Firmness Retention in Pickled Peppers as Affected by Calcium Chloride, Acetic Acid, and Pasteurization

H. P. FLEMING, R. L. THOMPSON, and R. F. McFEETERS

ABSTRACT

Critical factors influencing firmness retention in pickled peppers were studied. The addition of $CaCl_2$ (0.2%, w/v, optimum) to whole, pickled 'Red Cherry' peppers increased firmness retention as determined by a puncture test using an Instron Universal Testing Machine. Pasteurization reduced firmness in the absence, but not in the presence, of added $CaCl_2$. $CaCl_2$ significantly ($P \leq 0.01$) reduced softening during storage of 'Red Cherry' peppers at higher temperatures (36.7, 46.7°C), and resulted in a slight increase in firmness at 26.7°C. $CaCl_2$ did not significantly ($P \geq 0.05$) improve firmness retention in 'Jalapeno' peppers, but resulted in greater uniformity of firmness. $CaCl_2$ also improved firmness retention in pickled cucumbers. Firmness of unpasteurized peppers and cucumbers was not influenced significantly ($P \geq 0.05$) by acetic acid concentrations of 2, 3 or 4%.

Key Words: peppers, pickling, calcium chloride, acetic acid, pasteurization, brining, firmness, texture

INTRODUCTION

PICKLED PEPPERS have become increasingly popular because of their various flavors and colors. They enhance the sensory properties of many foods. Most pickling varieties are within the species *Capsicum annuum* L. and include popular, commonly named varieties such as 'Red Cherry', 'Banana' and 'Jalapeno' (Smith et al., 1987). Peppers may be preserved by brining or pasteurization.

Brining is an economic method of temporarily preserving peppers in bulk containers. Peppers traditionally have been brined at sufficiently high concentrations of sodium chloride to prevent fermentation. More recently, vinegar (or acetic acid) has been added to pepper storage brines to effectively reduce the concentration of sodium chloride required to maintain product quality. After bulk storage, brined peppers may or may not be pasteurized, depending upon the product.

Pasteurization is commonly used to preserve pickled, fresh peppers at relatively low concentrations of sodium chloride and acetic acid. The pasteurization process involves heating the product to an internal temperature of 74°C and holding for 15 min, typical of the process developed for fresh-pack cucumbers (Monroe et al., 1969). A lower heat process is used by some processors to improve texture retention of the product, but at an increased risk of microbial spoilage. Sliced peppers (e.g., pepper rings) are particularly susceptible to softening during pasteurization. Some processors add sufficiently high concentrations of acetic acid to avoid the need for pasteurization and, thereby, retain desired textural properties. Although such preservative concentrations of acetic acid are too tart for many pickled items, such may not be the case for pickled peppers, which are consumed as condiments in relatively small quantities and in composite foods.

The use of preservative concentrations of acetic acid has been practiced in the British food industry for many years, where such products are referred to as acetic acid preserves. The concentration of acetic acid necessary for preservation of vegetable products has been determined to be 3.6% of the total volatile constituents of the product, and is referred to as the "preservation index" (Campbell-Platt and Anderson, 1988). This concentration of acetic acid also was found sufficiently high to result in preservation of cucumber pickles without the addition of other preservatives (Bell and Etchells, 1952). The addition of sugar and sodium benzoate allowed the use of lower concentrations of acetic acid. By varying the concentration of these ingredients, a "preservation-prediction" chart was prepared which still is in use in the USA.

The cold-packing (preservation without heat processing) of whole peppers has been viewed with caution because of uncertainty of the rate of acid penetration into the pepper interior. Ito et al. (1976) found that acetic acid penetrated sufficiently rapidly into pasteurized, whole cucumbers to prevent growth of *Clostridium botulinum*. Acetic acid penetration into unheated, whole 'Red Cherry' peppers was shown to require as long as 150 hr to acidify certain regions of the pepper interior to pH 4.6 or lower (Daeschel et al., 1990).

If questions of safety can be resolved, cold-packing could become increasingly popular because of energy savings and possible improved product quality. Texture retention might be improved in some products if pasteurization were not required. The addition of calcium salts has been shown to greatly en-

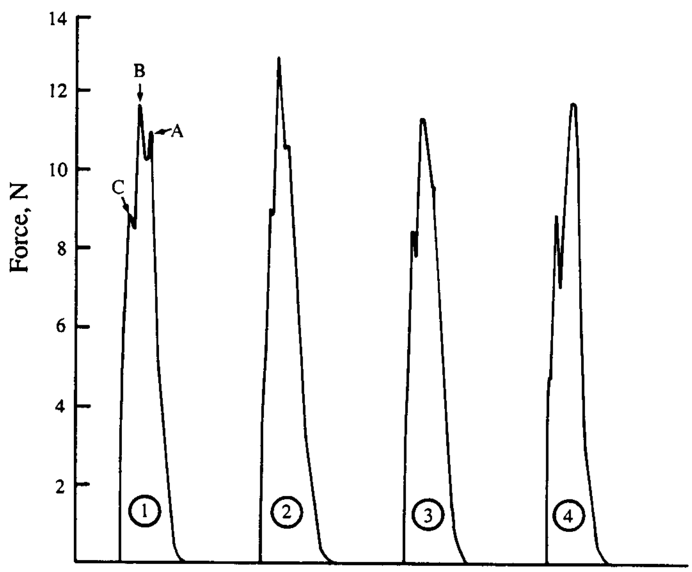

Fig. 1—Force distance profile from puncturing the flesh of a 'Red Cherry' pepper. An Instron UTM fitted with a 0.315 cm diameter punch was used for these tests. Pepper sections were placed on a die assembly with the skin down. Crosshead speed, 20 cm/min; chart speed, 50 cm/min. Identification of peaks: A, failure of mesocarp tissue; B, failure of skin tissue; C, frictional forces created between tissue and punch as punch entered die. Examples of four different puncture profiles are shown.

The authors are affiliated with the Food Fermentation Laboratory, USDA-ARS, and North Carolina Agricultural Research Service, Dept. of Food Science, North Carolina State Univ., Raleigh, NC 27695-7624.

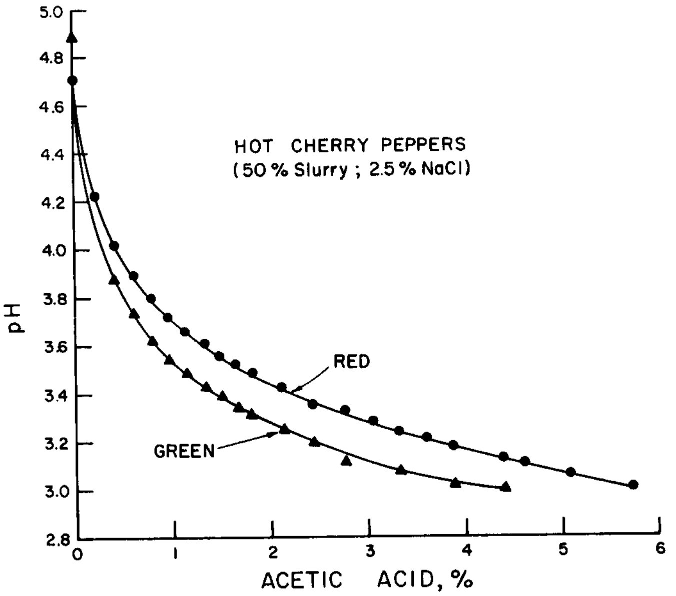

Fig. 2—Titration of 'Red Cherry' pepper homogenates with acetic acid.

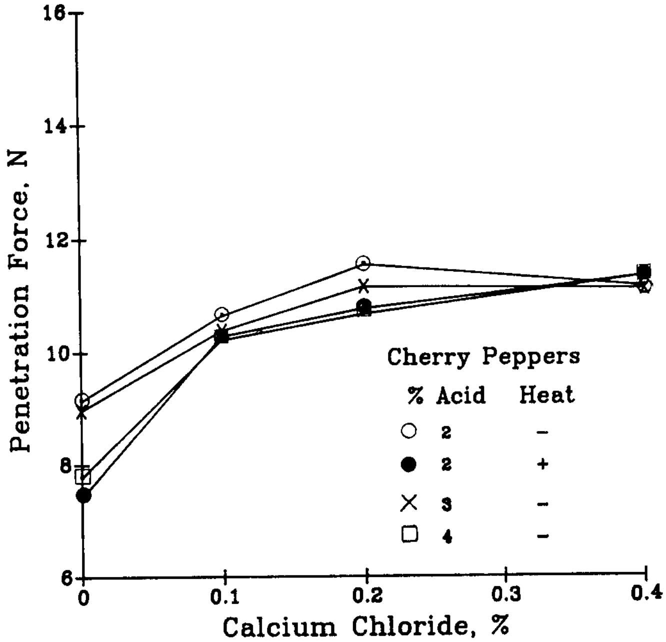

Fig. 4—Effect of $CaCl_2$ on firmness of acidified, whole 'Red Cherry' peppers. Products stored 6 months at 26°C.

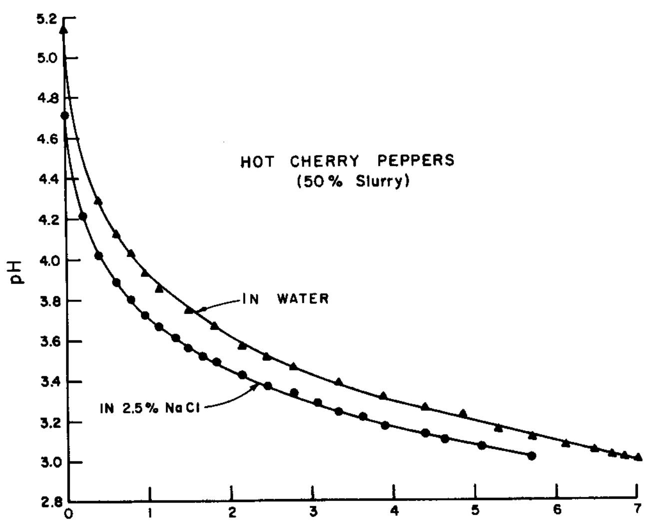

Fig. 3—Effect of NaCl on the pH of 'Red Cherry' pepper homogenates titrated with acetic acid. Red fruit were used.

hance firmness retention in fresh-pack (Etchells et al., 1977) and in brined cucumbers (Buescher et al., 1979; Fleming et al., 1978; McFeeters and Fleming, 1990) which were temporarily preserved without the use of heat. Although commercial processors have been adding calcium chloride ($CaCl_2$) to brined, as well as pasteurized, peppers for several years because of its proven value with pickled cucumbers, no systematic study of its value for texture improvement in pickled peppers has been reported. However, addition of calcium salts improved firmness of canned 'Jalapeno' peppers (Saldana and Meyer, 1981).

Objectives of our study were to determine the effects of $CaCl_2$ and acetic acid concentrations on firmness retention of cold-packed and pasteurized whole peppers ('Red Cherry' and 'Jalapeno'). The procedures also were applied to cucumbers for comparative purposes and to establish the combined effects of the parameters studied on firmness retention. Although the beneficial effects of $CaCl_2$ on pickled cucumbers are known, interactions with acetic acid and pasteurization have not been reported.

MATERIALS & METHODS

Raw products

Peppers and pickling cucumbers were obtained from local commercial firms and were unidentified as to growing conditions. They were free of obvious disease and mechanical injury. The peppers were of the *Capsicum annuum* L. species and consisted of the cultivars Red Cherry (pungent, i.e., hot, 2.5 to 3.1 cm diameter) and Jalapeno (3.8 to 5.0 cm length). The cucumbers were size no. 2 (3.1 to 3.8 cm diameter).

Brining

Peppers were packed into (≈355cc) jars at pack-out ratios (g product/mL brine) of 39/61 for 'Red Cherry' peppers and 42/58 for 'Jalapeno' peppers. Cucumbers were packed into (≈947cc) jars at a pack-out ratio of 50/50. The brine added to the jars contained 5% (w/v) NaCl. Sufficient $CaCl_2$ and acetic acid were added to the brine to

Table 1—Effect of heating on acid penetration into whole 'Red Cherry' peppers[a]

Time after packing	Unheated				68°C Blanch 5 min				74°C Process 15 min			
	Green		Red		Green		Red		Green		Red	
	pH	TA[b]	pH	TA	pH	TA	pH	TA	pH	TA	pH	TA
Fresh	5.24	0.12	5.02	0.20	—	—	—	—	—	—	—	—
24 Hr	4.05	0.73	4.39	0.69	3.55	0.98	3.95	1.12	3.62	1.49	4.14	1.04
4 Days	3.33	1.91	3.67	1.63	3.16	2.20	3.72	1.58	3.24	2.08	3.53	1.71
9 Months	2.84	3.09	2.94	2.74	2.77	2.94	2.82	3.38	2.83	2.99	2.88	2.88

[a] Pack-out ca. 35% peppers by weight in 473 ml jars. The cover brine contained 5.1% NaCl and 4.8% acetic acid (vinegar). Values represent a composite of 5 peppers blended to a homogenate.

[b] TA = titratable acidity expressed as % acetic acid.

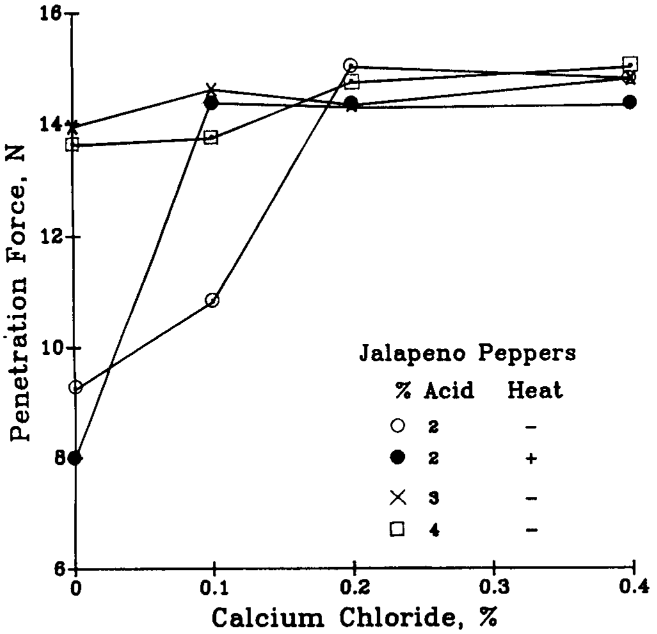

Fig. 5—Effect of $CaCl_2$ on firmness of acidified, whole 'Jalapeno' peppers. Products stored 6 months at 26°C.

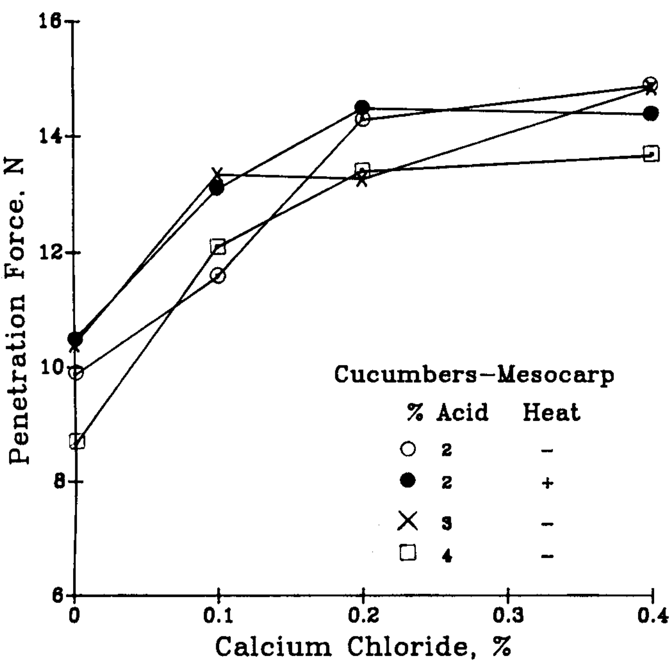

Fig. 6—Effect of $CaCl_2$ on firmness of mesocarp and endocarp tissues of acidified whole cucumbers. Products stored 6 months at 26°C.

equilibrate with the fruit at concentrations so indicated. Although $CaCl_2 \cdot 2H_2O$ was the form of calcium used, concentrations are expressed herein in terms of anhydrous $CaCl_2$.

Heating

'Red Cherry' peppers were blanched in water at 68°C for 5 min before packing to determine the effect of blanching on rate of acid penetration. Effects of pasteurization on rate of acid penetration into 'Red Cherry' peppers and on firmness rentention in peppers and cucumbers were determined. Products were pasteurized after packing by submerging closed jars in a water bath until the internal product temperature reached 74°C, and then holding for 15 min. The metal stem of a dial thermometer was inserted through a rubber septum in the jar cap and into a pepper or cucumber near the jar center for temperature monitoring.

Chemical analyses

Titratable acidity (calculated as acetic acid) and NaCl concentrations were determined as previously described (Fleming et al., 1984). The pH values were determined with an Orion model 901 pH meter. For determination of acidification rates in 'Red Cherry' peppers, they were removed from acidified brines at times indicated, rinsed briefly in distilled water, and blotted dry. The stem and calyx were removed, and the peppers were then quartered and homogenized in a Waring Blendor and the pH of the homogenate determined.

Firmness measurement

Instrumental firmness measurements were made with an Instron model 1122 or 1130 Universal Testing Machine (UTM) and punch and die assembly previously described (Thompson et al., 1982). Although a range of conditions was tested, for the data reported herein the punch diameter was 0.315 cm, and the crosshead speed was 20 cm/min.

For cucumbers, a 7 mm thick cross-sectional slice was cut from the middle of seven fruit from each jar. The slices were punched once each in the mesocarp and endocarp tissues according to Thompson et al. (1982). Thus, treatment means represent seven cucumbers from each of two replicate jars, for a total of 14 punches per mean.

After removal of the stem and calyx, 'Red Cherry' peppers were sliced in half, longitudinally. The seeds were removed and the two halves were again halved, resulting in four quarters. In preliminary tests, the pepper tissue was tested with the skin placed in both the up and down positions on the die assembly. Since the skin down position resulted in a lower coefficient of variation among replicate tests (9.8 vs 16.6%), all data reported were obtained with the skin down. The 'Red Cherry' peppers consisted of both red and green fruit. Wall thickness was greater for the red (5.3 to 5.8 mm) than the green (4.4 to 4.8 mm) fruit. The green fruit were significantly ($P < 0.01$) firmer than the red fruit (19.9 vs 14.2 N). Since red fruit were more numerous than green in sample lots used for firmness studies, all firmness data reported were based on red fruit. However, the limited data on green peppers indicated that they behaved similar to the red in response to $CaCl_2$, acidification, and pasteurization. Firmness determinations were made on both fresh and brined fruit. With fresh fruit, two distinct peaks were consistently observed in the force-distance curve, but with brined fruit the occurrence of a single peak was common. When two peaks occurred with brined fruit, the first peak (A, Fig. 1) was assumed to represent failure of the mesocarp tissue and the second (B, Fig. 1) to represent failure of the skin tissue, as recently indicated for delineation of puncture forces for cucumber mesocarp and skin tissues (Thompson et al., 1992). When the puncture test was applied to brined fruit, the force peak assumed to represent mesocarp tissue distinctly occurred only 35% of the time. Thus, all puncture force readings are means of maximum force values for 10 peppers/jar, four punctures/pepper, and two jars/treatment or storage time.

Fresh 'Jalapeno' peppers, after calyx and stem removal, were sliced longitudinally and the seeds removed. Puncture forces were determined at five locations along the longitudinal axis of each half. Force

Table 2—Analysis of variance for effects of calcium chloride and acetic acid on firmness of peppers and cucumbers

		Cucumbers						Peppers					
		Mesocarp			Endocarp			'Red Cherry'			'Jalapeno'		
Source	df	MS	F-ratio	Pr>F	MS	F-ratio	PR>F	MS	F-ratio	Pr>F	MS	F-ratio	Pr>F
Acid	2	2.24	1.90	0.19	0.68	1.94	0.19	0.98	2.64	0.11	9.49	1.93	0.19
Calcium	3	26.03	22.06	0.01	2.21	6.26	0.01	9.31	25.08	0.01	9.69	1.98	0.17
Calcium*acid	6	0.92	0.78	0.60	0.33	0.95	0.50	0.52	1.39	0.30	4.18	0.85	0.55
Jar (acid calcium)	12	1.18			0.34			0.37			4.90		

Table 3—Analysis of variance for effects of calcium chloride and heat on firmness of peppers and cucumbers

		Cucumbers						Peppers					
		Mesocarp			Endocarp			'Red Cherry'			'Jalapeno'		
Source	df	MS	F-ratio	Pr>F	MS	F-ratio	Pr>F	MS	F-ratio	Pr>F	MS	F-ratio	Pr>F
Calcium	3	16.44	19.52	0.01	1.24	2.53	0.13	6.42	38.08	0.01	29.61	1.89	0.21
Heat	1	0.62	0.74	0.42	1.08	2.20	0.18	2.06	12.19	0.01	0.60	0.04	0.84
Calcium*heat	3	0.70	0.84	0.51	0.53	1.08	0.41	1.13	6.69	0.01	4.45	0.28	0.84
Jar (calcium heat)	8	0.84			0.49			0.17			15.66		

Table 4—Effects of acetic acid and calcium chloride on coefficients of variation of firmness in brined peppers and cucumbers

Treatments		Commodities			
		Peppers		Cucumbers	
% Acetic acid	% Calcium	'Red Cherry'	'Jalapeno'	Mesocarp	Endocarp
Unheated treatments					
2	0.0	21.2	47.3	15.1	25.6
2	0.1	19.8	40.0	22.9	22.4
2	0.2	15.7	11.9	14.6	39.9
2	0.4	15.1	14.0	9.7	24.4
3	0.0	29.4	13.0	27.5	27.6
3	0.1	17.4	12.8	22.4	27.4
3	0.2	16.5	15.7	17.9	23.0
3	0.4	18.0	15.0	10.9	31.8
4	0.0	27.2	17.1	19.4	26.6
4	0.1	17.5	18.7	21.0	19.9
4	0.2	18.6	12.1	13.0	23.8
4	0.4	14.6	12.5	17.5	21.9
Heated treatments					
2	0.0	28.4	72.6	15.0	29.9
2	0.1	19.3	14.2	11.5	39.9
2	0.2	25.3	16.2	13.6	26.9
2	0.4	18.6	20.0	14.2	17.9

readings did not vary significantly ($P > 0.05$) along the longitudinal axis. In preliminary tests, force readings were determined for peppers with skin in both the up and down positions on the die assembly. The skin down position resulted in a lower coefficient of variation (13.8 vs 23.4%) and, thus, was used for the reported data. Pepper wall thickness ranged from 3.5 to 4.0 mm. All puncture force readings reported are averages of 12 peppers/jar, four punctures/pepper, and two jars/treatment.

Taste panel

A panel of 12 members evaluated the firmness of brined 'Red Cherry' peppers used in a storage study of firmness loss as influenced by time and temperature. Peppers were evaluated after storage for 82 days at the three storage temperatures used (26.7, 36.7, and 46.7°C), including samples with and without added $CaCl_2$. The wide range of firmness provided sufficient data for a meaningful correlation between instrumental and taste panel analyses. Pepper firmness was rated on a 10-point scale, with 10 = very firm and 1 = very soft. Taste panel means were regressed against Instron UTM force readings.

Statistical analyses

To test the effects of calcium, heat, and acid on the three commodities, a two-way factorial design with nested subsampling was used. All statistical data reported are based on means of duplicate jars of products. To analyze for effects of pasteurization and calcium, only the 2% acetic acid treatment was imposed. To analyze for effects of acetic acid and $CaCl_2$ concentrations, only the nonpasteurization treatment was imposed. Thus, the experimental design was balanced, while keeping the study to a manageable size. The ANOVA and REG procedures of SAS (Statistical Analysis System, Cary, NC) were used for all statistical computations and inferences. Linear regression procedures were used to relate firmness measurements of 'Red Cherry' peppers by Instron UTM and taste panel.

First-order rate constants for firmness loss in peppers were calculated as follows: Slopes of the linear regression of a plot of the natural logarithm of the initial firmness were divided by the firmness at subsequent sampling times (McFeeters et al., 1989).

RESULTS & DISCUSSION

Acidification of peppers

Effects of blanching (68°C, 5 min) and pasteurization (74°C, 15 min) on penetration of acetic acid into whole 'Red Cherry' peppers were measured (Table 1). The pH of all pepper homogenates, for heated and unheated peppers, was < 4.6 after 24 hr. The pH of homogenates of all peppers was < 4.0 after 4 days in unheated as well as blanched and pasteurized peppers. At that time the acetic acid concentration in the peppers had attained 47–74% of final equilibrium values after 9 mo. Thus, heating did not have a major effect on acid penetration into the peppers. Although Stroup et al. (1985) reported that 30 days were required for equilibrium of acetic acid with whole 'Red Cherry' peppers, our attainment of pH values < 4.6 after 24 hr based on homogenized tissue, suggests that growth and

Table 5—Brine composition of acidified peppers and cucumbers after storage[a]

Treatment combinations			'Red Cherry' peppers		'Jalapeno' peppers		Pickling cucumbers	
Calcium %	Acid %	Heat	pH	Titratable acidity, %	pH	Titratable acidity, %	pH	Titratable acidity, %
0.0	2	–	3.44	2.23	3.29	2.12	3.24	2.12
0.1	2	–	3.34	2.22	3.28	2.26	3.22	2.13
0.2	2	–	3.31	2.16	3.29	2.17	3.12	2.11
0.4	2	–	3.23	2.12	3.27	2.28	3.14	2.14
0.0	2	+	3.36	2.17	3.34	2.13	3.36	2.10
0.1	2	+	3.35	2.16	3.28	2.23	3.21	2.06
0.2	2	+	3.38	2.03	3.21	2.17	3.22	2.10
0.4	2	+	3.32	2.11	3.21	2.14	3.20	2.06
0.0	3	–	3.23	3.31	3.28	2.82	3.16	3.03
0.1	3	–	3.31	3.57	3.22	3.08	3.13	3.12
0.2	3	–	3.05	3.16	3.18	3.24	3.20	3.45
0.4	3	–	3.15	3.16	3.15	3.24	3.04	3.20
0.0	4	–	3.29	4.22	3.10	4.29	3.14	4.11
0.1	4	–	3.36	4.16	3.12	4.21	2.99	4.17
0.2	4	–	3.02	4.13	3.05	4.13	3.02	4.15
0.4	4	–	3.04	4.26	3.13	4.31	3.03	4.22

[a] The pickled commodities were sampled 6 months (26°C storage) after brining. The pack-out contents of the jars, by % weight of the contents, were: 39% ('Red Cherry' peppers), 46% ('Jalapeno' peppers), and 50% (cucumbers). Titratable acidity is expressed as acetic acid on a weight basis. The NaCl concentrations (w/v) averaged over the four treatments with no $CaCl_2$ added were: 2.8% ('Red Cherry' peppers), 2.8% ('Jalapeno' peppers) and 2.4% (cucumbers).

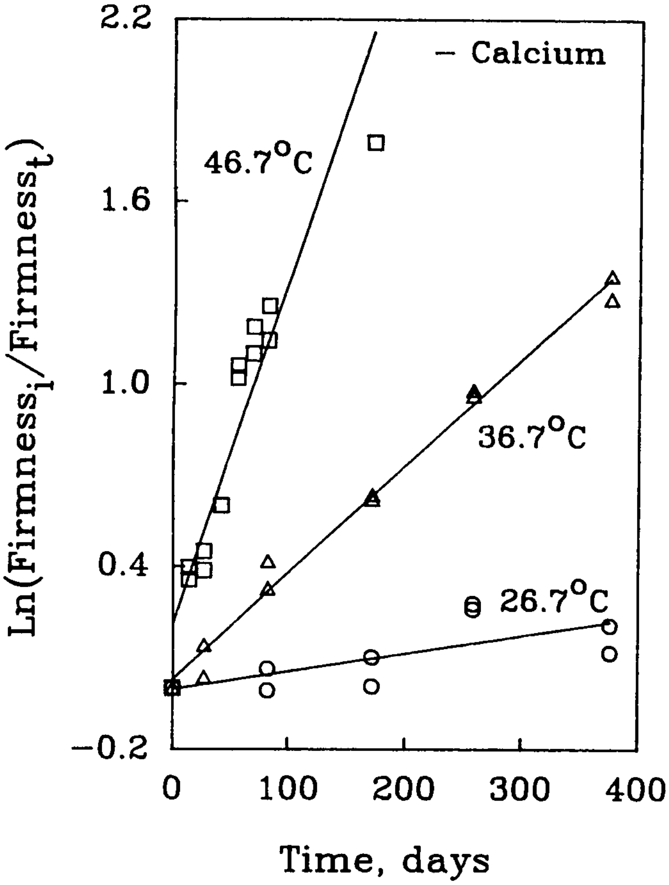

Fig. 7—Effect of storage temperature on firmness loss of acidified, whole 'Red Cherry' peppers without added $CaCl_2$. The subscript "i" is the initial firmness, and "t" is the firmness at specified times.

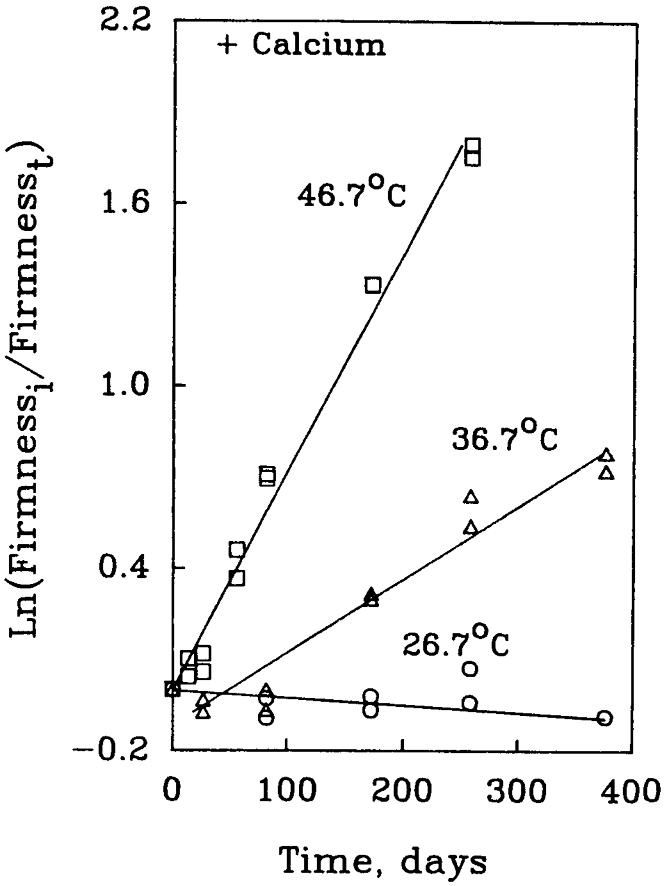

Fig. 8—Effect of storage temperature on firmness loss of acidified, whole 'Red Cherry' peppers with 0.2% $CaCl_2$ added. The subscript "i" is the initial firmness, and "t" is the firmness at specified times.

toxin formation by *C. botulinum* should not be a problem with whole, acidified peppers. Note, however, that care was taken to assure that all peppers were completely submerged in the acidifying brine. The primary avenue for acid penetration into whole peppers is through the stem area (Daeschel et al., 1990). When the stem end of the pepper was not submerged in the brine, acid penetration was not as rapid. Also, individual regions of whole 'Red Cherry' peppers required as long as 6 days for pH 4.6 to be reached when the peppers were brined with 2.5% acetic acid (Daeschel et al., 1990).

The pH of homogenates of fresh red and green peppers was 5.02 and 5.24, respectively (Table 1). It was shown earlier that malic and citric acids (2.2 and 5.2 mM for red and 2.6 and 2.4 mM for green, respectively) were the predominant organic acids in 'Red Cherry' peppers (Daeschel et al., 1990). The buffer capacity of the green peppers was less than that of the red, as indicated by titration of pepper homogenates with acetic acid (Fig. 2). The presence of 2.5% NaCl suppressed the pH of pepper homogenates about 0.4 pH unit in the absence of added acetic acid, but the suppression was less at progressively higher concentrations of acetic acid (Fig. 3). Although pepper maturity and presence of NaCl may be important factors as they influence pH in minimally acidified peppers (Sapers et al., 1980), they were less important with relatively high concentrations of acetic acid.

Factors affecting firmness retention

Addition of $CaCl_2$ to packing brines of peppers and cucumbers increased firmness retention of those products during the 6-mo storage period (Fig. 4 to 6). The firming effect plateaued at about 0.20% $CaCl_2$, with no appreciable increase in firmness retention at 0.4% $CaCl_2$. In the absence of added $CaCl_2$, pasteurization of 'Red Cherry' or 'Jalapeno' peppers appeared to reduce firmness retention, while the opposite effect seemed apparent with cucumbers (Fig. 4 to 6). Effects of acetic acid concentration on firmness were variable among commodities in the absence of added $CaCl_2$, but this variability was less at 0.2 and 0.4% $CaCl_2$ than at 0 and 0.1%.

Statistical analyses (Table 2) confirmed that $CaCl_2$ significantly increased firmness retention of cucumber mesocarp and endocarp tissues in 'Red Cherry' peppers ($P < 0.01$) but not 'Jalapeno' peppers. Acetic acid did not significantly influence firmness, nor was there an interactive effect between calcium and acid. Pasteurization significantly ($P < 0.01$) reduced the firmness of 'Red Cherry' peppers, but had no significant effect on 'Jalapeno' peppers or cucumbers ($P > 0.05$; Table 3). There was significant ($P < 0.01$) interaction between calcium and heat effects on firmness of 'Red

Table 6—Effect of calcium chloride addition on rate of firmness loss in acidified, whole 'Red Cherry' peppers

Storage temp, °C	Rate of firmness loss × 10[5a]			
	$CaCl_2$ not added	$CaCl_2$ added	No $CaCl_2$-$CaCl_2$	Pr>F[b]
46.7	1466	722	744	0.0001
36.7	351	241	110	0.0001
26.7	59	−24	83	0.0137

[a] Rate of firmness loss is defined as the slope of the regression line of Ln (firmness$_i$/firmness$_t$) vs days as illustrated in Fig. 7 and 8. The loss per day has been multiplied by 10^5 to yield the figures shown.

[b] Significance level for differences in rates of firmness loss, $CaCl_2$ not added vs $CaCl_2$ added (0.2%), as determined by regression analysis.

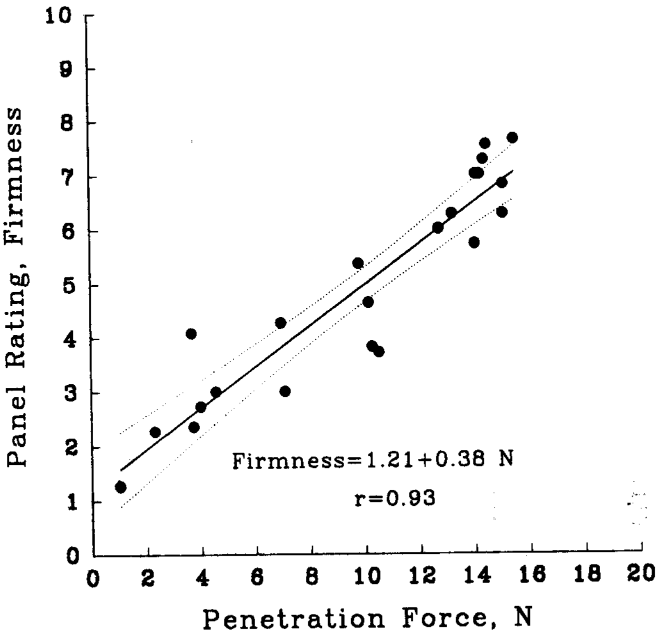

Fig. 9—Relationship between firmness of 'Red Cherry' peppers as detemined by taste panel and by Instron UTM. Peppers stored for 82 days at these temperatures were used in the study (see Fig. 7 and 8). Broken lines indicate 95% confidence limits of the solid regression line.

Cherry' peppers, with calcium offsetting the softening effect of heating (Table 3).

The major effect, statistically, of calcium on firmness retention seemed to be in reducing the variability in firmness among individual fruit (Table 4). For example, from Fig. 5 it would seem obvious that calcium had a firming effect on 'Jalapeno' peppers. However, such an effect was not confirmed statistically (Tables 2 and 3). The reason for this apparent paradox becomes apparent from the relatively high variabilities for firmness of 'Jalapeno' peppers at 0.0 and 0.1% $CaCl_2$ (Table 4). In general, coefficients of variation were higher for both types of peppers without added $CaCl_2$, but this effect was not as apparent with cucumbers.

The relatively high variability in firmness of peppers without added $CaCl_2$ could be a reflection of the variability of natural concentrations of calcium in these fruit, variability in cell wall hydrolytic enzyme activity or other factors. The rate of cucumber softening by the presence of NaCl has been shown to vary inversely with calcium concentration in the tissue (McFeeters and Fleming, 1989). Unfortunately, calcium determinations were not made on fruits used in this study.

Possible microbial action in unheated products, particularly at 2% acetic acid was of concern. This concentration is well below the approximate concentration of 3.6% (in the absence of other preservatives) that has been reported to insure against microbial spoilage in sweet cucumber pickles (Bell and Etchells, 1952) and a variety of products referred to as acetic acid preserves (Campbell-Platt and Anderson, 1988). A few jars of product held at 2% acetic acid were under slight pressure after 6-mo storage. This pressure may have been due to respiratory activity of the fruit at low acid concentrations, as no direct evidence of microbial activity was observed. Visual turbidity did not occur in the brine. Microscopic examination of brine and liquid from the fruit interior of jars under pressure revealed no evidence of microbial growth. Furthermore, brine compositions (pH and titratable acidity) after 6-mo storage gave no evidence of microbial growth. Note that brine compositions for products at 2% acetic were nearly identical for pasteurized and unpasteurized products (Table 5).

Effect of calcium and storage temperature on firmness loss in 'Red Cherry' peppers

The effect of storage temperature on rate of firmness loss in 'Red Cherry' peppers in the absence (Fig. 7) and presence (Fig. 8) of added $CaCl_2$ was determined. Overall effects are summarized in Table 6. Calcium addition had the greatest effect on reducing rate of firmness loss at higher incubation temperatures, although the effect was highly significant, at all temperatures (Table 6). There was no significant interaction between calcium addition and storage temperature on rate of firmness loss. At 26.7°C, firmness appeared to increase slightly during storage in the presence of added $CaCl_2$ (Fig. 8), but the slope of the line in Fig. 8 is not significantly different ($P \geq 0.05$) from 0. A firming effect during storage of brined cucumbers has previously been reported (Fleming et al., 1987; Pangborn et al., 1959). Thus, it seems likely that the rates of firmness loss, (Table 6 and Fig. 7 and 8) were composites of the effects of at least two reactions during product storage. Apparently, at least one reaction was responsible for softening, and at least one other was responsible for firming of tissue.

Taste panel scores correlated well with penetration readings by the Instron UTM (Fig. 9). Although the penetration test did not distinguish between mesocarp firmness and skin toughness, as would have been preferred and as illustrated previously for other commodities (Thompson et al., 1992), the overall force readings predicted sensory impressions reasonably well.

CONCLUSIONS

THE ADDITION of $CaCl_2$ to pickled 'Red Cherry' peppers, whether pasteurized or not, improved firmness retention during storage. $CaCl_2$ had no effect on firmness retention in pickled 'Jalapeno' peppers but uniformity of firmness was improved, particularly at 2% acetic. Unpasteurized, pickled peppers and cucumbers acidified to 2, 3, or 4% acetic acid were microbiologically stable over 6-mo storage. The rate of acid penetration into whole 'Red Cherry' peppers was not greatly influenced by pasteurization. Thus, pasteurization may not be necessary to insure microbial stability in these peppers in the presence of 2–4% acetic acid. The puncture test method, using an Instron UTM, correlated well with sensory firmness evaluation in 'Red Cherry' peppers.

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