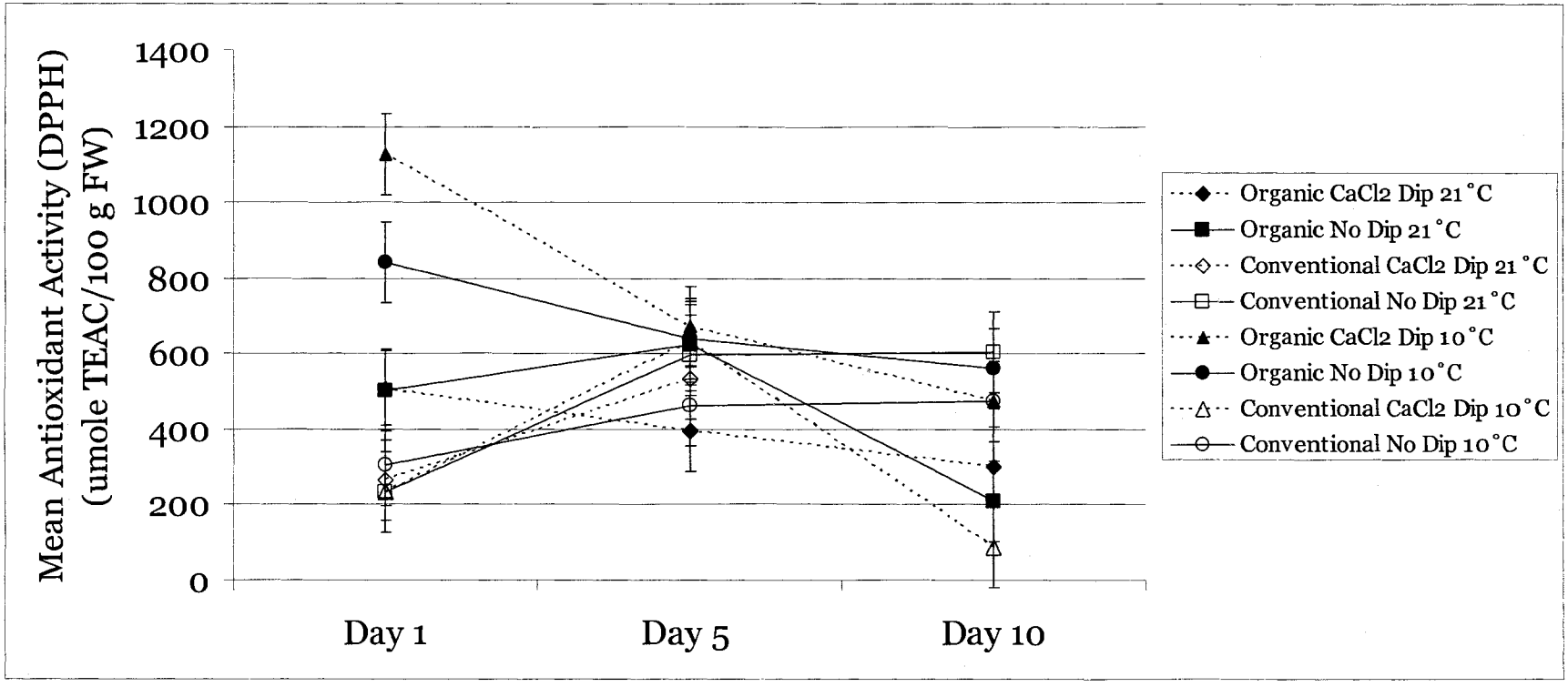

Figure 4.19. Mean antioxidant activity ($DPPH^+$). Organic and conventionally grown melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each data point represents the average results of 3 melons. Error bars indicate the standard error.

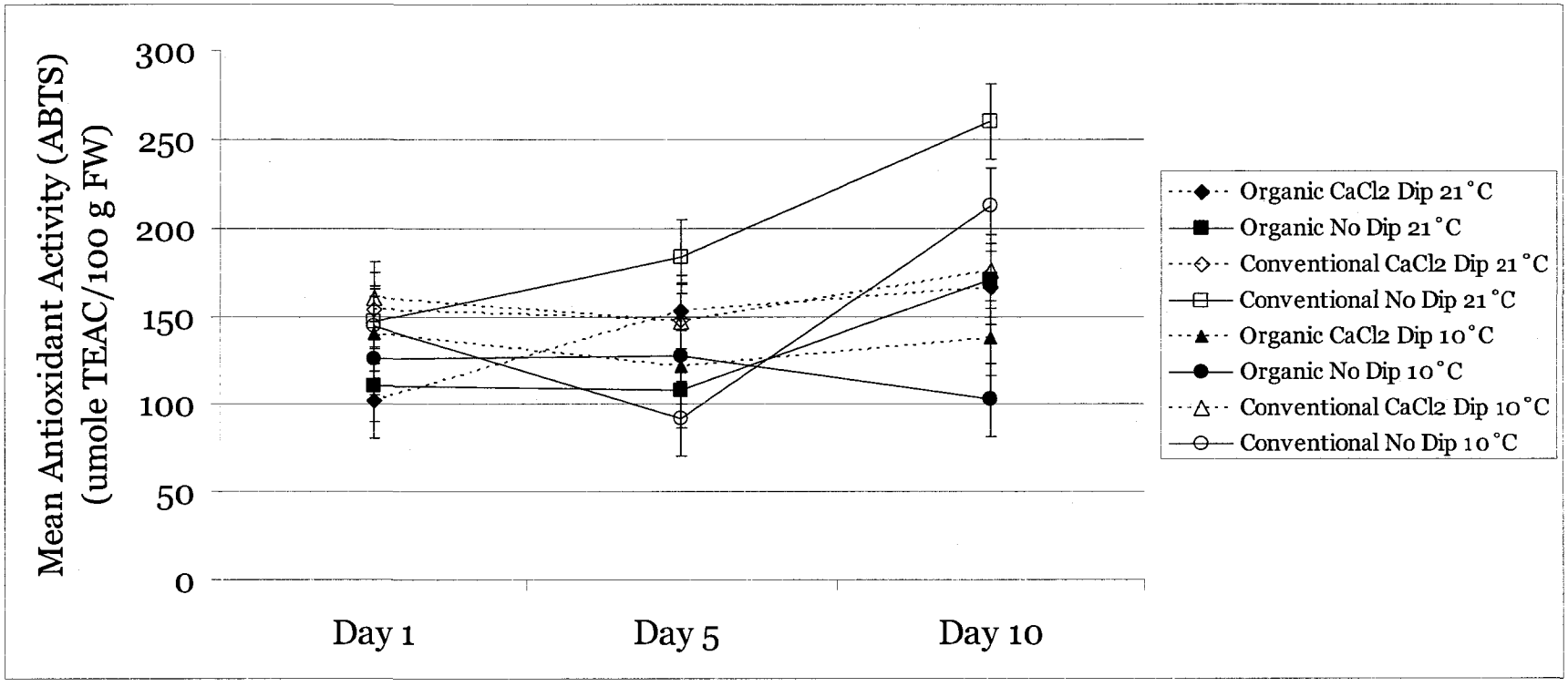

Figure 4.20. Mean antioxidant activity ($ABTS^{\cdot+}$). Organic and conventionally grown melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each data point represents the average results of 3 melons. Error bars indicate the standard error.

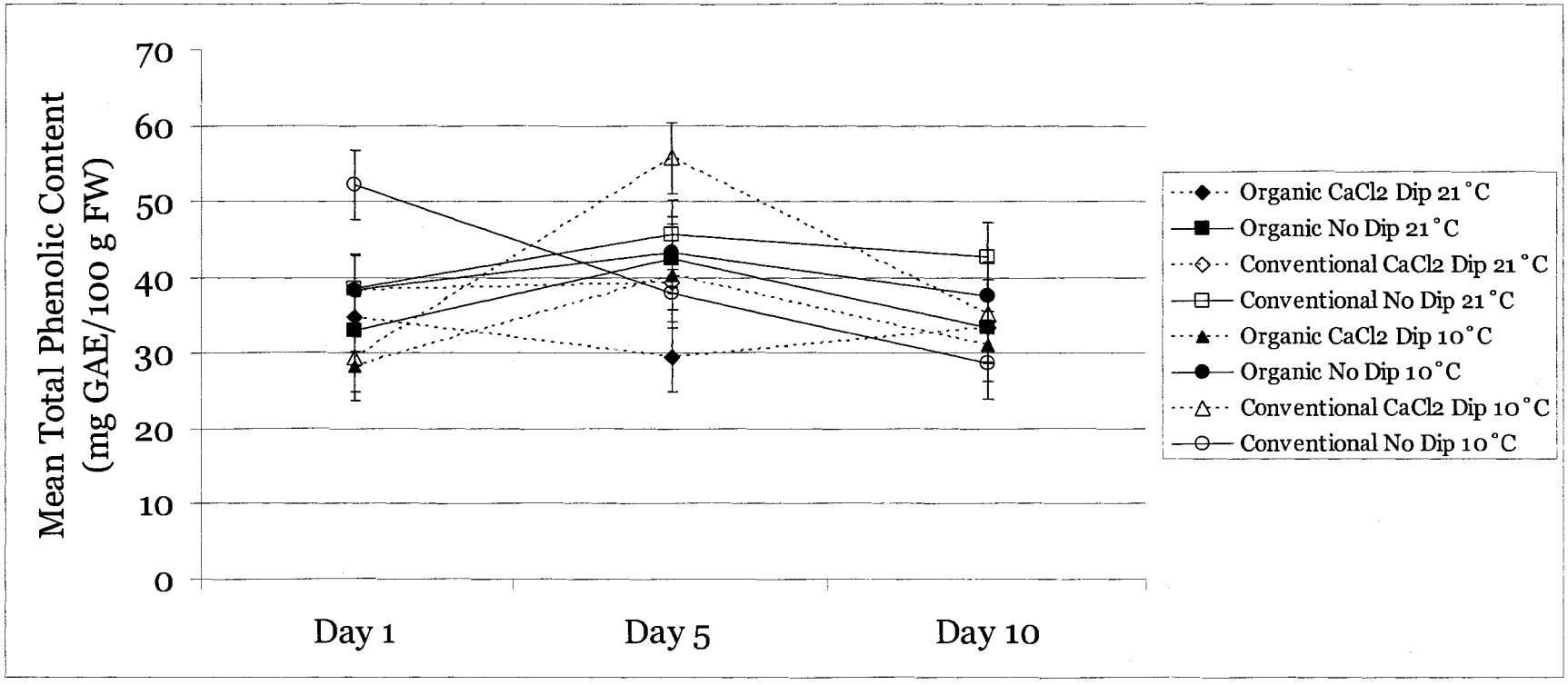

Figure 4.21. Mean total phenolic content. Organic and conventionally grown melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each data point represents the average results of 3 melons. Error bars indicate the standard error.

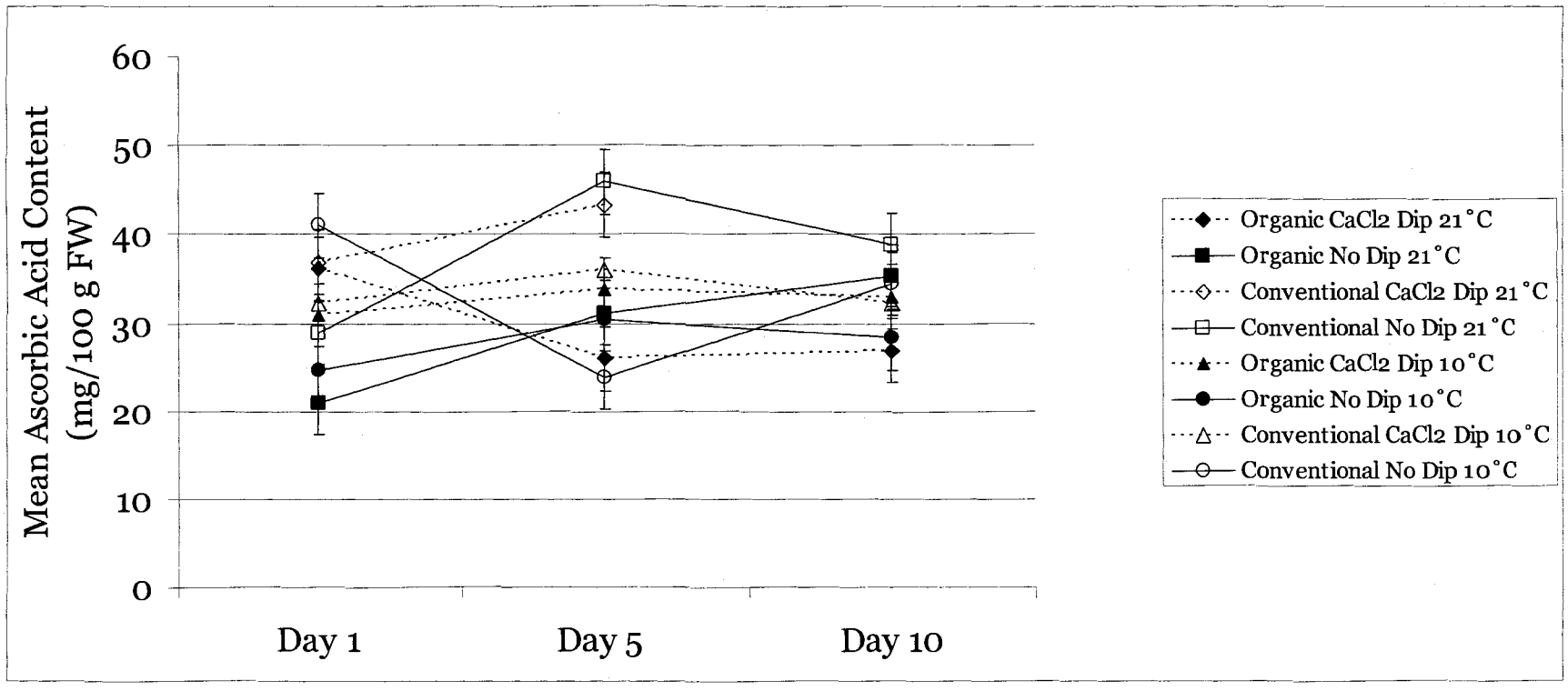

Figure 4.22. Mean ascorbic acid content. Organic and conventionally grown melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each data point represents the average results of 3 melons. Error bars indicate the standard error.

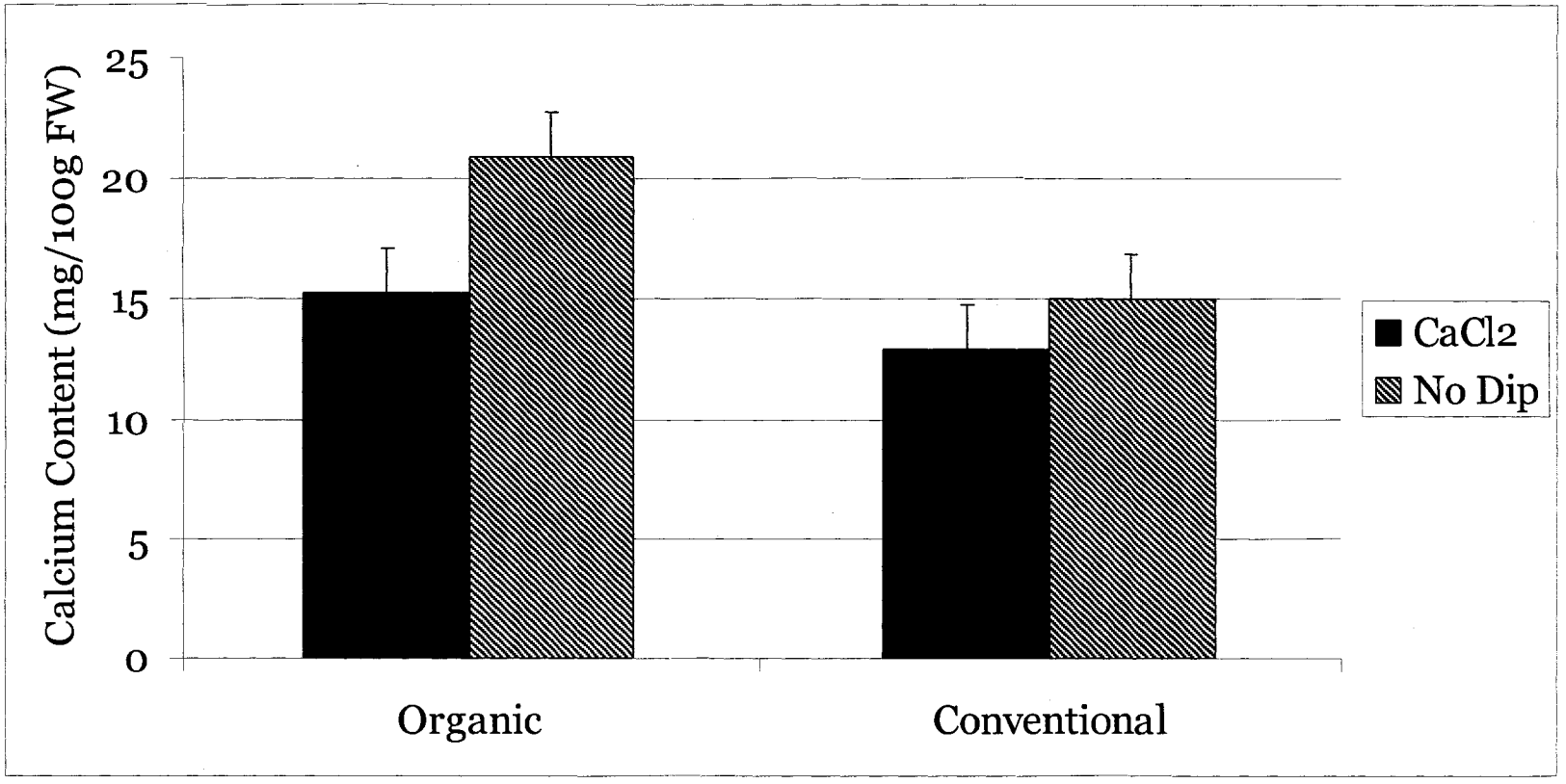

Figure 4.23. Mean calcium content. Organic and conventionally grown melons were either immersed in a 0.08 M $CaCl_2$ solution for 20 minutes or not treated, then stored for 1 day at 21° C. Each data point represents the average results of 3 melons. Error bars indicate the standard error.

Table 4.1. Analysis of variance on the effects of time, storage temperature, dip treatment, and growing method

Effect	Appearance	Flavor	Texture	Overall	Color a*	Color b*	Color L*
Time	<0.0001***	0.0204*	<0.0001***	0.0019**	<0.0001***	<0.0001***	<0.0001***
Temp	0.0004***	0.7705NS	<0.0001***	0.0080**	0.0983NS	<0.0001***	<0.0001***
Time* Temp	0.2856NS	0.0031**	0.3584NS	0.1812NS	0.1795 NS	<0.0001***	<0.0001***
Dip	0.0257*	0.0799NS	<0.0001***	0.0001***	0.0008***	0.0040**	0.1573NS
Time*Dip	0.3173 NS	0.0210*	0.0552NS	0.3608NS	0.0087**	0.0008***	0.0002***
Temp*Dip	0.1300 NS	0.9894NS	0.2967NS	0.2594NS	<0.0001***	<0.0001***	0.0056**
Time*Temp*Dip	0.3862NS	<0.0001***	0.3975NS	<0.0001***	0.0039**	<0.0001***	<0.0001***
Method	0.0141*	0.3388NS	<0.0001***	0.0278*	0.3207NS	<0.0001***	0.9574NS
Time*Method	0.3799NS	0.0438*	0.0090**	0.0134*	0.9725NS	<0.0001***	<0.0001***
Temp*Method	0.6522NS	0.8624NS	0.1544NS	0.9150NS	0.0682NS	0.0006***	0.8254NS
Time*Temp*Method	0.6940NS	<0.0001***	0.0084**	<0.0001***	0.2387NS	<0.0001***	0.5606NS
Dip*Method	0.0202*	0.1188NS	0.0004***	0.0152*	0.0008***	<0.0001***	0.0004***
Time*Dip*Method	0.0001***	<0.0001***	0.0029**	0.0010***	0.0282*	<0.0001***	0.6821NS
Temp*Dip*Method	0.7981NS	0.9019NS	0.2766NS	0.9325NS	0.4609NS	0.0054**	0.2004NS
Time*Temp*Dip*Method	0.4278NS	0.5961NS	0.2676NS	0.5955 NS	0.8852NS	0.0007***	0.2409NS

Expressed as p values for statistical significance.
NS, *, **, ***Non-significant or significant at p≤0.05, 0.01, or 0.001, respectively.

Table 4.1 (cont.)

Effect	% Wt Loss	SSC	TEAC (ABTS)	TEAC (DPPH)	TPC	Ascorbic Acid	Calcium Content
Time	$<0.0001^{***}$	0.0863^{NS}	0.0008^{***}	0.0088^{**}	0.0248^{*}	0.4314^{NS}	n/a
Temp	$<0.0001^{***}$	0.2996^{NS}	0.0866^{NS}	0.0086^{**}	0.8923^{NS}	0.2600^{NS}	n/a
Time* Temp	0.0106^{*}	0.0358^{*}	0.0717^{NS}	0.1251^{NS}	0.1556^{NS}	0.1567^{NS}	n/a
Dip	0.5843^{NS}	0.2217^{NS}	0.8248^{NS}	0.5602^{NS}	0.2069^{NS}	0.3875^{NS}	0.0212^{*}
Time*Dip	0.3021^{NS}	0.0804^{NS}	0.3342^{NS}	0.3141^{NS}	0.1839^{NS}	0.1309^{NS}	n/a
Temp*Dip	0.4608^{NS}	0.1409^{NS}	0.1410^{NS}	0.5228^{NS}	0.7019^{NS}	0.3976^{NS}	n/a
Time*Temp*Dip	0.7142^{NS}	0.0036^{**}	0.5813^{NS}	0.1749^{NS}	0.0023^{**}	0.0026^{**}	n/a
Method	0.1896^{NS}	0.0141^{*}	0.0002^{***}	0.0007^{***}	0.0146^{*}	0.0012^{**}	0.0267^{*}
Time*Method	0.5003^{NS}	0.0303^{*}	0.1177^{NS}	$<0.0001^{***}$	0.8921^{NS}	0.5842^{NS}	n/a
Temp*Method	0.7636^{NS}	0.3879^{NS}	0.4852^{NS}	0.0003^{***}	0.3454^{NS}	0.1835^{NS}	n/a
Time*Temp*Method	0.9059^{NS}	0.0731^{NS}	0.2476^{NS}	0.2142^{NS}	0.2591^{NS}	0.0076^{**}	n/a
Dip*Method	0.8074^{NS}	0.5613^{NS}	0.2117^{NS}	0.5025^{NS}	0.2019^{NS}	0.2709^{NS}	0.2290^{NS}
Time*Dip*Method	0.9367^{NS}	0.0395^{*}	0.1303^{NS}	0.2480^{NS}	0.0649^{NS}	0.0715^{NS}	n/a
Temp*Dip*Method	0.8570^{NS}	0.4509^{NS}	0.1316^{NS}	0.3249^{NS}	0.8437^{NS}	0.9114^{NS}	n/a
Time*Temp*Dip*Method	0.9431^{NS}	0.7477^{NS}	0.0684^{NS}	0.4012^{NS}	0.1845^{NS}	0.3350^{NS}	n/a

Expressed as p values for statistical significance.
$^{NS, *, **, ***}$Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table 4.2. Mean appearance scores of 'Haogen' melons[1]

		21° C Storage			10° C Storage		
		Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
Organic	$CaCl_2$ Dip[2]	7.96 ±0.21	7.89 ±0.20	n/a[3]	8.16[a] ±0.20	7.88[a] ±0.20	6.61[b] ±0.20
	No Dip	7.81[a] ±0.20	7.37[a] ±0.20	6.28[b] ±0.20	8.03 ±0.20	8.00 ±0.20	7.21[y] ±0.20
Conventional	$CaCl_2$ Dip[2]	7.64 ±0.20	7.59 ±0.20	n/a[3]	7.73 ±0.20	7.62 ±0.20	7.49[A] ±0.20
	No Dip	7.45 ±0.20	7.42 ±0.20	n/a[3]	7.76[a] ±0.20	7.69[a] ±0.20	6.23[B,b,z] ±0.20

[1] Means represent average scores given by consumer panelists (n=40) based on a 9-point hedonic scale (9=highly acceptable, 1=highly unacceptable).
[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.
[3] Samples too spoiled to be tested.

A,B: Dip Treatment Effect—means for same day, temperature, and method with different superscripts are significantly different ($p<0.05$).
a,b: Day Effect—means for same treatment, temperature, and method with different superscripts are significantly different ($p<0.05$).
y,z: Growing Method Effect—means for same treatment, day, and temperature with different superscripts are significantly different ($p<0.05$).

Table 4.3. Mean flavor scores of 'Haogen' melons[1]

		21° C Storage			10° C Storage		
		Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
Organic	$CaCl_2$ Dip[2]	$7.67^{A,a,Y}$ ±0.27	$6.07^{A,b,Y,y}$ ±0.26	n/a[3]	$6.36^{a,Z}$ ±0.26	$8.10^{b,Z}$ ±0.25	6.51^{a} ±0.26
	No Dip	$6.03^{B,a}$ ±0.25	$7.41^{B,b}$ ±0.26	8.00^{b} ±0.26	6.58^{y} ±0.26	7.50^{y} ±0.25	6.89 ±0.26
Conventional	$CaCl_2$ Dip[2]	6.81 ±0.25	7.47^{y} ±0.26	n/a[3]	7.16^{ab} ±0.26	$7.69^{A,a}$ ±0.25	6.07^{b} ±0.26
	No Dip	5.84^{Y} ±0.25	7.07^{Y} ±0.26	n/a[3]	$7.85^{a,Z,z}$ ±0.26	$5.68^{B,b,Z,z}$ ±0.26	6.56^{b} ±0.26

[1] Means represent average scores given by consumer panelists (n≥40) based on a 9-point hedonic scale (9=highly acceptable, 1=highly unacceptable).
[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.
[3] Samples too spoiled to be tested.

A,B: Dip Treatment Effect—means for same day, temperature, and method with different superscripts are significantly different ($p<0.05$).
a,b: Day Effect—means for same treatment, temperature, and method with different superscripts are significantly different ($p<0.05$).
Y,Z: Storage Temperature Effect—means for same treatment, day, and method with different superscripts are significantly different ($p<0.05$).
y,z: Growing Method Effect—means for same treatment, day, and temperature with different superscripts are significantly different ($p<0.05$).

Table 4.4. Mean texture scores of 'Haogen' melons[1]

		21° C Storage			10° C Storage		
		Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
Organic	$CaCl_2$ Dip[2]	7.77 ±0.22	7.19^{Y} ±0.21	n/a[3]	7.63 ±0.21	8.22^{Z} ±0.21	7.50 ±0.21
	No Dip	7.33 ±0.21	7.24^{y} ±0.21	6.97 ±0.21	7.56 ±0.21	7.88^{y} ±0.21	7.48^{y} ±0.21
Conventional	$CaCl_2$ Dip[2]	7.19 ±0.21	7.32 ±0.21	n/a[3]	7.83 ±0.21	7.69 ±0.21	7.49 ±0.21
	No Dip	6.88^{Y} ±0.21	6.07^{z} ±0.21	n/a[3]	7.87^{a,Z} ±0.21	6.90^{b,z} ±0.21	6.30^{b,z} ±0.21

[1] Means represent average scores given by consumer panelists (n≥40) based on a 9-point hedonic scale (9=highly acceptable, 1=highly unacceptable).
[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.
[3] Samples too spoiled to be tested.

a,b: Day Effect—means for same treatment, temperature, and method with different superscripts are significantly different ($p<0.05$).
Y,Z: Storage Temperature Effect—means for same treatment, day, and method with different superscripts are significantly different ($p<0.05$).
y,z: Growing Method Effect—means for same treatment, day, and temperature with different superscripts are significantly different ($p<0.05$).

Table 4.5. Mean overall acceptability scores of 'Haogen' melons[1]

		21° C Storage			10° C Storage		
		Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
Organic	$CaCl_2$ Dip[2]	7.69^{A} ±0.23	6.67^{Y} ±0.23	n/a[3]	6.83^{a} ±0.23	$8.06^{b,Z}$ ±0.23	6.58^{a} ±0.23
	No Dip	6.32^{B} ±0.22	7.16 ±0.23	7.11 ±0.23	6.87 ±0.23	7.65 ±0.23	7.01 ±0.23
Conventional	$CaCl_2$ Dip[2]	6.91 ±0.22	7.45 ±0.23	n/a[3]	7.48 ±0.23	7.48^{A} ±0.23	6.62 ±0.23
	No Dip	6.08^{Y} ±0.22	6.72 ±0.23	n/a[3]	$7.79^{a,Z}$ ±0.23	$6.06^{B,b}$ ±0.23	6.21^{b} ±0.23

[1] Means represent average scores given by consumer panelists (n≥40) based on a 9-point hedonic scale (9=highly acceptable, 1=highly unacceptable).
[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.
[3] Samples too spoiled to be tested.

A,B: Dip Treatment Effect—means for same day, temperature, and method with different superscripts are significantly different ($p<0.05$).
a,b: Day Effect—means for same treatment, temperature, and method with different superscripts are significantly different ($p<0.05$).
Y,Z: Storage Temperature Effect—means for same treatment, day, and method with different superscripts are significantly different ($p<0.05$).

Table 4.6. Mean percent weight loss of 'Haogen' melons[1]

		21° C Storage			10° C Storage		
		Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
Organic	$CaCl_2$ Dip[2]	1.05[a] ±0.85	2.98[ab] ±1.20	7.49[b] ±1.47	0.56 ±0.85	1.64 ±1.20	3.16 ±1.20
	No Dip	1.28 ±1.20	5.31 ±1.20	6.66 ±1.20	0.53 ±1.47	1.78 ±1.20	2.01 ±1.20
Conventional	$CaCl_2$ Dip[2]	1.00 ±1.20	4.43 ±1.20	n/a	0.62 ±0.85	2.05 ±1.20	3.46 ±1.20
	No Dip	0.87[a] ±1.20	6.81[b] ±0.85	8.31[b] ±1.20	0.49 ±1.20	2.81 ±1.20	3.30 ±1.20

[1] Means represent three replications (±SE) of the percent weight loss. (Calculated from [initial weight in grams-final weight in grams)]/[initial weight in grams] x 100.)
[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.

a,b: Day Effect—means for same treatment, temperature, and method with different superscripts are significantly different ($p<0.05$).

Table 4.7. Mean color a* values of 'Haogen' melons[1]

		21° C Storage			10° C Storage		
		Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
Organic	$CaCl_2$ Dip[2]	-7.10 ±0.42	-6.84 ±0.42	-6.16^{A,Y} ±0.42	-6.55^{a} ±0.42	-5.29^{ab} ±0.42	-3.77^{b,Z} ±0.42
	No Dip	-7.67^{a} ±0.42	-5.13^{b} ±0.42	-2.91^{B,c} ±0.42	-8.17^{a} ±0.42	-7.12^{a} ±0.42	-4.18^{b} ±0.42
Conventional	$CaCl_2$ Dip[2]	-7.25 ±0.42	-6.84 ±0.42	n/a[3]	-8.57^{a} ±0.42	-5.65^{b} ±0.42	-4.04^{b} ±0.42
	No Dip	-5.57^{a} ±0.42	-4.76^{a} ±0.42	-2.35^{b} ±0.42	-7.22^{a} ±0.42	-6.62^{a} ±0.42	-3.80^{b} ±0.42

[1] Means represent the average (±SE) a* value of the interior melon color, based on three readings of three replications.
[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.
[3] Sample was too spoiled to test.

A,B: Dip Treatment Effect—means for same day, temperature, and method with different superscripts are significantly different ($p<0.05$).
a,b: Day Effect—means for same treatment, temperature, and method with different superscripts are significantly different ($p<0.05$).
Y,Z: Storage Temperature Effect—means for same treatment, day, and method with different superscripts are significantly different ($p<0.05$).

Table 4.8. Mean color b* values of 'Haogen' melons[1]

		21° C Storage			10° C Storage		
		Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
Organic	$CaCl_2$ Dip[2]	$33.21^{A,a}$ ±0.75	$36.84^{ab,Y}$ ±0.75	$37.19^{b,Y}$ ±0.75	$33.26^{A,a}$ ±0.75	$29.15^{A,b,Z}$ ±0.75	$29.55^{A,b,Z}$ ±0.75
	No Dip	$38.10^{B,a,y}$ ±0.75	$38.11^{a,Y,y}$ ±0.75	33.61^{b} ±0.75	$39.28^{B,a,y}$ ±0.75	$33.43^{B,b,Z,y}$ ±0.75	$34.35^{B,b,y}$ ±0.75
Conventional	$CaCl_2$ Dip[2]	32.67^{a} ±0.75	$36.62^{A,b,Y}$ ±0.75	n/a[3]	35.58^{a} ±0.75	$30.17^{A,b,Z}$ ±0.75	26.53^{b} ±0.75
	No Dip	29.70^{z} ±0.75	$31.88^{B,Y,z}$ ±0.75	29.15 ±0.75	$32.76^{a,z}$ ±0.75	$37.85^{B,b,Z,z}$ ±0.75	$28.63^{a,z}$ ±0.75

[1] Means represent the average (±SE) b* value of the interior melon color, based on three readings of three replications.
[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.
[3] Sample was too spoiled to test.

A,B: Dip Treatment Effect—means for same day, temperature, and method with different superscripts are significantly different ($p<0.05$).
a,b: Day Effect—means for same treatment, temperature, and method with different superscripts are significantly different ($p<0.05$).
Y,Z: Storage Temperature Effect—means for same treatment, day, and method with different superscripts are significantly different ($p<0.05$).
y,z: Growing Method Effect—means for same treatment, day, and temperature with different superscripts are significantly different ($p<0.05$).

Table 4.9. Mean color L* values of 'Haogen' melons[1]

		21° C Storage			10° C Storage		
		Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
Organic	$CaCl_2$ Dip[2]	71.28 ±1.02	66.78^{Y} ±1.02	71.70^{Y} ±1.02	$70.97^{a,y}$ ±1.02	$72.86^{A,a,Z}$ ±1.02	$78.78^{b,Z}$ ±1.02
	No Dip	72.71 ±1.02	68.60 ±1.02	71.03 ±1.02	72.93^{a} ±1.02	$66.48^{B,b}$ ±1.02	74.65^{a} ±1.02
Conventional	$CaCl_2$ Dip[2]	68.44 ±1.02	68.25^{Y} ±1.02	n/a[3]	$64.56^{A,a,z}$ ±1.02	$74.50^{b,Z}$ ±1.02	76.60^{b} ±1.02
	No Dip	70.07 ±1.02	72.56 ±1.02	72.02^{Y} ±1.02	$71.62^{B,a}$ ±1.02	70.83^{a} ±1.02	$78.51^{b,Z}$ ±1.02

[1] Means represent the average (±SE) L* value of the interior melon color, based on three readings of three replications.
[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.
[3] Sample was too spoiled to test.

A,B: Dip Treatment Effect—means for same day, temperature, and method with different superscripts are significantly different ($p<0.05$).
a,b: Day Effect—means for same treatment, temperature, and method with different superscripts are significantly different ($p<0.05$).
Y,Z: Storage Temperature Effect—means for same treatment, day, and method with different superscripts are significantly different ($p<0.05$).
y,z: Growing Method Effect—means for same treatment, day, and temperature with different superscripts are significantly different ($p<0.05$).

Table 4.10. Mean soluble solids content of 'Haogen' melons[1]

		21° C Storage			10° C Storage		
		Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
Organic	$CaCl_2$ Dip[2]	10.70 ±1.04	6.77 ±1.04	7.53 ±1.04	8.50 ±1.04	12.10 ±1.04	8.10 ±1.04
	No Dip	8.03 ±1.04	11.67 ±1.04	11.50 ±1.04	7.40[y] ±1.04	11.97 ±1.04	8.77 ±1.04
Conventional	$CaCl_2$ Dip[2]	11.33 ±1.04	9.47 ±1.04	n/a[3]	11.33 ±1.04	12.83 ±1.04	8.93 ±1.04
	No Dip	9.67 ±1.04	10.60 ±1.04	11.30 ±1.04	13.47[z] ±1.04	9.83 ±1.04	9.70 ±1.04

[1] Means represent three replications (±SE) measured using a refractometer (expressed as °Brix).
[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.
[3] Sample too spoiled to test.

y,z: Growing Method Effect—means for same treatment, day, and temperature with different superscripts are significantly different ($p<0.05$).

Table 4.11. Mean antioxidant activity ($DPPH^+$) of 'Haogen' melons[1]

		21° C Storage			10° C Storage		
		Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
Organic	$CaCl_2$ Dip[2]	506.39[Y] ±106.81	395.63 ±106.81	299.39 ±106.81	1126.88[a,Z,y] ±106.81	672.02[ab] ±106.81	475.70[b] ±106.81
	No Dip	503.19 ±106.81	623.99 ±106.81	210.79 ±106.81	844.05 ±106.81	639.22 ±106.81	561.59 ±106.81
Conventional	$CaCl_2$ Dip[2]	264.64 ±106.81	534.90 ±106.81	n/a[3]	232.95[z] ±106.81	631.36 ±106.81	85.75 ±106.81
	No Dip	234.32 ±106.81	596.54 ±106.81	604.78 ±106.81	305.63 ±106.81	462.53 ±106.81	472.97 ±106.81

[1] Means represent three replications (±SE) of the $DPPH^+$ antioxidant activity test (expressed as µmole TEAC/100 g FW).
[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.
[3] Sample too spoiled to be tested on day 10.

a,b: Day Effect—means for same treatment, temperature, and method with different superscripts are significantly different ($p<0.05$).
Y,Z: Storage Temperature Effect—means for same treatment, day, and method with different superscripts are significantly different ($p<0.05$).
y,z: Growing Method Effect—means for same treatment, day, and temperature with different superscripts are significantly different ($p<0.05$).

Table 4.12. Mean antioxidant activity ($ABTS^{\bullet+}$) of 'Haogen' melons[1]

		21° C Storage			10° C Storage		
		Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
Organic	$CaCl_2$ Dip[2]	102.11 ±20.99	152.79 ±20.99	166.29 ±20.99	140.14 ±20.99	121.33 ±20.99	137.75 ±20.99
	No Dip	110.71 ±20.99	107.60 ±20.99	170.46 ±20.99	126.05 ±20.99	127.50 ±20.99	102.64 ±20.99
Conventional	$CaCl_2$ Dip[2]	153.93 ±20.99	137.79 ±20.99	n/a[3]	160.28 ±20.99	147.12 ±20.99	175.57 ±20.99
	No Dip	146.75 ±20.99	183.99 ±20.99	260.20 ±20.99	144.33^{ab} ±20.99	91.74^{a} ±20.99	212.50^{b} ±20.99

[1] Means represent three replications (±SE) of the $ABTS^{\bullet+}$ antioxidant activity test (expressed as µmole TEAC/100 g FW).
[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.
[3] Sample too spoiled to be tested on day 10.

a,b: Day Effect—means for same treatment, temperature, and method with different superscripts are significantly different ($p<0.05$).

Table 4.13. Mean total phenolic content of 'Haogen' melons[1]

		21° C Storage			10° C Storage		
		Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
Organic	$CaCl_2$ Dip[2]	34.88 ±4.61	29.64 ±4.61	33.40 ±4.61	28.35 ±4.61	40.36 ±4.61	30.98 ±4.61
	No Dip	32.95 ±4.61	42.47 ±4.61	33.32 ±4.61	38.33 ±4.61	43.36 ±4.61	37.49 ±4.61
Conventional	$CaCl_2$ Dip[2]	38.40 ±4.61	39.38 ±4.61	n/a[3]	29.48 ±4.61	55.67 ±4.61	35.10 ±4.61
	No Dip	38.57 ±4.61	45.71 ±4.61	42.72 ±4.61	52.16 ±4.61	37.92 ±4.61	28.62 ±4.61

[1] Means represent three replications (±SE) of the total phenolic content (expressed as mg GAE/100 g FW).
[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.
[3] Sample too spoiled to be tested on day 10.

Table 4.14. Mean ascorbic acid content of 'Haogen' melons[1]

		21° C Storage			10° C Storage		
		Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
Organic	$CaCl_2$ Dip[2]	36.15 ±3.61	25.97 ±3.61	26.94 ±3.61	30.94 ±3.61	33.72 ±3.61	33.00 ±3.61
	No Dip	20.97 ±3.61	31.16 ±3.61	35.26 ±3.61	24.63 ±3.61	30.40 ±3.61	28.35 ±3.61
Conventional	$CaCl_2$ Dip[2]	36.90 ±3.61	43.35 ±3.61	n/a[3]	32.31 ±3.61	36.04 ±3.61	32.24 ±3.61
	No Dip	28.89 ±3.61	45.93 ±3.61	38.88 ±3.61	41.01 ±3.61	23.88 ±3.61	34.48 ±3.61

[1] Means represent three replications (±SE) of the ascorbic acid content (expressed as mg/100 g FW).
[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.
[3] Sample too spoiled to be tested on day 10.

Table 4.15. Mean calcium content of 'Haogen' melons[1]

	Organic	Conventional
$CaCl_2$ Dip[2]	15.24 ±1.89	12.91 ±1.89
No Dip	20.89 ±1.89	15.00 ±1.89

[1] Means represent three replications (±SE) of the calcium content (mg/100g FW).
[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.

•CHAPTER V•

Effects of a Post-Harvest $CaCl_2$ Dip and Storage Temperature on Selected Quality Characteristics of Tomatoes

ABSTRACT

Tomatoes (*Solanum lycopersicum* L.) are widely consumed in the United States and well-known for their health benefits, many of which have been associated with the high levels of lycopene and other antioxidants present in tomatoes. A variety of factors influence produce quality during the storage time from harvest to consumption. Published research is lacking on the best post-harvest handling methods for ripe, fresh tomatoes, especially those grown by smaller-scale farmers who often sell directly to consumers. This study evaluated the impact of a 15-minute 0.06 M $CaCl_2$ post-harvest dip treatment as well as storage temperature on selected sensory and nutritional qualities of organically grown ripe tomatoes stored up to ten days. Storage temperature significantly impacted many tomato qualities in this study. The lower temperature (10° C) minimized percent weight loss, yet negatively impacted many sensory and nutritional qualities. Storing tomatoes at 21° C and the use of a $CaCl_2$ dip improved many sensory qualities and some antioxidant levels, as well as maintained a deeper red color of fresh tomatoes during storage. Post-harvest handling methods greatly influence the quality of tomatoes, and additional research should be conducted to explore the use of a $CaCl_2$ dip as well as optimal storage temperatures for tomatoes harvested at peak maturity.

INTRODUCTION

Tomatoes (*Solanum lycopersicum* L.) are widely consumed, ranking second to potatoes among vegetable and melon per capita use in the United States (Lucier and Dettman 2008b). Tomatoes are good sources of vitamin C, folate, and potassium as well as many phytochemicals (Beecher 1998; Leonardi, et al. 2000; Djuric and Powell 2001; Willcox, et al. 2003). The high carotenoid levels present in tomatoes, especially lycopene, have been associated with many cardiovascular and anticarcinogenic benefits (Giovannucci 2002; Giovannucci, et al. 2002; Giovannucci 2005; Singh and Goyal 2008).

Awareness for the important role fruits and vegetables have in a healthy diet is increasing (Goldman 2003; Bazzano 2006), as is the number of farmers' markets in the United States. According to the United States Department of Agriculture (USDA), the number of U.S. farmers' markets more than doubled from 1,755 in 1994 to 4,385 in 2006 (USDA-AMS 2006). Also, based on the results of a national survey conducted in 2006, 3 out of 4 respondents had shopped at a farmers' market within the last year (Keeling-Bond, et al. 2006).

This increased popularity and demand for high quality, fresh produce, along with the growing interest in locally produced and organic produce (Keeling-Bond, et al. 2006), provides small-scale growers with a unique opportunity. While much research has focused on enhancing the quality of tomatoes harvested in unripe

stages (Kader, et al. 1978; Chomchalow, et al. 2002), little research has focused on how post-harvest handling methods effect tomatoes harvested at the ripe, red stage, which is common practice of growers utilizing direct marketing.

The stage of maturity at harvest appears to affect tomato qualities such as flavor, color, and antioxidant content, though there are mixed results on how the level of maturity affects antioxidant levels. In a study by Arias et al. (2000b), higher overall likeably sensory scores were given to vine-ripened tomatoes than to post-harvest ripened tomatoes. Vine-ripened tomatoes have also been found to have significantly higher ascorbic acid (Wold, et al. 2004; Kumar, et al. 2007), β-carotene (Arias, et al. 2000b; Raffo, et al. 2002), lycopene (Thompson, et al. 2000; Raffo, et al. 2002), and a deeper red color (Arias, et al. 2000b) compared to post-harvest ripened tomatoes. There is also evidence that degree of maturity at harvest may not affect the ascorbic acid content of tomatoes after ripening (Arias, et al. 2000b; Raffo, et al. 2002) or post-harvest ripened tomatoes could have higher antioxidant levels than vine-ripened tomatoes (Giovanelli, et al. 1999).

Research is needed to determine the most beneficial post-harvest conditions for smaller-scale growers to use, who often harvest tomatoes at peak maturity and sell produce directly to consumers. Once tomatoes reach peak maturity, they are highly perishable (Kader 1992), and thus would benefit from a post-harvest treatment to increase their shelf-life.

One post-harvest treatment showing positive results on fruit such as strawberries, lemons, melons, and peaches has been application of calcium chloride ($CaCl_2$) dips (Garcia, et al. 1996; Tsantili, et al. 2002; Manganaris, et al. 2007; Martin-Diana, et al. 2007). Calcium plays an important role in maintaining the cell wall structure in fruit by interacting with pectic acid to form calcium pectate, which has a firming effect on plant cell walls (Poovaiah 1986). Concentrations of $CaCl_2$ used in previous studies have ranged from 0.045 M-0.27 M, with 0.06-0.09 M producing the best results for most fruit (Garcia, et al. 1996; Tsantili, et al. 2002; Manganaris, et al. 2007; Martin-Diana, et al. 2007).

Based on the $CaCl_2$ concentrations used in other studies and preliminary research conducted in our lab, we chose to evaluate the impact of a 15-minute 0.06 M $CaCl_2$ post-harvest dip treatment as well as storage temperature on selected sensory and nutritional qualities of organically grown tomatoes harvested at the ripe, red stage and stored up to ten days.

METHODS AND MATERIALS

Plant Material

Tomatoes (cultivar 'Early Girl') (Harris Seeds, Rochester, NY) were grown at Colorado State University's Horticulture Field Research Center (HFRC) in Fort Collins, CO during the summer of 2007. Soil at the HFRC is classified as Nunn

clay with a pH of 7.8, and the tomatoes were grown on organic plots that have been certified organic since 2001.

Plants were started in the Colorado State University Plant Environmental Research Center greenhouses in 3-inch peat pots using Sunshine Organic Basic planting media (Sun Gro Horticulture, Bellvue, WA) with 20% vermicompost (local source). After six weeks, the tomatoes were transplanted to the field, spaced evenly in black plastic mulched beds (rows 18 inches apart and beds 60 inches apart).

Prior to planting, soil tests were conducted on the organic and conventional plots. The certified organic plots contained 2.0-2.4% higher levels of organic matter derived from green manure plough-down of legume and cereal cover crops and from thoroughly composted chicken manure. Otherwise, nutrient content of nitrogen, phosphorus, and potassium was made approximately equivalent at the beginning of the growing season from either organic or conventional fertilizers. 'Evergreen' poultry compost (A1 Organics, Eaton, CO) was applied to the organic plot with a Millcreek spreader and rototilled into the soil. To match nutrient levels in the organic fertilizer, urea (45-0-0) and triple superphospate (0-20.1-0) were applied to the conventional plot using a broadcast spreader.

Crops were irrigated using drip irrigation with municipal water. Irrigation levels were determined using 'Watermark' granular matrix sensors (Irrometer

Company, Riverside, CA). Irrigation levels were monitored to ensure the tomatoes were watered adequately.

Once the tomatoes reached peak maturity as indicated by full red coloring, they were harvested manually early in the morning. Tomatoes were transported at ambient temperature to the laboratory for processing within 30 minutes.

Treatments

Tomatoes (6 ± 1 cm diameter) were randomly assigned into $CaCl_2$ dip and no dip treatment groups (Figure 5.1). Thirty-six tomatoes were used for the sensory taste tastes and 36 tomatoes were used for the objective quality measurements and chemical analyses (total harvested tomatoes=72). Any visible soil was brushed off melons using paper towels. Half the tomatoes were dipped in a 0.06 M $CaCl_2$ solution (6.6 grams $CaCl_2$ per liter of water) and half were left untreated. To make the dip, food grade $CaCl_2$ (DOW Chemical Company, Midland, MI) was mixed with water (21° ± 1° C) in 68 L plastic tubs (Sterile, Townsend, MA) until dissolved. Dipped tomatoes were completely immersed for 15 minutes, then removed and allowed to air dry on paper towels for 1 hour.

Tomatoes were then individually wrapped in loose tissue paper labeled with the sample ID information and placed in new 30.5x38.1x25.4-cm cardboard boxes (Weyerhaeuser, Federal Way, WA), keeping treatment groups separate. Tomatoes were stored at 21° ± 1° C (relative humidity 30 ± 5%) or 10° ± 1° C

(relative humidity 70 ± 5%). On days 1, 5, and 10, tomatoes were randomly selected for sensory evaluations as well as for objective quality measurements and chemical analyses.

Sensory Evaluations

The protocol for the tomato sensory evaluations was reviewed and approved by the Colorado State University Human Research Committee before beginning this project. Forty untrained consumer panelists were recruited from CSU faculty, staff, and students for each sensory evaluation. On days 1, 5, and 10 of storage, three tomatoes per treatment group were randomly selected, thoroughly rinsed with water (21° ± 1° C), sliced into eight wedges, and the wedges were cut into two or three uniform pieces, yielding approximately 3-cm sized triangles. Samples were coded with a three-digit number and given to panelists in a random order. Distilled water and unsalted crackers were given to panelists to cleanse their palate between samples. Four to six samples were tested in each session and panelists were asked to rate the appearance, flavor, texture, and overall acceptability of the samples using a 9-point hedonic scale, with 9=highly acceptable and 1=highly unacceptable (Figure 5.2).

Objective Quality Measurements

Percent Weight Loss

The weight of all tomatoes was recorded at harvest. On the day of testing, tomatoes were weighed again and the percent weight loss was calculated as

[(initial weight-final weight)/initial weight] x 100. Measurements were taken in grams on three tomatoes per treatment group.

Color

Color values were determined by cutting a 5-cm diameter disc off the bottom of each tomato and placing it interior side down in the chamber of a HunterLab ColorFlex spectrocolorimeter (Hunter Associates Laboratory, Inc., Reston, VA). L* (100=white, 0=black), a* (positive=red, negative=green), and b* (positive=yellow, negative=blue) values were read three times, averaged for each of the three sample replications per treatment group.

pH

The pH of the tomatoes was tested using an Accument AB15 pH meter (Fisher Scientific, Pittsburgh, PA). The pH meter was calibrated using 4, 7, and 10 standards before and after each test session. Approximately one-fourth of each tomato was squeezed by hand into a beaker. Our preliminary studies showed that the pH value was the same when tomatoes were manually mashed or mechanically pureed. Therefore, the pH of the squeezed tomato pulp was tested, with three different tomatoes evaluated per treatment group.

Soluble Solids Content

Percent soluble solids of each tomato sample was measured using an AR200 Reichert Digital, Temperature-Compensated Refractometer (Reichert Analytical

Instruments, Depew, NY). An eyedropper was used to transfer a drop of tomato juice from the cavity of a cut tomato to the sample well. Three tomatoes were measured per treatment group and results expressed as °Brix.

Chemical Analyses

Sample Preparation

On days 1, 5, and 10 of storage, three tomatoes from each treatment group were cut in half vertically and then cut into thin slices. For each tomato, 35-40 g of thin slices was freeze-dried using a Genesis Freeze Drier (Virtis, Inc., Gardiner, NY). Lyophilized samples were then weighed to determine dry matter content and ground in preparation for extraction. The dried samples were ground into a powder using a mortar and pestle and sieved with a No. 20 Tyler sieve (WS Tyler Inc., Mentor, OH).

Samples were then extracted by placing 5 mL of 80% acetone (Fisher Chemicals, Fair Lawn, NJ) and 200 mg powder from each replicate in 15 mL centrifuge tubes. The tubes were vortexed until thoroughly mixed then rotated in the dark (4° C) for 15 minutes. Samples were then centrifuged (4° C; 4,000 rpm) for 15 minutes. One mL of supernatant was transferred to an Eppendorf tube and vacufuged at 45° C to dryness (approximately 2-3 hours). Samples were stored at -20° C until analytical tests were completed.

Total Phenolic Content

Total phenolic content was measured using a microplate-based Folin-Ciocalteu assay adapted from Singleton and Rossi (1965), Spanos and Wrolstad (1990), and Rivera et al. (2006). Vacufuged extractions were reconstituted with 1.0 mL of 80% acetone, then 100 µL of this solution was diluted with 900 µL nanopure water. In triplicate, 35 µL of the diluted sample was pipetted into microplate wells. Using a multichannel pipette, 150 µL of 0.2 M Folin-Ciocalteu reagent (Sigma-Aldrich, Inc., St. Louis, MO) was added to all wells. The plate was shaken for 30 seconds and held for 5 minutes at room temperature. Then 115 µL of 7.5% (w/v) Na_2CO_3 (Fisher Chemicals) was added to all wells, shaken for 30 seconds, and held for 5 minutes at room temperature. The microplate was incubated at 45° C for 30 minutes, and then cooled to room temperature for 1 hour before reading at 765 nm in a Spectra Max Plus (Molecular Devices, Sunnyvale, CA) spectrophotometer using Softmax Pro software (Molecular Devices). Total phenolic content was calculated by comparing to a gallic acid (Sigma Chemical Co., St. Louis, MO) standard curve and expressed as milligrams per 100 gram of tomato fresh weight (mg GAE/100 g FW).

$ABTS^{\bullet+}$ Trolox Equivalent Antioxidant Capacity

The 2,2' azinobis (3-ethlbezothazoline-6-sulfonic acid) diammonium salt ($ABTS^{\bullet+}$) assay was used to estimate antioxidant capacity. This assay is based upon measuring the capacity of an extract to scavenge and detoxify the $ABTS^{\bullet+}$

radical and is considered an estimate of hydroxyl scavenging activity (Miller and Rice-Evans 1997). The protocol used was based on the microplate method described by Rivera et al. (2006), as modified from Miller and Rice-Evans (1997).

The $ABTS^{\bullet+}$ solution was prepared by mixing 40 mg ABTS (Calbiochem, EMD Biosciences, La Jolla, CA), 15 mL distilled water, and 2.0 ± 0.5 g MnO_2 (Sigma-Aldrich). After 20 minutes, the MnO_2 was removed using double filtration, first with a vacuum filtration and second with a 0.2 µm syringe filter. The absorbance value of the $ABTS^{\bullet+}$ solution was read at 734 nm in the Spectra Max Plus (Molecular Devices, Sunnyvale, CA) spectrophotometer using Softmax Pro software (Molecular Devices) and adjusted to 0.70 absorbance units (AU) by adding 5.0 mL phosphate buffer solution. Once the $ABTS^{\bullet+}$ solution was adjusted, it was held at 30° C and used within 4 hours.

Vacufuged samples were reconstituted with 1 mL 80% acetone (Fisher Chemical). Twenty-five µL of each reconstituted sample was mixed with 250 µL of the $ABTS^{\bullet+}$ solution, and after 60 seconds, the absorbance value was read. $ABTS^{\bullet+}$ antioxidant capacity was reported as Trolox equivalent antioxidant capacity (TEAC) per gram of sample on a fresh weight basis (TEAC/g FW) and was calculated by comparing to a Trolox (Calbiochem) standard curve. Analyses were run in triplicate at 3 dilutions for a total of 9 assays per sample.

$DPPH^+$ Trolox Equivalent Antioxidant Capacity

The 2,2-diphenyl-1-picryhydrazl ($DPPH^+$) assay was also used to estimate antioxidant capacity and was measured using the method of Lu and Foo (2000) with some modifications. Vacufuged samples were reconstituted with 1.0 mL of 5.0 mM Phosphate buffer solution. A 0.1 mM $DPPH^+$ solution was made by mixing 7.89 mg DPPH with 100% methanol. Absorbance was read in the Spectra Max Plus (Molecular Devices, Sunnyvale, CA) spectrophotometer using Softmax Pro software (Molecular Devices) at 515 nm and adjusted to 0.95 AU.

Fifteen µL of the reconstituted samples were mixed with 285 µL of the $DPPH^+$ solution, held for three minutes at 25° C, then read at 515 nm. The results were compared to a Trolox (Calbiochem) standard curve and expressed as TEAC/100 g FW.

Ascorbic Acid Content

Ascorbic acid (vitamin C) content was determined using a high-performance liquid chromatography (HPLC) method as described by Rivera et al. (2006) and modified from Dale and others (2003). Freeze-dried samples were extracted with a 5% w/v aqueous solution of metaphosphoric acid containing 1% w/v dithiothreitol (DTT) (Promega Corp., Madison, WI), and then allowed to rotate for 15 minutes at 4° C. The samples were then centrifuged for 5 minutes at 4,000 rpm and 4° C before the supernatant was filtered through a 0.45 mm nylon

syringe filter. The extraction process was repeated and the supernatant from both extractions was placed in an amber HPLC vial.

Ascorbic acid standards were made by mixing 100 mg DTT (Pormega Corp.), 10 mg ascorbic acid (Sigma-Aldrich), and 10 mL of 100% methanol before diluting to five concentrations for the standard curve. All analyses were run in duplicate and were analyzed by HPLC chromatography (Hewlett Packard Model 1050 Series, Palo Alto, CA) using Chem Station for LC Rev A 09.01 software (Agilent Technologies, Palo Alto, CA). Samples were injected into an Inertsil C4 column (Agilent Technologies) run with a phosphoric acid/methanol gradient and absorbance read at 254 nm.

Calcium Content

Freeze-dried tomato samples (1 g ground powder each) were sent to the Soil-Water-Plant Testing Laboratory at Colorado State University to determine the calcium content. Calcium content was tested using inductively coupled plasma-atomic emission spectroscopy (Miller and Kotuby-Amacher 1994). Three replications of the dipped and non-dipped day 1 tomatoes stored at 21° C were tested to determine if the dip affected the calcium content of the tomatoes.

Data Analysis

Results were analyzed using SAS Proc Mixed (Version 9.1, Cary, NC). A factorial analysis of variance was performed with differences between means assessed

using a significance of $p<0.05$ with the Tukey-Kramer adjustment for multiple comparisons. Fixed effects included time, temperature, and dip; replication (or panelist for sensory tests) was included as a random effect.

RESULTS

Sensory Evaluation

Storage temperature had a significant effect on all sensory scores (Table 5.1), with higher scores overall ($p<0.05$) given to tomatoes stored at 21° C than those stored at 10° C (Figure 5.3). Overall, the dip treatment also influenced sensory scores—the $CaCl_2$-dipped tomatoes were preferred over the non-dipped tomatoes, with flavor and overall acceptability scores significantly higher ($p<0.05$) (Figure 5.4). When combining all treatment groups, day 1 sensory scores were highest, then day 10 scores, and day 5 scores were the lowest for each sensory attribute (Figure 5.5).

The results within appearance, flavor, texture, and overall acceptability also experienced many significant interactions (Table 5.1), though they did not always follow the same trends. Appearance scores (Figure 5.6, Table 5.2) did not experience much variation over time, storage temperature, or dip, except for non-dipped tomatoes stored at 10° C which had lower scores on day 10 than day 1. $CaCl_2$-dipped tomatoes stored at 21° C had the overall highest appearance scores, though they declined slightly over time (from 8.46 to 7.90), while the non-dipped tomatoes stored at 21° C went up slightly over time (from 7.89 to 8.10).

Flavor scores (Figure 5.7, Table 5.3) for non-dipped tomatoes stored at 21° C increased over time (from 7.24 to 7.49), yet when stored at 10° C they decreased over time (from 6.99 to 6.34). $CaCl_2$-dipped tomatoes did not follow a consistent trend, and in fact, 21° C storage for 5 days and 10° C storage for 10 days tied for the highest flavor score of 7.74. When tomatoes are stored for 10 days at 10° C, the $CaCl_2$-dipped tomatoes were significantly preferred over non-dipped tomatoes. Non-dipped tomatoes stored at 21° C were also found to be significantly preferred compared to the non-dipped 10° C tomatoes. $CaCl_2$-dipped tomatoes stored at 21° C were preferred at days 1 and 5, yet fell in the middle of the results by day 10.

Day 10, $CaCl_2$-dipped tomatoes stored at 10° C had the highest texture score of 7.80 (Figure 5.8, Table 5.4), while at day 1 and 5, the $CaCl_2$-dipped 21° C tomatoes had the highest texture scores (7.67 and 7.48, respectively). When refrigerated for 10 days, the dipped tomatoes had significantly higher texture scores than the non-dipped tomatoes.

For overall acceptability (Figure 5.9, Table 5.5), panelists preferred day 1, $CaCl_2$-dipped tomatoes stored at 21° C (7.80), followed by $CaCl_2$-dipped 21° C tomatoes stored for 5 days (7.73), then $CaCl_2$-dipped 10° C tomatoes stored for 10 days (7.68). After 10 days of storage, non-dipped 10° C tomatoes were the least

preferred (6.38), with the $CaCl_2$-dipped 10° C tomatoes and non-dipped 21° C tomatoes scoring significantly higher ($p<0.05$).

Objective Quality Measurements

Percent Weight Loss

The percent weight loss during storage was significantly affected by time, temperature, and dip treatment (Table 5.1). Overall, day 10 tomatoes had the most weight loss (5.3%), while day 1 tomatoes experienced the least (1.2%) (Figure 5.10, Table 5.6). Tomatoes stored at 21° C had more weight loss ($p<0.001$) than those stored at 10° C (4.6 compared to 1.4%) and the use of a $CaCl_2$ dip increased weight loss ($p<0.01$) at both temperatures (3.7 compared to 2.3%).

Color

Overall, time, temperature, and the $CaCl_2$ dip had little effect on the color a* values (Table 5.1). On day 1, non-dipped tomatoes stored at 10° C had a significantly lower red value than dipped tomatoes, but by days 5 and 10, the color a* value of these tomatoes were more consistent with the other treatment groups (Figure 5.11, Table 5.7).

Color b* values were significantly affected by storage temperature, time, and dip (Table 5.1). Tomatoes stored at 10° C overall became more yellow over time while the 21° C tomatoes experienced less color change (Figure 5.12, Table 5.8).

The dip effect was also significant, with $CaCl_2$-dipped tomatoes showing more yellow hues overall than the non-dipped tomatoes (28.6 compared to 27.8).

With regards to the color L* values, all treatment groups became darker from day 1 to day 5, then lighter on day 10, except for the $CaCl_2$-dipped tomatoes stored at 21° C, which continued to get darker (Figure 5.13, Table 5.9). Overall, the tomatoes stored at 10° C were lighter than the tomatoes stored at 21° C, which corresponds to the increased yellow values, which would indicate the tomatoes became more orange over time.

pH

Tomato pH values ranged from 4.10-4.40 (Figure 5.14, Table 5.10). Overall, tomatoes stored at 21° C had higher pH values than those stored at 10° C (4.3 compared to 4.2) (Table 5.1), while dip treatment and storage time did not impact the pH.

Soluble Solids Content

Soluble solids content ranged from 3.27 to 5.13 °Brix (Figure 5.15, Table 5.11). Storage temperature and dip treatment significantly impacted the soluble solids content of the tomatoes tested (Table 5.1). Overall, the tomatoes stored at the higher temperature had higher ($p<0.05$) soluble solids content (4.6 compared to 4.0 °Brix) and those dipped in $CaCl_2$ had lower ($p<0.05$) soluble solids content (4.0 compared to 4.6 °Brix) than the non-dipped tomatoes.

Chemical Analyses

Total Phenolic Content

Total phenolic content of the tomatoes ranged from 62.54-86.76 mg GAE/100 g FW (Figure 5.16, Table 5.12). None of the fixed effects or the differences between means were significant for this test (Table 5.1).

$ABTS^{\cdot+}$ Trolox Equivalent Antioxidant Capacity

Time significantly impacted antioxidant capacity results of the $ABTS^{\cdot+}$ test (Table 5.1), yet the trends were not consistent among treatment groups (Figure 5.17, Table 5.13). Overall, the TEAC of non-dipped tomatoes decreased. When $CaCl_2$-dipped tomatoes were stored at 21° C, the TEAC went down on day 5 and up again on day 10 and when stored at 10° C, the TEAC values increased over time. By day 10, the $CaCl_2$-dipped tomatoes at both temperatures had higher TEAC than the non-dipped tomatoes.

$DPPH^+$ Trolox Equivalent Antioxidant Capacity

Differences in the $DPPH^+$ TEAC values were unaffected by time, temperature, dip treatment, or interactions (Figure 5.18, Table 5.1, Table 5.14).

Ascorbic Acid Content

Tomatoes stored at 21° C overall had higher ($p<0.01$) levels of ascorbic acid than those stored at 10° C (53.2 compared to 43.0 mg/100 g FW) (Figure 5.19, Table

5.15). However, the temperature-dip interaction was also significant (Table 5.1), with day 10 $CaCl_2$-dipped tomatoes stored at 21° C overall having the highest levels of ascorbic acid and day 10 dipped tomatoes stored at 10° C had the overall lowest values. Non-dipped tomatoes at both temperatures had little change in their ascorbic acid content.

Calcium Content

The $CaCl_2$-dipped tomatoes had a slightly higher calcium content than non-dipped tomatoes, though this was not statistically significant (Figure 5.20, Table 5.16).

DISCUSSION

The overall negative effect of cold temperature on sensory characteristics of tomatoes is consistent with research by Lamikanra et al. (2005), indicating that storage temperatures less than 7°-10° C can cause chilling injury in ripe tomatoes, which impacts sensory qualities. Other studies have shown tomatoes stored at 5°, 10°, or 12.5° C had lower scores in ripe aroma, sweetness, and tomato flavor compared to tomatoes stored at 20° C (Maul, et al. 2000) and refrigerated storage led to lower volatile scores for tomatoes, which decreases flavor at such temperatures (Stern, et al. 1994).

Flavor, texture, and overall acceptability scores experienced a similar trend. $CaCl_2$-dipped tomatoes stored at 21° C had the highest scores for days 1 and 5, yet

the $CaCl_2$-dipped tomatoes stored at 10° C had the highest scores for day 10. This may indicate $CaCl_2$ was able to minimize some of the negative flavor effects of the refrigerated storage temperature when a longer shelf-life is needed for tomatoes. By day 10, the 21° C tomatoes were still edible, but probably near the end of their shelf-life. Additional research is needed to understand why the scores increased significantly for the $CaCl_2$-dipped 10° C tomatoes from day 5 to day 10.

Little formal research has looked at the sensory impact of using $CaCl_2$ on whole tomatoes and other fresh produce. One of the main fruits where sensory qualities have been studied with the use a post-harvest $CaCl_2$ treatment has been melons. One study using a $CaCl_2$ dip on cut melons found the dip to negatively impact sensory qualities (Luna-Guzman and Barrett 2000), while another study found $CaCl_2$ to positively impact sensory qualities of whole melons (Lester and Grusak 2001). The discrepancy could be due to using different forms of melons and using different concentrations of $CaCl_2$, and the sensory effects on other produce is unknown. Based on the melon sensory results of this project discussed in Chapter IV, as well as the tomato results presented here, it appears $CaCl_2$ positively affects sensory attributes. Further research on other produce would be important to assure consumer acceptance of such a treatment before recommending it be used by growers.

In this study, post-harvest handling methods significantly impacted objective quality characteristics such as weight loss, color, pH, and soluble solids. As in

this project, other researchers have shown time and higher temperatures lead to greater weight loss in fresh tomatoes, with the explanation that higher temperatures may allow tomatoes to maintain higher transpiration rates, which would contribute to higher weight loss (Javanmardi and Kubota 2006). Although the $CaCl_2$ dip treatment did enhance several quality and shelf-life characteristics, it also resulted in increased tomato weight loss at both temperatures. This is also consistent with findings by Garcia et al. (1995), who found more weight loss in tomatoes given a pre-harvest foliar $CaCl_2$ treatment. Glenn and Poovaiah (1989) found Ca^{2+} leads to cell wall rigidity, but does not necessarily decrease the permeability of cell membranes.

Past studies have not assessed how the interior color of tomatoes is affected by post-harvest storage conditions. Intensity of a tomato's color has been linked to its lycopene content (Arias, et al. 2000a; Brandt, et al. 2006). Also, based on the findings by Thompson et al. (2000), the color of tomato puree was found to be a better indicator of lycopene content than surface color. Therefore, based on the findings in this study, time, temperature, and dip have the ability to influence interior color changes during storage, and in turn, perhaps the lycopene content.

As seen in this study, research done by Garcia and colleagues (1995) found tomatoes stored at a refrigeration temperature (8° C) had lower pH values than tomatoes stored at 20° C. The foliar pre-harvest $CaCl_2$ treatment in the study by

Garcia et al. also did not impact the pH of stored tomatoes, similar to the results found in this project from the post-harvest $CaCl_2$ dip treatment.

Research done by Javanmardi and Kubota (2006) found storage temperature did not affect the total soluble solids of the tomatoes in their study. Javanmardi and Kubota used hydroponically grown tomatoes, which may explain why they experienced a different response than the tomatoes used in our study, which found the SSC to be higher at 21° C than 10° C.

Due to the complexity of foods and the different mechanisms involved in antioxidant activity, there is not a single assay for measuring total antioxidant levels (Huang, et al. 2005; Prior, et al. 2005; MacDonald-Wicks, et al. 2006). Therefore, it is difficult to compare antioxidant results from different research groups and results from different tests. In order to best estimate a food's antioxidant levels, using multiple tests is recommended (Huang, et al. 2005; Sun and Tanumihardjo 2007). The antioxidant results in this study indicate some antioxidants may have been affected by post-harvest conditions and some not.

Research by Toor and Savage (2006) found time and temperature did not significantly impact phenolic content of fresh tomatoes during post-harvest storage, consistent with the findings of this study. Toor and Savage also tested their tomatoes for ascorbic acid and the results were similar to the trend seen in this study. Their tomatoes showed a slight accumulation of ascorbic acid,

regardless of storage temperature (7° C, 15° C, and 21° C), with the tomatoes stored at 7° C experiencing the least accumulation.

Another study looking at TEAC using $ABTS^{\bullet+}$ found the antioxidant activity of tomatoes stored for 7 days to be similar for tomatoes stored at 25°-27° C compared to 12° C. However, a significant increase in antioxidants was observed when the 12° C tomatoes were stored another 7 days at 5° C. These authors explain the increased antioxidant activity may be due to chilling stress activating antioxidant biosynthesis (Javanmardi and Kubota 2006). In our study, temperature itself did not significantly impact TEAC levels of the $ABTS^{\bullet+}$ test; however, the interactions between temperature and dip as well as time, temperature, and dip were significant. Post-harvest conditions have the ability to impact antioxidant levels of tomatoes during storage, and additional research is needed to better understand the mechanisms involved.

The effect of a $CaCl_2$ dip on the calcium content in tomatoes has not been previously studied, and in other fruit, the use of a $CaCl_2$ dip has had mixed results on the calcium content of the fruit flesh. Fruit such as strawberries (Garcia, et al. 1996) and peaches (Manganaris, et al. 2007) have shown increased fruit calcium levels when dipped in $CaCl_2$ after harvest. Yet, the melon results in Chapter IV as well as another study using whole honeydew melons dipped in $CaCl_2$ found decreased calcium levels in the flesh compared to the control melons (Lester and Grusak 2001). The authors' explanation of this outcome was that $CaCl_2$ does not

allow for the diffusion of calcium through the epidermis and into the hypodermal-mesocarp tissue of the melon. Based on the results of this study, it appears tomato calcium levels may not be significantly influenced one way or the other by a $CaCl_2$ dip.

In determining the best practices for maximizing sensory and nutritional qualities of tomatoes and other produce, it is also critical to consider the impact such methods would have on microbial growth. Lower storage temperatures have been associated with lower bacterial growth on fresh produce, including both spoilage organisms and pathogenic organisms (Hao and Brackett 1993; Zagory 1999; Francis and O'Beirne 2001) and as found in Chapter III. Therefore, encouraging tomato storage at higher temperatures should be done with caution. Also, little is known about the microbial impacts of using a post-harvest $CaCl_2$ dip treatment. Use of a pre-harvest $CaCl_2$ treatment was found to decrease bacterial growth on fresh mushrooms in a study by Chikthimmah et al. (2005), which may indicate potential for reducing bacteria growth when applied post-harvest as well.

CONCLUSIONS

In this study, the effect of storage temperature, $CaCl_2$ dip treatment, and time, as well as their complex interactions impacted post-harvest qualities of ripe Early Girl tomatoes. More research is needed to better understand these effects, but it appears storage at 21° C and the use of a $CaCl_2$ dip can improve sensory qualities and some antioxidant levels, as well as maintain a deeper red color of fresh

tomatoes during storage. The lower storage temperature in this study may decrease weight loss and extend the shelf-life of tomatoes, but it also negatively impacted many sensory and nutritional qualities. However, if longer term, refrigerated storage is needed, the use of a $CaCl_2$ dip appears to be beneficial in maintaining flavor, texture, and overall acceptability of tomatoes.

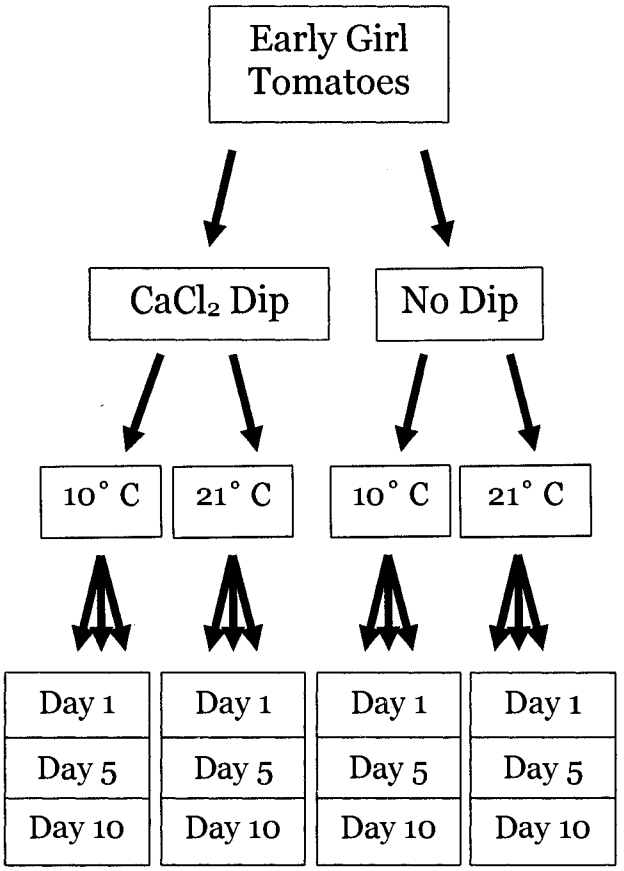

Figure 5.1. Research Design.

Figure 5.2. Sensory scorecard used to rate appearance, flavor, texture, and overall acceptability of Early Girl Tomatoes.

Panelist #_____

SCORE SHEET FOR FRESH PRODUCE

Sample 127	Highly Acceptable	Acceptable	Moderately Acceptable	Slightly Acceptable	Neither Acceptable nor Unacceptable	Slightly Unacceptable	Moderately Unacceptable	Unacceptable	Highly Unacceptable
Appearance	☐	☐	☐	☐	☐	☐	☐	☐	☐
Flavor	☐	☐	☐	☐	☐	☐	☐	☐	☐
Texture	☐	☐	☐	☐	☐	☐	☐	☐	☐
Bitterness	☐	☐	☐	☐	☐	☐	☐	☐	☐
Overall Acceptability	☐	☐	☐	☐	☐	☐	☐	☐	☐

Comments: _____

Sample 443	Highly Acceptable	Acceptable	Moderately Acceptable	Slightly Acceptable	Neither Acceptable nor Unacceptable	Slightly Unacceptable	Moderately Unacceptable	Unacceptable	Highly Unacceptable
Appearance	☐	☐	☐	☐	☐	☐	☐	☐	☐
Flavor	☐	☐	☐	☐	☐	☐	☐	☐	☐
Texture	☐	☐	☐	☐	☐	☐	☐	☐	☐
Bitterness	☐	☐	☐	☐	☐	☐	☐	☐	☐
Overall Acceptability	☐	☐	☐	☐	☐	☐	☐	☐	☐

Comments: _____

Sample 916	Highly Acceptable	Acceptable	Moderately Acceptable	Slightly Acceptable	Neither Acceptable nor Unacceptable	Slightly Unacceptable	Moderately Unacceptable	Unacceptable	Highly Unacceptable
Appearance	☐	☐	☐	☐	☐	☐	☐	☐	☐
Flavor	☐	☐	☐	☐	☐	☐	☐	☐	☐
Texture	☐	☐	☐	☐	☐	☐	☐	☐	☐
Bitterness	☐	☐	☐	☐	☐	☐	☐	☐	☐
Overall Acceptability	☐	☐	☐	☐	☐	☐	☐	☐	☐

Comments: _____

(PLEASE TURN OVER)

Sample 603	Highly Acceptable	Acceptable	Moderately Acceptable	Slightly Acceptable	Neither Acceptable nor Unacceptable	Slightly Unacceptable	Moderately Unacceptable	Unacceptable	Highly Unacceptable
Appearance	❑	❑	❑	❑	❑	❑	❑	❑	❑
Flavor	❑	❑	❑	❑	❑	❑	❑	❑	❑
Texture	❑	❑	❑	❑	❑	❑	❑	❑	❑
Bitterness	❑	❑	❑	❑	❑	❑	❑	❑	❑
Overall Acceptability	❑	❑	❑	❑	❑	❑	❑	❑	❑

Comments: _____

_____

Sample 819	Highly Acceptable	Acceptable	Moderately Acceptable	Slightly Acceptable	Neither Acceptable nor Unacceptable	Slightly Unacceptable	Moderately Unacceptable	Unacceptable	Highly Unacceptable
Appearance	❑	❑	❑	❑	❑	❑	❑	❑	❑
Flavor	❑	❑	❑	❑	❑	❑	❑	❑	❑
Texture	❑	❑	❑	❑	❑	❑	❑	❑	❑
Bitterness	❑	❑	❑	❑	❑	❑	❑	❑	❑
Overall Acceptability	❑	❑	❑	❑	❑	❑	❑	❑	❑

Comments: _____

_____

Sample 535	Highly Acceptable	Acceptable	Moderately Acceptable	Slightly Acceptable	Neither Acceptable nor Unacceptable	Slightly Unacceptable	Moderately Unacceptable	Unacceptable	Highly Unacceptable
Appearance	❑	❑	❑	❑	❑	❑	❑	❑	❑
Flavor	❑	❑	❑	❑	❑	❑	❑	❑	❑
Texture	❑	❑	❑	❑	❑	❑	❑	❑	❑
Bitterness	❑	❑	❑	❑	❑	❑	❑	❑	❑
Overall Acceptability	❑	❑	❑	❑	❑	❑	❑	❑	❑

Comments: _____

_____

Please write in the sample number in the space provided by ranking the samples in order of your preference (1=liked most; 6=liked least):

1)_____ 2)_____ 3)_____ 4)_____ 5)_____ 6)_____

THANK YOU FOR YOUR PARTICIPATION!

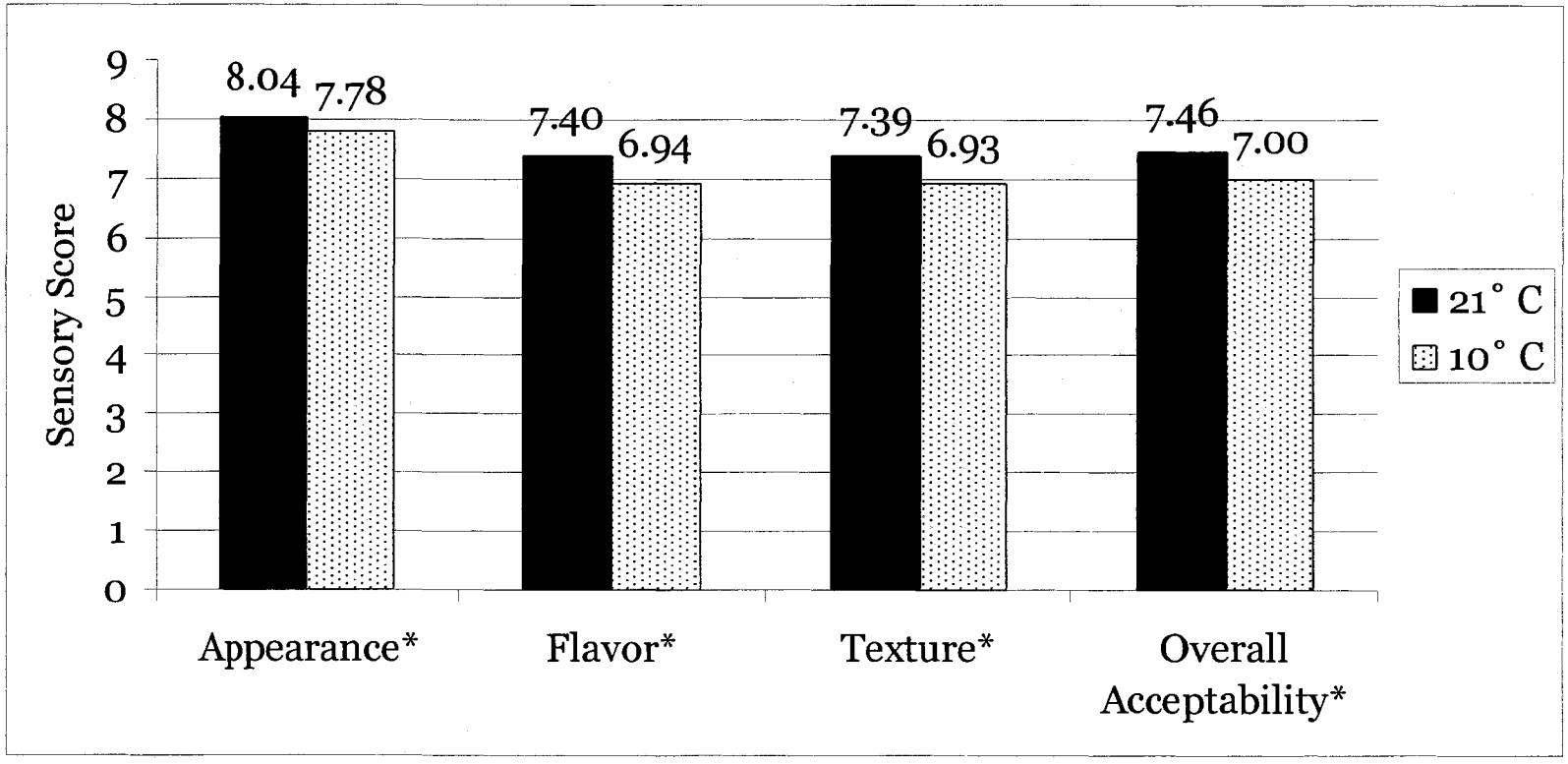

Figure 5.3. Effect of storage temperature on tomato sensory scores. Tomatoes were either immersed in a 0.06 M $CaCl_2$ solution for 15 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each bar represents the mean sensory score of all tomatoes stored at that temperature, regardless of day and dip treatment (n=240 for each bar). Sensory tests marked by an asterisk (*) are significantly different ($p<0.05$) between temperatures. Sensory scale: 9=highly acceptable, 1=highly unacceptable.

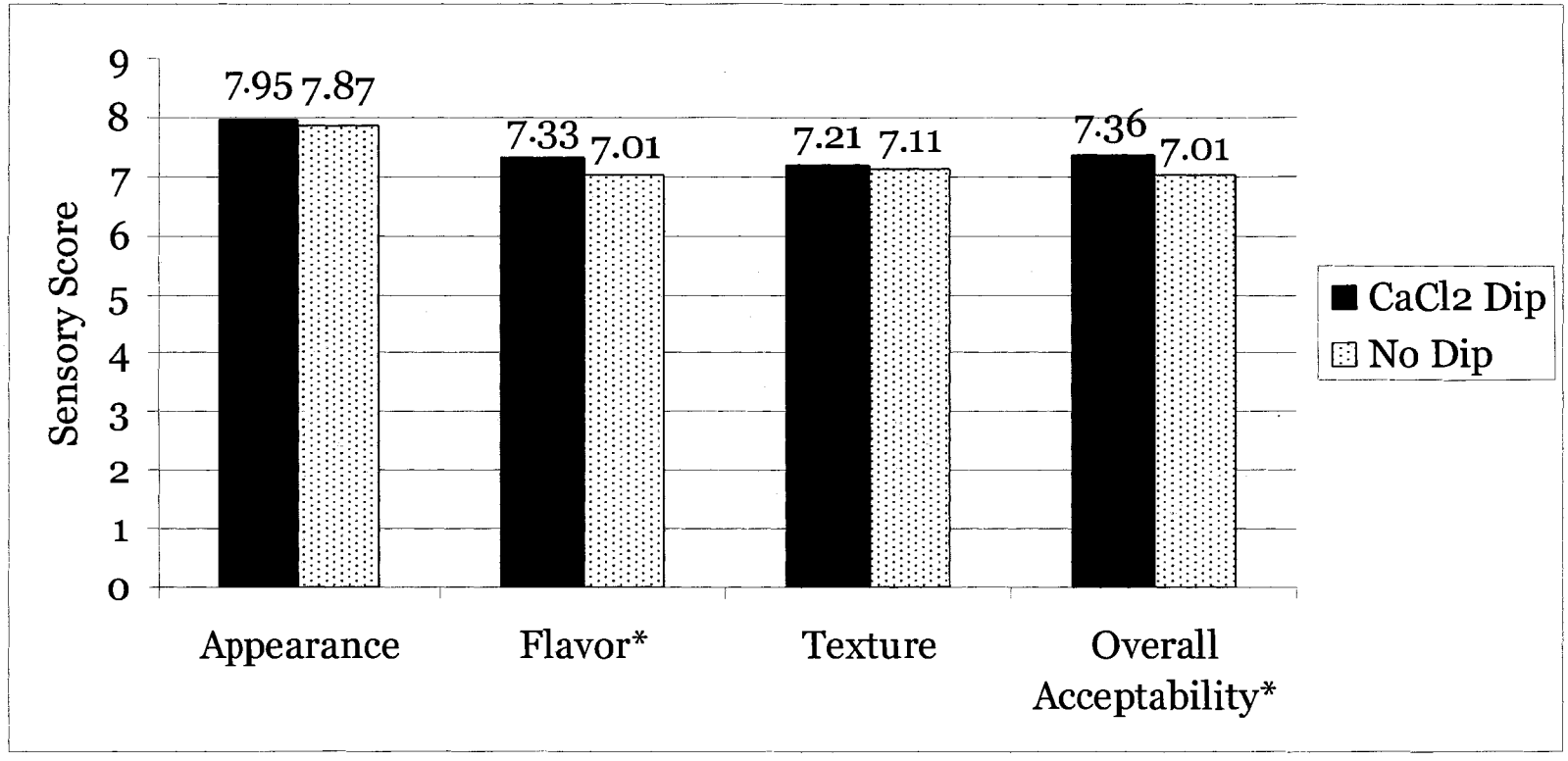

Figure 5.4. Effect of $CaCl_2$ dip on tomato sensory scores. Tomatoes were either immersed in a 0.06 M $CaCl_2$ solution for 15 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each bar represents the mean sensory score of all dipped or non-dipped tomatoes, regardless of day and storage temperature (n=240 for each bar). Sensory tests marked by an asterisk (*) are significantly different ($p<0.05$) between dip treatments. Sensory scale: 9=highly acceptable, 1=highly unacceptable.

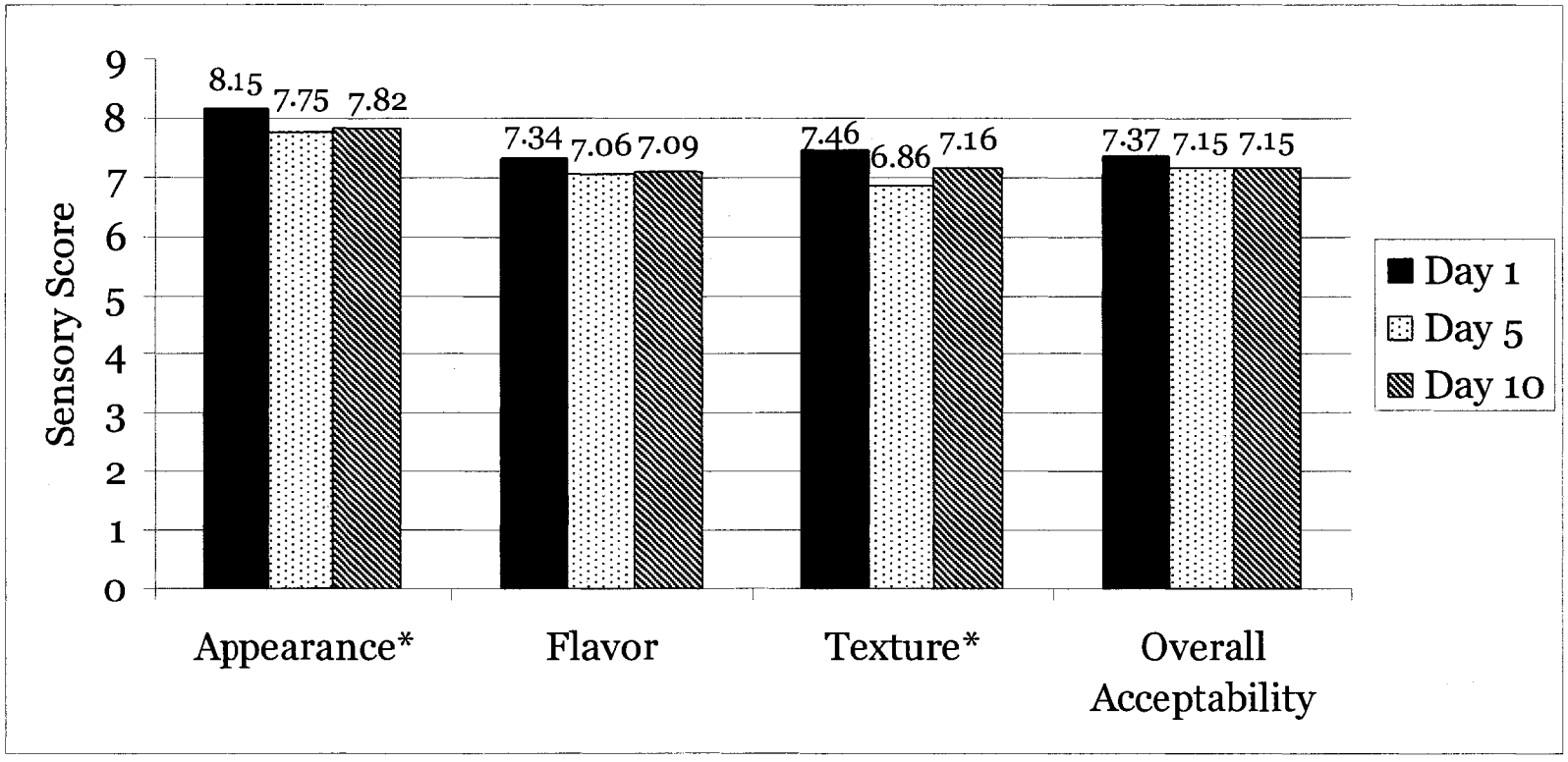

Figure 5.5. Effect of time on tomato sensory scores. Tomatoes were either immersed in a 0.06 M $CaCl_2$ solution for 15 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each bar represents the mean sensory score of all day 1, 5, or 10 tomatoes, regardless of storage temperature and dip treatment (n=160 for each bar). Sensory tests marked by an asterisk (*) are significantly different ($p<0.05$) between days. Sensory scale: 9=highly acceptable, 1=highly unacceptable.

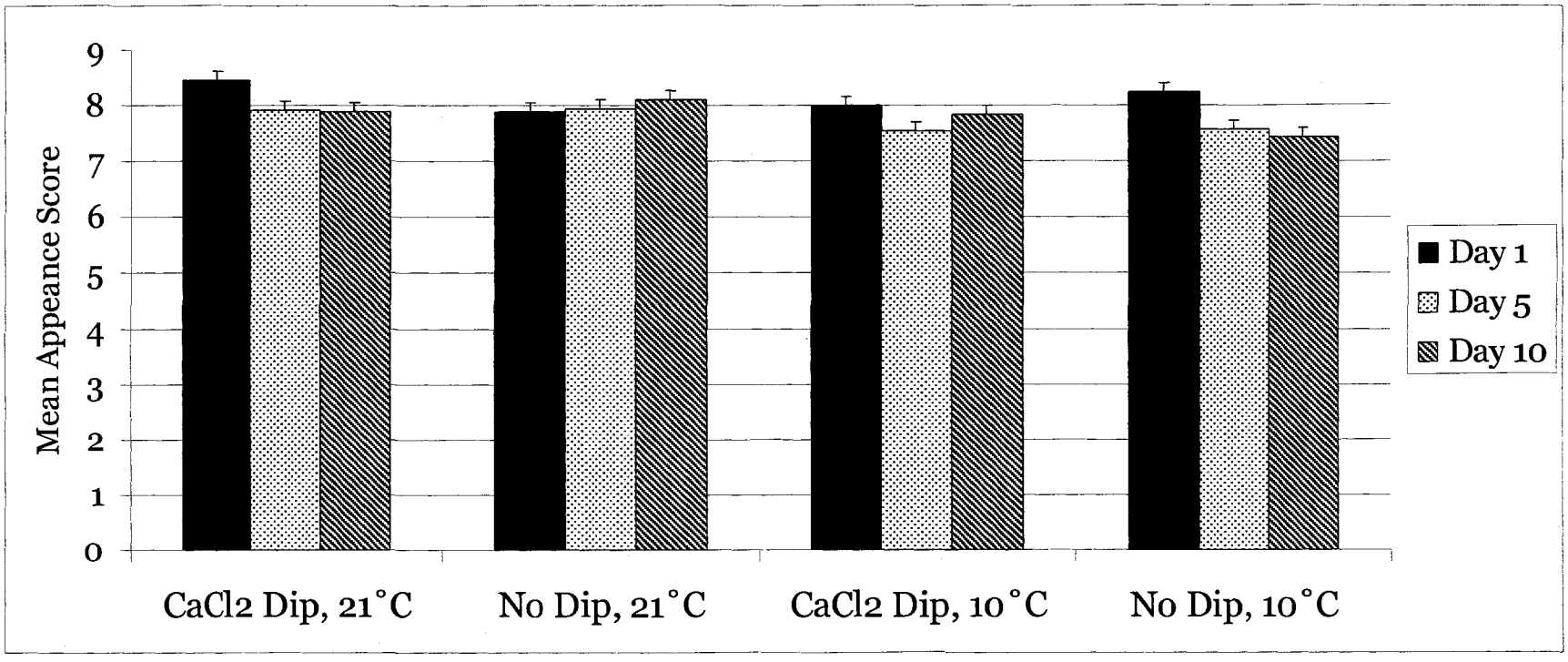

Figure 5.6. Mean appearance scores. Tomatoes were either immersed in a 0.06 M $CaCl_2$ solution for 15 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each bar represents the average scores of 40 taste panelists. Error bars indicate the standard error. Sensory scale: 9=highly acceptable, 1=highly unacceptable.

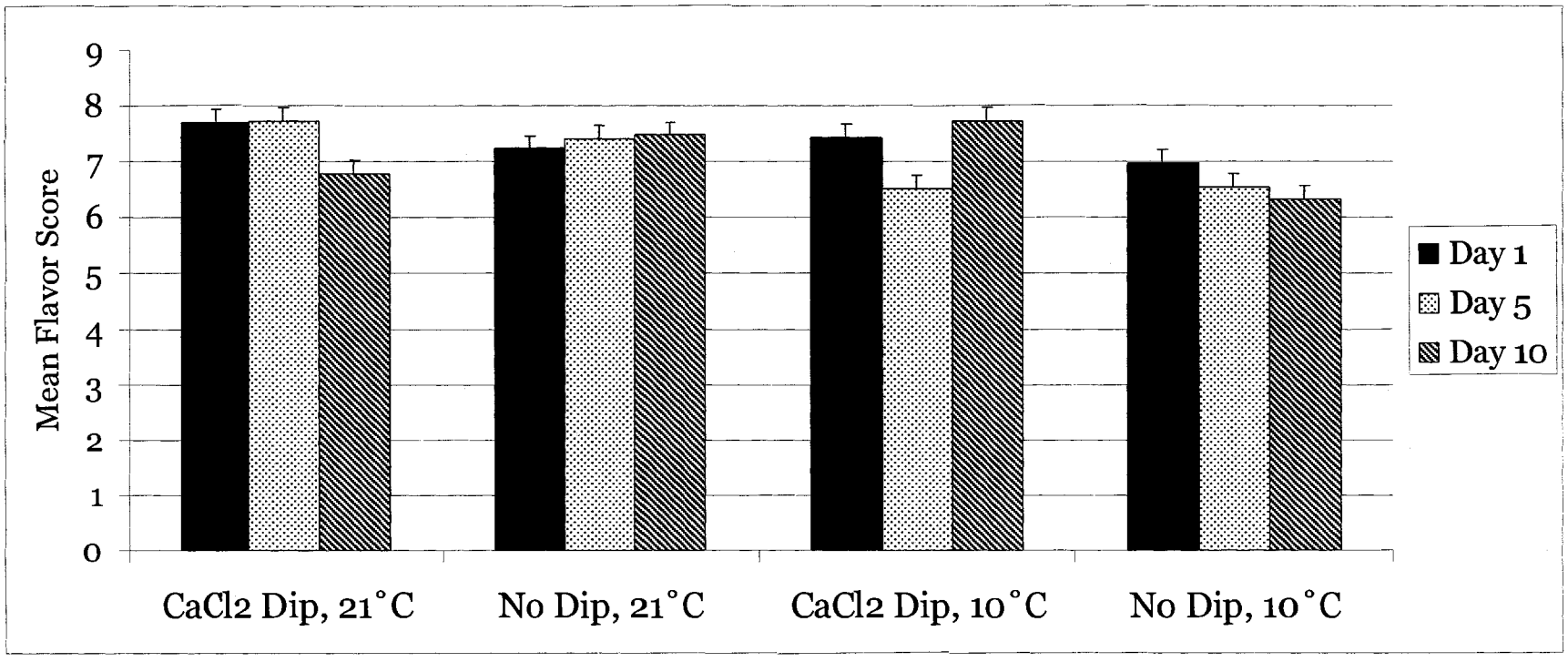

Figure 5.7. Mean flavor scores. Tomatoes were either immersed in a 0.06 M $CaCl_2$ solution for 15 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each bar represents the average scores of 40 taste panelists. Error bars indicate the standard error. Sensory scale: 9=highly acceptable, 1=highly unacceptable.

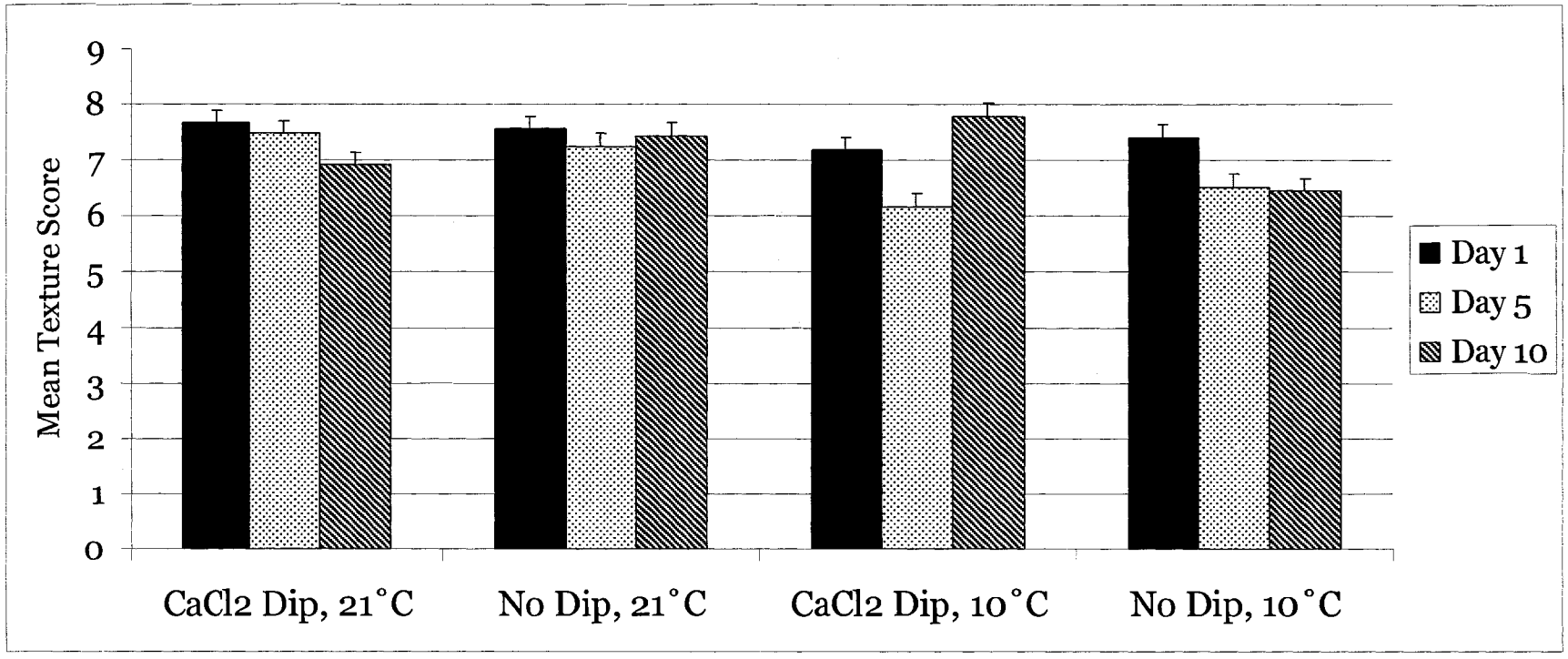

Figure 5.8. Mean texture scores. Tomatoes were either immersed in a 0.06 M $CaCl_2$ solution for 15 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each bar represents the average scores of 40 taste panelists. Error bars indicate the standard error. Sensory scale: 9=highly acceptable, 1=highly unacceptable.

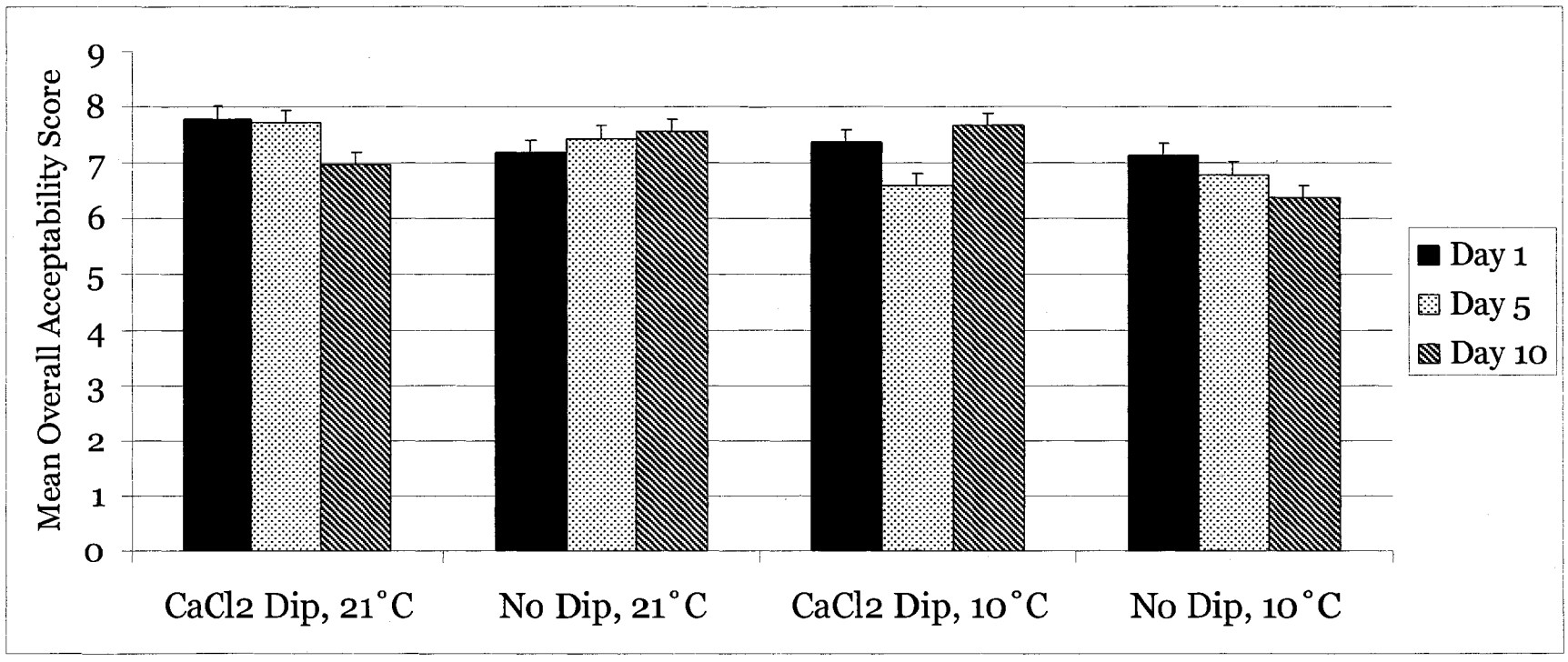

Figure 5.9. Mean overall acceptability scores. Tomatoes were either immersed in a 0.06 M $CaCl_2$ solution for 15 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each bar represents the average scores of 40 taste panelists. Error bars indicate the standard error. Sensory scale: 9=highly acceptable, 1=highly unacceptable.

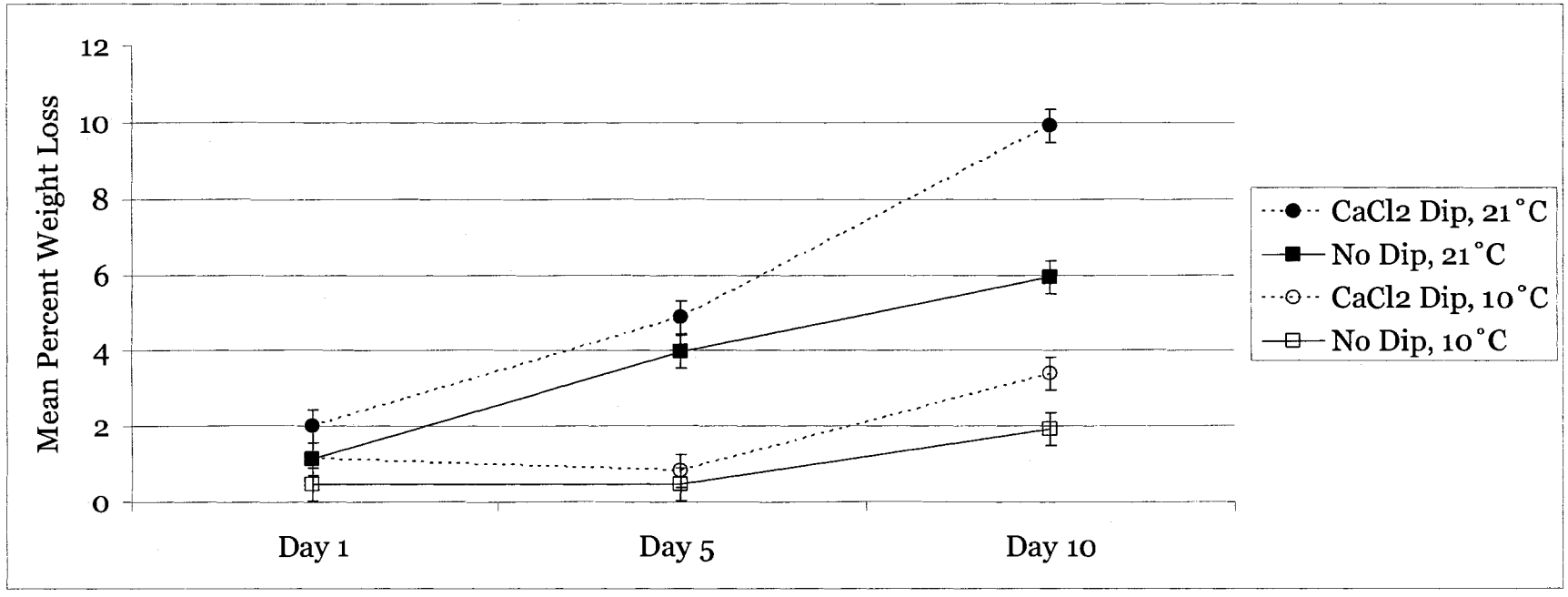

Figure 5.10. Mean percent weight loss. Tomatoes were either immersed in a 0.06 M $CaCl_2$ solution for 15 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each data point represents the average percent weight loss of 3 tomatoes. Error bars indicate the standard error.

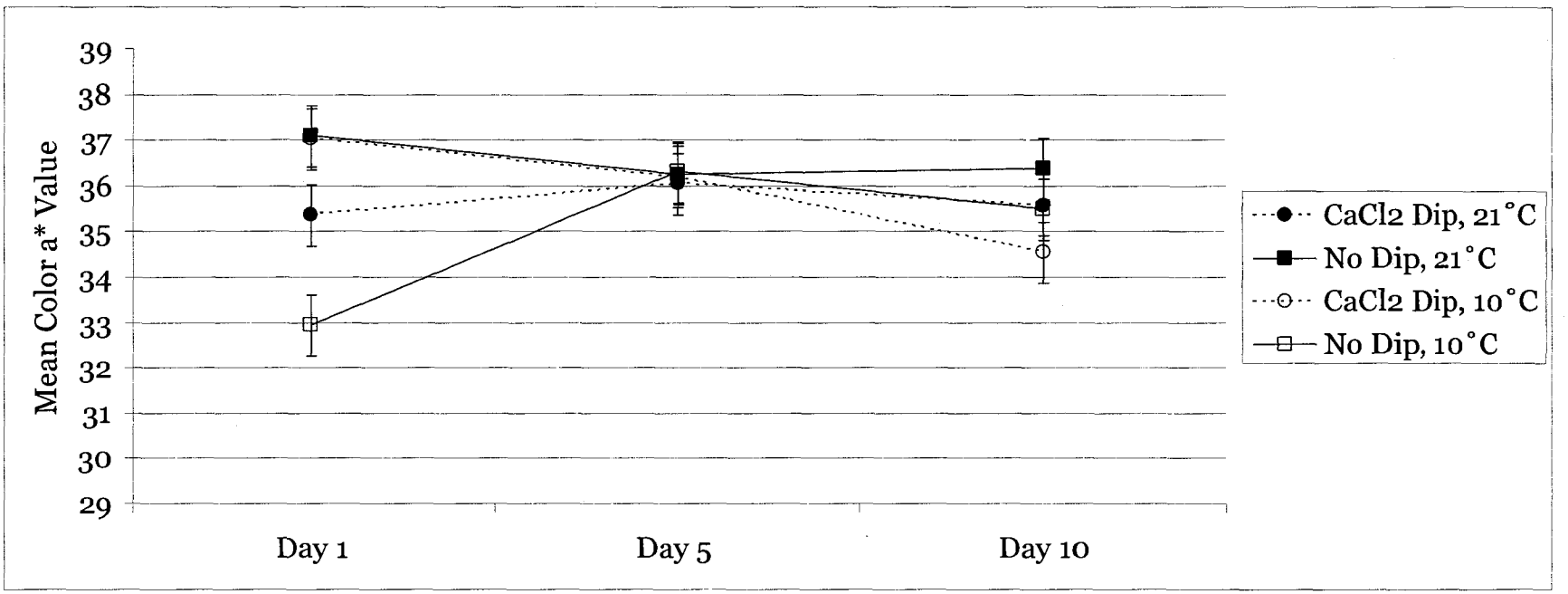

Figure 5.11. Mean color a* values. Tomatoes were either immersed in a 0.06 M $CaCl_2$ solution for 15 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each data point represents the average of 3 tomatoes tested 3 times each. Error bars indicate the standard error.

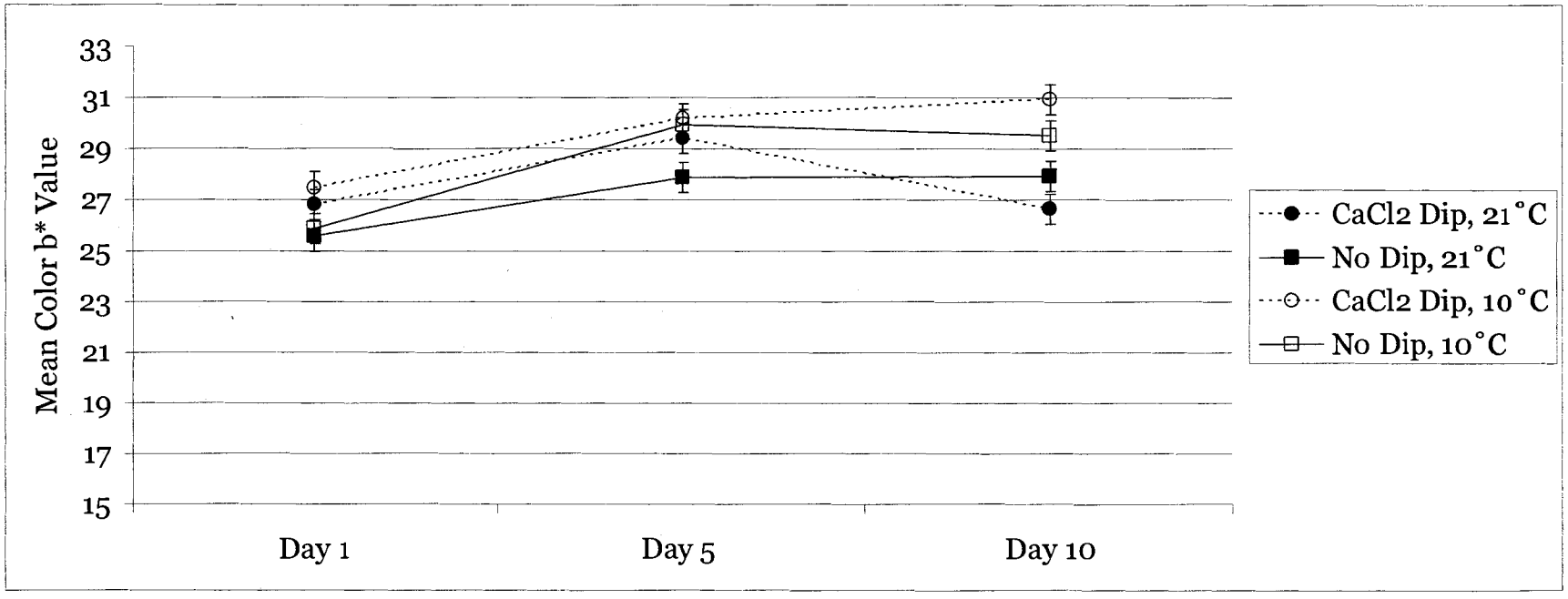

Figure 5.12. Mean color b* values. Tomatoes were either immersed in a 0.06 M $CaCl_2$ solution for 15 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each data point represents the average of 3 tomatoes tested 3 times each. Error bars indicate the standard error.

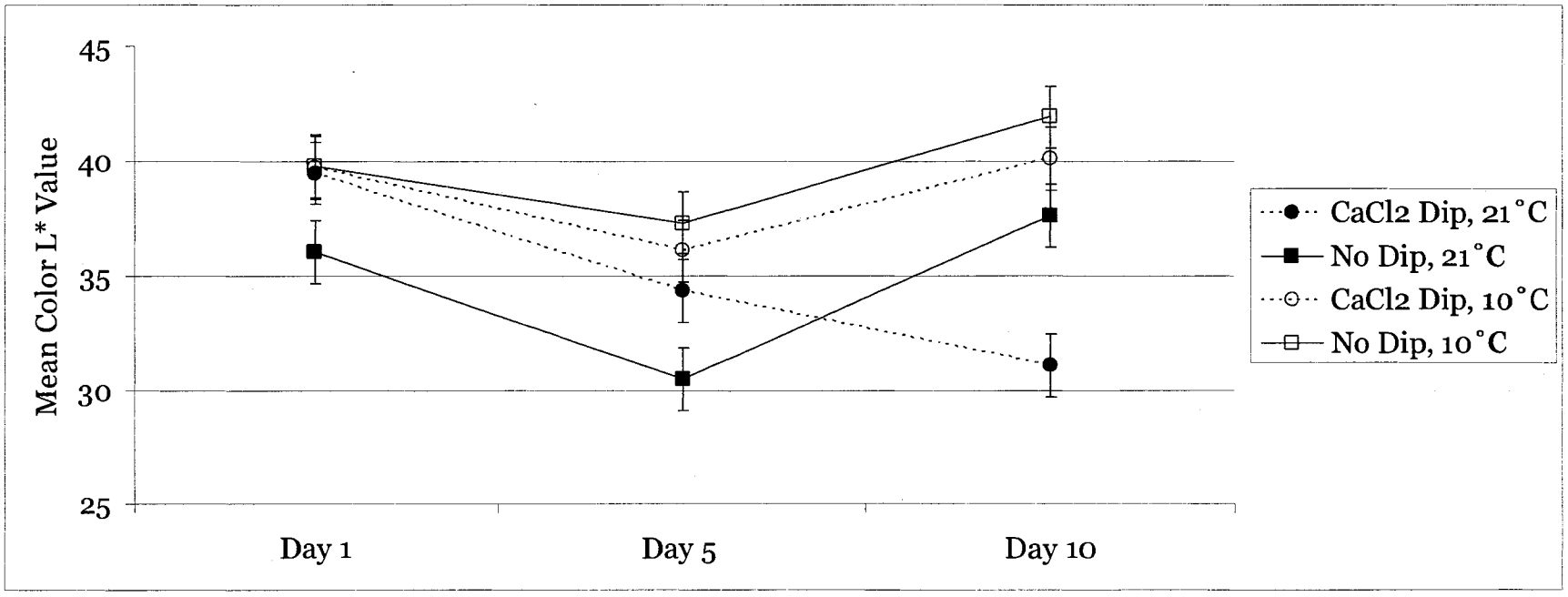

Figure 5.13. Mean color L* values. Tomatoes were either immersed in a 0.06 M $CaCl_2$ solution for 15 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each data point represents the average of 3 tomatoes tested 3 times each. Error bars indicate the standard error.

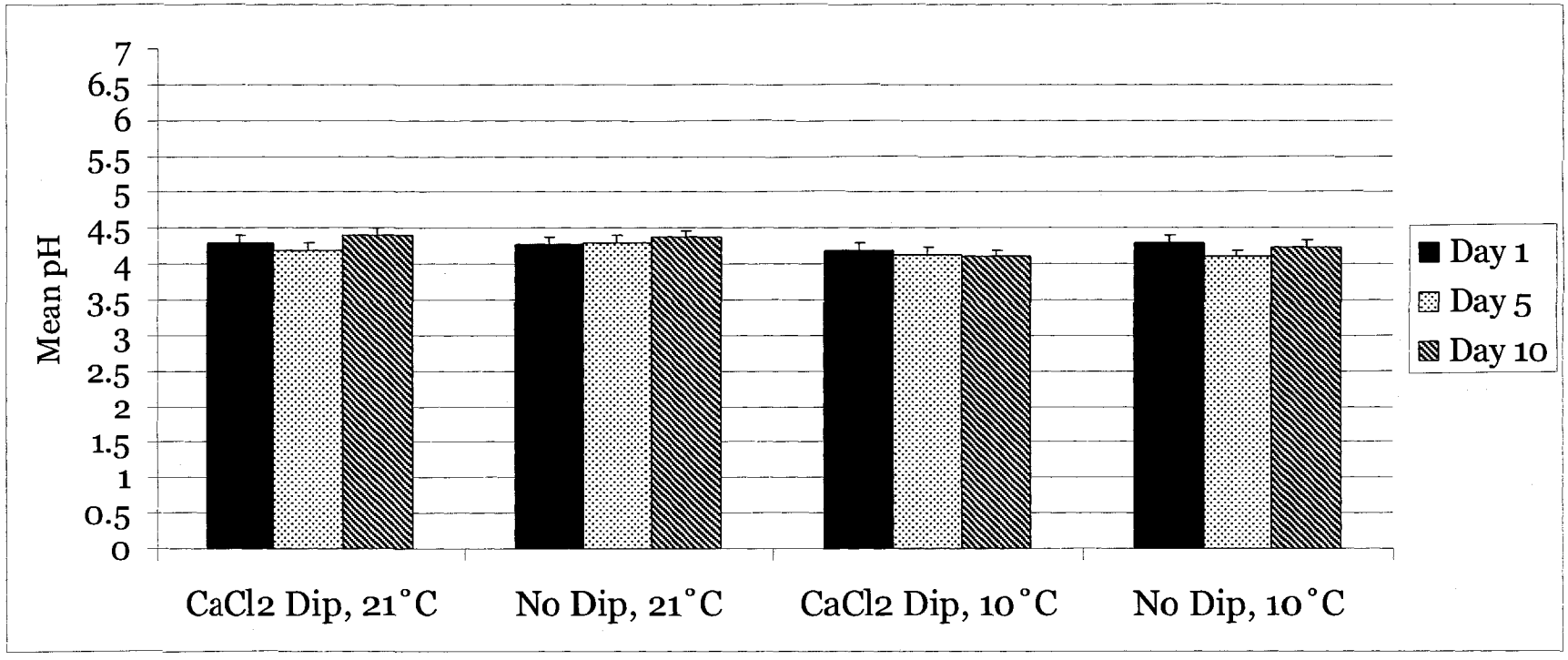

Figure 5.14. Mean pH. Tomatoes were either immersed in a 0.06 M $CaCl_2$ solution for 15 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each data point represents the average pH of 3 tomatoes. Error bars indicate the standard error.

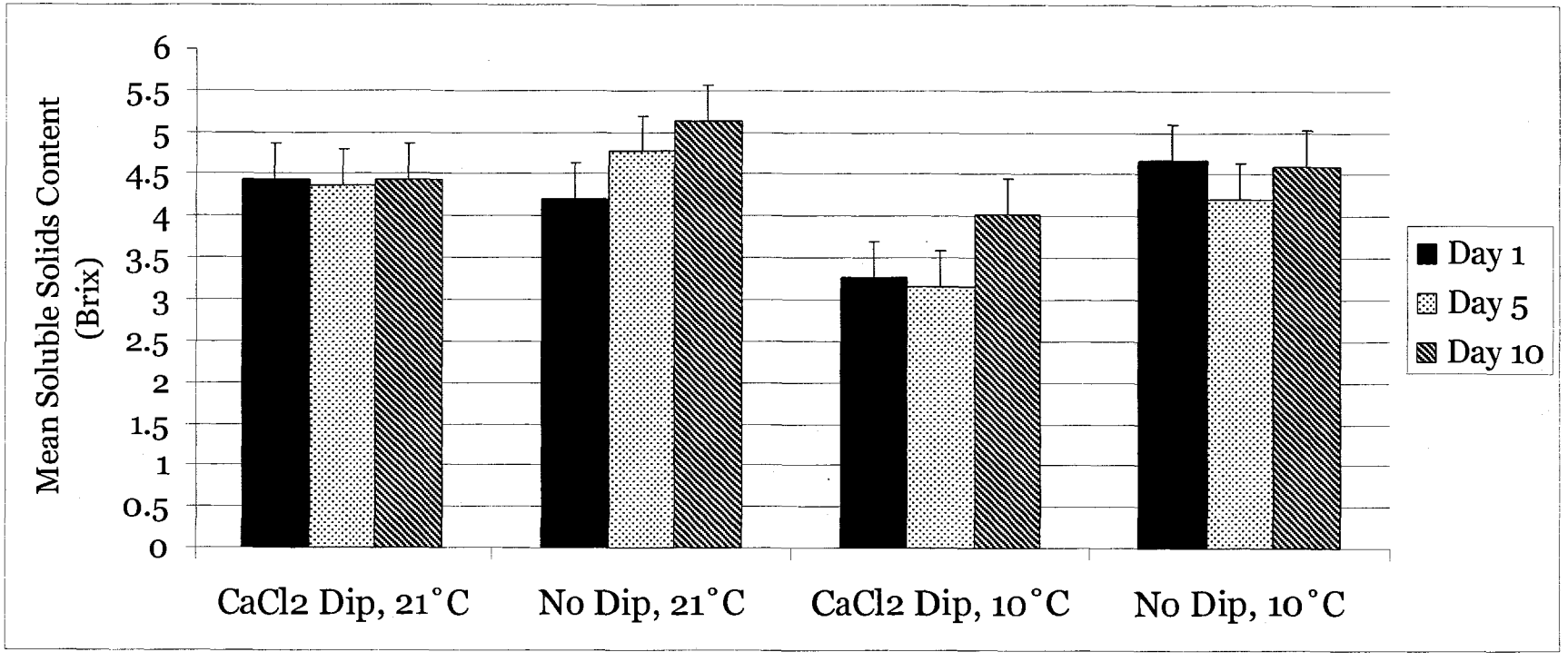

Figure 5.15. Mean soluble solids content. Tomatoes were either immersed in a 0.06 M $CaCl_2$ solution for 15 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each data point represents the average soluble solids content of 3 tomatoes. Error bars indicate the standard error.

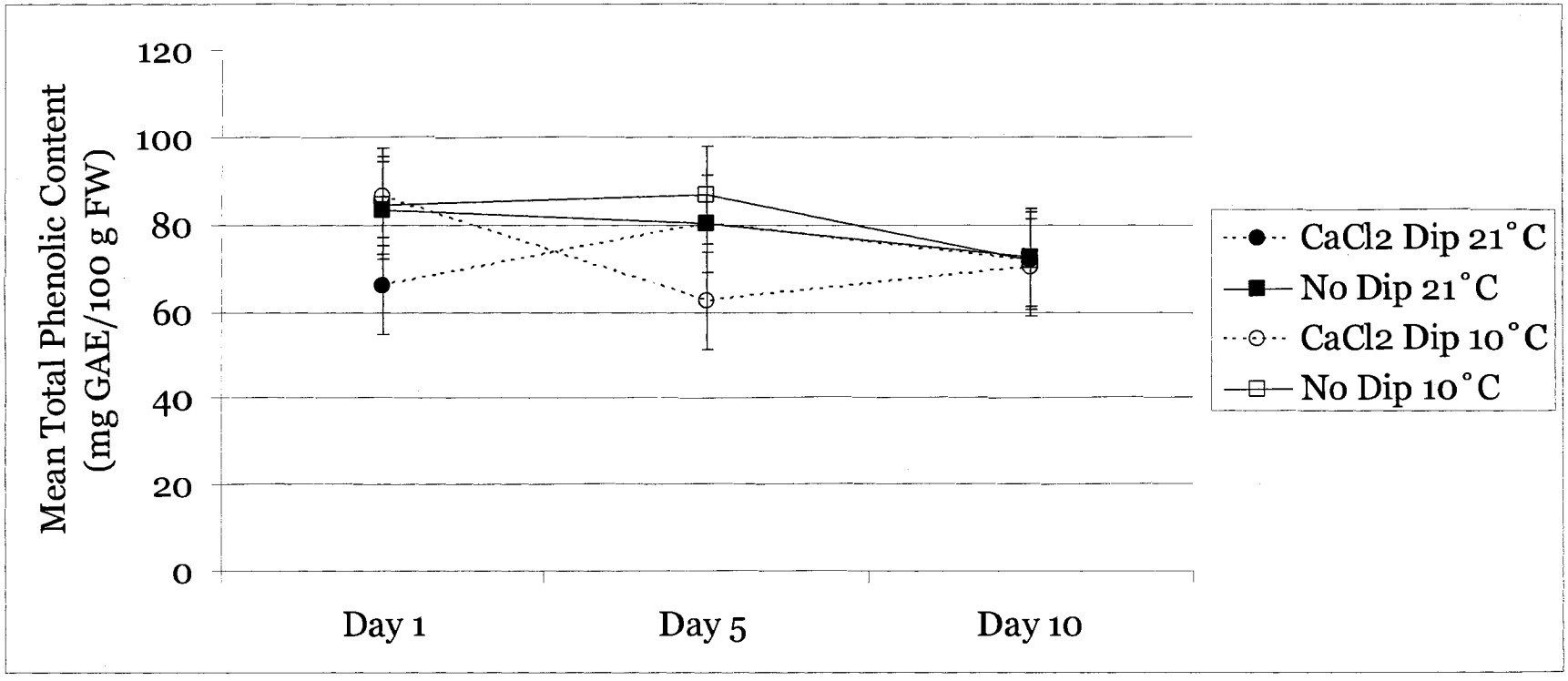

Figure 5.16. Mean total phenolic content. Tomatoes were either immersed in a 0.06 M $CaCl_2$ solution for 15 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each data point represents the average results of 3 tomatoes. Error bars indicate the standard error.

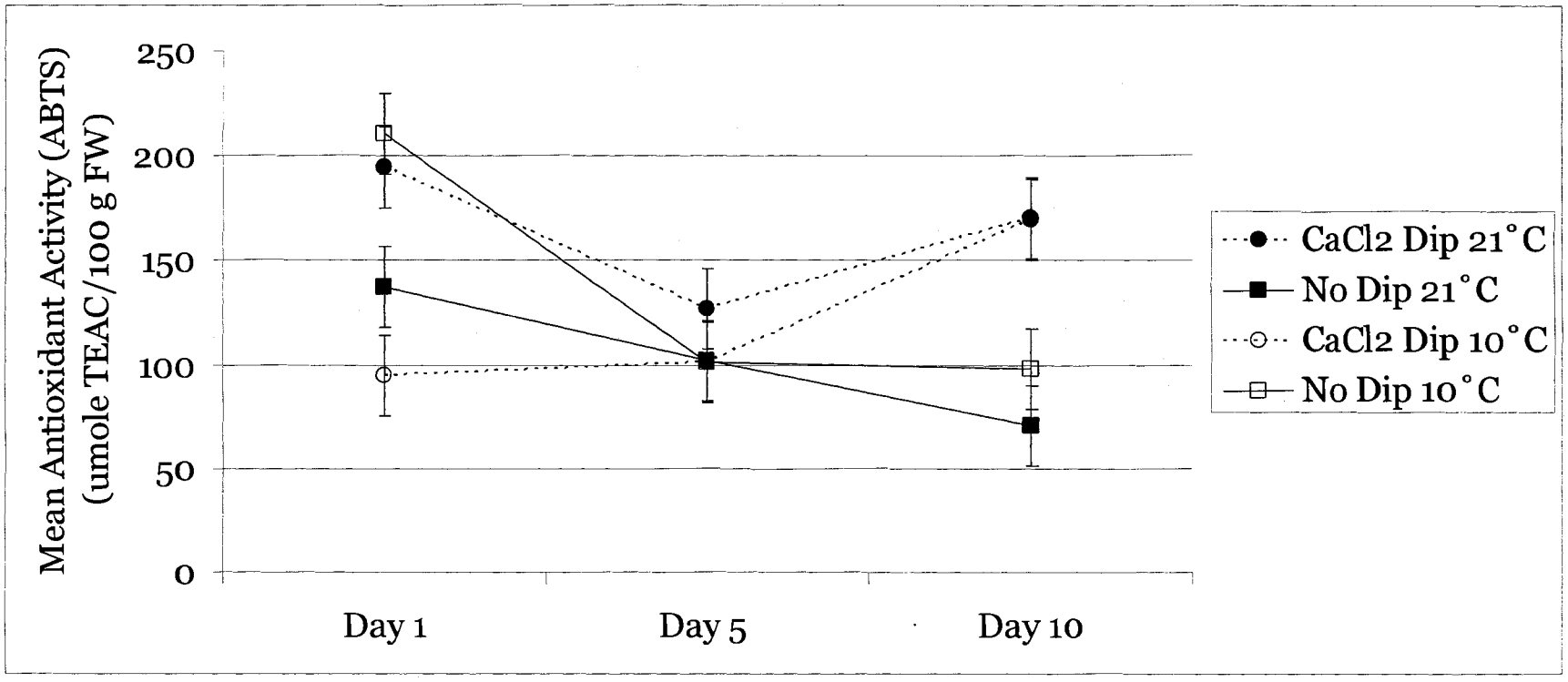

Figure 5.17. Mean antioxidant activity ($ABTS^{\bullet+}$). Tomatoes were either immersed in a 0.06 M $CaCl_2$ solution for 15 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each data point represents the average results of 3 tomatoes. Error bars indicate the standard error.

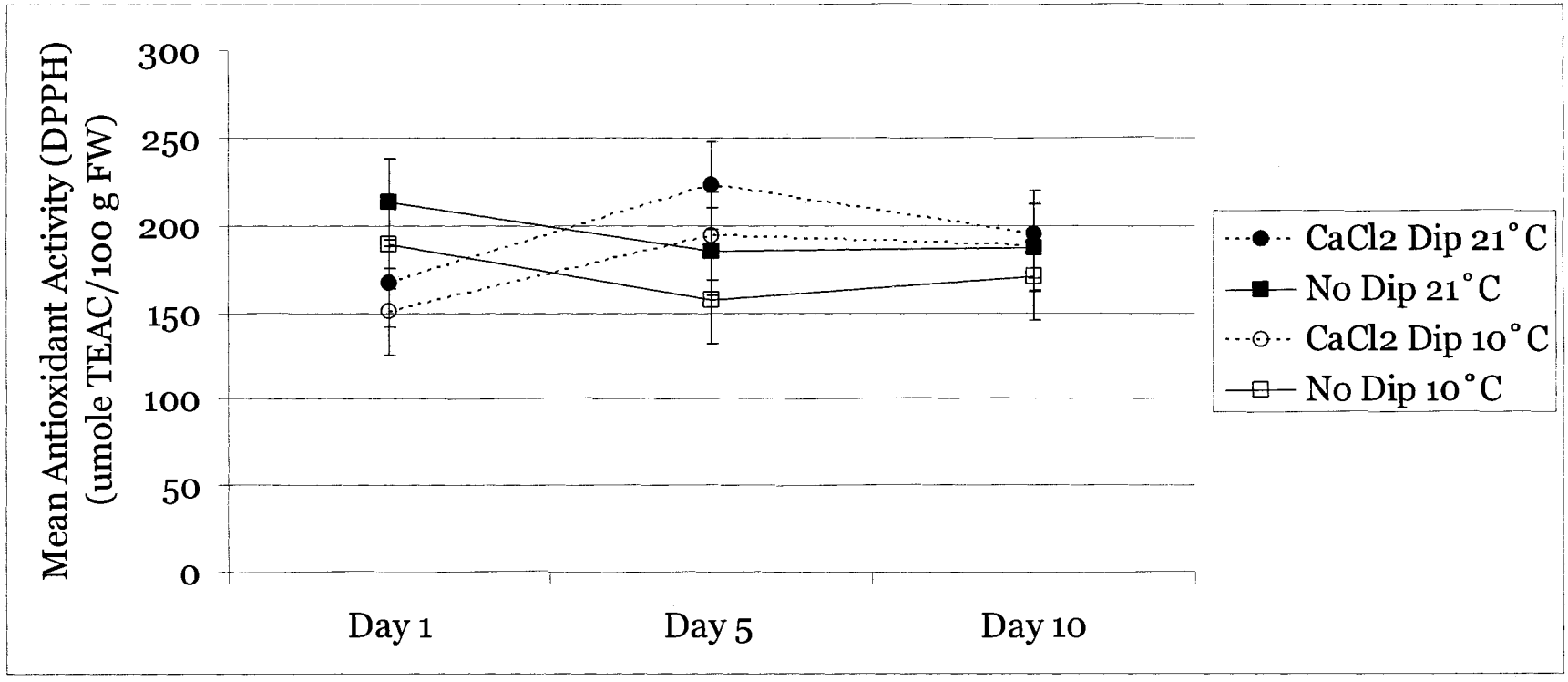

Figure 5.18. Mean antioxidant activity ($DPPH^+$). Tomatoes were either immersed in a 0.06 M $CaCl_2$ solution for 15 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each data point represents the average soluble solids content of 3 tomatoes. Error bars indicate the standard error.

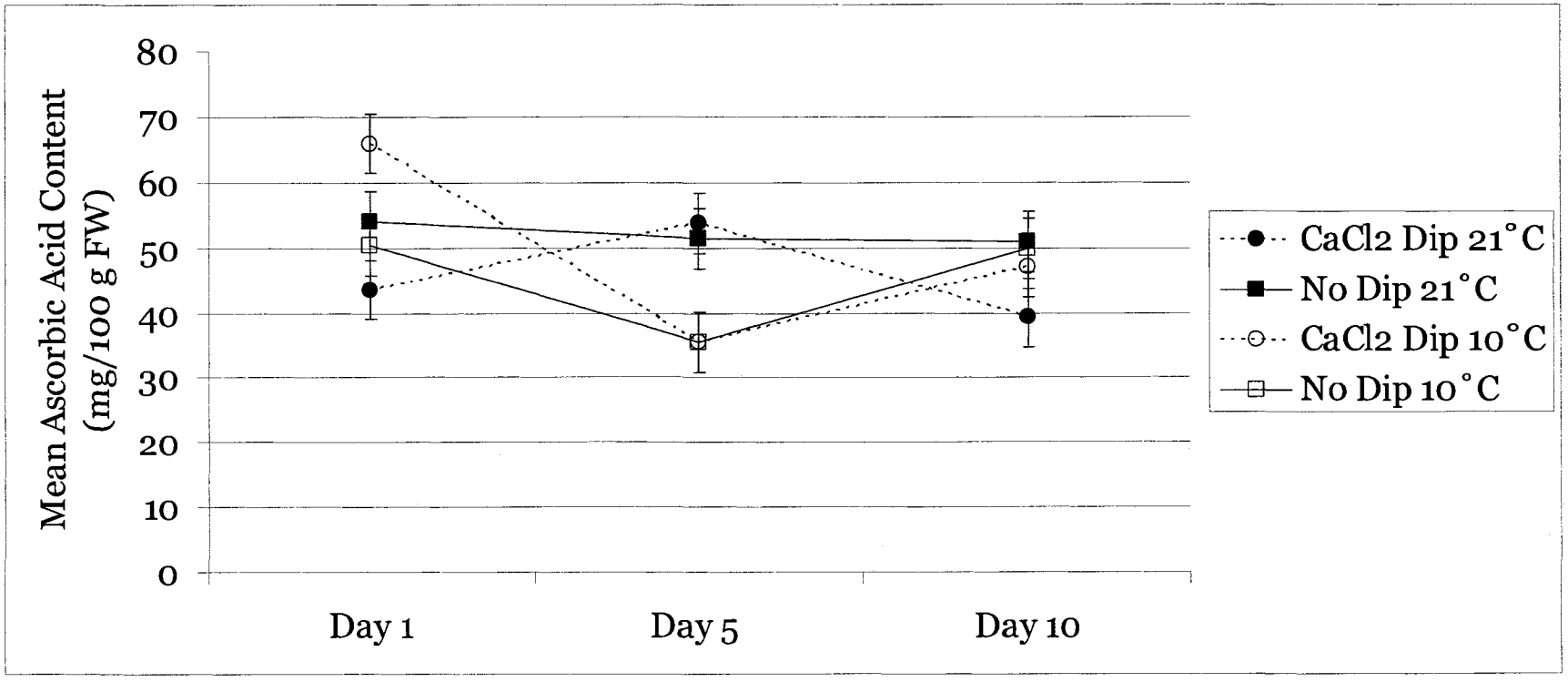

Figure 5.19. Mean ascorbic acid content. Tomatoes were either immersed in a 0.06 M $CaCl_2$ solution for 15 minutes or not treated, then stored for 1, 5, and 10 days at 21° C or 10° C. Each data point represents the average results of 3 tomatoes. Error bars indicate the standard error.

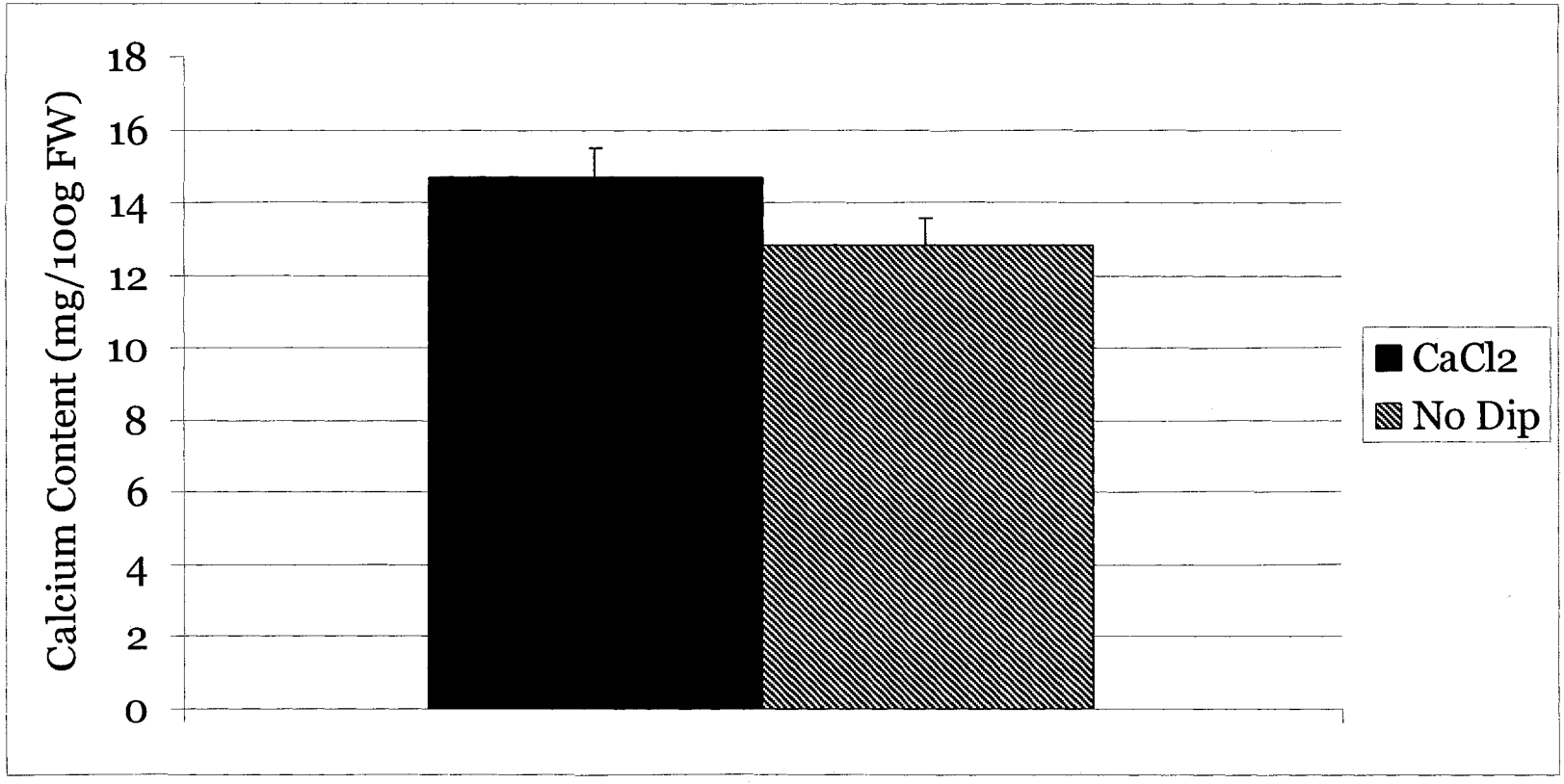

Figure 5.20. Mean calcium content. Tomatoes were either immersed in a 0.06 M $CaCl_2$ solution for 15 minutes or not treated, then stored for 1 day at 21° C. Each data point represents the average results of 3 tomatoes. Error bars indicate the standard error.

Table 5.1. Analysis of variance on the effects of time (T), storage temperature (S), and dip treatment (D)

	T	S	T*S	D	T*D	S*D	T*S*D
Appearance	0.0014^{**}	0.0015^{**}	0.1913^{NS}	0.3044^{NS}	0.5959^{NS}	0.6810^{NS}	0.0021^{**}
Flavor	0.1944^{NS}	0.0002^{***}	0.0049^{**}	0.0094^{**}	0.5756^{NS}	0.0198^{*}	$<0.0001^{***}$
Texture	0.0014^{**}	0.0001^{***}	0.0027^{**}	0.4345^{NS}	0.1785^{NS}	0.1774^{NS}	$<0.0001^{***}$
Overall	0.2596^{NS}	$<0.0001^{***}$	0.0264^{*}	0.0145^{*}	0.3178^{NS}	0.1191^{NS}	$<0.0001^{***}$
% Wt Loss	<0.0001	$<0.0001^{***}$	$<0.0001^{***}$	$<0.0001^{***}$	0.0033^{**}	0.0392^{*}	0.1400^{NS}
Color a*	0.2708^{NS}	0.0672^{NS}	0.3181^{NS}	0.9010^{NS}	0.0878^{NS}	0.0139^{*}	0.0021^{*}
Color b*	$<0.0001^{***}$	$<0.0001^{***}$	0.0149^{*}	0.0241^{*}	0.2552^{NS}	0.3856^{NS}	0.0575^{NS}
Color L*	$<0.0001^{***}$	$<0.0001^{***}$	0.0578^{NS}	0.6265^{NS}	0.0044^{**}	0.4239^{NS}	0.0281^{*}
pH	0.4207^{NS}	0.0400^{*}	0.3808^{NS}	0.4022^{NS}	1.0000^{NS}	0.6398^{NS}	0.4207^{NS}
Soluble Solids	0.2699^{NS}	0.0250^{*}	0.6300^{NS}	0.0121^{*}	0.9732^{NS}	0.1456^{NS}	0.3267^{NS}
Total Phenolics	0.5369^{NS}	0.2555^{NS}	0.8710^{NS}	0.9409^{NS}	0.3165^{NS}	0.6758^{NS}	0.8176^{NS}
TEAC (ABTS)	0.0037^{**}	0.7056^{NS}	0.5375^{NS}	0.0512^{NS}	0.0013^{**}	0.0029^{**}	0.0192^{*}
TEAC (DPPH)	0.4911^{NS}	0.6692^{NS}	0.1447^{NS}	0.4181^{NS}	0.8825^{NS}	0.4208^{NS}	0.4823^{NS}
Ascorbic Acid	0.1545^{NS}	0.0009^{***}	0.2473^{NS}	0.0783^{NS}	0.1563^{NS}	0.0096^{**}	0.4153^{NS}
Calcium	n/a	n/a	n/a	0.2250^{NS}	n/a	n/a	n/a

Expressed as p values for statistical significance.
$^{NS, *, **, ***}$Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table 5.2. Mean appearance scores of organic 'Early Girl' tomatoes[1]

	21° C Storage			10° C Storage		
	Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
$CaCl_2$ Dip[2]	8.46 ±0.16	7.93 ±0.16	7.90 ±0.16	8.01 ±0.16	7.55 ±0.16	7.85 ±0.16
No Dip	7.89 ±0.16	7.95 ±0.16	8.10 ±0.16	8.24^{a} ±0.16	7.58^{ab} ±0.16	7.45^{b} ±0.16

[1] Means represent average scores given by consumer panelists (n=40) based on a 9-point hedonic scale (9=highly acceptable, 1=highly unacceptable).
[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

a,b: Day Effect—means for same treatment, temperature, and method with different superscripts are significantly different ($p<0.05$).

Table 5.3. Mean flavor scores of organic 'Early Girl' tomatoes[1]

	21° C Storage			10° C Storage		
	Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
$CaCl_2$ Dip[2]	7.72 ±0.23	7.74^{Y} ±0.23	6.79 ±0.23	7.44^{ab} ±0.23	$6.54^{a,Z}$ ±0.23	$7.74^{A,b}$ ±0.23
No Dip	7.24 ±0.23	7.41 ±0.23	7.49^{Y} ±0.23	6.99 ±0.23	6.56 ±0.23	$6.34^{B,Z}$ ±0.23

[1] Means represent average scores given by consumer panelists (n=40) based on a 9-point hedonic scale (9=highly acceptable, 1=highly unacceptable).
[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

A,B: Dip Treatment Effect—means for same day, temperature, and method with different superscripts are significantly different ($p<0.05$).
a,b: Day Effect—means for same treatment, temperature, and method with different superscripts are significantly different ($p<0.05$).
Y,Z: Storage Temperature Effect—means for same treatment, day, and method with different superscripts are significantly different ($p<0.05$).

Table 5.4. Mean texture scores of organic 'Early Girl' tomatoes[1]

	21° C Storage			10° C Storage		
	Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
$CaCl_2$ Dip[2]	7.67 ±0.22	7.48[Y] ±0.22	6.92 ±0.22	7.20[b] ±0.22	6.18[a,Z] ±0.22	7.80[A,b] ±0.22
No Dip	7.57 ±0.22	7.26 ±0.22	7.45 ±0.22	7.42 ±0.22	6.53 ±0.22	6.47[B] ±0.22

[1] Means represent average scores given by consumer panelists (n=40) based on a 9-point hedonic scale (9=highly acceptable, 1=highly unacceptable).
[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

A,B: Dip Treatment Effect—means for same day, temperature, and method with different superscripts are significantly different ($p<0.05$).
a,b: Day Effect—means for same treatment, temperature, and method with different superscripts are significantly different ($p<0.05$).
Y,Z: Storage Temperature Effect—means for same treatment, day, and method with different superscripts are significantly different ($p<0.05$).

Table 5.5. Mean overall acceptability scores of organic 'Early Girl' tomatoes[1]

	21° C Storage			10° C Storage		
	Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
$CaCl_2$ Dip[2]	7.80 ±0.22	7.73^{Y} ±0.22	6.98 ±0.22	7.38^{ab} ±0.22	6.60^{a,Z} ±0.22	7.68^{A,b} ±0.22
No Dip	7.20 ±0.22	7.45 ±0.22	7.55^{Y} ±0.22	7.13 ±0.22	6.80 ±0.22	6.38^{B,Z} ±0.22

[1] Means represent average scores given by consumer panelists (n=40) based on a 9-point hedonic scale (9=highly acceptable, 1=highly unacceptable).
[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

A,B: Dip Treatment Effect—means for same day, temperature, and method with different superscripts are significantly different ($p<0.05$).
a,b: Day Effect—means for same treatment, temperature, and method with different superscripts are significantly different ($p<0.05$).
Y,Z: Storage Temperature Effect—means for same treatment, day, and method with different superscripts are significantly different ($p<0.05$).

Table 5.6. Mean percent weight loss of 'Early Girl' tomatoes[1]

	21° C Storage			10° C Storage		
	Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
$CaCl_2$ Dip[2]	2.00^{a} ±0.43	$4.87^{b,Y}$ ±0.43	$9.93^{A,c,Y}$ ±0.43	1.13^{a} ±0.43	$0.83^{a,Z}$ ±0.43	$3.40^{b,Z}$ ±0.43
No Dip	1.13^{a} ±0.43	$3.97^{b,Y}$ ±0.43	$5.93^{B,c,Y}$ ±0.43	0.47 ±0.43	0.47^{Z} ±0.43	1.93^{Z} ±0.43

[1] Means represent three replications (±SE) of the percent weight loss. (Calculated from [initial weight in grams-final weight in grams)]/initial weight in grams x 100.)
[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

A,B: Dip Treatment Effect—means for same day, temperature, and method with different superscripts are significantly different ($p<0.05$).
a,b,c: Day Effect—means for same treatment, temperature, and method with different superscripts are significantly different ($p<0.05$).
Y,Z: Storage Temperature Effect—means for same treatment, day, and method with different superscripts are significantly different ($p<0.05$).

Table 5.7. Mean color a* values of 'Early Girl' tomatoes[1]

	21° C Storage			10° C Storage		
	Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
$CaCl_2$ Dip[2]	35.37 ±0.67	36.05 ±0.67	35.59 ±0.67	37.03^{A} ±0.67	36.19 ±0.67	34.54 ±0.67
No Dip	37.09 ±0.67	36.26 ±0.67	36.37 ±0.67	$32.94^{B,a}$ ±0.67	36.32^{b} ±0.67	35.49^{ab} ±0.67

[1] Means represent the average (±SE) a* value of the interior tomato color, based on three readings of three replications.
[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

A,B: Dip Treatment Effect—means for same day, temperature, and method with different superscripts are significantly different ($p<0.05$).
a,b: Day Effect—means for same treatment, temperature, and method with different superscripts are significantly different ($p<0.05$).

Table 5.8. Mean color b* values of 'Early Girl' tomatoes[1]

	21° C Storage			10° C Storage		
	Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
$CaCl_2$ Dip[2]	26.85 ±0.59	29.43 ±0.59	26.64^{Y} ±0.59	27.50^{a} ±0.59	30.15^{ab} ±0.59	$30.93^{b,Z}$ ±0.59
No Dip	25.61 ±0.59	27.91 ±0.59	27.96 ±0.59	25.88^{a} ±0.59	29.95^{b} ±0.59	29.52^{b} ±0.59

[1] Means represent the average (±SE) b* value of the interior tomato color, based on three readings of three replications.
[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

a,b: Day Effect—means for same treatment, temperature, and method with different superscripts are significantly different ($p<0.05$).
Y,Z: Storage Temperature Effect—means for same treatment, day, and method with different superscripts are significantly different ($p<0.05$).

Table 5.9. Mean color L* values of 'Early Girl' tomato[1]

	21° C Storage			10° C Storage		
	Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
$CaCl_2$ Dip[2]	39.47^{a} ±1.36	34.33^{ab} ±1.36	$31.07^{A,b,Y}$ ±1.36	39.72 ±1.36	36.09 ±1.36	40.11^{Z} ±1.36
No Dip	36.03^{ab} ±1.36	$30.51^{a,Y}$ ±1.36	$37.60^{B,b}$ ±1.36	39.76 ±1.36	37.31^{Z} ±1.36	41.90 ±1.36

[1] Means represent the average (±SE) L* value of the interior tomato color, based on three readings of three replications.
[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

A,B: Dip Treatment Eeffect—means for same day, temperature, and method with different superscripts are significantly different ($p<0.05$).
a,b: Day Effect—means for same treatment, temperature, and method with different superscripts are significantly different ($p<0.05$).
Y,Z: Storage Temperature Effect—means for same treatment, day, and method with different superscripts are significantly different ($p<0.05$).

Table 5.10. Mean pH values of 'Early Girl' tomatoes[1]

	21° C Storage			10° C Storage		
	Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
$CaCl_2$ Dip[2]	4.30 ±0.10	4.20 ±0.10	4.40 ±0.10	4.20 ±0.10	4.13 ±0.10	4.10 ±0.10
No Dip	4.27 ±0.10	4.33 ±0.10	4.37 ±0.10	4.33 ±0.10	4.10 ±0.10	4.23 ±0.10

[1] Means represent three replications (±SE) of pH values.
[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

Table 5.11. Mean soluble solids content of 'Early Girl' tomatoes[1]

	21° C Storage			10° C Storage		
	Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
$CaCl_2$ Dip[2]	4.43 ±0.43	4.37 ±0.43	4.43 ±0.43	3.27 ±0.43	3.17 ±0.43	4.03 ±0.43
No Dip	4.20 ±0.43	4.77 ±0.43	5.13 ±0.43	4.67 ±0.43	4.20 ±0.43	4.60 ±0.43

[1] Means represent three replications (±SE) measured using a refractometer (expressed as °Brix).
[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

Table 5.12. Mean total phenolic content of 'Early Girl' tomatoes[1]

	21° C Storage			10° C Storage		
	Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
$CaCl_2$ Dip[2]	65.97 ±11.25	83.20 ±11.25	86.48 ±11.25	62.54 ±11.25	86.76 ±11.25	71.86 ±11.25
No Dip	84.53 ±11.25	80.43 ±11.25	80.40 ±11.25	72.55 ±11.25	70.21 ±11.25	71.60 ±11.25

[1] Means represent three replications (±SE) of the total phenolic content (expressed as mg GAE/100 g FW).
[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

Table 5.13. Mean antioxidant activity ($ABTS^{\cdot+}$) of 'Early Girl' tomatoes[1]

	21° C Storage			10° C Storage		
	Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
$CaCl_2$ Dip[2]	194.19 ±19.31	126.70 ±19.31	170.22^{A} ±19.31	95.21^{A} ±19.31	100.98 ±19.31	169.96 ±19.31
No Dip	137.46 ±19.31	102.09 ±19.31	70.43^{B} ±19.31	210.45^{B,a} ±19.31	101.11^{b} ±19.31	97.79^{b} ±19.31

[1] Means represent three replications (±SE) of the $ABTS^{\cdot+}$ antioxidant activity test (expressed as μmole TEAC/100 g FW).
[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

A,B: Dip Treatment Effect—means for same day, temperature, and method with different superscripts are significantly different ($p<0.05$).
a,b: Day Effect—means for same treatment, temperature, and method with different superscripts are significantly different ($p<0.05$).

Table 5.14. Mean antioxidant activity ($DPPH^+$) of 'Early Girl' tomatoes[1]

	21° C Storage			10° C Storage		
	Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
$CaCl_2$ Dip[2]	167.01 ±25.13	213.04 ±25.13	150.56 ±25.13	194.11 ±25.13	157.21 ±25.13	195.02 ±25.13
No Dip	188.82 ±25.13	223.09 ±25.13	185.53 ±25.13	187.53 ±25.13	188.51 ±25.13	170.51 ±25.13

[1] Means represent three replications (±SE) of the $DPPH^+$ antioxidant activity test (expressed as μmole TEAC/100 g FW).
[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

Table 5.15. Mean ascorbic acid content of 'Early Girl' tomatoes[1]

	21° C Storage			10° C Storage		
	Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
$CaCl_2$ Dip[2]	43.58 ±4.60	54.03 ±4.60	65.96[Y] ±4.60	35.58 ±4.60	35.51 ±4.60	39.24[Z] ±4.60
No Dip	50.44 ±4.60	53.75 ±4.60	51.47 ±4.60	50.89 ±4.60	46.96 ±4.60	49.82 ±4.60

[1] Means represent three replications (±SE) of the ascorbic acid content (expressed as mg/100 g FW).
[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

Y,Z: Storage Temperature Effect—means for same treatment, day, and method with different superscripts are significantly different ($p<0.05$).

Table 5.16. Mean calcium content of 'Early Girl' tomatoes[1]

$CaCl_2$ Dip[2]	No Dip
14.72 ±0.78	12.81 ±0.78

[1] Means represent three replications (±SE) of the calcium content (mg/100g FW).
[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

•CHAPTER VI•

Conclusions and Recommendations

General Conclusions

Post-harvest handling methods impacted many of the melon and tomato quality and safety characteristics studied in this project. Here is a recap of the overall conclusions:

$CaCl_2$ Dip Treatment

- Use of a $CaCl_2$ dip had a positive effect on the sensory scores of melons and tomatoes.
- Enterobacteriaceae bacteria growth may be minimized by dipping melons in $CaCl_2$ at harvest, especially when the melons are grown organically and stored at room temperature.
- Overall, melons and tomatoes dipped in $CaCl_2$ had fewer post-harvest flesh color changes.
- Antioxidant tests overall were unaffected by use of a $CaCl_2$ dip for both melons and tomatoes.
- Melons dipped in $CaCl_2$ overall had lower calcium content levels in the fruit, while tomato calcium levels were unaffected by the dip treatment.
- Tomatoes dipped in $CaCl_2$ had significantly more weight loss during storage than non-dipped tomatoes.

Storage Temperature

- Storage temperature was the most significant main effect influencing safety and quality characteristics of melons and tomatoes.
- Melons stored at 10° C had significantly less aerobic and Enterobacteriaceae counts than melons stored at 21° C.
- Melons stored at 10° C were preferred over melons stored at 21° C, while tomatoes stored at 21° C were preferred over tomatoes stored at 10° C.
- Both melons and tomatoes experienced more weight loss when stored at 21° C.
- Storing melons and tomatoes at 10° C led to many significant fruit color changes. Both fruit had lighter flesh color overall at 10° C, with the tomatoes less red and the melons less green than those stored at 21° C. Such color changes may indicate the presence of chilling injury, though additional research would be necessary to confirm.
- Tomatoes stored at 21° C had significantly higher soluble solids content than those stored at 10° C, while melon soluble solids content was unaffected by storage temperature.
- Melon antioxidant tests were mostly unaffected by temperature, except for $DDPH^+$ test values which were higher for melons stored at 10° C. Tomatoes had higher scores for $ABTS^{\bullet+}$ and ascorbic acid tests when stored at 21° C while $DPPH^+$ and total phenolic tests were unaffected by storage temperature.
- Tomatoes stored at 21° C had a significantly higher pH than those stored at 10° C.

Time

- Time significantly impacted sensory scores with day 10 melons and tomatoes receiving overall lower sensory scores than days 1 and 5. Also, 75% of the melons stored for 10 days at 21° C were past an acceptable shelf-life.
- Both melons and tomatoes experienced more weight loss as time increased.
- Fruit flesh color of melons and tomatoes was impacted by time, with potentially negative changes occurring as time increased.
- Overall, several melon and tomato antioxidant test results were affected by time, though some results went up and some went down over time.
- Time itself did not impact melon microbial counts, though significant interactions occurred over time with storage temperature and growing method.

Growing method

- Organically grown melons received overall higher sensory scores than conventionally grown melons.
- Organic melons, especially when stored at 21° C, had higher aerobic bacteria counts than those grown conventionally.
- Conventionally grown melons had higher soluble solids content and calcium levels than organic melons.

- Growing method significantly impacted all melon antioxidant tests, with $DPPH^+$, total phenolic, and ascorbic acid test values higher for conventionally grown melons and $ABTS^{\bullet+}$ test values higher for organically grown melons.

Application

- Use of a $CaCl_2$ dip appeared to be beneficial as a post-harvest treatment for whole, ripe melons and tomatoes.
- Melons stored at 10° C for up to 10 days had overall higher sensory scores and decreased microbial counts than those stored at 21° C. Especially for more delicate melon cultivars, such as those used in this study, it appeared refrigeration is necessary to maximize shelf-life and maintain overall post-harvest quality.
- Tomatoes stored at 21° C for up to 10 days had overall higher sensory scores and antioxidant levels than those stored at 10° C. Storing whole, ripe tomatoes at ambient temperature appeared to maximize overall post-harvest quality.
- However, if longer term, refrigerated storage is needed, the use of a $CaCl_2$ dip appears to be beneficial in maintaining flavor, texture, and overall acceptability of tomatoes.

This study evaluated several post-harvest variables, which was a valuable method to determine preliminary answers to many post-harvest research questions, but this also limited the ability to draw specific overall conclusions and uncovered even more questions.

Recommendations for Future Studies

Post-harvest produce research affects every level of the food chain—from farm to fork—and much more research is necessary to understand how steps along the way can improve safety and quality attributes of fresh melons and tomatoes, as well as other fresh produce. Here are a few recommendations for future studies based on the results of this research project.

- Many of the results in this study may be cultivar or produce dependant and additional research should be conducted to determine if the same trends are experienced by additional cultivars as well as other fruits and vegetables.

- The microbial component of this project could be greatly expanded. Additional areas to explore include comparing microbial levels of $CaCl_2$-dipped produce to water-dipped produce, treatment effects on inoculated produce, additional comparisons between organically and conventionally grown produce, and the potential of other dip treatments to improve produce safety.

- Temperature was especially significant for many of the safety and quality characteristics studied. Since this project was only able to evaluate two temperatures, it would be useful to determine effects on sensory, antioxidant, and safety characteristics of melons and tomatoes at additional storage temperatures, such as standard consumer refrigerator temperatures. Since there is potential for both melons and tomatoes to experience chilling injury at refrigerated temperatures, it would also be beneficial to include tests to monitor whether chilling injury is present when produce is stored at cooler temperatures.

- The post-harvest methods used in this project targeted those used by smaller scale farmers who sell directly to consumers. Little research is available addressing knowledge and practices of such growers. Before making recommendations to this audience, it would be useful to conduct an assessment to define areas where education and Extension programs could best target improving produce safety and quality.

- Finally, many consumers store melons and tomatoes for several days before consuming. The results of this project could also be expanded to include the safety and quality impact of common consumer handling practices. This combined with an assessment of current knowledge and methods to best target recommendations would be a useful means to help consumers optimize sensory, nutritional, and safety characteristics when storing fresh produce.

•CHAPTER VII•

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•APPENDICES•

Appendix I. Human Subject Approval Letter.

Colorado State University

Office of Regulatory Compliance
Office of Vice President for Research
Fort Collins, CO 80523-2011
(970) 491-1553
FAX: 491-2293

Notice of Human Research Amendment Approval

Principal Investigator:	Pat Kendall, FSHN, 1571
Title:	Differentiating Farm Produce Offerings through Nutritionally Superior Cultivars, Marketing, and Extension Programs
Protocol #:	05-114H
Committee Action:	**Amendment Approved:** June 26, 2007
HRC Administrator:	Janell Meldrem

The Human Research Committee reviewed and approved your request to amend the above-referenced project. The approved amendments are below.

Amendment(s):

- to recruit for sensory panels to taste melons and tomatoes using the revised consent form, score card and flyers reflecting this change.

Investigator Responsibilities:

- It is the responsibility of the PI to immediately inform the Committee of any serious complications, unexpected risks, or injuries resulting from this research.
- It is also the PI's responsibility to notify the Committee of any changes in experimental design, participant population, consent procedures or documents. This can be done with a memo describing the changes and submitting any altered documents.
- Students serving as Co-Principal Investigators may not alter projects without first obtaining PI approval. The PI is ultimately responsible for the conduct of the project.

This approval is issued under Colorado State University's OHRP Federal Wide Assurance 00000647.

If you have questions, please contact me at 1-1655 or janell.meldrem@colostate.edu.

attachment Date of Correspondence: 6/26/07

Appendix II. Consent form for sensory evaluation.

Consent to Participate in a Research Study
Colorado State University

TITLE OF STUDY: Differentiating Small Farm Produce Offerings through Nutritionally Superior Cultivars, Marketing, and Extension Programs: Sensory Evaluation of Post-Harvest Storage Treatments for Colorado-Grown Produce

PRINCIPAL INVESTIGATOR: Patricia A. Kendall, Ph.D., R.D.
CO-PRINCIPAL INVESTIGATOR: Heather Troxell, M.S. (970) 491-3747

WHY AM I BEING INVITED TO TAKE PART IN THIS RESEARCH? The information you provide will assist in the selection of post-harvest storage treatments aimed at helping small farm producers provide consumers with higher quality produce. Information may also be used in the development of educational materials designed to assist farmers or consumers in storing fresh produce.

WHO IS DOING THE STUDY? This study is being conducted by researchers from the Department of Food Science and Human Nutrition, Horticulture and Landscape Architecture, and Agricultural Resource Economics at Colorado State University and is funded by the United States Department of Agriculture - Cooperative State Research, Education, and Extension Service (USDA-CSREES).

WHAT IS THE PURPOSE OF THIS STUDY? This study involves sensory evaluation of different post-harvest storage treatments designed to extend the shelf-life of produce grown at the CSU Horticulture Research Center during the 2007 growing season.

WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST? The sensory evaluations will take place at the Gifford Building on the campus of Colorado State University and will not take more than 30 minutes. Approximately different six taste test evaluations will take place over the harvest season and you may participate in just one evaluation or as many as you are available. If you are interested in participating in the additional taste panels, we will contact you.

WHAT WILL I BE ASKED TO DO? You will taste samples of melon or tomato prepared in a food laboratory in the Department of Food Science and Human Nutrition. Whole produce may have been dipped in various solutions approved by the FDA and USDA's National Organic Program for use with organic produce. You will evaluate the samples for qualities like visual appearance, flavor, texture, bitterness, and overall acceptability. Each training and sample testing session will not take more than 30 minutes. You will not be videotaped or audiotaped during any tastings. You will receive a complimentary beverage at the completion of the tasting sessions.

ARE THERE REASONS WHY I SHOULD NOT TAKE PART IN THIS STUDY? Any consumer familiar with the produce being tested may take part in this study, there are no restrictions.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS? It is not anticipated that taking part in the sensory evaluations will lead to distress but if you are uncomfortable for any reason, you have the option to leave the tasting session at any time. It is not possible to identify all potential risks in a research study but the researchers have taken reasonable safeguards to minimize any known and potential, but unknown, risks.

ARE THERE ANY BENEFITS FROM TAKING PART IN THIS STUDY? Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled.

DO I HAVE TO TAKE PART IN THE STUDY? Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled.

WHAT WILL IT COST ME TO PARTICIPATE? There are no costs to participate.

WHO WILL SEE THE INFORMATION THAT I GIVE? Strict confidentiality of information will be maintained by recording data using sequential numbers to identify participants. Resulting data will be reported in research materials in aggregate. Only the investigators and necessary personnel (graduate students) will have access to the individual sensory evaluation sheets.

CAN MY TAKING PART IN THE STUDY END EARLY? Your participation in this sensory evaluation is voluntary. You may withdraw your consent and stop participating at any time during the tasting session without penalty.

WILL I RECEIVE ANY COMPENSATION FOR TAKING PART IN THIS STUDY? You will receive a complimentary beverage at the time of the sensory evaluation even if you decide to stop participating before the end of the tasting session.

WHAT HAPPENS IF I AM INJURED BECAUSE OF THE RESEARCH? The Colorado Governmental Immunity Act determines and may limit Colorado State University's legal responsibility if an injury happens because of this study. Claims against the University must be filed within 180 days of the injury.

WHAT IF I HAVE QUESTIONS? Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions about the study, you can contact the investigator, Heather Troxell at (970) 491-3747. If you have any questions about your rights as a volunteer in this research, contact Janell Barker, Human Research Administrator at 970-491-1655. We will give you a copy of this consent form to take with you.

Your signature acknowledges that you have read the information stated and willingly sign this consent form. Your signature also acknowledges that you have received, on the date signed, a copy of this document containing 2 pages.

_____ _____
Signature of person agreeing to take part in the study Date

_____
Printed name of person agreeing to take part in the study

_____ _____
Name of person providing information to participant Date

_____
Signature of Research Staff

Obtain your parent's permission ONLY if you are under 18 years of age.

PARENTAL SIGNATURE FOR MINOR

As parent or guardian I authorize _____ (print name) to become a participant for the described research. The nature and general purpose of the project have been satisfactorily explained to me by _____ and I am satisfied that proper precautions will be observed.

_____
Minor's date of birth

_____
Parent/Guardian name (printed)

_____ _____
Parent/Guardian signature Date

Appendix III. 'Arava' Melons Statistical Analysis

Results were transformed into log scale and analyzed using SAS Proc Mixed (Version 9.1, Cary, NC). A factorial analysis of variance was performed with differences between means assessed using significance of $p<0.05$ with the Tukey-Kramer adjustment for multiple comparisons. Fixed effects included time, temperature, dip, and growing method; replication was included as a random effect.

SAS commands used:

```
data Micro;
input Time Temp $ Dip $ Rep Method $ Aerobic Enterobac;
l_Enterobac=log10(Enterobac);
l_Aerobic=log10(Aerobic);

datalines;
(insert data here)

proc mixed;

class Time Temp Dip Method;
model l_Aerobic=Time|Temp|Dip|Method;
Random Rep;
lsmeans Time|Temp|Dip|Method/diff adj=tukey;

class Time Temp Dip Method;
model l_Enterobac=Time|Temp|Dip|Method;
Random Rep;
lsmeans Time|Temp|Dip|Method/diff adj=tukey;

run;
```

Table A.1. 'Arava' Melons
Statistical analysis of mean aerobic bacteria counts

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Method	2	C O
Rep	6	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	115	1.37	0.2575
Temp	1	115	28.82	<0.0001
Time* Temp	2	115	2.78	0.0660
Dip	1	115	7.48	0.0072
Time*Dip	2	115	1.28	0.2827
Temp*Dip	1	115	3.80	0.0537
Time*Temp*Dip	2	115	4.09	0.0193
Method	1	115	3.97	0.0487
Time*Method	2	115	3.83	0.0245
Temp*Method	1	115	0.67	0.4141
Time*Temp*Method	2	115	0.94	0.3932
Dip*Method	1	115	2.86	0.0934
Time*Dip*Method	2	115	4.51	0.0130
Temp*Dip*Method	1	115	0.60	0.4394
Time*Temp*Dip*Method	2	115	2.68	0.0725

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Method	Growing method; C=conventional, O=organic
Rep	Sample replications; 6 melons

Table A.2. 'Arava' Melons
Main effect means for aerobic bacteria counts[1]

Dip Treatment**	$CaCl_2$ Dip[2]		No Dip
	6.16 ± 0.10		6.54 ± 0.10
Storage Temperature***	21° C		10° C
	6.72 ± 0.10		5.98 ± 0.10
Storage Time[NS]	Day 1	Day 5	Day 10
	6.19 ± 0.12	6.44 ± 0.12	6.43 ± 0.12
Growing Method*	Conventional		Organic
	6.21 ± 0.10		6.49 ± 0.10

[1] Means represent six replications (± SE) of log colony forming units (CFU/mL).

[2]$CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.

[NS, *, **, ***]Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.3. 'Arava' Melons
Statistical analysis of mean *Enterobacteriaceae* bacteria counts

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Method	2	C O
Rep	6	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	116	0.25	0.7802
Temp	1	116	40.03	<0.0001
Time* Temp	2	116	2.15	0.1212
Dip	1	116	12.39	0.0006
Time*Dip	2	116	7.56	0.0008
Temp*Dip	1	116	0.57	0.4527
Time*Temp*Dip	2	116	1.31	0.2728
Method	1	116	0.34	0.5609
Time*Method	2	116	0.79	0.4543
Temp*Method	1	116	1.03	0.3134
Time*Temp*Method	2	116	0.85	0.4310
Dip*Method	1	116	16.37	<0.0001
Time*Dip*Method	2	116	2.53	0.0838
Temp*Dip*Method	1	116	0.00	0.9446
Time*Temp*Dip*Method	2	116	4.05	0.0199

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment, Ca=$CaCl_2$ dip, ND=no dip
Method	Growing method; C=conventional, O=organic
Rep	Sample replications; 6 melons

Table A.4. 'Arava' Melons
Main effect means for *Enterobacteriaceae* bacteria counts[1]

Dip Treatment**	$CaCl_2$ Dip[2]		No Dip
	5.39 ± 0.10		5.87 ± 0.10
Storage Temperature***	21° C		10° C
	6.06 ± 0.10		5.20 ± 0.10
Storage Time[NS]	Day 1	Day 5	Day 10
	5.56 ± 0.12	5.65 ± 0.12	5.67 ± 0.12
Growing Method[NS]	Conventional		Organic
	5.59 ± 0.10		5.67 ± 0.10

[1] Means represent six replications (± SE) of log colony forming units (CFU/mL).

[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.

[NS, *, **, ***] Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Appendix IV. 'Haogen' Melons Statistical Analysis

Results were analyzed using SAS Proc Mixed (Version 9.1, Cary, NC). A factorial analysis of variance was performed with differences between means assessed using significance of $p<0.05$ with the Tukey-Kramer adjustment for multiple comparisons. Fixed effects included time, temperature, dip, and growing method; replication (or panelist for sensory tests) was included as a random effect.

SAS commands used:

data (Haogen test*);
input Time Temp $ Dip $ Rep Method $ (Haogen test*);

datalines;
(insert data here)

proc mixed;

class Time Temp Dip Method Rep;
model (Haogen test*)=Time|Temp|Dip|Method;
Random Rep;
lsmeans Time|Temp|Dip|Method/diff adj=tukey;

run;

*Haogen tests analyzed include:
- appearance
- flavor
- texture
- overall acceptability
- percent weight loss
- color a* value
- color b* value
- color L* value
- soluble solids content
- total phenolic content
- antioxidant activity ($ABTS^{\bullet+}$)
- antioxidant activity ($DPPH^{+}$)
- ascorbic acid content
- calcium content

Table A.5. 'Haogen' Melons
Statistical analysis of mean appearance scores

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Method	2	C O
Panelist	88	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	747	51.37	<0.0001
Temp	1	747	12.67	0.0004
Time* Temp	2	747	1.26	0.2856
Dip	1	747	5.00	0.0257
Time*Dip	2	747	1.15	0.3173
Temp*Dip	1	747	2.30	0.1300
Time*Temp*Dip	1	747	0.75	0.3862
Method	1	747	6.06	0.0141
Time*Method	2	747	0.97	0.3799
Temp*Method	1	747	0.20	0.6522
Time*Temp*Method	1	747	0.15	0.6940
Dip*Method	1	747	5.42	0.0202
Time*Dip*Method	2	747	8.98	0.0001
Temp*Dip*Method	1	747	0.07	0.7981
Time*Temp*Dip*Method	1	747	0.63	0.4278

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Method	Growing method; C=conventional, O=organic
Panelist	40 panelists used for each evaluation; 88 unique panelists used (random effect)

Table A.6. 'Haogen' Melons
Main effect means for appearance scores[1]

Dip Treatment*	$CaCl_2$ Dip[2]		No Dip
	7.66 ± 0.42		7.39 ± 0.62
Storage Temperature**	21° C		10° C
	7.49± 0.50		7.53 ± 0.58
Storage Time***	Day 1	Day 5	Day 10
	7.82 ± 0.23	7.68 ± 0.23	6.76 ± 0.56
Growing Method*	Conventional		Organic
	7.46 ± 0.45		7.56 ± 0.63

[1] Means represent average scores (± SD) given by consumer panelists (n=40) based on a 9-point hedonic scale (9=highly acceptable, 1=highly unacceptable).

[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.

NS, *, **, ***Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.7. 'Haogen' Melons
Statistical analysis of mean flavor scores

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Method	2	C O
Panelist	88	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	747	3.91	0.0204
Temp	1	747	0.09	0.7705
Time* Temp	2	747	5.84	0.0031
Dip	1	747	3.08	0.0799
Time*Dip	2	747	3.88	0.0210
Temp*Dip	1	747	0.00	0.9894
Time*Temp*Dip	1	747	52.18	<0.0001
Method	1	747	0.92	0.3388
Time*Method	2	747	3.14	0.0438
Temp*Method	1	747	0.03	0.8624
Time*Temp*Method	1	747	42.69	<0.0001
Dip*Method	1	747	2.44	0.1188
Time*Dip*Method	2	747	10.29	<0.0001
Temp*Dip*Method	1	747	0.02	0.9019
Time*Temp*Dip*Method	1	747	0.28	0.5961

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Method	Growing method; C=conventional, O=organic
Panelist	40 panelists used for each evaluation; 88 unique panelists used (random effect)

Table A.8. 'Haogen' Melons
Main effect means for flavor scores[1]

Dip Treatment[NS]	$CaCl_2$ Dip[2]		No Dip
	7.00 ± 0.73		6.86 ± 0.80
Storage Temperature[NS]	21° C		10° C
	6.93 ± 0.79		6.91 ± 0.75
Storage Time[**]	Day 1	Day 5	Day 10
	6.79 ± 0.73	7.12 ± 0.83	6.81 ± 0.73
Growing Method[NS]	Conventional		Organic
	6.82 ± 0.77		7.01 ± 0.76

[1] Means represent average scores (± SD) given by consumer panelists (n=40) based on a 9-point hedonic scale (9=highly acceptable, 1=highly unacceptable).

[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.

[NS, *, **, ***] Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.9. 'Haogen' Melons
Statistical analysis of mean texture scores

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Method	2	C O
Panelist	88	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	747	11.01	<0.0001
Temp	1	747	35.95	<0.0001
Time* Temp	2	747	1.03	0.3584
Dip	1	747	26.16	<0.0001
Time*Dip	2	747	2.91	0.0552
Temp*Dip	1	747	1.09	0.2967
Time*Temp*Dip	1	747	0.72	0.3975
Method	1	747	27.74	<0.0001
Time*Method	2	747	4.74	0.0090
Temp*Method	1	747	2.03	0.1544
Time*Temp*Method	1	747	6.99	0.0084
Dip*Method	1	747	12.54	0.0004
Time*Dip*Method	2	747	5.90	0.0029
Temp*Dip*Method	1	747	1.19	0.2766
Time*Temp*Dip*Method	1	747	1.23	0.2676

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Method	Growing method; C=conventional, O=organic
Panelist	40 panelists used for each evaluation; 88 unique panelists used (random effect)

Table A.10. 'Haogen' Melons
Main effect means for texture scores[1]

Dip Treatment***	$CaCl_2$ Dip[2]		No Dip
	7.58 ± 0.32		7.13 ± 0.59
Storage Temperature***	21° C		10° C
	7.11 ± 0.46		7.52 ± 0.50
Storage Time***	Day 1	Day 5	Day 10
	7.51 ± 0.34	7.31 ± 0.66	7.15 ± 0.52
Growing Method***	Conventional		Organic
	7.15 ± 0.62		7.53 ± 0.35

[1] Means represent average scores (± SD) given by consumer panelists (n=40) based on a 9-point hedonic scale (9=highly acceptable, 1=highly unacceptable).

[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.

NS, *, **, ***Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.11. 'Haogen' Melons
Statistical analysis of mean overall acceptability scores

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Method	2	C O
Panelist	88	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	747	6.34	0.0019
Temp	1	747	7.06	0.0080
Time* Temp	2	747	1.71	0.1812
Dip	1	747	14.62	0.0001
Time*Dip	2	747	1.02	0.3608
Temp*Dip	1	747	1.27	0.2594
Time*Temp*Dip	1	747	23.62	<0.0001
Method	1	747	4.86	0.0278
Time*Method	2	747	4.33	0.0134
Temp*Method	1	747	0.01	0.9150
Time*Temp*Method	1	747	35.73	<0.0001
Dip*Method	1	747	5.92	0.0152
Time*Dip*Method	2	747	6.98	0.0010
Temp*Dip*Method	1	747	0.01	0.9325
Time*Temp*Dip*Method	1	747	0.28	0.5955

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Method	Growing method; C=conventional, O=organic
Panelist	40 panelists used for each evaluation; 88 unique panelists used (random effect)

Table A.12. 'Haogen' Melons
Main effect means for overall acceptability scores[1]

Dip Treatment***	$CaCl_2$ Dip[2]		No Dip
	7.18 ± 0.52		6.82 ± 0.60
Storage Temperature**	21° C		10° C
	6.90 ± 0.52		7.05 ± 0.64
Storage Time**	Day 1	Day 5	Day 10
	7.00 ± 0.62	7.16 ± 0.64	6.71 ± 0.36
Growing Method*	Conventional		Organic
	6.88 ± 0.64		7.09 ± 0.53

[1] Means represent average scores (± SD) given by consumer panelists (n=40) based on a 9-point hedonic scale (9=highly acceptable, 1=highly unacceptable).

[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.

NS, *, **, ***Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.13. 'Haogen' Melons
Statistical analysis of mean percent weight loss

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Method	2	C O
Rep	3	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	54	25.43	<0.0001
Temp	1	54	24.61	<0.0001
Time* Temp	2	54	4.95	0.0106
Dip	1	54	0.30	0.5843
Time*Dip	2	54	1.22	0.3021
Temp*Dip	1	54	0.55	0.4608
Time*Temp*Dip	2	54	0.34	0.7142
Method	1	54	1.76	0.1896
Time*Method	2	54	0.70	0.5003
Temp*Method	1	54	0.09	0.7636
Time*Temp*Method	2	54	0.10	0.9059
Dip*Method	1	54	0.06	0.8074
Time*Dip*Method	2	54	0.07	0.9367
Temp*Dip*Method	1	54	0.03	0.8570
Time*Temp*Dip*Method	1	54	0.01	0.9431

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Method	Growing method; C=conventional, O=organic
Rep	Sample replications; 3 melons

Table A.14. 'Haogen' Melons
Main effect means for percent weight loss[1]

Dip Treatment[NS]	$CaCl_2$ Dip[2]		No Dip
	2.59 ± 2.07		3.35 ± 2.74
Storage Temperature[***]	21° C		10° C
	3.38 ± 2.88		1.87 ± 1.14
Storage Time[***]	Day 1	Day 5	Day 10
	0.80 ± 0.29	3.48 ± 1.87	3.72 ± 1.74
Growing Method[NS]	Conventional		Organic
	3.10 ± 2.58		2.87 ± 2.37

[1] Means represent three replications (±SD) of the percent weight change. (Calculated from [initial weight in grams-final weight in grams)]/initial weight in grams x 100.)

[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.

[NS, *, **, ***] Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.15. 'Haogen' Melons
Statistical analysis of mean color a* values

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Method	2	C O
Rep	9	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	176	100.79	<0.0001
Temp	1	176	2.76	0.0983
Time* Temp	2	176	1.73	0.1795
Dip	1	176	11.59	0.0008
Time*Dip	2	176	4.87	0.0087
Temp*Dip	1	176	38.11	<0.0001
Time*Temp*Dip	2	176	5.74	0.0039
Method	1	176	0.99	0.3207
Time*Method	2	176	0.03	0.9725
Temp*Method	1	176	3.37	0.0682
Time*Temp*Method	2	176	1.44	0.2387
Dip*Method	1	176	11.71	0.0008
Time*Dip*Method	2	176	3.64	0.0282
Temp*Dip*Method	1	176	0.55	0.4609
Time*Temp*Dip*Method	1	176	0.02	0.8852

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Method	Growing method; C=conventional, O=organic
Rep	Sample replications; 3 readings took of 3 melon samples (9 results)

Table A.16. 'Haogen' Melons
Main effect means for color a* values[1]

Dip Treatment**	$CaCl_2$ Dip[2]		No Dip
	-6.19 ± 1.42		-5.46 ± 1.92
Storage Temperature[NS]	21° C		10° C
	-6.01 ± 1.77		-5.92 ± 1.71
Storage Time***	Day 1	Day 5	Day 10
	-7.26 ± 0.93	-6.03 ± 0.92	-3.74 ± 0.49
Growing Method[NS]	Conventional		Organic
	-5.70 ± 1.83		-5.91 ± 1.65

[1] Means represent the average (±SD) a* value of the interior melon color, based on three readings of three replications.

[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.

[NS, *, **, ***] Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.17. 'Haogen' Melons
Statistical analysis of mean color b* values

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Method	2	C O
Rep	9	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	176	26.12	<0.0001
Temp	1	176	23.54	<0.0001
Time* Temp	2	176	30.20	<0.0001
Dip	1	176	8.51	0.0040
Time*Dip	2	176	7.43	0.0008
Temp*Dip	1	176	66.82	<0.0001
Time*Temp*Dip	2	176	17.14	<0.0001
Method	1	176	51.71	<0.0001
Time*Method	2	176	10.54	<0.0001
Temp*Method	1	176	12.21	0.0006
Time*Temp*Method	2	176	11.28	<0.0001
Dip*Method	1	176	45.61	<0.0001
Time*Dip*Method	2	176	11.10	<0.0001
Temp*Dip*Method	1	176	7.95	0.0054
Time*Temp*Dip*Method	1	176	12.05	0.0007

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Method	Growing method; C=conventional, O=organic
Rep	Sample replications; 3 readings took of 3 melon samples (9 results)

Table A.18. 'Haogen' Melons
Main effect means for color b* values[1]

Dip Treatment**	$CaCl_2$ Dip[2]		No Dip
	32.80 ± 3.58		33.90 ± 3.74
Storage Temperature***	21° C		10° C
	34.67 ± 3.27		32.55 ± 3.87
Storage Time***	Day 1	Day 5	Day 10
	34.32 ± 3.15	34.26 ± 3.57	30.53 ± 3.34
Growing Method***	Conventional		Organic
	31.96 ± 3.57		34.67 ± 3.30

[1] Means represent the average (±SD) b* value of the interior melon color, based on three readings of three replications.

[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.

NS, *, **, ***Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.19. 'Haogen' Melons
Statistical analysis of mean color L* values

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Method	2	C O
Rep	9	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	176	35.88	<0.0001
Temp	1	176	30.52	<0.0001
Time* Temp	2	176	16.52	<0.0001
Dip	1	176	2.02	0.1573
Time*Dip	2	176	8.78	0.0002
Temp*Dip	1	176	7.87	0.0056
Time*Temp*Dip	2	176	15.52	<0.0001
Method	1	176	0.00	0.9574
Time*Method	2	176	19.34	<0.0001
Temp*Method	1	176	0.05	0.8254
Time*Temp*Method	2	176	0.58	0.5606
Dip*Method	1	176	12.88	0.0004
Time*Dip*Method	2	176	0.38	0.6821
Temp*Dip*Method	1	176	1.65	0.2004
Time*Temp*Dip*Method	1	176	1.38	0.2409

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Method	Growing method; C=conventional, O=organic
Rep	Sample replications; 3 readings took of 3 melon samples (9 results)

Table A.20. 'Haogen' Melons
Main effect means for color L* values[1]

Dip Treatment[NS]	$CaCl_2$ Dip[2]		No Dip
	71.34 ± 4.25		71.83 ± 3.00
Storage Temperature[***]	21° C		10° C
	69.97 ± 2.01		72.77 ± 4.32
Storage Time[***]	Day 1	Day 5	Day 10
	70.32 ± 2.73	70.11 ± 3.01	75.91 ± 3.20
Growing Method[NS]	Conventional		Organic
	71.63 ± 3.95		71.56 ± 3.37

[1] Means represent the average (±SD) L* value of the interior melon color, based on three readings of three replications.

[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.

[NS, *, **, ***] Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.21. 'Haogen' Melons
Statistical analysis of mean soluble solids content (°Brix)

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Method	2	C O
Rep	3	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	44	2.59	0.0863
Temp	1	44	1.10	0.2996
Time* Temp	2	44	3.59	0.0358
Dip	1	44	1.54	0.2217
Time*Dip	2	44	2.67	0.0804
Temp*Dip	1	44	2.25	0.1409
Time*Temp*Dip	2	44	6.42	0.0036
Method	1	44	6.54	0.0141
Time*Method	2	44	3.79	0.0303
Temp*Method	1	44	0.76	0.3879
Time*Temp*Method	2	44	2.78	0.731
Dip*Method	1	44	0.34	0.5613
Time*Dip*Method	2	44	3.48	0.0395
Temp*Dip*Method	1	44	0.58	0.4509
Time*Temp*Dip*Method	1	44	0.10	0.7477

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Method	Growing method; C=conventional, O=organic
Rep	Sample replications; 3 melons

Table A.22. 'Haogen' Melons
Main effect means for soluble solids content[1]

Dip Treatment[NS]	$CaCl_2$ Dip[2]		No Dip
	9.78 ± 1.99		10.33 ± 1.76
Storage Temperature[NS]	21° C		10° C
	9.97 ± 1.73		10.24 ± 2.02
Storage Time[NS]	Day 1	Day 5	Day 10
	10.05 ± 2.04	10.66 ± 1.96	9.40 ± 1.30
Growing Method[*]	Conventional		Organic
	10.77 ± 1.44		9.42 ± 2.01

[1] Means represent three replications (±SD) measured using a refractometer (expressed as °Brix).

[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.

[NS, *, **, ***] Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.23. 'Haogen' Melons
Statistical analysis of mean total phenolic content

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Method	2	C O
Rep	3	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	44	4.03	0.0248
Temp	1	44	0.02	0.8923
Time* Temp	2	44	1.94	0.1556
Dip	1	44	1.64	0.2069
Time*Dip	2	44	1.76	0.1839
Temp*Dip	1	44	0.15	0.7019
Time*Temp*Dip	2	44	6.98	0.0023
Method	1	44	6.47	0.0146
Time*Method	2	44	0.11	0.8921
Temp*Method	1	44	0.91	0.3454
Time*Temp*Method	2	44	1.39	0.2591
Dip*Method	1	44	1.68	0.2019
Time*Dip*Method	2	44	2.91	0.0649
Temp*Dip*Method	1	44	0.04	0.8437
Time*Temp*Dip*Method	1	44	1.82	0.1845

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Method	Growing method; C=conventional, O=organic
Rep	Sample replications; 3 melons

Table A.24. 'Haogen' Melons
Main effect means for total phenolic content[1]

Dip Treatment[NS]	$CaCl_2$ Dip[2]		No Dip
	35.97 ± 7.74		39.47 ± 6.33
Storage Temperature[NS]	21° C		10° C
	37.26 ± 4.98		38.15 ± 8.83
Storage Time*	Day 1	Day 5	Day 10
	36.64 ± 7.44	41.81 ± 7.38	33.10 ± 3.46
Growing Method*	Conventional		Organic
	40.34 ± 8.40		35.97 ± 4.93

[1] Means represent three replications (±SD) of the total phenolic content (expressed as mg GAE/100 g FW).

[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.

[NS, *, **, ***] Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.25. 'Haogen' Melons
Statistical analysis of mean antioxidant activity ($ABTS^{\bullet+}$)

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Method	2	C O
Rep	3	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	44	8.40	0.0008
Temp	1	44	3.07	0.0866
Time* Temp	2	44	2.80	0.0717
Dip	1	44	0.05	0.8248
Time*Dip	2	44	1.12	0.3342
Temp*Dip	1	44	2.25	0.1410
Time*Temp*Dip	2	44	0.55	0.5813
Method	1	44	16.66	0.0002
Time*Method	2	44	2.25	0.1177
Temp*Method	1	44	0.50	0.4852
Time*Temp*Method	2	44	1.44	0.2476
Dip*Method	1	44	1.61	0.2117
Time*Dip*Method	2	44	2.13	0.1303
Temp*Dip*Method	1	44	2.36	0.1316
Time*Temp*Dip*Method	1	44	3.49	0.0684

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Method	Growing method; C=conventional, O=organic
Rep	Sample replications; 3 melons

Table A.26. 'Haogen' Melons
Main effect means for antioxidant activity ($ABTS^{\bullet+}$)[1]

Dip Treatment[NS]	$CaCl_2$ Dip[2]		No Dip
	145.01 ± 20.72		148.71 ± 50.19
Storage Temperature[NS]	21° C		10° C
	140.68 ± 44.31		140.58 ± 32.23
Storage Time[**]	Day 1	Day 5	Day 10
	135.54 ± 20.70	133.73 ± 28.59	159.78 ± 41.51
Growing Method[**]	Conventional		Organic
	164.93 ± 43.73		130.45 ± 23.61

[1] Means represent three replications (±SD) of the $ABTS^{\bullet+}$ antioxidant activity test (expressed as µmole TEAC/100 g FW).

[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.

[NS, *, **, ***] Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.27. 'Haogen' Melons
Statistical analysis of mean antioxidant activity ($DPPH^+$)

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Method	2	C O
Rep	3	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	44	5.28	0.0088
Temp	1	44	7.56	0.0086
Time* Temp	2	44	2.18	0.1251
Dip	1	44	0.34	0.5602
Time*Dip	2	44	1.19	0.3141
Temp*Dip	1	44	0.41	0.5228
Time*Temp*Dip	2	44	1.81	0.1749
Method	1	44	13.48	0.0007
Time*Method	2	44	13.70	<0.0001
Temp*Method	1	44	15.36	0.0003
Time*Temp*Method	2	44	1.60	0.2142
Dip*Method	1	44	0.46	0.5025
Time*Dip*Method	2	44	1.44	0.2480
Temp*Dip*Method	1	44	0.99	0.3249
Time*Temp*Dip*Method	1	44	0.72	0.4012

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Method	Growing method; C=conventional, O=organic
Rep	Sample replications; 3 melons

Table A.28. 'Haogen' Melons
Main effect means for antioxidant activity ($DPPH^+$)[1]

Dip Treatment[NS]	$CaCl_2$ Dip[2]		No Dip
	475.06 ± 280.05		504.97 ± 183.67
Storage Temperature[**]	21° C		10° C
	430.04 ± 158.07		542.55 ± 276.84
Storage Time[*]	Day 1	Day 5	Day 10
	502.26 ± 326.55	569.52 ± 96.93	361.36 ± 202.64
Growing Method[**]	Conventional		Organic
	402.40 ± 185.15		571.57 ± 243.73

[1] Means represent three replications (±SD) of the $DPPH^+$ antioxidant activity test (expressed as µmole TEAC/100 g FW).

[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.

[NS, *, **, ***] Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.29. 'Haogen' Melons
Statistical analysis of mean ascorbic acid content

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Method	2	C O
Rep	3	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	44	0.86	0.4314
Temp	1	44	1.30	0.2600
Time* Temp	2	44	1.93	0.1567
Dip	1	44	0.76	0.3875
Time*Dip	2	44	2.13	0.1309
Temp*Dip	1	44	0.73	0.3976
Time*Temp*Dip	2	44	6.83	0.0026
Method	1	44	12.06	0.0012
Time*Method	2	44	0.54	0.5842
Temp*Method	1	44	1.83	0.1835
Time*Temp*Method	2	44	5.46	0.0076
Dip*Method	1	44	1.24	0.2709
Time*Dip*Method	2	44	2.80	0.0715
Temp*Dip*Method	1	44	0.01	0.9114
Time*Temp*Dip*Method	1	44	0.95	0.3350

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Method	Growing method; C=conventional, O=organic
Rep	Sample replications; 3 melons

Table A.30. 'Haogen' Melons
Main effect means for ascorbic acid content[1]

Dip Treatment[NS]	$CaCl_2$ Dip[2]		No Dip
	33.41 ± 4.81		31.99 ± 7.43
Storage Temperature[NS]	21° C		10° C
	33.84 ± 7.65		31.75 ± 4.71
Storage Time[NS]	Day 1	Day 5	Day 10
	31.48 ± 6.62	33.81 ± 7.76	32.67 ± 2.69
Growing Method[**]	Conventional		Organic
	35.81 ± 6.43		29.79 ± 4.56

[1] Means represent three replications (±SD) of the ascorbic acid content (expressed as mg/100 g FW).

[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.

[NS, *, **, ***] Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.31. 'Haogen' Melons
Statistical analysis of mean calcium content

Class Level Information:

Class	Levels	Values
Dip	2	Ca ND
Method	2	C O
Rep	3	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Dip	1	6	9.60	0.0212
Method	1	6	8.51	0.0267
Dip*Method	1	6	1.79	0.2290

Key:

Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Method	Growing method; C=conventional, O=organic
Rep	Sample replications; 3 melons

Table A.32. 'Haogen' Melons
Main effect means for calcium content[1]

Dip Treatment*	$CaCl_2$ Dip[2]	No Dip
	14.08 ± 1.64	17.95 ± 1.64
Growing Method*	Conventional	Organic
	13.96 ± 1.64	18.07 ± 1.64

[1] Means represent three replications (±SE) of the calcium content (mg/100g FW).

[2] $CaCl_2$ treated melons were immersed in a 0.08M $CaCl_2$ solution (21° ± 1° C) for 20 minutes and allowed to air dry for 1 hour.

NS, *, **, ***Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Appendix V. 'Early Girl' Tomatoes Statistical Analysis

Results were analyzed using SAS Proc Mixed (Version 9.1, Cary, NC). A factorial analysis of variance was performed with differences between means assessed using significance of $p<0.05$ with the Tukey-Kramer adjustment for multiple comparisons. Fixed effects included time, temperature, and dip; replication (or panelist for sensory tests) was included as a random effect.

SAS commands used:

data (Early Girl test*);
input Time Temp $ Dip $ Rep Method $ (Early Girl test*);

datalines;
(insert data here)

proc mixed;

class Time Temp Dip Method Rep;
model (Early Girl test*)=Time|Temp|Dip|Method;
Random Rep;
lsmeans Time|Temp|Dip|Method/diff adj=tukey;

run;

*Early Girl tests analyzed include:
- appearance
- flavor
- texture
- overall acceptability
- percent weight loss
- color a* value
- color b* value
- color L* value
- pH
- soluble solids content
- total phenolic content
- antioxidant activity ($ABTS^{\cdot+}$)
- antioxidant activity ($DPPH^{+}$)
- ascorbic acid content
- calcium content

Table A.33. 'Early Girl' Tomatoes
Statistical analysis of mean appearance scores

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Panelist	78	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	391	6.69	0.0014
Temp	1	391	10.17	0.0015
Time* Temp	2	391	1.66	0.1913
Dip	1	391	1.06	0.3044
Time*Dip	2	391	0.52	0.5959
Temp*Dip	1	391	0.17	0.6810
Time*Temp*Dip	2	391	6.26	0.0021

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Panelist	40 panelists used for each evaluation; 78 unique panelists used (random effect)

Table A.34. 'Early Girl' Tomatoes
Main effect means for appearance scores[1]

Dip Treatment[NS]	$CaCl_2$ Dip[2]		No Dip
	7.95 ± 0.08		7.87 ± 0.08
Storage Temperature[**]	21° C		10° C
	8.04 ± 0.08		7.78 ± 0.08
Storage Time[**]	Day 1	Day 5	Day 10
	8.15 ± 0.10	7.75 ± 0.10	7.82 ± 0.10

[1] Means represent average scores (± SE) given by consumer panelists (n=40) based on a 9-point hedonic scale (9=highly acceptable, 1=highly unacceptable).

[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

[NS, *, **, ***] Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.35. 'Early Girl' Tomatoes
Statistical analysis of mean flavor scores

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Panelist	78	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	391	1.64	0.1944
Temp	1	391	14.17	0.0002
Time* Temp	2	391	5.38	0.0049
Dip	1	391	6.82	0.0094
Time*Dip	2	391	0.55	0.5756
Temp*Dip	1	391	5.47	0.0198
Time*Temp*Dip	2	391	9.77	<0.0001

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Panelist	40 panelists used for each evaluation; 78 unique panelists used (random effect)

Table A.36. 'Early Girl' Tomatoes
Main effect means for flavor scores[1]

Dip Treatment**	$CaCl_2$ Dip[2]	No Dip
	7.33 ± 0.12	7.01 ± 0.12
Storage Temperature**	21° C	10° C
	7.40 ± 0.12	6.94 ± 0.12

Storage Time[NS]	Day 1	Day 5	Day 10
	7.35 ± 0.14	7.06 ± 0.14	7.09 ± 0.14

[1] Means represent average scores (± SE) given by consumer panelists (n=40) based on a 9-point hedonic scale (9=highly acceptable, 1=highly unacceptable).

[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

NS, *, **, ***Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.37. 'Early Girl' Tomatoes
Statistical analysis of mean texture scores

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Panelist	78	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	391	6.66	0.0014
Temp	1	391	15.30	0.0001
Time* Temp	2	391	6.01	0.0027
Dip	1	391	0.61	0.4345
Time*Dip	2	391	1.73	0.1785
Temp*Dip	1	391	1.83	0.1774
Time*Temp*Dip	2	391	10.80	<0.0001

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Panelist	40 panelists used for each evaluation; 78 unique panelists used (random effect)

Table A.38. 'Early Girl' Tomatoes
Main effect means for texture scores[1]

Dip Treatment[NS]	$CaCl_2$ Dip[2]	No Dip
	7.21 ± 0.12	7.12 ± 0.12
Storage Temperature[***]	21° C	10° C
	7.39 ± 0.12	6.93 ± 0.12
Storage Time[**]	Day 1	Day 5	Day 10
	7.46 ± 0.14	6.86 ± 0.14	7.16 ± 0.14

[1] Means represent average scores (± SE) given by consumer panelists (n=40) based on a 9-point hedonic scale (9=highly acceptable, 1=highly unacceptable).

[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

NS, *, **, ***Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.39. 'Early Girl' Tomatoes
Statistical analysis of mean overall acceptability scores

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Panelist	78	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	391	1.35	0.2596
Temp	1	391	16.74	<0.0001
Time* Temp	2	391	3.67	0.0264
Dip	1	391	6.03	0.0145
Time*Dip	2	391	1.15	0.3178
Temp*Dip	1	391	2.44	0.1191
Time*Temp*Dip	2	391	11.61	<0.0001

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Panelist	40 panelists used for each evaluation; 78 unique panelists used (random effect)

Table A.40. 'Early Girl' Tomatoes
Main effect means for overall acceptability scores[1]

Dip Treatment*	$CaCl_2$ Dip[2]		No Dip
	7.36 ± 0.11		7.09 ± 0.11
Storage Temperature***	21° C		10° C
	7.46 ± 0.11		7.00 ± 0.11
Storage Time[NS]	Day 1	Day 5	Day 10
	7.38 ± 0.14	7.15 ± 0.14	7.15 ± 0.14

[1] Means represent average scores (± SE) given by consumer panelists (n=40) based on a 9-point hedonic scale (9=highly acceptable, 1=highly unacceptable).

[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

[NS, *, **, ***] Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.41. 'Early Girl' Tomatoes
Statistical analysis of mean percent weight loss

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Rep	3	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	22	95.25	<0.0001
Temp	1	22	173.10	<0.0001
Time* Temp	2	22	28.39	<0.0001
Dip	1	22	30.79	<0.0001
Time*Dip	2	22	7.48	0.0033
Temp*Dip	1	22	4.81	0.0392
Time*Temp*Dip	2	22	2.15	0.1400

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Rep	Sample replications; 3 tomatoes

Table A.42. 'Early Girl' Tomatoes
Main effect means for percent weight loss[1]

Dip Treatment***	$CaCl_2$ Dip[2]		No Dip
	3.69 ± 0.18		2.32 ± 0.18
Storage Temperature***	21° C		10° C
	4.64 ± 0.18		1.37 ± 0.18
Storage Time***	Day 1	Day 5	Day 10
	1.18 ± 0.22	2.53 ± 0.22	5.30 ± 0.22

[1] Means represent three replications (±SE) of the percent weight change. (Calculated from [initial weight in grams-final weight in grams)]/initial weight in grams x 100.)

[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

NS, *, **, ***Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.43. 'Early Girl' Tomatoes
Statistical analysis of mean color a* values

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Rep	9	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	88	1.33	0.2708
Temp	1	88	3.44	0.0672
Time* Temp	2	88	1.16	0.3181
Dip	1	88	0.02	0.9010
Time*Dip	2	88	2.50	0.0878
Temp*Dip	1	88	6.30	0.0139
Time*Temp*Dip	2	88	6.60	0.0021

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Rep	Sample replications; 3 readings took of 3 tomato samples (9 results)

Table A.44. 'Early Girl' Tomatoes
Main effect means for color a* values[1]

Dip Treatment[NS]	$CaCl_2$ Dip[2]	No Dip
	35.80 ± 0.30	35.75 ± 0.30
Storage Temperature[NS]	21° C	10° C
	36.12 ± 0.30	35.42 ± 0.30

Storage Time[NS]	Day 1	Day 5	Day 10
	35.61 ± 0.36	36.20 ± 0.36	35.50 ± 0.36

[1] Means represent the average (±SE) a* value of the interior melon color, based on three readings of three replications.

[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

[NS, *, **, ***] Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.45. 'Early Girl' Tomatoes
Statistical analysis of mean color b* values

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Rep	9	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	88	26.82	<0.0001
Temp	1	88	21.63	<0.0001
Time* Temp	2	88	4.42	0.0149
Dip	1	88	5.27	0.0241
Time*Dip	2	88	1.39	0.2552
Temp*Dip	1	88	0.76	0.3856
Time*Temp*Dip	2	88	2.95	0.0575

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Rep	Sample replications; 3 readings took of 3 tomato samples (9 results)

Table A.46. 'Early Girl' Tomatoes
Main effect means for color b* values[1]

Dip Treatment*	$CaCl_2$ Dip[2]		No Dip
	28.59 ± 0.24		27.80 ± 0.24
Storage Temperature***	21° C		10° C
	27.40 ± 0.24		28.99 ± 0.24
Storage Time***	Day 1	Day 5	Day 10
	26.46 ± 0.30	29.36 ± 0.30	28.76 ± 0.30

[1] Means represent the average (±SE) b* value of the interior melon color, based on three readings of three replications.

[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

NS, *, **, ***Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.47. 'Early Girl' Tomatoes
Statistical analysis of mean color L* values

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Rep	9	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	88	10.17	<0.0001
Temp	1	88	30.02	<0.0001
Time* Temp	2	88	2.94	0.0578
Dip	1	88	0.24	0.6265
Time*Dip	2	88	5.77	0.0044
Temp*Dip	1	88	0.65	0.4239
Time*Temp*Dip	2	88	3.72	0.0281

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Rep	Sample replications; 3 readings took of 3 tomato samples (9 results)

Table A.48. 'Early Girl' Tomatoes
Main effect means for color L* values[1]

Dip Treatment[NS]	$CaCl_2$ Dip[2]		No Dip
	36.80 ± 0.56		37.18 ± 0.56
Storage Temperature[***]	21° C		10° C
	34.83 ± 0.56		39.15 ± 0.56
Storage Time[***]	Day 1	Day 5	Day 10
	38.75 ± 0.68	34.56 ± 0.68	37.67 ± 0.68

[1] Means represent the average (±SE) L* value of the interior melon color, based on three readings of three replications.

[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

[NS, *, **, ***] Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.49. 'Early Girl' Tomatoes
Statistical analysis of mean pH

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Rep	3	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	22	0.90	0.4207
Temp	1	22	4.77	0.0400
Time* Temp	2	22	1.01	0.3808
Dip	1	22	0.73	0.4022
Time*Dip	2	22	0.00	1.0000
Temp*Dip	1	22	0.23	0.6398
Time*Temp*Dip	2	22	0.90	0.4207

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Rep	Sample replications; 3 tomatoes

Table A.50. 'Early Girl' Tomatoes
Main effect means for pH values[1]

Dip Treatment[NS]	$CaCl_2$ Dip[2]		No Dip
	4.22 ± 0.04		4.27 ± 0.04
Storage Temperature*	21° C		10° C
	4.31 ± 0.04		4.18 ± 0.04
Storage Time[NS]	Day 1	Day 5	Day 10
	4.28 ± 0.05	4.19 ± 0.05	4.28 ± 0.05

[1] Means represent three replications (±SE) of pH values.

[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

NS, *, **, ***Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.51. 'Early Girl' Tomatoes
Statistical analysis of mean soluble solids content (°Brix)

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Rep	3	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	22	1.39	0.2699
Temp	1	22	5.78	0.0250
Time* Temp	2	22	0.47	0.6300
Dip	1	22	7.48	0.0121
Time*Dip	2	22	0.03	0.9732
Temp*Dip	1	22	2.28	0.1456
Time*Temp*Dip	2	22	1.18	0.3267

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Rep	Sample replications; 3 tomatoes

Table A.52. 'Early Girl' Tomatoes
Main effect means for soluble solids content[1]

Dip Treatment*	$CaCl_2$ Dip[2]		No Dip
	3.95 ± 0.21		4.59 ± 0.21
Storage Temperature*	21° C		10° C
	4.56 ± 0.21		3.99 ± 0.21
Storage Time[NS]	Day 1	Day 5	Day 10
	4.14 ± 0.24	4.13 ± 0.24	4.55 ± 0.24

[1] Means represent three replications (±SE) measured using a refractometer (expressed as °Brix).

[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

[NS, *, **, ***] Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.53. 'Early Girl' Tomatoes
Statistical analysis of mean total phenolic content

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Rep	3	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	22	0.64	0.5369
Temp	1	22	1.36	0.2555
Time* Temp	2	22	0.14	0.8710
Dip	1	22	0.01	0.9409
Time*Dip	2	22	1.21	0.3165
Temp*Dip	1	22	0.18	0.6758
Time*Temp*Dip	2	22	0.20	0.8176

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Rep	Sample replications; 3 tomatoes

Table A.54. 'Early Girl' Tomatoes
Main effect means for total phenolic content[1]

Dip Treatment[NS]	$CaCl_2$ Dip[2]		No Dip
	76.14 ± 4.59		76.62 ± 4.59
Storage Temperature[NS]	21° C		10° C
	80.17 ± 4.59		72.59 ± 4.59
Storage Time[NS]	Day 1	Day 5	Day 10
	71.40 ± 5.62	80.15 ± 5.62	77.58 ± 5.62

[1] Means represent three replications (±SE) of the total phenolic content (expressed as mg GAE/100 g FW).

[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

[NS, *, **, ***] Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.55. 'Early Girl' Tomatoes
Statistical analysis of mean antioxidant activity ($ABTS^{\bullet+}$)

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Rep	3	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	22	7.29	0.0037
Temp	1	22	0.15	0.7056
Time* Temp	2	22	0.64	0.5375
Dip	1	22	4.25	0.0512
Time*Dip	2	22	9.14	0.0013
Temp*Dip	1	22	11.25	0.0029
Time*Temp*Dip	2	22	4.75	0.0192

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Rep	Sample replications; 3 tomatoes

Table A.56. 'Early Girl' Tomatoes
Main effect means for antioxidant activity ($ABTS^{\bullet+}$)[1]

Dip Treatment[NS]	$CaCl_2$ Dip[2]		No Dip
	142.88 ± 7.88		119.89 ± 7.88
Storage Temperature[NS]	21° C		10° C
	133.52 ± 7.88		129.25 ± 7.88
Storage Time[**]	Day 1	Day 5	Day 10
	159.33 ± 9.65	107.72 ± 9.65	127.10 ± 9.65

[1] Means represent three replications (±SE) of the $ABTS^{\bullet+}$ antioxidant activity test (expressed as µmole TEAC/100 g FW).

[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

[NS, *, **, ***] Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.57. 'Early Girl' Tomatoes
Statistical analysis of mean antioxidant activity ($DPPH^+$)

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Rep	3	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	22	0.73	0.4911
Temp	1	22	0.19	0.6692
Time* Temp	2	22	2.11	0.1447
Dip	1	22	0.68	0.4181
Time*Dip	2	22	0.13	0.8825
Temp*Dip	1	22	0.67	0.4208
Time*Temp*Dip	2	22	0.75	0.4823

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Rep	Sample replications; 3 tomatoes

Table A.58. 'Early Girl' Tomatoes
Main effect means for antioxidant activity ($DPPH^+$)[1]

Dip Treatment[NS]	$CaCl_2$ Dip[2]		No Dip
	179.49 ± 13.16		190.67 ± 13.16
Storage Temperature[NS]	21° C		10° C
	188.01 ± 13.16		182.15 ± 13.16
Storage Time[NS]	Day 1	Day 5	Day 10
	184.37 ± 14.80	195.46 ± 14.80	175.41 ± 14.80

[1] Means represent three replications (±SE) of the $DPPH^{\bullet+}$ antioxidant activity test (expressed as µmole TEAC/100 g FW).

[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

[NS, *, **, ***] Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.59. 'Early Girl' Tomatoes
Statistical analysis of mean ascorbic acid content

Class Level Information:

Class	Levels	Values
Time	3	1 5 10
Temp	2	A R
Dip	2	Ca ND
Rep	3	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Time	2	22	2.04	0.1545
Temp	1	22	14.74	0.0009
Time* Temp	2	22	1.49	0.2473
Dip	1	22	3.41	0.0783
Time*Dip	2	22	2.02	0.1563
Temp*Dip	1	22	8.05	0.0096
Time*Temp*Dip	2	22	0.91	0.4153

Key:

Time	Length of storage; day 1, day 5, day 10
Temp	Storage temperature; A=21° C, R=10° C
Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Rep	Sample replications; 3 tomatoes

Table A.60. 'Early Girl' Tomatoes
Main effect means for ascorbic acid content[1]

Dip Treatment[NS]	$CaCl_2$ Dip[2]		No Dip
	45.65 ± 1.88		50.55 ± 1.88
Storage Temperature[**]	21° C		10° C
	53.20 ± 1.88		43.00 ± 1.88
Storage Time[NS]	Day 1	Day 5	Day 10
	45.12 ± 2.30	47.56 ± 2.30	51.62 ± 2.30

[1] Means represent three replications (±SE) of the ascorbic acid content (expressed as mg/100 g FW).

[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

[NS, *, **, ***] Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.

Table A.61. 'Early Girl' Tomatoes
Statistical analysis of mean calcium content

Class Level Information:

Class	Levels	Values
Dip	2	Ca ND
Rep	3	(random effect)

Type 3 Tests of Fixed Effects:

Effect	Num DF	Den DF	F Value	Pr > F
Dip	1	2	3.01	0.2250

Key:

Dip	Dip treatment; Ca=$CaCl_2$ dip, ND=no dip
Rep	Sample replications; 3 tomatoes

Table A.62. 'Early Girl' Tomatoes
Main effect means for calcium content[1]

Dip Treatment[NS]	$CaCl_2$ Dip[2]	No Dip
	14.72 ± 0.78	12.81 ± 0.78

[1] Means represent three replications (±SE) of the calcium content (mg/100g FW).

[2] $CaCl_2$ treated tomatoes were immersed in a 0.06M $CaCl_2$ solution (21° ± 1° C) for 15 minutes and allowed to air dry for 1 hour.

[NS, *, **, ***] Non-significant or significant at $p \leq 0.05$, 0.01, or 0.001, respectively.