

FACTORS INFLUENCING THE BRINING OF PICKLING CUCUMBERS— QUESTIONS AND ANSWERS¹

by
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Summary

The discussion presented herein —by use of the "question and answer" technique — is designed to give members of the pickle industry, suppliers, and other interested persons a clearer understanding of the natural fermentation of commercially brined cucumbers as the "state of the art" exists today. It has been our contention that meaningful control procedures could not be developed until the necessary basic information on the microbiological, chemical, physical, and enzymological changes taking place during fermentation was first collected and understood. Also, we have tried to give the industry and others a better appreciation of the

complexity of the natural brine fermentation, together with examples of some of the more important factors that can materially influence fermentation behavior and the quality of the resulting brine-stock. Finally, useful suggestions have been offered for those who may wish to revise their present brining procedures in order to control economic losses due to spoilage or deterioration of brine-stock pickles.

Moderator's Introductory Remarks

Moderator
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We are visiting today with Dr.
John L. Etchells here in Raleigh,

¹Paper number 3304 of the Journal Series of the North Carolina State University Agricultural Experiment Station, Raleigh, North Carolina 27607. The discussion material contained herein is based primarily on previously published work from the cooperative (NCSU-USDA-PPI) pickle research project, located at 322-A, Food Science Building, North Carolina State University.

CAUTION: The suggested procedures described herein relating to the overall brining operation should first be carefully considered in their entirety prior to any decision as to their use.



SCIENCE

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THINK PICKLES"**

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Moderator's Introductory Remarks

(Continued from cover)

North Carolina. He is in charge of the U.S. Food Fermentation Laboratory located in the Department of Food Science at North Carolina State University. Dr. Etchells is a joint employee of the U.S. Department of Agriculture and the University. He holds professorships in two departments: Food Science and Microbiology, and also is a member of the University's Graduate School Faculty. For more than thirty-five years he has studied both the fundamental and applied aspects of the pickling of many vegetables, and certain fruits such as olives, and is an acknowledged authority in his field. He has received many awards and honors and has been recognized by the pickling industry as a valuable source of information throughout a long and productive career.

For those interested in making themselves more familiar with pickling research, we suggest that they obtain a copy of the collected works of Dr. J. L. Etchells and his co-workers at the Food Fermentation Laboratory. These papers, which include more than 800 pages of printed scientific information published in various journals, have been collected into two volumes—by Pickle Packers International, Inc.—making it comparatively easy for an interested person to review the available literature on pickling from this laboratory. We are indeed indebted to this prolific researcher for the information he and his associates have contributed to the preservation of various fruits and vegetables by brining, salting, or pickling.

Pickling has been an art through the ages, and only with the introduction of the patented process on controlled fermentation have Dr. J. L. Etchells and co-workers suggested methods which can reduce this art to a science by following specific recommendations for making pickles in this new manner. Controlled fermentation offers remarkable advantages in reducing spoilage losses, improving product quality, introducing savings in handling, and in solving some knotty

and perplexing problems in handling waste materials, including spent salt brines.

It has become apparent that for many processors to understand controlled fermentation they must first have a better understanding of the art of pickling as it has been practiced throughout the ages.

We have had reports of extensive economic losses due to spoilage and deterioration of brine-stock pickles. Much of this could have been avoided by a better understanding of known information on the changes occurring in the brining tanks and by practicing more up-to-date brining procedures. An enormous amount of microbiological activity goes on in a typical tank of fermenting cucumbers. It has been estimated that as many as 2 billion microorganisms per 20 drops of brine (about 1 ml) are at work at the height of fermentation activity. This is not readily visible to the onlooker, except that the brine is cloudy. On the other hand, the pressure built up by a vigorous gaseous fermentation is well known to picklers. Most briners have seen 2x4's or 4x4's snapped and tank covers ripped loose. Also, they have all seen the hollow pickles known as "bloaters" which are the result of activity by gas-producing yeasts, gas-producing lactics, and other gas-forming microbes in the pickle brine.

We have asked Dr. Etchells to discuss more or less informally the "Art of Pickling" to help us better understand this interesting yet complex subject.¹

¹For those desiring background information on the natural fermentation of brined cucumbers, please refer to Appendix A. Additional information on pure culture pickles appears in Appendix B.

Etchells' Introductory Remarks

MODERATOR: Dr. Etchells, why have we not had more useful, reliable, and practical information about the brining of cucumbers presented in a step-by-step fashion?

ETCHELLS: Because the natural fermentation of brined vegetables, such as cucumbers (resulting from heterogeneous microbiological activ-

ity), is a very complex process with much variation between fermentations. There are no simple answers; and that is why this process has remained an "art" not a "science," at least so far as the natural fermentation of cucumbers brined in bulk is concerned. There are so many variables that enter into the picture that no one set of specific recommendations, covering all brining areas of the country, can be given. Anything that we discuss here has to be qualified. In talks to the industry, I have attempted from time to time to give an indication of the numerous variables or, if you wish, factors that enter into the pickling process.

But, I don't want to discourage you! By practicing certain known and acceptable brining procedures, and being as neat, clean, and as sanitary as practical, it is possible to control brine-stock losses due to enzymatic softening and to reduce bloater damage and thereby make very significant savings. For instance, we are aware of a large, long-established firm which, after revising its basic brining procedure, has recently been able to document savings in excess of \$150,000 over a three-year period. In contrast, we both know of operators that are still dry-salting their cucumbers, much like one would salt down herring in wooden pails. Also, we know of companies that are still using very strong cover-brines (45° salometer) plus dry salt to maintain this strong concentration from the start. Brining treatments such as these are hard on cucumber structure and favor shriveled, flat, brine-stock pickles; further, this deterioration is usually accompanied by a high percentage of bloaters, particularly in the larger sizes. Surely the examples cited are enough to interest picklers in better brining practices; particularly those who really want to improve the overall quality of their brine-stock.

I should mention that in early October, 1966, with the advent of what amounted to the first real fall cucumber crop in North Carolina, we did provide briners in the southeastern and southwestern areas of the country with step-by-step directions for brining this crop. By May, 1968, we found it necessary to revise the equilibrated cover-brine strength downward — from

25° salometer to 20°. This was because the fall brine temperatures were found to be lower than first anticipated. Even so, these directions have been used, with certain modifications, by briners in various sections of the country, reputedly with a good deal of success, for their regular summer harvest.

QUESTIONS DISCUSSED

Care of Tanks and Calculating Tank Capacity

MODERATOR: Thank you, Dr. Etchells. With that introduction you indicated that you will give us some information based on your practical experience, but qualified because of the variations caused by everything from geographical differences to size and variety of the cucumber used. Let us start with a study of the tanks, right from the time they are prepared for filling.

ETCHELLS: Let us assume then that we are starting with an empty tank. It should have been cared for properly during the time it was empty and should have been kept clean and sanitary because we are using it to make a basic product intended for human consumption. We should not allow algae, mosquito larvae, or other growths to accumulate in the water used to keep the tanks tight. The sanitary precautions and the good housekeeping rules recommended by the PPI, Inc., in their *Rules of Sanitation*, should be practiced, not just posted. Storage of empty tanks presents different problems in the North because of the more severe winter weather than in the South; here (North), of necessity the tanks are kept empty and with bungs out. In the South, assuming no sustained freezing temperatures, the tanks can be filled with water and hydrated lime added to keep them sweet and free of microbial and insect growth. They should be checked frequently to see that rainwater does not dilute the lime solution, thus permitting various microbial and insect growths to occur.

Each tank should be measured (metered is best), so that the volume in gallons will be known. The volume should be determined by filling the tank with water to a given mark. This mark should be

the final brine level above the tank head. The volume in gallons, and its equivalent weight in pounds (calculated as water), can be painted on the side of the tank; also, this information should be entered in the tank-yard record book. It is customary in calculating total tank volume to subtract approximately 1 in. of tank height for head-boards.

It is important to know the correct tank volume so that the solids-to-liquid ratio (in %) of the tank can be calculated on a weight basis. This detail alone is overlooked in many cases, and it results in a condition that can cause much difficulty or even failure in carrying out a given brining procedure correctly. Whereas most operators keep a record of the weight of green-stock going into a tank, they rarely know how much brine is added. Now, if they have the volume of the tanks correctly calibrated in pounds or gallons to a given point above the head, they will always be in a position to calculate the brine-to-solids ratio, provided they have either of two figures; namely, (1) the total weight of cucumbers put in the tank or (2) the total volume of brine added—including the cushion and that poured over the head-boards.

Role of Salt in Pickling

MODERATOR: What really is the role of salt in the pickling of cucumbers?

ETCHELLS: Salt is used to restrict or hold down the high populations of undesirable, competitive microorganisms present naturally on the cucumbers, so that the significantly lower populations of salt-tolerant lactic acid bacteria can properly develop in the brine. Numerically, the lactic acid bacteria are almost the lowest in population on the green cucumbers, as compared to many other naturally occurring organisms. Fortunately, the lactics are moderately salt-tolerant, rather acid-tolerant, and are able to develop rapidly in the cucumber brine under conditions of rather low oxygen tension (=they are microaerophilic microbes). These important properties help them in their struggle to gain ascendancy over competitive groups in the fermentation proper. Salt also helps these hard-working, highly desirable

friends of pickle briners because their food, the soluble materials from the cucumbers, diffuses into the brine as the result of the action of the salt on the cucumber tissue. This is a rather brief, basic statement on the role of salt. However, its selective action on the naturally occurring microbes and its preservative effect, based on the combined action of the sodium chloride and the developed acidity, are probably the most important functions of this long-used chemical in the brine preservation process for foods.

The naturally occurring lactic acid fermentation of cucumbers is greatly influenced by both the equilibrated starting brine strength used and by the rate at which it is increased. Although we said earlier that the lactic acid bacteria were moderately salt-tolerant, there is a direct relationship between the numbers of these organisms that develop during fermentation and the brine strength used. Of course, their orderly restricted development, by the use of increasing salt concentrations, will be reflected in correspondingly decreasing amounts of brine acid being formed, and at slower rates.

For example, the use of lower equilibrated brine strengths—such as 20 to 30° salometer (5.3 and 7.9% salt by wt)—favor a more rapid development of brine acidity than do brine strengths somewhat above 30° salometer, say 35 to 45° salometer (9.2 and 11.9% salt by wt). Further, the use of slower rates of increasing the equilibrated brine strength (by the addition of dry salt on the head-boards)—within the salt-tolerance range for good growth by the lactic acid bacteria—favor the development of higher final levels of brine acidity, lower brine pH's, and a more desirable use of the fermentable cucumber sugars. Conversely, faster rates of raising the brine strength result in lower final acidities and higher brine pH's.

The use of equilibrated brine strengths of 50° salometer (13.3% salt) and higher would rather effectively inhibit the growth of the naturally occurring lactic acid bacteria; and as a consequence, significant amounts of brine acid would not be produced.

Effect of Washing Cucumbers

MODERATOR: What is the effect of a "washing" treatment for cucumbers that are to be brined?

ETCHELLS: In order to answer that question, you really should define what you mean by washing! Because, as I just said, the lactic acid-producing microbes are one of the smallest groups numerically among the total population of organisms present on the cucumber. If one really scrubs, washes, and rinses, it is possible to so reduce the numbers of naturally occurring lactic acid-forming bacteria to the extent that they cannot grow sufficiently to predominate in competition with the other organisms. Washing to get rid of pieces of adhered dirt and to flush away excessive debris is certainly in order. Fluming cucumbers to tanks in a salt brine probably just helps emulsify the microflora and more or less coat the pickles with various microbial groups, including the lactic acid-formers. This is assuming that the fluming process does not flush away the fluming brine and replace it with a wholly new brine. The wetting, washing action that green pickles get when 10,000 to 50,000 lb bulk truck loads are first dumped in water pits and later sprayed at the vibrating grader complex should alert the operator to keep in mind the above discussion.

MODERATOR: Your "washing" reply sounds interesting, but rather technical and, perhaps, a little on the theoretical side. Don't you have a first-hand experience with the brining of washed stock that would strike a responsive cord with card-carrying briners?

ETCHELLS: You asked about washed cucumbers "that are to be brined" not that "are brined." You want an example? Well, here it is. We washed 40-bushel lots of No. 1B size stock (1 to 1½" diameter) thoroughly in a Brüser, brush type rotary washer, rinsed them twice, and brined them according to regular plant practice. This was done at five intervals during the harvest season and at two cooperating pickle plants located 1,200 miles apart. We were able to record up to 22% bloaters in cured brine-stock made from washed cucumbers brined at certain of the harvest

intervals. Unwashed, control lots were free of bloaters for all harvest intervals in both brining areas (Etchells, Bell, Klumb, Breeland, and Griffith, unpublished data).

Role of Temperature

MODERATOR: What is the role of temperature in these fermentations?

ETCHELLS: It is one of the more important of the many influencing factors entering into the cucumber fermentation. Also, it is one of the main reasons why no one brining treatment can be offered for the different geographical brining areas of the country. However, in general, a rule-of-thumb to be remembered is that lower brining strengths should be used in areas where cooler brine temperatures prevail. When we are talking about brine temperatures we are referring to temperatures at the approximate center of the tank. You realize, of course, that the temperature can vary depending on where the thermometer is placed, or the area of the tank from where the brine sample is removed, and checked for temperature; for instance, at the top, bottom, center, or near the side of the tank. Tight sample boxes, without provisions for free movement of brine within, are apt to provide samples that will give erroneous results as to chemical, microbial, and physical (temperature) changes taking place in the brine proper. This is particularly true for samples from the top area of such sample boxes.

The growth rate of lactic acid bacteria, and their resultant acid production, increase in brined cucumber fermentations as the brine temperature increases, up to the optimum of about 90°F. Assume for instance you had cucumbers under controlled pure culture conditions at 20° salometer kept at a uniform brine temperature of 70°F, as opposed to 90°F. It would take about 3 weeks to ferment to the maximal acid level at the lower temperature, but only about 5 days at the 90°F temperature.

Pack-Out Ratio and Buffering Action

MODERATOR: What is the role of the pack-out ratio, or the

percentage of solids to liquid you referred to earlier?

ETCHELLS: The pack-out ratio is important because it influences the buffering action that takes place in the fermentation. Don't let that word "buffering" bother you; I will try to explain that in a minute. To get started with an example, consider a given acid fermentation using only No. 1 size cucumbers with a pack-out ratio in the tank of 65% solids (=cucumbers) to 35% liquid (=brine, calculated as water at 8.34 lb/gal) by weight. Here, we would expect the acid fermentation to proceed to completion with the sugar being utilized completely by the lactics, because the brine pH will not have reached the limiting level for growth of the lactic acid bacteria. This is due to buffering action of the small cucumbers. Buffering action means the brine pH does not drop as rapidly or as far as in a less buffered or a nonbuffered system. In short, buffering compounds offer resistance to pH change without affecting the titratable acidity. A key figure to remember is that the lactic acid fermentation will continue until a pH of close to 3.15 is reached; this pH level will usually stop further growth of the lactic acid-forming bacteria. The amount of brine-acid required to reach this pH level will depend on several factors, such as: (1) the brine-sugar content available for fermentation, (2) the solids-to-liquid pack-out ratio of the contents of the tank, and (3) the buffering capacity of the cucumber size being used. Further, these three factors are interrelated.

Now consider filling a tank with large-sized cucumbers, say No. 3's (1½ to 2" diameter). Here it is harder to obtain the desired 65% solids to 35% liquid ratio. A looser fill will contribute to a situation where the 3.15 pH cutoff level is reached quicker and, thus, smaller amounts of brine acid will be produced, even though all of the brine-sugar is not used by the lactic acid bacteria. Now, let us assume the proper fill is obtained (65:35%) with No. 3's; the lesser buffering capacity of the large-sized stock would still result in a residual brine-sugar content of around 0.35% even after the lactic acid fermentation has practically stopped.

We have researched this matter and found that the size of stock in a tank can materially influence the equilibrated brine pH, although the brine acidity shows no appreciable change (Etchells, Bell, and Fleming, *unpublished data*). We can illustrate this by using a constant brine strength, a constant amount of added acetic acid, a constant container size, and a constant amount of stock, *but*, with two different size ranges of freshly brined green cucumbers, all of the same variety (see Table 1, Appendix C). The equilibrated acidities for the same acid additions are essentially the same for both sizes of cucumber stock packed. However, the higher equilibrated pH's of the smaller sized stock reflect a much greater buffering capacity than the larger stock. This is probably due chiefly to the greater nitrogenous content of smaller cucumbers. As to fermentation behavior, the brine sugars were completely fermented from all acidification treatments of the small-sized stock by *L. plantarum* (at 90°F) in four to six days. However, in the less buffered fermentations of the acidified, large-sized cucumbers, there was 0.20 to 0.30% brine-sugar left in most treatments even after 21 days.

Thus, the lactic acid fermentation behavior, particularly with respect to the rapid and complete utilization of the naturally occurring fermentable vegetable sugars, will be greatly influenced by the buffering capacity of the packed material. This relationship, described above, is related to "in container" pure culture fermentations such as dill pickles; however, the same basic relationship is equally important in the inoculated, or naturally fermented bulk fermentation of cucumbers (and other vegetables) for brine-stock purposes.

Let me repeat then; in the larger sizes — say No. 3's or 4's — even with the desired 65 to 35% by weight pack-out ratio in the salting tank, the 3.15 pH is usually reached, and the lactic acid fermentation is normally over, before all the sugars in these larger cucumbers are used up. Generally, from 0.20 to 0.40% brine-sugar remains, and this is usually used by fermentative yeasts or other gas-forming organisms. This is why we have been asking the plant breeders to try to

select or breed cucumber varieties that will have just about one-half the sugar content of present ones.

I can see that you and the briners are thinking, "Well, it doesn't seem to matter what you do to brine the No. 3's (or larger), you just can't win!" Mr. Moderator, sir, that's just about right, but it provides added impetus for pushing ahead with the controlled fermentation of cucumbers brined in bulk that will be properly buffered and inoculated with cultures of high-performance lactic acid bacteria.

Getting the Desired Pack-Out Ratio

MODERATOR: How does one get the desired pack-out ratio when filling tanks with large-sized cucumbers?

ETCHELLS: I doubt seriously, Mr. Moderator, if the average brine-yard foreman thinks in terms of pack-out ratios when it comes to filling his tanks. In most cases, an experienced briner usually knows from years spent on the brining platform what his different sized tanks will hold in terms of bushels of cucumbers of different sizes. These figures are frequently recorded in his tank record book. Also, most briners have a pretty good idea of the capacity of their tanks in gallons and sometimes these figures are painted on the tank. Also, he may estimate tank capacity in bushels up to the head by dividing total gallons to that point by 8 (=estimate of volume in gallons occupied by a 50 lb bushel of cucumbers). Tank capacities in gallons can be readily obtained from prepared tables on *Cylindrical Tank Dimensions and Capacities*. But, as most experienced briners will tell you, their tanks often are not really cylindrical; they taper, they may be slightly oval and more or less out of round. Then, too, the stave lengths are not always as first thought to be. Generally, stave length does not necessarily refer to the usable inside depth, but rather to the given length as measured from the outside of the tank. Now, let us assume the operator has the correct volume of a given tank in gallons. He will first have to subtract about 12 in. of usable tank capacity to provide: (1) for the

wooden "false-head," and the 2x4's or 4x4's required to key the head-boards down securely; but, more important, (2) most of the space must be allowed for 4 to 6 in. of brine which will be added over the head. Also, he doesn't want to bring the brine level too close to the top of the tank because he may have to add about a half-ton or more of salt on the head to maintain the initial cover-brine strength. This amount of salt will require considerable space both in the solid and dissolved state. Thus, he must be careful to avoid running salt brine over the top of the tank staves and thereby contribute to the already acute saline waste-disposal problem.

Let us further assume that our briner now has his tank filled properly and has 500 bu (25,000 lb) of small No. 3's, all correctly headed down with brine added just up to the head-boards (1,098 gal). Calculated on a weight basis, our man at this point has about 73% cucumbers and 27% brine. Now, he adds 6 in. of brine above the head; this takes 392 gallons. This amount of brine added over the head, on a weight basis, is equal to about 26% of the total cover-brine in the tank and 8.7% of the total contents of the tank! Further, now the final solids-to-liquid ratio of the tank is 67:33% by wt.

This example has been given in some detail to emphasize the fact that the amount of cover-brine used, particularly that portion above the head, can be a most important factor in determining the ratio of solids-to-brine in a tank of brined pickles. The figures cited in the above example were based on the average of two 500 bu lots of cucumbers brined by this researcher and W. G. Griffith, when he was plant manager at Lutz and Schramm, Ayden, North Carolina; he is now affiliated with the Philadelphia plant of Vlasic Food Products, Lathrup Village, Michigan.

I am sorry, Mr. Moderator, that I have digressed somewhat from your original question on "how one gets the desired pack-out ratio with large-sized stock." However, it seemed necessary to point out that the term "pack-out ratio" is probably much better known in the pickle plant by those persons re-

sponsible for packing filled pickle products in, rather than by the brine-yard people. Also, it seemed important to emphasize certain of the items in the actual brining operation that can influence the solids-to-brine ratio.

Returning to your question; really, obtaining what we consider a desirable cucumber-to-brine pack-out ratio (65:35%/wt) is rather difficult to do with the large-sized stock—being brined at the rate of intake today—without some sort of a pre-shrinking treatment or back-filling of the tank. Further, one does not want to shrivel the stock noticeably in the process. In cases where the green-stock is flumed to the tanks in brine, the cucumbers tend to get a pre-shrinking treatment not only en route 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 mass to the bottom of the tank where the brine return hose is located.

Now, in other cases, a portion of the dry salt required to maintain the equilibrated brine strength is scattered over the cucumbers during the actual filling operation; this usually amounts to about 1 to 1½ lb of salt per 50 lb bushel of cucumbers (2 to 3 lb/cwt). This, of course, tends to shrink the stock noticeably during the filling and settling periods.

In still other cases, the operator fills a tank, allows it to settle only a short time, heads it out, and adds the cover-brine and dry salt on the head to maintain the desired, equilibrated brine strength. He then may refill the tank once or twice later to get what he considers the "desired" tank capacity. Usually, he figures on getting about 70% of his "desired" capacity by a rapid fill at the outset; 20% or more on the first refill three days later, and 10% on the second refill, after about the sixth day. Of course, all this means extra labor in draining off brine and adding cucumbers and in unheading and reheading tanks. Just what this method of refilling accomplishes in terms of pack-out ratio of cucumbers to brine on a percentage basis, either as to weight or volume, has not been reported to my knowledge either in print or conversation. My

could be that these tanks, especially those filled with No. 3 or larger, would be undesirably overpacked. As mentioned earlier, it would seem to be a better practice to know what you actually have in a tank on a weight basis as to cucumbers and brine (65:35%).

Calculating Salt and Draining Tanks

MODERATOR: How does one calculate the correct amount of salt to add to maintain, say, a 20° salometer cover-brine that has just been added to a headed-out tank containing 500 bu of cucumbers?

ETCHELLS: First, you must know the total cucumber weight or number of 50 lb bushels. Then, for every hundredweight (cwt=2 bu) of green-stock add 3 lb of dry salt on the "false" head of the tank. Next, the following day (after about 24 hr), add 2 more pounds of salt per 100 lb of cucumbers in the tank (=total of 5 lb salt/cwt of cucumbers). Thus, for 500 bu of cucumbers (=250 cwt) in the tank, a total weight of 1,250 lb of salt will be needed; of this amount, 750 lb are added on the head at time of brining and the remaining 500 lb are added the following day.

Small-sized stock (up through 2A size, or up to 1¼" diameter) brined in production areas of the southeastern and southwestern USA should, of course, be drained. The same applies to larger sizes that show even slight evidence of mold or disease. The original cover-brine should be drained off 36 to 48 hr after heading and brining the tanks; it is promptly replaced with a new cover-brine of the same strength.

Some southern operators prefer to use a different procedure for draining small-sized stock. Here, a 55-60° salometer cover-brine is used. This concentration drops to about 18 to 20° salometer by the time of draining—36 to 48 hr after heading the tank. A new cover-brine of 25° salometer is used to replace that drained off. The equilibrated brine strength then should be close to the 20° salometer strength. If a 25° salometer equilibrated brine is desired, then the drained brine should be replaced with a 30° salometer brine.

When the brine is drained off a

tank of No. 1's, the stock settles and, of course, the head-boards drop. Some briners use this opportunity to refill the tank with *undrained*, green-stock. This is a handy way to get the proper tank-fill, but the practice has an obvious, built-in risk, because the added, undrained stock could contribute softening enzymes to a system that has just received a treatment (draining) designed to control softening. Even so, the years of experience of operators following this refill practice indicate that the amount of stock added (about 10% of the tank's capacity) is not enough to cause any appreciable texture loss in the cured brine-stock.

Maintaining a 25° Salometer Cover-Brine

MODERATOR: Can you give me another example of an equilibrated brining treatment—say, a 25° salometer?

ETCHELLS: For maintaining a cover-brine strength of a 25° salometer treatment, a total of about 6½ lb of salt per cwt (=two 50 lb bushels) of cucumbers in the tank will be required on the "false" head; of this amount 4 lb are added at the time of brining and the remaining 2½ lb the next day. Thus, for a 500 bu tank of 50 lb per bushel of cucumbers, a total of 1,550 lb of dry salt will be required to maintain the 25° salometer cover-brine. Of this amount, 1,000 lb are added on the head of the tank at the time of brining and the remainder, 550 lb, the next day.

Increasing the Initial Brine Strength

MODERATOR: Are the equilibrated cover-brines in the two examples—20° and 25° salometer—ever increased during fermentation?

ETCHELLS: As mentioned earlier, we suggest that the initial, equilibrated brine strength be maintained until the brine acidity reaches about 0.60% calculated as lactic acid. Then the brine strength is gradually raised at the rate of about 3 to 5° salometer per week, depending on the geographical area, to the usual holding concentration practiced by the company. About ¾ to ½ lb of salt is required for

every 100 lb (cwt) of cucumbers in the tank to raise the brine 1° salometer (= 0.26% salt/wt). Figured on the basis of a 50 lb bushel of cucumbers, this would amount to about ¼ lb of salt. These calculations are based on a ratio of cucumbers-to-brine of 65:35% by weight.

Brining No. 1's Separately

MODERATOR: Are No. 1 size cucumbers brined separately?

ETCHELLS: In the South, they are usually brined separately or combined with size 2A's. This is because these sizes are normally drained 36 to 48 hr after brining to control enzymatic softening. We also have several operators who brine the various sizes separately and not only drain the No. 1's but No. 2's, 3's, and 4's as well (=stock ⅝" through 2⅞" diameter). They report improved firmness of the larger sizes as the result of the draining technique.

Brining to Size

MODERATOR: Is there an advantage in the practice of brining to size?

ETCHELLS: That depends on the operation and if, as mentioned earlier, the small sizes are drained. It seems to me rather expensive to receive graded stock, then mix it back to field-run sizes in the brining tank, and then again resort it as brine-stock. There is some value in brining field-run stock from a fermentation standpoint; however, it is doubtful if any advantage so gained today would not be offset by increased handling and grading costs. Even so, I don't intend to discuss this matter further here.

Problems in Brining No. 3's

MODERATOR: What are the particular problems of brining No. 3 size stock and larger?

ETCHELLS: Today, the large-sized stock is the most difficult to brine because of bloater damage. With the increased use of sliced pickles, such as hamburger dills, operators don't want cavities in the brine-stock. We simply don't have a brining treatment for No. 3's that will, day in and day out, preclude bloating. As I said at the outset, if we had foolproof brining treatment

for all sizes of all varieties, and for all products, all brining areas of the country, we could stop the pure culture fermentation research for cucumbers brined in bulk!

Best Brining Practice?

MODERATOR: In the absence of a foolproof brining procedure, what is the best practice?

ETCHELLS: Although we have discussed brining of cucumbers, and given examples of figuring amount of dry salt to add to maintain a given cover-brine strength, I don't believe it is possible for me, in a discussion of this kind, to spell out step-by-step directions, tabulations, and qualifications necessary for a meaningful presentation of a procedure for brining large-sized stock in different brining areas of the country. You are thinking, "Well, he just doesn't want to do it"; or, "He really can't do it—even after all those 34 years of experience." Perhaps this is true. However, let me say that we are now in the process of expanding the basic concept of our *Procedure for Brining Fall Crop Cucumbers*. . . . Here, the equilibrated brine temperature (=temperature of the brine-cucumber mass after the cucumbers and the cover-brine have come to equilibrium) will be the determining factor that will dictate what the actual brining procedure will be.

Tables are being prepared that will permit the brining operator to predict, in advance and within acceptable limits, what the equilibrated brine temperature should be, *providing* he has obtained reasonably accurate temperature readings of the green-stock to be brined and of the cover-brine to be added. Armed with this information, other tabulations will help him select a given brining treatment, including the cover-brine strength to use and the amount of dry salt to add on the cover to maintain the initial strength selected. Also, he will be informed on how to increase the initial brine strength gradually *after* about one-half of the usually expected brine acidity (calculated as lactic) has been developed. Further, he will be provided with a simple test that will tell him in about three minutes, right at tank-side, whether a given fermentation has reached the desired acidity level.

This test, called "Q-bat" (=quick brine acidity test), is now undergoing evaluation under commercial conditions by members of the PPI, Inc., Research Committee, headed by L. J. Turney (H. W. Madison Company, Division of J. M. Smucker Company, Medina, Ohio).

Realizing that the average pickle plant doesn't pipe brine of several different strengths around the brining area, we have prepared tabulated information on how to obtain several different equilibrated brine strengths using either a 25 or a 30° salometer cover-brine. Accompanying this information will be the required amounts of dry salt to put on the tank head to maintain the desired equilibrated brine concentration. For people in cooler or colder climates, we have revised our original *Fall Brining* table on the heating of cover-brines (before adding to cucumbers) so that equilibrated cucumber-brine mass temperatures of 80, 85, and 90°F can be obtained. This will be of added importance when the pure culture process for cucumbers brined in bulk leaves its present experimental stage. Thus, Mr. Moderator, I hope you can see, after all of this, why a step-by-step brining procedure could not be presented in a narrative style here!

Repeat Question on Pack-Out

MODERATOR: Is the pack-out ratio the reason for fermentation problems in the larger cucumber sizes?

ETCHELLS: No! Not really; I believe we discussed this earlier under the "buffering action" of different sizes of brined green-stock. Actually, the *lack of buffering capacity* is the major reason for difficulty in brining the larger sizes.

Time-Lapse Between Harvest and Brining

MODERATOR: I'm sorry; I recall that discussion now. Let me ask then, how important is the time-lapse between picking and brining?

ETCHELLS: Extremely important. It is vital for several reasons to get the freshly picked cucumbers into brine as quickly as possible. I'm sure you realize that at 80°F or warmer, with high humidity,

mold growth can be luxurious in just a few hours. Stock that waits in trucks, or on unloading docks, or that is left piled up in tanks without cover-brine is just deteriorating as to quality. All kinds of microbial growth may occur, and this is to be avoided. Also, if green-stock is allowed to dessicate to the point that it becomes wrinkled, usually at the stem end, the brine-stock pickles or whole, fresh-pack dills made from such stock may never recover from this condition. From cucumber storage studies now being prepared for publication, we observed an average weight-loss per day for No. 1B size cucumbers of about 10% when stored at 80°F with a relative humidity range of 80 to 85% (Etchells, Costilow, and Bell, unpublished data).

A Set Schedule for Increasing the Brine Strength

MODERATOR: We have heard of people who are using brining schedules which refer to increasing the original equilibrated cover-brine strength according to the day of the week.

ETCHELLS: That is not a good practice. If, from the start, one raises the equilibrated cover-brine strength because of the day of the week, or according to some other inflexible schedule, he could actually foster bloater formation. How? Well, during a cool spell, he could raise the salt concentration beyond the active growth range of the lactic acid bacteria and stop or retard their activity and thus leave more residual brine-sugar for gas-forming microbes, such as yeasts. Better, one should not start to add dry salt regularly until about one-half the amount of the usual expected brine acidity for their area and brining procedure has been developed.

Care of Tank-Yard

MODERATOR: How much attention should be given the tank-yard?

ETCHELLS: All tanks should be checked on a daily basis. Some of the serious trouble operators experience is that they walk away after an exhausting green-intake season and neglect the tank-yard, particularly the carry-over stock. Just plain negligence, such as not

adding salt to compensate for dilution of the brine by rainwater, can cause a great deal of deterioration and spoilage; not to mention serious insect larvae infestations. The PPI, Inc., *Sanitation Code* for brining stations should be conspicuously posted, read, understood, and followed. For those wishing suggestions for a *Tank Salting Report Card* or a *Tank Analysis Report Card* in order to keep meaningful records of their brining activities, we will be glad to send copies of various versions of such record cards we consider to be useful.

Dry-Salting Cucumbers

MODERATOR: What about dry-salting cucumbers; we understand this method is being practiced?

ETCHELLS: This method has long since fallen into disuse by the industry in general, primarily because of the severe shriveling, desiccating action of the dry salt on the cucumbers, particularly the larger sizes. We don't recommend it, period! You must remember, the pickle people buy their green cucumbers on a weight basis, but sell most of their brine-cured pickle items on a volume basis. Thus, in the basic brining process, it is important to retain as much of the original cucumber volume as possible. You cannot depend on the desalting treatment (=processing) to plump up shriveled, wrinkled salt-stock resulting from poor brining practices.

Use of Different Kinds of Salt

MODERATOR: That leads us to the question as to the desirability of different types or kinds of salt for brining, such as granulated, rock, and solar salt.

ETCHELLS: As near as I recall the results from cooperative studies with Dr. A. F. Borg (now with the National Science Foundation, Washington, D.C.), there was no particular difference found between solar, granulated, or rock salt intended for use in natural cucumber fermentations. Solar salt that had been kiln-dried would be preferred over nondried solar. As a rule, raw solar salt has not been recommended for use in finished pickle products. More technical information is available for those who want to study

the results of the microbiological and chemical tests made by Dr. A. F. Borg et al.

Heating the Cover-Brine

MODERATOR: If the brine temperature is "coolish"—let us say 60°F or below—would you go so far as to recommend warming the brine?

ETCHELLS: Yes; providing the cucumbers are also in about the same temperature range as the brine. Knowing the temperature of the cucumbers, then the correct temperature to heat the cover-brine—prior to being added—can be readily determined so as to obtain temperatures in the desired range for the equilibrated brine-cucumber mass. The tabulated information we have compiled covering temperature adjustment of brined material will be of particular importance in the process for controlled fermentation of cucumbers brined in bulk, using pure culture starters.

Pumping or Circulating Tanks During Fermentation

MODERATOR: I believe some operators pump and circulate the brine in their tanks. Under what conditions is this recommended, or is it recommended?

ETCHELLS: Gentle pumping with proper equipment is advisable to see that the brine strength in a tank is reasonably uniform. This avoids layering, particularly in the lower regions of the tank where salt may have fallen through. Please remember, though, that the lactic acid bacteria are "microaerophilic"; meaning they tolerate only very, very small amounts of oxygen. Thus, they don't really enjoy air being whipped into the brine by overzealous pumpers, circulators, or aerators! In contrast, the undesirable, gas-forming, brine yeasts will greatly increase their numbers in an aerated brine. They are "facultative" as to their oxygen demands. This term means simply that the fermentative species of yeasts have the power to exist under a wide range of conditions with respect to the oxygen content of the brine.

It must be emphasized that the choice of pumps to be used for circulation of the brine must be made with care. Those that "whip" or incorporate air into the brine

are to be avoided. As mentioned earlier, gentle circulation of brine is advisable for the reasons given. Also, this practice, properly done, may have other beneficial effects—such as reducing the dissolved gas content of fermenting brine. More specific information on this research area will be presented at a later date.

Starting "Slow" Tanks

MODERATOR: How does one go about inoculating a tank of brined cucumbers considered to be a "slow starter?" Couldn't you use brine from a tank that has already started to ferment? Is this a recommended practice?

ETCHELLS: No, it certainly is not a recommended practice; at least as far as we are concerned. One had better not try to be an amateur microbe hunter! Unless you know what is being transferred as a "starter," you might better leave it to nature. So-called "slow starter" tanks are not as bad as one being inoculated with a "fast starter" yeast fermentation or equally destructive gas-forming lactic fermentation. Hold off on the brine inoculation business until the pure culture process for brining in bulk becomes a reality.

Mechanical Control of Bloaters

MODERATOR: I would like to ask you research people have ever considered the control of "bloaters" (hollow pickles) by mechanical means, such as pricking or piercing the green cucumbers prior to brining.

ETCHELLS: I think it is pretty well known in the over-nite, Kosher dill pickle trade that piercing the green-stock will rather effectively control balloon type bloaters. We worked with several of these prickers in the New York City area several years ago and learned that piercing (10-15 pierces per large cucumber) with a German-made "steck" (stick) machine would do the job. After all, the over-nite dill packer does not have any use for bloated (hollow) pickles. Later, at a pickling plant in eastern North Carolina, we applied the same type of piercing machine to large-sized Model variety cucumbers (1½ to 2" diameter) brined in 25 bu amounts at 35° salometer and maintained at that strength for one

week, then raised 5° salometer/week. The results of this study (Etchells, Borg, Bell, and Griffith, *unpublished data*) involving four pierced and eight control lots demonstrated that piercing practically eliminated balloon type bloaters in the cured brine-stock (24% vs 1%) and also effectively reduced the number and size of lens type bloaters.

A concurrent study included pricking large-sized cucumbers (1½ to 2" diameter) with a machine consisting of a hopper and three descending baffles fitted with needles extending out about ¾" and spaced in squares ½" apart. All baffles vibrated during the operation. The machine had a capacity of about 150 bu/hr. The results of a two-season study involving twenty-four 25 bu tanks (brined at 30° salometer, raised 5° salometer/wk) are shown in Table 2, Appendix C.

It is apparent that the pricking treatment was probably not quite so effective as complete piercing in bloater control. But, even so, pricking probably could be more readily adapted to a high-speed operation than piercing. However, the operator must be fully aware of all the facts on the brining of pierced or pricked green-stock. In order to ensure control of enzymatic softening, the stock *must* receive the draining treatment or receive an efficient washing treatment, or both, prior to brining. Of course, no softening trouble would be expected from clean, freshly harvested No. 3 size stock, but today, in the era of automated harvest and bulk handling with long-distance hauling, one does not really know the true age of the cucumbers being received, and it is not possible visually to tell whether or not they have mold growth. Considerable mold growth plus softening enzyme activity can be present on or in the cucumber, but it is not noticeable to the naked eye.

Absorption of Salt by Cucumbers

MODERATOR: I don't recall your explaining why you suggest putting only two-thirds to three-fourths of the required amount of dry salt on the "false" head at the time the tanks are brined and then add the balance about 24 hours later?

ETCHELLS: This suggestion was primarily directed to brining of the large-sized cucumbers, such as No. 2B's, 3's, and 4's. The reason is rather simple. There is no need to add more salt than the stock can absorb in a given time period; it only results in higher initial brine strengths than desired. I'm sure that experienced briners are well aware of the difference in equilibration time of, say, 3,000 count (=number per 45 gal cask) cucumbers compared with, say, 800 count. They also are aware that less time is required as the brine temperature increases due to warmer weather conditions. There is no need to pile on the dry salt to run the initial brine strength up 5 to 10° salometer higher than originally desired at the outset, as this will just slow down the onset of the lactic acid fermentation, and may let undesirable gas-forming microbes get the upper hand.

For those who may want a little better idea of the salt absorption of different sized cucumbers, I have prepared tabulated information (Table 3, Appendix C) based on data from a publication by the late, distinguished professor of microbiology at Michigan State University, Dr. F. W. Fabian, and his graduate student, R. C. Fulde, entitled "Rate of Salt Penetration into Pickles Charted, Size by Size" (see Selected References for complete citation).

Variables: Discussed and Not Discussed

MODERATOR: We have touched on a few main variables and we can see the important roles they play in fermenting pickles. We have talked about the influence of salt, microflora, temperature, buffering action, brine acid, brine pH, washing of green-stock, brine circulation, and pack-out ratios. What other variables enter the picture?

ETCHELLS: Remember, there are still the differences attributed to cucumber variety, cucumber size, within-season and between-season variation, container size and configuration, and, probably, several other variables we have failed to mention. Many of the common variables will be eliminated by the pure culture process; this will permit control of the bulk fermentation of brined cucumbers.

SELECTED REFERENCES

General

PROGRESS IN PICKLE RESEARCH

Etchells, J. L., and Jones, I. D.

Glass Packer 30 (4): 264-65, 298, 300, 302; 30 (5): 358-60, 372, 376, 378, 380. 1951

ADVANCES IN CUCUMBER PICKLING

Etchells, J. L., Jones, I. D., and Bell, T. A.

Yearbook of Agr. (U.S. Dept. Agr.) 1950-51, 229-36
(Yearbook Separate No. 2195)

NOTES ON CUCUMBER SALTING

Veldhuis, M. K., Etchells, J. L., Jones, I. D., and Veerhoff, Otto

Fruit Prod. J. 20 (11): 341-42. 1941

Methods

A METHOD FOR TESTING CUCUMBER SALT-STOCK BRINE FOR SOFTENING ACTIVITY

Bell, T. A., Etchells, J. L., and Jones, I. D.

U.S. Dept. Agr. ARS-72-5, 15 pp. 1955

METHODS OF EXAMINATION OF FRESH CUCUMBER PICKLE

Etchells, J. L., and Goresline, H. E.

Fruit Prod. J. 19 (11): 331-35. 1940

PROCEDURE FOR BACTERIOLOGICAL EXAMINATION OF BRINED, SALTED, AND PICKLED VEGETABLES AND VEGETABLE PRODUCTS

Etchells, J. L., and Jones, I. D.

Am. J. Public Health 36: 1112-23. 1946

Bacteriological Studies—General

THE INFLUENCE OF SORBIC ACID ON THE GROWTH OF CERTAIN SPECIES OF BACTERIA, YEASTS, AND FILAMENTOUS FUNGI

Bell, T. A., Etchells, J. L., and Borg, A. F.

J. Bacteriol. 77: 573-80. 1959

INFLUENCE OF GAMMA RADIATION ON THE MICROFLORA OF CUCUMBER FRUIT AND BLOSSOMS

Etchells, J. L., Costilow, R. N., Bell, T. A., and Rutherford, H. A.

Appl. Microbiol. 9: 145-49. 1961

BACTERIOLOGICAL CHANGES IN CUCUMBER FERMENTATION

Etchells, J. L., and Jones, I. D.

Food Inds. 15 (2): 54-6. 1943

BACTERIOLOGICAL CHANGES DURING THE FERMENTATION OF CERTAIN BRINED AND SALTED VEGETABLES

Etchells, J. L., Jones, I. D., and Lewis, W. M.

U.S. Dept. Agr. Tech. Bull. No. 947, 64 pp. (October) 1947

FILAMENTOUS FUNGI FROM BLOSSOMS, OVARIES, AND FRUIT OF PICKLING CUCUMBERS

Raymond, F. L., Etchells, J. L., Bell, T. A., and Masley, P. M.

Mycologia 51: 492-511. 1960

Bacteriological Studies—on Yeasts

SUGAR AND ACID TOLERANCE OF SPOILAGE YEASTS FROM SWEET CUCUMBER PICKLES

Bell, T. A., and Etchells, J. L.

Food Technol. 6: 468-72. 1952

CLASSIFICATION OF YEASTS FROM THE FERMENTATION OF COMMERCIALY BRINED CUCUMBERS

Etchells, J. L., and Bell, T. A.

Farlowia 4: 87-112. 1950

(Continued on next page)

MORPHOLOGY AND PIGMENTATION OF CERTAIN YEASTS FROM BRINES AND THE CUCUMBER PLANT

Etchells, J. L., Bell, T. A., and Jones, I. D.

Farlowia 4: 265-304. 1953

IDENTIFICATION OF YEASTS FROM COMMERCIAL CUCUMBER FERMENTATIONS IN NORTHERN BRINING AREAS

Etchells, J. L., Costilow, R. N., and Bell, T. A.

Farlowia 4: 249-64. 1952

Chemical Studies

SALTING OF CUCUMBERS: INFLUENCE OF BRINE SALINITY ON ACID FORMATION

Jones, I. D.

Ind. Eng. Chem. 32: 858-61. 1940

PHYSICAL AND CHEMICAL CHANGES IN CUCUMBER FERMENTATION

Jones, I. D., and Etchells, J. L.

Food Inds. 15 (1): 62-4. 1943

CHEMICAL AND BACTERIOLOGICAL CHANGES IN DILL PICKLE BRINES DURING FERMENTATION

Jones, I. D., Veldhuis, M. K., Etchells, J. L., and Veerhoff, Otto

Food Res. 5: 533-47. 1940

INFLUENCE OF SUGAR ADDITION TO BRINES IN PICKLE FERMENTATION

Veldhuis, M. K., Etchells, J. L., Jones, I. D., and Veerhoff, Otto

Food Inds. 13 (10): 54-6; 13 (11): 48-50. 1941

Enzymatic Softening of Brine-Stock Pickles

INFLUENCE OF SALT (NaCl) ON PECTINOLYTIC SOFTENING OF CUCUMBERS

Bell, T. A., and Etchells, J. L.

J. Food Sci. 26: 84-90. 1961

SOFTENING ENZYME ACTIVITY OF CUCUMBER FLOWERS FROM NORTHERN PRODUCTION AREAS

Bell, T. A., Etchells, J. L., and Costilow, R. N.

Food Res. 23: 198-204. 1958

SOFTENING OF COMMERCIAL CUCUMBER SALT-STOCK IN RELATION TO POLYGALACTURONASE ACTIVITY

Bell, T. A., Etchells, J. L., and Jones, I. D.

Food Technol. 4: 157-63. 1950

POPULATIONS AND SOFTENING ENZYME ACTIVITY OF FILAMENTOUS FUNGI ON FLOWERS, OVARIES, AND FRUIT OF PICKLING CUCUMBERS

Etchells, J. L., Bell, T. A., Monroe, R. J., Masley, P. M., and Demain, A. L.

Appl. Microbiol. 6: 427-40. 1958

CUCUMBER BLOSSOMS IN SALT-STOCK MEAN SOFT PICKLES

Etchells, J. L., Bell, T. A., and Jones, I. D.

Research and Farming 13, Nos. 1-4: 14-15. 1955

Enzyme and Microbial Inhibitors

OCCURRENCE OF AN INHIBITOR OF LACTIC ACID BACTERIA IN GREEN OLIVES

Fleming, H. P., and Etchells, J. L.

Appl. Microbiol. 15: 1178-84. 1967

INHIBITION OF PECTINOLYTIC AND CELLULOLYTIC ENZYMES IN CUCUMBER FERMENTATIONS BY SERICEA

Bell, T. A., Etchells, J. L., Singleton, J. A., and Smart, W. W. G., Jr.

J. Food Sci. 30: 233-39. 1965

INHIBITION OF PECTINASE AND CELLULASE BY CERTAIN

(Continued on next page)

PLANTS

Bell, T. A., Etchells, J. L., Williams, C. F., and Porter, W. L.
Botan. Gaz. 123: 220-23. 1962

Bloater (Hollow-Stock) Formation

BLOATER FORMATION BY GAS-FORMING LACTIC ACID BACTERIA IN CUCUMBER FERMENTATIONS

Etchells, J. L., Borg, A. F., and Bell, T. A.

Appl. Microbiol. 16: 1029-1035. 1968

YEASTS: BRIGANDS IN BRINE

Etchells, J. L., Jones, I. D., and Bell, T. A.

Research and Farming (N. Carolina Agr. Expt. Sta.), 10 (1): 3-4. 1951

OBSERVATIONS ON BLOATER FORMATION IN CUCUMBER FERMENTATION

Jones, I. D., Etchells, J. L., Veerhoff, Otto, and Veldhuis, M. K.

Fruit Prod. J. 20 (7): 202-206; 219-20. 1941

Salt Absorption by Cucumbers

THE RATE OF SALT PENETRATION INTO PICKLES CHARTED, SIZE BY SIZE

Fabian, F. W., and Fulde, R. C.

Food Packer 31 (9): 23, 38, 41; (10): 28-29, 38-40, 51. 1950

THE ABSORPTION OF SALT BY CUCUMBERS DURING FERMENTATION

Pederson, C. S., and Albury, M. N.

Food Technol. 16: 126-30. 1962

Pasteurized Pickles

RATE OF HEAT PENETRATION DURING THE PASTEURIZATION OF CUCUMBER PICKLE

Etchells, J. L.

Fruit Prod. J. 18 (3): 68-70. 1938

PASTEURIZATION OF PICKLE PRODUCTS

Etchells, J. L., and Jones, I. D.

Fruit Prod. J. 21 (11): 330-32. 1942

PROCEDURE FOR PASTEURIZING PICKLE PRODUCTS

Etchells, J. L., and Jones, I. D.

Glass Packer 23 (7): 519-23, 546. 1944

THE IMPORTANCE OF CARE IN THE PASTEURIZATION OF PICKLE PRODUCTS

Etchells, J. L., and Jones, I. D.

Canner 98 (9): 28, 64. 1944

PASTEURIZED PICKLES?

Etchells, J. L., Ohmer, H. B., and Jones, I. D.

Research and Farming (N. Carolina Agr. Expt. Sta.), 10 (2): 11. 1951

INFLUENCE OF VARIOUS ACIDITIES AND PASTEURIZING TEMPERATURES ON THE KEEPING QUALITY OF FRESH-PACK DILL PICKLES

Monroe, R. J., Etchells, J. L., Pacilio, J. C., Borg, A. F., Wallace, D. H.,

Rogers, M. P., Turney, L. J., and Schoene, E. S.

Food Technol. 23: 71-77. 1969

Pure Culture Fermentation

CONTROLLED FERMENTATION IMPROVES PICKLING

Etchells, J. L., Bell, T. A., and Costilow, R. N.

Food Process. Marketing 27: 150-51. 1966

PURE CULTURE FERMENTATION OF GREEN OLIVES

Etchells, J. L., Borg, A. F., Kittel, I. D., Bell, T. A., and Fleming, H. P.

Appl. Microbiol. 14: 1027-41. 1966

(Continued on next page)

PURE CULTURE FERMENTATION OF BRINED CUCUMBERS
Etchells, J. L., Costilow, R. N., Anderson, T. E., and Bell, T. A.
Appl. Microbiol. 12: 523-35. 1964

Varieties for Pickling

CUCUMBER VARIETIES IN PICKLE MANUFACTURE

Jones, I. D., and Etchells, J. L.
Canner 110 (1): 34, 36, 38, 40. 1950

VARIETAL DIFFERENCES IN CUCUMBERS FOR PICKLING

Jones, I. D., Etchells, J. L., and Monroe, R. J.
Food Technol. 8: 415-18. 1954

Patents Related to Pickling

ENZYME INHIBITOR FOR PREVENTING SOFTENING IN BRINED FOODS

Bell, T. A., Etchells, J. L., and Smart, W. W. G., Jr.
Patent No. 3,374,099. March 19, 1968

PURE CULTURE FERMENTATION PROCESS FOR PICKLED CUCUMBERS

Etchells, J. L., Bell, T. A., and Costilow, R. N.
Patent No. 3,403,032. September 24, 1968

PROCESS AND MEDIA FOR PRODUCING CELLS OF LACTIC ACID BACTERIA

Etchells, J. L., and Costilow, R. N.
Patent No. 3,410,755. November 12, 1968

PURE CULTURE FERMENTATION OF GREEN OLIVES

Etchells, J. L., Bell, T. A., and Kittel, I. D.
Patent No. 3,480,448. November 25, 1969

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Delos H. Wallace, Atkins Pickle Company, Atkins, Arkansas

In this country, the manufacture of cucumber pickles requires annually about 550,000 tons of pickling cucumbers. Last year's (1969) crop had a farm value of about \$50 million, which represented an important, early cash crop for about 80,000 growers. Of the average annual crop, approximately 40% is made directly into fresh-pack or pasteurized pickle products (such as whole dills, spears, sweet slices, dill chips, etc.), which is essentially a canning operation developed by our earlier cooperative research. The remaining 60% of the crop is converted into brine-stock pickles by the natural fermentation in brine. The cured brine-stock is then desalted and manufactured into various staple pickle products (sweets, sour, mixed pickle, processed dills, hamburger slices, relishes, etc.). Substantial amounts of other commodities are brine-cured in this country each year, including Spanish type green olives (5,000 tons), citron (5,000 tons), onions (3,000 tons), and lesser amounts of peppers, cauliflower, green tomatoes, and okra.

Green cucumbers are brined in wooden tanks ranging in size from 100 to 2,000 bushels. After the tanks are filled, they are fitted with a loosely constructed "false" head or cover made of wooden boards and keyed down securely by heavier wooden timbers. Salt brine of a suitable concentration is added to a level of a few inches above the head. Next, dry salt is added on the cover to maintain the initial brine concentration, which otherwise would be diluted by the water content of the cucumber (ca. 95%). With equilibrated brine strengths in the range of 20 to 30° salometer¹ (=5.3 to 7.9% salt by wt), and with brine temperatures in the 75-80°F range, salt-tolerant microorganisms grow for about three months. The microbes that cause the fermentation come chiefly from the cucumbers and adhering particles of soil. They use as their food the soluble, nutritive materials—principally sugars—that diffuse into the brine as the result of the action of the salt brine on the cucumber tissue.

The growth of the naturally occurring microbes, introduced by the cucumber, is called the "natural fermentation." Their growth produces lactic and acetic acids, alcohols, and gases (carbon dioxide and hydrogen). The type of fermentation, with respect to the microbial group involved and the end products formed, is influenced to a great extent by the starting brine strength used and the rate at which it is increased. The curing process usually takes about two to three months, at which time the cucumber has changed from the green, opaque, buoyant fruit to olive-to-straw colored, translucent, gas-free brine-stock.

¹ In the cucumber pickling industry, brine salinity is usually recorded in terms of degrees salometer, as measured by a hydrometer calibrated in percentages of saturation with respect to sodium chloride 0° to 100° salometer). For convenience of those persons not familiar with this method of measuring brine salinity, the salometer values shown are usually followed by their equivalents in percentage of salt by weight in brine.

During the natural fermentation of brined cucumbers, the following salt-tolerant microbial groups may be active: gas-forming and nongas-forming species of lactic acid bacteria; gas-forming bacteria of the *Aerobacter* genus; fermentative (gas-forming) and oxidative types of yeasts; and gas-forming, obligate, halophilic (=salt-loving) bacteria. Of these groups, only the nongas-forming species of lactic acid bacteria are desired. But, compared to the various groups of microorganisms provided as inoculum for the fermentation by the cucumber, the desirable lactic acid bacteria that occur on a small-sized cucumber (1" diameter) are present in very low numbers (about 50,000) as compared to extremely high populations (about 50 million) of undesirable coliform bacteria.

These microbiological findings readily lead to the conclusion that natural fermentation is rather complex and could easily be highly variable too.

(Continued on next page)

Such unrestricted, hetero-geneous microbiological activity not only leads to much variation between fermentations, but it also can be responsible for certain defects and various types of deterioration and spoilage of the cured brine-stock. The economic loss to the industry as the result of the uncontrolled, natural fermentation can, at times, be both staggering and unpredictable.

Actually, the brine preservation of cucumbers under commercial conditions, as practiced today, is essentially the same as when man first made an effort to store edible food material for his future consumption. Today, as earlier, practically the only fermentation control measure the packer has is the use of salt; but salt has little effect on some brine organisms that cause difficulty, and may actually foster their growth. Several years ago, numerous experiments conducted on commercial-scale clearly established the fact that no single brining treatment devised and used by industry was capable of giving the same quality of brine-stock (as to bloater content and degree of firmness) from one year to another. However, our brining research has provided the industry with valuable procedures and techniques to: (1) control enzymatic softening of the brine-stock pickles during fermentation, curing, and storage; and (2) reduce bloater (hollow stock) formation resulting from gaseous fermentations. Even so, the ultimate and continuing objective of our brining studies has been to develop a feasible, controlled bulk fermentation process, for the pickle industry, based on inoculation with pure cultures of high-performance lactic acid bacteria that will virtually eliminate the defects and spoilage now commonly associated with the uncontrolled natural fermentation of brined vegetable material; namely, brine-stock pickles that are:

1. soft or inferior as to texture,
2. bloated (=hollow stock) or show gassy deterioration (=spongy),
3. shriveled or flat,
4. poor in color, such as showing external and/or internal bleaching, and
5. unclean as to odor and taste.

Progress toward achieving the controlled fermentation objective has been most encouraging, and the brining tests have left the laboratory state and are now being conducted under conditions typical of industry.

Appendix B: Products Made by the Pure Culture Process

The long-term objective of our cooperative research, as mentioned earlier, has been to place the pickle industry among the controlled fermentation industries. Perhaps a part of this objective has been achieved with the advent of the pure culture process for "In Container" or "Ready to Eat" products such as dill pickles, tomatoes, peppers, okra, carrots, green beans, and other vegetables. The same process, minus the culture, permits the packing of certain fresh-pack pickle items in bulk containers (5 gal tin cans or plastic pails) which, in such amounts (about 25 lb lots), are most difficult if not impossible to pasteurize so as to retain even the minimal desired flavor and texture levels. Instead of adding the culture to the heat-shocked cucumbers, the packer adds his own acidified cover-brine that has been previously heated (170°F) and cooled (45°F) before use. This process is called "Insta-Pak." A separate public service patent has been granted to cover the pure culture fermentation of Spanish type green olives. This process has generated intense interest together with a number of successful small-scale (50 to 100 lb lots) tests by the olive industry. Two companies are anxious to make commercial-scale tests this coming harvest season (1970).

At this time, about 30 companies have been licensed to practice the pure culture process as it applies to "In Container" products and "Insta-Pak" products. However, there is still another category of products; those resulting from the fermentation process which has been accomplished in large quantities (hundreds of bushels) such as bulk salt-stock, pickles,

(Continued on next page)

subsequently made into finished pickle products, along the order of the processed pickle items now being produced by the industry.

The bulk process will employ the same basic principles as for "In Container" products, but there will be certain differences. The culture inoculation procedure will be the same except a two-species mixture of lactic acid bacteria will probably be employed. The chief difference will be that heat will not be used to sanitize the cucumbers. Rather, bulk sanitizing in the brining container will be employed, plus the use of certain acceptable additives to ensure that the introduced culture will predominate and that highly competitive microbial groups will be effectively suppressed.

Studies in this area during the past three harvest seasons have been most rewarding and clearly indicate that the controlled fermentation goal of cucumbers, brined in bulk, is truly in sight.

Appendix C: Tables

TABLE 1. Influence of cucumber size on the buffering action of the brine¹

Glacial acetic acid/gallon of brined material ml	Cucumber size brined			
	1-1/4 to 2" diameter (No. 2's and 3's)		1/4 to 1-1/16" diameter (No. 1's)	
	Brine acidity %	Brine pH	Brine acidity %	Brine pH
9	0.27	3.98	0.27	4.24
12	.37	3.86	.34	4.12
15	.45	3.80	.42	4.05
18	.51	3.75	.51	3.94
Nonacidified control	0.03	5.81	0.05	5.60

¹ Acidity (as % acetic acid) and pH values shown were made after a 24 hr equilibration period and just prior to inoculation with *L. plantarum*. Cucumbers were brined at 25° salometer plus dry salt added to maintain that concentration.

TABLE 2. Influence of mechanically pricking of cucumbers on bloater formation

Number of tanks	Treatment before brining	Bloaters found, %	
		Balloon type	Lens type
12	None	14	38
12	Pricked	5	12

TABLE 3. Salt absorption by different sizes of cucumbers¹

Time in hrs	Salt absorbed, in % of total, by ²		
	No. 1's 3,000 count ³	No. 2's 1,800 count ³	No. 3's and 4's 600-800 count ³
	1-1/6" diameter	1-3/16" diameter	1-3/4 to 2" diameter
6	85	60	30
24	95	85	55
60	96	95	90

¹ Values shown for salt absorption based on data from an article by F. W. Fabian and R. C. Fulde (Food Packer, 31 (9): 23, 38, 41; (10): 28-29, 38-40, 51. 1950.

² Cucumbers covered with a 66° salometer (17.4% salt) brine; pack-out ratio in 5 gal crocks was 47% cucumbers and 53% brine. Results for salt absorbed by cucumbers covered with a 20° salometer brine (5.3%) were essentially the same as those shown in the table above.

³ Figures refer to number of cucumbers per 45 gal cask.

NOTICE TO AUTHORS

Pickle Pak SCIENCE will publish articles on the aspects of research relating to brined, salted and pickled vegetables and fruit, stressing contributions of a fundamental or applied nature.

Manuscripts should be submitted in duplicate to the Editorial Office for first class mail in flat form.

FORM OF MANUSCRIPT.

Manuscripts should be typewritten or multilithed, with wide margins on high quality bond paper, using double spacing throughout. Subdivision of articles into Summary, Introduction, Materials and Methods, Results, Discussion, Acknowledgments, and References is recommended. The manuscript *must* begin with a Summary. Reviews of the literature should be restricted to pertinent papers. Tables, figures, names, quotations, and bibliography, and all text references to the same, should be carefully checked for errors.

FIGURES AND TABLES.

Number all figures consecutively with Arabic numbers and give each one a descriptive legend. All illustrations should be in finished form for the camera. Figures should be planned to fit the proportion of the printed page (7" x 10", column width: 2½"). Lettering on drawings should be made with a lettering set and should be large enough to take a reduction of 50-60 per cent. Drawings should be made with India ink on tracing linen, smooth surface white paper, or Bristol board.

Photographs should be glossy prints with strong contrasts, and the magnification should be indicated by a scale. Photographs should be cropped to eliminate background material so that reproduction might be possible without reduction. Grouping of photographs should be indicated.

Tables should be typed on separate pages, numbered consecutively with Arabic numbers, and put at the end of the manuscript. All tables must have descriptive headings and should be understandable without reference to the text.

REFERENCES. Names of authors should be mentioned in the text with the year of publication

in brackets. References should be listed alphabetically at the end of the paper as follows: Bawden, F. C., and Kassanis, B. Some effects of thiouracil on virus-infected plants. *J. Gen. Microbiol.* 10, 160-173, 1954. See, however, the instructions for Short Communications below. The names of journals should be abbreviated according to the *Style Manual for Biological Journals*, American Institute of Biological Science, 2000 "P" Street, N. W., Washington, D. C. References to books should include: author's name, year of publication, title of book (editor of book, if any), edition (if other than first), publisher, and place of publication.

Do not include in the reference list articles that are "in press", or citations to abstracts, but incorporate in the text "unpublished data", and "personal communication(s)".

ABBREVIATIONS AND SYMBOLS. Where abbreviations are employed the author is asked to follow the usage established by the *Style Manual for Biological Journals*, American Institute of Biological Science, 2000 "P" Street, N. W., Washington, D. C.

NOMENCLATURE OF MICROORGANISMS. Binomial Latin names, with authorities, should be used in accordance with the *International Rules of Nomenclature Binomials* should be underlined in the typewritten copy. A specific name should not be used without an accompanying capitalized generic name. The generic name for each species should be written in full where it first occurs in the text, and again in the summary. Where the generic name appears frequently in the text it may be abbreviated by using the initial letter.

SHORT COMMUNICATIONS.

This section is open to *short* reports of important findings. Illustrative material should be kept to a minimum (usually not more than one table or figure). Literature should be cited as follows: References should be given in the text, listing the author, name of journal, volume, first and last page, and year of publication.

This section *does not* provide an accelerated means of publication, but is designed to offer the opportunity to present in brief form noteworthy results of work.

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MAJOR CUCUMBER DISEASES

Prepared For

PICKLE PACKERS INTERNATIONAL, INC.

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by

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Anthracnose: infects young tissue and begins on a leaf vein as small yellowish circular spots. Very young leaves may be distorted. The spots gradually become brown and enlarge to $\frac{1}{4}$ inch. They remain circular and the center frequently drops out leaving a shot-hole appearance. Stem lesions are shallow, elongate, slightly sunken, and tan in color. Fruit lesions begin as small, circular, water-soaked spots which enlarge to $\frac{1}{2}$ inch and become tan. Under moist conditions pinkish spore masses cover these spots.

Gummy Stem Blight: is a warm weather southern disease. On leaves it begins as small brownish circular spots which rapidly expand into large tan lesions of round, indefinite size. On stems, circular tan lesions frequently elongate and turn gray. The lesions may exhibit brown gummy exudate on the surface and stems may be girdled. In prolonged rainy periods most of the foliage and vine may rapidly collapse. Fruit lesions appear as small water-soaked areas, similar to anthracnose, which rapidly enlarge to indefinite size. Also, a brown streak may appear in the blossom end of the fruit. Although this disease may attack young tissue, it is primarily a disease of older tissue.

Angular Leaf Spot: appears on leaves as small water-soaked spots whose increase in size is limited by veins to form an angular shape. The upper surface of the spot becomes tan, and a sticky milky bacterial ooze forms on the lower surface and dries into a white crust. Many of the diseased spots loosen and drop out leaving a shot-hole effect. On stems and fruits the water-soaked areas may also become covered with crusty white exudate. As fruits mature, brown lesions form in the flesh and continue as streaks down to the seed.

SCAB (Spot Rot): first appears on leaves as small, circular to angular water-soaked brownish spots difficult to distinguish from angular leaf spot. Scab lesions are not covered with a crusty white exudate. Under high humidity leaf sporulation occurs on these spots as an olivaceous or velvety mat. On young fruit a gummy brown exudate occurs on the surface of the water-soaked areas, and as the spot spreads, the tissue sinks and dries to form a tan scab. Brown streaks do not extend into the flesh as for angular leaf spot.

Downy Mildew: begins as small yellowish areas on the leaves. Early in the morning when moisture has been present overnight, young spots may appear as water-soaked, somewhat angular areas on the lower side. As the lesions enlarge in a somewhat angular manner they change from yellow to brown. On the lower side, purplish spore masses may be seen, and severely infected leaves may die in 10-14 days. Downy mildew does not attack stems or fruit.

Powdery Mildew: first occurs on stems and leaves as tiny, white superficial spots, becoming covered with powdery spore masses as they enlarge. Under ideal conditions rapid, early, shedding of leaves may occur as entire leaf surface becomes covered with the powdery spores. Fruit is not infected.

Pythium Rot: This common rot starts as a small water-soaked spot, particularly where fruit is touching the ground, which enlarges into a raised, water filled blister about $\frac{1}{4}$ inch in diameter. Further enlargement is very rapid, with the disappearance of the blister symptom coupled with the occurrence of soft, watery, brown rotten tissue covered with a fluffy white mat. This entire process may occur in a 48 hour period.

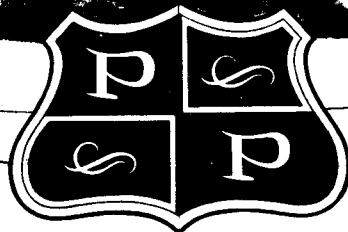
Mosaic: The yellow and green mosaic patterns of cucumber viruses, commonly seen on young leaves near the growing tip, often change to an indistinguishable mottle as the leaves mature. A dwarfing of the vines may become more conspicuous as leaf mottle symptoms tend to disappear. Cucumber mosaic and watermelon mosaic viruses attack cucumbers and produce similar symptoms; however, cucumber mosaic virus does produce a distinguishing symptom on fruit. Fruit infected with cucumber mosaic are characterized by a lack of color ("white pickle") in addition to the mottling and an extensive, bumpy, roughened appearance produced by all the cucurbit viruses.

Disease Survival: Viruses survive between cucumber crops on weeds, other crops, and other cucurbits (squash, watermelon, cantaloupe). They are spread from these hosts and between cucumber plants by aphids and beetles. Powdery mildew also survives on similar plants and is spread by wind currents. Scab, anthracnose, gummy stem blight and angular leaf spot survive on infected plant residues, on older plantings and volunteer cucurbits. All except scab may be seed borne. Scab may spread in dew whereas the others require rain to splash or blow the spores. Downy mildew survives on infected plants in subtropical areas and spreads northward in storm currents. Additionally all these diseases may be spread by machinery, personnel, animals or insects moving through the fields, especially when the foliage is wet.

Control: Consult your local agricultural Extension Service for the latest recommendations on the use of chemicals.

The use of resistant varieties; seed grown in the dry inner valleys of California; prompt destruction of old cucurbit crops, volunteers, and certain weeds; and practicing at least two years, preferably three, rotation between cucumber, watermelon and cantaloupe will avoid many of the disease problems.

NOTE: This printed page backed up by a page of full color illustrations of the diseases identified is available at \$2.00 each FOB Pickle Packers International, Inc., Box 31, St. Charles, Ill. 60174.



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