Observations on Bloater Formation in Cucumber Fermentation[1]

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AT the present time there is much difference of opinion concerning the condition to which the authors of this paper refer as "bloater" formation during the curing of salt stock or dills. There is little agreement among commercial pickle packers as to the nature or cause of this condition. However, it is generally admitted that bloaters occur at all pickle plants. The proportion may vary from year to year or may differ decidedly from one plant or station to another. The occurrence of bloaters is practically always considered undesirable and frequently is a source of economic loss, especially in the making of dills.

In the literature of cucumber salting are references to "floaters," "hollow pickles," and "bloaters." Certain investigators—LeFevre (4, 5) and Tanner (7)—mention both "floaters" and "hollow pickles" and suggest different explanation for the occurrence of each. Accordingly, it would seem that the terms "floaters" and "hollow pickles" were not used by these investigators as different names for the same form of cucumber but rather as designations of two different types found in cured salt stock or dills.

A multitude of opinions have been offered in attempts to explain the cause of floaters, hollow pickles or bloaters. Many of these views are directly contradictory in nature. Unfortunately most of the opinions have been unsupported by data collected from detailed experimental studies. From a review of the literature it appears that two principal causes are suggested for the occurrence of cucumbers which are classified under the terms mentioned above.

One cause suggested is that they are the result of structural characteristics of the cucumber. According to this view there might be hollow spaces in the interior of the cucumber prior to the time of brining, or peculiarities of structure might exist in certain varieties or in cucumbers grown under certain conditions which predispose the cucumbers to form floaters, hollow pickles, or bloaters during the curing process. This view has been expressed by LeFevre (4, 5), Tanner (7), Switzer (6), Campbell (1) and many packers.

The other suggested cause is that the above mentioned forms are produced by the curing method or by the fermentation process. The following factors have been mentioned as influencing the development of floaters, hollow pickles, and bloaters; hardening of the skin as the result of the action of the brine on the skin; gas formation in the interior of the cucumber occurring either naturally or as the result of faulty handling of the green cucumbers; the use of brine of improper strength; and improper heading of vats. LeFevre (4), Tanner (7), and many pickle packers have made these suggestions.

In this connection the observation of Wustenfeld and Kreipe (10) is significant. They reported that cucumbers did not become hollow in an experiment they conducted in which fermentation was prevented by the addition of an effective preservative to the liquid.

In order to simplify the presentation of data, the authors of this paper will use only the term "bloaters." This term will refer to cucumbers in either salt stock or dills which float on the brine when the head of the container is removed or to cucumbers which are hollow or have large hollow spaces in the interior.

AN investigation of the chemical, physical, and microbiological factors encountered in the commercial manufacture of cucumber pickles has been in progress at the Raleigh Station for the past six years. The National Pickling variety has been utilized in all of these experiments. In this investigation no definite study of the cause and prevention of bloater formation has been planned. However, from the very nature of the experiments, and of the observations and measurements which are made during the curing process, much light has been shed on this puzzling problem of pickle manufacturing. Accordingly, the results which are reported will be presented as a series of observations.

An extensive investigation of the influence of brine salinity on the curing process and salt stock quality has been conducted. At first these studies were made in barrels but for the past three years small sized vats also have been utilized. In connection with other measurements made on the salt stock produced, counts of the

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number of bloaters formed in lots receiving different salting treatments were made.

The earliest observations were on stock of medium* and large† sizes, salted separately according to a given procedure. Counts were made of the entire quantity of salt stock in barrels brined in duplicate. One hundred barrels of salt stock were counted during two seasons. Six different salting schedules, outlined in Table I, were followed.

The data obtained in these studies is presented graphically in Figure 1. From this data it will be seen that in every case a relatively low percentage of bloaters were

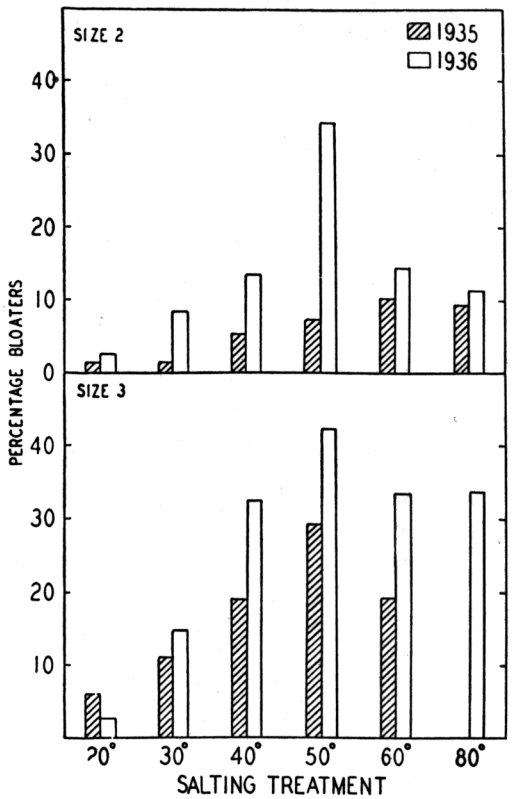

Figure 1. Relation between salting treatment followed and proportion of bloaters formed. Salt stock cured in barrels.

formed in lots receiving low salinity brines during the early portion of the curing period. The absolute values obtained with a given size were different for the two years reported. However, the same general trend was indicated for the different lots for both seasons. A further significant relationship is indicated in Figure 1. The proportions of bloaters formed in lots receiving any given treatment were always distinctly smaller in the medium sizes than in the large sizes of cucumbers.

These experiments were continued with vat studies made on a commercial scale. The salting schedules followed were essentially the same as before with the exception of the omission of the 50° treatment. The vats were filled with fresh cucumbers of mixed sizes, the proportion of each size roughly approximating field run. Special precautions were taken to assure that the cucumbers in each vat were as similar as was possible. This similarity was considered from the view points of appearance, time of harvest and locality in which grown.

In making bloater counts it was necessary to restrict observations to only a fraction of the total salt stock in the vat. A typical sample was obtained by forcing to the bottom of the vat a 14-inch galvanized tube having a length equal to the height of the vat. Placing the tube in the vat caused only negligible disturbance of the salt stock and the sample obtained was representative of the vat.

Figure 2 shows the results obtained from the bloater counts of such samples. A relationship very similar to that previously indicated was found. Again it should be noted that the relative proportion of bloaters which were found in stock of a given size receiving the same salting treatment was decidedly different for the two years reported.

Figure 3 presents a summarization of the data shown in Figures 1 and 2. The data show that extreme variation in the size of containers had little or no effect so far as the general relationship between early brine salinity and proportion of bloaters formed is concerned. The conclusions, which will be drawn from data to be presented later in this paper, will aid in explaining the variations in quantitative relationships as encountered in studies conducted during two different years or between the experiments involving barrels and vats as containers.

Observations on bloater formation in dills were made in connection with an experiment which has been previ-

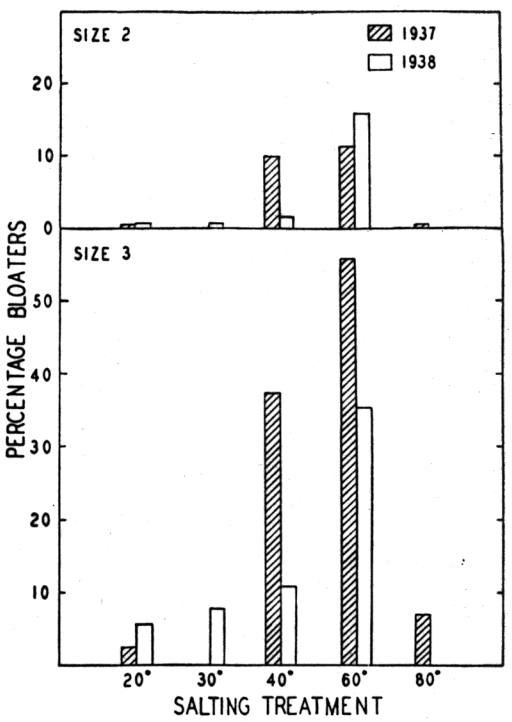

Figure 2. Relation between salting treatment followed and proportion of bloaters formed. Salt stock cured in small vats. Values are averages of duplicate vats for each treatment.

* Approximately 1800 to 2400 per 45-gallon cask.
† Approximately 1000 to 1200 " " " "

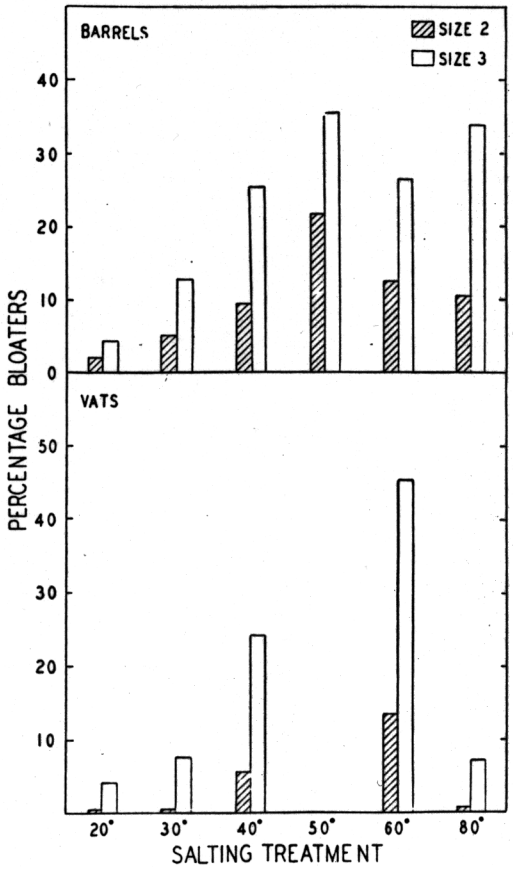

Figure 3. Relation between salting treatment followed and proportion of bloaters formed. Data obtained from studies involving 100 barrels and 18 vats.

ously reported (3). These bloaters counts were made approximately four months after the cucumbers were brined. In the dill experiment a number of different brining treatments were followed. Some of these treatments involved the addition of different quantities of vinegar to the brine. Furthermore, certain lots were acidified with lactic acid and sugar was added to others. Striking differences in bloater counts in lots receiving these different treatments were found. Table II outlines the treatments followed and the proportion of bloaters formed.

It will be seen from this table that the addition of lactic acid at the start, or of sugar either at the start or on the 10th day favored a great increase in the proportion of bloaters formed. Lots receiving one gallon of vinegar at the start yielded a somewhat larger proportion of bloaters than the non-acid treatment.

IN the studies which have been reported pertaining to salt stock or dill production the lots of fresh cucumbers required for the different treatments were reasonably similar at the time the salting experiment was started. After curing, however, decided differences in the proportions of bloaters were observed in the experimental lots. Accordingly, it is concluded that the differences observed between lots with respect to bloater formation were induced by the treatments followed and were not due to initial differences in the fresh cucumbers.

TABLE I

Schedule of Treatments Followed in Brine Salinity Studies

Initial Brine Concentration	Rate of Increase of Brine Concentration
20°	Up 5° per week to 60
30°	Up 5° per week to 60
40°	Up 2° per week to 60
50°	Up 1° per week to 60
60°	Held at 60°
80°	Held at 80°

TABLE II

Dill Curing Treatments and Proportion of Bloaters Formed

	Percentage Bloaters [1]
No acid added	33
1.0 gallon vinegar at start	48
Lactic acid (= 1.75 gallon vinegar) at start	67
Sugar (3.5 lbs. per barrel) at start	78
Sugar (3.5 lbs. per barrel) on 10th day	70

[1] All values are the average of duplicate lots for each treatment.

For the determination of bloater counts the usual plant method was followed for detecting whether the cucumbers were bloated; namely, the squeezing of individual cucumbers. If they were bloated they would break generally at one of the grooves parallel to the long dimension of the fruit. This method has, on the whole, proven satisfactory.

As a part of the investigation upon salt stock production, a number of cucumbers were removed from the brine at frequent intervals during the curing process and preserved for chemical analyses. The cucumbers were prepared for preservation by cutting, first lengthwise and then cross-wise. In the process of this preparation it became evident that many different types of lesions or injuries of the inner tissues of the cucumber might be made during the curing of salt stock. These lesions were quite varied in appearance but always resulted in the formation of hollow spaces in the interior of the cucumbers. For this reason it is considered that there must be a relationship between this tissue injury and bloater formation.

Photographs of a number of examples of tissue injury are presented here. These photographs were taken in 1939 but are also representative of observations made in the 1937 and 1938 curing seasons. Probably the most common conception of a bloater is the typical "balloon" type in which the seed mass has more or less completely shrunken to a thin layer which lies against the inner surface of the rind. Such a bloater when cut length-wise presents the appearance of a trough, and when cut cross-wise appears as a ring with a large open center as shown in Figure 4. Examples of less extreme tissue injury are shown in Figure 5. Cucumbers of this type probably should be considered as bloaters, inasmuch as distinct hollow spaces are present.

It is doubtless commonly known that the bloaters of the "balloon" type are completely gas-filled when taken from the brine early in the curing period. Also the condition known as "frying" is frequently observed during the early curing stages. In this latter case there is a "sizzling" of the cucumber tissue when the fruit is

ship may be suggested by the fact that hydrogen was often found in the gas obtained from bloaters.

The results presented in Table III indicate the presence of a very large proportion of carbon dioxide in many of the bloaters on which gas analyses were made. This fact suggests yeast as a possible microbiological factor in these cases. Etchells (2) has called attention to the fact that the yeast fermentation is common to all cucumber fermentations.

In the report on dill pickle studies (3) a relationship was shown to exist between the dill curing treatments followed and the yeast populations which developed. These data are graphically summarized in Figure 6. The curves are especially significant in view of the fact that the proportion of bloaters formed differed greatly from treatment to treatment. These differences are also shown in this figure.

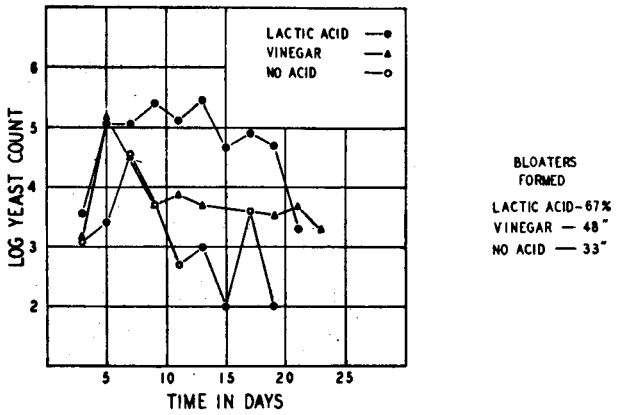

Figure 6. Yeast population in dill brines and proportion of bloaters produced.

It then seemed that if this presumed relationship between yeast activity and bloater formation existed, it should be possible to demonstrate this fact experimentally. In order to make such a test, an experiment described by Veldhuis, Etchells, Jones and Veerhoff (9) was conducted. In this case 4 barrels of large-sized cucumbers, well mixed to assure uniformity, were covered with 40° brine and held at this concentration for 10 days, after which the partially cured salt stock was removed from the brine and equally divided between four other barrels. The transferred salt stock was then covered with equal portions of brine from the four original barrels. So far all conditions had been the same for the entire lot of salt stock. At this point 3.5 pounds of dextrose per barrel were added to one pair of barrels and the other pair was held as a check.

A most vigorous gaseous fermentation took place in the barrels receiving sugar. Gas evolution began within a few hours after the sugar was added and practically ceased after a period of 48 hours. Chemical analyses of the brine indicated that the sugar which was added was utilized during the same period of time. No significant change occurred in the brine acidity during or following this period of active fermentation. All indications are that the sugar added to brine of the one pair of barrels was utilized by an extremely active yeast fermentation.

Counts of these four barrels after the curing process was completed (12th week) showed more than three times as many bloaters in the lots to which sugar was added than in the control lots as shown in Table IV.

From this experiment it would seem evident that the decided increase in percentage of bloaters formed, occurred as a result of the gaseous fermentation induced by the addition of dextrose to the brine of the partially cured salt stock.

TABLE IV

Influence of addition of 3.5 pounds of dextrose per barrel to salt stock* on 10th day

Treatment	Percentage Bloaters
Sugar-added lot	
S 29	91.3
S 30	92.6
Average	91.5
Control lot (no sugar added)	
S 27	30.9
S 28	24.1
Average	27.5

* Cured 40° schedule.

IT seems desirable to enlarge upon the dill experiment described earlier. The data summarized in Table II indicate the occurrence of a relatively high percentage of bloaters in lots receiving suger or lactic acid as outlined previously in this paper. It has been shown in another report (3) that when lactic acid was added to the brine in appreciably large quantities at the beginning of the curing period the nature of the fermentation process was distinctly altered. Under such conditions the microbiological activity of the brine was greatly retarded, and acid fermentation was practically inhibited. Accordingly, a comparatively high brine sugar concentration developed. As shown in Figure 6 of this report an active yeast fermentation then started on the fifth day and continued for two weeks. The effect, therefore, of adding this lactic acid to the brine was somewhat similar to that produced by the supplementary addition of sugar to the brine, in that it favored the development of high brine sugar concentration and a subsequently vigorous gaseous (yeast) fermentation. The addition of relatively large quantities of vinegar to the brine at the beginning of the curing period probably exerts an effect similar to that described for the action of lactic acid. In this connection the inhibitory influence of vinegar on acid-forming bacteria is much less marked than is the similar action of lactic acid in comparable concentration.

Reference is again made to the data presented in Figures 1 and 2. It will be recalled that a general relationship was indicated between the salting treatment followed and the proportion of bloaters formed in lots receiving the different treatments during any given year. There was no close quantitative agreement shown, however, in the percentage of bloaters formed in lots receiving a given salting treatment over a period of two or more years. An explanation for the occurrence of these variations may be seen in light of the evidence which has

been shown indicating that bloater formation is related to microbiological activity. Factors such as temperature or degree of inoculation greatly influence microbiological activity. Such factors may vary enough from year to year to account for the observed differences which have been shown in the percentage of bloaters formed.

Summary and Conclusions

THE authors have presented a number of observations made in connection with a general study of the production of salt stock and dill pickles. Such observations were presented with reference to the nature and proportion of bloaters formed in lots of cucumbers receiving different curing treatments. Attention has been called to the presence and nature of gas in bloaters. Evidence pointing to a relationship between microbiological activity with respect particularly to yeast population and the proportion of bloaters formed has been shown.

These studies conducted under the conditions described have shown that various modifications of the salting procedure will decidedly influence the proportion of bloaters formed. Relatively large percentages of bloaters are formed when brines of high salinity are used during the early portion of the curing period in salt stock production. The addition of appreciable quantities of lactic acid to dills at the time of brining and the addition of sugar to the brines of either dills or salt stock, also favors the formation of relatively high percentages of bloaters. This response was observed when sugar in quantities as small as one percent of the cucumbers used was added either at the beginning of the curing period or subsequently during active fermentation. The addition of lactic acid or sugar to the brines as outlined above was also found to favor the development of greatly increased yeast populations during the curing period.

From these studies it is concluded that bloater formation is related to a gaseous fermentation. Factors which favor the development of a vigorous gaseous fermentation favor the production of appreciably large quantities of bloaters.

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