

CONTROLLED FERMENTATION OF SLICED CUCUMBERS

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ABSTRACT

A process is described for the controlled fermentation of sliced, large cucumbers which results in improved firmness of the tissue. The cucumbers are sliced, blanched in water, cooled, brined in a solution of NaCl and calcium acetate at pH 4.3–4.6 and inoculated with a *Lactobacillus plantarum* starter culture. The fermentation is essentially complete within 1 wk at 27°C. Buffering of the brines with calcium acetate had the dual advantage of insuring complete fermentation, and firming of the cucumber tissue. Heated slices, when brined at 0–6.5% NaCl according to this process, were firm after 3 months' storage; whereas, unheated slices became soft at lower levels of NaCl. The process offers a possible means of reducing or eliminating the problem of soft centers in large cucumbers. The process also improved the firmness of small, whole cucumbers.

INTRODUCTION

THE ADVENT of mechanical harvesting and the increased demand for hamburger dill chips have resulted in the harvest of larger sizes of pickling cucumbers in recent years. Bloaters damage and soft centers are two problems that are especially serious in brine fermentation and storage of large cucumbers.

A controlled fermentation process for brine fermentation of pickling cucumbers is highly effective in preventing bloater damage in large cucumbers (Etchells et al., 1973). In the process, CO₂ is purged from the brines as a means of preventing bloater formation (Fleming et al., 1973). Purging of CO₂ from natural fermentations also was reported to reduce bloater damage (Costilow et al., 1977). However, the problem of soft centers in large cucumbers is not eliminated by the above process.

Soft centers in brined, whole cucumbers are unpredictable from visual observation of the green fruit, but are generally associated with large cucumbers (ca 5 cm diam or larger) as the seeds become enlarged. Not all large cucumbers exhibit soft centers upon brining, and occasionally this condition occurs in small cucumbers. The degree of softening may vary from a slight softening surrounding individual seeds to complete softening of the seed area and softening of the mesocarp tissue, all of which become evident only after brine storage.

Pickling cucumbers contain pectinolytic enzymes that are most active in large fruits as they approach maturity (Bell, 1951). Pressey and Avants (1975) found an exopolysaccharuronase in cucumbers. Although natural pectinases and possibly other enzymes of the cucumber may be related to the problem of soft centers, no direct correlation has been reported. In contrast, softening problems in the brining of small fruits have been identified with fungal enzymes that are introduced into curing brines chiefly by way of fungus-laden flowers that remain attached to the cucumbers, and to a lesser

extent by fungal enzymes on the fruit itself (Etchells et al., 1958).

Etchells et al. (1964) described a procedure for the pure culture fermentation of cucumbers which involved blanching of small, whole cucumbers, addition of an acidified cover brine and inoculation with various species of lactic acid bacteria. The procedure provided a means for heat inactivation of undesirable microorganisms and enzymes prior to the fermentation.

Green and Hanover (1975) described a process for fermenting diced vegetables, including cucumbers. In that process, the diced vegetables are blanched, cooled, inoculated with lactic acid bacteria, and allowed to ferment until 0.6% lactic acid is reached. Cutting the cucumbers prior to blanching reduced the heating required for enzyme inactivation.

In this study, we tested the effects of heating sliced, large cucumbers prior to brining, sodium chloride concentration and calcium acetate and sodium acetate buffer additives on firmness of the fermented slices. Effects of heating and buffer additives on the firmness of small, whole cucumbers also were tested.

MATERIALS & METHODS

PICKLING CUCUMBERS of unknown cultivar were obtained from local pickle companies. The cucumbers were sorted to remove damaged, diseased and misshapen fruit.

Brining of sliced, large cucumbers

Size no. 3 (3.8–5.1 cm diam) or 4 (5.2–5.7 cm diam) cucumbers were hand washed and sliced into ca 0.5-cm thick cross sections with a hand-operated food slicer having a stainless steel, circular blade. Slices were placed in a wire basket for heating. The basket containing 5-lb lots of cucumbers was submerged in a 77°C water bath (62L) for 3.5 min. The basket was kept in constant motion to insure uniform heating of the slices. This is essentially the blanching treatment for size no. 1 cucumbers as suggested by Etchells et al. (1968), who reported that it destroyed asporogenous microorganisms on the surface of whole cucumbers and inactivated or attenuated enzymes in the tissue which can cause deterioration of texture and other quality factors. They specified progressively longer holding times in the 77°C water bath for larger sizes of whole cucumbers.

Heated slices were cooled for 5 min either in 18°C water saturated with lime [ca 0.15% Ca(OH)₂, pH 12.4] if the brine solution was to contain calcium acetate, or in 18°C water if calcium acetate was not to be added. Unheated slices also were held in the appropriate cooling solution for 5 min.

Sliced cucumbers were packed in 3.8-L jars with 0–6.5% NaCl and certain buffer additives. The pack-out ratio was ca 60/40, w/v, cucumbers/brine. Buffer additives tested were either sodium acetate prepared by adjusting 0.99% NaOAc to pH 4.3–4.6 with HCl, or calcium acetate prepared by adjusting 0.15% Ca(OH)₂ to pH 4.3–4.6 with acetic acid. Brines were inoculated with ca 10⁸ cells of *Lactobacillus plantarum* WSO per 3.8L of brined cucumbers. The culture was grown in cucumber juice broth (Fleming et al., 1967) containing 5% NaCl at 30°C until the broth reached O.D. 2–4. The jars were incubated at 27°C for 3 wk and then stored at room temperature until 3 months after brining. All treatments were duplicated.

Brining of whole, small cucumbers

Size no. 1 cucumbers (ca 2.5-cm diam) were washed and treated as described above except they were not sliced. They were brined to equalize at 1.4% NaCl. Each treatment was duplicated.

Assays

Brines were analyzed for pH, titratable acidity (calculated as % lactic acid), and sodium chloride according to Etchells et al. (1964), and reducing sugars according to Sumner and Somers (1944).

Evaluation of fermented cucumbers

Sliced, fermented cucumbers were evaluated by a taste panel of five people, three of whom have had extensive experience with cucumber pickles, for texture, flavor and appearance. Texture was judged on a 10-point scale with 9-10 = excellent, 7-8 = good, 5-6 = fair, 3-4 = poor, and 1-2 = unacceptable to barely acceptable. Texture evaluations were based on standard hamburger dill chips, rated by consensus as to texture according to the above scale prior to taste panel evaluation. Panel texture scores are averages of duplicate tests by the panelists for each treatment. Panelists were asked to describe texture characteristics of tissue in the seed area and to note differences in flavor and appearance.

Firmness of no. 1 size cucumbers was determined with a USDA Fruit Pressure Tester, 5/16-inch tip, according to Bell and Etchells (1961). Pressure test averages of 10 cucumbers per jar were determined. Pressure tests are related to firmness ratings thusly: 18 lb and above, very firm; 14-17 lb, firm; 11-13 lb, inferior, 5-10 lb, soft; 4 lb and below, mushy (Bell and Etchells, 1961).

RESULTS & DISCUSSION

IN BRINING WHOLE, large cucumbers by the controlled fermentation process (Etchells et al., 1973), it is necessary to delay inoculation of the brines until sufficient sugars and other nutrients diffuse from and salt diffuses into the cucumbers, usually 18-24 hr.

Sugar diffused into the brines of sliced cucumbers almost immediately after brining and the *L. plantarum* starter culture produced 0.2-0.3% acid within 24 hr (Fig. 1). The rapid diffusion of salt into sliced cucumbers permitted earlier addition of the starter culture than is advisable in brining whole cucumbers. Heated, sliced cucumbers released over twice as much sugar into the brine as unheated slices during the first 3 hr after brining. Final acidity, however, was higher for unheated than for heated slices due probably to a higher total sugar content because sugar was leached from heated slices during heating. This sugar loss, based on assay of the heating and cooling water, amounted to about 0.18% of the fresh weight of the cucumbers.

The fermentation of sliced cucumbers was over 80% completed within 6 days, as measured by acid production, but continued slowly for several more days (Fig. 1). Thus, the time for complete fermentation did not differ greatly between slices and whole cucumbers (Etchells et al., 1975). Reduced activity of the culture by low pH, as fermentation progressed, was

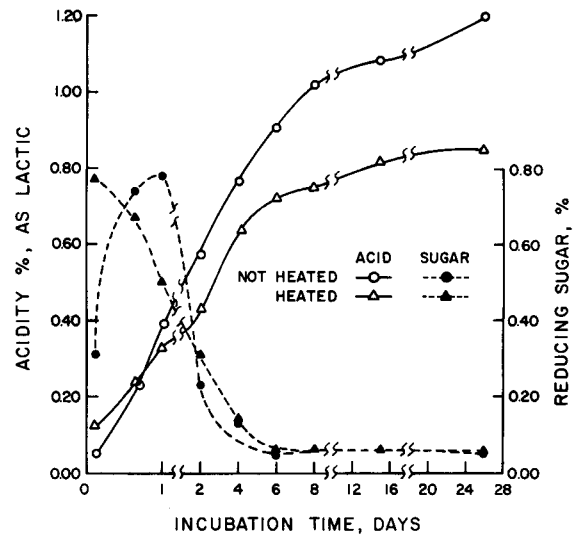


Fig. 1—Fermentation of sliced cucumbers. See Table 1, calcium acetate buffer, for details.

probably the most important factor influencing the time for completion of the fermentation in whole and sliced cucumbers when the brine was buffered as described herein; greater buffering, or pH control, may be necessary to effect complete fermentation in a shorter time at 27°C. Fermentation temperatures, in the range of 29-32°C, also would speed the rate of fermentation (Etchells et al., 1964).

Effect of buffer additives on heated and unheated slices

Heated cucumbers were firmer than nonheated with no buffer and with sodium acetate buffer, but the difference was not significant with the calcium acetate buffer (Table 1). Heated and unheated slices brined with calcium acetate were rated overall more firm than those brined with sodium acetate or with no buffer; the seed area was firm in both cases (Table 1). Without buffer the seed area of unheated slices was soft. Calcium chloride improves the firmness of cucumber pickles (Etchells et al., 1977), and calcium ions may account for the improvement we noted. Calcium salts enhance the firmness of blanched apple slices and were suggested as a means to enhance the texture of soft, overripe fruits and vegetables (Hills, 1950; Collins and Wiley, 1967).

Table 1—Effect of buffer additives on firmness of fermented sliced, size no. 4 cucumbers

Treatment		Final brine analyses ^b					Taste panel evaluation			
Heat treatment	Buffer additive ^a	NaCl (%)	pH	Total acid (%)	Acid formed (%)	Sugar (%)	Firmness ^c	Comments		
								Seed area	Flavor	Color
None	None	1.3	3.2	1.14	1.09	0.0	4.6d	Soft	Hay-like off flavor	Light straw
	Sodium acetate	1.3	3.3	1.30	1.12	0.0	5.7c	Sl. soft	Hay-like off flavor	Light straw
	Calcium acetate	1.3	3.3	1.20	1.00	0.0	7.5ab	Firm	Acid	Light straw
Heated	None	1.3	3.1	0.76	0.71	0.0	6.0c	Sl. firm	Acid	Raw, pale
	Sodium acetate	1.3	3.3	0.85	0.67	0.0	7.2b	Firm	Acid	Raw, pale
	Calcium acetate	1.3	3.5	0.88	0.68	0.0	8.1a	Firm	Acid	Raw, pale

^a The acetate concentration was 0.0728M in each of the buffered brines. Ca(OH)₂, 0.15%, was adjusted to pH 4.6 with acetic acid to form calcium acetate; NaOAc, 0.99%, was adjusted to pH 4.6 with HCl. Only cucumbers to be brined with calcium acetate were held in Ca(OH)₂ prior to brining.

^b Acid % calculated as lactic acid. Acid formed was corrected for acetic acid added in the initial cover brine. Initial cover brines were adjusted to pH 4.6 with acetic acid which amounted to 0.03% acetic acid for no buffer additive, 0.12% for sodium acetate, and 0.13% for calcium acetate, at equilibrium.

^c Mean values in the column with a common letter are not significantly different (P ≥ 0.05), according to Duncan's new multiple range test.

Table 2—Effect of heat and salt on firmness of fermented sliced, size no. 3 cucumbers

Heat treatment	Final brine analyses ^a					Taste panel evaluation			
	NaCl (%)	pH	Total Acid (%)	Acid formed (%)	Sugar (%)	Firmness ^b	Comments		
							Seed area	Flavor	Color
None	0.0	3.5	1.57	1.19	0.0	3.1c	Soft	Too acid	Straw, not uniform
	1.4	3.3	1.48	1.26	0.0	4.6b	Soft	Hay-like off flavor	Straw, not uniform
	3.9	3.2	1.38	1.21	0.0	5.2b	Soft	Hay-like off flavor	Straw, not uniform
	6.5	3.2	1.22	1.08	0.2	8.3a	Firm	Too salty, hay-like off flavor	Straw, not uniform
Heated	0.0	3.6	1.18	0.80	0.0	7.9a	Firm	Too acid	Raw, pale
	1.4	3.4	1.02	0.80	0.0	8.3a	Firm	Acid	Raw, pale
	3.9	3.3	1.03	0.86	0.0	8.6a	Firm	Too salty	Raw, pale
	6.5	3.2	0.92	0.78	0.0	8.9a	Firm	Too salty	Raw, pale

^a Acid % calculated as lactic acid. Acid formed was corrected for acetic acid added in the initial cover brine. Initial cover brines contained 0.15% Ca(OH)₂ and were adjusted to pH 4.3 with acetic acid which amounted to 0.63% acetic acid with 0% NaCl, 0.37% acid with 3.25% NaCl (= 1.4% final), 0.29% acid with 9.7% NaCl (= 3.9% final), and 0.24% acid with 16.3% NaCl (= 6.5% final).

^b Mean values in the column with a common letter are not significantly different ($P \geq 0.05$), according to Duncan's new multiple range test.

Cucumber slices were firmer when brined with than without sodium acetate (Table 1), possibly because of differences in final pH. Firmness of pickled cucumbers is reduced at high concentrations of lactic acid (Bell et al., 1972).

The taste panel evaluated slices for overall firmness, but also noted texture characteristics of the seed area tissue (Table 1). Firmness varied within each slice; the taste panel generally rated mesocarp tissue considerably firmer than the seed area tissue. Firmness scores were consistent, however, with the comments noted for the seed area. The seed area tissue was intact with all treatments. In contrast, we have observed brined, whole, large cucumbers in which the seed area was liquified. In extreme cases, the entire flesh may liquify and leave only the skin intact.

Effect of heat and salt on sliced cucumbers

Similar amounts of acid were formed in fermentations of sliced cucumbers at 0–3.9% NaCl (Table 2). Total acidities were higher at low than at high concentrations of NaCl because of the greater amounts of acetic acid required to adjust the initial cover brines to pH 4.3; less acid was required to attain pH 4.3 at higher concentrations of NaCl. The rate of fermentation also was similar at 0–3.9% NaCl, as indicated by acid formation, but the rate was less at 6.5% NaCl (data not shown) and less acidity was formed. The percent reducing sugars that remained after termination of the lactic acid fermentation of 6.5% NaCl (unheated) could account for the deficiency of acidity formed as compared to fermentations at 0–3.9% NaCl (Table 2).

Heated cucumber slices fermented in the calcium acetate buffer solution did not vary significantly in firmness regardless of NaCl concentration (Table 2). Unheated slices, however, decreased in firmness with the concentration of NaCl. Firmness scores and comments on firmness of the seed area agreed. The seed area was intact in all cases. At 6.5% NaCl, firmness did not differ between heated and unheated slices. The seed area was firm in heated slices regardless of NaCl concentration, but was soft in the unheated slices except at 6.5% NaCl (Table 2). We suspect that loss of firmness of unheated slices at low NaCl was due to natural pectinolytic enzymes of the cucumber. The activity of fungal pectinases on cucumbers is greatly suppressed at 6–8% as compared to 0% NaCl (Bell and Etchells, 1961), and salt may affect cucumber pectinases similarly. McFeeters and Palnitkar (1975) fermented unheated, sliced cucumbers without buffer additives or inoculation and found that slices softened if the NaCl concentration fell below

Table 3—Effect of heat and buffer additives on firmness of whole, size no. 1 cucumbers

Heat treatment	Buffer additive ^a	Brine analyses ^b			Firmness ^c	
		pH	Total Acid (%)	Acid formed (%)	3 months 6 months	
None	None	3.5	0.99	0.96	9.1c	8.4c
	Sodium acetate	3.5	1.16	1.04	10.7b	10.6b
	Calcium acetate	3.6	1.19	1.06	14.9a	15.3a
Heated	None	3.4	1.22	1.19	14.9a	16.3a
	Sodium acetate	3.4	1.12	1.00	15.1a	16.2a
	Calcium acetate	3.6	1.11	0.98	16.6a	16.8a

^a The acetate concentration was 0.0728M in each of the buffered brines. Ca(OH)₂, 0.15%, was adjusted to pH 4.6 with acetic acid to form calcium acetate; NaOAc, 0.99%, was adjusted to pH 4.6 with HCl. Only cucumbers to be brined with calcium acetate were held in Ca(OH)₂ prior to brining.

^b Acid % calculated as lactic acid. Acid formed was corrected for acetic acid added in the initial cover brine. Initial cover brines were adjusted to pH 4.6 with acetic acid which amounted to 0.03% acid for no buffer additive, 0.12% for sodium acetate, and 0.13% for calcium acetate. Equalized NaCl was 1.4%.

^c Firmness as measured by the USDA Fruit Pressure Tester. Mean values in the column with a common letter are not significantly different ($P \geq 0.05$), according to Duncan's new multiple range test.

5.5%. This observation agrees with ours on unheated slices and no calcium buffer.

Heated slices retained a uniform white or raw appearance as compared to the irregular, straw color of unheated slices (Table 2). These observations are similar to those published for pasteurized and unpasteurized, sliced cucumbers (Etchells, 1938). The heated slices tended to become translucent upon storage for 6–9 months in the present work, but remained pale in contrast to the typical straw color of salt-stock cucumbers. Some experienced panelists noted a hay-like, off flavor and odor in unheated slices, whereas, heated slices had a clean, fermented flavor and odor (Tables 1 and 2).

Effect of heat and buffer additives on small, whole cucumbers

Fermented, small, whole cucumbers were firmer when they were heated before brining (Table 3), which is similar to the findings with sliced, large cucumbers (Tables 1 and 2). Heated,

whole cucumbers did not vary significantly ($P \geq 0.05$) in firmness due to buffer additive. Unheated cucumbers were firmer with the calcium acetate buffer than with sodium acetate, and firmness was lowest without buffer (Table 3). These differences in firmness did not appear to be due to pH. It is possible that pectinolytic activity of microbial origin accounted for the lower firmness in the unheated cucumbers.

Optimum conditions for retention of firmness

The firmness of sliced, large and small, whole cucumbers was improved either by blanching, calcium addition, buffering, or a combination of these treatments used herein. Optimum conditions for each of these three treatments will vary, however, depending on the nature of the cucumbers used. The blanching treatment improved the firmness of cucumbers in the present studies, but may not be sufficient to completely inactivate heat resistant microbial enzymes which could possibly contaminate the raw fruit. Likewise, it is possible that variations exist in the heat resistance of natural enzymes of cucumbers which may be associated with the problem of soft centers.

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