Firmness and Phytochemical Losses in Pasteurized Yellow Banana Peppers (*Capsicum annuum*) As Affected by Calcium Chloride and Storage

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The effect of calcium chloride brine treatment on firmness and retention of phytochemicals in pastuerized yellow banana peppers was studied. Shear force values declined during processing and storage, but $CaCl_2$ treatment resulted in greater firmness retention. Processing reduced ascorbic acid content by 63%, and after 124 days, <10% of ascorbic acid remained. Quercetin and luteolin contents declined 45% during processing, but levels stabilized during storage. Capsaicinoid content was stable during processing and storage. $CaCl_2$ treatment did not affect ascorbic acid, flavonoid, or capsaicinoid retention during pasteurization and storage. Retention of phytochemicals appeared to be related to their solubility and structural properties.

Keywords: *Peppers; phytochemicals; calcium chloride; pasteurization*

INTRODUCTION

Peppers native to the New World tropics are an excellent source of β-carotene, a precursor of vitamin A, and ascorbic acid. Some pepper cultivars contained high concentrations of phytochemicals, such as ascorbic acid, β-carotene, and the flavonoids quercetin and luteolin (Howard et al., 1994a; Lee et al., 1995). Flavonoids have high pharmacological potency in addition to general antioxidant functions (Havesteen, 1983). Flavonoids consisting of flavanones, flavones, flavonols, and isoflavones also exhibit antiviral and antiallergic effects and are potent lipoxygenase and cyclooxygenase inhibitors in animal systems (Stavric and Matula, 1992). Luteolin also has shown strong antimutagenic activity against the dietary carcinogen Trp-p-2 (Samegima et al., 1995).

Phytochemical processing and storage stability are affected by environmental factors such as pH, oxygen, light, temperature, and the presence of other phytochemicals. Pasteurization of jalapeno cultivars resulted in a 25% decrease of total provitamin A activity and a 75% decrease in total ascorbic acid content (Howard et al., 1994a). Nutrients may also be lost via physical leaching into the brine solution during processing and storage (Cain, 1967; Price et al., 1997). Flavonoids and ascorbic acid are unstable in neutral or high-pH conditions, but are relatively stable under acidic conditions (Bors et al., 1993). Flavonoids can prevent ascorbic acid degradation by chelating prooxidant metal ions (Harfer et al., 1969).

Brining and pasteurization are commonly used to preserve fresh peppers, and calcium addition to pepper brine has been shown to reduce softening during pasteurization and storage (Fleming et al., 1993; Howard et al., 1994b). Calcium firms plant tissues by forming ionic cross-linkages with polysaccharide polyelectrolytes, especially galacturonans (Grant et al., 1973), resulting in a structure that retards both enzymatic (Buescher and Hudson, 1986) and nonenzymatic softening (Howard and Buescher, 1990). Increasing the cohesive properties of the cell wall-middle lamella complex may prevent leaching of phytochemicals out of pepper fruit during pasteurization and storage, resulting in greater antioxidant retention. In this study, we measured losses of phytochemicals in hot yellow "banana" peppers during pasteurization and storage and determined the effect of $CaCl_2$ on firmness and phytochemical retention.

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MATERIALS AND METHODS

Preparation and Processing. Fresh yellow "banana" peppers (*Capsicum annuum* var. *annuum*) were obtained from a local supermarket. Peppers were packed in glass jars to obtain a pack out ratio of 60% pepper and 40% brine (w/v). Brine treatments provided 4% NaCl, 0.7% acetic acid, and 0 or 0.08% $CaCl_2$ in the final product. Peppers were pasteurized to an internal temperature of 74 °C, held for 10 min, cooled with tap water, and stored at 23 °C. Firmness and chemical analyses were conducted on fresh peppers and 1, 7, 21, 49, and 124 days after processing.

Phytochemical Determination. Flavonoid extraction and analysis as described by Lee et al. (1995) was used. After acid hydrolysis, flavonoid aglycons were quantified at 370 nm using a 4 mm × 15 cm, Nova-Pak C_{18} column with a solvent system of methanol/water (45:65), pH 2.4 with phosphoric acid at 1 mL/min. Ascorbic acid analysis was performed according to the HPLC method of Wimalasiri and Wills (1983). A 4 mm × 30 cm Bondapak-NH_2 column with a mobile phase of acetonitrile/water (70:30), containing 0.01 M ammonium phosphate (pH 4.3), at 2 mL/min was used. For capsaicinoid analysis, peppers (50 g) were extracted with 100 mL of acetone. Evaporated acetone extracts were dissolved with ethyl acetate. Ethyl acetate fractions were then evaporated, solubilized in 5 mL of methanol, and injected into a GC equipped with an HP-1 capillary column (methyl silicone gum, 30 m × 0.53 mm × 2.65

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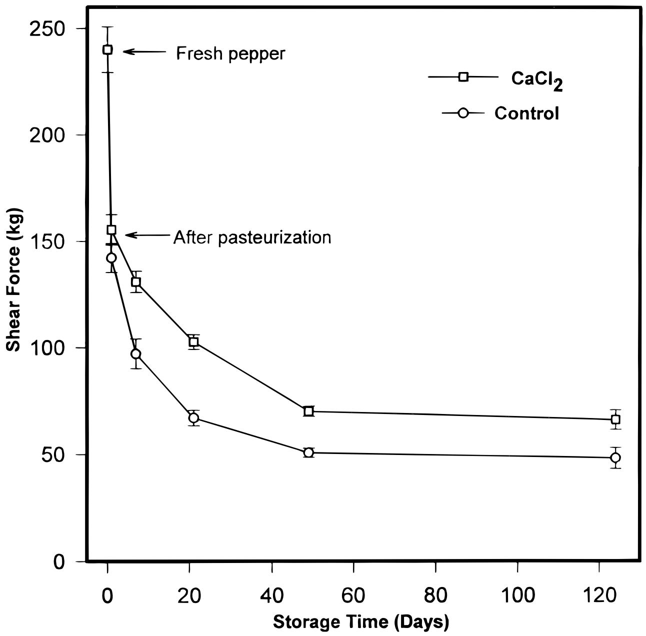

Figure 1. Firmness of pasteurized banana peppers as affected by $CaCl_2$ and storage at 23 °C. Bars represent standard error of the mean ($n = 3$).

μm film thickness; Hewlett-Packard, Palo Alto, CA) and a flame ionization detector. Injector temperature was 250 °C, and detector temperature was 275 °C. Oven temperature was isothermal at 230 °C.

Phytochemicals were quantified using external standards.

Firmness Measurement. Peppers were cut into 10 mm thick rings, and firmness was determined using a TP-6 texture press and model TR-5 texturecorder (Food Technology Corp., Rockville, MD). Pepper rings (75 g) were placed in a model CS-1 standard compression cell, and the peak height of the force required to shear the sample was recorded.

RESULTS AND DISCUSSION

Pepper shear force values decreased 40% after pasteurization, continued to decline up to 50 days, and then stabilized from 50 to 120 days (Figure 1). Peppers treated with $CaCl_2$ had greater shear force values than non-calcium-treated peppers throughout the study. Disruption of cell membranes during pasteurization in salt−acid brines results in loss of turgor pressure, which is an important factor affecting cell integrity. Supplementation of calcium in brine solution is important because Ca^{2+} binds with pectic substances to create a structure that resists both enzymatic and nonenzymatic softening (Howard and Buescher, 1990). Calcium chloride treatment resulted in higher shear force values in canned jalapeno peppers compared to non-calcium-treated peppers, after 3 months of storage (Saldana and Meyer, 1981), and prevented acid-catalyzed softening during pasteurization of jalapeno pepper rings (Howard et al., 1994b).

Calcium treatment affected pepper weight after processing, with less weight gain observed in calcium-treated rings (Figure 2). Calcium ions presumably complexed with cell wall polyuronides, creating a stronger cell wall that resisted expansion and associated absorption of water and solutes.

Large losses of ascorbic acid in yellow banana peppers occurred during pasteurization and storage (Figure 3). The largest losses occurred during pasteurization and within 1 week after processing. Jalapeno cultivars that were blanched prior to pasteurization lost 75% of their ascorbic acid (Howard et al., 1994a), whereas Matthews and Hall (1978) reported a 40% loss of ascorbic acid during water blanching of green peppers. In contrast, ascorbic acid was well retained in jalapeno peppers after blanching and pasteurization (Saldana and Meyer, 1981). Differences in ascorbic acid retention in these studies may be attributed to differences in pepper genetics, brine composition, blanching method, and pasteurization time and temperature.

In our study, the large osmotic gradient between the brine solution and pepper fruit promoted leaching of water soluble components, including ascorbic acid, out of the fruit. The 30% loss of fresh weight observed after

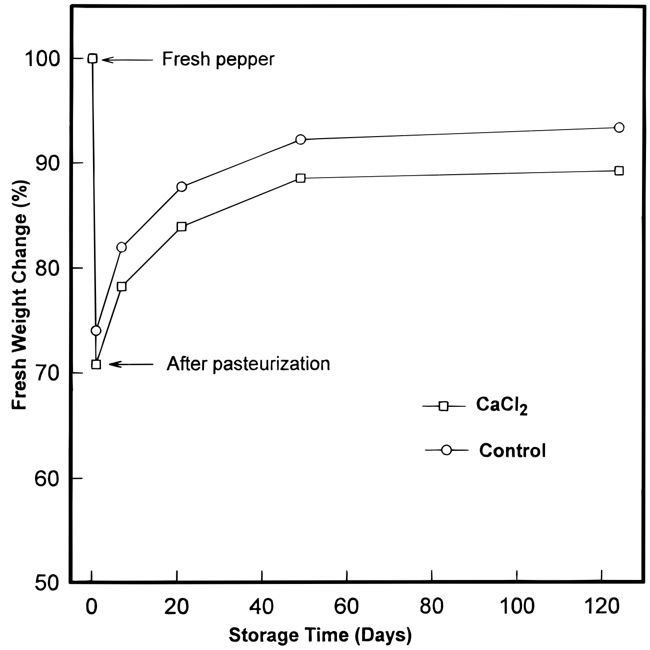

Figure 2. Changes in fresh weight of pasteurized banana peppers as affected by $CaCl_2$ and storage at 23 °C. Bars represent standard error of the mean ($n = 3$).

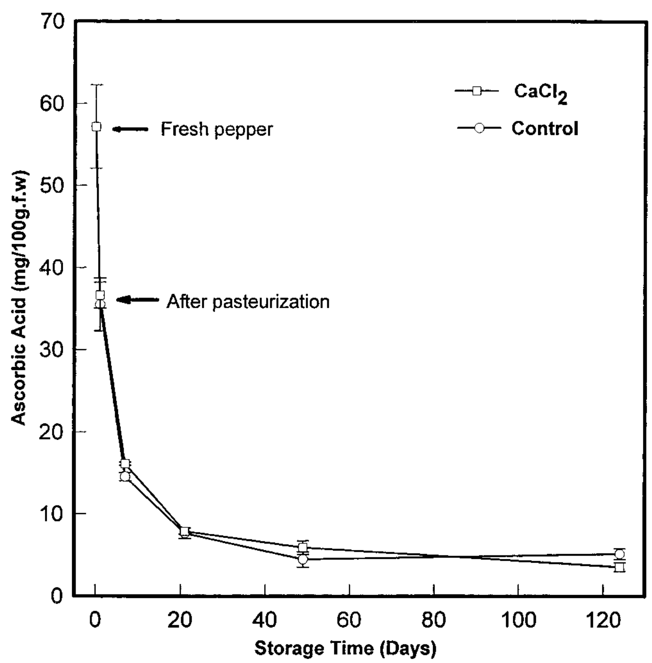

Figure 3. Ascorbic acid content of pasteurized banana peppers as affected by $CaCl_2$ and storage at 23 °C. Bars represent standard error of the mean ($n = 3$).

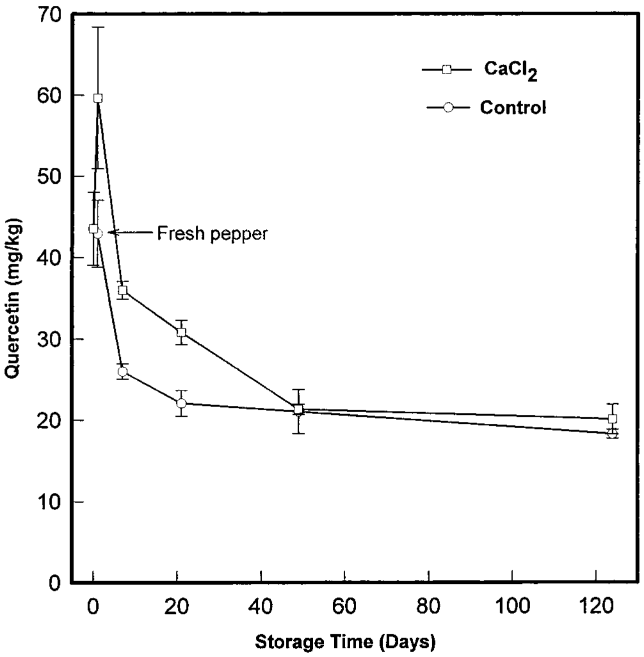

Figure 4. Quercetin content of pasteurized banana peppers as affected by $CaCl_2$ and storage at 23 °C. Bars represent standard error of the mean ($n = 3$).

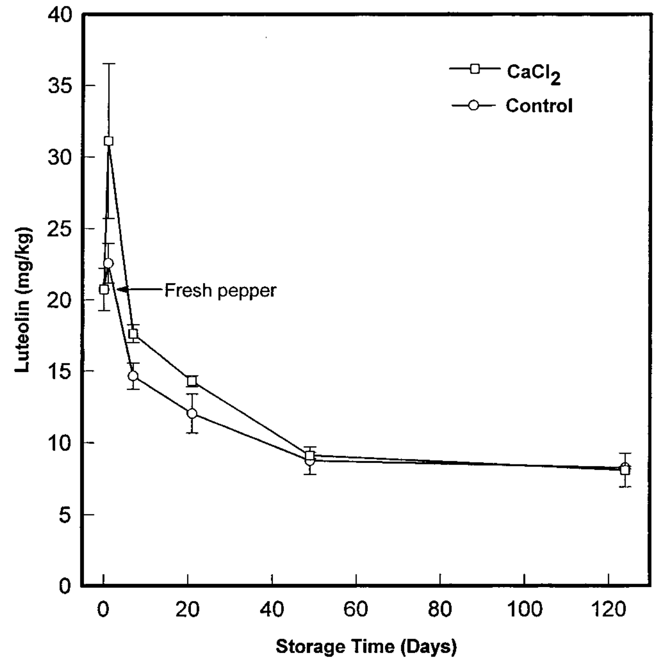

Figure 5. Luteolin content of pasteurized banana peppers as affected by $CaCl_2$ and storage at 23 °C. Bars represent standard error of the mean ($n = 3$).

processing (Figure 2) may include substantial amounts of ascorbic acid. The ascorbic acid content continuously declined even when peppers regained fresh weight, indicating that oxidation contributed to ascorbic acid decline. Oxidation could be caused by residual air space and dissolved oxygen in the canned product or by enzymatic reactions such as peroxidase or ascorbic acid oxidase. Ascorbic acid is labile to heat, light, oxygen, metals, and pH >7. Contact with water during fruit and vegetable processing is undesirable, because ascorbic acid is water soluble. However, blanching treatments have been shown to result in greater ascorbic acid retention in processed vegetables, due to inactivation of ascorbic acid oxidase and removal of residual oxygen from vegetable tissue (Selman, 1994). More studies are needed to optimize blanching and pasteurization parameters to prevent losses of water soluble nutrients in pepper fruit.

Calcium chloride treatment did not affect ascorbic acid loss during pasteurization and storage of yellow banana peppers. Calcium chloride brine treatment was also ineffective in preventing ascorbic losses during pasteurization and storage of jalapeno peppers (Saldana and Meyer, 1981).

Quercetin and luteolin contents increased after pasteurization (Figures 4 and 5). These gains were due to a concentration effect that occurred when fresh peppers were pasteurized in the high-salt brine solution. Quercetin and luteolin contents then decreased during storage. After 120 days of storage, peppers retained 40–45% of quercetin and luteolin found in fresh peppers. Quercetin glucoside content declined 25% when onions were boiled, due to leaching into the cooking water (Price et al., 1997).

The $CaCl_2$ treatment did not affect quercetin and luteolin losses during long-term storage. Because flavonoids were relatively stable and retained well in processed peppers after equilibration with brine solution, it may be beneficial to use peppers cultivars that have high flavonoid contents for processing.

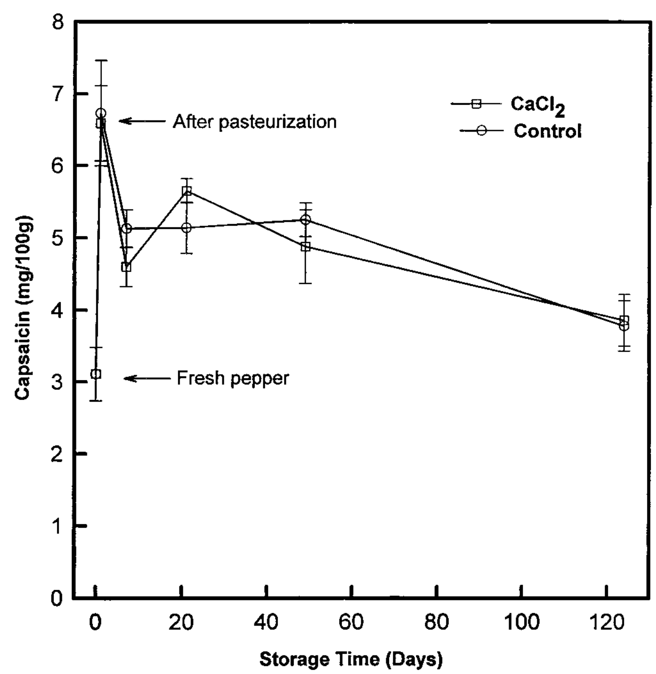

Figure 6. Capsaicin content of pasteurized banana peppers as affected by $CaCl_2$ and storage at 23 °C. Bars represent standard error of the mean ($n = 3$).

Capsaicinoids were the most stable antioxidant nutrient measured. Capsaicin and dihydrocapsaicin contents initially increased after processing, but their retention rates after 4 months were 70–90% of levels found in fresh peppers (Figures 6 and 7). Increased capsaicinoid content was caused by reduction in pepper weight after processing in high-acid/salt brine solution. High salt (8% NaCl) content created an osmotic potential gradient between the brine solution and pepper tissue, resulting in water migration out of the pepper rings. Additionally, some of the capsaicinoid increase may have resulted from liberation of capsaicin from complexed compounds during cooking (Harrison and Harris, 1985). The cap-

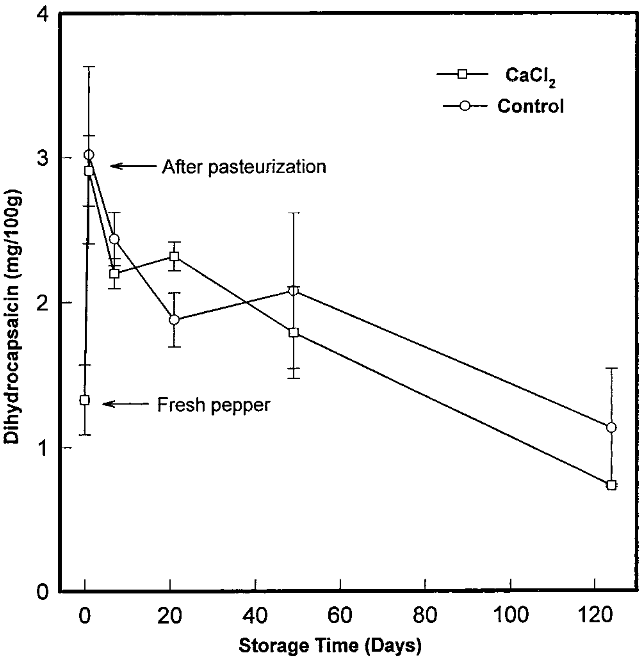

Figure 7. Dihydrocapsaicin content of pasteurized banana peppers as affected by $CaCl_2$ and storage at 23 °C. Bars represent standard error of the mean ($n = 3$).

saicinoid content in jalapeno peppers in one study increased 19% after cooking for 10 min at 100 °C, whereas in another study no changes in capsaicin content occurred after blanching and pastuerization of jalapeno peppers (Saldana and Meyer, 1981). The nonpolar, water insoluble nature of capsaicinoids contributed to greater retention during brine equilibration and storage. These results are consistent with previous studies in which 75% of the nonpolar compound β-carotene was retained in jalapeno pepper cultivars after blanching and pasteurization (Howard et al., 1994a), whereas no loss of vitamin A was observed in jalapeno peppers after blanching and pasteurization (Saldana and Meyer, 1981). Capsaicinoids are an important flavor contributor and antioxidant in peppers, and their levels were well retained during 4 months of storage.

Calcium chloride did not affect capsaicinoid losses during storage of yellow banana peppers. Saldana and Meyer (1981) also reported that capsaicin levels in jalapeno peppers were not influenced by various calcium salt brine solutions after blanching and pasteurization.

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