BAG-IN-BOX TECHNOLOGY:
Storage Stability of Process-Ready, Fermented Cucumbers

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ABSTRACT

Process-ready, fermented cucumbers were microbiologically stable for up to 6 months when held at 4% salt, and up to 12 months when 0.1% sodium benzoate also was present. At 2% salt, some fermentations were unstable at 6 months of storage. Microbial instability was associated with a rise in brine pH (from 3.5 initially), increases in CO_2 and acetic acid concentrations, and a decrease in lactic acid concentration. A rise in CO_2 concentration was associated with bloater formation. The composition of the bag in which the fermented cucumbers were held influenced the growth of oxidative (film-forming) yeasts in brine near the bag surface. These yeasts seemed to grow to an extent limited by the rate of oxygen permeation through the plastic bag. Ultra-low density polyethylene (3-mil, 4-ply) seemed too oxygen-permeable for extended (several months) storage of the brine-stock in the bags. A polynylon layer in the bag provided a greater but not complete oxygen barrier.

INTRODUCTION

The use of high concentrations of salt traditionally has been used to assure the microbial and quality stability of brine-fermented cucumbers held in bulk tanks. The brined cucumbers are held in the tanks from a few to many months as a means of extending the processing season. The tanks have open tops, which facilitate filling and emptying. During storage, the brine surface must be exposed to UV rays of sunlight to prevent the growth of oxidative yeasts and molds which will utilize the acid produced during fermentation, resulting in a rise in pH with resultant growth of spoilage and potentially pathogenic microorganisms.

There has long been a concern for holding the cucumbers in open tanks, and particularly outdoors because of possible entry of foreign material. Also, oxygen from air exposure is known to cause flavor and other quality problems during storage. Various methods have been tested to solve the above problems, including use of oil to blanket the brine surface and, thereby, prevent surface growth of yeasts and molds (Etchells and Veldhuis, 1939), addition of a plastic tank cover before fermentation (Finlay and Johnston, 1956) and a post-fermentation tank cover (J. L. Etchells, unpublished), holding the tanks indoors with artificial UV light mounted over the brine surface (Fabian and Bryan, 1932), and fermenting/storing the cucumbers in anaerobic tanks (Fleming et al., 1983). Sufficient problems or objections with all of these procedures have prevented their broad acceptance.

The bag-in-box concept (Fleming et al., 2002) is an attempt to find a commercially acceptable method to answer the above concerns, while offering a means of eliminating wastes and improving product quality. However, the fermented cucumbers must be stable from microbiological and quality standpoints for commercial acceptability. The objectives of this study were to determine the storage stability of bag-in-box fermented cucumbers and factors influencing this stability. Some of the factors studied included salt concentration, use of the preservatives sodium benzoate and potassium sorbate, and type of material used to construct the bags.

MATERIALS AND METHODS

Microbiological Analyses

Brines were analyzed for total aerobes, lactic acid bacteria, yeasts, and molds with plating media, as described by Fleming et al. (2001). Dilutions for plating were made in sterile 0.85% saline and were then plated with a model D Spiral Plater (Spiral Systems, Inc., Cincinnati, OH).

Chemical Analyses

Malic, lactic, and acetic acids were analyzed by HPLC with an HPX-87H column (Bio-Rad, Richmond, CA) with 0.03N sulfuric acid as the eluant. The column was heated to 140°F (60°C) at a flow rate of 0.8 mL/min. A photodiode array detector (model UV6000, Thermal Separations) set at 210 nm (Frayne, 1986) was used for the detection of these organic acids. Sorbic acid was also analyzed by HPLC using a Bio-Rad Fast Acid column with 0.03N sulfuric acid at 0.9 mL/min and 140°F. The sorbic acid was detected at 240 nm. Fructose, glucose, and ethanol were detected on a refractive index detector (model 410, Waters Associates, Inc., Milford, MA) coupled in series after the photodiode array UV detector. Dissolved CO_2 was measured as described by Fleming et al. (1974). Salt (NaCl) was measured by titration, as described by Fleming et al. (2001).

Headspace Gas Analysis

For taking gas samples by needle and syringe, a strip of duct tape (~6 x 2 inches) was adhered to the outer surface of the bag in the area above the brined cucumbers near the base of the bag snout (see Fig. 7 of Fleming et al., 2002). A 21-gauge needle, attached to a 12 cc plastic syringe (Monoject), was inserted through the taped portion of the bag and about 10 cc of the gas was withdrawn. The needle end was inserted into a solid rubber stopper to prevent escape of the gas. Three replicate samples were taken and transported to the laboratory for analysis that day when possible. After sampling, another strip of duct tape was placed over the strip of duct tape through which the sampling needle was inserted. When analysis was delayed, the syringed samples were stored under water until analysis, as suggested by Blankenship and Hammett (1987). The samples were analyzed with a Hach Carle Gas Chromatograph (Series 400 AGC, EG & G Chandler Engineering, Broken Arrow, OK) as described by McConnell (2001). Composition of the gas was expressed as percentages of CO_2, O_2 and N_2, based on a standard gas mixture.

Product Evaluation

Fermented cucumbers were evaluated for bloater damage, and the damage was expressed as "bloater index," as described by Fleming et al. (1977). Cucumber firmness was measured with a USDA Fruit Pressure Tester, as described by Bell et al. (1955).

Experimental Design for Storage Stability

After opening the fermentation/storage bag and evaluating the cucumbers, 5-gal pails of cucumbers and brine were returned to the

laboratory for repacking into either 46-oz or 1-gal jars in duplicate for storage. The cucumbers were fermented at either 2 or 4% salt. If fermented at 2% salt, some jars were supplemented with extra salt to raise the concentration to 4%. Also, 0.1% sodium benzoate was added to some jars. The stored products were evaluated after 6 and 12 months. The jars were packed with fermented cucumbers, filled with brine to ~5 mm headspace, capped with heat-softened gasketed caps, inverted, and held on storage racks at 78°F (26°C). The typical experimental storage design for products from five storage runs is summarized in Table 1.

Table 1. Experimental design for storage stability of fermented cucumbers.[1]

Jar no.	% Salt	% Na benzoate	Storage time (months)	Reps.
1,2	2	-	6	2
3,4	2	-	12	2
5,6	2	0.1	12	2
7,8	4	-	6	2
9,10	4	-	12	2
11,12	4	0.1	12	2

[1]The cucumbers were fermented in a bag-in-box and repacked with the fermentation brine into 46-oz or 1-gal jars in duplicate. The jars were filled to ~5 mm headspace with brine, tightly capped, inverted on a storage rack, and held at 77°F (25°C ±2) for the times indicated.

RESULTS AND DISCUSSION

The brining system designed for bag-in-box technology is intended to eliminate waste and improve product quality and uniformity. High concentrations of salt traditionally have been used to ensure product stability, but at the expense of generating waste when excess salt is washed from the brine-stock during processing. The problem of microbial and product stability can occur if the salt concentration is too low, resulting in growth of undesirable microorganisms and gaseous and other spoilage of the cucumbers. Cucumbers have been successfully fermented and stored in the absence of NaCl, provided they were blanched (3 min, 171°F, 77°C), inoculated with a culture of lactic acid bacteria, brined in calcium acetate buffer, and held in 1-gal jars under laboratory conditions (Fleming et al., 1995). These ideal conditions do not exist under pilot and commercial conditions. It was later shown under less than these ideal conditions that microbial and textural stability of cucumbers fermented/stored at 4.4% can be optimized by assuring a final pH of 3.5 (Fleming et al., 1996; 2002). Addition of 0.1% sodium benzoate after fermentation further assured stability, even at slightly higher pH. These and other considerations were applied to the bag-in-box concept, as is described below.

Brine Stratification

The cover brine occupied about 45% of the bag contents in our current studies. About half of the brine was added to the bag before the blanched cucumbers were added. The culture was added just before addition of the cucumbers. After all cucumbers were in the bag, the remaining brine was added, gas pockets were eliminated as the top of the bag and snout were collected for sealing, and then the bag snout was heat-sealed. The bag-in-box was held on a pallet, and no effort was made to agitate, invert, or otherwise cause mixing of the contents. Contents of the bag extended to a depth of 28 inches. At the end of storage and before evaluation of the cucumbers, brine was sampled at depths of 1, 12, and 28 inches. The chemical analyses of bag contents from three different storage times are summarized in Table 2. At the bottom of the bag, the salt concentration was considerably higher than for samples taken at 1 and 12 inches. This problem is similar to that in large commercial tanks, where salt concentration below the cucumbers is higher unless the brine is circulated. This is because cucumbers shrivel somewhat in brine and rise because of their lower density, leaving a space near the tank bottom where no cucumbers exist during the early stages of brining. Under commercial conditions with large tanks, however, the brine is usually circulated by mechanical or air-lift pumping. Not only did salt stratify, but acetic acid, which was added in the cover brine, also was higher at the bottom. Lactic acid, which was formed by the lactic acid bacteria from sugars that diffuse from the cucumbers, was higher at 1 and 12 inches depth than at 18 inches until about 6 weeks, but thereafter became more equalized.

Table 2. Stratification of brine components in bag-in-box fermented cucumbers (EX 15-00, runs 1, 4, 5).

Run no. (cucumber size) (day's storage)	Cover brine NaCl (%)	Cover brine Acetic acid (mM)	Depth in bag (inches)	After fermentation/storage pH	NaCl (%)	Acetic acid (mM)	Lactic acid (mM)
1	4.6	116	1	3.51	1.8	49	120
(2b)	(2.0)[1]		12	3.52	1.9	51	116
(13)			28	4.55	3.5	108	18
4	4.1	119	1	3.40	1.6	47	121
(3a)	(2.0)[1]		12	3.41	1.7	48	120
(42)			28	3.64	2.5	64	90
5	8.8	115	1	3.36	2.5	41	111
(2b)	(4.0)[1]		12	3.36	2.9	42	111
(161)			28	3.42	5.0	57	101
5	8.9	117	1	3.26	2.6	47	102
(3a)	(4.0)[1]		12	3.29	3.2	47	103
(161)			28	3.40	4.2	52	106

[1]Values in parentheses are intended equilibrium values.

Storage Stability

A total of five runs of bag-in-box cucumber fermentations was done in 2000, referred to by experiment no. EX15-00 (runs 1-5). It should be noted that cucumbers from these five runs were held in the bags for 13-161 days before opening and sampling, depending upon experiment number. The product at the time of bag opening was of acceptable quality with a pleasant, fermented, cucumber odor. There was a small amount of film yeast on the brine surface under the bag snout, but no obvious spoilage. We chose to study the storage stability of the fermented cucumbers by packing samples in glass jars, with various adjustments or additions as indicated in Table 1. Samples from each of the five runs were stored in duplicate 1-gal jars for 6 and 12 months to determine microbial storage stability, as indicated by chemical changes and product quality (summarized in Table 3). The intended salt equilibrium was 2% for runs 1-4 and 4% for run 5 (Table 2). However, for extended storage studies, the salt was increased to 4% for some jars, and 0.1% sodium benzoate was added to others (Table 3). The results from these storage studies are indicated in Table 3 as storage failure rates. Microbial instability, as indicated by certain chemical changes, was considered as failure. The indication of

Table 3. Effects of salt concentration and sodium benzoate on microbial stability of fermented cucumbers during storage (EX 15-00, runs 1-5).

Run no.	Cucumber size	Storage time (months)	Storage failure rates at[2] 2% Salt	2% Salt + benzoate[3]	4% Salt	4% Salt + benzoate[3]
1 (13)[1]	2b	6	2/2		0/2[4]	
		12	2/2	0/2	0/2[4]	0/2
2 (48)	2b	6	0/2		0/2[4]	
		12	0/2	0/2	0/2[4]	0/2
	2b	6	2/2		0/2[4]	
		12	2/2	0/2	0/2[4]	0/2
3 (42)	2b	6	2/2		0/2[4]	
		12	2/2	2/2	2/2[4]	0/2
4 (48)	3a	6	0/2		0/2[4]	
		12	0/2	0/2	0/2[4]	0/2
5 (161)	2b	6			0/2	0/2
		12				
	3a	6			0/2	0/2
		12				
	Totals	6	6/10		0/14	0/4
		12	6/10	2/10	2/10	0/10

[1]Days of fermentation/storage in bag before evaluation. The dates of storage for each run were: (1) 3/17/00-3/30/00; (2) 5/25/00-7/12/00; (3) 8/10/00-9/21/00; (4) 10/12/00-11/29/00; (5) 12/6/00-5/16/01. The cucumbers were held under ambient conditions near Clinton, NC.

[2]Failure rate indicates the number of 1-gal jars of fermented cucumbers that were microbiologically unstable during storage for 6 or 12 months at room temperature. The jars were packed from the bag-in-box fermented cucumbers after fermentation.

[3]Sodium benzoate (0.1%) was added after fermentation.

[4]The salt concentration in these jars was increased from the 2% used for fermentation to 4% for storage.

microbial instability typically was characterized by a rise in pH, a reduction in lactic acid concentration, and a rise in both acetic acid and CO_2 concentrations. In all cases, the incidence of instability was associated with pressure buildup in the jar due to CO_2 production. From run 1, for example, duplicate jars with 2% salt at both 6 and 12 months failed, but when 0.1% sodium benzoate was added, the jars were stable for 12 months. The jars also were stable when 4% salt was present for storage, with or without added sodium benzoate. Overall results from the five runs are given in the "totals" at the bottom of Table 3. At 2% salt, six of ten jars failed. At 2% salt plus 0.1% sodium benzoate, only two of ten jars failed, and those two failures were after 12 months; there were no jars with benzoate stored for only 6 months. When all samples were stored at 4% salt, none of 14 jars failed after 6 months, and only two of ten failed after 12 months. No failures resulted after 12 months at 4% salt when 0.1% sodium benzoate was present. Previously, microbial instability of fermented cucumbers held at 2.3% salt resulted in butyric acid spoilage (Fleming et al., 1989). In addition to butyric acid, propanol and propionic acid also were formed. No butyric acid spoilage was evident in any of the current studies.

Chemical changes of the brined cucumbers associated with stable and unstable storage are typified in Table 4 for run 1. Initial and final (12 months) chemical compositions of the brine are indicated. Brines were stable when either 0.1% sodium benzoate or 4% salt was present. The pH was 3.4 and 3.6 in these two treatments. The lactic acid was slightly lower and the acetic acid slightly higher than the initial values. The CO_2 was considerably higher than the initial value, but not so high as to cause a bloater problem. The concentration was well below saturation.

Table 4. Chemical composition typical of fermented cucumbers that were microbiologically stable or unstable during storage.

Run no.	Microbial stability[1]	Storage time, months	0.1% Benzoate added	Salt (%)	pH	CO_2 (mg/100 mL)	Lactic Acid (mM)	Acetic Acid (mM)
1	Initial	0	-	2	3.5	41	116	51
	Stable	12	+	2	3.6	74	106	53
	Unstable	12	-	2	4.1	212	43	89
	Stable	12	-	4	3.4	85	102	56

[1]The cucumbers were fermented with 2% salt in the bag-in-box for 13 days (EX 15-00(1)) and then packed into 1-gal jars. Shown are data from typical jars representing stable and unstable samples.

Table 5. Quality stability typical of fermented cucumbers that were microbiologically stable or unstable, as summarized in Table 3.[1]

Run no.	Microbial stability	Cucumber size	Storage time (months)	Cure (%)	Bloater	Firmness (FPT, lbs)[2]
1	Initial	2b	0	45	0.5	18.8 (2.3)
	Stable	2b	12	98	2	15.7 (1.5)
	Unstable	2b	12	95	70	16.3 (2.1)
	Stable	2b	12	93	1	17.8 (1.7)

[1]See Tables 3 and 4 for related data.

[2]Values in parentheses are standard deviations.

The quality of the brine-stock indicated as stable (Table 5) was acceptable after 12 months of storage. The bloater index was negligible and the firmness acceptable. However, the unstable cucumbers were severely bloated (Table 5), which was expected due to the extremely high level of CO_2 (Table 4). None of the stored samples had unacceptable firmness, either in the examples given in Table 5, or in other data related to the storage stability (summarized in Table 3). Apparently the instability problem is associated only with gas formation, perhaps because of lactic acid being degraded to acetic acid and CO_2 by lactic acid bacteria, as suggested by Lindgren et al. (1990), or other bacteria that can utilize the lactic acid under the stressful conditions.

The concern should be raised as to the validity of doing the extended storage studies with samples of brined cucumbers in glass jars. It is conceivable that the product became contaminated during opening the bags, transporting brine-stock samples back to our laboratory, and then repacking into the jars. Perhaps some of the samples exhibiting microbial instability would not have done so if left undisturbed in the plastic bag.

Gas Composition of the Bag Headspace

Permeability of the storage bag to gases may play an important role in quality of brine-fermented cucumbers. Bags are available with various permeabilities to oxygen, but expense is an important consideration for use by the pickle industry. We tested two types of bag material that were recommended to us by the supplier of bags to us. Our major concern is the rate of oxygen transfer from the outside air into the bag. Oxygen inside the bag can influence quality of the brine-stock. Also, microbial growth can be affected, especially that of aerobic microorganisms such as yeasts and molds. A lesser consideration is how pressure buildup within the bag can influence

bag integrity due to the buildup of CO_2 from the fermentation. Although we used a malate-negative strain of *Lactobacillus plantarum* that produces very low levels of CO_2, other microorganisms present could produce excessive CO_2.

The time course of gas compositional changes and pressure buildup of run 3 is summarized in Table 6. The snout of the bag was heat-sealed near the end and loosely rolled. Within 4 days, the concentration of CO_2 in the headspace had increased to 51%, and the oxygen had decreased to 1.3% from 21.2% originally present in the air. The snout (36 inches long x 12 inches x 15 inches), which had unrolled and become distended, was under considerable pressure. After 11 days, pressure within the bag snout was less, but still kept it slightly distended. No pressure was obvious after 18 days, but increased slightly after 25 days. During this 25-day period, the CO_2 concentration increased to about 60% and then decreased to about 52%, while the oxygen remained 1+% until day 25 (2+%).

Further studies within other fermentation runs yielded the results reported in Table 7. However, the storage periods for these runs extended from 48-210 days. The snout in these cases was under no pressure. The oxygen content in the bag had risen to as high as 8% in some bags, but was relatively low (1-3%) in others.

Film yeast growth was noted on the area of the brine surface that was exposed to headspace gas for all bags held for 2 months or longer before opening. Although the snout was rolled up and heat-sealed, there was always a small gas pocket above the brine. Film yeast could be observed before opening the bag, but was more clearly obvious upon opening of the bag. Mold growth was not obvious. On one occasion, algal growth was noted on the interior bag surface after 210 days upon opening. For the most part, cucumbers near the surface containing film yeast were firm, with a few soft cucumbers occurring occasionally. This was evidence that sufficient oxygen diffused through the bag to encourage growth of oxidative (film-forming) yeasts. Previous research in our unit (unpublished) has indicated that oxidative yeasts will grow to an extent limited by the level of oxygen. We attribute the low levels of oxygen observed in the headspace of the bags to utilization by oxidative yeasts. Apparently it was the yeast growth that resulted in low levels of oxygen in the headspaces of the bags.

Table 8 summarizes the microbiological activity at various locations within a bag of fermented cucumbers after storage for 7 months. We wanted to learn how yeast growth varied throughout the bag. Yeast growth was highest in the brine under the snout, where surface growth of the film yeast was noted. Next highest numbers were in brine just inside the surface of the bag, either on the side or top of the bag where no gas pocket was evident. The lowest numbers were found in the center of the bag at mid and bottom depths (only about 1% of the numbers present near the bag surface). This indicated that oxygen diffusion through the bag encouraged oxidative yeast growth near the bag surface. Analytical chemical data in Table 9 for the same areas of the bag from which oxidative yeasts were enumerated indicate no major variability of lactic acid. Oxidative yeasts consume lactic acid, but apparently diffusion of this acid was sufficiently high to avoid great variability in concentration throughout the bag. However, lactic acid concentration was higher and salt concentration was lower at the bottom depth, as was noted before (Table 2). Potassium sorbate (a yeast inhibitor) was added in the cover brine (0.06%) of this run (EX 27-01(2)), and the residual levels at various locations throughout the bag are given in Table 9. Note that the residual potassium sorbate concentration was lower near the bag surface than in the center. Perhaps oxygen caused degradation of the

Table 6. Gas composition and pressure buildup in the headspace of bag-in-box pickles (EX 15-00(3)).[1]

Storage (days)	Snout pressure[2]	Headspace (snout) composition		
		% CO_2	% O_2	% N_2
0 (air)	-	0.0[3]	21.2	78.8
4	+++	51.4	1.3	47.2
11	+	60.2	1.5	38.3
18	-	54.8	1.1	44.0
25	+	52.2	2.2	45.5

[1]Bag (41 in x 45 in x 39 in) was ultra-low density polyethylene (ULDPE) from Custom Packaging Systems, Inc. (Manistee, MI).

[2]Visible pressure as noted by snout distension: +++ = snout fully distended; + = snout slightly distended; - = no pressure obvious.

[3]Air typically contains about 0.03% CO_2.

Table 7. Composition of gas in the headspace of heat-sealed bags of fermented cucumbers.

Experiment no.	Bag (box) type	Storage time (days)	Headspace composition[1]		
			% CO_2	% O_2	% N_2
Air			<0.1	20.5	79.5
15-00(4)	ULDPE, 3 ply, 4 mil (Saeplast, D335)	48	33.4	1.4	65.1
15-00(5)	PE/nylon/EVOH/PE 3 ply, 4 mil (Saeplast, D335)	65	28.7	8.0	63.3
		65	50.2	1.2	48.6
		93	26.3	4.2	69.3
		93	33.3	6.5	60.0
		150	41.8	2.1	56.2
		150	47.2	2.6	50.2
27-01(2)	ULDPE, 2 ply, 4 mil (EZ-Pak collapsible box)	210	6.9	2.6	90.5

[1]Each data point represents an average of three samples.

Table 8. Microbiology of brine taken at termination of EX 27-01(2).1

Bag location	CFU/mL			
	Total	Lactic acid bacteria	Yeasts	Molds
Side	8×10^4	<400	1×10^5	<400
Top, under snout	2×10^7	5×10^6	5×10^6	<400
Top, side	8×10^4	7×10^3	1×10^5	<400
Center, mid-depth	2×10^5	4×10^4	9×10^2	6×10^2
Center, bottom depth	2×10^5	4×10^6	6×10^2	<400

[1]Sole and final sampling 5/8/02. Brined 10/11/01 (7 months' storage). Bag was flaccid, no pressure. Film yeast was observed at the brine surface within the bag snout. Cucumber size 2b.

Table 9. Chemistry of brine taken at termination of EX 27-01(2).[1]

Bag location	Salt (%)	pH	CO_2 (mg/100 mL)	Lactic acid (mM)	Acetic (mM)	K sorbate (mM)
Side	3.6	3.5	19.2	107	48	0.097
Top, under snout	3.1	3.5	12.7	105	41	0.065
Top, side	3.1	3.5	8.0	105	41	0.072
Center, mid depth	3.8	3.5	19.6	103	49	0.128
Center, bottom depth	6.4	4.0	25.4	51	79	1.68
Cover brine				ND	112	4.04 (1.81)[2]

[1]Size 2b cucumbers. ND = None detected.

[2]K-sorbate in the cover brine was 4.04 mM (0.06%), which equates to 1.81 mM (0.027%) at equilibrium with the cucumbers, assuming uniform distribution and based on the 55/45, cucumbers/brine pack-out ratio used.

compound near the bag surface, or oxidative yeasts might have caused the degradation. This is the only run in which the use of potassium sorbate was tested.

We prefer that no preservatives be required for bag-in-box brine-stock. The source of the oxidative yeasts whose growth was encouraged by oxygen diffusion through the bag is uncertain. Perhaps a few yeast cells survived blanching of the cucumbers. It was not requested from the supplier that the bags used be sterile, so they could have harbored some yeast cells, or the contents of the bag could have been re-contaminated during transfer of the blanched cucumbers and brine into the bag-in-box. While cucumbers brined by bag-in-box technology were adequately stable for 1-2 months without serious yeast growth, resolving a potential problem for longer term storage in plastic bags will require further research. Use of bags with lower oxygen transmission rates seems a preferred approach, since oxygen exclusion also would favor greater retention of flavor and color in the brine-stock.

CONCLUSIONS

Process-ready, fermented cucumbers (Fleming et al., 2002) were stable from microbiological and quality standpoints for the period that they were held sealed in plastic bags (13-161 days). When transferred to glass jars, the stability was extended to 6 months at 4% salt and to 12 months when 0.1% sodium benzoate also was present. It was not ascertained if instances of microbial instability during extended storage were exacerbated by transfer of samples from the plastic bags to glass jars. Thus, extended storage studies within the fermentation bag are warranted. However, bags with lower oxygen transmission rates should be investigated, so as to reduce or eliminate the growth of oxidative yeasts, which can utilize lactic acid and result in spoilage. The use of preservatives such as sodium benzoate and potassium sorbate may increase storage stability, but their use is not preferred. Some system for inverting the bag-in-boxes should be considered for overcoming the problem of brine stratification, which may influence microbial stability and product quality and uniformity.

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ABOUT THE COVER:

Bulk storage in brine has been an economic means of extending the processing season of pickling cucumbers since before the 1930's (1). When larger sizes of cucumbers began to constitute a higher proportion of the crop in the 1960's, bloater formation resulted in buoyancy force sufficient to rupture tank heading timbers (2), but purging of CO_2 from the brine reduced bloater damage and buoyancy forces within the tank (3). However, use of high concentrations of salt in brine storage requires washing of the excess from the brine-stock before conversion to finished products, which requires the use of aeration ponds to biodegrade the organic matter (4), but still results in problems in the handling of salt and other non-biodegradable wastes. The use of fiberglass and polyethylene tanks (5) has reduced salt leakage that was prominent with wooden tanks (1-3), but relatively high salt concentrations are still used to serve as insurance against vagaries of nature due to tanks being open to the atmosphere. Closed tanks have been considered by the industry (6), but various factors have resulted in modernized brine yards of open-top, fiberglass and polyethylene tanks and a waste handling system (7). This issue of the journal is devoted largely to summarizing efforts to design and test a pilot system (8) for preserving "process-ready," brined cucumbers with improved quality and reduced wastes, and with intended benefits to the producer and processor of pickling cucumbers.

"For Those Who THINK PICKLES"

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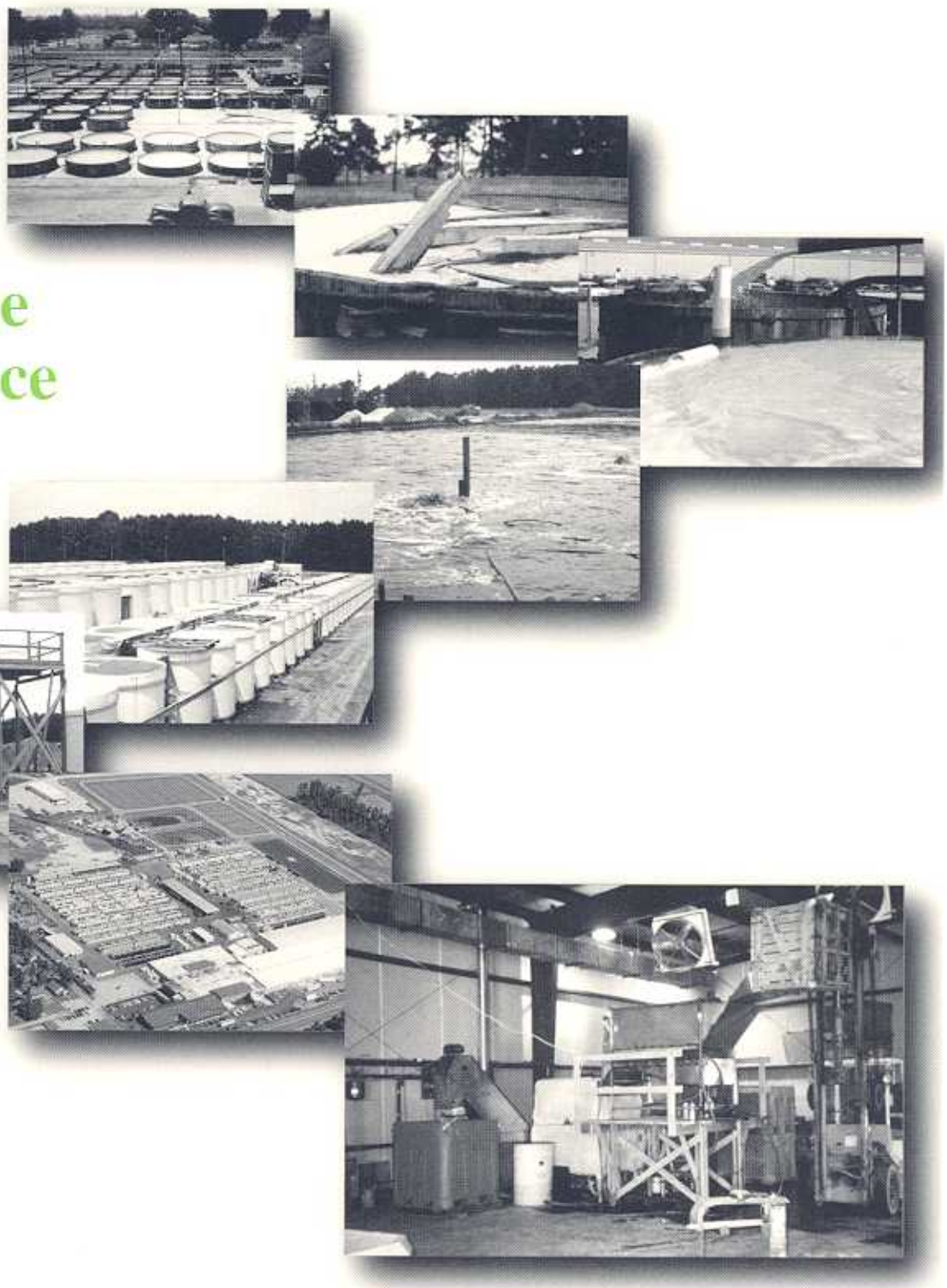
SCIENCE

Bulk Storage in Brine Since the 1930's



A journal reporting research relating to brined, salted and pickled vegetables and fruit.