SUGGESTED PROCEDURE FOR THE CONTROLLED FERMENTATION OF COMMERCIALLY BRINED PICKLING CUCUMBERS—THE USE OF STARTER CULTURES AND REDUCTION OF CARBON DIOXIDE ACCUMULATION[1]

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ABSTRACT

A procedure is suggested for the controlled lactic acid fermentation of cucumbers and other vegetables brined in bulk. The new procedure, evolved from many years of studying the natural fermentation of brined material, incorporates features designed to minimize or eliminate the usual defects of brine-stock pickles (bloaters, poor texture, poor color, shriveled or flat stock, and unclean odor and taste) associated with the unrestricted, heterogeneous, highly complex, variable, natural fermentation. The controlled brining procedure includes: thorough washing of the green stock; in-container sanitizing; acidification; buffering; purging to reduce the CO_2 content in the brine; and, inoculation with species of lactic acid bacteria with known performance for rapid, vigorous growth and acid production for the brining conditions described. The new procedure will, with the suggested brine-strength shown, complete the fermentation in 7-12 days at brine temperatures in the 78-85°F range. Hopefully, the new procedure will also permit substantial reduction of salt content for storing brine-stock pickles now in practice.

Introduction

According to Etchells and Moore (1971) the commercial brine preservation of cucumbers and other vegetables, as practiced today, is essentially the same as it has been since man first learned to store certain foods by the use of salt. We were finally convinced by studies over the years at the plant level that no single brining treatment devised and used by industry was capable of giving the same quality brine-stock, as to texture and bloater content (= hollow stock) from one year to another, or even within a given season, or even for two tanks brined with the same treatment at the same time and with the same size of cucumbers from the same general production area! However, our brining research—in cooperation with the pickle industry—has produced a number of valuable procedures and techniques that have greatly inproved the overall quality of commercial brine-stock pickles (see Etchells and Moore, 1971, for a list of 43 selected references under 12 categories of pickling research; four public service patents related to pickling are also cited).

Even so, the ultimate and continuing objective for our brining studies has always been the same: To develop a feasible, *controlled bulk fermentation process* for the pickle industry that will virtually eliminate the defects and spoilage now commonly associated with the uncontrolled natural fermentation of brined cucumbers and other vegetable material. We believe that much progress toward achieving this long sought goal of controlled fermentation has been made. Numerous, successful controlled fermentations, with resultant high quality brine-stock pickles, have been made during the past few years, progressing from container sizes of 1 qt, 1 gal, 5 gals, 500 gals, and 6,000 gals. It is not our purpose here to give detailed results of countless experiments, but rather to suggest the procedure to industry so it can be carried out faithfully and without question or doubt as to the details contained in the various steps involved.

The step-by-step brining instructions given herein were published in part earlier by Etchells and Hontz (1972). Those procedures referred particularly to the use of 25° salometer (6.6% NaCl) brining treatment, although additional tabulated information was provided, based on the average brine-cucumber-mass

[1] Paper no. 4106 of the Journal Series of the North Carolina Agricultural Experiment Station, Raleigh.

temperature (Table 1).[2] This Table is again shown because the information remains very pertinent to the *new information provided here*, which deals specifically with controlling the lactic acid fermentation of cucumbers and other vegetables brined in bulk.[3] The suggested procedure deals with the addition of pure cultures, of brine origin, with known high performance for the conditions described, coupled with the control of carbon dioxide (CO_2) gas responsible for most bloater (hollow-stock) formation. The control of the fermentation gases and those released by the brined cucumber is accomplished by a sweeping or purging action from the brine by an inert gas such as nitrogen.

Hopefully, the "Controlled Fermentation Procedure" described herein will permit a marked reduction of the salt content of holding brine now in general practice for cured brine-stock pickles (about 60 to 65° salometer = about 16 to 17% NaCl by weight). The anticipated reduction will depend, of course, on the protection of the brine surface from dilution by rain and surface growth that will utilize the brine acid. In areas with cold winter climates, freezing of the brine-stock could be a problem. Even so, we believe that these problems are in the final stages of solution. In most cases, it is not what one **wants** to do, but what one will **have** to do to stay in business. Accordingly, we believe the procedure described herein, if carried out carefully, will help meet the saline control standards under consideration by the various regulatory and ecological agencies—both State and Federal. The same applies to the sanitary regulations of brining stations, the brining tanks, and the brine-stock pickles produced.

Procedure for Controlled Bulk Fermentation Process According to the 25° Salometer Treatment

1. CUCUMBERS:

Examine the green stock carefully as to quality; grade out stock that is diseased, broken, or moldy.

2. WASHING:

Wash graded stock thoroughly with a brush- or reel-type washer. If the stock comes directly from refrigerated trucks or storage, then temper it to 65-75°F with a warm water pre-soak before or during the washing treatment.

3. IN-TANK SHRINKING:

Shrinking the cucumbers may be necessary by allowing the cushion brine to reduce the mass to the desired head level, with a ratio of about 60% cucumbers to 40% brine by weight. To accomplish this, put a 10- to 12- inch depth cushion of a 25° salometer brine (= 6.6% salt by weight) containing about 80 ppm available chlorine, in a well-cleaned tank. Fill the tank heaping full with freshly harvested cucumbers, either graded to size (no. 1's = up to 1 1/16 inches in diameter; no. 2's = 1 1/16 to 1 1/2 inches; no. 3's = 1 1/2 to 2 inches; no. 4's = over 2 inches in diameter) or field-run = all sizes. Allow the stock to settle to about one foot below the top of the tank. Keep a record of the number of 50 lb bushels, or total weight of cucumbers in the tank in cwts (= 100 lbs).

In cases where the green-stock is flumed to the tanks in brine, the cucumbers tend to get a preshrinking treatment not only enroute to the tank, but probably more so during the actual filling operation, because the fluming brine continues to pour over them and down through the cucumber mass to the bottom of the tank where the return brine hose is located (Etchells and Moore, 1971). For details on other "In-Tank Shrinking Treatments," refer to the article by the above-named authors, particularly, the section entitled, "Getting the Desired Pack-Out Ratio."

4. COVERING AND HEADING:

Cover the cucumbers at the previously determined volume level with a "false" head made of wooden boards, about 1 inch thick and 6-12 inches wide and keyed down securely with 2 x 4 inch or 4 x 4 inch lumber of appropriate length. The head boards should provide plenty of avenues for the fermentation and purging gases to escape. To help gas escape more easily, bore a number of 3/8 inch holes, spaced to give about 10 holes per square foot of covered brine surface. This requirement takes on added importance because of the gas purging technique to be described later.

5. COVER BRINE:

Add a chlorinated (about 80 ppm) 25° salometer brine until the liquid level is 4 to 6 inches above the head boards, and about 4 inches below the top of the tank.[4] Remember, depending on the size of the tank being used, a ton or more of dry salt will have to be put on the head boards. This salt will take up space, either in the solid or dissolved state. *The brine should be chlorinated again about 10-12 hrs before inoculation.*

6. ACIDIFICATION:

The chlorinated cover brine must be *very carefully acidified with acetic acid (glacial) or its equivalent amount of vinegar; avoid breathing the chlorine gas fumes.* The brine

[2] All tables appear under Appendix A, but are referred to only by their Arabic number.

[3] Perhaps a part of the original "controlled fermentation" objective has been accomplished with the advent of the pure culture process for "In-Container" or "Ready to Eat" products such as: dill pickles; dill tomatoes; dill green beans; various types of peppers; dill okra; dill carrots, whole or dill strips; and the like. The detailed processes for these and related products are described in, and covered by, public service patent no. 3,403,032 (Etchells, Bell and Costilow, 1968); this patent may also cover some of the basic concepts of bulk brining with pure cultures to be described herein. In addition, the same "In-Container" process minus the culture, called "Instant Pack," permits the packing of certain fresh-pack vegetable products such as cucumbers in bulk containers, such as 5 gal tins or plastic pails which, in amounts of about 25-lb lots, are most difficult, if not impossible, to pasteurize, at 165°F internal product temperature, so as to retain even the minimal desired flavor and texture—particularly the latter characteristic. *Most important:* Instead of adding the starter culture to the previously heat-shocked and cooled cucumbers (or other vegetables), the packer adds his own acidified, spiced and flavored brine after it is first heated (to 170°F) and then cooled (to 40°F). The cover brine is then added to the aseptically packed product and sealed with a chlorine-sanitized closure. A separate public service patent has been granted to cover the pure culture fermentation of Spanish-type green olives (no. 3,780,448; Etchells, Bell and Kittel, 1969).

[4] See Tables 1A and 1B for suggested equilibrated brine strengths to use according to the *natural* temperature of the brined mass. For further information on how to get the brine and cucumbers to equilibrate at desired temperature range (±2°F), see Tables 3 to 6 (Appendix A).

usually is acidified as it is added.[5] Acetic acid is added at the rate of 6 ml per gallon of total cucumbers and brine. For example, a properly brined tank of 500 bu of stock would require about 7.3 gallons of acetic acid (= 27.7 liters) or 73 gallons of 100 grains vinegar (Table 2). Briners should refer to the article by Etchells and Moore (1971) for information on the care of tanks and especially for calculating tank capacity which is essential to the controlled fermentation process because the *total volume* in gallons occupied by the cucumbers and brine *must be known;* it will be helpful to know the total volume at the desired head level as well as at the final brine level above the head boards (Table 2).

7. SALT ADDITIONS:

Assuming we are brining a 500 bu tank of cucumbers (25,000 lbs or 250 cwt); add the amount of salt on the head boards to maintain the desired, initial 25° salometer salt concentration. This amounts to about 6 lbs of salt for every 100 lbs (cwt = two, 50 lb bu) of cucumbers in the tank, or a total of 1,500 lbs (Table 1). In the case of small sizes (less than 1¼ inches diameter), most of the 6 lbs/cwt is added on the head at the time of brining. For sizes 1¼ to 2 inches in diameter, ½ to ⅔ of the salt is added on the head at the outset (3 to 4 lbs/cwt or about 1,000 lbs); then, add the remainder (2 to 3 lbs/cwt or about 500 lbs) 12 to 36 hours later.

For sizes 2 inches in diameter and over, brined at 78-85°F (equilibrated brine temperature), we suggest that about 50% of the required amount of salt be added at the outset, then add 30% after 24 hours, and, the remainder, 20%, 48 hours after brining. The main objective is to keep the brine strength at the desired salometer reading during this critical period, just prior to the culture addition. Today, when cucumbers may be in transit for long times, from production areas to the manufacturers, loss in moisture content should be taken into account. When cucumbers are noticeably shriveled, particularly at the stem end, the third addition of salt may have to be reduced or even eliminated!

For specific suggestions as to salt additions for different temperature conditions and using cover-brines of different salt concentrations, see Tables 1A and 1B.

8. MAINTAINING BRINE STRENGTH:

The brine strength of the fermentation should be held at 25° (±2°) salometer until the brine acidity (calculated as lactic) shows no significant change for at least two consecutive samplings, at 1- to 2-day intervals. This should take about 7-12 days at brine temperatures in the range of 78-85°F.[6] Then, raise the brine strength gradually (Etchells and Hontz, 1972) to that concentration practiced by the company.

9. ACETATE ADDITIVE:

Technical- or laboratory-grade sodium acetate ($CH_3COONa \cdot 3 H_2O$), approved by FDA, is added 2-3 hours before the culture, as well as before the second salt addition, at the rate of 0.5% sodium acetate by weight (= 18.8 grams per gallon of packed and brined material with brine calculated as water). For example, a 500-bu tank of cucumbers (about 4,600 gals total) would require about 191 lbs of sodium acetate (Table 2). In the case of small cucumbers, also add the sodium acetate 2-3 hours before the culture; but, no further salting should be required when the new cover-brine is added following the draining procedure recommended above for these sizes.

10. CULTURE ADDITION:

Inoculation is usually made with a special strain of *Lactobacillus plantarum* which is very acid-tolerant and capable of rapidly fermenting out all of the sugars under the brining conditions described herein. A special culture of *Pediococcus cerevisiae,* because of its good growth at rather high salt concentrations, has, in some instances, been added with *L. plantarum* to establish an early lactic acid fermentation, particularly where the desired equilibration of the brine concentration is slow, or where "oversalting" has occurred. In this case, *P. cerevisiae* initiates the fermentation, and is then succeeded by the more acid-tolerant *L. plantarum* which continues to produce acid until all of the sugar is used. With our procedure, the buffer additive usually holds the final brine pH at about 3.4 to 3.5 even after all the brine sugars are fermented. Growth by *L. plantarum* usually will continue to a brine pH of 3.15 (±0.05) *without* the buffer additive, whereas, growth by *P. cerevisiae* ceases at pH 3.75 (±0.05). Without the buffer, 0.4 to 0.5% sugar may remain in the brine which, as a rule, is usually used by acid- and salt-tolerant, fermentative yeasts with resultant bloater formation.

The starter culture should be added about 18-24 hours *after* the brining and just before the second addition of salt, *but* 2-3 hours *after* the acetate addition. It is important that the culture is added when the first salt addition has equilibrated with the corresponding moisture content equivalent from the brined material.[7] *The brine must be shown to be chlorine-free before culture addition.* We recommend a total inoculum of about 4 billion viable cells per gallon of brined material (cucumbers and brine). The culture(s) *must* have a high level of viability, proper count and, *particularly, the ability to regenerate rapidly in the equilibrated brine strength to which they are added.* Check these important factors with your culture supplier to insure that all requirements are fully met. Details as to shipping, storage, handling, and means of addition of the starter culture should be the re-

[5] We prefer to add the acid by a siphon arrangement directed into a 4-inch diameter plastic tube mounted in the approximate center of the tank and held securely in position at the bottom of the tank, and at the top, by a hole in the head board(s) of appropriate size. The tube is perforated with ⅜-inch diameter holes and saw-toothed-notched up to 3 inches at the bottom. It should extend about 2-3 inches above the final brine level. It also provides a convenient method for brine sampling for carbon dioxide (CO_2) tests, in order to determine the effectiveness of the purging schedule. The tube also provides a means of adding the starter culture at the appropriate time.

[6] Q-BAT tablets (= Quick Brine Acidity Test, reported by Bell et al., 1971) can also be used to help determine when the final acidity is reached. See Appendix C Statement and tabular material. These tablets are available from "Pickle Packers International, Inc., P. O. Box 31, St. Charles, Illinois 60174, USA.

[7] Etchells and Moore (1971, Appendix C, Table 3) give the approximate percentages of salt absorbed by no. 1, 2 and 3 size cucumbers in 24 hours; the values were: 95, 85 and 50%, respectively. These figures were based on studies by F. W. Fabian and R. C. Fulde, as cited in the Table referred to above.

sponsibility of the supplier. He also should be knowledgeable about the particular strains of each of the two named species that should be used; if not, contact the authors.

11. PURGING ACTION:

Carbon dioxide gas (CO_2), calculated in terms of mg/100 ml brine, dissolves in fermentation brines in much the same manner as in champagne or carbonated soft drinks. The CO_2 enters the cucumbers or pickles, and, if the concentration is great enough, may cause bloaters (Etchells et al., 1968; Etchells and Hontz, *unpublished*). Thus, measurements of carbon dioxide concentration in the brine can provide useful information relating to the potential bloater formation in the tank during the fermentation. It is important to understand that CO_2 is developed from more than one source. Natural cucumber respiration into the brine, as well as that from so-called, "non-gas-forming" species of the lactic acid bacteria, contribute to the total CO_2 content *even* in a pure culture fermentation (Fleming et al., 1973a; 1973b). A procedure for determining CO_2 in fermenting brines has been described briefly (Fleming et al., 1973a). A more detailed account of this procedure, including pictures of the CO_2 assay assembly and of a brine-sampling device, has been prepared (Fleming, Thompson and Etchells) and will appear in the January, 1974, issue of the *Journal of the Association of Official Analytical Chemists*.

Because of the shape of most brining tanks, diffusion of CO_2 from the brine surface usually is not adequate to avoid some degree of bloater formation in large sizes (no. 3's and 4's). To help lower the CO_2 content to a level that would minimize bloater formation, we suggest use of a *nitrogen-gas purging system* (Fleming et al., 1973a). With this system, the bubbling action of the nitrogen gas, up through the brined cucumbers, literally sweeps or carries the CO_2 to the brine surface and allows it to escape into the atmosphere.[8] A satisfactory CO_2 bloating index depends on several conditions: brine strength; brine temperature; tank configuration; cucumber-to-brine ratio; cucumber size; and, chemical composition of the brine. For a given geographical area, the pickle processor will, by careful tests, have to work out the best procedure for his own area. These tests should be in cooperation with competent engineers, and knowledgeable suppliers of gas products and equipment used for taking oxygen out of the air and "scrubbing" to remove residual CO_2.

We have given suggested schedules for intermittent and continuous purging with nitrogen gas that may be helpful (Table 7). These schedules cover a wide range of container sizes and conditions. The fact that air is generally available at most pickle plants for use in circulating during desalting and sweetening is no reason to believe it is recommended for purging — *because it is not,* for several reasons not discussed here. Further, nitrogen is a much better gas to use in the plant and would result in less chance for oxidation and "off" flavors in the desalting and sweetening operations during the preparation of standard, processed pickle products. Equipment is readily available to take the oxygen out of the air on a commercial basis. Its use should be carefully considered by the pickle processor whether he is concerned with gas-purging brine-stock or not.

The question has arisen about purging natural fermentations. The high variability of these fermentations, as mentioned earlier, and problems associated therewith, have caused unpredictable results in our studies. We do not recommend this procedure.

Important Modification of the Procedure for Small Cucumbers:

If small cucumbers (no. 1's, up to 1 1/16 inches in diam and 2A's, 1 1/16 to 1 1/4 inches diam) are being brined according to the above pure culture process, the original 25° salometer cover brine (with 80 ppm chlorine) should be drained off 36-48 hours after filling and brining the tank, and replaced with a new brine of the same strength (25° salometer with 80 ppm chlorine, *acidified*). This procedure is designed to drain away naturally-occurring softening enzymes, chiefly from the mold-laden retained blossoms, that diffuse into the cover brine and thence into the brined cucumbers, and otherwise would deteriorate the texture of the brined material. The draining procedure, used in natural fermentations since 1954, is a necessary and widely accepted practice in southeastern and southwestern areas of the country. After this draining procedure, the remaining steps of the pure culture process (nos. 6 to 11) listed above are followed.

Studies under the direction of Professor T. A. Bell of our laboratory, chiefly as to removal of softening enzymes and other undesirable chemical constituents and specifically directed to reuse of the "drained off" brine are now in final stages of completion: this important information should be available to the industry in the very near future.

Acknowledgments

We are indebted to W. R. Moore, Jr., Executive Vice President, Pickle Packers International, who has, since the beginning of the pure culture pickle work, been a constant source of dedicated support and encouragement. We also sincerely thank the following persons for their generous help throughout the developmental stages of the procedure presented herein; we are also grateful for the facilities and various materials supplied by the companies of these cooperators:

Delos H. Wallace, Mark W. Lingle, Leonard Beasley, Mrs. Lillian Bizzell, and Carl C. Hall; Atkins Pickle Company, Atkins, Arkansas.

I. D. Kittel[9], Clifford R. White, Mrs. E. Happ, and Gedney Tuttle; M. A. Gedney Company, Chaska, Minnesota.

R. L. Sellars, R. S. Porubcan, and M. L. Longreen; Chr. Hansen's Laboratory, Inc., Milwaukee, Wisconsin.

W. G. Griffith[10] and C. M. Cavileer; Lutz & Schramm, Inc., Division of Beatrice Foods, Ayden, North Carolina.

Lloyd H. Hontz and John N. Walker, Mount Olive Pickle Company, Mount Olive, North Carolina.

Sidney D. Rubin, Jesse Eisenberg, Buck Fleming, and Michael Bershad; Perfect Packed Products

[8] The purging action for the suggested intervals might also be considered as increasing the brine surface area by the constant bubbling action of the nitrogen gas.

[9] Present address: Vlasic Food Products, Imlay City, Michigan.

[10] Present address: Vlasic Food Products, Millsboro, Delaware.

Company, Henderson, North Carolina.

Herman B. Blum, Syl. Peace, I. D. Kittel and Albert Dubin; Vlasic Food Products, Imlay City Division, Imlay City, Michigan.

J. C. Pacilio, H. W. Ohlhaver, and Robert P. White; White Cap Division, Continental Can Company, Inc., Chicago, Illinois.

Fred M. Brainard, Robert E. Thomsen, James L. Kinsey, and David F. Brainard; Standard Metal Products Company, Inc., Franklin Park, Illinois.

Eugene S. Schoene[11]; Green Bay Foods, Green Bay, Wisconsin.

F. J. Hassler, E. G. Humphries, and Ralph B. Greene, Department of Biological and Agricultural Engineering, North Carolina State University, Raleigh, North Carolina.

[11] Mr. Shoene was employed by M. A. Gedney Company, Chaska, Minnesota, when the early pure culture work he participated in was done. Essentially, the same was true for I. D. Kittel and D. H. Wallace. However, for the latter two persons named, a good deal of cooperative pure culture pickling research has taken place since they have taken their present positions.

NOTE: The authors are also indebted to Arthur D. Jones (deceased), Thomas O. Marziani, and Mrs. Lucille Dieter while they were employed by the pickle plant of Monarch Food Processors, Consolidated Foods Corporation, West Chicago, Illinois. This plant is no longer in operation.

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APPENDIX A—TABLE 1A

Brining Cucumbers:

Suggested equilibrated brine strengths, based on the calculated average brine-cucumber-mass temperature

Expected average brine-cucumber-mass temperature[1]	Brine strength at equilibration:		Cover brine strength used	Approximate amount of dry salt to add on head-boards	
	Desired	Acceptable		At start	Next day
in °F.	*° salom.*[2]	*° salom.*[2]	*°salom.*	*lbs/cwt of cucumbers*[3]	*lbs/cwt of cucumbers*[3]
68 & below (cool to very cool)	20	18-20	25	3	1
			30	2	1½
			35	2	1
69 to 75 (cool to mild)	25	23-25	25	4	2
			30	3	2¼
			35	3	1¾
76 to 80 (mild to warm)	25	25-27	25	4	2
			30	3	2½
			35	3	1¾
81 to 85 (warm)	28	27-29	25	5	2
			30	4	2½
			35	4	2
86 & above[4,5] (very warm)	30	30-32	25	5	3
			30	5	2¼
			35	4	2¾

[1]The "Cucumber-Brine-Mass Temperature" can be estimated provided one knows: the average cucumber temperature, the cover-brine temperature, and the *expected* percentages of cucumbers and brine by weight, when the tank is filled, headed, and brined. Now, assuming the cucumber temperature is 75°F, the brine temperature 60°F, and the percentages of cucumbers and brine figured at 65% and 35% by weight, then, the formula is:

$$T = \frac{(\text{cucumber percentage x cucumber temperature}) + (\text{brine percentage x brine temperature})}{100}$$

$$\text{Example: } T = \frac{(65 \times 75) + (35 \times 60)}{100} = \frac{4875 + 2100}{100} = \frac{6975}{100} = 69.75 \text{ or about } 70°F.$$

[2]The equivalents in percentage of salt by weight for 20, 25, 28, 30, and 35° salometer brines would be about 5.3, 6.6, 7.4, 7.9, and 9.2%, respectively.

[3]Cwt means per hundred weight, or 100-lbs.

[4]For an alternate method of determining the cucumber-brine-mass temperature *after* brining, see Table 1B.

[5]See Tables 3, 4, 5, and 6 (Appendix A) for cover brine temperatures needed for cucumbers of different temperatures to obtain equilibrated brine-mass-temperatures of 75, 80, 85, and 90°F. Actually, these tables can provide necessary information for obtaining the desired fermentation temperature ranges for any given salometer treatment, but particularly for that of the 25° salometer treatment at 78-85°F. The two extremes, 75° and 90°F may be of help when cucumbers are likewise either very hot or very cold.

APPENDIX A—TABLE 1B

Brining cucumbers: Suggested brine strengths to use for different cucumber sizes based on the equilibrated brine-cucumber-mass temperature (mid-depth) taken about one-hour after brining and heading the tanks[1]

Recorded brine temp-erature after one hour	Brine strength at final equilibration with cucumbers		Strength of cover brine to use for cucumbers	Approximate amount of dry-salt to add on head boards (calculations adjusted to cucumber size)											
				At start				Next day				2nd day			
				Size no.				Size no.				Size no.			
	Desired	Acceptable		1A, 1B & 2A	2B	3	4	1A, 1B & 2A	2B	3	4	1A, 1B & 2A	2B	3	4[2]
°F	° *salom.*	° *salom.*	° *salom.*	*lbs/cwt cucs.*				*lbs/cwt cucs.*				*lbs/cwt cucs.*			
68° & Below (cool to very cool)	20	18-20	25	3	2½	2	1½	1	1	1	0	0	½	1	1
			30	2	1½	1½	1	1½	1½	1	½	0	½	1	½
69 to 75° (Cool to mild)	25	23-25	25	4	3½	3	2	2	2	1	1	0	½	1[2]	1
			30	3	2½	2	1½	2¼	2¼	1½	1	0	½	1[2]	1
76 to 80° (Mild to warm)	25	25-27	25	4	3½	3	2	2½	2	1	1	0	1	1[2]	1
			30	3	2½	2	2	2½	2	2	1½	0	1	1½	1
81 to 85° (Warm)	28	27-29	25	5	4	3	2½	2	3	2½	2	0	0	1½	1
			30	4½	4	3½	2¼	2	2½	3	2	0	0	0	1½
86° & Above (very warm to hot)	30	30-32	25	5	4	4	4	3	4	3	2	0	0	1	1
			30	5	4	3	3	2¼	3¼	3	3	0	0	1¼	1¼

[1]Compiled by L. H. Hontz and J. L. Etchells *(unpublished data)* as an alternate method (see Table 1A) for determining the cucumber-brine-mass temperature *after brining* with a cover-brine strength that would appear suitable for existing temperature conditions.

[2]Additional salt may be needed the following day. Note: One-half pound of salt per 100-lbs cucumbers raises the salometer 1 degree. This is also applicable to raising the salometer after the 0.6% lactic is achieved.

APPENDIX A—TABLE 2

Brining Cucumbers:

Weights and volumes of cucumbers including brine additives[1] required for the controlled fermentation process using starter cultures

Pickling cucumbers		Volume occupied by		Total volume of cucumbers plus brine		Brine additives			
						Acetic acid added[2]		Sodium acetate added[2]	
Bush-els	Weight	Cucumbers only	Brine only	In terms of		In terms of		In terms of	
no.	*lbs*	*gallons*	*gallons*	*gallons*	*liters*	*ml*	*oz* (liquid)	*grams*	*oz* (wt)
1	50	6[3]	3.2	9.2	34.8	55	1.9	173	6.1
2	100	12	6.4	18.4	69.6	110	3.7	346	12.2
3	150	18	9.7	27.7	104.8	166	5.6	521	18.4
4	200	24	12.9	36.9	139.7	221	7.5	694	24.5
5	250	30	16	46	174	276	9.3	865	30.5
								kg	**lbs**
6	300	36	19	55	208	330	11.2	1.0	2.3
7	350	42	23	65	246	390	13.2	1.2	2.7
8	400	48	26	74	280	444	15.0	1.4	3.1
9	450	54	29	83	314	498	16.5	1.6	3.4
10	500	60	32	92	348	552	18.7	1.7	3.8
						liters	**gallons**		
20	1000	120	64	184	696	1.1	0.29	3.5	7.6
30	1500	180	97	277	1048	1.7	.44	5.2	11.5
40	2000	240	129	360	1397	2.2	.58	6.9	15.3
50	2500	300	161	461	1745	2.8	.73	8.7	19.1
60	3000	360	193	553	2093	3.3	.88	10.4	22.9
70	3500	420	226	646	2445	3.9	1.03	12.1	26.7
80	4000	480	258	738	2793	4.4	1.17	13.9	30.6
90	4500	540	290	830	3142	5.0	1.32	15.6	34.4
100	5000	600	322	922	3490	5.5	1.45	17.3	38.1
200	10000	1200	645	1845	6983	11.1	2.93	34.7	76.5
300	15000	1800	967	2767	10473	16.1	4.25	52.0	114.6
400	20000	2400	1289	3689	13963	22.1	5.84	69.4	153.0
500	25000	3000	1612	4612	17456	27.7	7.32	86.7	191.1
600	30000	3600	1934	5534	20946	33.2	8.77	104.0	229.3
700	35000	4200	2256	6456	24436	38.7	10.22	121.4	267.0
800	4000	4800	2579	7379	27930	44.3	11.70	138.7	305.8
900	45000	5400	2901	8301	31419	49.8	13.17	156.1	344.1
1000	50000	6000	3223	9223	34909	55.3	14.61	173.4	382.3
1100	55000	6600	3546	10146	38403	60.9	16.10	190.7	420.4
1200	60000	7200	3868	11068	41892	66.4	17.54	208.1	458.8

[1]Values shown are based on about 65% cucumbers and 35% brine; adjustments should be made for pack-out ratios that differ from this ratio, particularly if large-sized stock is brined (1¾ to 2¼ inches in diameter).

[2]Acetic acid (glacial) is added at rate of 6 ml per gallon of brined material; sodium acetate is added at the rate of 0.50% per gallon (by wt) of brined material = 18.92 grams/gallon; 1 gallon = 8.328 lbs as water or 3.778 kg.

[3]We get 270 lbs of cucumbers into 50 gal of a 55 gal drum; thus, 270 ÷ 50 = 5.4 bu; and, 50 ÷ 5.4 = 9.25 gal occupied by 1 bu of cucumbers + brine; then 9.25 x 65% (= pctg of cucs.) = 6.019 gal occupied by 1 bu of cucumbers alone, which is rounded off to 6.0 gallons.

APPENDIX A—TABLE 3

Cover-brine temperatures required for cucumbers (of different temperatures) to obtain an equilibrated cucumber-brine-mass temperature of **75°F** for bulk fermentation.

Amount of cover-brine in % by wt[1]	Average cucumber temperature (°F)									
	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°
	Required cover-brine temperature (°F)									
25	165	150	135	120	105	90	75	60	45	30
30	145	134	122	110	99	87	75	64	52	40
35	131	122	112	103	94	84	75	66	56	47
40	120	112	105	98	90	82	75	68	60	52
45	111	105	99	93	87	81	75	69	63	57
50	105	100	95	90	85	80	75	70	65	60

[1]Refers to amount of brine in % by weight of the total contents of the tank (cucumbers + brine). Brine is calculated at 8.34 pounds per gallon.

APPENDIX A—TABLE 4

Cover brine temperatures required for cucumbers (of different temperatures) to obtain an equilibrated cucumber-brine-mass temperature of **80°F** for bulk fermentation.

Amount of cover-brine in % by wt[1]	Average cucumber temperature (°F)									
	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°
	Required cover-brine temperature (°F)									
25	185	170	155	140	125	110	95	80	65	50
30	162	150	138	127	115	103	92	80	68	56
35	145	135	126	117	108	98	89	80	70	61
40	132	125	118	110	102	95	88	80	72	65
45	123	117	111	104	98	92	86	80	74	68
50	115	110	105	100	95	90	85	80	75	70

[1]Refers to amount of brine in % by weight of total contents of the tank (cucumbers + brine). Brine is calculated at 8.34 pounds per gallon.

APPENDIX A—TABLE 5

Cover-brine temperatures required for cucumbers (of different temperatures) to obtain an equilibrated cucumber-brine-mass temperature of **85°F** for bulk fermentation.

Amount of cover brine in % by wt[1]	Average cucumber temperature (°F)									
	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°
	Required cover-brine temperature (°F)									
25	205	190	175	160	145	130	115	100	85	70
30	178	167	155	143	132	120	108	97	85	73
35	159	150	141	131	122	113	103	94	85	76
40	145	138	130	122	115	108	100	92	85	78
45	134	128	122	116	110	103	97	91	85	79
50	125	120	115	110	105	100	95	90	85	80

[1]Refers to amount of brine in % by weight of total contents of the tank (cucumbers + brine). Brine is calculated at 8.34 pounds per gallon.

APPENDIX A—TABLE 6

Cover-brine temperature required for cucumbers (of different temperatures) to obtain an equilibrated cucumber-brine-mass temperature of **90°F** for bulk fermentation.

Amount of cover brine in % by wt[1]	Average cucumber temperature (°F)									
	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°
	Required cover-brine temperature (°F)									
25	—	210	195	180	165	150	135	120	105	90
30	195	183	172	160	148	137	125	113	102	90
35	174	164	155	146	136	127	118	109	99	90
40	157	150	142	135	127	120	112	105	97	90
45	154	139	133	127	121	114	108	102	96	90
50	135	130	125	120	115	110	105	100	95	90

[1]Refers to amount of brine in % by weight of total contents of tank (cucumbers + brine). Brine is calculated at 8.34 pounds per gallon.

APPENDIX A—TABLE 7

Suggested nitrogen gas flow rates used for purging CO_2 from brined cucumbers[1]

Container size in gallons	Method of purging	Interval of purging (hours or days)	Length of purging	Gas flow rate (as nitrogen)
5	Intermittent	2 hours/day	7 days	400 ml/minute
5	Continuous	24 hours	7 days	5-100 ml/minute
55	Continuous	24 hours	7 days	65-300 ml/minute
500	Continuous	24 hours	7-12 days	2-5 cu ft/hour
5,000—6,000	Continuous	24 hours	7-12 days	20-25 cu ft/hour
5,000—6,000	Intermittent	1 hour, 4 times/day, then reduced as shown in Appendix B.	7-12 days	100-125 cu ft/hour

[1]These are examples of purging methods and nitrogen gas flow rates that have been successfully used by the authors and their cooperators to reduce the concentration of CO_2 in fermenting cucumber brines and, as a consequence, reduce the usual high percentage of bloaters (hollow-stock) in large-sized, brined material. The figures shown are not necessarily the optimum or minimum conditions required for most efficient CO_2 removal, even under controlled conditions. Factors which influence rate of buildup in CO_2 concentration and removal of CO_2 by purging include temperature of the brined cucumber-mass; brine strength; percentages of cucumbers and brine; and condition of the material brined. For example, post-harvest injured cucumbers will show bloater damage that is absent in non-damaged fruit.

Most of our work has been done with large size nos. 3 and 4 (1½ to 2¼ inches diam) because these are the most difficult to brine with minimal development of bloater damage. As mentioned earlier, the demand continues to increase for sound, unbloated larger-sized, cured brine stock. *One* hamburger chain alone is reputed to use some 26-30 million hamburger slices per day!

Several variables that influence both the accumulation and removal of CO_2 from the controlled fermentation of cucumber brines are mentioned above. In TABLES 8 and 9 that follow, we have tabulated information on controlled fermentations conducted in the environmental control chambers that made possible our progress to this point, and emphasized the need for purging to remove CO_2 in the brine originating from the cucumbers and the starter culture. These data deal with: (1) brine temperature, (2) depth of the brine-cucumber-mass (TABLE 8); and (3) the percentage of solids to liquid, namely, cucumbers to brine (TABLE 9). The Tables, for the most part, are self-explanatory, even so, some explanation of the results are given under the Tables.

APPENDIX A—TABLE 8

Influence of temperature and depth of brine-cucumber-mass on bloater formation in cucumbers brined under controlled fermentation conditions in environmental growth chambers.[1]

Treatment no. and year[4]		Brining information: Incubation temperature	Fill of container (am't)	Depth of container fill	Weight of cucumbers brined	Volume to surface area ratio	Bloater data: Percentage and types of bloaters found in 100, no. 3-size salt-stock pickles cut; Chipper variety, 1.5-2.0 inches in diameter			
no.	*yr.*	°F	*fraction*	*inches*	*pounds*	*v/a*	*balloon %*	*lens %*	*h.c.*[2] *%*	*total %*
I	1969	90	3/3	28	270	2.5	30 -	1 -	17 -	48
	1970	90	3/3	28	270	2.5	23-a[3]	9-m	17-m	49
	1970	80	3/3	28	270	2.5	10-s	8-s	7-s	25
II	1969	90	2/3	19	180	1.6	10 -	0 -	14 -	24
	1970	90	2/3	19	180	1.6	11-m	7-m	3-m	21
	1970	80	2/3	19	180	1.6	8-s	4-s	5-m	17
III	1969	90	1/3	9.3	90	0.80	4 -	1 -	5 -	10
	1970	90	1/3	9.3	90	0.80	7-s	4-s	1-s	12
	1970	80	1/3	9.3	90	0.80	8-s	6-s	2-s	16

[1]These experiments were conducted in 55 gal drums, using 50 gal of brined material under the head for the 3/3 treatment. All treatments were in duplicate except the 1/3 lots which were in triplicate. The controlled, inoculated, bulk brining treatment described herein was used both years with one exception, *nitrogen purging was not employed*. There were two environmental growth chambers used, one for 90°F and one for 80°F. These were built for such work at a cooperating pickle plant; each chamber can easily accommodate about 16, 55 gal drums. It is important to EMPHASIZE that all drums of cucumbers were at the assigned temperature (80° or 90°F) for 24 hrs a day for their total 7-10 days' fermentation period. This would be a rare occurrence for material brined under natural conditions.

[2]Refers to "Honeycomb" bloater, consisting of small gas pockets around three or more seeds.

[3]Symbols refer to degree or severity of bloater damage: *s* = slight; *m* = moderate; and *a* = advanced condition. NOTE: The bloater content at 80°F usually was less than at 90°F and the degree or severity was also less. This is attributed to greater solubility of CO_2 at 80°F and better opportunity for diffusion and escape into the atmosphere.

[4]The cucumbers were brined at 25° salometer (6.6% NaCl) and maintained at that concentration during the fermentation period (7-10 days). The percentage of solids to liquid for all treatments (I, II & III) was the same—65% cucumbers and 35% brine (by wt).

NOTE: This material was compiled from Etchells and Hontz *(unpublished)*.

APPENDIX A—TABLE 9

Influence of percentage of solids to liquid (cucumbers to brine) on bloater formation of cucumbers brined under controlled fermentation conditions in environmental growth chambers at 90°F with the 25° salometer brining treatment.[1]

Treatment	Brining information (55 gal drums)						Bloater data			
	Cucumber wts and % of total contents brined		Drum contents		Cover brine added and % of contents		Percentage and types of bloaters found in 50, no. 3 size salt-stock pickles cut; Chipper variety, 1.5-2.0 inches in diam.			
			Depth below the head	Total volume						
no.	*lbs*	*%*	*inches*	*gal*	*gal*	*%*	*% balloon*	*% lens*	*% h.c.*[2]	*% total*
IV	270	65	28	50	17.5	35	20	2	32	54
V	228	55	28	50	22.5	45	17	0	18	35
VI	187	45	28	50	27.5	55	10	0	9	19
VII[3]	270	65	28	50	17.5	35	59 & 50	24 & 28	11 & 12	94 & 90

[1]Specific information on the experimental procedure used, including the environmental growth chambers employed, and the 25° sal. brining treatment, may be found earlier in this report (items 1-10, under "Procedure for Bulk Fermentation Process," etc., etc.) as well as in the footnotes of TABLE 8. We again repeat that nitrogen purging *was not used* and the incubation temperature, 90°F, was maintained 24 hrs/day throughout the fermentation period of 7-10 days.

It will be noted that as the percentage of brine increased, the bloater content decreased under controlled, inoculated, buffered conditions. This bloater decrease, under very carefully controlled fermentation conditions, is attributed to the greater amount of brine for dissolving the CO_2 formed; likewise, more brine was available for CO_2 diffusion into the atmosphere.

It is of further interest to note that only 2 lens bloaters were found in the samples of brine-stock. Of more importance was the fact that as the percentage of brine increased, the balloon bloater content was about the same as the honeycomb-type bloaters found. In brief, bloater formation decreased as the percentage of brine increased from 35% to 55%. This would indeed be difficult to reproduce under natural conditions of brining, without the complete control mentioned earlier. Usually, in a loosely filled tank, lack of buffering action causes the brine pH to drop precipitously, inhibiting the lactic acid bacteria, thus allowing the yeasts to take over the residual brine sugars; usually resulting in bloater formation.

[2]See Table 8 for explanation.

[3]Data for natural controls for Tables 8 and 9. First figure shown under "Bloaters" refers to "90°F incubation;" second figure for "80°F." Balloon and lens bloaters were in the advanced condition for both incubation temperatures.

NOTE: This material was compiled from data from Etchells and Hontz *(unpublished)*.

APPENDIX B STATEMENT:

SUGGESTED NITROGEN PURGING SYSTEM USED FOR COMMERCIAL PICKLE TANKS ON AN EXPERIMENTAL BASIS

1. Based on smaller lots, we calculated that about 20-25 cubic feet/hour of nitrogen on a continuous purging basis should be used for a tank having dimensions of about 12 feet diameter and 7 feet 6 inches deep (approximately 6,000 gals).

2. A 1-1/4 inch manifold plastic pipe was run to the experimental tanks with take-offs provided at each tank to be purged.

3. Each tank also was provided with a valve to cut off the gas flow when not needed.

4. A 3/4 -inch plastic, flexible pipe was run down the inside wall of the tank to an "L" fitting. The pipe was then formed into a converging spiral on the bottom of the tank. The total 75 feet of pipe was held down with plastic straps secured with stainless steel nails. The end of the spiral pipe was plugged to force gas out the holes.

5. The spiral pipe was drilled with 14, 1/64-inch holes. The holes were spaced to develop the best possible wide-spread bubble coverage to purge the tank.

6. If the brine depth or tank diameter are different from the values given in Item no. 1 above, the approximate purging action achieved by the conditions stated in Item nos. 1-5 can be met by adjustment of the number of 1/64-inch holes in the 3/4-inch, plastic pipe and the manifold pressure as follows:
   (a) no. of 1/64-inch holes in the 3/4-inch tubing = 1/10 x diameter of tank in feet *squared*.
   (b) manifold pressure (psi) = 5 + 0.5 x depth of brine and cucumbers in feet.

7. A suggested schedule of four, one/hour/day intermittent nitrogen purgings of 100-125 cu ft /hour for the tank size and conditions described above for a 10-12-day fermentation period follows:

Fermentation time in days → → → →	0[1]	1	2	3	4	5	6	7	8	9	10-12[3]
Number of one-hour purges each day[2] (100-125 cu ft/ hr) → → → →	1-4	4	4	4	4	4	4	3	2	2	1-1

[1]Means after the initial brining operation; the time when the tank has been filled with cucumbers, headed out and covered with the desired brine strength and the calculated first addition of salt has been added. Thus, the first day means 24 hours after the initial time of brining with 1-hour purgings scheduled at each of four, six-hour intervals: 10:00 a.m., 4:00 p.m., 10:00 p.m., and 6:00 a.m. (= 8 hrs.). When purgings drop to 3/day, use a 10:00 a.m., 4:00 p.m. and 10:00 p.m. schedule; for 2/day, purge at 10:00 a.m. and 10:00 p.m.; and, for 1/day, purge at 10:00 a.m.

[2]Experienced briners know that during the periods of heavy intake of green stock, it is difficult, to say the least, to predict the time a given tank will be headed out and brined. For this reason, depending on the time it is headed out and brined, it should be purged as soon as practical (for 1 hour), and then, be sure that the next interval before purging does not exceed 6 hours (±2) until the tank can be put on the regular purging schedule given above.

[3]If, after 10-12 days of purging, or sooner (7-8 days), there is (a) no appreciable increase in brine acidity for two consecutive 1- to 2-day samplings; and (b), if the reducing sugars are 0.05% or less; and (c), if the CO_2 tests on the brine consistently show low values (20 mg/100 ml of brine or less for samples taken from the near bottom area of the tank), *then* the purging with nitrogen can be stopped.

APPENDIX C STATEMENT: SUGGESTED USE OF Q-BAT TABLETS FOR CONTROLLED FERMENTATION OF CUCUMBERS BRINED IN BULK

The bulk fermentation of brined cucumbers described herein is acidified at the outset with about 0.30% acetic acid (= 0.45% when calculated as lactic). When such fermentations have essentially completed their acid development of brine acid, the titratable acidity as lactic ranges from about 1.0% to 1.50%, depending on such factors such as: cucumber size, pack-out ratio, brine temperature, and brine-strength. Suggestions as to the number of Q-BAT tablets and amount of test brine needed to determine the final stages of the fermentation follow:

Number of Q-BAT tablets	Amount of test brine	Fermentation acid calculated as lactic only[1]	Total titratable brine acid calculated as lactic[2,3]
2	6 ml	0.55%	1.00%
2	5 ml	0.75%	1.20%
2	4 ml	1.05%	1.50%

[1]Values shown *do not* include initial addition of 0.30% acetic acid.

[2]Values shown include the initial 0.30% acetic acid addition, calculated as lactic acid (= 0.45%).

[3]A positive test will give a distinct yellow color; a near positive will be a yellow-orange color; and, a negative test will be shown by a red color.