

Comparison of calcium chloride and calcium lactate effectiveness in maintaining shelf stability and quality of fresh-cut cantaloupes

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Abstract

Fresh-cut cantaloupe cylinders were dipped for 1 min in 2.5% solutions of either calcium chloride (CaCl_2) at $\sim 25^\circ\text{C}$ or calcium lactate at ~ 25 and 60°C . Firmness, microbiological (total plate count, yeast and mold, and microaerophilic bacteria) and sensory characteristics, respiration (CO_2) and ethylene (C_2H_4) production were evaluated during 12 days storage at 5°C and 95% relative humidity air. Both calcium salts maintained melon firmness throughout cold storage. CaCl_2 , but not calcium lactate, imparted undesirable bitterness to the fruit pieces. No significant differences were observed in the physiological behavior of the treated fresh-cut compared to just-cut samples. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

Shelf life extension of fresh-cut products is relevant for the industry because of its economic impact. It is important that treatments applied to fresh-cut fruits help maintain their appearance (i.e. color, integrity, absence of excessive drippings in the package), as this is the first characteristic a consumer perceives as quality of the product. However, parallel to maintaining adequate appearance and texture of the product, potential

treatments should not negatively affect fresh-cut product flavor or jeopardize microbiological safety.

Fresh-cut cantaloupe shelf life may be extended by using modified atmospheres (Madrid, 1993; Nguyen-the and Carlin, 1994; Cantwell et al., 1996; O'Connor-Shaw et al., 1996) or calcium chloride dips alone or in combination with heat treatments (Luna-Guzmán et al., 1999). Calcium chloride is commonly used industrially as a firming agent for canned tomatoes and cucumber pickles. Other products in which texture is improved or maintained by calcium chloride dips include whole apples (Sams et al., 1993), whole hot peppers (Mohammed et al., 1991), whole and

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sliced strawberries (Rosen and Kader, 1989; García et al., 1996), diced tomatoes (Floros et al., 1992), and whole peaches (Wills and Mahendra, 1989). The firming effect provided by calcium chloride can be explained by: (1) the complexing of calcium ions with cell wall and middle lamella pectin (Grant et al., 1973; Van-Buren, 1979; Morris, 1980); (2) stabilization of the cell membrane by the calcium ions (Picchioni et al., 1995); and/or (3) effect of calcium on cell turgor pressure (Mignani et al., 1995).

Heat treatments have also resulted in tissue firming in products such as whole potatoes (Bartolome and Hoff, 1972), cherries (Van-Buren, 1974), tomatoes (Floros et al., 1992), potato strips (Aguilar et al., 1997), and whole melons (Barkai-Golan et al., 1993). Firming effects obtained from heat treatments alone or combined with calcium chloride treatments may be attributed to the action of heat-activated pectin methyl esterase (PME) and/or to increased calcium diffusion into the tissue (Bartolome and Hoff, 1972; García et al., 1996).

Although beneficial for product texture, the use of calcium chloride may impart bitterness or flavor differences (Olsen et al., 1966; Bolin and Huxsoll, 1989; Monsalve-Gonzalez et al., 1993). Following the dip treatment, a residual amount of calcium chloride remains on the surface of the product, thus increasing likeliness of bitterness detection by the consumer. Calcium lactate represents an alternative calcium source. Calcium lactate (0.5–2%) has been used as a firming agent for processed strawberries (Morris et al., 1985; Main et al., 1986), and grapefruit (Baker, 1993) without reported flavor differences. However, to the best of our knowledge, its potential for use in fresh-cut products has not been previously reported.

The objectives of this study were to compare the effects of calcium lactate (alone or in combination with heat) with calcium chloride dips on firmness, microbiological (total plate count, yeast and mold, and microaerophilic bacteria) and sensory characteristics, respiration (CO_2) and ethylene (C_2H_4) production of fresh-cut cantaloupe.

2. Materials and methods

2.1. Sample preparation

Cantaloupe melons (*Cucumis melo* L. var. *reticulatus*) were harvested ripe (3/4 to full slip) and stored for no longer than 72 h at 2.5°C and 95% RH before samples were prepared. Fruit sampling was based on physical appearance: background color, net development, and abscission of the stem. All cutting utensils used (knife, cork borer and cutting board) were washed with soap and water and rinsed with 1000-ppm sodium hypochlorite solution prior to use. Fruit were washed in soap and water, rinsed clean and air-dried.

Only the central part of the fruit was used to obtain melon cylinders, therefore fruit diameter limited the possible number of applicable treatments to five. Two different experiments were performed to instrumentally evaluate treatment effects on the firmness, microbiology, CO_2 and C_2H_4 production rates of fresh-cut cantaloupe: experiment 1 evaluated the effects of heat treatments and calcium lactate alone or combined with heat, and experiment 2 evaluated the effects of calcium chloride, calcium lactate and heat alone. A third experiment was performed to evaluate the effects of calcium chloride, calcium lactate and heat treatments on the sensory characteristics of fresh-cut cantaloupe.

2.2. Sampling design and treatment application

2.2.1. Sampling design

Due to the high inherent variability in cantaloupe firmness, a systematic sampling design was used instead of a randomized one. The use of this sampling design increases the power of the subsequent analysis of variance because it subtracts the inherent variability from the error term. For each experiment, melon cylinders corresponding to all treatments, replicates, and evaluation times were obtained from the same melon. From each of the seven fruit used in each experiment, five rings of ~2 cm thickness were cut from the equatorial region, discarding both blossom and stem ends. Cylinders were obtained from melon

rings using a 1.8-cm diameter cork borer. Cylinders were dipped in a 50-ppm sodium hypochlorite solution (commercial bleach — 5.25% sodium hypochlorite w/w), drained, and placed on a plastic tray covered with cheesecloth which had been dampened with 1000-ppm chlorinated water. A total of 12 melon cylinders were obtained per ring and marked using a paper tag covered with transparent tape and anchored with a sterile sewing pin. Samples for replicates and storage times came from adjacent cylinders in the same ring, while samples for different treatments came from adjacent rings.

For sensory evaluation, experimental samples were obtained from a different set of fruit. A total of four or five 2-cm wide rings were cut from the equatorial region of each fruit to obtain 48 cylinders. Before treatment application, cylinders were sanitized as described above.

2.2.2. Treatment application

In experiment 1, cylinders were dipped in water or 2.5% calcium lactate (Sigma, St Louis, MO, USA) (w/w) for 1 min at either room temperature (RT ~ 25°C) or 60°C using a temperature controlled water bath (model 730, Fisher Scientific, New Jersey, USA). In experiment 2, cylinders were dipped in water at RT, 2.5% calcium chloride or 2.5% calcium lactate at either RT or 60°C for 1 min. A non-sanitized control was also included for microbiological analysis in experiment 2.

In experiment 1, a total of 60 cylinders were obtained from each melon and further divided into two sets: set 'A' (40 cylinders) and set 'B' (20 cylinders). Set 'A' was used to evaluate texture and CO₂ and C₂H₄ production, while set 'B' was used to evaluate microbial growth. Therefore, a total of 280 cylinders were available for set 'A' (40 cylinders/melon × 7 melons). Each of the five treatments was applied to 56 cylinders (7 melons × 2 replicates × 4 storage times) by dipping samples into 6 l of the treatment solutions. Set 'B' consisted of 20 cylinders per melon, or a total of 140 (20 × 7 melons).

Experiment 2 followed the same design as experiment 1, but included 24 cylinders per melon for set 'B' (total of 216 = 24 × 9). The four extra

cylinders were just-cut and not sanitized. Melon cylinders were drained and cooled (if heat treated) to ~ 20°C in a -20°C freezer and stored as described below.

Experimental samples for sensory evaluation were dipped in 1 or 2.5% calcium chloride or calcium lactate solutions at RT, and 1% calcium solutions at 60°C for 1 min. Samples were evaluated the same day they were prepared.

2.3. Storage

After treatment, the cylinders were drained, put into labeled glass containers (236.6 ml) corresponding to each storage time, and transferred to a 5°C cold room. Glass containers, lids and connecting tubing were rinsed with 1000-ppm sodium hypochlorite solution prior to use. Containers were connected to a humidified air-flow system (95% RH) by using glass capillaries and rubber tubing. Melon cylinders were kept under high humidity conditions to avoid surface dehydration that could possibly introduce artifacts into the firmness measurements. Air-flow rates used were 1.50, 1.68 or 2.80 l h⁻¹ (depending on the particular experiment and therefore the amount of sample put into the containers) so that the maximum accumulation of CO₂ was 0.5%. An on-line filter (Gelman, Ann Arbor, MI) with a 25-mm diameter 4-μm polycarbonate membrane (Nucleopore, Pleasanton, CA) was used on each connecting tube to avoid possible airborne contamination. Jars with samples corresponding to microbiological and firmness analysis were withdrawn from storage at each evaluation period. For experiment 2, two intact fruit were also placed in containers and connected to the humidified air-flow system. For sensory analysis, samples were kept at 25°C for no longer than 6 h covered with cheese cloth previously dampened with 1000-ppm sodium hypochlorite solution.

2.4. Texture analysis

Tissue firmness was evaluated by a puncture test on days 0, 4, 8, and 12 of the storage period using the TA.XT2 Texture Analyzer (Texture Technologies, Scarsdale, NY) with a 25-kg load

cell. The test was performed on the flat side of each cylinder at the end closest to the blossom end of the melon. During the puncture test, a 5-mm diameter flat-head stainless steel cylindrical probe traveled 30% of the height of the cylinder at 1 mm s^{-1} . Firmness measurements were taken as the area under the curve from 0- to 6-mm strain in the puncture test (Nm).

2.5. Sensory analysis

Two paired-comparison tests were first used to determine that differences in bitterness and firmness of calcium chloride and calcium lactate treated samples could be detected by untrained consumers. Samples were put in 30-ml plastic cups and labeled with three-digit random number codes. For each calcium chloride or calcium lactate test, two sessions were performed. During the calcium chloride sessions, 19 untrained panelists (six males, 13 females, ages 20–32) were presented with a total of 24 pairs: 12 pairs for firmness evaluation and 12 pairs for bitterness evaluation. These 12 pairs were three replicates of four combinations: just-cut versus 1%/RT, just-cut versus 2.5%/RT, just-cut versus 1%/60°C, and 1%/RT versus 1/60°C. For calcium lactate sessions, 18 panelists (seven males, 11 females, ages 20–30) were presented with a total of 30 pairs: 15 pairs for firmness evaluation and 15 pairs for bitterness evaluation. The 15 pairs were three replicates of five combinations: just-cut versus 0.5%/RT, just-cut versus 1%/RT, just-cut versus 2.5%/RT, just-cut versus 1%/60°C, and 1%/RT versus 1%/60°C. The order of presentation was randomized to eliminate position and other biases.

A descriptive analysis was also performed using six different trained panelists (four males, two females, ages 24–32, consumers of cantaloupe) following a modified version of the QDA[®] method (Stone et al., 1974). Testing was done on selected products, the panel leader functioned as an orientator more than as a training facilitator, and no standards were used. During five orientation sessions, panelists developed aroma, taste and texture attributes and defined corresponding evaluation procedures by tasting fresh-cut cantaloupe from melons either locally grown or pur-

chased from a local retailer. For familiarization purposes, some fruit pieces were dipped in calcium chloride or calcium lactate solutions of different concentrations (0–5%). A total of three additional sessions were conducted for evaluation of experimental samples. Melon cylinders were treated with 1 or 2.5% calcium chloride or calcium lactate solutions for 1 min at RT, or just-cut (control) and put in 30-ml plastic cups labeled with three-digit random codes. Panelists in individual booths under white light were presented with one tray at a time for evaluation of each attribute. Each tray had five cups (one cup per treatment plus the control) labeled with a three-digit random number code different for all samples to avoid judge bias. Cups containing samples for melon flavor evaluation were covered with a small watch glass to retain volatiles for at least 5 min before evaluation. Panelists were provided with water for mouth rinsing between samples and with a score sheet. A 10-cm non-anchored scale was used for each attribute with each judge marking the corresponding intensity of the attribute for all samples. For all attributes, the left side of the scale represented low intensity while the right side represented high intensity.

2.6. Microbiological analysis

2.6.1. Sample preparation

A total of 25 g randomly taken from different cylinders were blended with 225 ml of 2% peptone water for 2 min under sterile conditions. A series of dilutions were prepared as needed according to standard procedures.

2.6.2. Spread plates

From each dilution, 0.1-ml aliquots were aseptically pipetted onto duplicate plates. A glass spreader was used to evenly distribute the inoculum on the plates.

2.6.3. Tubes

From each dilution of the non-sanitized samples from experiment 2, 1-ml aliquots were inoculated in series of three tubes.

2.6.4. Media and incubation conditions

Standard methods agar (SMA) was used for total plate count (TPC) plates, acidified potato dextrose agar (PDA) was used for yeast and mold (YM) plates and lactobacilli deMan, Rogose and Sharpe agar (MRS) was used for microaerophilic bacteria (lactic acid bacteria, LAB) plates and tubes. Inoculation conditions were: 30°C for 48 h for TPC and LAB, and RT for 24 h for YM. LAB plates were put in a BBL GasPak[®] jar with an Anaerobic System envelope with catalyst (Becton Dickinson Microbiology Systems, Cockeysville, MD). All media were from Difco (Difco, Detroit, MI).

2.7. Gas production

Respiration (CO₂) and ethylene (C₂H₄) production rates were determined on duplicate samples every 12 h throughout the storage period by sampling the gas outlets of jars with samples corresponding to the last evaluation day, i.e. day 12. CO₂ concentrations were measured by injecting a 1-ml gas sample into an infrared gas analyzer (model PIR-2000, Horiba, Japan) using N₂ as the carrier gas. Ethylene concentrations were determined by injecting a 1-ml gas sample into a gas chromatograph (model 8000, Carle Instruments, Fullerton, CA) equipped with a NaCl modified Alumina F1 60/80 mesh column and a flame ionization detector interfaced with an integrator (model SP4270, Spectra-Physics, San Jose, CA).

2.8. Statistical analysis

A three-factor mixed model analysis of variance was performed with melon and melon interaction terms as random effects and treatments and evaluation days as fixed effects using the GLM procedure for firmness results. When significantly different ($P < 0.05$), means were compared using Fisher's LSD test ($P < 0.05$). Results from the paired comparison sensory test were treated as one-tailed binomial tests, except when comparing 1%/RT versus 1%/60°C which were treated as two-tailed (O'Mahony, 1985, Tables G.4a and G.4b). Intensity scores from the descriptive analysis were assigned a numerical value and analyzed

by ANOVA. Correlation analysis was performed on the instrumental and sensory data. GLM, ANOVA and correlation analysis were performed using the statistical software SAS (SAS Institute, 1989).

3. Results and discussion

3.1. Firmness

A calcium lactate dip applied at either 25 or 60°C resulted in significantly firmer samples (~25–33%) than a water dip during storage (Fig. 1). Heat treatments alone affected sample firmness during storage only on day 12 in experiment 1. Although initially higher than water dipped samples, firmness of just-cut samples decreased faster than all other samples throughout the 12 days of storage in both experiments. Calcium chloride and calcium lactate provided the same firming effect initially, but maintenance of firmness tended to be higher in calcium lactate treated samples throughout storage (Fig. 2). A firming effect by a combination of calcium chloride dip and heat treatment has also been shown in fresh-cut melons by Luna-Guzmán et al. (1999).

The effect of calcium in tissue firmness is generally explained by its complexing to cell wall and middle lamella polygalacturonic acid residues imparting improvement of structural integrity (Grant et al., 1973; Van-Buren, 1979; Morris, 1980). Increasing firmness during low temperature blanching of green beans and carrots has also been correlated with PME-catalyzed reduction in pectin methyl esterification (Stanley et al., 1995). It is well known that PME is activated in the 55–70°C range (Bartolome and Hoff, 1972). The deesterified pectin chains may crosslink with either endogenous calcium or added (exogenous) calcium to form a tighter, firmer structure (Grant et al., 1973). However, calcium ions may also impact tissue firmness by contributing to an increased membrane integrity and the consequent maintenance or increase of cell turgor pressure (Christiansen and Foy, 1979; Mignani et al., 1995).

3.2. Sensory analysis

Difference tests showed that 1 or 2.5% calcium chloride treated samples were scored as significantly ($P < 0.1$) firmer and more bitter than just-cut samples. In other words, at least 15 out of 19 judges consistently selected the 1 or 2.5% calcium chloride treated samples (in at least five out of the six replications) as being firmer or more bitter than just-cut samples. However, samples treated with 1% calcium chloride/60°C were scored as significantly ($P < 0.1$) more bitter but not firmer than just-cut samples. Panelists were not able to detect significant differences in bitter taste and firmness between 1% calcium chloride treated samples at either 25 or 60°C.

Calcium lactate treated samples at any of the assayed concentrations were less bitter than non-treated samples, and only 1% calcium lactate samples were firmer than just-cut samples ($P < 0.07$). Additionally, bitterness of heat treated samples

(1% calcium lactate/60°C) was not significantly different than either 1% calcium lactate/25°C or controls. These results indicate that 1% dips using either calcium salt maintain the firmness of fresh-cut cantaloupes. However, calcium chloride dips impart bitterness, while calcium lactate dips do not. Neither bitterness nor firmness increased with increased dip temperatures.

The trained panel developed six attributes to describe fresh-cut cantaloupe quality: melon flavor, sweetness, bitterness, hardness, crunchiness, and moisture content (Table 1). Highly significant differences were obtained for bitterness. However, the attributes, crunchiness and sweetness, were not different among samples analyzed (1-min dips in 1 and 2.5% calcium chloride or calcium lactate at RT, and just-cut) (data not shown). Calcium chloride treated samples at either concentration were significantly more bitter than calcium lactate treated or just-cut samples (Table 2). Typical melon flavor was significantly

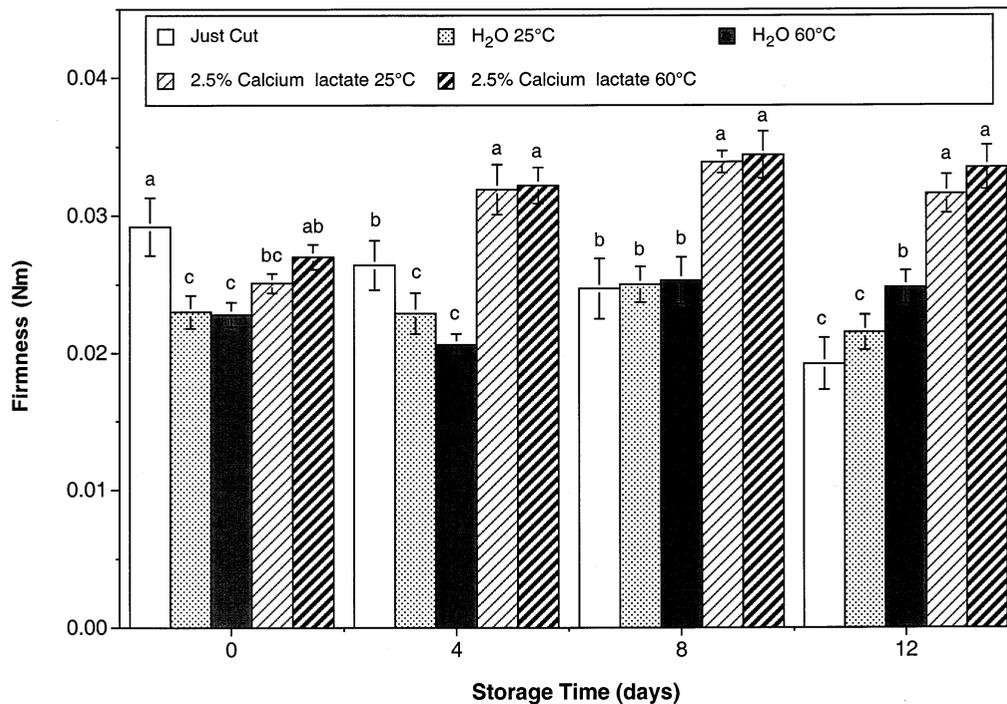


Fig. 1. Firmness (Nm) of fresh-cut cantaloupe from experiment 1, dipped in water or 2.5% calcium lactate for 1 min at 25 or 60°C, and stored under air at 5°C and 95% RH. For each evaluation day, columns with same letter are not significantly different ($P < 0.05\%$). $n = 14$, vertical bars indicate $2 \times$ S.E.

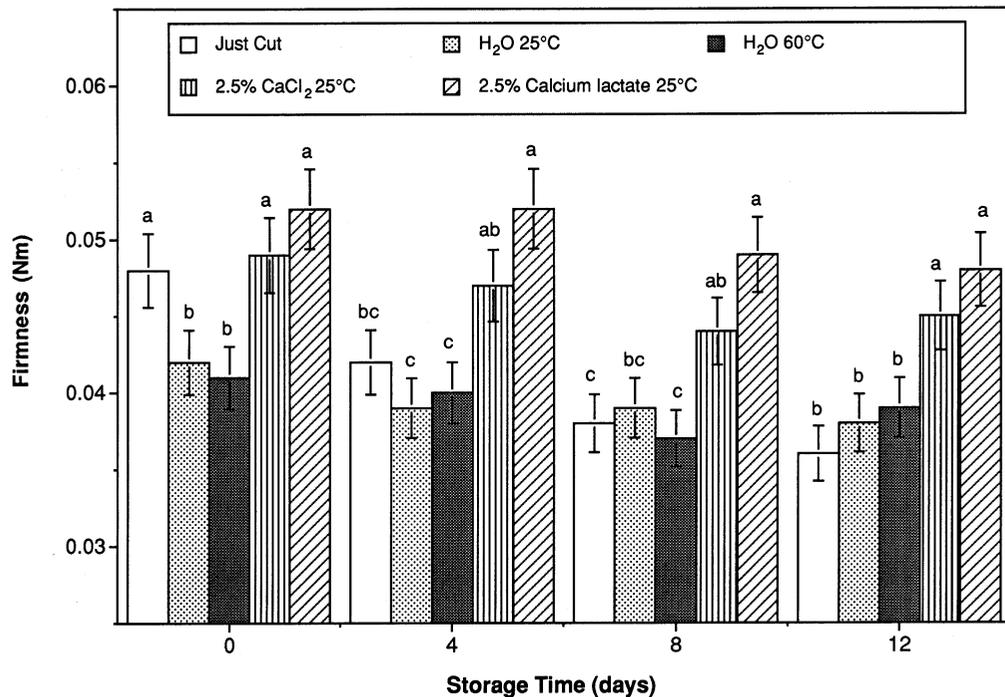


Fig. 2. Firmness (Nm) of fresh-cut cantaloupe from experiment 2, dipped in 2.5% calcium lactate or 2.5% calcium chloride for 1 min, and stored under air at 5°C and 95% RH. For each evaluation day, columns with same letter are not significantly different ($P < 0.05\%$). $n = 14$, vertical bars indicate $2 \times$ S.E.

Table 1
Sensory attributes developed during descriptive analysis of fresh-cut melon

Attribute	Definition	Assessment
<i>Aroma</i>		
Melon flavor	Typical melon flavor	Immediately after removing watch glass from cup
<i>Taste</i>		
Sweetness	Natural melon sweetness	Throughout chewing process
Bitterness	Foreign bitter taste	Throughout chewing process
<i>Texture</i>		
Crunchiness	Force required to bite through melon cylinder	Biting with molars on diameter of melon cylinder
Hardness	Initial force required to bite throughout melon cylinder	Biting with front teeth on diameter of melon cylinder
Moisture content	Amount of moisture released by the melon cylinder when biting on it	Throughout chewing process

more detectable in 1% calcium lactate treated samples as compared to 1% calcium chloride ones ($P < 0.05$). The firming effect was similar after

2.5% calcium lactate, 1 or 2.5% calcium chloride treatments. A significantly lower moisture content ($P < 0.05$) was obtained using 2.5% calcium chlo-

ride, 1% calcium lactate or 2.5% calcium lactate; only 1% calcium chloride dipped samples did not have a significantly different moisture content as just-cut samples.

These results may indicate that the firming effect is accompanied by improved water holding capacity due to a more crosslinked pectin network; thus, less juice is released when biting through calcium treated melon pieces. Additionally, higher water holding capacity could be related to increased firmness due to higher turgor pressure which is supported by a significant correlation between moisture content and hardness attributes (data not shown).

3.3. Microbiology

Typical growth behavior was observed in the total plate count (TPC) test (Fig. 3) with relatively low initial counts and no effect from any treatment compared to the control throughout storage. Yeast and mold (YM) counts remained at low levels up to day 8 when counts started to increase, particularly in water at 60°C. By day 12, the lowest populations were those from 2.5% calcium lactate at 60°C and water at RT. The highest final counts were in the just-cut sample followed by 2.5% calcium lactate at RT. The growth of lactic acid bacteria (LAB) showed a similar trend to that of TPC, with the lowest count corresponding to water at 60°C probably due to competition with YM. Microbial counts did not exceed 10^9 and were similar to counts obtained in other fresh-cut products (Nguyen-the and Carlin, 1994).

Because of the low pH in fruit, microflora are usually restricted to fungi and lactic acid bacteria. However, mature cantaloupe pH is close to neutral (~ 6.5). Therefore, they can serve as an excellent medium for the growth of bacteria, especially at warmer temperatures (Golden et al., 1993; Del Rosario, 1995). If cantaloupes are stored under anaerobic conditions, bacteria and mold could raise the pH and potentially allow *Clostridium botulinum* growth (Lund, 1983). Low temperature storage may select for psychrotrophic microorganisms such as *Aeromonas hydrophila* and *Listeria monocytogenes*. *A. hydrophila* has a high CO₂ requirement (Sinell, 1980) and it is more likely to grow under cold modified atmosphere storage.

In theory, microbial growth (in particular human pathogens) may be inhibited by competing bacteria such as LAB or by naturally occurring antimicrobials released during the cutting operations. Lactic acid starter cultures and calcium salts of lactic acid can lower intracellular pH or reduce water activity (Shelef, 1994) and provide a protective antimicrobial barrier against food borne pathogens in milk and meat products (Schillinger and Lücke, 1990; El-Gazaar et al., 1991; Weaver and Shelef, 1993). It has also been hypothesized that antimicrobial substances could be released from the plant cells during cutting operations (Nguyen-the and Carlin, 1994). Due to the exploratory nature of our microbial analysis, further studies should be performed to investigate possible microbial and/or pathogenic inhibition by competing LAB or calcium salts of lactic acid in fresh-cut melons. We consider that the most

Table 2
Mean sensory scores of fresh-cut cantaloupe dipped in calcium chloride or calcium lactate solutions*

Treatment	Sensory attribute			
	Bitterness	Flavor	Hardness	Moisture content
Just-cut	2.6 ^c	4.6 ^{a,b}	3.4 ^c	5.9 ^{a,b}
1.0% Calcium chloride	4.8 ^{a,b}	3.1 ^b	5.1 ^{a,b}	6.4 ^a
2.5% Calcium chloride	5.8 ^a	4.2 ^{a,b}	4.8 ^{a,b,c}	4.8 ^{b,c}
1.0% Calcium lactate	2.7 ^c	5.6 ^a	4.7 ^{b,c}	4.5 ^c
2.5% Calcium lactate	3.4 ^{b,c}	4.7 ^{a,b}	6.0 ^a	4.5 ^{b,c}

* Under each attribute, means followed by same letter are not significantly different ($P < 0.05$). For each attribute a higher number represents higher intensity on a 0–10 scale.

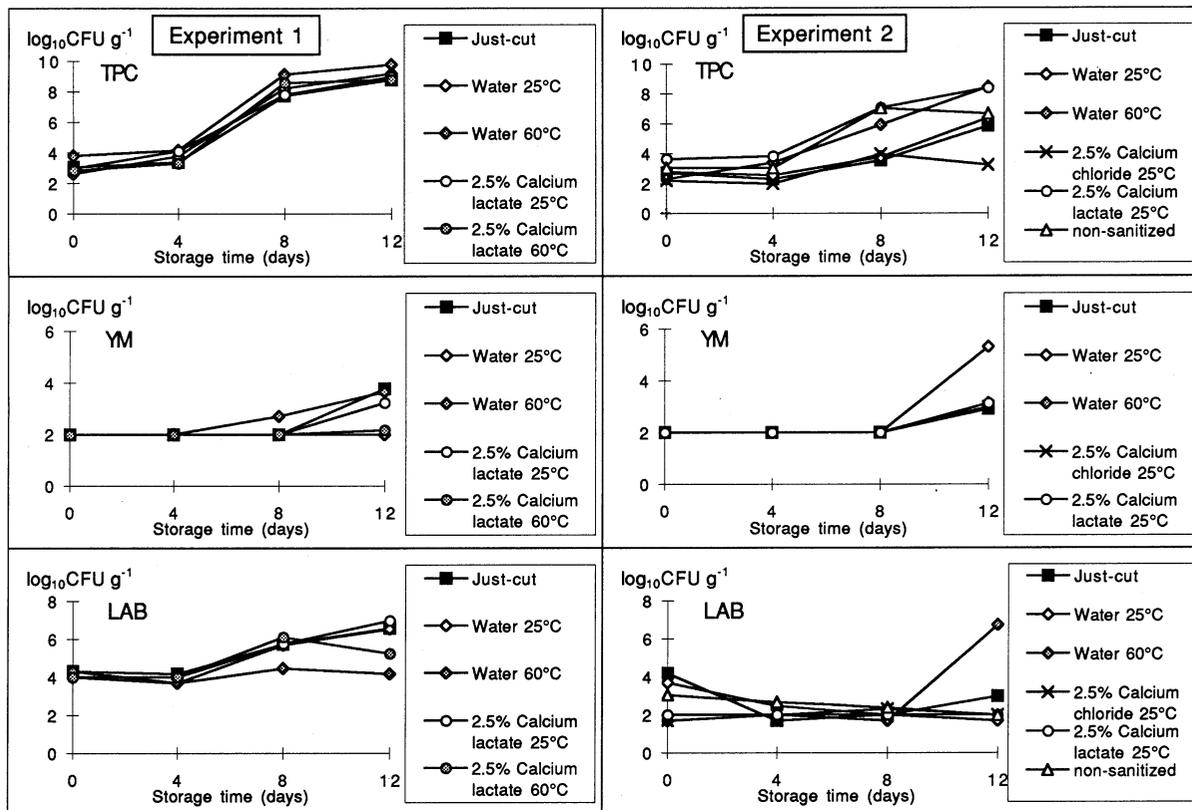


Fig. 3. Microbial counts ($\log_{10} \text{CFU g}^{-1}$) of fresh-cut cantaloupe from experiments 1 and 2, and stored under air at 5°C and 95% RH during 12 days.

important factor that kept microbial growth at a relatively low rate in our samples was the constant temperature control at 5°C during storage, combined with good sanitation practices. However, these conditions are rarely found commercially.

In the case of experiment 2, TPC showed similar behavior, starting at about the same initial concentration as in experiment 1. The highest counts were those from water at 60°C, 2.5% calcium lactate and non-sanitized samples (Fig. 3). The YM count remained low and constant until day 12, when counts of water treated samples increased considerably. In general, non-sanitized samples had a very similar microbial load compared to just-cut, water and calcium dip samples. The TPC counts obtained were low in non-sani-

tized samples which suggests that an efficient sanitation of the intact fruit and cutting utensils may be enough for significantly reducing microaerophilic and mesophilic bacterial growth and subsequent rapid decay. Even though fresh-cut cantaloupe spoilage may be due to non-microbial causes, as previously reported in shredded chicory salads and shredded carrots (Brocklehurst et al., 1987), mesophilic bacterial counts could be used as an indicator of storage stability as in the case of shredded lettuce (Brocklehurst et al., 1987).

Calcium chloride treated samples (experiment 2) had lower TPC and YM counts than water dipped samples (25°C) towards day 12. These results coincide with previous findings of reduced microbial growth rate after 5°C storage of 1% calcium chloride treated carrot shreds (Izumi and

Watada, 1994). Calcium could enhance tissue resistance to fungal or bacterial attack by stabilizing or strengthening cell walls (Conway and Sams, 1984; Bolin and Huxsoll, 1989).

The surface drying effect detected especially in calcium lactate treated fresh-cut cantaloupe (as reflected by lower sensory moisture content), could reduce the likeliness of bacterial spoilage because of the reduction of available moisture (Lund, 1981). Possible antimicrobial effects from calcium lactate were only observed in experiment 1 in both TPC and YM.

Heat or calcium treatments may have provided an inhibitory effect on YM growth, while water alone allowed for spore spreading and actually increased counts. With respect to the microaerophilic bacteria, water dips at 60°C had the highest counts. Higher temperature could have facilitated diffusion of microorganisms into the tissue allowing them to remain in microenvironments with low oxygen content. Again, the exploratory nature of these analyses do not support definite conclusions about the effect of the calcium treatments on the microbial behavior of fresh-cut melon. Future studies to analyze microbial population dynamics should be performed in order to gain a better understanding of the effects of such treatments on fresh-cut cantaloupe during cold storage.

3.4. CO_2 and C_2H_4 production

In experiment 1, ethylene levels were not affected by any treatment compared with the control (data not shown). CO_2 production remained at a low level ($\sim 1.94 \text{ mg kg}^{-1} \text{ h}^{-1}$) for all samples until day 6 when levels started to increase. During that rise, either calcium lactate or water dipped and heat treated samples showed significantly lower CO_2 levels than untreated samples. In experiment 2, very low C_2H_4 levels were detected for all samples (data not shown). Heat treated samples had the highest C_2H_4 production, while calcium lactate treated samples had the lowest production levels. Observed increases in respiration after day 6 or so may have been due to microbial spoilage, which can be correlated with the microbiological data for TPC.

4. Conclusions

Calcium lactate treatment is a potential alternative to calcium chloride for shelf life extension of fresh-cut cantaloupe, since it provided similar or better tissue firming ($\sim 25\text{--}33\%$ firmer than just-cut samples) without providing undesirable bitterness. No significant differences were observed during storage in the physiological behavior of the calcium treated fresh-cut as compared to just-cut samples. Further studies are required to investigate the possible antimicrobial effects of calcium treatments on fresh-cut cantaloupe.

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