# Physical and Chemical Changes In Cucumber Fermentation*

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This and a later article review information accumulated through research and practical observation relative to chemical, physical and bacteriological changes during production of salt stock and dill pickles. Part of the information represents conclusions drawn from small-scale commercial project

THE brine fermentation of cucumbers in the commercial production of pickles is a practice which is old and well established and one which is common throughout the civilized world. However, in spite of the well-established nature of the general practice, the details vary greatly according to localities and individual companies concerned. There is not even uniformity in the procedure followed by companies in a given locality. The existence of these variations is strong evidence that many unknown factors are involved in this method of food preservation.

Since 1935, cooperative work on commercial cucumber fermentation has been carried on by the Bureau of Agricultural Chemistry and Engineering of the U. S. Department of Agriculture and the Department of Horticulture of the North Carolina Agricultural Experiment Station. The summer investigations were at one of the large pickling plants in eastern North Carolina and lasted from about the middle of June until the last part of August.

This work was undertaken because it was felt that if the nature of the changes which occur during curing were known, a fundamentally sound salting procedure could be devised. The observations to be reported at this time were made chiefly on cucumber fermentations carried on in vats of 85-bu. capacity, salted under outside conditions.

In salting cucumbers for dill pickles or for salt stock, the chemical and physical changes are similar, but may vary in total magnitude, depending on the product to be formed. Their extent may be greatly influenced by the salting treatment followed. The changes which take place in curing dill pickles are typical.

### *Dill Fermentation*

Freshly picked cucumbers have approximately the composition shown by Table I. Definite differences in composition exist between cucumbers of different size, representing fruit in different stages of maturity.

When cucumbers are placed in brine they undergo rapid physical and chemical changes. There is a vigorous withdrawal of water from the cucumbers and, therefore, a decided shrinkage of the fruit as well as a great dilution of the brine. Evidence of this change may be obtained by various methods. Brine-strength changes, which may be readily followed by means of a salometer, indicate that the greatest dilution occurs during the first 48 hours of the curing process.

The brine also causes the cells of the cucumber tissue to become permeable. This disorganization of the tissue permits the diffusion of soluble cellular constituents such as sugar and other organic substances from the cucumbers into the brine, and of salt from the brine into the cucumbers.

During the first 48 hours of the salting process the brine causes a marked initial loss in weight of the fruit, due to loss of water and soluble substances. Following this, there is a slower but prolonged gain in weight

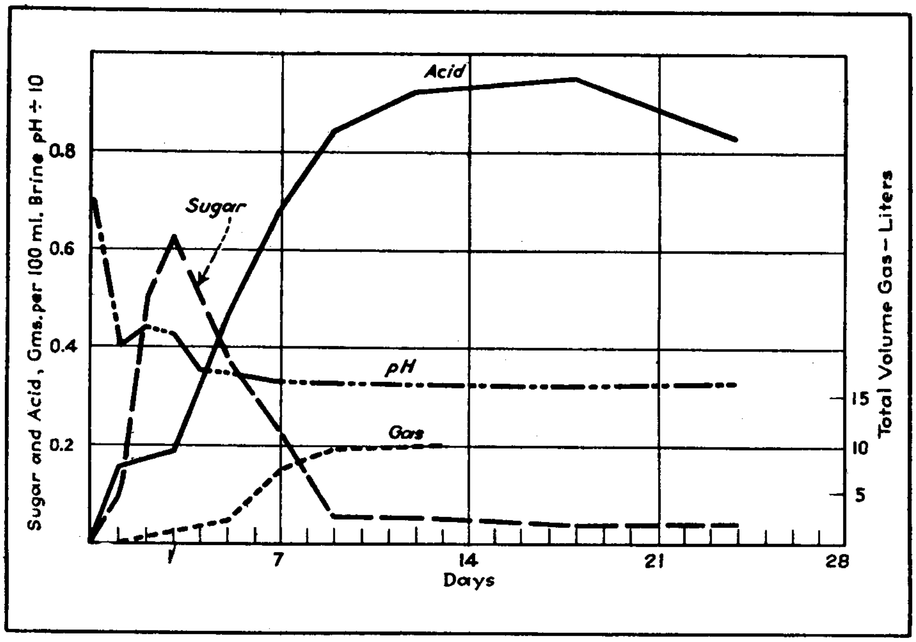


FIG. 1. Relationship of changes in titratable brine acidity, brine sugar concentration and gas evolution from brine surface for a typical dill fermentation. Acidity calculated as lactic acid, sugar concentration as reducing sugar.

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due primarily to penetration of salt into the cucumbers. Part of the gain in weight results from reabsorption of water, thereby overcoming a portion of the shrinkage at first encountered.

Shortly after the semipermeability of the cucumber tissue has been destroyed and sugar has diffused into the brine, microorganisms on the surfaces of the cucumbers start an active fermentation. The nature of this fermentation will be discussed in detail in the second paper of this series, but the following facts are important to us at this time.

The microorganisms utilize the sugar and perhaps other organic substances which have passed from the cucumbers into the brine. Consequently, these organic substances disappear or are reduced to a very low level as the fermentation proceeds. Through the activity of the microorganisms many end-products are formed, including gases, organic acids, alcohols and other compounds, some of which may be formed in small quantities.

An example of relative changes which occur in a cucumber fermentation is presented by Fig. 1. The curves indicate changes in brine-sugar concentration, brine acidity and gas evolution in a representative dill fermentation. Brine sugar is expressed as grams of reducing sugar per 100 ml. of brine. The concentration of sugar in the brine increases rapidly for the first few days and then it decreases again at a rapid rate until it attains a very low level.

The diffusion of sugar from the cucumbers into the brine begins immediately after the cucumbers are salted, and continues for a longer period than may be suggested by the curve. The decrease in brine-sugar concentration is the result of the activity of microorganisms. The time at which this decrease begins and the speed with which the sugar disappears give evidence of the activity of the organisms.

Acid was determined by titration, and is expressed as lactic acid. Figure 1 indicates that the formation of acid begins very soon after the cucumbers have been brined and continues at a rapid rate for the first 10 to 12 days.

TABLE I—Moisture and Sugar Content of Recently Harvested Cucumbers of Different Sizes

| Cucumber size | Water as fresh wt. | Reducing sugar as % fresh wt. | Nonsugar solids as fresh wt. |
|---|---|---|---|
| Small 3000's* | 94.0 | 1.87 | 4.10 |
| Medium 1200's* | 94.9 | 2.17 | 2.91 |
| Large 800's* | 95.1 | 2.24 | 2.69 |

* Count per 45-gal. cask.

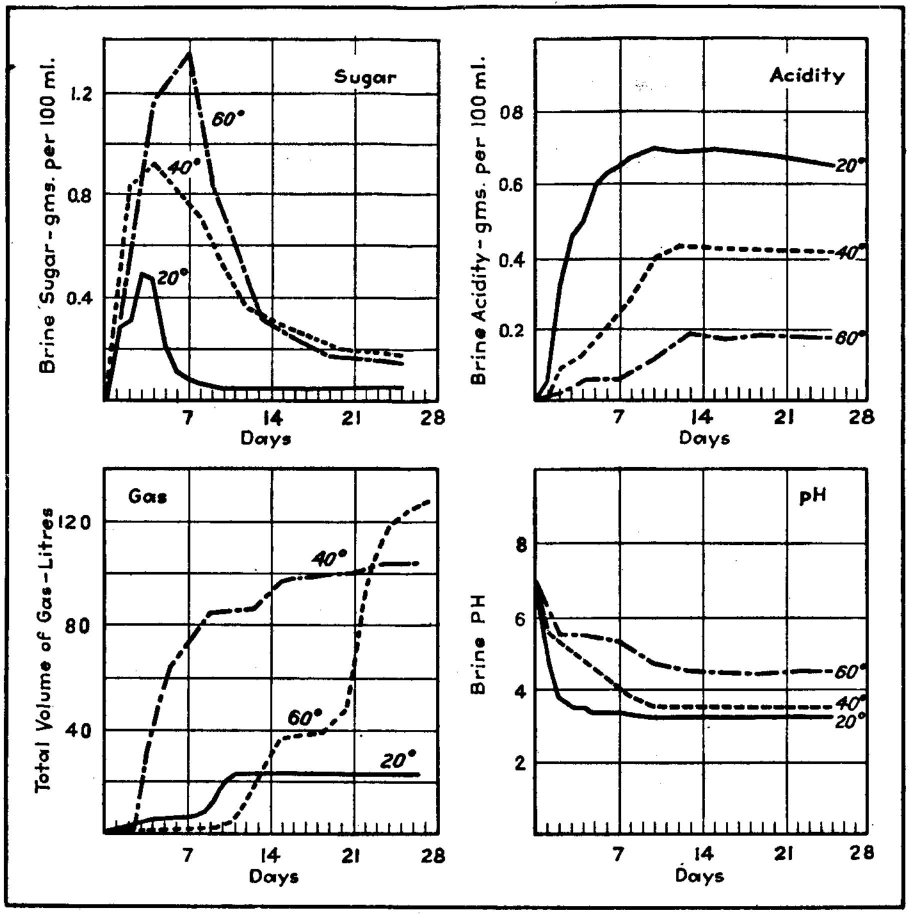


FIG. 2. Influence of brine salinity on changes during curing in sugar content, titratable acidity of the brine, pH and gas evolution from the brine surface. Acidity calculated as lactic acid.

Coincident with the formation of acid there is a corresponding change in hydrogen ion concentration or pH, as is also indicated by this figure.

The fourth curve of Fig. 1 shows the total gas evolved at different times during the period of active fermentation. This gas evolution was slow for the first 5 days, then proceeded at a much faster rate for the next 4 days, and ceased abruptly on about the ninth day.

In these studies all vats were of the same size, filled with the same volume of cucumbers and brine. Therefore the results obtained are entirely comparable throughout. The vats were 6 ft. in diameter, filled with a mass of cucumbers and brine to a depth of 4½ ft. Gas was collected by means of a stainless steel funnel 14 in. in diameter placed immediately under the head of each vat.

In the production of salt stock the general trends are the same as those in Fig. 1. However, the salting schedules followed by different individuals or companies vary greatly.

As part of our research program we studied the influence of initially different brine concentrations on the fermentations. The general salting schedule followed in these experiments is shown in Table II.

TABLE II—Schedule of Treatments Followed in Salinity Studies.

| Treatment designation | Brine concentration first week (deg. sal.) | Rate of increase of brine concentration |
|---|---|---|
| 20 deg. | 20 | Up 10 deg. per week to 60 deg. |
| 40 deg. | 40 | Up 5 deg. per week to 60 deg. |
| 60 deg. | 60 | Hold at 60 deg. |

The importance of the differences induced by unlike salting treatment is shown by comparison of the degree of change or the time at which changes occur.

A series of curves shown in Fig. 2 indicate the comparative changes in brine-sugar concentration, titratable brine acidity, brine pH and volume of gas evolved in fermentations occurring with the three experimental salting treatments.

From these curves it is seen that the time at which a decrease in sugar concentration sets in and the time at which maximum brine sugar concentration is

*Percent saturation with respect to sodium chloride.

attained are progressively retarded with increasingly higher initial salt concentrations. Stated differently, the use of increasingly stronger brine at the outset of the salting procedure causes an increasingly greater delay in the development or activity of microorganisms in the brine.

This is further strongly indicated by the development of brine acidity in lots salted according to the three schedules. The curves show that if, at the beginning of the salting procedure, brines of increasingly greater salinity are used, during the fermentation period there will be two effects; namely, a progressively slower rate of acid formation and a marked progressive decrease in the total amount of acid formed. The change in the acid concentration of the brine is reflected by corresponding changes in brine pH.

Again, the relationship between brine salinity and the activity of microorganisms is brought out by the curves which show the total volume of gas evolved from the surface of brines. It will be seen that for the 40- and 60-deg. brines there is a break or change of direction in the middle portion of the gas-evolution curves. This is explained by the fact that each of these curves represents at least two gaseous fermentations rather than one. Analysis of the gas at intervals during the period of evolution indicated that hydrogen was present in relatively large proportions (35 to 50 percent) during the fermentation represented by the first part of each curve. The gas evolved during the active period of the second fermentation consisted almost entirely of carbon dioxide.

To facilitate comparison graphs showing changes in sugar content, acid content and gas evolution are grouped together in Fig. 3. This figure is divided into three portions which show changes that occur in 20-, 40- and 60-deg. brines, respectively. Two principal facts are brought out. The first is that with the 20-deg. treatment the brine-sugar concentration had been reduced to a very low level before the maximum acidity was attained and also before the very limited gaseous fermentation got under way. This is in contrast to the conditions which existed in the 40- and 60-deg. brines. The second fact emphasized by Fig. 3 is that the gaseous fermentation in the 40- and 60-deg. brines was responsible for the utilization of an appreciable portion of the sugar found in the brine. This is particularly true in the case of the 60-deg. brine, where the formation of acid was especially slow and of small magnitude.

So far there has been no mention of

**TABLE III—Relation Between Salting Treatment and Percentage of Bloaters Formed During Curing of Salt Stock.**

Values given represent averages based on observations made over a 4-year period involving 28 vats.

| Salting treatment | Bloaters formed (percent) |
|---|---|
| 20 deg. | 6.5 |
| 40 deg. | 22.9 |
| 60 deg. | 43.6 |

the microorganisms which utilize the sugar that diffuses from the cucumbers into the brine and which are responsible for the formation of acid and gas. It may be well to state that lactic acid-forming bacteria are largely responsible for the acid produced, that hydrogen-forming bacteria are responsible for the major portion of the gas produced during the period when hydrogen is liberated, and that yeasts are responsible for the gas produced during the period when appreciable quantities of carbon dioxide only are formed. For all three salting treatments considered, the period of formation of the acid and gaseous end products coincides with the period when an appreciable concentration of sugar was present in the brine.

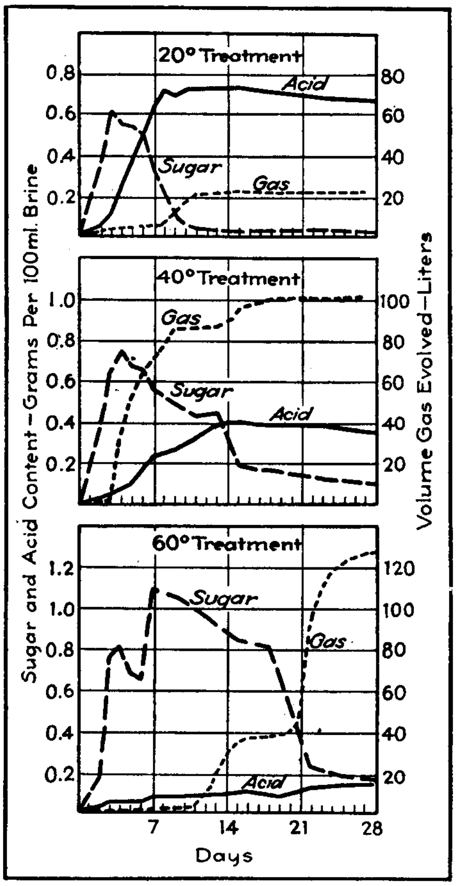


FIG. 3. Changes in brines from experimental lots salted at 20, 40 and 60 deg. sal. initial salt concentration. These results represent a single experiment during curing.

### Bloater Formation

The discussion thus far has dealt largely with chemical changes during the brining procedure. Certain physical changes that also occur in the cucumbers at this time should not be overlooked. Reference has already been made to the early shrinkage of the cucumbers caused by immersion of the fresh fruit in brine. It has been indicated that a recovery from this severe shrinkage slowly takes place as the salt stock remains in the brine over a long period of time. There is frequently, however, one physical change from which there is no recovery. That is bloater formation. In salt-stock production, that portion which becomes bloaters can no longer be considered highest quality stock.

Much evidence has been accumulated on factors contributing to bloater formation. It has been shown that in salt-stock production the proportion of bloaters formed among the larger sizes of cucumbers gradually becomes larger as brines of increasing strength are employed at the outset of the salting process. This relationship is indicated in Table III. Also, gas evolution from the brine surface has been shown to be much greater from lots started at high salinity than in lots started at low salinity.

Furthermore, the disruption and deformity of the tissue comprising the seed mass of the cucumber strongly suggests gas pressure as the cause. Therefore, we conclude from our research results obtained to date that bloater formation in cucumbers is associated with vigorous gaseous fermentations.

### Summary


To summarize, the use of brines of relatively low salinity during the first days (1 to 5) of the curing process will favor rapid acid formation and the production of a comparatively large quantity of acid with only relatively small quantities of gas. On the other hand, the use of brines of high salinity will retard the rate of acid formation, drastically reduce the amount of acid produced, and favor a vigorous gaseous fermentation. In addition, the use of brines of high salinity will favor the production of a comparatively large proportion of bloaters.


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