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Factors Influencing Texture Retention of Salt-free, Acidified, Red Bell Peppers during Storage†

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Red bell peppers were stored in a salt-free, acidified cover solution with sulfite as a microbial preservative. The texture retention of stored peppers was evaluated as a function of pH, acid, calcium, blanch treatment, and growing conditions of the peppers. Field-grown peppers softened at a faster rate than greenhouse-grown peppers and exhibited more variability in their ability to maintain texture during storage. Improved firmness retention of red peppers stored at 30 °C was observed when the pH was adjusted to be in the range of 3.4−3.8, when at least 5 mM calcium was added to the peppers, and when red peppers were blanched at 75 °C for at least 1 min.

KEYWORDS: ***Capsicum annuum*; acetic acid; gluconic acid; sodium metabisulfite**

INTRODUCTION

Red bell pepper is a high-value vegetable that is used as an ingredient in a variety of processed foods, such as pickle mixes, frozen pizzas, and pastas. Storage procedures for peppers used as ingredients in such products include freezing, pasteurization, and brining in acid and salt. The freeze/thaw cycle for frozen product results in a soft texture of the peppers. In addition, thawing the peppers is inconvenient. Pasteurization limits the size of the container to about 4 L or smaller. Bulk preservation of peppers by brining is accomplished by immersion of the washed, destemmed peppers in an acetic acid/salt solution to equilibrate at pH 3.5 and 15% salt (*1*). Peppers brined by this procedure are susceptible to softening. In addition, the high-salt brine generated is a waste disposal problem. Alternative methods for bulk storage of red peppers that avoid the limitations and problems of current procedures could increase commercial utilization of red bell peppers.

A few papers are available on procedures for acidification and canning of bell peppers and pimento peppers. Powers et al. (*2*) acidified pimientos to lower the pH to 4.6 or below so that the peppers could be safely processed in a boiling water bath. They observed that addition of calcium chloride to the containers increased the firmness of the final product. Hoover (*3*) found that dipping red bell pepper pieces in calcium hydroxide solution improved the texture of acidified, canned red bell peppers more than either calcium chloride or calcium sulfate treatment. Flora et al. (*4*, *5*) developed acidification procedures to ensure that the equilibrated pH of canned pimientos would be ≤4.6 by evaluating the effects of different acids, acid concentrations, pepper ripeness, and peeling procedures on pH. They also evaluated the processed acidified pimientos to ensure that they maintained acceptable quality (*4*).

McFeeters (*6*) has shown that nonheated cucumbers can be preserved without added NaCl in an acid solution with sodium metabisulfite added to prevent microbial growth. A similar approach to preservation for the purpose of bulk storage was applied to red bell peppers. Preservation without salt would minimize generation of nonbiodegradable waste and also make it unnecessary to remove salt from bulk stored peppers prior to their use in the manufacture of other products. The objective of this study was to determine the effects of pH, acid, calcium, blanch treatment, and growing conditions on firmness retention of red bell peppers stored in a salt-free, acidified cover solution with sulfite added to inhibit microbial growth.

MATERIALS AND METHODS

Field-grown or greenhouse-grown red bell peppers (*Capsicum annuum* L., cv. unknown) were obtained from local wholesale produce companies. The peppers were free of obvious mechanical injury. Sodium metabisulfite, $CaCl_2 \cdot 2H_2O$, acetic acid, HCl, and NaOH were purchased from Aldrich Chemical Co. (Milwaukee, WI). D-Gluconic acid lactone was purchased from Sigma Chemical Co. (St. Louis, MO).

Sample Preparation. Stems and seeds were removed from peppers. Peppers were cut into 4−6 cm^2 pieces, and then 118 g of pepper pieces was packed into 236-mL (8 oz) jars and covered with 118 g of liquid to give a 50:50 pack-out ratio. Sufficient amounts of acetic acid or gluconic acid and calcium chloride were added to the cover solution to equilibrate with the fruit at the concentrations indicated.

Calculated amounts of 3 N HCl or 3 N NaOH were added to make pH adjustments. Immediately prior to sealing, 3 mL of a 46.7 mg/mL solution of sodium metabisulfite was added to each jar to equilibrate at 400 ppm, calculated as SO_2. Jars were hermetically sealed by heating the caps in boiling water and then closing by hand. A single rubber

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septum was put in each cap to allow removal of liquid samples during incubation. Jars were stored at 30 °C.

Blanching. In experiments where a blanch treatment was included, pepper pieces (1−2 kg) were placed in a wire mesh basket and blanched in a steam-jacketed kettle containing 120−150 L of tap water. The effect of blanch temperature on firmness retention was determined by blanching red pepper pieces for 3 min at 45, 55, 65, 70, 75, or 85 °C. Blanch time was evaluated by heating pepper pieces at 75 °C for 1, 3, 5, and 7 min. After heating, peppers were submerged into cold tap water (10−20 °C) for 3 min to cool. Peppers were then drained of excess water and packed in glass jars.

Measurement and Adjustment of pH. The pH was measured with a Fisher Accumet digital pH meter (model 825MP) equipped with a Corning semimicro combination electrode (catalog no. 76157). The pH meter was calibrated with pH 7.00 and pH 4.01 buffers. Samples and standard buffers were at the same temperature.

When pH adjustment was necessary, the amount of HCl or NaOH required to adjust the pH was determined by blending 5−10 peppers, after removal of stems and seeds, to make a uniform slurry. Then, 100 g of pepper slurry was mixed with 100 mL of a solution containing sufficient acetic or gluconic acid, sodium metabisulfite, and calcium chloride to equilibrate with the pepper slurry at the intended concentrations. This mixture was titrated with aliquots of 3 N HCl or 3 N NaOH until the pH was, respectively, lower or higher than the lowest/highest pH intended for the experiment. From this titration curve, the amount of HCl or NaOH solution required in a cover solution to give the intended equilibrated pH values in the jars was calculated. The acid or base solution was added along with acetic or gluconic acid and calcium chloride to the cover solutions. Reported pH values were measured after equilibration of the stored peppers.

Texture Analysis. Firmness measurements were made with a TA.XT2 texture analyzer (Texture Technologies Corp., Scarsdale, NY/ Stable Micro Systems, Godalming, Surrey, UK) with a 25-kg force cell and a 3-mm-diameter stainless steel punch. Data were collected and analyzed with a Gateway GP6−350 personal computer (Gateway, North Sioux City, SC) using Texture Expert version 1.22 software (Texture Technologies Corp.). Pepper pieces (>3 mm thick) were placed skin-side down, and the peak force required to puncture the first layer of pepper flesh was recorded and expressed in newtons. This measurement of firmness was done on 15 pieces of pepper tissue from each of two jars at each sampling time (*7*). Texture analysis was conducted after a 1-week equilibration period, defined herein as time = 0, and then periodically for up to 9 months.

Statistical Analysis. The ANOVA and GLM procedures of SAS (Statistical Analysis System, Cary, NC) were used for all statistical computations and inferences. Duncan's new multiple range test was used to determine whether there were differences among sample treatments.

RESULTS AND DISCUSSION

Effect of pH. The textural effect of pH on nonheated, greenhouse-grown red bell peppers was determined in the pH range of 2.8−4.0. The pH at which red bell peppers were held had a marked influence on their texture retention (**Figure 1**). In the pH range of 3.4−3.8, tissue remained relatively firm over a 9-month storage period. Significant ($P \leq 0.05$) firmness loss occurred as pH decreased below 3.4. Texture degradation was also significant ($P \leq 0.05$) above pH 3.8. Howard et al. (*8*) found that pasteurized jalapeño rings stored for 1 month softened to a greater extent as the pH was lowered from 3.8. The peppers were extremely soft when the pH was reduced to the 3.2−3.3 range. The effect of pH on softening of the red bell peppers was similar to that observed for fermented cucumber tissue (*9*, *10*).

Tissue softening may be caused by enzymatic and/or nonenzymatic cell wall degradation (*11*). It is possible that the observed softening at pH >3.8 was due to enzymatic degradation of pectin by polygalacturonase (PG) in the peppers or from fungi that may infect the fruit. PG in red bell peppers has been reported to have dual pH optima in the range of 4.8−6.0 (*12*). Fungal PGs generally have a pH optimum in the region 4.0−5.5 (*13*).

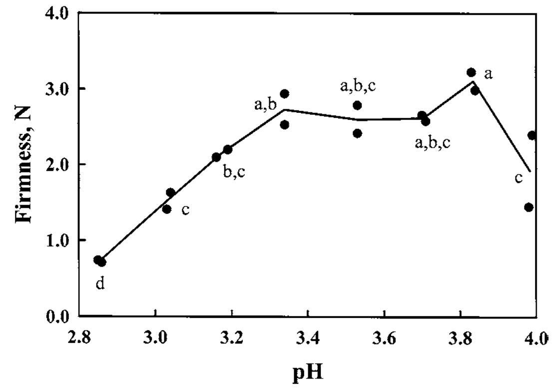

Figure 1. Effect of pH on firmness of red bell peppers stored for 9 months. Peppers contained 60 mM gluconic acid, 400 ppm sulfite, and 10 mM $CaCl_2$. Data points with different letters are significantly different ($P \leq 0.05$). At time = 0, the mean firmness of the pepper pieces was 3.60 N.

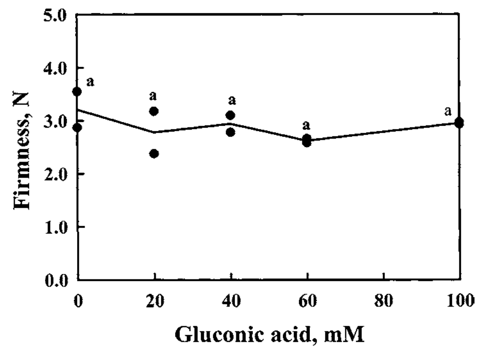

Figure 2. Effect of gluconic acid concentration on firmness retention of red bell peppers stored for 9 months. Treatments were adjusted to pH 3.8. All treatments contained 400 ppm sulfite and 10 mM $CaCl_2$. Gluconic acid concentrations with the same letter are not significantly different in firmness ($P \leq 0.05$). At time = 0, the mean firmness of the pepper pieces was 3.63 N.

The observed softening at pH <3.4 is more likely to result from nonenzymatic degradation of cell wall components, since most cell-wall-degrading enzymes have considerably higher pH optima. Firmness losses of acid fruit and vegetable products (pH 2.5−4.5) have been attributed to acid hydrolysis of polygalacturonic acid (*14*). More recently, however, an analysis of the thermodynamics of cucumber tissue softening and pectin hydrolysis at pH 3.0 suggested that the rate-limiting step for plant tissue softening is unlikely to be a hydrolytic reaction in this pH range (*15*, *16*).

Effect of Different Acids and Acid Concentration on Firmness. Acetic and gluconic acids (100 mM) were evaluated for their effect on the firmness of red peppers during storage at pH 3.8. Acetic acid is the most common acid added to fresh-pack pickled products (*17*). Gluconic acid can lower the pH while giving a low intensity of acid flavor (*18*). There was not an obvious reason for selecting between gluconic acid and acetic acid on the basis of their effects on the textural changes in nonheated pepper tissue. Changing the gluconic acid concentration between 0 and 100 mM at constant pH showed no effect on firmness retention of red pepper tissue after 9 months of storage (**Figure 2**). This result indicated that pH is a more important factor than acid concentration in affecting the firmness of red bell peppers.

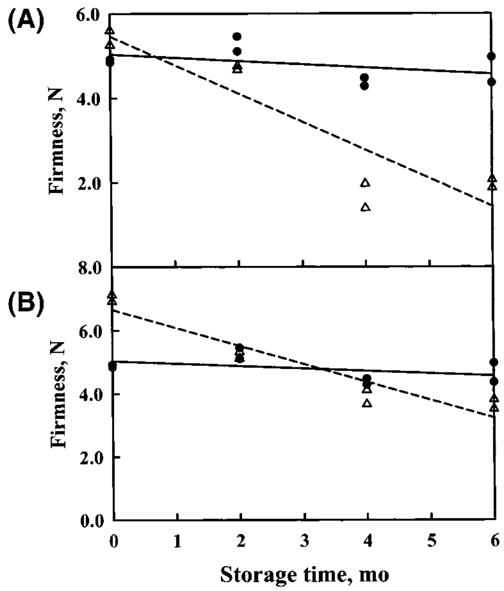

Figure 3. Comparison of softening of greenhouse-grown (●) and field-grown red bell peppers (Δ), stored at pH 3.5 with 10 mM added calcium. Panels A and B show different lots of peppers. Peppers were stored at pH 3.6 in 150 mM acetic acid and 400 ppm sulfite.

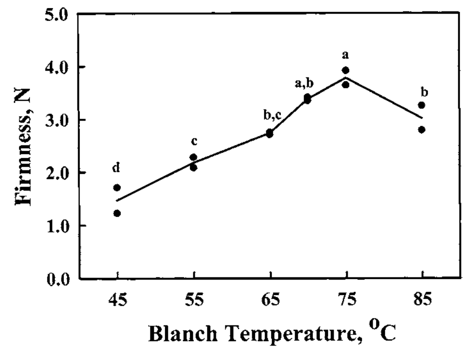

Figure 4. Effect of blanch temperature on firmness retention of pH 3.9 red bell peppers stored for 4 months at 30 °C. Blanch time was 3 min. Blanch temperatures with the same letter are not significantly different in firmness ($P \leq 0.05$). At time = 0, the mean firmness of the pepper pieces was 7.35 N.

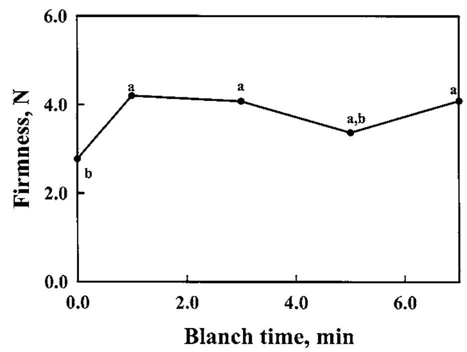

Figure 5. Effect of blanch time at 75 °C on firmness retention of red bell peppers after 2 months of storage at 30 °C. Treatments contained 150 mM acetic acid and 400 ppm sulfite and were adjusted to pH 3.5. Data points with different letters were significantly different ($P \leq 0.05$). Initial firmness of the pepper pieces was 7.18 N. There was no significant difference among treatments.

Effect of Growing Conditions. Greenhouse-grown peppers were used in initial laboratory experiments because they had fewer structural defects and disease problems than the field-grown fruit. However, field-grown peppers would be utilized for processing applications. Two lots each of greenhouse peppers and field-grown peppers were stored for 6 months and the firmness changes evaluated (**Figure 3**). Both lots of greenhouse-grown peppers maintained texture relatively well during storage, but there was notable variation in the ability of field-grown peppers to maintain firmness. After 6 months, field-grown peppers in one lot (**Figure 3A**) became extremely soft, but another lot (**Figure 3B**) retained somewhat greater firmness. Field-grown peppers probably exhibit more variability because they are typically exposed to more variable environmental conditions than greenhouse-grown peppers. Since different cultivars are typically grown, genetic differences between greenhouse- and field-grown peppers might also explain these observations. The variability of field grown peppers resulted in the decision to determine whether blanch treatments could improve the retention of firmness.

Effect of Blanch Treatment. Peppers were blanched for 3 min at temperatures from 45 to 85 °C. The 3-min blanch time was sufficient for pepper pieces to thermally equilibrate with the blanch water (*19*). Firmness increased significantly ($P \leq 0.05$) as blanch temperature increased to 75 °C and then declined at 85 °C **(Figure 4**). Similar results were observed in a second lot of peppers (data not shown). Since 75 °C gave the best firmness retention during storage, this temperature was used to determine the effect of blanch time on firmness retention. A blanch treatment for 1 min (the shortest time tested) was sufficient to produce a significantly firmer texture than non-blanched peppers during a 2-month storage period. Extending the blanch time to 7 min did not result in any significant change in firmness retention compared to a 1-min blanch (**Figure 5**).

Inhibition of softening by extended low-temperature blanch treatments has previously been demonstrated in several commodities (*20*, *21*). For sliced jalapeño peppers, Howard et al. (*22*) showed texture improvement after a blanch treatment at 50 °C for 60 min. Texture improvement by extended blanch treatments has been attributed to demethylation of pectin after release and activation of pectin methyl esterase by the blanch treatment. However, the short duration of blanch treatment required suggested that inactivation of cell-wall-degrading enzymes in the pepper tissue or from microorganisms infecting peppers was the more likely reason for texture improvement. Jen and Robinson (*12*) reported that bell pepper PG is inactivated by heating at 60 °C for 20 min.

Effect of Calcium Chloride Addition. Blanched and non-blanched peppers were stored with equilibrated concentrations of 0−30 mM added $CaCl_2$. Results showed that, for both blanched and nonblanched peppers, addition of 5 mM $CaCl_2$ resulted in significantly ($P \leq 0.05$) firmer texture than that found for peppers without added $CaCl_2$ over a 4-month storage period (**Figure 6**). Combination of a blanch treatment with calcium ion addition gave a firmer product than either treatment by itself. Interestingly, firmness of blanched peppers increased significantly ($P \leq 0.05$) with increasing concentrations of $CaCl_2$. However nonblanched peppers did not increase in firmness with $CaCl_2$ additions greater than 5 mM.

Calcium has been shown to inhibit softening in many acid or acidified fruits and vegetables. Specifically for peppers, Fleming et al. (*23*) showed that addition of $CaCl_2$ to pickled Red Cherry peppers improved firmness retention during a 6-month storage period. Saldana and Meyer (*24*) found that calcium addition improved the texture of canned jalapeño peppers after 3 months of storage. In addition to improving the firmness retention of brined jalapeño peppers, calcium altered the extractability of cell wall pectins (*8*).

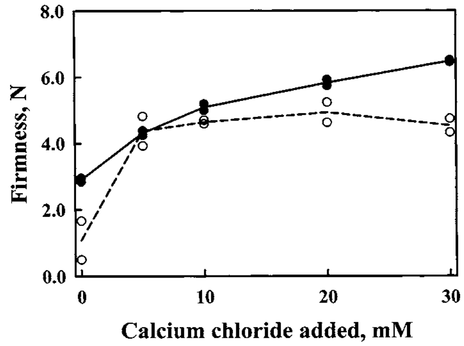

Figure 6. Effect of added calcium chloride on firmness retention of pH 3.5 blanched (75 °C, 3 min) (●) and nonblanched (○) red bell peppers after 4 months of storage at 30 °C. Treatments contained 150 mM acetic acid and 400 ppm sulfite and were adjusted to pH 3.5.

Conclusions. Acidified red bell peppers are susceptible to rapid softening, particularly field-grown peppers. Improved firmness retention of red peppers stored at 30 °C was observed when the pH was adjusted to be in the range of 3.4−3.8, when at least 5 mM calcium was added to the peppers, and when red peppers were blanched at 75 °C for at least 1 min.

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