Influence of Sugar Addition to Brines In Pickle Fermentation

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PART I—This paper*† summarizes a series of tests that show that the addition of sugar to brines in the manufacture of salt stock or dill pickles not only fails to increase the acidity of the brines to a useful degree, but also leads to an increase in the proportion of bloaters in the stock.

IN the fermentation which takes place during the curing of salt stock or dills the fermentable carbohydrates of the cucumbers, largely reducing sugars, are almost completely converted into organic acids and certain other products of fermentation. The principal acid formed is lactic. Most commercial manufacturers consider that the development of an appreciable brine acidity is not only desirable but essential for the satisfactory curing of cucumbers and the subsequent storage of the stock produced.

Furthermore, it is the opinion of many that acid formation should start promptly after the beginning of the brining process and should take place at a rapid rate.

Several investigators have suggested the addition of sugar to brines in the manufacture of salt stock or dills, in order to accelerate acid formation or to favor the production of a greater quantity of acid. This latter effect was considered particularly desirable in the case of the brining of cucumbers, which possess a relatively low sugar content.

The idea of adding sugar to fermenting pickle brines is by no means new. In 1899 Aderhold recommended the addition of 0.05 or 0.10 percent of dextrose to the brine and claimed that acid formation took place at a more rapid rate and that more acid was produced when sugar was added.

LeFevre reported that by adding a fermentable sugar (corn sugar and molasses were used) at the beginning of the salting process "a more speedy onset of fermentation took place and a higher acidity was developed."

Joslyn stated that the addition of dextrose to dill pickles decreased spoilage by increasing the rate of acid production. He also reported a slight increase in the quantity of acid produced. Joslyn suggested the addition of 5 lb. of dextrose per barrel of cucumbers.

Fabian and Wickerham conclude from a biochemical and bacteriological study of the curing process in the production of genuine dill pickles that "the addition of 2 lb. of sugar per barrel increases the number of bacteria at the beginning of the fermentation. This is considered desirable since it insures a more rapid production of acid."

Fabian considered the addition of sugar to fermenting dill brines advisable as a protective measure against spoilage and states that it insures an adequate supply of sugar for all organisms.

Fellers, Miller and Onsdorf reported the addition of dextrose to cucumbers and sweet green peppers before the beginning of the fermentation. They state that the "addition of dextrose in the rates of 1 to 2 percent of the weight of the vegetable materially increased the titratable acid, reduced spoilage and improved keeping quality and texture." They further stated that "the added dextrose serves to accelerate the fermentation as well as produces a much greater quantity of lactic acid due to stimulation of lactobacilli by readily available sugar."

Campbell advised the addition of from 1 to 2 percent of glucose or any other cheap fermentable sugar when making up brine to be used in the curing of salt stock if it were desired to produce a higher percentage of acid than normally occurs.

All the reports of previous investigators are unanimous in claiming that the use of sugars in advantageous.

Problems and Methods

During the past few years several experiments on the addition of sugars to fermenting cucumber brines have been conducted in Eastern North Carolina. These studies were made in connection with salt stock formation and dill pickle production during four different seasons.

The cucumbers used were found by analysis to contain approximately 2.1 percent of sugar. The lots to which sugar was added received a quantity equal to or greater than 1.75 percent of the total weight of the fresh cucumbers employed in these studies.

This quantity represented a supplementary addition of sugar equal to or greater than 80 percent of the quantity introduced by the fresh cucumbers. On this basis a distinct increase in brine acidity might be expected following the addition of sugar to the brine if the supplementary sugar is converted into acid with the same efficiency as the sugar introduced by the green fruit.

In the salt stock experiments the cucumbers were cured in barrels (3 bu. lots) and in a vat (85 bu. lot). These containers were fitted with false heads.

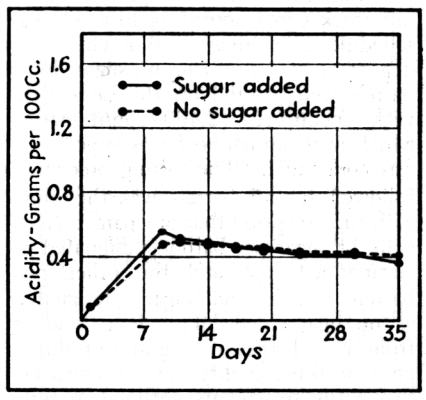

Fig. 1. 1934 salt stock, showing influence of addition of sugar (3.5 lb. of dextrose on start) to 40 deg. brine. Salting schedule—40 deg. first week, raised 2 deg. per week.

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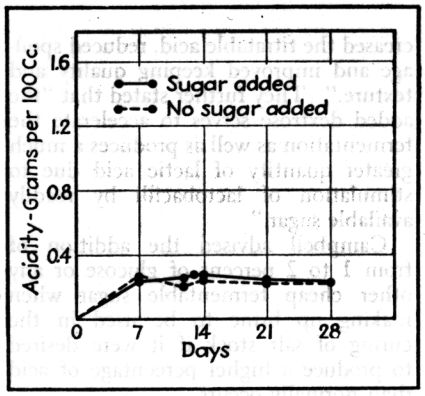

Fig. 2. 1939 salt stock, showing influence of addition of sugar (3.5 lb. of dextrose on eleventh day) to 40 deg. brine. Salting schedule—40 deg. first week, raised 2 deg. per week.

They were kept outside, and therefore, there was no growth of scum on the surface of the brine. All the dill experiments were conducted in barrels which were headed and loosely bunged during the fermentation period. The detailed procedure following in the dill experiments has been previously outlined.

In this study all experiments conducted in barrels were carried out in duplicate. So all values reported are the average of two observations.

The chemical analyses which were made included observations on changes in concentration of the titratable acidity and the reducing sugars of the brine during the curing period. In presenting the data, titratable acidity has been expressed as grams of lactic acid per 100 c.c. of brine.

The methods followed in the chemical and bacteriological analyses have been previously reported.

Experimental Results

A graphical presentation of a portion of the data obtained in these studies follows:

In Fig. 1 are shown the results of adding 6 lb. of sugar (sucrose) per barrel at the start, in the production of salt stock cured according to a 40 deg. schedule as compared to a check 40 deg. treatment receiving no sugar. Four barrels were started on the same date with cucumbers (2,400 count size*) which were similar so far as appearance was concerned. The salting procedure followed for all barrels was the same with the exception that one pair received 6 lb. of sugar per barrel (designated as sugar-added lot) and the other two barrels received no sugar (designated as no-sugar-added lot). It is evident from Fig. 1 that no significant differences in brine acidity were observed between the treatments outlined in spite of the fact that in the sugar-added lots the total available sugar content exceeded that of the no-sugar-added lots by more than 100 percent.

The addition of sugar to fermenting brines in the production of salt stock was repeated in 1939 under somewhat different conditions. In this experiment the fruit was of the 800 and 1000 sizes (numbers per 45 gal. cask.) The entire lot of cucumbers required to fill four barrels were thoroughly mixed before placing in the barrels in order to assure uniformity of the fresh stock. The barrels received a uniform salting treatment (40 deg. schedule) for eleven days. At this time the partially cured cucumbers were thoroughly mixed by distributing the stock from each of the four original barrels into four new barrels, four cucumbers at a time. The brine used to cover the new set of barrels was that taken from the original barrels after thorough mixing. These precautions were taken to be certain that the cucumbers and brine in any given barrel were similar to those in any other barrel. One pair of barrels was followed as a check and to each of the other pairs was added 3.5 lb. of dextrose. Otherwise the treatment of all lots was exactly the same. Figure 2 indicates the differences in brine acidity which were observed following these treatments. No significance is attached to the slight differences observed in this experiment.

A series of observations were made on the influence of the addition of sugar to dill brines at different periods of the fermentation process. The results obtained are graphically presented in Figs. 3 to 7, inclusive. Curves indicating changes in brine sugar concentration for the various experimental treatments are shown in addition to the brine acidity curves.

In the normal salting of cucumbers two processes occur which alter the sugar concentration in the brine during the curing period. The first process is the leaching of the naturally occurring sugar from the cucumber into the brine. The second is the utilization of sugar from the brine by microorganisms

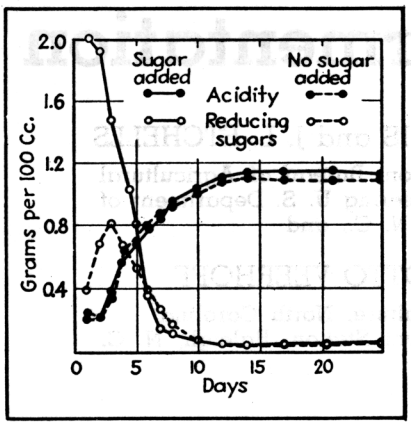

Fig. 3. 1937 dills, showing influence of addition of sugar (3.5 lb. of sucrose at start) to dill brine containing 0.5 gal. of 110 grain vinegar.

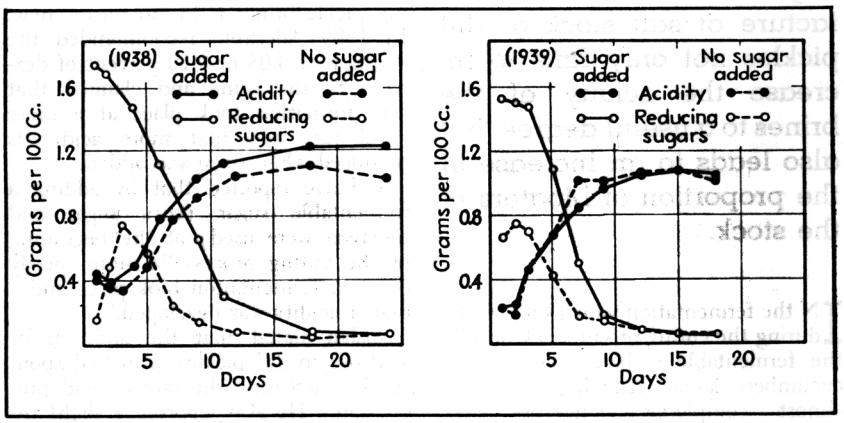

Fig. 4. ~~1938 dills~~, showing influence of addition of sugar (3.5 lb. of dextrose at start) to dill brine containing 0.5 gal. of 110 grain vinegar.

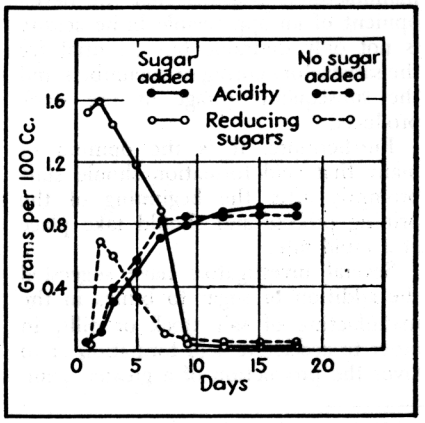

Fig. 5. 1939 dills, showing influence of addition of sugar (3.5 lb. of dextrose at start) to dill brines to which no ~~sugar~~ vinegar was added.

* Number per 45 gallon cask.

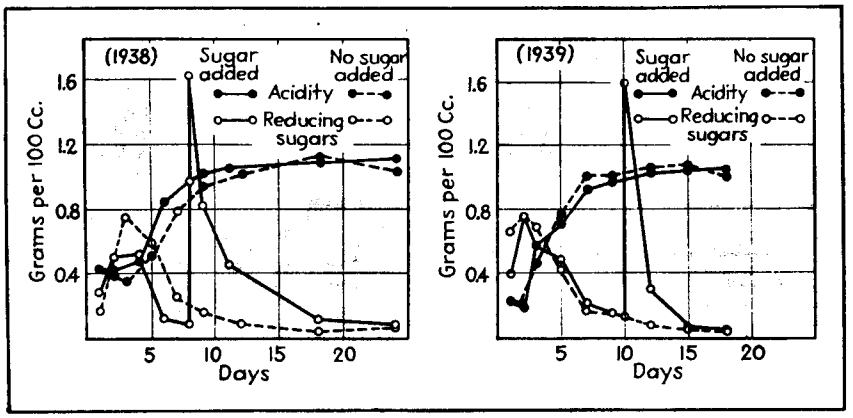

Fig. 6. Curves showing influence of addition of sugar (3.5 lb. of dextrose) to dill brines on seventh and tenth days.

after the fermentation begins. Accordingly, a curve representing changes in sugar concentration in dill brines to which no sugar has been added will show a fairly rapid increase in sugar content for approximately three days and then a correspondingly rapid decrease caused by the utilization of sugar in the fermentation.

The curves for brine sugar concentration in brines to which sugar has been added are somewhat different in shape. In this case the concentration is high at the time the sugar is added but decreases very rapidly as a result of the dilution of the brine with water withdrawn from the cucumber and of the utilization of the sugar by microorganisms after fermentation begins.

Figures 3, 4 and 5 present the results of experiments made in 1937, 1938, and 1939. In these experiments sugar was added at the rate of 3.5 lb. per barrel to each of two barrels at the beginning of the curing period and two comparable barrels to which no sugar was added were followed as check or control lots. The sugar curves indicate that the sugar concentration was reduced at a very much more rapid rate in the brines to which sugar was added than in the brines of the no-sugar-added lots. In spite of this more rapid sugar utilization, only slight differences were observed in the rate of acid production or in the final acidity developed in the brine of lots receiving the two different treatments. As will be emphasized later these differences were too small or too irregular to be considered significant.

Experiments on the effect of the addition of the sugar to the brine after the acid formation had become well started have been made. The results of these studies are presented in Fig. 6. The values shown in the 1938 graph may be considered by some to indicate that the addition of sugar accelerates acid formation. It should be borne in mind, however, that in this case the

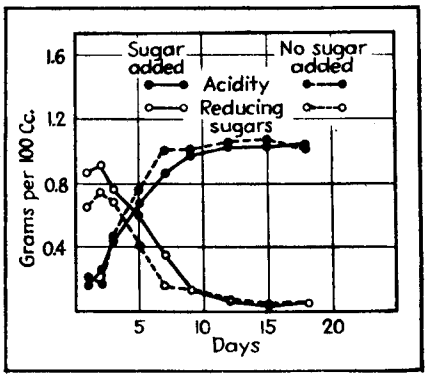

Fig. 7. 1939 dills, showing influence of addition of sugar (0.7 lb.—initially and on the fourth, sixth, eighth and tenth days) to dill brines containing 0.5 gal. of 110 grain vinegar.

sugar was not added until the seventh day and the greatest difference in the acidity of the brines for the lots receiving the given treatments was observed prior to this date. Furthermore, no greater differences in acidity between the sugar and no sugar treatments developed following the addition of this appreciable quantity of sugar.

The 1939 graph indicates the results obtained in a repetition of the 1938 study. In this case, the differences were actually reversed. Accordingly, little or no significance can be attributed to the small differences observed.

Inasmuch as no appreciable difference in brine acidity was observed to be induced by the addition of 3.5 lb. of sugar at a given time either at the start or after 7 or 10 days, it seemed desirable to approach this study in another manner. It was thought that by adding the 3.5 lb. of sugar in small quantities at intervals over an extended period of time, the added sugar might be converted more efficiently into acid, thereby resulting in the formation of an increased quantity of acid. Accordingly, in 1939 the effect of a more gradual addition of 3.5 lb. of sugar per barrel was tested. To each of the sugar-added barrels was added 0.7 lb. of dextrose at the start and on the 4th, 6th, 8th and 10th days after starting. The analyses of brines from this treatment are given in Fig. 7 and show that such a method of adding sugar resulted in the maintenance of a somewhat higher concentration of sugar in the brine for the first nine days. In spite of this, the acidity curve for this treatment at no time prior to the eighteenth day even equaled that of the treatment receiving no added sugar.

References

1. R. Alderhold. Untersuchungen uber das Einsauern von Fruchten und Gemusen, Part II, *Cent. fur Bakt*, Vol. 5, 511-514, 1899.
2. C. H. Campbell, Outdoor Season Booms Pickle Volume, *Canning Age*, Vol. 18, 221-224, 228-229, 232, 1937.
3. F. W. Fabian. Some Important Factors Influencing the Fermentation of Dill Pickles, *Fruit Products Journal*, Vol. 17, 240, 1937.
4. F. W. Fabian and L. J. Wickerham, Experimental Work on Cucumber Fermentation, Part VIII, *Technical Bulletin* 146, Michigan Agricultural Experiment Station, 1935.
5. C. R. Fellers, J. Miller and T. Onsdorf. Dextrose in the Manufacture of Fruit and Vegetable Products, *Industrial and Engineering Chemistry*, Vol. 29, 946-949, 1937.
6. M. A. Joslyn. Some Observations on the Softening of Dill Pickles, *Fruit Products Journal*, Vol. 8, No. 8, 19-29, 1929.
7. M. A. Joslyn. Some Observations on the Softening of Dill Pickles, *Fruit Products Journal*, Vol. 8, No. 9, 16, 17, 21, 1929.
8. E. LeFevre. Pickle Processing Investigations, *The Canner*, Vol. 50, 230-232, 1920.
9. E. LeFevre. Bacteriology of Sauerkraut and Pickles. *Chemical Age*, Vol. 30, 34, 1922.
10. I. D. Jones, M. K. Veldhuis, J. L. Etchells and Otto Veerhoff. Chemical and Bacteriological Changes in Dill Pickle Brines During Fermentation, *Food Research*, Vol. 5, 533-547, 1940.
11. Unpublished data.

PART II

A GENERAL reconsideration of the individual experiments which have been conducted indicates that the data has consistently shown that there was no appreciable increase in acid formation induced by the addition of sugar to brine prior to or during the period of active fermentation. Small differences between treatments in comparative brine acidity have been shown from one experiment to another. The results of the experiments involved are collected in table form (Table I). These results have been analyzed to determine if the small differences observed between treatments were significant. This analysis indicated that greater variation was encountered between treatments than between duplicate lots within a treatment. However,

the observed differences between treatments was too small to be considered significant (tested by analysis of variance).

To further clarify this matter, the acidity values for four different experiments have been averaged for respective treatments and presented graphically (Fig. 8). Each curve represents an average of values from eight barrels for each treatment. Two conclusions are drawn from the curves shown in Fig. 8: (1) The difference in brine acidity between the lots receiving added sugar and those to which no sugar was added was never greater than 0.06 percent; (2) there was no evidence indicating that acid formation was accelerated by the addition of sugar at the start of the experiment. From the evidence presented in Table I and Fig. 8, the authors conclude that the addition of sugar to dill brines during the curing process did not result in significant change in brine acidity.

In connection with these experiments involving the addition of sugar to salt stock and dill brines, observations upon changes other than in brine acidity have been made.

At the end of the 1938 season it was found that in the lots of dills to which sugar was added the proportion of bloaters formed was many times greater than in the control lots. Bloater formation is particularly undesirable in dill production. A discussion of the subject of the formation of bloaters during the curing of salt stock or dills is not properly included here but has been reported separately. However, reference is made at this time to certain data showing a distinct relationship between the percentage of bloaters formed and the addition of sugar to the brine during the curing process. Table II gives data obtained during two seasons in connection with the manufacture of dill pickles. The results show that a marked increase in the percentage of bloaters formed occurred when sugar was added to the brine and points strongly to the undesirability of such additions.

Bloater counts were also made in connection with the salt stock experiment involved in Fig. 2. Special precautions were taken to insure uniformity of stock before the dextrose was added on the 11th day. The results of the counts given in Table III show more than a three-fold increase in bloaters in barrels to which sugar was added.

Particular importance is attributed to the results of this experiment because of the precautions taken to keep all factors constant except the quantity of sugar added. It demonstrates not only the ineffectiveness of the practice of adding sugar to the brine to increase brine acidity (see Fig. 2), but also the decided undesirability of the practice from the viewpoint of the quality of the salt stock produced.

So far the studies which have been reported have been confined to those of the production of salt stock or dills cured in small lots; that is, three or four

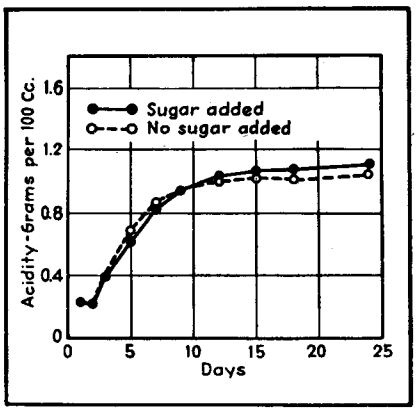

Fig. 8. Influence of the addition of sugar (3.5 lb. of dextrose at start) to dill brines. Graph represents comparative averages of values from four experiments conducted in three seasons.

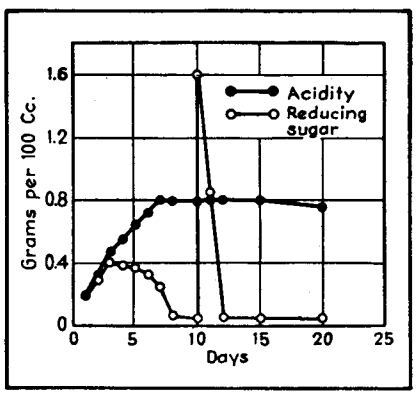

Fig. 9. 1939 salt stock, vat study, showing influence of addition of sugar to 20-deg. brine on tenth day. Salting schedule: 20 deg. first week, raised 10 deg. per week thereafter.

bushels of cucumbers cured in barrels. A single experiment involving the use of a vat of cucumbers has been conducted and the observations were very striking. This experiment is outlined as follows:

An 85-bu. vat, salted according to a 20-deg. schedule, was inoculated during the first 24 hours with 20 gal. of a brine which was undergoing a rapid acid fermentation. This vat in turn exhibited an active acid fermentation during the first week of the curing process. On the tenth day, 85 lb. of dextrose was added to the brine. The brine was then mixed by pumping-over for an hour. Observations made include change in brine sugar concentration, brine acidity changes, comparative rate of gas evolution and

TABLE I—Influence of Addition of Sugar to Dill Brines During Fermentation.

(Brine acidity, on 18th day, of individual lots receiving treatments listed below. Acidity expressed as grams lactic acid per 100 ml. brine.)

	Treatment			
			Sugar added	
Year	No sugar added (control)	At start	On 7th or 10th day	At 2-day intervals
1937	1.08	1.16	.....	.....
	1.12	1.13	.....	.....
Mean	1.100	1.145	.....	.....
1938	1.01	1.20	1.08	.....
	1.21	1.24	1.10	.....
Mean	1.110	1.220	1.090	.....
1939	0.98	1.12	1.07	0.97
	1.03	1.00	1.04	1.11
Mean	1.005	1.06	1.055	1.040

changes in the microbiological flora induced by this treatment. Fig. 9 presents the observed changes in brine acidity and brine sugar concentration during the first 25 days of the curing of this vat. It is evident that the addition of sugar to this lot of fermenting salt stock was of no significance whatever, in respect to acid formation. The disappearance of sugar was exceedingly rapid. To further indicate the rate of sugar decomposition, Table IV has been prepared.

Gas evolution took place so rapidly that several gallons of brine overflowed

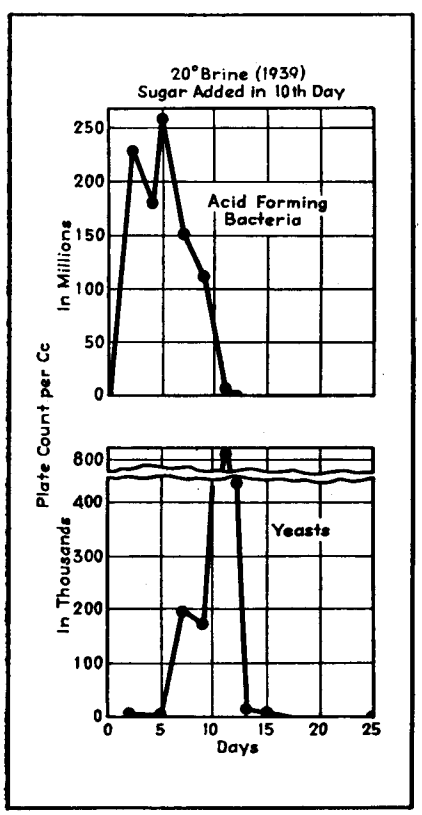

Fig. 10. 1939 salt stock, vat study, showing influence of addition of sugar to 20-deg. brine on tenth day upon the growth of acid-forming bacteria and yeasts.

TABLE II — Bloaters Formed During Production of Dills.*

[In lots which received sugar at different times during the fermentation and in lots which received no additional sugar (control).]

Time of addition of sugar to brine	Percentage of bloaters: 2,400 count size (1939 studies) Sugar added lot	Control	800–1,000 count size (1938 studies) Sugar added lot	Control
At start.....	18	4	78	20
On 7th day.....	..	..	70	20
On 10th day....	26	4	..	..
** At intervals..	17	4	..	..

* Salting schedules: All lots received standard treatment involving addition of dill weed, mixed spices, 0.5 gal. 110 grain vinegar, and salt at rate of 0.45 lb. per gallon capacity of barrel at start. Barrels were headed, filled with water and rolled at frequent intervals early.

Sugar-added lots received 3.5 lb. dextrose at times indicated.

** 0.7 lb. dextrose added at start and subsequently on 4th, 6th, 8th and 10th days.

TABLE III — Bloaters Formed During Production of Salt Stock.*

[In a lot which received 3.5 lb. of dextrose on eleventh day and a lot which received no additional sugar (control).]

Treatment	Percentage of bloaters
Sugar-added lot.....	91
Control (no added sugar).....	28

* Cured according to 40 deg. salting schedule.

TABLE IV—Changes in Titratable Acidity and Sugar Concentration of Brines.

(Immediately preceding and following the addition of 85 lb. of dextrose to an 85-bu. vat of salt stock on tenth day.)

Starting (days)	Titratable acidity (Expressed as gm. lactic per 100 ml.)	Sugar concentration (Expressed as gm. glucose per 100 ml.)
8.....	0.79	0.06
10 (prior to addition of sugar).....	0.79	0.04
10 (after addition of sugar calculated...	....	1.6 or greater
11 (11:00 a.m.).....	0.80	0.85
11 (4:00 p.m.).....	0.80	0.53
11 (11:00 p.m.).....	0.81	0.12
12.....	0.80	0.05
15.....	0.80	0.05

the vat, because of volume changes induced by gas formation. This extremely rapid gas production and rapid sugar destruction indicated intense microbiological activity. Bacteriological analyses of the brine of this vat were made at daily intervals during the period of active fermentation. Microbial population relationships are shown in Fig. 10. The curve in the upper part of this figure shows that the acid-forming bacteria count was high during the first week, the peak being reached on the fifth day. Subsequent to this time, a rapid decline in numbers occurred in spite of the addition of sugar to the brine on the tenth day. This fermentation is shown to have been more or less complete on the twelfth day.

The yeast population on the other hand (lower part of curve) presents an entirely different picture. The yeast count increased rapidly after the fifth day, attained an apparent maximum on the seventh day and then started to decrease. Upon addition of sugar on the tenth day, the yeast count jumped to the exceedingly high figure of 810,000 per cubic centimeter on the eleventh day and dropped rapidly to a very low figure on the thirteenth day.

It will be recalled that, in Table IV, chemical analysis of the brine indicated that the brine sugar concentration on the twelfth day had already diminished to a very low equilibrium level.

Additional data on differences in microbial population induced by the addition of sugar to brines is shown in Fig. 11. These represent observations on some of the dill experiments previously described in this report.

Part A of Fig. 11 represents the 1937 studies. The acid forming bacteria curve (upper part) indicate that there was a marked increase in the number of these organisms in the case where sugar was added to the brine as compared with the no sugar treatment. The lower curves of part A show the yeast population in the same brines. As was true for acid-forming bacteria, the yeast counts attained a much higher level and were higher over a considerably longer period in the treatment receiving added sugar than in the control lot.

In part B of Fig. 11 (1939 studies) a general relationship very similar to that shown in part A is seen. In this latter case, however, the difference in the population of acid-forming bacteria was not as great between treatments as in the 1937 studies. However, the lower curves of part B indicate that the yeast population was markedly different between the treatment receiving added sugar and the control.

It would therefore seem, from the limited bacteriological observations presented here, that the addition of sugar to brines at the start of the curing of salt stock or dills results in a condition favoring the development of increased microbial populations. The quantitative relationships in this respect may vary considerably from one time to another. This increase in the number of organisms may appear in some cases to be that of the acid-forming bacteria, in other cases that of the yeasts, and in still other cases there may be greater numbers of both types of organisms. The observed increase in acid-forming bacteria which developed when sugar was added to brines before or during the fermentation has not been reflected

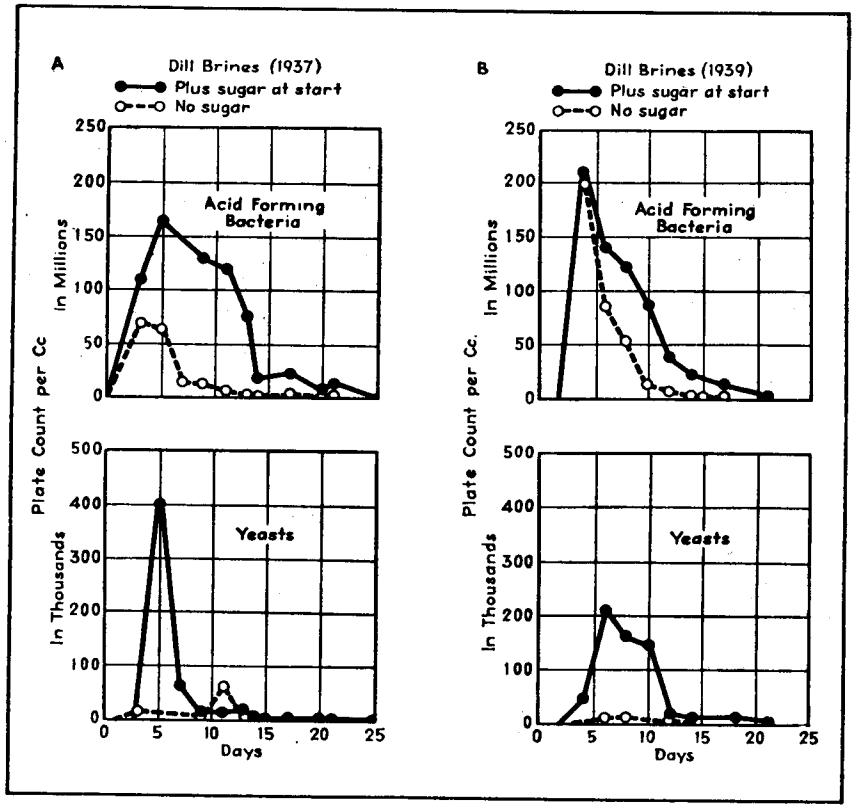

Fig. 11. Dill studies, showing influence of addition of sugar at the start upon growth of acid-forming bacteria and yeasts.

in a significant increase in brine acidity.

Summary and Conclusions

Under the conditions described, observations have been reported on the addition of sugar to brines before fermentation begins, or during fermentation, in the production of dills and salt stock. This report deals with studies conducted during four curing seasons, involving several salting treatments.

The addition of sugar to salt stock or dill brines, prior to or during active fermentation, caused no significant change in brine acidity as compared to control treatments. Furthermore, there was no evidence of an acceleration of acid formation when sugar was added at the start or after the fermentation was in progress.

The addition of sugar brought about a large increase in the proportion of bloaters formed during the production of either salt stock or dills.