ascorbic) were equally effective in maintaining desirable slice color for up to six hours exposure to air after refrigerated storage periods up to eight weeks duration. The three blend treatments were significantly better than the citric acid treatments alone or the control (Table 1). The 5.0% citric acid treatment was superior to the 2.5% citric acid treatment.

Conclusions

Citric acid - ascorbic acid blends were superior to either citric or ascorbic acid used alone in retaining maximum yellow color of refrigerated vacuum packaged carambola slices. Erythorbic acid was as effective as ascorbic acid when used in citric-erythorbic acid blend treatments. Calcium EDTA was as effective as ascorbic acid when used in citric acid - calcium EDTA blends. Excellent yellow color of carambola slices was maintained for up to six hours exposure to air following refrigerated storage periods of eight weeks.

Literature Cited


EVALUATION OF CARAMBOLA CULTIVARS FOR THE LIGHTLY PROCESSED MARKET

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Abstract. Blanching and chemical treatments were evaluated to reduce browning in sliced carambola. Slices were vacuum sealed in oxygen barrier pouches and stored at 4.4C. Slices dipped in a 1% ascorbic acid plus 2% citric acid solution had the best color retention of all treatments when slices were exposed to air, after 14 days of storage. The browning susceptibility of carambola slices from 9 cultivars was also studied. When pouches were opened, cultivar Fwang Tung and selection WA 3-23-1 had the best color retention. Polyphenoloxidase was located by adding catechol to sliced fruit. After air exposure, brown pigments mainly developed between fruit segments. Analysis of ascorbic acid concentrations in fruit tissue showed that endogenous ascorbic acid in stored sliced fruit degraded at a faster rate than in stored whole fruit when both were exposed to air. Cultivar Arkin had the lowest ascorbic acid concentration and highest browning susceptibility when compared with cultivars Fwang Tung and Kary. This indicates that cultivars with higher ascorbic acid retention are more suitable for the cut market.

Carambola (Averrhoa carambola L.) is a tropical tree fruit belonging to the Oxalidaceae family. The fruit is native to Asia, but was introduced to Florida more than a century ago. The fruit remained a curiosity for many years due to the tart flavor found in the first cultivars grown in the state. However, with the introduction of sweeter cultivars with better handling resistance, the fruit has become more popular. It is estimated that 400 acres are planted in the southern part of Florida with an estimated 1995 production of 5 million pounds of packed fruit. Carambola production is expected to increase, therefore alternative products are needed. Traditional carambola products (juice, dried slices, jellies) have been studied by different authors (Matthews, 1989; Campbell and Campbell, 1983; Morton, 1987). A different approach to traditional processing, is the production of carambola slices for the lightly processed market, where the slices can be used for fresh consumption or garnishing. The lightly processed market is expected to account for 25% of the produce sales in America by the year 2000 (Sloan, 1995).

The main limitation of slicing is the production of brown pigments, induced by the oxidation of phenolic compounds catalyzed by enzymes. The browning susceptibility of fruits is known to vary depending on the polyphenol oxidase activity and the phenolic concentration. Lee et al. (1990) found that browning in 15 peach cultivars was correlated with their polyphenol oxidase activity. The enzyme activity in artichoke and apples has been reported to increase during aging or after stress conditions during storage (Lattanzio et al. 1994; Nicolas et al. 1994). Adnan et al. (1986) reported that polyphenoloxidase activity in carambola had an optimal pH activity of 7.2. The enzyme was found to be more susceptible to heat-induced denaturation than the enzymes from grapes, pears, and mangos. Some authors have suggested that factors like pH and ascorbic acid concentration of the tissue might play an important role in the browning susceptibility of plant tissue (Amiot et al. 1992).

Different methods have been tested to control enzymatic reactions. In the past, browning of fresh fruits and vegetables was mainly controlled by the action of sulfite, a chemical with a broad spectrum of action (Fennema, 1985). However, the use of this compound has declined due to allergic reactions in asthmatic persons. Other chemicals have been studied to replace sulfites. The combination of ascorbic and citric acid was found to be an effective inhibitor of enzymatic browning in apple slices (Santerre et al. 1988). Matthews et al. (1989) studied different treatments to extend the shelf life of carambola slices. They found that slices dipped in a 1% citric acid solution and vacuum packed in an oxygen barrier pouch retained quality for 6 weeks when stored at 4C.
Materials and Methods

Fruit Source. Carambola fruit was obtained from the USDA Subtropical Horticultural Research Station in Miami, Florida. The fruit was transported for processing to the Food Science and Human Nutrition Department in the University of Florida, Gainesville, FL.

Fruit slicing. Eight to ten fruit from each cultivar were soaked in a 200 ppm sodium hypochlorite solution for 10 minutes and then drained. The fruit was cut cross sectionally into 0.65 cm slices using a Tomato King slicer (TKII A, Redco Inc., Wilmington, DE).

pH, Titratable Acidity and Soluble Solids. Carambola juice was prepared from slices from eight to ten fruit. Slices were macerated in a blender and filtered through cheesecloth. The pH was measured using a glass electrode pH meter, Fisher Scientific Co., Fair Lawn, NJ). Titratable acidity was determined by mixing 10 mL of juice with 90 mL of water and titration with 0.1 N sodium hydroxide to an endpoint pH of 8.2. Soluble solids were measured by a Mark II Digital Refractometer (Reichert Scientific Instruments, Buffalo, NY).

Catechol test. To establish the location of polyphenoloxidase, 5 drops of catechol (0.05 M) were added and spread over the cut surface of 5 carambola slices. The slices were exposed to air at ambient temperature for 5 hours after the solution was added.

Packaging and Storage. Slices (20-25) were placed in a 23 x 15 cm pouch (P-640, Cryovac Division, W. R. Grace & Co., Duncan, S.C.). The pouches were vacuum sealed at 960 mbars with a Multivac packing machine (A 316, Koch Supplies Inc., Kansas City, MO) and stored at 4.4°C until analysis.

Color measurement. The color of 5 slices from each cultivar was recorded initially and at 2, 4, and 6 hours of air exposure using a Minolta CR-250 hand-colorimeter (Japan).

Antioxidant treatment. Slices were dipped in an antioxidant solution containing 1% ascorbic acid and 2% citric acid for 5 min. Control slices were dipped in distilled water for 5 min. After dipping, slices were drained for 5 min on a plastic screen.

Ascorbic acid analysis. Ascorbic acid concentration was determined using the indophenol method (AOAC, 1984).

Experiment 1. Slices from cultivar Arkin were treated with: (a) Ascorbic/citric acid treatment: slices were dipped for 5 min in a solution of 1% ascorbic acid plus 2% citric acid. (b) 4-Hexylresorcinol: slices were dipped for 5 min in a 0.176% aqueous solution of 4-hexylresorcinol. (c) Ethanol: slices were dipped in a 2.5% ethanol solution for 5 min. (d) Blanching: slices were blanched for 30, 60, 90 and 120 sec using free steam in a pilot plant blancher (Dixie Canner, Athens, GA), and then sprayed with water for 2 min. (e) Control: slices were dipped in distilled water for 5 min. After each treatment, slices were drained for 5 min on a plastic screen, vacuum sealed in oxygen barrier pouches and stored for 15 days at 4.4°C. After storage, slices were exposed to air at ambient temperature for 24 hrs. The color of the slices was recorded after the pouches were opened and after 24 hrs of air exposure.

Experiment 2. Slices from cultivars Arkin, Kary, Fwang Tung and Demak and the selections WA 3-23-1, WA 3-22-36, WA 3-22-2, WA 3-22-20 and WA 3-21-2 were dipped in distilled water or an antioxidant solution (1% ascorbic acid + 2% citric acid), vacuum sealed in oxygen barrier pouches and stored for 30 days at 4.4°C. After storage, their color was recorded after 0, 2, 4 and 6 hours of air exposure. The catechol test, pH, titratable acidity and soluble solids were conducted on fresh slices before storage.

Experiment 3. Slices from cultivars Arkin, Kary and Fwang Tung were vacuum sealed and stored at 4.4°C. Whole fruit from these cultivars were also stored at 4.4°C in standard carambola cardboard boxes. Whole and sliced fruit were stored for 6 weeks. Prior to analysis, whole fruit were sliced. Color of slices was recorded for stored whole and stored sliced fruit after 0 and 6 hours of air exposure at 0, 2, 4 and 6 weeks of storage. Ascorbic acid content of whole fruit was analyzed after 0 and 6 hours of air exposure at 2, 4 and 6 weeks of storage.

Results and Discussions

The first experiment was designed as a screening test to evaluate different treatments that could extend the shelf life of carambola slices. The chemicals tested in this experiment were previously used to control browning in sliced apples (Monsalve-Gonzales et al., 1995; Nicolas et al., 1994; Santerre et al., 1988). Blanching, a traditional method of enzyme inactivation, was studied as an alternative non-chemical method. After 15 days of storage, slices were exposed to air at ambient temperature for 24 hours. The color data from this experiment is presented in Table 1. Color of slices was measured in the HunterLab scale where the ‘L’ value represents the light-

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Color at slicing</th>
<th>Color after 14 days of Storage</th>
<th>Delta 'L'</th>
<th>Color after 24 hours of air exposure</th>
<th>Delta 'L'</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>46.9 (2.0)</td>
<td>39.9 (3.7)</td>
<td>7.6</td>
<td>37.4 (1.3)</td>
<td>9.5</td>
</tr>
<tr>
<td>1% Ascorbic + 2% Citric</td>
<td>46.9 (2.0)</td>
<td>44.5 (4.6)</td>
<td>2.4</td>
<td>42.7 (3.9)</td>
<td>4.2</td>
</tr>
<tr>
<td>4-Hexylresorcinol</td>
<td>46.9 (2.0)</td>
<td>40.0 (4.8)</td>
<td>6.9</td>
<td>39.1 (2.4)</td>
<td>7.8</td>
</tr>
<tr>
<td>Ethanol</td>
<td>46.9 (2.0)</td>
<td>40.2 (3.1)</td>
<td>6.7</td>
<td>38.0 (2.1)</td>
<td>8.9</td>
</tr>
<tr>
<td>Blanching 30 sec</td>
<td>46.9 (2.0)</td>
<td>43.1 (3.24)</td>
<td>3.8</td>
<td>36.2 (2.4)</td>
<td>10.7</td>
</tr>
<tr>
<td>Blanching 60 sec</td>
<td>46.9 (2.0)</td>
<td>42.1 (2.9)</td>
<td>4.8</td>
<td>36.9 (2.7)</td>
<td>10.0</td>
</tr>
<tr>
<td>Blanching 90 sec</td>
<td>46.9 (2.0)</td>
<td>54.1 (3.4)</td>
<td>-7.2</td>
<td>51.4 (7.1)</td>
<td>-4.5</td>
</tr>
<tr>
<td>Blanching 120 sec</td>
<td>46.9 (2.0)</td>
<td>51.4 (2.8)</td>
<td>-4.5</td>
<td>52.7 (3.8)</td>
<td>-5.8</td>
</tr>
</tbody>
</table>

1Color values are an average of 15 readings from 5 slices (±SD).

2Delta ‘L’; Color difference between color at slicing and color after 14 days of storage at 0 or 24 hours of air exposure.
ness of an object on a scale that varies from 0 (black) to 100 (white). It was found that when the ‘L’ value was lower than 40, browning became visible. Samples blanched for 90 and 120 sec had the best color retention. However, their texture was mushy and accompanied by a strong cooked aroma. Slices blanched for 30 and 60 seconds had an acceptable texture but developed enzymatic browning when exposed to air due to insufficient blanching time. Of the chemical treatments, slices treated with 4-hexylresorcinol and ethanol developed browning when slices were exposed to air, while the slices treated with the combination of ascorbic acid plus citric acid retained their color. The color retention was due to a synergistic action of citric and ascorbic acid. Citric acid helped to lower the pH of the tissue and reduced the level of enzyme activity. It also works as a chelating agent for the enzyme prosthetic group. Ascorbic acid can aid in preventing the enzymatic reaction by reducing the quinone back to the phenolic state (Baurenfeind, 1958). This treatment was evaluated in all the cultivars and selections in the following experiment.
The chemical composition of the different carambola cultivars and selections are presented in Table 2. The composition found is in agreement with the values presented by Wilson (1990). Polyphenoloxidase location has been found to vary widely between different fruits (Vamos-Vigyazo, 1981). In this experiment, brown pigments mainly developed at fruit slice segments after the catechol was added (Fig. 1). The pigments developed when catechol was oxidized by the action of polyphenoloxidase. The lack of reaction in the rest of the tissue, suggests that the enzyme was present in a lower concentration or that it was in a latent form with little reactivity toward catechol. The degree of reaction varied between cultivars. It was found that cultivar Fwang Tung and selection WA 3-23-1 had a lower reaction than the rest of the cultivars. The fresh slices not treated with catechol retained their color after 6 hours of air exposure.

After 30 days of storage slices were exposed to air. The color of the slices is presented in Figure 2. It was found that browning became visible in most of the cultivars after 2 hours of air exposure. The increase of browning after storage indicates that polyphenoloxidase may have become more soluble and active during storage. It is also possible that phenolic compounds increased their solubility or concentration as a reaction to the stress caused by slicing. Cultivar Fwang Tung and selection WA 3-23-1 retained their color even after 6 hours of air exposure, showing that some cultivars are less susceptible to enzymatic browning. Perhaps these cultivars contain lower levels of polyphenoloxidase as evidenced by their reactions to catechol (Fig. 1). The slices treated with the antioxidant solution retained their color when exposed to air for 6 hours, as found during experiment 1 (Fig. 3).

The ascorbic acid values (Fig. 4) are in agreement with the values presented by Wilson (1990) and confirm that carambola is a good source of ascorbic acid (vitamin C). It was also found that ascorbic acid in stored sliced fruit degraded at a faster rate than in stored whole fruit. Ascorbic acid degradation was increased when slices from stored whole and presliced fruit were exposed to air for 6 hours (Fig. 5). Of the three cultivars studied, Arkin had a significantly lower ascorbic acid concentration in both whole and sliced fruit when compared with Fwang Tung and Kary. Arkin’s lower ascorbic acid concentration matches its higher browning susceptibility (Figs. 6 and 7). Cultivar Fwang Tung had a significantly higher ascorbic acid concentration and developed no browning when exposed to ambient air. This indicates that cultivars with higher ascorbic acid concentration are more suitable to be used in the lightly processed fruit market, for both reasons of nutrition and appearance.

Figure 2. Color of sliced carambola after 30 days of refrigerated storage.

Figure 3. Color of sliced-antioxidant-treated carambola after 30 days of refrigerated storage.

Figure 4. Ascorbic acid concentration of Arkin, Kary and Fwang Tung, in whole and sliced fruit, during 6 weeks of storage after 0 hours of air exposure (W = whole - S = sliced).

Figure 5. Ascorbic acid concentration of Arkin, Kary and Fwang Tung, in whole and sliced fruit, during 6 weeks of storage after 6 hours of air exposure (W = whole - S = sliced).
Conclusions

The combination of ascorbic plus citric acid solution, was observed to be effective in the retention of the color of carambola slices. A higher polyphenol oxidase activity was found in the middle of the carambola slices. Cultivar Fwang Tung and selection WA 3-23-1 had a lower polyphenol oxidase activity toward catechol. When the slices were exposed to air after storage, most of the cultivars developed brown pigments after 2 hours of exposure. Cultivar Fwang Tung and selection WA 3-23-1 showed the best color retention. This matched their lower catechol reaction, showing that the catechol test can be used to predict browning potential between different carambola cultivars. Slices treated with 1% ascorbic acid and 2% citric acid had a good color retention after air exposure.

In the third experiment it was found that stored sliced fruit was more susceptible to the development of brown pigments than slices from stored whole fruit. The higher browning susceptibility of sliced fruit is attributed to a higher ascorbic acid degradation that took place in sliced fruit when exposed to air.

References