A Bacteriological Study of the Manufacture of Fresh Cucumber Pickle*,**

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PREVIOUS publications[2, 3] have pointed out that the successful manufacture of a quality-type of fresh cucumber pickle depends chiefly upon controlled pasteurization (160° F. for 20 min. or 165° F. for 15 min.) followed by prompt cooling. Attention has been called to the fact that while sufficient heat should be employed to destroy the microorganisms responsible for spoilage, care should be exercised to not overheat, since this would result principally in an excessive loss of crispness of the slices, due to physical changes in their structure. Hence, it is self-evident that the correct temperature for pasteurization, as well as that during the subsequent holding period, must be arrived at through careful determinations that give adequate consideration to the principal factors involved, namely, (a) the types and numbers of organisms to be killed and (b) the possible changes in the physical structure of the slices. By establishing a proper correlation between heat and the above factors, it is possible to arrive at a product which will not only remain free from spoilage but will retain the maximum fresh characteristics over a period of several months' storage.

During the past several season, investigational work has been carried out on the commercial manufacture of fresh cucumber pickle. Bacteriological analyses have shown that yeasts and acid-forming bacteria are the principal types of organisms involved in the spoilage of unpasteurized or inadequately pasteurized fresh cucumber pickle. Also, it has been shown that, under the usual conditions of manufacture, controlled pasteurization at 160° F. for 20 min. or at 165° F. for 15 min. is sufficient to kill the microbial life responsible for spoilage, and still allow the slice to retain a major portion of the natural crispness over a period of several months' storage.

Furthermore, as part of the regular plant procedure, routine bacteriological control has been carried out on the manufacture of this type of pickle. Examinations have been made with respect to the microorganisms in unpasteurized and pasteurized pickle as well as upon the pickle at various stages of manufacture. In addition, routine observations have been made with respect to crispness, flavor, appearance, acidity and degrees Baume' on the finished product, and amount of vacuum in the containers.

The material to be presented here will deal chiefly with routine bacteriological findings during the manufacture of fresh cucumber pickle.

Experimental Procedure

THE bacteriological and physical methods of analysis, as well as the preparation of the pickle, were the same as those previously described[3] and will not be discussed in detail. Likewise, the method and equipment for pasteurizing fresh cucumber pickle have been discussed in a previous publication [2].

Briefly, the preparation of the pickle was as follows: Sound pickling cucumbers, 1200-1800 count size*, were washed in a rotary vegetable washer, sliced by machine and then placed in wooden tanks of 40-bushel capacity. The slices were covered with 30° salometer brine and allowed to remain overnight. Upon removal from the tanks, the slices were packed in glass jars (12.5 or 25 oz.) which contained about a level teaspoonful of mustard and celery seed, the ratio being 2 to 1. Hot liquor at approximately 160°-170° F. was poured on the slices; the liquor was made up to finish at 14-15 grains acetic acid and 16-17 degrees Baume' and included turmeric for coloring. The final ratio of slices to liquor was about 5 to 3 by volume. After closing**, the jars were packed into rectangular, wooden crates which were loaded into the pasteurizing tank, having a capacity of 100 crates, and pasteurized at 160° F. for 20 min. or at 165° F. for 15 min., followed by prompt cooling. Prior to and during the holding period, the temperatures of jars at the top and bottom of the tank were recorded at 10 min. intervals. The water temperature was also taken at the same time.

Jars from various levels throughout the tank were selected for bacteriological analyses. In the early studies

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* Number per 45-gallon cask.

** 1937, Halyard Crown Cap; 1938, Vacuum White Cap; 1939, same as 1938; 1940, Vapor-Vacuum White Cap.

(1937) usually jars from each of the five tiers of crates were examined. Later on, during the following seasons, it was found possible to limit the number of jars examined from each pasteurized batch so that only two representative areas from the tank were sampled.

Bacteriological plate counts were made by plating the liquor, or dilutions of the liquor on nutritive caseinate agar (Difco.). Yeast counts were determined in the same manner except that tartaric acid agar* was used as the plating medium. Plates made with the nutritive caseinate agar were incubated 48-72 hours at 35° C. (95° F.) and counted; plates made with tartaric acid agar were incubated five days at 35° C. and counted. At each plating interval, observations were made with respect to crispness, flavor and appearance of the slices. Vacuum readings on the containers were taken prior to opening for the bacteriological analyses of the contents. Samples of the liquor were examined as to the acidity by titrating a six cc. sample with N/10 sodium hydroxide, using phenolphthalein as the indicator and expressing the results in grains of acetic acid. Also, the degrees Baume' of the liquor was recorded.

Discussion of Results

THE percentage of each pack examined during the period of manufacture from 1937 to 1940 is shown in Table 1. During this period, the pack increased from about 5,000 (1937) to 50,000 dozens (1940). It is noted that a relatively higher percentage of jars was examined during the 1937 season. Since this was the first season of commercial-scale production, a greater number of samples was taken from the pasteurized and unpasteurized batches of pickle. During the subsequent seasons, the number of jars examined was reduced materially. However, a sample of each pasteurized batch (100 crates) was always examined. With the exception of the 1940 season, unpasteurized samples were taken at random during each day's run.

It has been found that the cucumbers as they come in from the field may have on their surfaces millions of microorganisms. The major portion of the organisms at this stage are the resistant spore-forming bacteria. However, yeasts and acid-forming bacteria are also present, and in spite of thorough washing they are carried over by the slices into the brining tanks. Even during the short period the slices are in the brine, relatively high populations of the acid-forming bacteria and yeasts may develop. This is clearly shown by the following observations. During the 1937 season, with a series of five different batches, examinations were made of the brine just after the slices were placed in the tanks as well as of the brine at the time the slices were removed. The generalized results, with respect to microorganisms per cc. of brine were as follows: (a) Just after the slices were added, range of 9,000 to 16,000 bacteria and 1,500 to 4,500 yeasts; (b) at the time the slices were removed, 26,000 to 7,600,000 bacteria and 650 to 38,000 yeasts.

The bacterial populations were composed chiefly of acid-forming bacteria; there was no particular change in the number of resistant spore-forming bacteria during the brining period. Other observations showed that when care was not exercised during the cleaning of the tanks after each batch of slices was removed, a considerable number of acid-forming bacteria and yeasts remained which, added to the number introduced with the next batch of slices, provided a greater inoculum for growth during the next brining period.

It is evident from the observations on the growth of the acid-forming bacteria and yeasts in the brine during the overnight brining interval, that spoilage of unpasteurized or inadequately pasteurized pickle is due to these organisms, since either one type or the other, and often both, survive the application of hot liquor.

The spices used provide another source of microorganisms which enter into the pickle during manufacture. The results shown in Table 2 are based on several analyses made from time to time upon the bulk (barreled) spices employed. The total numbers of organisms found are comparable to those reported by other recent workers.[1, 4] The results in Table 2 show that yeasts were absent from the lowest dilution plated, namely, 1-10; also, the bacteria found were mostly of the non-spore-forming types. The typical acid-formers were not noted. Whether the organisms from the spices are capable of fermenting the unpasteurized pickle is problematical, since it depends on their ability to survive the hot liquor as well as on their ability to grow at the finished acid content of about 14 to 15 grains of acetic acid. The observations made so far have indicated that principally the yeasts, and to a less extent, the typical acid-forming bacteria of cucumber origin, are associated with spoilage because they are able to tolerate the acid content of the pickle.

Table 1. Number of jars of pickle examined over a four-year period. (1937-1940)*

Year	Unpasteurized jars	Pasteurized jars	Total number of jars examined	Percent of pack examined
1937	58	448	506	0.843
1938	139	823	962	0.334
1939	77	286	363	0.112
1940	0	211	211	0.035
4-year total	274	1,768	2,042	

* Over a four-year period of manufacture 0.16 percent of all jars packed were examined; of these, 0.14 percent were pasteurized and .02 percent were unpasteurized.

Table 2. Results of bacteriological examination of spices used in manufacture of fresh cucumber pickle.

Spice used	Bacteria*	Yeasts*
Celery seed	340,000	0†
Mustard seed	2,250	0†
Turmeric powder	110,000	0†

* Per gram.
† Less than 10 colonies per gram.

Table 3 shows the results of routine examination, with respect to bacteria and yeasts, of one day's run (Batch 14) of pasteurized pickle consisting of seven separate pasteurizations or sub-batches. Initial counts following pasteurization are shown as well as counts after one- and eight-month storage periods. The initial value shown for unpasteurized pickle is representative of the day's run.

* Laboratory Manual (Methods of Analysis of Milk and Its Products) Int. Assn. of Milk Dealers, p. 81 (1933).

Table 3. Results of routine bacteriological examination of one day's run* of pasteurized fresh cucumber pickle (Batch 14, 1937).

Batch No. 14	Bacteria per cc. Initial	After 1 mo.	After 8 mo.	Yeasts per cc. Initial	After 1 mo.	After 8 mo.
Unpasteurized	6,460			0†		
Pasteurized						
14A	2,490	1,820	2,030	0†	0†	0†
14B	1,820	1,340	3,100	0†	0†	0†
14C	3,390	2,700	940	0†	0†	0†
14D	2,566	1,450	1,970	0†	0†	0†
14E	2,840	3,080	840	0†	0†	0†
14F	4,030	3,940	725	0†	0†	0†
14G	1,370	520	..	0†	0†	0†

* Chosen at random.
† Less than 10 colonies per cc.

In general, the results show that pasteurization reduced the count below the initial count on the unpasteurized pickle and that, presumably, only the heat resistant, spore-forming organisms from cucumbers and soil survived. During the storage there was little change in the counts other than those to be expected from using different jars at each examination interval. It is noted that with this particular batch, the application of the hot liquor succeeded in killing the yeasts carried over from the slices; however, this is the exception rather than the rule.

Near the conclusion of the 1937 season, the washing procedure was modified as follows: Prior to washing in the rotary washer, the cucumbers were soaked and stirred successively in two wooden tubs made from an olive cask cut in two, each of approximately 10 bushel capacity, removing from the first tub to the second. The water was changed frequently in both tubs.

It was found that by paying strict attention to this phase of the washing procedure, a marked decrease in the number of resistant spore-forming organisms surviving pasteurization could be effected. Furthermore, this treatment aided materially in loosening the adhering particles of soil from the cucumbers, thus increasing the efficiency of the rotary washing treatment.

A comparison of the numbers of surviving organisms in fresh cucumber pickle put up in jars of two sizes, 12.5- and 25-oz., is shown in Table 4. No significant differences are shown, the mean counts for the 12.5- and the 25-oz. jars being practically the same.

Since the above relationship was found to exist, no attempt was made to separate the data with respect to jar size for the 1939 and 1940 seasons. The calculations of the mean seasonal averages for these years include data for jars of both sizes.

The mean seasonal averages with respect to organisms present in unpasteurized, pasteurized and stored pickle are shown in Table 5. In general, the same relationship exists that has been previously discussed, namely, that only the resistant organisms survive pasteurization and these evidence little change in numbers during storage. Also, yeasts were found to comprise a portion of the counts on unpasteurized pickle but these likewise were unable to withstand pasteurization. There were differences with respect to counts for both unpasteurized and pasteurized pickle between seasons. These can be attributed in part to slight variations in plant procedure as well as to yearly changes in the introduced microflora. The initial counts on pasteurized pickle for the 1938 season, during which soaking of the cucumbers prior to washing was introduced as regular procedure, tended to be somewhat less than those for the following season (1939). It is possible that the same care was not exercised in washing in the latter case. Progressive improvement in routine procedure, control measures and attention to detail during the 1940 season is reflected in part by the relatively low counts on the pasteurized samples.

Table 4. Comparison of bacterial counts on samples of pickle put up in jars of different size.

1939	12.5-oz. jars	25-oz. jars
Bacterial count per cc.*	1,872	1,915
Maximum	3,520	4,120
Minimum	790	975

* Bacterial counts averaged for 20 successive batches for each size jar.

The examination of the manufactured fresh cucumber pickle with respect to acid content, degrees Baume' and vacuum in the containers over the four-year period is shown in Table 6. The calculations are based on a representative number of consecutive runs (see footnote in Table 5) for all years shown. Of particular interest are the results with respect to crispness. This physical characteristic was determined by biting or chewing a number of slices; the degree of crispness, being a relative value, was recorded as the proportion of crispness as compared to that originally present in the slices. The results for 1937 and 1938 indicate that following the one-month storage period, there was a loss of crispness. It was also observed that there was a loss of whiteness of the slices.

Several general observations with respect to plant procedure are presented with the view to helping the plant operator.

It has been consistently found that jars with a final vacuum somewhat in excess of 10 inches of mercury will lose their attractive whiteness and take on the appearance of cured cucumbers within a very short time after being opened (5-10 min.). This change is not accompanied by any appreciable loss in crispness, but seems to be purely a gas exchange relationship. However, it must be admitted that for discriminating manufacturers, the appearance of the opened product is of considerable importance. It is felt that for this product the final vacuum obtained should be only sufficient for the adequate closure of the jar during pasteurization. Here the determining factor is the temperature used in the pasteurization procedure.

It has been found that cucumbers showing even slight evidence of molds, resulting from improper handling or shipping, are unsuitable for the manufacture of fresh cucumber pickle. The final product results in a definite "woody" or "earthy" flavor, imparted to the slices by the entrance of mold growth into the tissue.

Finally, care must be exercised to keep all equipment clean during manufacture in order to guard against the

Table 5. Incidence of microorganisms* in unpasteurized, pasteurized, and stored fresh cucumber pickle, covering a four-year period of manufacture (1937-1940).

	Bacteria				Yeasts			
		Pasteurized				Pasteurized		
1937	Unpasteurized	Initial	After 1 mo.	After 8 mo.	Unpasteurized	Initial	After 1 mo.	After 8 mo.
						†	†	†
Count per cc.	14,671	2,102	2,030	2,097	13	0	0	0
Maximum	42,920	2,855	2,780	3,055	60	0	0	0
Minimum	5,100	1,607	1,425	1,370	0	0	0	0
1938								
Count per cc.	6,032	895	550		344	0	0	
Maximum	23,860	1,274	726		2,218	0	0	
Minimum	1,133	640	295		36	0	0	
1939								
Count per cc.	9,340	1,666	3,077		73	0	0	
Maximum	41,833	2,178	4,056		643	0	0	
Minimum	2,833	1,143	1,982		0	0	0	
1940								
Count per cc.		314				0		
Maximum		490				0		
Minimum		138				0		

* The figures shown represent the mean seasonal average with respect to microorganisms per cc. of unpasteurized, pasteurized and stored pickle, based on 10 daily runs for each year reported and representing the following number of sub-batches: 38(1937); 50(1938); 50(1939); 100(1940).
† Less than 10 per cc.

Table 6. Examination of pasteurized fresh cucumber pickle with respect to acid content, degrees Baume', vacuum and crispness over a four-year period.

Year	Acid content**	Degrees Baume'	Vacuum in two jar sizes* 12.5-oz. jar	Vacuum in two jar sizes* 25-oz. jar	Crispness Initial	Crispness 1 mo.	Crispness 8 mo
			inches	inches			
1937†	14-15	16-17	...	5.1	+++±	+++±	+±±
1938	14.2	15.5	9.5	12.8	+++±	+++±	+±±
1939	15.4	17.0	6.1	7.2	++++	+++	. ....
1940	14.6	17.3	12.5	13.5	+++±	+++±	.....

* Inches of mercury.
** Grains of acetic acid.
† Approximate values for acetic acid and Baume'.

introduction of large numbers of organisms. The slices should be handled in enameled ware or suitable metal containers. Rough finished wooden boxes are unsatisfactory since they cannot be cleaned and a luxuriant mold growth will take place during the period of shut-down over the week-end. The same is true for wooden packing tables or similar equipment coming in contact with the liquor or the juice from the slices. A satisfactory method of controlling mold growth on wooden packing tables is as follows: Wash the tables thoroughly with soap and water and allow to dry; then apply hot, two successive coats of boiled linseed oil.

Summary and Conclusions

THE results of a routine bacteriological study of the manufacture of fresh cucumber pickle over a four-year period (1937-1940) have been presented.

Routine analyses were made on the unpasteurized and pasteurized pickle with respect to the bacteria and yeasts present as indicated by plate counts. Observations as to crispness, degrees Baume' and acid content of product and vacuum in the container were made at each plating interval.

In general, the bacteriological findings showed that only the resistant, spore-forming bacteria survived the pasteurizing procedure (160° F. for 20 min. or 165° F. for 15 min.) and that these, in general, showed little or no increase during storage. Considerable populations of acid-forming bacteria and yeasts were built up during the overnight brining period of the slices. Since these organisms generally survive the application of hot liquor, adequately controlled pasteurization must be employed or spoilage will result.

Successful manufacture of fresh cucumber pickle, having all the desired qualities responsible for the wholesome appeal of the characteristically crisp slices of the fresh cucumbers, can be realized through the employment of bacteriological control in conjunction with controlled pasteurization.

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