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Effects of chemical treatments on fresh-cut papaya

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ABSTRACT

Four treatments (control, 0.1% cinnamaldehyde, 0.75% calcium chloride and combination of 0.1% cinnamaldehyde and 0.75% calcium chloride) were used to evaluate chemical effects on shelf life, quality and sensory acceptability of fresh-cut papaya (*Carica papaya* L.). Papaya slices were packed and covered with polypropylene film, stored at 5 °C; and evaluated after 1, 3, 6, 9, 12, and 15 days for microbiological and physicochemical changes. A sensory evaluation was performed at 1, 3, 6, 9, and 12 days. There was no occurrence of Salmonella, *Escherichia coli* or psychotropic bacteria. The cinnamaldehyde alone and a combination of cinnamaldehyde and calcium chloride treatments yielded better control of the total coliforms. The combination treatment decreased the CO_2 concentration and increased the maintenance of papaya firmness. All the treatments had acceptability. The combination treatment was the most effective treatment for flavor, taste, and preservation until day 12.

1. Introduction

Papaya (*Carica papaya* L.) is one of the world's most important fruit (Ali, Muhammad, Sijam, & Siddiqui, 2011), and Brazil currently ranks first in the world for papaya production, accounting for 26% of the world's supply (FNP Consultoria & Comércio, 2010). In recent years, foreign consumers have developed a taste for the Brazilian fruit.

Papaya is a climacteric tropical fruit and is known to have a very short postharvest life involving weight loss, rapid pulp softening, and the presence of microbial growth (Gonzalez-Aguilar et al., 2009). Under normal environmental conditions, it completes its maturity in about a week. This period may be reduced because of pre- and post-harvest factors that may manifest in the fruits alone or together, providing quantitative and qualitative losses at different stages of marketing (Costa & Balbino, 2002). Because it is so highly perishable, about 30% of production is compromised (Kaur et al., 1997).

Brazilian production of papaya is based on the "Hawaii" and "Formosa" cultivars. Despite overall consumer acceptance, the 'Formosa' cultivar is not very consumer-friendly because it requires peeling and seed removal before consumption (Godoy et al., 2003). Minimally processed papaya (MP) provides convenient, uniqueness and nutritional quality, which could create marketing opportunities (Wall, Nishijima, Fitch, & Nishijima, 2010). The use of certain chemical treatments decreases bacterial colony formation and subsequent contamination. The use of bioactive extracts applied to the fruit for the purpose of preservation is an alternative to chemical preservatives and helps to accommodate consumer demand for fresh, nutritious, safe fruits, and vegetables that are free of synthetic additives (Ayala-Zavala, Rosas-Domínguez, Vega-Veja, & González-Aguilar, 2010).

Cinnamaldehyde is known to inhibit the growth of *Escherichia coli* O157:H7 and *Salmonella typhimurium*. It has a sweet cinnamon–honey odor (Zhou et al., 2007). Although it has been studied extensively, its use as an antimicrobial substance is limited. Doses sufficiently high to be effective against microorganisms may change the taste and thus the acceptability of the product (Koutsoumanis, Lambropoulou, & Nychas, 1999).

The food industry has adopted the use of natural preservatives to achieve safety and high quality of fresh-cut fruits. This has resulted in a continuous search for effective natural antimicrobial compounds that preserve fresh-cut quality without causing deterioration of its sensory attributes (Ayala-Zavala, Gonzalez-Aguilar, & del-Toro-Sanchez, 2009).

This study evaluated the effects of three chemical treatments on the: physical and physicochemical properties, microbiological and sensory evaluation on fresh-cut papaya stored under refrigeration, and their effect on shelf life, quality and acceptance.

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2. Materials and methods

2.1. Materials

Papaya fruits (*C. papaya* L.) were selected; the "Formosa" cultivar with 70–80% of yellow color in the skin was selected (Kaur et al., 1997).

The fruits were from a single production area of Barreiras County, State of Bahia (geographical coordinates 12° 09′10″S 44° 59′ 24″ W) and acquired in Companhia de Entrepostos e Armazéns Gerais de São Paulo (CEAGESP), São Paulo-SP.

Sodium dichloroisocyanurate dihydrate (NaDCC – Johnson Diversey Brasil Ltda, Socorro, São Paulo, Brazil) was used for sanitization. Cinnamic aldehyde (Sigma–Aldrich Chemie GMBH, Steinheim, Germany) 98% PA (MW = 132.16) and calcium chloride dehydrate (Vetec Química Fina, Duque de Caxias, Rio de Janeiro, Brazil) 99% PA (MW = 147.01) were used for the other treatments. The cinnamic aldehyde solution (0.1%) was prepared with 0.3 g of calcium lactate and 0.4 g of citric acid in 100 mL of drinkable water.

2.2. Processing

The papayas were selected on the basis of size, color, and the absence of mechanical damage. The fruits were washed with neutral detergent under running water. They were then sanitized for 10 min at 5 °C in a solution of NaDCC with 200 mg/L of active chlorine, placed on paper towels for 10 min to remove excess solution, and kept in a refrigerated chamber at 12 °C for 12 h.

Once cut in half to remove the seeds and placenta, the fruits were peeled with a manual peeler and cut into half slices approximately 2.5 cm thick (Hernández, Lobo, & González, 2007).

After immersion for 2 min in NaDCC solution with 100 mg/L of active chlorine and drainage for 2 min (Arruda, Jacomino, Sarantópoulos, & Moretti, 2003), the samples were divided into four different treatment groups:

(1) Control: sanitized only.
(2) Immersion in 0.1% cinnamic aldehyde for 2 min, and drainage for 2 min.
(3) Immersion in 0.75% calcium chloride for 2 min, and drainage for 2 min.
(4) Immersion in 0.1% cinnamic aldehyde for 2 min, and drainage for 2 min, followed by immersion in 0.75% calcium chloride for 2 min, and drainage for 2 min.

2.3. Packaging

The samples were packed in polypropylene (220 × 167 × 56 mm) coated biaxially oriented polypropylene film with a thickness of 0.050 mm, with an O_2 transmission rate [23 °C/90% relative humidity (RH)] of 785 cc/m^2 and a vapor permeability to water rate (38 °C/90% RH) of 2.36 m^2/g per day.

A semiautomatic heat sealer (500®; ULMA Packaging Ltda., São Paulo-SP, Brazil) was configured with a sealing temperature of 110 °C and a weld time of 2 s and used to seal the film on the tray.

Each tray contained two half slices of papaya, with an average weight of 150 g. The products were kept in cold storage at 5 ± 1 °C and 90 ± 2% RH.

Physical and physicochemical analyses were performed at 1, 3, 6, 9, 12, and 15 days of storage. The sensory and microbiological analyses were performed at 1, 3, 6, 9, and 12 days of storage.

2.4. Microbiological analysis

Microbiological analysis was performed according to the Brazilian instruction n° 62, August 26, 2003 (Brasil, 2003). We evaluated the amount of total coliforms, psychotropic bacteria, yeasts, and molds and also examined the presence of *S. typhimurium* and *E. coli* (60 samples).

2.5. Physical and physicochemical analyses

To evaluate the concentration of CO_2 for each evaluation period, measurements were made in triplicate (three trays, one reading per tray) for each treatment (72 samples). The concentration of CO_2 was measured using a portable gas analyzer (model Check Point O_2/CO_2®; PBI Dansensor, Ringsted, Denmark). The needle gas collector was introduced into the packaging through the septa. The septa were made using silicone glue and double-sided tape on the surface of polyethylene terephthalate.

Nine trays were used to test for firmness, pH, soluble solids, and titratable acidity by the means of three readings for each treatment in six periods of storage (216 samples by variable).

The firmness was measured with a manual penetrometer (Fruit Pressure Tester Model 327 FT®; Facchini Srl; Alfonsine, Italy), using a stainless steel probe with a diameter of 8 mm, a penetration depth of 4 mm, and a penetration time of 3 s. Three readings were made per tray, two at the ends of a half slice and one in the central region of another half slice.

The measurement of soluble solids was obtained by direct reading with a manual refractometer (Model Master-T®; Atago Co., Ltd., Ribeirão Preto-SP, Brazil), according to the Association of Official Analytical Chemists method of analysis 932.12 (AOAC, 2005).

The pH was determined with a potentiometer (Model TEC-3P-MP®; Tecnal Equipamentos Ltda, Piracicaba-SP, Brazil) according to the AOAC method of analysis 981.12 (AOAC, 2005), and titratable acidity was calculated by titration and expressed as a percentage of citric acid according to the AOAC method of analysis 942.15 (AOAC, 2005).

The color of the samples was analyzed with a Minolta colorimeter (Model CR400b®; Minolta Co., Osaka, Japan). This colorimeter uses the Munsell color system, which specifies a color on the basis of three dimensions: lightness, hue angle, and chromaticity.

The color values L^*, a^*, and b^* indicate lightness (0 = black and 100 = white), redness, and yellowness of the sample, respectively. The hue angle (h°) or hue is equivalent to [arctan (b^*/a^*)] and represents changes in the color of fruit, which ranges from red (0°), to yellow (90°), to green–blue (180°), to blue (270°). Chroma (C^*) was calculated using the formula $C = [(a^{*2} + b^{*2})^{1/2}]$, and levels describe the degree of saturation or the intensity of color (Minolta, 1994).

Two readings were taken at the ends of one half slice of papaya, and a third reading was taken in the central region of another half slice contained in the same tray. Nine trays were used per treatment (4 treatments) in six evaluation periods (216 samples).

2.6. Sensory evaluation

Appearance, taste, flavor, and texture were evaluated by 30 untrained students and campus employees (Meilgaard, Civille, & Carr, 1999). The samples were served at 12 °C on white plates arranged randomly on white plastic trays in a room illuminated with fluorescent lamps.

Evaluators used a hedonic rating scale of 9 points (1 = dislike extremely, 5 = neither like/nor dislike, 9 = like extremely) to evaluate sensory acceptability (ABNT, 1993). A score of ⩾6, which corresponds to "I liked it slightly," was used to indicate acceptability.

2.7. Statistical analysis

We used a complete randomized block design for sensory analysis. For physical and physicochemical analyses, we used a complete randomized split plot design where treatments are in plots, and storage periods are in subplots.

Data were subjected to analysis of variance (ANOVA, $P < 0.05$). The treatment comparisons were calculated using Tukey's test. Storage periods were analyzed by linear and quadratic regression. The results were obtained with WinSTAT® software (version 2.11, UFPel, Pelotas-RS, Brazil). Analysis of basic assumptions for ANOVA was generated using SAS® software (version 9.0, SAS Inst. Inc., Cary, NC, USA).

3. Results and discussion

3.1. Microbiological analysis

The presence of *S. typhimurium* was not detected in any of the treatments. These results are in agreement with the Brazilian Legislation (BL) (Brasil, 2001) and the European Community (EC) (EC, 2005), which establish the absence of *S. typhimurium* in 25-g samples. Values <10 CFU/g were obtained *for E. coli*, a satisfactory level according to the EC (<100 CFU/g). The fecal coliform counts were always below 10 CFC/g, and the fruits showed good hygienic conditions in all treatments. The count of psychotropic bacteria was <10 CFU/g for all evaluation periods.

Up to 9 days, the fecal coliforms were within the standards established by the BL (Brasil, 2001). A higher fecal coliform value of 5.2×10^2 CFU/g was obtained at day 12 for the control group, which was above the limit of 5.0×10^2 CFU/g (Table 1). On day 12, the samples in cinnamic aldehyde treatment group and the combination treatment group showed lower total coliform counts compared with those in the control group and calcium chloride treatment group (Table 1).

Yeasts and molds appeared at day 9 in the control groups and the calcium chloride treatment group. Yeasts and molds appeared at day 12 in the samples in the cinnamic aldehyde and combination treatment groups. The best treatment for decreasing fungi and yeast growth was the cinnamic aldehyde treatment, and the second best was the combination treatment. Lower yeast and mold levels could be explained by the effect of cinnamic aldehyde on the conservation of the fresh-cut papayas (Oussalah, Caillet, Saucier, & Lacroix, 2007). Working with papaya MP stored for 8 days at 5 °C, Oliveira, Carlos, Cordeiro, Coelho, and Araújo (2007) were able to achieve the absence of *E. coli*, *S. typhimurium*, total coliforms, fungi, and yeast. Although the legislation does not set limits for this product, the values remained below 10^5 CFU/g, the maximum allowable level for these microorganisms established by Vitti et al. (2004).

Table 1
Means of microbiological analysis in minimally processed papaya submitted to four treatments for five storage periods at 5 °C.

Treatments	Storage periods (days)				
	1	3	6	9	12
Total coliforms (CFU g^{-1})					
Control	<10^2	<10^2	<10^2	<10^2	5.2×10^2
Cinnamic aldehyde 0.1%	<10	<10	<10	<10	<10
Calcium chloride 0.75%	<10^2	<10^2	<10^2	<10^2	4.6×10^2
Aldehyde + chloride	<10	<10	<10	<10	<10
Molds and yeasts (CFU g^{-1})					
Control	<10	<10	<10	3.1×10^2	5.9×10^2
Cinnamic aldehyde 0.1%	<10	<10	<10	<10	3.0×10
Calcium chloride 0.75%	<10	<10	<10	1.7×10^2	3.8×10^2
Aldehyde + chloride	<10	<10	<10	<10	1.1×10^2

3.2. Physical and physicochemical analyses

3.2.1. CO_2

Samples in the combination treatment group had a lower mean CO_2 concentration on days 3, 6, 12, and 15 (Table 2).

All the treatments had increased CO_2 concentrations ($P < 0.05$, Tukey's test). Samples in the combination treatment group had a lower CO_2 concentration over time (Fig. 1a, $P < 0.05$, regression

Table 2
Means and Tukey's Test for CO_2, firmness, soluble solids, titratable acidity and pH, in minimally processed papaya submitted to four treatments for six storage periods at 5 °C.

Treatments	Storage periods (days)					
	1	3	6	9	12	15
Concentration of CO_2 (%)						
Control	1.48^{ab}	2.63^{a}	3.02^{ab}	3.09^{a}	3.24^{a}	3.72^{a}
Cinnamic aldehyde 0.1%	2.29^{a}	3.47^{a}	3.80^{a}	3.47^{a}	3.09^{a}	4.57^{a}
Calcium chloride 0.75%	1.35^{b}	2.75^{a}	3.39^{a}	3.39^{a}	3.31^{a}	3.89^{a}
Aldehyde + chloride	1.45^{ab}	2.29^{a}	1.99^{b}	3.31^{a}	2.09^{a}	3.16^{a}
Firmness (N)						
Control	2.89^{a}	3.42^{a}	1.25^{b}	1.25^{c}	2.13^{b}	1.80^{b}
Cinnamic aldehyde 0.1%	2.86^{a}	3.20^{ab}	2.59^{a}	1.59^{bc}	1.82^{b}	1.06^{c}
Calcium chloride 0.75%	1.61^{b}	2.28^{b}	1.37^{b}	2.76^{a}	3.20^{a}	1.46^{bc}
Aldehyde + chloride	2.69^{a}	3.46^{a}	1.69^{b}	2.28^{ab}	2.16^{b}	3.65^{a}
Soluble solids (°Brix)						
Control	11.82^{d}	12.82^{b}	11.98^{a}	12.01^{bc}	11.92^{a}	11.93^{a}
Cinnamic aldehyde 0.1%	12.31^{c}	12.01^{c}	12.14^{a}	12.41^{a}	12.23^{a}	11.40^{bc}
Calcium chloride 0.75%	14.06^{a}	13.52^{a}	12.06^{a}	12.27^{ab}	12.02^{a}	11.30^{c}
Aldehyde + chloride	13.22^{b}	13.23^{a}	11.98^{a}	11.88^{c}	11.95^{a}	11.67^{ab}
Titratable acidity (g citric acid 100 g^{-1})						
Control	0.21^{b}	0.22^{a}	0.30^{b}	0.32^{a}	0.35^{a}	0.40^{a}
Cinnamic aldehyde 0.1%	0.29^{a}	0.25^{a}	0.36^{a}	0.34^{a}	0.30^{a}	0.48^{a}
Calcium chloride 0.75%	0.32^{a}	0.22^{a}	0.35^{ab}	0.32^{a}	0.29^{a}	0.32^{a}
Aldehyde + chloride	0.21^{b}	0.21^{a}	0.32^{ab}	0.34^{a}	0.35^{a}	0.38^{a}
pH						
Control	5.45^{a}	5.31^{a}	5.30^{a}	5.21^{b}	5.20^{b}	4.78^{b}
Cinnamic aldehyde 0.1%	5.31^{b}	5.20^{b}	5.21^{b}	5.19^{b}	5.23^{ab}	4.84^{b}
Calcium chloride 0.75%	5.36^{b}	5.36^{a}	5.26^{ab}	5.25^{b}	5.23^{ab}	5.04^{a}
Aldehyde + chloride	5.28^{b}	5.28^{a}	5.27^{ab}	5.31^{a}	5.31^{a}	5.11^{a}

Values within columns with uncommon character (a–d) were significantly different ($P < 0.05$).

analysis). The lower concentration of CO_2 in the this group can be attributed to calcium that accumulates between the cell wall and middle lamella as well as to the calcium pectate present as a constituent of the cell wall (Gonçalves, Carvalho, & Gonçalves, 2000). Arruda et al. (2003) reported no significant change in the gas composition in an evaluation of the quality of melon MP stored at 3 °C in a passive modified atmosphere. In these study, was explained by the relationship between the effective area of permeation of the pack (896 cm^2) and the mass of papaya (240 g) associated with a low respiratory rate. Factors found to influence the CO_2 concentration were permeability to water vapor, CO_2 concentration inside the package, and the relationship between the surface area of the barrier and the mass of the product (Smith, Geeson, & Stow, 1987).

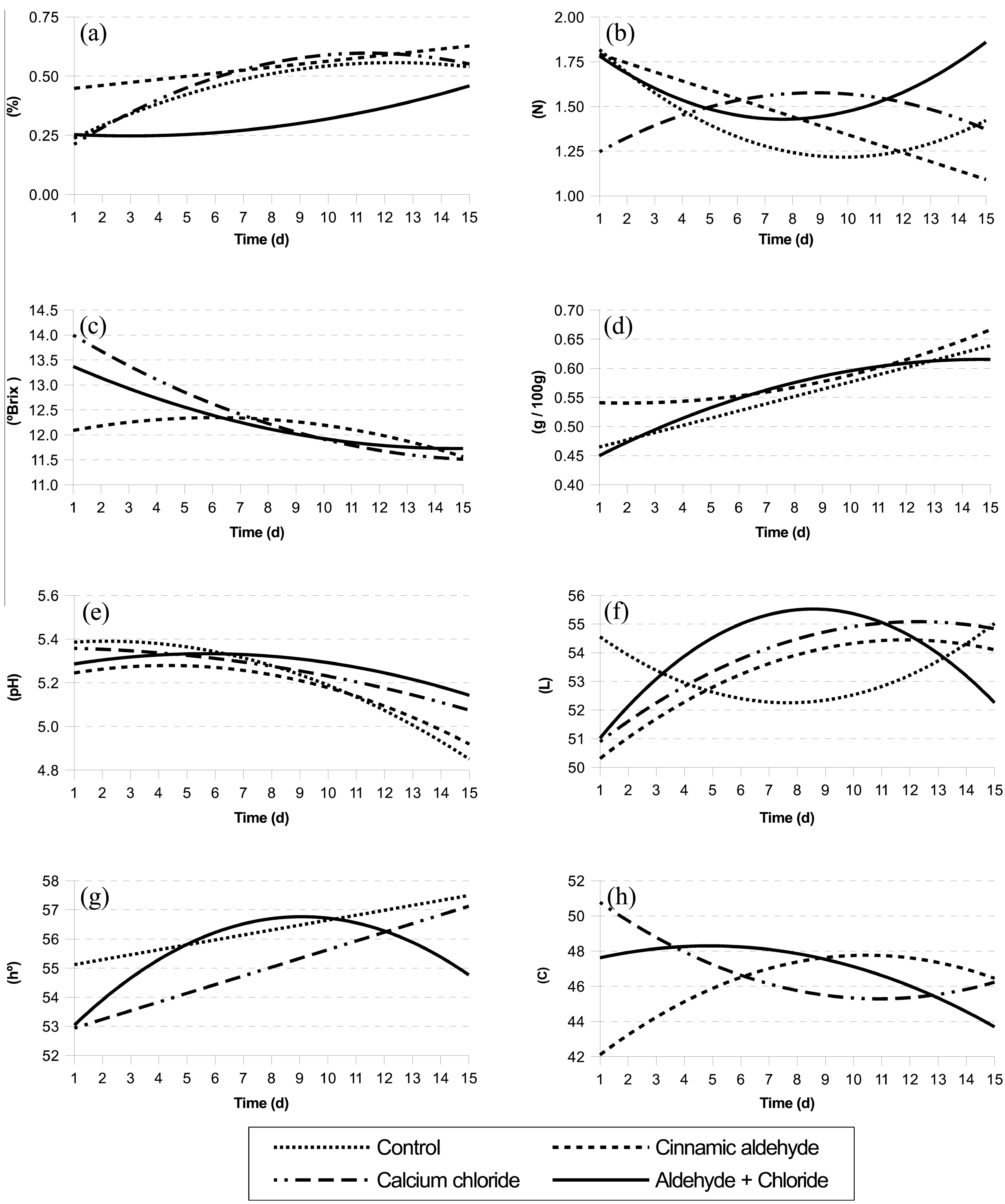

Fig. 1. Regression analysis for CO_2 (a), firmness (b), soluble solids (c), tritatable acidity (d), pH (e), lightness (f), hue angle (g) and chromaticity (h) in minimally processed papaya submitted to four treatments during 15 days of storage at 5 °C.

3.2.2. Firmness

On day 3, the samples in the combination treatment group showed significantly greater firmness ($P < 0.05$, Tukey's test) than those in the 0.75% calcium chloride treatment group (Table 2). The control group and combination treatment group had reduced firmness on day 15. The calcium chloride treatment group had increased firmness until day 12 (Fig. 1b, $P < 0.05$, regression analysis), probably because of the presence of calcium, which delays maturation. Calcium creates covalent linkages between pectin molecules in the cell wall and the middle lamella. This generates calcium pectate, which limits the action of enzymes responsible for the loss of texture and firmness (Salunke, Bolin, & Reddy, 1991). Asmar, de Abreu, Lima, Corrêa, and dos Santos (2010) evaluated papaya treated with 1-MCP and stored it for 8 days at 22 °C and found that the firmness decreased in all treatments. Fruits treated with 1-MCP significantly differed from the control fruit, with a slight reduction in firmness. The use of 1-MCP promoted a reduction in ripening and senescence and preserved firmness. The reduction in firmness on day 15 in the control group and combination treatment group may be a consequence of the natural process of softening and senescence of the fruit.

3.2.3. Soluble solids

On day 3, the samples in the calcium chloride treatment group and the combination treatment group had significantly higher means ($P < 0.05$, Tukey's test) than those in the control group and the cinnamic aldehyde treatment group (Table 2). Until day 6, samples in the combination treatment group showed fewer soluble solids than those in calcium chloride treatment group. After day 6, the treatment means were similar. Until day 6, the samples in the calcium chloride treatment group and the combination treatment group showed a greater reduction in soluble solids than the other treatment groups. The greater reduction may be due to double immersion in these treatments which produced the most pigment leaching. After day 6, the means of the samples in all the treatment groups stabilized and were similar (Fig. 1c, $P < 0.05$, regression analysis). Rivera-López, Vásquez-Ortiz, Ayala-Zavala, Sotelo-Mundo, and González-Aguilar (2005) compared different cuts of papaya stored for 18 days at 5 °C and 20 °C and found a decrease in the levels of solids and a sharp drop in soluble solids, respectively. This effect could be explained by an increased fruit respiration rate.

3.2.4. Titratable acidity

On day 1, samples in the control group had a significantly lower mean than those in the combination treatment group ($P < 0.05$, Tukey's test) and on day 6, the mean was lower in the cinnamic aldehyde treatment group. After day 9, there were no significant differences between the treatment groups (Table 2). The control group and cinnamic aldehyde and combination treatment groups showed a significant increase in acidity during storage (Fig. 1d, $P < 0.05$, regression analysis). The extremely high values obtained for the cinnamic aldehyde treatment group in the beginning were probably due to the acidity of the product. Pinto et al. (2006) package tested whole papayas at 10 °C and observed that the acidity tended to increase until day 4.

3.2.5. pH

On day 1, samples in the control group had a significantly higher mean than those in the other treatment groups and until day 6, the mean was significantly greater than that of the cinnamic aldehyde treatment group. After day 9, the control group and cinnamic aldehyde treatment group did not differ and showed lower means than the other treatment groups. Calcium chloride was the best for controlling pH (Table 2) because of the effect of calcium. Up to day 9, all treatment groups showed a tendency to remain stable (Fig. 1e, $P < 0.05$, regression analysis). After day 9, the control group and cinnamic aldehyde treatment group showed a greater pH reduction than the calcium chloride treatment group. Oliveira et al. (2007) worked with papaya MP stored for 8 days at 5 °C and found a slight decrease in pH during storage. The decrease in pH and the increase in acidity can be attributed to acid degradation that occurs in senescence.

3.2.6. Lightness

On day 1, samples in the control group significantly differed from those in the other treatment groups ($P < 0.05$, Tukey's test), showing greater lightness. On day 6, the control group and cinnamic aldehyde treatment group significantly differed in lightness ($P < 0.05$, Tukey's test) from the other treatment groups, showing low lightness (Table 3). The clarifying effect of calcium may explain the higher lightness levels of samples treated only with calcium chloride at day 6. On day 9, the combination treatment group showed higher lightness compared with the other treatment groups, suggesting that cinnamic aldehyde reduced the absorption of calcium chloride (Fig. 1f, $P < 0.05$, regression analysis). All

Table 3
Means and Tukey's test for lightness, hue angle and chromaticity in minimally processed papaya submitted to four treatments for six storage periods at 5 °C.

Treatments	Storage periods (days)					
	1	3	6	9	12	15
Lightness (L^*)						
Control	55.50^{a}	52.44^{a}	51.36^{b}	52.92^{ab}	54.46^{a}	54.21^{a}
Cinnamic aldehyde 0.1%	49.80^{b}	53.17^{a}	51.18^{b}	55.73^{a}	53.89^{a}	54.16^{a}
Calcium chloride 0.75%	50.75^{b}	51.40^{a}	56.57^{a}	52.57^{b}	55.02^{a}	55.23^{a}
Aldehyde + chloride	50.68^{b}	53.36^{a}	55.47^{a}	55.29^{ab}	54.07^{a}	52.58^{a}
Hue angle ($h°$)						
Control	56.82^{a}	53.63^{bc}	55.43^{a}	56.63^{a}	57.64^{a}	57.33^{a}
Cinnamic aldehyde 0.1%	55.11^{a}	55.95^{a}	54.82^{a}	56.73^{a}	55.85^{a}	57.72^{a}
Calcium chloride 0.75%	52.20^{b}	53.30^{c}	56.27^{a}	56.29^{a}	56.78^{a}	56.42^{a}
Aldehyde + chloride	52.10^{b}	55.63^{ab}	56.80^{a}	54.70^{a}	55.46^{a}	56.32^{a}
Chromaticity (C^*)						
Control	43.12^{c}	46.51^{a}	43.39^{b}	46.08^{a}	43.34^{b}	43.43^{b}
Cinnamic aldehyde 0.1%	41.06^{c}	46.66^{a}	44.17^{b}	48.98^{a}	47.06^{a}	46.59^{a}
Calcium chloride 0.75%	51.13^{a}	48.52^{a}	45.95^{ab}	45.97^{a}	45.74^{ab}	45.91^{ab}
Aldehyde + chloride	47.30^{b}	48.24^{a}	48.77^{a}	47.93^{a}	44.62^{ab}	44.35^{ab}

Values within columns with uncommon character (a–c) were significantly different ($P < 0.05$).

Table 4
Means and Tukey's test for appearance, taste, flavor and texture in minimally processed papaya submitted to four treatments for five storage periods at 5 °C.

Treatments	Storage periods (days)				
	1	3	6	9	12
Appearance					
Control	6.61[a]	6.85[a]	7.50[a]	7.29[a]	7.69[a]
Cinnamic aldehyde 0.1%	6.77[a]	7.22[a]	6.77[a]	7.22[a]	7.36[a]
Calcium chloride 0.75%	7.29[a]	7.07[a]	6.85[a]	7.15[a]	7.69[a]
Aldehyde + chloride	7.22[a]	7.63[a]	7.56[a]	7.29[a]	7.43[a]
Taste					
Control	6.78[ab]	7.21[a]	7.18[a]	7.26[a]	7.31[a]
Cinnamic aldehyde 0.1%	6.03[b]	6.64[a]	7.02[a]	6.57[a]	7.12[a]
Calcium chloride 0.75%	6.72[ab]	7.18[a]	6.38[a]	6.60[a]	6.99[a]
Aldehyde + chloride	6.97[a]	7.41[a]	6.91[a]	7.01[a]	6.86[a]
Flavor					
Control	7.00[a]	6.93[ab]	7.94[a]	6.85[a]	7.76[a]
Cinnamic aldehyde 0.1%	5.26[b]	6.53[b]	7.63[a]	6.29[a]	7.29[a]
Calcium chloride 0.75%	7.36[a]	7.82[ab]	7.22[a]	7.00[a]	7.50[a]
Aldehyde + chloride	7.63[a]	8.11[a]	7.50[a]	7.50[a]	7.15[a]
Texture					
Control	7.04[a]	6.50[b]	7.36[a]	7.29[a]	7.82[a]
Cinnamic aldehyde 0.1%	6.61[a]	6.86[ab]	7.11[a]	7.07[a]	7.07[a]
Calcium chloride 0.75%	7.07[a]	7.50[a]	7.14[a]	7.04[a]	7.25[a]
Aldehyde + chloride	7.57[a]	7.64[a]	7.71[a]	7.25[a]	6.93[a]

Values within columns with uncommon character (a–b) were significantly different ($P < 0.05$).

treatment groups had increased lightness during storage. Alandes, Quiles, Pérez-Munuera, and Hernando (2009) worked with melon MP stored for 28 days at 4 °C and found a slight decrease in lightness during storage.

3.2.7. Hue angle

On day 1, samples in the calcium chloride treatment group and the combination treatment group did not differ but showed significantly smaller means than those in the other treatment groups ($P < 0.05$, Tukey's test). There was a trend of no difference between treatment groups in the other storage periods (Table 3). The control group and calcium chloride and combination treatment groups showed a slight increase in hue angle during storage (Fig. 1g, $P < 0.05$, regression analysis) and had an intense color of ripe fruit. Sancho, Yahia, Martínez-Téllez, and González-Aguilar (2010) demonstrated an increase in the intensity of papaya color.

3.2.8. Chromaticity

On day 1, samples in the calcium chloride treatment group showed the highest mean of all the readings, as well as a significant difference between this and the other treatment groups ($P < 0.05$, Tukey's test). On the other days, samples in the calcium chloride treatment group showed the highest means, indicating better performance (Table 3). After day 3, the treatments were stable, indicating the preservation of color intensity during storage (Fig. 1h, $P < 0.05$, regression analysis). Silveira, Conesa, Aguayo, and Artes (2008) worked with melon MP stored for 10 days at 5 °C and found a slight decrease in lightness and chromaticity during storage.

In all treatment groups, there were no drastic changes in the three dimensions of color: lightness, hue angle, and chromaticity.

3.3. Sensory analysis

3.3.1. Appearance

All treatment groups were rated 100% acceptable. On days 1 and 3, the control group had the lowest means (Table 4). According to the evaluators, the lower appearance scores for the control group were due to the parched appearance of the fruit surface. The means of the combination treatment group increased during storage (Fig. 2a, $P < 0.05$, regression analysis). One possible explanation is the occurrence of water condensation inside the package. The external appearance was not affected by the treatments, but it did decrease with storage time. Silveira et al. (2008) worked with melon MP stored for 10 days at 5 °C and submitted them to different washing treatments and observed an acceptable product appearance and a decrease in scores during storage.

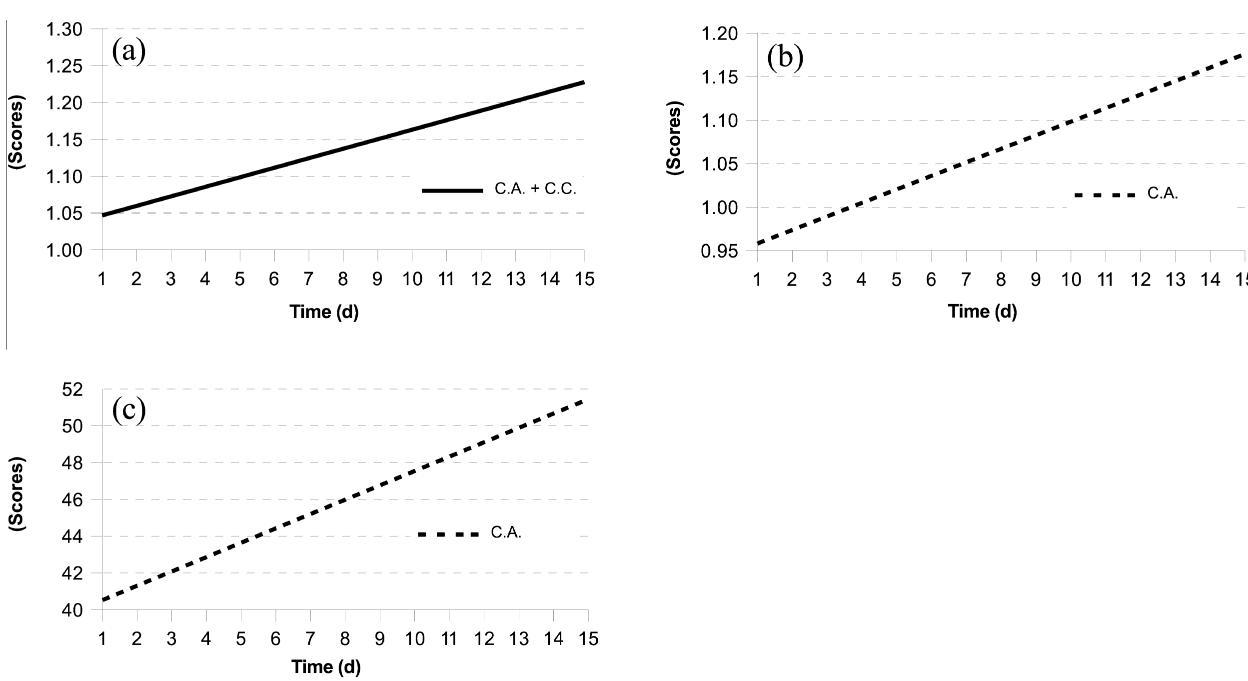

Fig. 2. Regression analysis for appearance (a), taste (b) and flavor (c) in minimally processed papaya submitted to four treatments (cinammic aldehyde C.A., cinammic aldehyde + calcium chloride C.A. + C.C.) during 12 days of storage at 5 °C.

3.3.2. Taste

After day 3, there was a 100% acceptance rate (Table 4). At day 1, the mean of the cinnamic aldehyde treatment group was the lowest and it significantly differed from the means for the combination treatment group ($P < 0.05$, Tukey's test) possibly because of the strong taste and presence of aromatic compounds in the aldehyde. During storage, the cinnamic aldehyde treatment group increased the scores (Fig. 2b) with a linear trend ($P < 0.05$, regression analysis).

3.3.3. Flavor

There was a 100% acceptance rate in all treatment groups (Table 4). On day 1, the cinnamic aldehyde treatment group had the lowest mean, and it significantly differed from the means of the other treatment groups ($P < 0.05$, Tukey's test). The cinnamic aldehyde treatment group showed an increasing linear trend for scores (Fig. 2c) ($P < 0.05$, regression analysis). The increase can be attributed to the volatilization of cinnamic aldehyde.

3.3.4. Texture

There was a 100% acceptance rate for all treatment groups in all periods (Table 4). On day 3, the mean of the control group was the lowest, and it significantly differed from the means of the cinnamic aldehyde and combination treatment groups.

Consistent with the findings of other studies, this experiment obtained an acceptability rate of 100% (appearance, taste, flavor, and texture). Trigo et al. (2012) evaluated papaya MP coated in carbohydrate and stored for 15 days at 5 °C obtained acceptability for the same sensory attributes. Eswaranandam, Hettiarachchy, and Meullenet (2006) evaluated chemical treatments on melon MP stored for 7 days at 5 °C and obtained acceptability during storage.

4. Conclusions

Chemical treatments increased the shelf life of papaya in 3 days and met the marketing requirements. The treatments did not affect sensory acceptability. Samples in the combination treatment group showed the best performance under the temperature and humidity conditions used in this study (5 ± 1 °C; 90 ± 2% RH). Microbiological analyses were satisfactory and met the BL and EC standards.

Other experiments using different concentrations of cinnamic aldehyde and calcium chloride could be performed to verify the possibility of extending the shelf life of a papaya to 12 days with quality and consumer acceptability.

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