ABSTRACT: The aim of the present study was to investigate the effect of postharvest warm dipping with calcium chloride (CaCl₂) on atemoya fruit (Annona cherimola L x Annona squamosa L) storage. Fruits were immersed in 6% CaCl₂ solution at 20 and 40°C for 20 min followed by storage at room temperature. The effectiveness of the treatment was assessed in terms of its impact on peel and flesh appearance, weight loss, total soluble solids (TSS), total titratable acidity (TTA), pH, ascorbic acid content, total phenolics, and enzyme activities of polyphenoloxidase (PPO) and peroxidase (POD). Treatment at 40°C preserved eatable conditions up to 6 days, although calcium affected the appearance of the peel as soon as 4 days. Flesh browning was detected only on the 8th day in untreated fruits, after an increase in PPO and POD activities and total phenolics, and a decrease in ascorbic acid content. The weight loss was continuous throughout the storage period, with no significant difference between treatments. TTA and TSS contents increased and pH decreased during the experiment. Results suggest that CaCl₂ dipping had a positive effect on flesh browning, which was reduced, while heat treatment showed a synergic effect, which could be related broadly with a fall in PPO activity. The variations in ascorbic acid content during storage suggest that the warm dipping combined with CaCl₂, contributed to the antioxidant capacity of the fruit.

KEYWORDS: Atemoya; postharvest; storage; heat dip; calcium chloride.

INTRODUCTION

The most important commercial fruits of the family Annonaceae are cherimoya (Annona cherimola Mill.), sugar apple (Annona squamosa L.) and the hybrid atemoya (Annona cherimola x Annona squamosa). There are many cultivar of atemoya, and in Brazil the most prevalent are: Thompson, Pink’s Mammoth, Gefner, African Pride, QAS and PR. Atemoya fruit has a short shelf life when stored at room temperatures, and it is characterized by rapid skin browning and softening. Ripening of some tropical and sub-tropical fruits can be retarded by storage at lower temperatures; however, atemoya is very sensitive to low temperatures, presenting chilling injury symptoms, typically peel blackening, flesh browning and loss of aroma and flavor.

Postharvest heat treatments have attracted recent research interest as a promising new technique to maintain fruit quality during storage; which might be an alternative to or reduce the need for chemical disinfestation of fruit and could modify its response to other stresses. Exposure of fruit to temperatures of 40-42°C can induce resistance to chilling injury, delay the ripening process, and modify its quality.

Calcium chloride has shown promise in quality retention of fruits and vegetables. Pre- and postharvest application of calcium may help to reduce senescence during commercial and retail storage of fruit, with no detrimental effect on consumer acceptance. Calcium dips have been employed to improve firmness and extend the postharvest shelf life of a wide range of fruits and vegetables; the effectiveness of such treatments may be influenced by the combination of time and temperature. Increasing the calcium content can help to delay softening and decrease the incidence of physiological disorders. Calcium chloride has been reported to reduce the onset of ripening in sugar apple, avocado and strawberry, but not in banana or mango. According to Lima, 16 sugar apples treated with CaCl₂ (6%) and stored at 16°C showed reduced weight loss, respiration rates, control of the...
peroxidase activity, and maintained higher firmness, as the biochemical processes of ripening were delayed. Treatment with 4% calcium chloride did not extend the shelf life of mangoes from four cultivars. In recent years, significant advances have been made in fruit storage by the use of CaCl2 dipping alone or combined with other treatments.

A combination of hot water treatment at 46°C for 25 min and modified atmosphere packaging succeeded in maintaining the high quality of peaches and nectarines during postharvest handling for up to a week. This treatment delayed softening and substantially reduced fruit losses from fungal growth, but did not show any significant increase in total phenol content in the juice, relative to control fruits, after 1 or 2 weeks of cold storage. Pretreatment of satsumas by hot water dipping was effective in maintaining their postharvest quality during storage and marketing. The treatment had no adverse effects on quality attributes, including pH, titratable acidity, soluble solids contents, weight loss and firmness; the treatment at 60°C for 20s also improved fruit appearance. Treatment at 38°C for 48h before storage at 2°C prevented the development of chilling injury in tomatoes. Direct exposure of untreated fruit to low temperatures produced severe symptoms of chilling injury in the same storage period.

The aim of the present study was to investigate the effects of postharvest warm dipping (40°C/20min.) in 6% aqueous CaCl2 on the storage of atemoya cv. Gefner at room temperature.

MATERIAL AND METHODS

Material

Atemoya fruits cv. Gefner used in this work were from Sítio São José, located in Vista Alegre do Alto - São Paulo, Brazil. The city is 619 m above sea level, at 21° 10' 14" S by 48° 37' 45" W. Sixty fruits were harvested in March (2006) at physiological maturity, in the morning, placed in fruit boxes and delivered to the laboratory immediately, where they were selected and distributed in three homogeneous groups.

Treatments and storage conditions

The control group, without any treatment, was stored at room temperature (24.2–29.3°C; RH 70%); groups HWT-40 and HWT-20 were subjected to hot water treatment (HWT) at 40°C and 20°C, respectively, in 6% CaCl2 for 20 min and stored at room temperature (24.2–29.3°C; RH 70%). Bath temperature was controlled by an electronic thermostat and circulating water, to within 1°C of the required temperature. The room temperature was controlled by an electronic thermostat and relative humidity (RH) by a digital hygrometer.

Methods

On the first day (called “day zero”) and on the 4th, 6th and 8th days, five fruits from each treatment were analyzed by chemical and visual methods.

Weight loss

Atemoyas were weighed on an analytical scale at the beginning of the experiment and thereafter each day during the storage period. Weight loss was expressed as a percentage of the initial total weight.

The peel was removed from the weighed fruit and the pulp was cut into small pieces and homogenized, then maintained in an ice bath for subsequent analysis, performed on three replicates:

Total soluble solids (TSS)

TSS was determined by the AOAC method, with a refractometer at 20°C, and expressed as a percentage (°Brix).

Total Titratable acidity (TTA)/ pH

TTA was determined by titrating the sample against 0.1 mol/L NaOH as in the AOAC method, and expressed as g citric acid per 100g fresh weight. pH was determined directly in the homogenized pulp with a digital pH meter.

Vitamin C (ascorbic acid)

Ascorbic acid was determined by the 2,6-dichlorophenol indole titration method.

Total phenolic compounds

A 2 g sample of the homogenized flesh was extracted in acetone: water (70:30) for 60 min in the dark and then filtered in Buchner funnel at low temperature. For the quantitative analysis, the colorimetric Folin-Ciocalteau method modified by Simonovska et al. was used. Gallic acid was used as a standard to establish the calibration curve (1 to 30 μg at 760 nm).

External and internal appearance

The appearance of the peel and the pulp were assessed during the experiment in accordance with the Australian Organization for Economic Cooperation and Development (OECD) schedule for custard apples, cited by Batten for atemoyas. The appearance of the peel was rated on a scale of 1-5, where 1= very bad (> 70% blackened) and 5= very good (no discoloration). A rating < 3 would render the fruit unsaleable. Flesh appearance was also rated on a scale of 1-5, where 1= very bad discoloration or browning, 3= slight discoloration and 5= no discoloration (pearly white). A rating < 3 would be unacceptable commercially.
Enzyme extraction

Freshly chopped pulp (20g) was homogenized in 40 mL 0.1mol/L phosphate buffer, pH 6.0. The homogenate was centrifuged at 10,000 x g for 40 min. The supernatant was used as PPO and soluble POD enzyme extract. All procedures were carried out at 4°C.

Enzyme assays

Soluble peroxidase (POD) activity was determined by the change in absorbance at 460 nm due to o-dianisidine oxidation by hydrogen peroxide in the presence of the enzyme extract. The reaction mixture consisted of 0.2 mL 15 mM o-dianisidine; 0.2 mL 10 mM hydrogen peroxide, 0.1 M potassium phosphate-citrate buffer, pH 5.0, and enzyme solution to make a total volume of 3.0 mL in the cuvette. Polyphenoloxidase (PPO) activity was determined by measuring the initial linear rate of quinone formation at 30°C, indicated by an increase in absorbance at 420 nm, with 4-methylcatechol (4-methyl-1,2-benzenediol) as the substrate. The reaction mixture contained the substrates in 0.05 M phosphate buffer, pH 6.0, and enzyme solution, to a total volume of 3.0 mL in the cuvette. The initial rate of the enzyme-catalyzed reaction was linear over the first 3 min. In all determinations, POD and PPO activities were assayed in triplicate measurements and one unit was defined as a change of 0.001 absorbance units per min. at the appropriate wavelength for each substrate. An Ultrospec 2000 (Pharmacia Biotech) spectrophotometer was employed throughout.

Statistical analysis

Data were treated for multiple comparisons by ANOVA with Tukey’s multiple range tests, to determine differences between means at the 5% significance level.

RESULTS AND DISCUSSION

After two days of storage, small (discrete) dark spots appeared on the peel of all calcium-treated fruit, which became more evident during the experimental period. Fruits treated at 40°C (HWT-40) were already at the limit of acceptance for commercialization on the 4th day, while the controls and those treated at 20°C were in an adequate condition (Table 1).

Irrespective of treatment, all fruits were appropriate for consumption until the 4th day of storage, when 27.7% of HWT-40 and 22% of HWT-20 and control fruits already showed slightly splits on the receptacle. This observation coincided with high values of weight loss and total soluble solids (TSS) (Table 2). On this day, the fruits that exhibited the best external characteristics were HWT-20, which remained firm, “tender”, and with 90% of the peel colored an intense green. On the 6th day, the HWT-20 peel was more blackened (50-55%) than that of the control fruits, but the flesh remained clear, showing that these fruits were fit for consumption, although not saleable according to the established commercial classification. The dark spots on the peel seemed to be related to the calcium concentration used (6%), and may have been accentuated by the thermal treatment at 40°C, suggesting a higher accumulation of calcium on peel irregularities, with consequent tissue browning, since control fruits developed relatively distinct, smaller browning spots, compared to treated ones.

The internal appearance of all fruits, irrespective of treatment, indicated extremely clear pulp until the 6th day of storage (Table 1). At this time, the fruit remained appropriate for consumption, although HWT-40 and HWT-20 fruits were not saleable, due to the appearance of the peel. At this point, HWT-20 resembled control fruits, with a lower degree splitting, which could have resulted from lower TSS contents; however, HWT-20 and control had practically the same weight loss. In fruits treated with calcium, the flesh remained clear of discoloration for 8 days of storage (Table 1).

<table>
<thead>
<tr>
<th>STORAGE DAYS</th>
<th>CONTROL</th>
<th>HWT 20</th>
<th>HWT 40</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Appearance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>5.00 ± 0.11 aA</td>
<td>5.00 ± 0.12 aA</td>
<td>5.00 ± 0.12 aA</td>
</tr>
<tr>
<td>4</td>
<td>4.00 ± 0.14 aB</td>
<td>4.33 ± 0.58 aA</td>
<td>3.00 ± 0.13 bB</td>
</tr>
<tr>
<td>6</td>
<td>3.33 ± 0.58 aB</td>
<td>2.33 ± 0.58 abB</td>
<td>2.00 ± 0.12 bc</td>
</tr>
<tr>
<td>8</td>
<td>1.17 ± 0.87 abC</td>
<td>1.50 ± 0.98 abB</td>
<td>1.50 ± 0.98 abC</td>
</tr>
<tr>
<td>Internal Appearance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>5.00 ± 0.11 aA</td>
<td>5.00 ± 0.12 aA</td>
<td>5.00 ± 0.11 aA</td>
</tr>
<tr>
<td>4</td>
<td>4.33 ± 0.58 abB</td>
<td>5.00 ± 0.13 aA</td>
<td>4.33 ± 0.58 abB</td>
</tr>
<tr>
<td>6</td>
<td>4.00 ± 0.12 abB</td>
<td>4.00 ± 0.11 abB</td>
<td>4.00 ± 0.12 abB</td>
</tr>
<tr>
<td>8</td>
<td>2.50 ± 0.09 bC</td>
<td>3.50 ± 0.08 abB</td>
<td>3.50 ± 0.09 abB</td>
</tr>
</tbody>
</table>

*HWT 20 and 40 (fruits treated with 6% calcium chloride at 20°C and 40°C, then stored at room temperature: 24.2-29.3°C; RH 70%). Control untreated. External appearance [1 = very bad darkening of peel (> 70% blackened), 5 = very good (no discoloration). A rating < 3 would render the fruit unsaleable]. Different letters (lower case in row and capital letters in column) indicate significant differences at P < 0.05 by the Tukey test.
On the 8th day of storage, all fruits were apparently unsaleable and improper for consumption, even though many values indicate the opposite (Table 1). Beyond this point, about 50% of the fruits, irrespective of treatment, exhibited molds and about 50-70% had more than 70% of the peel blackened, some with intense loss of texture and beginning to rot.

Hernández-Muñoz et al., 10 studying the effects of postharvest dips of 1% calcium gluconate and 1% calcium gluconate + 1.5% chitosan on strawberries, observed that control fruits and those treated with 1% calcium gluconate, stored for 4 days at 20°C and 70% RH, showed 91% and 61% of mold incidence, respectively. In the same study, calcium gluconate alone had no effect on fruit firmness, and gradual losses in firmness were observed after the 3rd day of storage.

Atemoya fruits stored at room temperature lasted for 7 days, while at lower temperatures (15°C, 85% RH), they remained in good condition for 12 days. 20 Batten 3 found that African Pride atemoya stored at 12°C, spoiled in appearance after 6 days, although its eating quality was good up to 10 days; however, this time fell to 4.8 days at 20°C. Lower temperatures, such as 4°C, combined with high humidity, produced “chilling injury” symptoms, characterized by peel and pulp browning; nevertheless, fruits kept at 4°C for 5 days, when transferred to 20°C, ripened and had an excellent “flavor”. African Pride atemoyas stored at 24 and 25°C ripened after 4.8 and 4 days, respectively. 35 Perera & Karunaratne 25 observed in bananas that 4% calcium chloride treatment followed by storage under an ethylene atmosphere at room temperature led to changes in the texture of the fruits. The authors observed that the ethylene atmosphere kept the fruits firmer, but, without prolonging the shelf life. Paull 23 observed that atemoya splitting occurred simultaneously with the respiration peak, start of ethylene production and rise in TSS content, weight loss, and reduction in receptacle diameter and fruit circumference. The author suggests that osmotic and subsequent turgor changes, related to the production of neutral sugar during ripening, led to a movement of water from the peel and possibly the receptacle to the pulp.

Continuous weight loss was observed during the course of storage, without significant differences between treatments (Table 2). On the 4th day, average values of weight loss were around 10%, irrespective of treatment, and on the basis of their, external and internal appearance, at this point fruits showed their highest quality. On the 6th day, approximately 15% weight loss was observed, without significant variation between treatments. This loss still did not impair the quality of the fruit, which remained fit for consumption.

Only on the 8th day, when weight loss approached 20% (Table 2), control fruits became both unsaleable and unfit for consumption, whereas HWT-20 and HWT-40 fruits were unsaleable, on account on external appearance, but still fit for consumption in terms of pulp quality. Humidity losses between 3 and 6%, while having minimal influence on biochemical processes, are enough

<table>
<thead>
<tr>
<th>STORAGE DAYS</th>
<th>CONTROL</th>
<th>HWT 20</th>
<th>HWT 40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight loss (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0 ± 0.39</td>
<td>9.75 ± 0.97</td>
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<td>17.20 ± 1.49</td>
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<td>20.68 ± 1.71</td>
<td>19.07 ± 1.16</td>
<td>20.93 ± 0.79</td>
</tr>
<tr>
<td>Total soluble solids (Brix)</td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>3.50 ± 0.11</td>
<td>3.50 ± 0.11</td>
<td>3.50 ± 0.11</td>
</tr>
<tr>
<td>4</td>
<td>17.93 ± 0.11</td>
<td>16.80 ± 0.1</td>
<td>21.4 ± 0.35</td>
</tr>
<tr>
<td>6</td>
<td>19.00 ± 0.08</td>
<td>15.13 ± 0.11</td>
<td>19.00 ± 0.08</td>
</tr>
<tr>
<td>8</td>
<td>15.07 ± 0.11</td>
<td>15.07 ± 0.46</td>
<td>21.00 ± 0.07</td>
</tr>
<tr>
<td>Titratable acidity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0.109 ± 0.03</td>
<td>0.109 ± 0.03</td>
<td>0.109 ± 0.03</td>
</tr>
<tr>
<td>4</td>
<td>0.295 ± 0.01</td>
<td>0.234 ± 0.03</td>
<td>0.230 ± 0.01</td>
</tr>
<tr>
<td>6</td>
<td>0.290 ± 0.01</td>
<td>0.353 ± 0.02</td>
<td>0.279 ± 0.02</td>
</tr>
<tr>
<td>8</td>
<td>0.310 ± 0.03</td>
<td>0.376 ± 0.01</td>
<td>0.253 ± 0.01</td>
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<tr>
<td>pH</td>
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<tr>
<td>0</td>
<td>5.40 ± 0.01</td>
<td>5.40 ± 0.01</td>
<td>5.40 ± 0.01</td>
</tr>
<tr>
<td>4</td>
<td>4.62 ± 0.01</td>
<td>4.69 ± 0.01</td>
<td>4.71 ± 0.01</td>
</tr>
<tr>
<td>6</td>
<td>4.62 ± 0.02</td>
<td>4.76 ± 0.03</td>
<td>4.58 ± 0.01</td>
</tr>
<tr>
<td>8</td>
<td>4.56 ± 0.01</td>
<td>4.55 ± 0.02</td>
<td>4.60 ± 0.01</td>
</tr>
</tbody>
</table>

*HWT 20 and 40 (fruits treated in 6% calcium chloride at 20°C and 40°C, then stored room temperature: 24.2–29.3°C; RH 70%). Control untreated. Different letters (lower case in row and capital letters in column) indicate significant differences at P < 0.05 by the Tukey test.
to cause a reduction in the quality of some fruits, whereas others, with losses above 10%, are still suitable for commercialization. Differences in TSS contents between the three treatments were statistically significant on the 4th day (Table 2); however, on the 8th day only HWT-40 fruits showed significant differences from the others. In varieties of atemoya fruits from Brazil, the TSS content can vary from 4 up to a maximum of 27°Brix during ripening. In one study, fruits of atemoya cv. Gefner, without treatment, stored at 15.5°C and 85-90% RH, reached the point of consumption on the 12th day after picking with a TSS content of 20°Brix. Yamashita et al. reported that atemoya, cv. PR3, ripened after 4-5 days of storage at 25°C had exhibited a TSS content of 20.7°Brix, close to the present for cv. Gefner. Batten observed variations in TSS between 22 to 24.8% for atemoya stored at 16, 19 and 24°C for 8.6, 2.1 and 4.8 days, respectively.

Diverse authors agree that the total titratable acidity (TTA) of annonaceas tends to rise during ripening, A, B, C, D, E. The opposite of what happens in many fruits. Table 2 shows that the measured TTA rose form 0.109 to a maximum of 0.376%, with consequent decreases in pH during storage, for all treatments. After 8 days, pH values were not significantly different between control and treated fruits. Beerh et al. reported values between 0.30 and 0.40% citric acid in the pulp of several annona cultivars at the ripe stage. Mosca observed an increase in TTA contents from 0.13 to 0.35%, up to 9 days of storage, for atemoya (cv. Gefner) at ambient temperature (27°C, 85% RH), near the values found in this study. Yamashita et al. have observed in atemoya (cv PR3) an increase in TTA contents from 0.09 to 0.13%, during 9 days of storage at 25°C. Those authors, discussing these low values, pointed out that differences in organic acid concentrations can be due to a variety of factors, such as: cultivar, climatic conditions, cultivation practices and harvest time.

Ascorbic acid is one of the most abundant antioxidants present in fruits. In all treatment groups, a significant decrease in ascorbic acid contents was observed, to between 11.5 to 17.5% of the initial contents after 8 days of storage (Table 3). Despite the similar decrease profiles during the storage period, results suggest that treatments caused significantly lower losses of antioxidant capacity by the end of storage, when treated fruits were compared to the untreated group. Gradual increases in ascorbic acid contents have been observed during the development of sugar apples, reaching maximum concentrations at physiological maturity, after which they decreased during ripening. In a study of exotic fruits, ascorbic acid contents in atemoya resembled those found in mangoes and liches, and were lower than in passion fruit, pineapple, kiwi, orange and papaya. Those authors showed losses in ascorbic acid content between 30 to 72.8%, in various fruits stored at ambient temperature in a sealed nylon bag for one week. Vicent et al. achieved a higher ascorbic acid contents in strawberries after storing for 14 days at 0°C, followed by 2 days at 20°C, as a result of thermal pretreatment at 45°C for 3 h; this contributed to a higher antioxidant capacity in the fruits.

Parallel to the decline in ascorbic acid, peroxidase (POD) and polyphenoloxidase (PPO) enzymes showed differing trends (Figures 1 and 2). POD activity appeared to be influenced by the treatments, since it did not change in control fruits until the 6th day, showing a large increase on the 8th; while it peaked on the 6th day in treated fruits, decaying to below the initial levels on the 8th day (Figure 1). Only in control fruits did POD activity remain high on the 8th day of storage, when the fruits showed more intense flesh browning, suggesting a possible involvement of POD in enzymatic browning. These observations may be related to very low ascorbic acid content and high content of total phenols in the control fruits on this day, compared to treated fruit, demonstrating a lower antioxidant capacity and higher levels of possible substrates. Results of the application of calcium to fruits and its effects on POD activity have been inconsistent, sometimes showing an increase A, B, C and sometimes a decrease in enzyme activity; A, B, C on the other hand, some authors indicate calcium concentration as a determining factor for POD activity. A, B, C

<table>
<thead>
<tr>
<th>STORAGE DAYS</th>
<th>CONTROL</th>
<th>HWT 20</th>
<th>HWT 40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ascorbic Acid</td>
<td>0</td>
<td>19.293 ± 0.09 A</td>
<td>19.293 ± 0.09 A</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4.391 ± 0.03 B,C</td>
<td>6.053 ± 0.32 B</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>8.277 ± 0.13 B</td>
<td>6.117 ± 0.10 B</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>2.193 ± 0.10 D</td>
<td>3.393 ± 0.01 C</td>
</tr>
<tr>
<td>Total Phenolics</td>
<td>0</td>
<td>2.305 ± 0.03 D</td>
<td>2.305 ± 0.03 D</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>6.048 ± 0.14 A</td>
<td>5.408 ± 0.01 B,A</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>4.334 ± 0.10 B</td>
<td>4.170 ± 0.11 C</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>5.563 ± 0.22 C</td>
<td>4.602 ± 0.13 B</td>
</tr>
</tbody>
</table>

A HWT 20 and 40 (fruits treated in 6% calcium chloride at 20°C and 40°C, then stored room temperature: 24.2–29.3°C; RH 70%). Control untreated. Different letters (lower case in row and capital letters in column) indicate significant differences at P < 0.05 by the Tukey test.
At the beginning of storage PPO activity was very low, reaching its maximum in 6 days, and then returning to the level of the 4th day, irrespective of treatment (Figure 2). Treated fruits showed lower increases than the controls. Data suggest that calcium treatment caused a significant reduction in PPO activity during storage, which was greater at 40°C so that temperature exhibited a synergic effect.

While all fruits showed an increase in total phenolic contents, calcium treatment and heating at 40°C led to significantly lower contents from the 4th day of storage (Table 3). Phenolic compounds represent the main substrates used by oxidative enzymes with consequences in terms of color and quality changes, as well as being associated with plant defense mechanisms against stress situations that can affect the postharvest period. In this study we analyzed total phenolic contents during storage, but not all phenolics are substrates of PPO and POD. The individual phenolic contents should be studied to determine which are present in atemoya, in order to know which of them are consumed and which are produced during storage, under various conditions. The present data may suggest that control fruits, which showed a higher rise in total phenols during storage, did this to protect themselves, whereas HWT–40 fruits, which showed the lowest increase in these compounds, were protected by the thermal treatment and the CaCl₂. Pineapples, hydrothermally treated and not with CaCl₂, were evaluated 7 days after their withdrawal from storage at 9°C and 90% RH for 15 days. Treated fruits showed lower PPO and POD activities, and also lowest degree of internal browning. The authors suggested that
the maintenance of cellular integrity conferred by CaCl₂ diminished the possible contact of the enzyme-with its substrate, resulting in lower rate of enzymatic browning.⁹

Summarizing, atemoya cv. Gefner showed an excellent quality for commercialization and consumption on the 4th day of storage at room temperature (24.2-29.3°C; RH 70%), irrespective of treatment. However, heating at 40°C in the presence of 6% calcium chloride ensured good conditions for consumption until the 6th day. Although the calcium concentration used affected the external appearance in the first 4 days, it led to an improvement in the internal appearance of fruit at the end of storage period, compared to untreated control. In control and treated fruit the internal browning was only detected on the 8th day of storage, following the rise in oxidative enzymes activities, fall in ascorbic acid contents and increase in total phenolic compounds.

CONCLUSIONS

The results suggest that the calcium treatment exerted a positive effect in reducing enzymatic browning and that the heat treatment had a synergic effect, influencing the associated factors, such as ascorbic acid metabolism, total phenolic content and oxidative enzyme activity, especially that of PPO.

ACKNOWLEDGMENTS

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