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SALTING OF CUCUMBERS

Influence of Brine Salinity on Acid Formation

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THE commercial manufacture of cucumber pickles generally involves two principal processes. The first is the production of salt stock by curing or salting fresh cucumbers in sodium chloride brines of suitable concentration. The second is the processing of salt stock to form the finished pickle. Spoilage of salt stock during the curing period or subsequently while it is in storage prior to processing is a loss frequently encountered by commercial manufacturers.

The use of sodium chloride or the brine of this salt in the household or in the commercial preparation of cucumber pickles has long been practiced. In spite of the established nature of this processing method, only a limited amount of exact information concerning the reactions involved has been obtained.

Rahn (*3*), Hasbrouck (*4*), Campbell (*2*), Brown (*1*), Fabian, Bryan, and Etchells (*3*), and others have made valuable contribution to our knowledge of the processes involved in the salting of cucumbers for the manufacture of pickles.

These investigators have shown that, in the preservation of green cucumbers by sodium chloride, certain salt-tolerant microorganisms are responsible for the disintegration of various organic fractions of the cucumber fruits. Chemical changes are reflected in the fermentation of soluble carbohydrates to form organic acids, principally lactic, and in some cases in the deterioration of the structure of the cucumber.

Microbiological activity is decidedly influenced by environmental temperature. Climatic conditions current in North Carolina at the time cucumbers are salted are decidedly different than those which prevail during the corresponding season in the more northern cucumber-growing areas where most of the previous investigational work has been carried on. In this state cucumbers are normally harvested from early June to late July. Therefore, salting begins and the curing process takes place during a period of high temperatures.

The view is commonly held, particularly in the South, that these different climatic conditions which prevail during the curing season require salting practices different from those followed in the northern sections of the country. It is believed that, under southern conditions, cucumbers must be cured in brines of relatively high salt content in order to prevent spoilage losses during the curing or storage periods.

In view of the more common use of brines of higher salt content in the southern than in the northern regions, it seemed important to study more thoroughly the influence of salt concentration of brines on the composition of such brines during the curing process, and on the physical nature and keeping quality of the salt stock produced under such conditions.

Commercial Salting Procedure

The salting procedure followed at commercial pickle plants is outlined briefly as follows: Barrels or vats are nearly filled with recently harvested cucumbers, a false head is fitted to the container (to keep cucumbers well submerged), and the container is filled with brine of the desired salt concentration. Salting may be done in unsheltered vats, as is more common in the South, or in vats under a roof or within a building.

The curing process commences immediately after the cucumbers are brined and continues for 3 or 4 months. During this period numerous microbiological, chemical, and physical changes take place. The cucumber tissue is killed by the salt, and the soluble cellular constituents diffuse into the brine. These organic constituents dissolve in the brine and serve as nutrients for salt-tolerant microorganisms. Large numbers of soil-borne microorganisms are carried on the cucumbers. Many of these are more or less salt tolerant. As a result an active fermentation commences in the brine almost immediately. This fermentation continues, under southern climatic conditions, for 2 to 6 weeks, depending upon the salting procedure. The fermentation is evidenced by the development of brine turbidity, the formation of an appreciable quantity of lactic acid, and the evolution of a considerable volume of gas.

The significance of the numerous changes occurring during the fermentation process has not been established. Most pickle manufacturers, however, consider that acid formation is both desirable and essential for the satisfactory production and subsequent storage of salt stock.

Previous Studies

Numerous investigators (*2*, *3*, *4*, *7*) have stressed the importance of carefully controlled salt concentrations of the brine involved in salt stock production.

Hasbrouck (*4*) recommended an initial brine concentration of 30° if the weather was cool and 32–33° if the days were warm. Salt concentration is expressed as degrees salometer (per cent saturation). The range 0–100° salometer represents 0–100 per cent saturation with respect to sodium chloride. A saturated solution contains 26.4 per cent sodium chloride by weight at 60° F.

Campbell (*2*) observed that a low or weak brine favored rapid fermentation whereas a high or strong brine checked or retarded fermentation.

Fabian, Bryan, and Etchells (*3*) investigated the influence of low-salt curing and high-salt curing on the fermentation process and salt stock quality. With the low-salt treatment (30° initially) brine acidity developed more rapidly and attained a higher value than with the high-salt treatment (40° initially). However, these authors point out that "after about a month's time there is very little difference between the total acidity of the two brines".

Le Fevre (*7*), on the other hand, reported appreciably greater acid formation in moderately strong brines (32–40°) than in weak brines (20–28°).

Present Studies

This report is based on studies made during 1934, 1935, and 1936. Salting was done in 45-gallon barrels. All treatments were salted in duplicate. More than 200 barrels of cucumbers were involved in this study. The experiments were carried on

at a commercial pickling plant in order that conditions might be typical of the industry. All containers were unsheltered throughout the curing and storage period.

The cucumbers were graded for size by mechanical means as they were received. Those used in these experiments fell into the following three classes based on diameter measurements; size 1, smaller than 1 inch but greater than $^5/_8$ inch; size 2, smaller than $1^3/_8$ but greater than 1 inch; size 3, greater than $1^3/_8$ inches but not ripe or odd-shaped. Cucumbers of given sizes were salted separately. Comparable lots of each size were started at different brine concentrations. These concentrations at the beginning of the experiment fell into the range of 20° to 80° salometer.

The experimental barrels received daily attention; salt concentration readings were taken and salt was added as required to hold at the desired salometer. Brine samples for chemical analyses were taken at intervals of 3 to 10 days during the period of active fermentation and at approximately 90-day intervals during the storage period.

These samples were placed in tightly capped bottles to which a small quantity of chloroform had been added as a preservative and were stored in this manner until analyzed.

Other periodic observations during the curing process and storage period included the inspection of salt stock to determine the physical quality of the cucumbers.

This paper is a report only of the chemical analysis of the brines for progressive changes in total titratable acidity and pH during the period of curing and early storage.

Analytical Methods and Salting Procedure

Total acidity was determined by titrating with 0.222 *N* sodium hydroxide, using phenolphthalein as an indicator, and was calculated as grams of lactic acid per 100 ml. of brine. The pH determinations were made with a glass electrode.

Fresh cucumbers, graded for size, were obtained from the receiving platform of a commercial salting station and packed into clean, sound barrels. In these studies 175-pound lots were utilized. Such a quantity left an unfilled space of approximately 4 inches in depth at the top of the barrel. False heads were fitted into place, and the barrel was nearly filled with brine of the desired salt concentration. This required roughly 20 gallons per barrel. A quantity of salt sufficient to maintain the brine at this same concentration for the first 24 hours was placed on the head.

TABLE I. SCHEDULE FOR TREATMENTS IN SALTING OF CUCUMBERS

Initial Brine Concn.	Rate of Increase of Brine Concn.
20°	Up 5° per week to 60°
30°	Up 5° per week to 60°
40°	Up 2° per week to 60°
60°	Held at 60°
80°	Held at 80°

The water required for making brine was untreated well water with a pH of 6.8–6.9. High-quality fine salt was used at all times.

In these salt concentration studies it was desired to investigate the influence of brine salinity over a range much wider than is generally utilized by commercial salters. The salting schedule followed is given in Table I.

Salt was placed on the head as required to maintain the desired salinity.

Throughout the curing period the brine concentrations were maintained as indicated in Table I. Therefore no daily salinity readings are presented. Each treatment is designated by the concentration of brine used at the start of the experiment.

Chemical analyses of brine samples taken on successive dates during the curing process indicated that a general relation existed between the initial salt concentration of the brine and the subsequent brine acidity developed. This general relation was observed throughout the study, and from year to year the results were in close agreement. For this reason the results presented will be those for the 1936 season only.

Duplicate lots of each of three different sizes of cucumbers were salted according to the treatments outlined in Table I. In general, the relation between brine salinity and the acidity developed was independent of size of cucumber used.

Figure 1 shows the titratable acidity curves of brines of different initial salt concentration at progressive dates during the curing process and early storage period. The data were obtained with lots of size 1 cucumbers. Curves for size 2 and

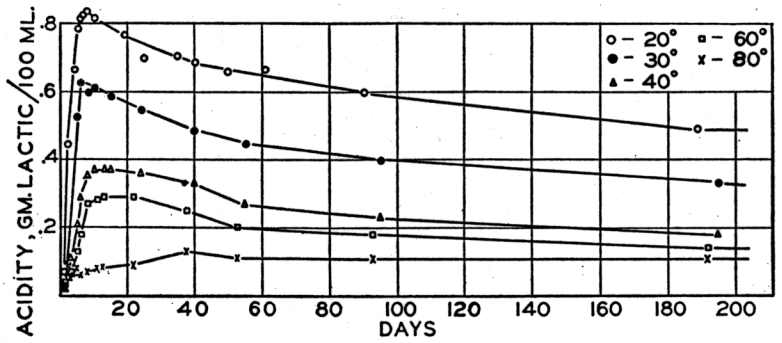

FIGURE 1. RELATION OF INITIAL SALINITY TO SUBSEQUENT TITRATABLE ACIDITY OF BRINES

3 cucumbers show the same general relation between early brine salinity and subsequent brine acidity as those for size 1, although absolute values are different for lots of fruit of different size. For this reason the data represent those obtained with one size of fruit only.

Figure 2 compares the pH values during the curing period for the brines of different salt concentrations.

Figure 3 indicates the relation between cucumber size and the titratable acidity and pH of the brine developed during the curing period for lots receiving the same salting treatment. The values given are for cucumbers of sizes 1, 2, and 3, cured according to the 20° salting schedule.

The same relation was observed in a comparison of the values for the three sizes cured according to other salting schedules. Accordingly the data presented relative to this phase of the study represents only one salting treatment.

Influence of Salt Concentration

Figure 1 indicates the influence of the salt concentration of the brines during the early portion of the fermentation period on subsequent acid formation. In the brines of relatively low salinity there was an extremely rapid development of brine acidity. For brines of increasingly higher initial salinity, acid formation occurred at increasingly slower rates.

With the exception of 80° brine the maximum acidity for all treatments was developed within the first 15 days. From a comparative standpoint the brines of lower initial salt content actually attained this maximum brine acidity slightly earlier than the brines of higher salinity.

Under the conditions of this experiment the brine of lowest early salt concentration produced and maintained an acidity considerably above that of all other treatments.

For the entire series of treatments involving the use of brines of successively higher initial salt concentration, the acid production occurred at successively slower rates, and correspondingly lower final total acidities were developed.

Emphasis should be laid on the fact that the curves in Figures 1 and 2 are designated by a figure indicating the concentration of the brine used at the beginning of the experiment. The salting schedule in Table I shows that the brine concentration in all treatments was gradually increased to a maximum of 60°. However, the greatest increase in brine

acidity in all treatments occurred during the first week of fermentation. During this period the treatments were the most dissimilar from a comparative standpoint.

With reference to the quantity of acid formed by fermentation in these experiments the following is important: All barrels used were of nearly equal volume. Also the quantity of fresh cucumbers placed in each barrel was uniform. Therefore the cucumber-brine ratio in all cases was essentially the same.

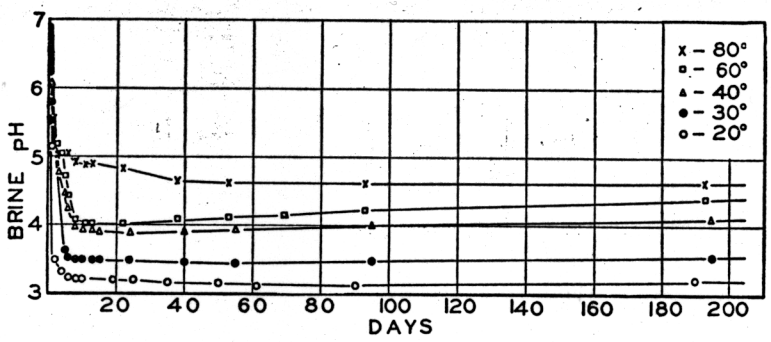

FIGURE 2. RELATION OF INITIAL BRINE SALINITY TO SUBSEQUENT BRINE pH

Such uniformity in salting methods would provide practically equal quantities of the soluble carbohydrates or other organic compounds utilized by acid-forming organisms. This condition might be expected to favor the development of practically equal quantities of acid for lots receiving different salting treatment, irrespective of brine salinity. Actually, decidedly different quantities of acid were formed in the different lots as shown by Figure 1.

The data indicate that the total quantity of acid formed during fermentation is not solely dependent upon the quantity of soluble carbohydrates or other organic compounds present in a given lot of cucumbers but is also dependent upon the salinity of the brine in which fermentation takes place.

In Figure 2 the pH curves for brines of different initial salt content exhibit great similarity as to shape but differ decidedly as to final values attained. In all cases the curves flatten out at approximately the same date when the maximum titratable acidity is attained. After this date relatively large decreases in titratable acidity produce only slight changes in the corresponding brine pH.

The results of these experiments relative to the influence of early brine salinity upon subsequent acid formation confirm the observations of Campbell (*2*) and Fabian, Bryan, and Etchells (*3*) who previously reported that acidity developed at a more rapid rate and attained a higher value in brines of lower than higher salinity.

The results reported here further indicate that there was no rapid reduction in brine acidity following the period of acid formation. This was found for all salting treatments, even over a storage period of more than 6 months. This observation is at variance with those of investigators who previously reported on this phase of the study (*3*).

The variation between the results of this study and those reported previously (*3*, *7*) may be explained by the conditions under which the different experiments were conducted. The present studies were carried on in containers which were unsheltered at all times. The experiments of the previous investigators (*3*, *7*) were conducted under sheltered or indoor conditions.

Rahn (*8*), Brown (*1*), and others reported that pseudo yeasts or pickle scum will develop on pickle brines if the brine surface is exposed to the air and is sheltered or protected from the direct rays of the sun. The development of these scum yeasts causes a reduction in brine acidity and will in time be responsible for the complete destruction of the acid formed by the fermentation process.

Fabian, Bryan, and Etchells (*3*) recognized that the growth of pickle scum in their experimental brines might have been partially responsible for the loss of brine acidity. In the studies reported here conditions were not favorable for pickle scum development and the resulting marked destruction of brine acidity.

Figure 3 presents data on the relation between brine acidity and the size of the cucumbers involved. Although equal quantities of green cucumbers are utilized in each lot, the smaller sizes favored the development of greater acidity.

Heinze (*5*), Kitahara (*6*), and others showed that cucumbers differ in composition according to size. This dissimilarity in composition might account for the formation of different quantities of acid even though such factors as weight of fresh fruit, volume of brine, and salinity of brine were constant for different lots of cucumbers. Further study relative to this phase is in progress.

Brine pH shown in Figure 3 is for size 1 fruit only. Differences so small as to be difficult to present graphically were observed in brine pH between lots of sizes 1, 2, or 3 fruit. These differences, although consistent throughout the period of observation, were of the magnitude of 0.1 pH unit or less. Accordingly, for clarity of presentation, only the values for the size 1 fruit are shown.

Summary

Experiments were conducted to determine the influence of the salt concentration of the brines involved in the curing of cucumbers on subsequent brine acidity. Brines of widely different initial salt concentrations were employed, covering the range from 20° to 80°.

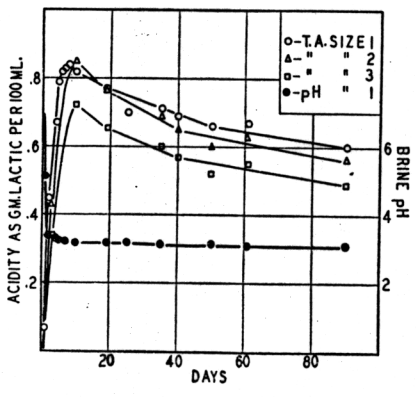

FIGURE 3. RELATION OF CUCUMBER SIZE TO TITRATABLE ACIDITY AND pH OF BRINE

These studies were conducted at a commercial pickle manufacturing plant over a period of three years under conditions typical for the industry. The data presented were obtained the last year of this period (1936). They are confirmed by comparable results from the entire period, representing observations from more than two hundred experimental barrels.

The following conclusions are drawn from these experiments:

1. Provided the cucumber-brine ratio be maintained constant, the total titratable acidity which will be developed in the brines in which the curing process takes place will be largely determined by the salt concentration of the brine during the early portion of the curing process.

2. Brines of low salt concentration favor the rapid formation of a relatively high amount of total titratable acid and the development of relatively low brine pH. Brines of increasingly higher initial salt content favor correspondingly retarded rates of acid formation, lower total quantities of acids produced, and higher brine reaction or pH values.

3. For brines of any given salt concentration the higher acidity will be produced in the curing of cucumbers of the smaller sizes and lower acidity during the curing of the larger sizes.

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