Calcium Treatments Affect Storage Quality of Shredded Carrots

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ABSTRACT

Carrot shreds, sticks and slices were dipped in solutions of $CaCl_2$ alone, or with chlorine and stored at 0, 5 or 10°C to determine the effects of calcium (Ca) on storage quality. A 0.5% or 1% $CaCl_2$ treatment maintained firmness and reduced microbial growth of carrot shreds at all temperatures. These treatments also resulted in lower tissue pH than in the water-dipped controls. Treatments increased Ca content slightly in sticks and slices and substantially in shreds and had no effect on storage quality of sticks or slices.

Key Words: carrot, lightly processed, calcium, texture, microbial population

INTRODUCTION

LIGHTLY PROCESSED vegetables may have exposed injured tissues as a result of the mechanical processes of peeling, slicing, and/or cutting. Such processing consequences create stress at the tissue, cellular, subcellular and biochemical levels and cause many undesirable changes during storage and distribution (Rolle and Chism, 1987; Huxsoll and Bolin, 1989; Watada et al., 1990) that must be controlled to maintain quality.

One approach to protecting intact fruits and vegetables from deterioration is to apply calcium (Ca) to the product. Ca is important in maintaining quality of intact fruits and vegetables (Shear, 1975; Bangerth, 1979; Poovaiah, 1986). Ca treatment of apples can reduce respiration (Bangerth et al., 1972; Faust and Shear, 1972; Poovaiah, 1986), suppress ethylene production (Poovaiah, 1986; Dilley, 1990), increase firmness retention (Bangerth et al., 1972; Mason, 1976; Conway and Sams, 1984; Poovaiah, 1986), and reduce the incidence of physiological disorder and decay (Bangerth et al., 1972; Shear, 1975; Conway and Sams, 1984; Dilley, 1990; Hewett and Watkins, 1991). Ca appears to help maintain structural integrity of membranes and cell walls (Bangerth, 1979; Poovaiah, 1986), thus extending shelf life and minimizing disorders.

Ca treatment may be beneficial to some lightly processed products. Ca treatment maintained firmness in sliced strawberries better than in whole strawberries (Morris et al., 1985). Ca alone or combined with other additives such as ascorbic acid or sulfur dioxide maintained firmness of pear and strawberry slices (Rosen and Kader, 1989) and carrot sticks (Bruemmer, 1987), and reduced browning of apple (Ponting et al., 1972) and pear slices (Rosen and Kader, 1989). In contrast, the storage life of shredded lettuce (Bolin et al., 1977) and cut lettuce (Krahn, 1977) was not extended by Ca treatment. The lack of response to Ca by lettuce compared to other products may be due to differences in attributes of the product, its form, concentration of solution, and storage temperature.

Our objective was to determine the effects of Ca treatments on the quality of lightly processed carrots. Bruemmer (1987) has reported the effects of Ca treatments on carrot sticks stored at 2°C. Our research was expanded to determine effects of Ca treatments also on shreds and slices stored at other temperatures. The expanded temperatures were included because, although the ideal storage temperature is 0°C, many lightly processed carrots are held commercially at 5°, and sometimes at 10°C. Since chlorine is widely used in the food and dairy industry as a disinfectant (Smith, 1962), one treatment included addition of chlorine to the Ca solution to determine if the disinfectant affected results from Ca treatment.

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MATERIALS & METHODS

CARROTS harvested in Bakersfield, CA were obtained from the Jessup, Maryland Wholesale Market and kept at 0°C for a maximum of 3 days. They were washed thoroughly, peeled, and trimmed of tap root and stem plate prior to preparation. A Cuisinart Food Processor, Model DLC-10, (Cuisinarts Corp.) was used to prepare carrot shreds (ca 4 mm wide, 50 mm long and 2 mm thick), sticks (ca 5 mm wide, 50 mm long and 4 mm thick) and slices (>20 mm diam and 5 mm thick). Processed carrots (600g) of each type were dipped in 2 L solution of 0.5% $CaCl_2$, 1% $CaCl_2$, 1% $CaCl_2$ containing 100 ppm sodium hypochlorite, or distilled water for 2 min at room temperature (≈23°C). Treated carrot shreds, sticks, and slices were centrifuged for 0.5, 1.5, and 2 min respectively at room temperature using the drying cycle of a washing machine to remove surface solution. A 100g sample was then placed in a 1L plastic tray. Four plastic trays, each containing one of the treatments, were placed in a 10L flat container, which was inserted in a polyethylene bag. Three replicated samples of each treatment were stored at 0°C, 5°C, and 10°C for 28, 21, and 11 days, respectively. A stream of humidified air was metered through the bag at sufficient rate to keep the CO_2 concentration < 0.5%. Two liters of distilled water were placed in each container to maintain high relative humidity. Sample trays were elevated to prevent contact of the cut produce with water. Sub-lots of each treatment were removed after scheduled storage periods for analyses of weight, texture, microbial population, pH, and color.

Ca concentration

Ca concentration was determined with an atomic absorption spectrophotometer (Conway and Sams, 1984). The treated and centrifuged samples were frozen in liquid nitrogen, freeze-dried, ground, and ashed. The ash was dissolved in dilute HCl and analyzed for Ca concentration. Ca values were recorded on a dry-weight basis.

Texture

Texture was based on the force required to shear the sample using a Food Technology Corporation Texture Test System (Model TMS-90) equipped with a standard shear-compression cell (Model CS-1). For this test, a 40g sample of carrot shreds, sticks or slices was placed

Table 1—Calcium concentration of carrot slices, sticks and shreds treated with $CaCl_2$ solutions

Treatment (% $CaCl_2$)	Cut form	Calcium conc (mg/g dry wt)
0	Shreds	2.0 [d]
1	Slices	2.3 [c]
1	Sticks	3.5 [b]
1	Shreds	7.4 [a]

[abcd] Means with different letters are significantly different ($p<0.01$).

Table 2—Calcium concentration of carrot shreds treated with calcium solutions

Treatment	Calcium conc (mg/g dry wt)
Control-water dip	2.0[c]
0.5% $CaCl_2$	5.1[b]
1% $CaCl_2$	7.4[a]
1% $CaCl_2$ + chlorine	7.4[a]

[abc] Means with different letters are significantly different ($p<0.01$).

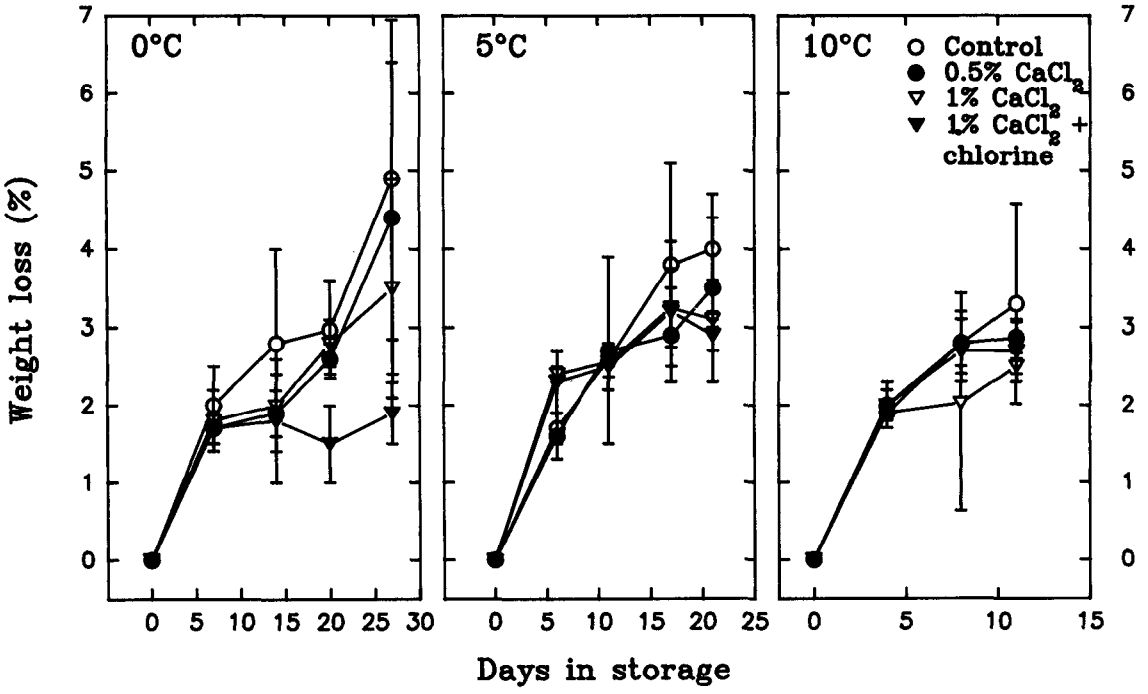

Fig. 1—Changes in weight loss of carrot shreds stored at 0°C, 5°C, and 10°C following $CaCl_2$ treatments. Means of three measurements. Vertical lines represent SE.

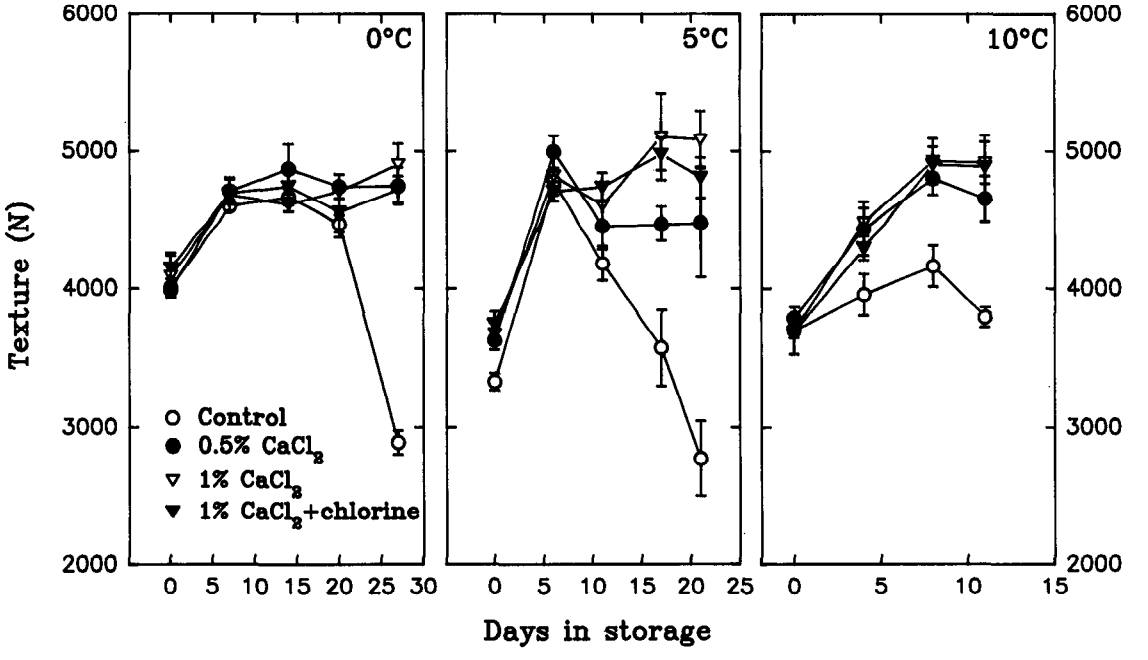

Fig. 2—Changes in texture based on shear force of carrot shreds stored at 0°C, 5°C, and 10°C following $CaCl_2$ treatments. Means of three measurements. Vertical lines represent SE. SE bars were not shown when masked by the graph symbol.

in the cell box perpendicular to the 10 shear blades. The force required to shear the sample was expressed in newtons (N).

Total microbial count

A 10-g sample of carrot tissue was transferred aseptically to 90 mL of sterile physiological saline solution (0.85% NaCl-water) and completely immersed and stirred with a sterile glass rod for 1 min. Serial dilutions of this solution were poured in duplicate standard methods agar plates to determine the total microbial count on the surface of the tissue. The plates were incubated at 25°C and numbers of colonies were counted after 48 hr. All samples, except the 0.5% $CaCl_2$ treatment, were assayed. Microbial counts were expressed as $\log_{10}$ count/g sample.

pH and color

A 30-g sample of carrot tissue in 30 mL of deionized water was blended for 2 min at high speed and the pH of the slurry was measured with an Orion Research pH meter (Model 811). The surface color of 10 carrot samples for each treatment was measured using a Minolta Chroma Meter (Model CR-300). The L*, a* and b* readings were recorded, and results also were expressed as the Whiteness Index (WI), $WI = 100 - [(100 - L^*)^2 + a^{*2} + b^{*2}]^{1/2}$, since it correlated

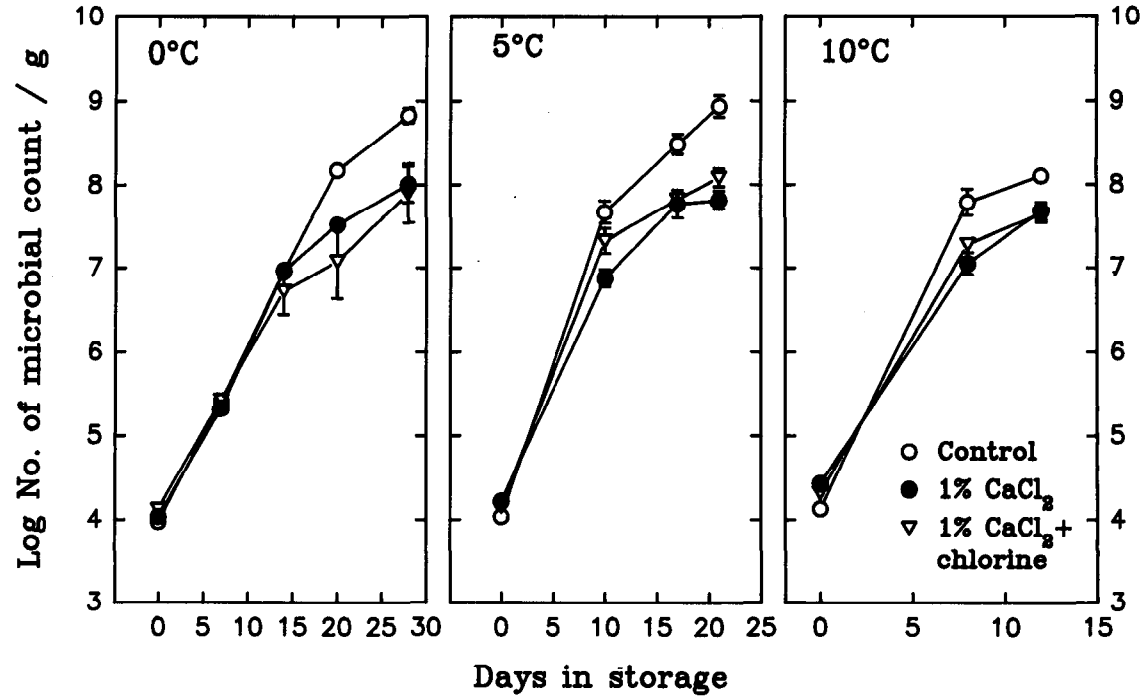

Fig. 3—Changes in total microbial count on surface tissue of carrot shreds stored at 0°C, 5°C, and 10°C following $CaCl_2$ treatments. Means of three measurements. Vertical lines represent SE. SE bars were not shown when masked by the graph symbol.

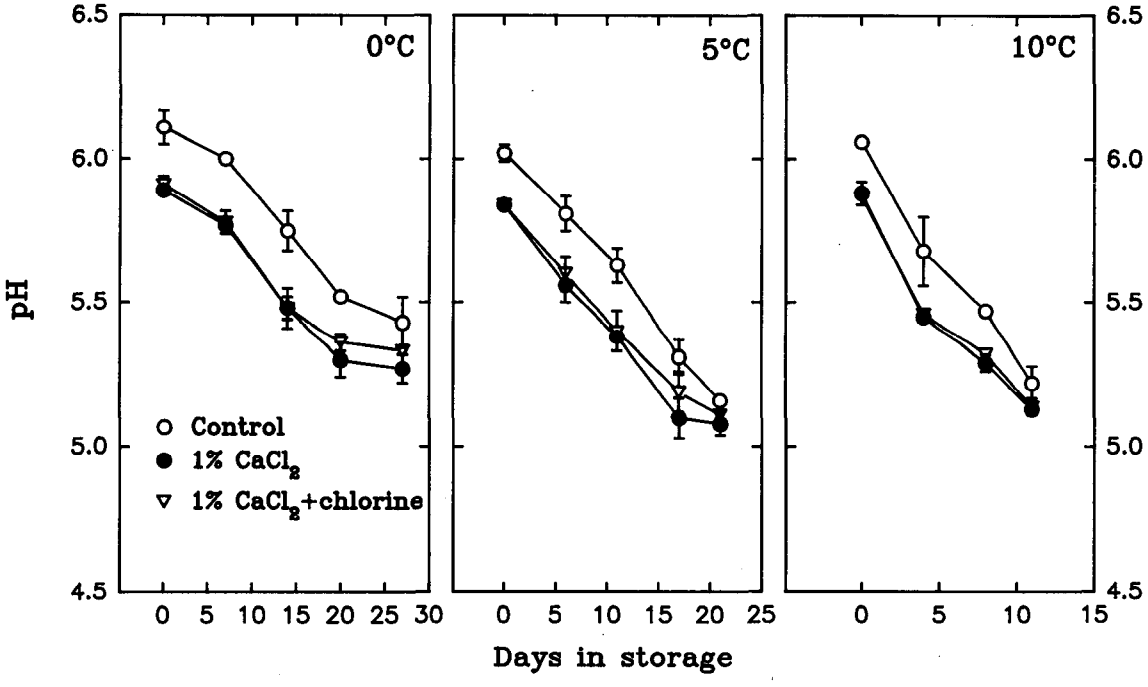

Fig. 4—Changes in pH of carrot shreds stored at 0°C, 5°C, and 10°C following $CaCl_2$ treatments. Means of three measurements. Vertical lines represent SE. SE bars were not shown when masked by the graph symbol.

better with the visual development of white material on the carrot surface than chroma values (Bolin and Huxsoll, 1991a).

Statistical analysis

Data were subjected to analysis of variance and the Duncan's Multiple Range test for tabulated data, and the standard error of each mean is presented in the figures.

RESULTS & DISCUSSION

Ca HAD NO EFFECT on weight loss, texture, microbial population or color of carrot slices and sticks (data not shown), so only the results of carrot shreds are presented. The lack of Ca effect on carrot slices and sticks presumably was due to insufficient Ca absorption by the tissue (Table 1). Carrot shreds had almost two and three times more Ca concentration than sticks and slices, respectively. Ca concentration in carrot shreds treated with $CaCl_2$ was higher than in those dipped in water (Table 2). A 0.5% $CaCl_2$ treatment increased Ca by almost 2.5-fold to 5.0 mg/g dry weight and the 1% treatment increased it 3.7-fold to 7.4 mg/g dry weight.

Weight loss of all samples increased during storage at all temperatures (Fig. 1). Because of the large sample variation

(large SE) and lack of consistency among treatments, Ca appeared to have no effect on weight loss. Based on shear force readings, textural quality of the control samples changed differently from that of Ca-treated samples (Fig. 2). Resistance to shear increased initially during the first 5 to 14 days at all temperatures, after which the control sample texture began to decrease. The texture of Ca-treated samples remained at an elevated level. No consistent differences in texture were noted between the 0.5% and 1% $CaCl_2$ treatments.

The texture was not correlated with Ca content of treated samples. Carrot shreds treated with 1% $CaCl_2$ contained more Ca than those treated with 0.5% $CaCl_2$ (Table 2), but there was no difference in texture between the two treatments (Fig. 2). The 0.5% $CaCl_2$ treatment may have added sufficient Ca to the tissues to maximize texture results. This was noted previously with stored strawberry slices (Morris et al., 1985; Rosen and Kader, 1989) and carrot sticks (Bruemmer, 1987). Ca is essential for the structure and function of cell walls and membranes. The maintenance of the cell wall structure depends upon Ca cross-linkage, particularly with pectin components of the middle lamella, as reviewed by Bangerth (1979) and Poovaiah (1986), and confirmed with carrot tissues by electron microscopy by Ahmed et al. (1991). Thus with the carrot shreds of our study, maintenance of texture probably was due to the Ca action in stabilizing membranes and cell walls.

The total microbial count on surfaces of carrot shreds increased during storage at all temperatures and the rates of increase were greater at the higher storage temperatures (Fig. 3). Treatment with 1% $CaCl_2$ alone, or with hypochlorite reduced the total microbial count on carrot shreds at all temperatures. Total counts of controls and Ca-treated samples were similar in early storage, but with time, the control counts increased at a greater rate than those of Ca-treated samples. The addition of chlorine to $CaCl_2$ did not affect growth of microbes. Bolin et al. (1977) reported that the microbial load of the initial product influenced storage stability of shredded lettuce. Since the effect of Ca was noted only after several days storage, the inhibitory effect of Ca probably resulted from increased resistance of tissue to bacterial infection rather than to a bactericidal action. Conway and Sams (1984) indicated that Ca enhanced tissue resistance to fungal attack by stabilizing or strengthening cell walls thereby making them more resistant to pectolytic enzymes produced by fungi.

The pH of all carrot shreds gradually decreased during storage at all temperatures (Fig. 4). Carrot shreds treated with 1% $CaCl_2$ without or with chlorine had a lower pH than that of the control shreds during storage. Other workers reported that pH did not change extensively during storage, but changes have occurred and such changes differ among vegetables (Carlin et al., 1989; King et al., 1991; Bolin and Huxsoll, 1991b). The cause for decreasing pH in some tissues is unknown, however bacterial spoilage is reduced when the pH is lowered to about 3.5 - 4 (Huxsoll and Bolin, 1989; Juliot et al., 1989). In our study the pH was not lowered to the inhibitory level by calcium treatment, but Ca had an inhibitory effect on increased microbial population. The pH may have decreased to the inhibitory level at some sites of microbial growth on surfaces of tissues, but such localized effects may not be apparent when pH was based on total tissue.

Based on chroma value, surface color of carrot shreds in all treatments faded during storage at all temperatures (data not shown). White tissue formed on the surface of stored carrot shreds and whiteness index values increased from about 23 at day 0 to about 30 at the end of storage at all temperatures. The changes in chroma value and whiteness index values were not affected by Ca treatment (data not shown). Bruemmer (1987) observed no effect of Ca treatment on color of carrot sticks. Bolin and Huxsoll (1991a) reported that development of white tissue was due to lignification, which apparently was not influenced by Ca treatment in our experiments.

CONCLUSIONS

Ca CONCENTRATION of carrot shreds was increased by treatment with 0.5% or 1% $CaCl_2$ and the treatments helped in retaining textural quality and reducing the rate of total microbial count increase. Ca treatments did not have any effect on carrot slices or sticks probably because insufficient Ca was absorbed.

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