MORTALITY OF MICROORGANISMS DURING PASTEURIZATION OF CUCUMBER PICKLE[1,2]

JOHN L. ETCHELLS

Bureau of Agricultural Chemistry and Engineering, U. S. Department of Agriculture, Raleigh, N. C.

AND

IVAN D. JONES

Department of Horticulture, North Carolina Agricultural Experiment Station, Raleigh, N. C.

(Received for publication, July 6, 1942)

During the manufacture of uncured pickle products, controlled pasteurization, 71.1°C.(160°F.) for 20 minutes or 73.9°C.(165°F.) for 15 minutes, must be employed or spoilage of such products will ultimately take place. Previous reports by Etchells (1938), Etchells and Goresline (1940), and Etchells and Ohmer (1941) have repeatedly stressed the importance of this fact. Often active fermentation in improperly pasteurized lots may not become apparent within one month after processing. To illustrate, it has been found that in the manufacture of fresh cucumber sliced pickle and fresh uncured dills, application of the appropriate hot liquor,[3] at approximately 76.7°C.(170°F.), may reduce the numbers of spoilage organisms markedly; and the products may appear to have keeping quality but upon storage may become a total loss owing to the growth of the few organisms which survived.

It is imperative, therefore, that the pasteurizing treatment destroy all microbial life capable of fermenting the liquor. Previous experimental work by Etchells and Goresline (1940) and Etchells and Ohmer (1941) has demonstrated that two groups of organisms are chiefly responsible for spoilage of cucumber pickle. These are (1) acid-forming bacteria and (2) yeasts. The fact that a few organisms of one group or the other and often of both usually survive the application of hot liquor, coupled with their ability to grow at the acid content of the finished uncured pickle products, explains the role these organisms play as a spoilage factor when there is improper pasteurization of such products.

The material to be presented will deal principally with the mortality of strains of acid-forming bacteria and yeasts added to cucumber pickle varying in acid content and subjected to various experimental pasteurizing temperatures.

---

[1] Presented at the Technical School for Pickle and Kraut Packers at East Lansing, Michigan, Feb. 17, 18, and 19, 1942.

[2] Agricultural Chemical Research Division Contribution No. 67. Approved for publication as paper No. 140 of the Journal Series of the North Carolina Agricultural Experiment Station.

[3] Hot liquor made up so the two types of pickle had the following final acid and sugar contents: fresh cucumber sliced pickle, 1.4 to 1.6 per cent acetic acid and 16 to 17 degrees Baumé; fresh dill pickle, .7 to .8 per cent acetic acid and no added sugar.

EXPERIMENTAL PROCEDURE

Previously manufactured fresh cucumber pickle was used in the experimental pasteurization studies. This pickle provided a desirable test medium since the slices and liquor had been in contact long enough to attain equilibrium. Furthermore, it was comparatively free from microorganisms; only the heat-resistant, spore-forming types were present and these occurred in such low numbers as not to interfere with the bacteriological analysis. The results (Table 1) of the examination of five representative 25-ounce jars of the same batch of pickle revealed (in addition to the presence of relatively few bacteria and the absence of yeasts) that the acid content ranged from 1.5 to 1.6 per cent acetic acid [4] and 16.5 to 17 degrees Baumé. Also, the ratio of slices to liquor was about five to three by volume.

Two variations in the acid and sugar contents of the original liquor covering the pickle were obtained by pouring off the liquor (250 c.c. taken

TABLE 1

Examination of Representative 25-Ounce Jars of Fresh Cucumber Pickle (1938 Season) Used for Experiments

Jar No.	Microorganisms		Acid content [1]	Degrees Baumé	Total volume of pickle	Volume of slices [2]	Volume of liquor
	Bacteria	Yeasts					
	per c.c.	*per c.c.*			*c.c.*	*c.c.*	*c.c.*
1	10	0	1.51	16.5	685	435	250
2	90	0	1.53	17.0	683	436	247
3	0 [3]	0	1.52	16.5	695	425	270
4	0 [3]	0	1.47	16.5	680	425	255
5	0 [3]	0	1.60	17.0	675	428	247
Mean			1.53	16.7	683.6	429.8	253.8

[1] Per cent acetic acid. [2] Ratio of slices to liquor, about 5:3 by volume. [3] Less than 10 per c.c.

as the average total amount per jar) and replacing fractions of it with sterile water. In this manner, in addition to using the undiluted liquor, designated as jar treatment A, dilutions of the liquor were made so that approximately one-half and one-quarter of the original amount of liquor remained; these were designated as jar treatments B and C, respectively. An outline of the jar treatments (A, B, and C) including the acidity, Baumé, and pH of the undiluted and diluted liquors, prior to returning them to the slices, is given (Table 2).

Five temperatures were employed in the pasteurization studies, 48.9, 54.4, 60.0, 65.6, and 71.1°C. (120, 130, 140, 150, and 160°F.). A certain number of jars were held at each temperature for 15 minutes and promptly cooled with running water. The pasteurizations were carried out by immersing the jars in water in enameled metal tubs (five and one-half gallon capacity) which were heated with two-burner Pyrofax gas stoves. During heating, the water was circulated by a small motor-driven stirrer.

Seven jars were included in each pasteurizing treatment, consisting of duplicate 25-ounce jars for each jar treatment (A, B, and C) and one jar for temperature control. The last was supplied with thermometer inserted

[4] Equivalent to 15 to 16 "grains" acetic acid.

through a hole in the metal cap and insulated from the metal by a cork bored to fit the thermometer. Temperature readings for both water bath and jar contents were taken at 10-minute intervals up to the holding period and then at five-minute intervals.

The test organisms used included one strain of an acid-forming bacterium and two strains of yeast. These were isolated from cucumber fermentations. Inoculations of each lot of pickle to be heated were made from young, vigorous cultures growing in dextrose (.5 per cent) tryptone (.5

TABLE 2

Jar Treatment for Experimental Lots of Pickle With Respect to Dilution of Original Liquor Covering Slices

Treatment	Lot A (full-strength)	Lot B (½ strength)	Lot C (¼ strength)
Amount of original liquor retained per jar	250 c.c.	125 c.c.	62.5 c.c.
Amount of sterile water added to replace liquor	0 c.c.	125 c.c.	187.5 c.c.
Acid content of liquor mixture [1]	1.53 [2]	.76 [2]	.37 [2]
Baumé of liquor mixture [1]	16.7°	8.6°	5.0°
pH of liquor mixture [1]	3.18	3.25	3.44

[1] These observations were made on liquors prior to returning to the slices. [2] Per cent acetic acid.

per cent) broth (Table 3). The inoculation procedure was as follows: At the time each pasteurizing run was made, the broth cultures were added to the final dilutions of the liquor going to make up jar treatments B and C. The mixtures were then shaken and returned to the slices. In the case of jar treatment A (undiluted), the liquor was poured off and the cultures

TABLE 3

Growth of Test Organisms in Dextrose-Tryptone Broth and Amount of Each Culture Added to Each Jar of Pickle

Experimental run	Incubation period for cultures at 35°C. (95°F.)	Plate count of broth cultures		Amount of broth culture added per 25-oz. jar	
		Acid-former [1]	Yeast [2]	Acid-former [1]	Yeast [2]
	hr.	*per c.c.*	*per c.c.*	*c.c.*	*c.c.*
1 (Table 4)	72	11,000,000	22,000,000	2	1
2 (Table 5)	72	57,000,000	40,000,000	3	1.5
3 (Table 7)	96	25,000,000	20,000,000	3	2
4 (Table 9)	96	19,000,000	20,000,000	225	225
.....	96	.....	18,000,000 [3]	.....	225 [3]

[1] Acid-former No. V-6. [2] Yeast No. F C. [3] Yeast No. V-13.

Note—In experimental runs No. 1, 2, and 3, the inoculum per duplicate set of jars was a composite of the amounts indicated. In experimental run No. 4, separate jars (in duplicate) for each of the three test organisms listed were used.

were added to it, after which the liquor was shaken and returned to the slices. As soon as the cultures were added, the three lots of jars in duplicate were placed in the water bath and heating was begun. Unheated, room-temperature control jars for treatments A. B. and C were likewise inoculated and examined at the start and finish of each pasteurization run with respect to the numbers of organisms present.

The bacteriological counts for the acid-forming bacteria in the jars of heated pickle as well as the room-temperature controls were made after

shaking the jars and plating dilutions of the liquor on nutritive caseinate agar (Difco) as described previously by Etchells and Goresline (1940). The yeast counts were made in the same manner except that acidified dextrose agar [5] was employed as the plating medium. All plates were incubated 72 hours at 35° C. (95° F.) and counted. Observations as to acidity, sugar content, and pH were made according to methods previously outlined by Etchells and Ohmer (1941).

Some experimental work was carried out to determine the effect of heat upon cultures added to jars of sterilized fresh cucumber slices to which no acid or sugar was added during preparation, the slices being covered with .85 per cent saline. In the first series of such experiments, the regular previously outlined procedure as to cultures, temperatures, and

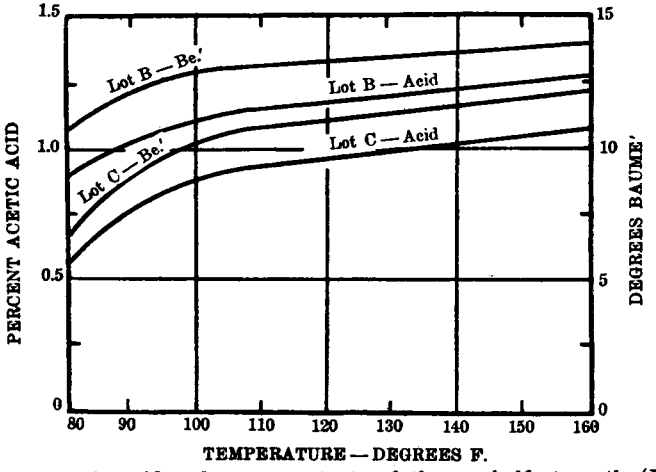

FIG. 1. Increase in acid and sugar contents of the one-half strength (Lot B) and one-quarter strength (Lot C) liquors during heating of 25-ounce jars of pickle to 71.1°C. (160°F.).

holding times was employed. In the second series, a very large inoculum was used (225-c.c. amounts of individual cultures) and the jars were sampled progressively for bacteriological analysis at the times they reached the following temperatures during heating: 48.9, 54.4, 60.0, 65.6, 71.1, and 76.7°C. (120, 130, 140, 150, 160, and 170°F.). Any further variations in the general procedure for certain experiments will be mentioned later.

DISCUSSION OF RESULTS

It is well to point out that during the heating of jars receiving treatments B and C (Table 1) there was an increase in acid and sugar contents of the liquors. This was due to the fact that the sugar and acid contents of the slices were unaltered prior to covering with the diluted experimental liquors, and therefore these constituents were at a higher concentration in the slices than in the liquor. Equalization began when the one-half strength (Lot B) and the one-quarter strength (Lot C) liquors were poured on the slices. The curves presented (Fig. 1) give a reasonable indication as to

[5] Laboratory Manual *(Methods of Analysis of Milk and Its Products)*, Internatl. Assoc. Milk Dealers, Chicago, 1933.

the increase in acid and sugar contents of the liquors for Lots B and C during the heating of the 25-ounce jars of pickle from 26.7 to 71.1°C. (80 to 160°F.). The time required for heating each lot was about 80 minutes. The approximate final values, with respect to acid and sugar contents, reached by jars of Lots B and C during the 80-minute heating interval to 160°F. were as follows: Lot B, 1.26 per cent acetic acid, 14 degrees Baumé; Lot C, 1.07 per cent acetic acid, 12.4 degrees Baumé. At the end of two hours, the values for the unheated room-temperature control lots were essentially the same as for the heated lots.

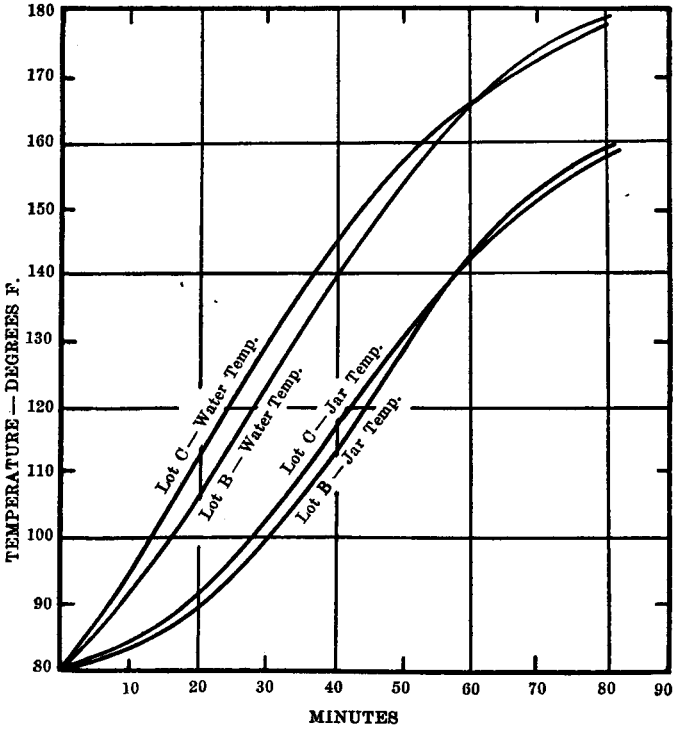

FIG. 2. Rate of heat penetration to center of 25-ounce jars of pickle covered with one-half strength (Lot B) and one-quarter strength (Lot C) liquors during heating to 71.1°C.(160°F.).

The rate of heating for the different lots must also be considered. Curves representing temperature changes in the water bath and jars for Lots B and C (Fig. 2) show that the water bath temperature rose slightly more rapidly for Lot C than Lot B and accordingly the jar temperatures for the two lots were correspondingly different. However, it is evident from these curves that there was no important difference in the rate of heat penetration into the jars of the two lots. A similar experiment involving the use of Lot A jars (full-strength liquor), when corrected for the difference in rate of heating of the water bath, showed a temperature change curve for the jars very similar to those presented for Lots B and C. Therefore, it is concluded that in the pasteurization of the different lots,

any small difference in rate of temperature change in the jar was of no significance so far as the effectiveness of the treatment was concerned.

The results of a preliminary run on the effect of temperatures from 120 to 160°F. for 15 minutes upon inoculated jars of duplicate 25-ounce amounts of pickle are shown (Table 4). In this instance, the initial numbers of acid-forming organisms for the three jar treatments (A, B, and C) ranged from 73,000 to 83,000 per c.c. of liquor, and the numbers of yeasts from 85,000 to 99,000. It will be noted that there is a definite correlation

TABLE 4

Effect Upon Microorganisms of Pasteurizing 25-Ounce Jars of Pickle at 120, 130, 140, 150, and 160°F. for 15 Minutes (First Run)

Pasteurization treatment	Jar treatment	Survival plate count	
		Acid-forming bacteria	Yeasts
°F.		*per c.c.*	*per c.c.*
Room-temperature controls [1]	A	73,000	91,000
	B	74,000	85,500
	C	81,000	99,000
120	A	0[2]	0[2]
	B	100	50
	C	1,100	5,000
130	A	0[3]	0[3]
	B	0[3]	200
	C	300	550
140	A	0[3]	0[3]
	B	0[3]	0[3]
	C	100	0[3]
150	A	0[4]	0[4]
	B	0[4]	0[4]
	C	30	70
160	A	0[4]	0[4]
	B	0[4]	0[4]
	C	0[4]	0[4]
Room-temperature controls [5]	A	0[2]	6,000
	B	4,500	21,500
	C	11,000	43,500

[1] At start of experiment (9:30 a.m.). [2] Less than 1,000 per c.c. [3] Less than 100 per c.c. [4] Less than 10 per c.c. [5] At end of experiment (12:00 noon).

between the strength of the liquor used and the destruction of both acid-forming bacteria and yeasts. Also, it will be noted that the 160°F. pasteurizing temperature was successful in reducing the organisms in all three treatments to insignificant numbers (less than 10 per c.c.). Since the plating dilutions were not low enough for Lot A pasteurized at 120, 130, and 140°F. and Lot B at 130 and 140°F., no exact estimate can be given as to the numbers of surviving organisms at these pasteurizing temperatures. However, it appears obvious that with the inoculum first used, the mortality in the A and B lots of pickle was rapid even at the lower temperatures. Furthermore, it is well to point out that there was a

marked reduction from the initial counts of organisms brought about by holding the control jars at room temperature for two and one-half hours. The most marked reduction was suffered by the acid-forming bacteria in the full-strength liquor (A). Here the initial count of 73,000 per c.c. was reduced to less than 1,000 per c.c. The yeast count in this lot was reduced from 91,000 to 6,000 per c.c. The initial counts of one-half strength lot (B) and one-quarter lot (C) likewise showed decreases, corresponding to the strength of the liquors. In general, it would appear that the yeasts

TABLE 5

Effect Upon Microorganisms of Pasteurizing 25-Ounce Jars of Pickle at 120, 130, 140, 150, and 160°F. for 15 Minutes (Second Run)

Pasteurization treatment	Jar treatment	Survival plate count	
		Acid-forming bacteria	Yeasts
°F.		*per c.c.*	*per c.c.*
Room-temperature controls [1]	A	650,000	150,000
	B	670,000	180,000
	C	720,000	190,000
120	A	550	140
	B	16,000	11,300
	C	64,000	20,800
130	A	Sp.[2]	0[3]
	B	470	450
	C	6,800	1,600
140	A	0[3]	0[3]
	B	270	50
	C	500	10
150	A	0[4]	0[4]
	B	10	0[4]
	C	25	20
160	A	0[4]	0[4]
	B	0[4]	0[4]
	C	0[4]	0[4]
Room-temperature controls [5]	A	8,000	45,000
	B	120,000	63,000
	C	370,000	67,000

[1] At start of experiment (11:30 a.m.). [2] Spreaders on 1-10 dilutions, no test organisms on 1-100 dilutions. [3] Less than 10 per c.c. [4] Less than two per c.c. [5] At end of experiment (1:15 p.m.).

were more resistant than the acid-forming bacteria with respect to the action of the liquor alone.

The numbers of organisms from heavier inoculations which survived pasteurizing temperatures of 120 to 160°F. for 15 minutes in pickle of different liquor strengths are shown (Table 5). In this run, about a nine-fold increase in acid-forming bacteria and nearly a twofold increase in yeasts over the numbers added in the preliminary run, were employed. Also, lower plating dilutions were used. The results show that even with the heavier inoculations the 160°F. pasteurization procedure was sufficient to reduce the acid-forming bacteria and yeasts in all three jar treatments

to insignificant numbers (less than two per c.c.). One point of interest in connection with the use of a larger number of organisms is that at temperatures below 150°F. a greater number survived the respective pasteurizations as compared with the surviving numbers in the first run (Table 4). Further examination of Table 5 reveals the previously mentioned relationship between the liquor strength (Lots A, B, and C) and the numbers of acid-forming bacteria and yeasts surviving the respective pasteurizing treatments up to the 160°F. treatment. Here it will be noted that in general the mortality of the two groups of organisms within any one pasteurization treatment is greatest in the more-acid liquor (Lot A) and correspondingly lower in less-acid liquors (Lots B and C). When the initial numbers of both groups of organisms are considered, it would ap-

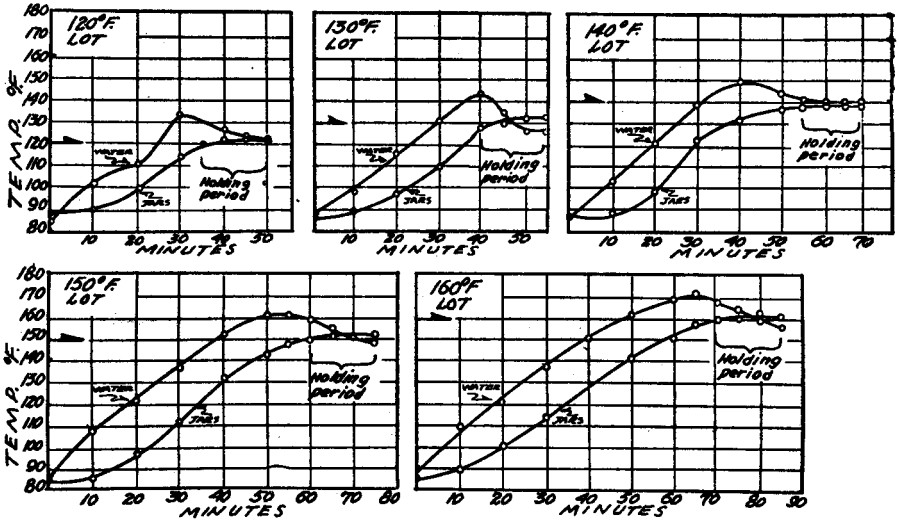

FIG. 3. Rate of heat penetration to center of 25-ounce jars of pickle during pasteurization treatments of 48.9, 54.4, 60.0, 65.6, and 71.1°C.(120, 130, 140, 150, and 160°F.) for 15 minutes.

pear from the percentage of surviving organisms, that the acid-forming bacteria are less resistant to pasteurization treatments under 160°F. than are the yeasts. In attempting to evaluate the data concerning the mortality of the test organisms during the various pasteurizing treatments, including the three liquor strengths used, one must bear in mind that even under room-temperature conditions a goodly proportion of the organisms would have been destroyed, owing presumably to the action of the acid. The survival plate counts for the room-temperature controls (Table 5) made at the conclusion of the pasteurizations bear out this relationship. These counts indicate that during the one hour and 45 minute interval, the acid-forming bacteria were more susceptible to the full-strength liquor than were the yeasts. Curves are given (Fig. 3) showing the rate of heat penetration to the center of 25-ounce jars for the various pasteurized lots previously discussed in connection with Tables 4 and 5.

The numbers of surviving organisms in the room-temperature control jars plated at intervals up to four days are further presented (Table 6). The results with respect to numbers of acid-forming bacteria and yeasts present in the three lots (A, B, and C) show that by the end of four days only a small proportion of the original inoculum survived.

The material presented so far has dealt with the effect of pasteurization on inoculated cucumber pickle containing added acid and sugar. Another series of pasteurizations was made with inoculated pickle containing no added acid or sugar, using essentially the same previously described procedure. The results with respect to numbers of organisms surviving the various heat treatments are presented (Table 7). In this particular run, 210,000 acid-forming bacteria and 155,000 yeasts per c.c. of liquor were

TABLE 6

Bacteriological Analysis of Duplicate 25-Ounce Jars of Inoculated Pickle, Held at Room Temperature (85°F.)

Jar treatment	Time interval	Acid-forming bacteria	Yeasts
		per c.c.	*per c.c.*
A	Initial	650,000	150,000
B	Initial	670,000	180,000
C	Initial	720,000	190,000
A	1¾ hr.	8,000	45,000
B	1¾ hr.	120,000	63,000
C	1¾ hr.	370,000	67,000
A	4½ hr.	4,000	24,000
B	4½ hr.	120,000	24,000
C	4½ hr.	350,000	56,000
A	24 hr.	10,000	24,000
B	24 hr.	75,000	23,000
C	24 hr.	340,000	30,000
A	4 days	5,000	800
B	4 days	17,000	300
C	4 days	87,000	.....

added at the start. The survival counts with respect to acid-forming bacteria show progressive sharp declines as higher pasteurizing temperatures were used, up to 150°F., this temperature applied for 15 minutes being successful in reducing the count to less than two per c.c. The results for the yeasts show a similar trend. It will be noted that both groups of organisms in the room-temperature controls slightly increased in numbers during the one and one-quarter hours required during the pasteurizations. The growth in similar material (in absence of added acid and sugar) over a longer period of time at room temperature is presented (Table 8). It will be seen that there was active fermentation by both groups of organisms using for their growth requirements only the naturally occurring constituents of the sterilized fresh cucumber slices. This activity was in direct contrast to the behavior of similarly treated lots to which sugar and acid had been added (compare Tables 8 and 6).

TABLE 7

Effect Upon Added Microorganisms of Pasteurizing 25-Ounce Jars of Sterilized, Fresh Cucumber Slices Containing No Added Vinegar or Sugar at 120, 130, 140, 150, and 160°F. for 15 Minutes

Pasteurization treatment	Survival plate count	
	Acid-forming bacteria	Yeasts
°F.	*per c.c.*	*per c.c.*
Unheated control [1]	210,000	155,000
120	47,000	100,000
130	450	380
140	20	0[2]
150	0[3]	0[3]
160	0[3]	0[3]
Unheated control [4]	260,000	186,000

[1] Room-temperature control at start of experiment (11:45 a.m.). [2] Less than 10 per c.c. [3] Less than two per c.c. [4] Room-temperature control at end of experiment (1:00 p.m.).

TABLE 8

Growth of Inoculated Microorganisms at Room Temperature (85°F.) in 25-Ounce Jars of Sterilized, Fresh Cucumber Slices Containing No Added Vinegar or Sugar

Time interval	Acid-forming bacteria	Yeasts
	per c.c.	*per c.c.*
Initial	770,000	190,000
1¾ hr.	1,500,000	100,000
4½ hr.	7,760,000	700,000
24 hr.	18,000,000	12,500,000
4 days	16,000,000	5,000,000

TABLE 9

Effect of Exposure to Temperatures of 120, 130, 140, 150, 160, and 170°F. Upon 225-Cubic Centimeter Amounts of Individual Cultures Added to 25-Ounce Jars Sterilized, Fresh Cucumber Slices

Maximum temperature attained	Survival plate count		
	Acid-former (No. V-6)	Yeast (No. F C)	Yeast (No. V-13)
°F.	*per c.c.*	*per c.c.*	*per c.c.*
Unheated controls [1]	19,800,000	18,000,000	20,000,000
120	5,200,000	1,800,000	14,000,000
130	10,000	16,000	3,800,000
140	0[2]	0[2]	600
150	0[2]	0[2]	50
160	0[2]	0[2]	0[2]
170	0[2]	0[2]	0[2]
Unheated controls [3]	22,000,000	19,000,000	24,000,000

[1] Room-temperature control at start of experiment (3:00 p.m.). [2] Less than 50 per c.c. [3] Room-temperature control at end of experiment (5:00 p.m.).

A second experiment using sterilized fresh cucumber slices was set up to test the effect of exposures to temperature ranging from 120 to 170°F. upon a very large inoculum of three organisms tested individually. Inoculation of the jars was in duplicate, using separate 225-c.c. amounts of broth culture for each of the three organisms (one acid-former and two yeasts). No holding time was employed; instead, the samples were removed and plated when the jars attained the desired temperature. An attempt was made to keep the inoculum approximately the same with respect to numbers of cells of each organism used. This would aid in determining any differences between organisms with regard to heat resistance; the results of this experiment are shown (Table 9). It will be noted that the reduction in numbers was most rapid in the case of the acid-forming bacteria, the count being reduced from 19,800,000 per c.c. to less than 10 per c.c. by the time the 140°F. temperature was reached. It must be pointed out, however, that in the case of the acid-forming bacterium, the four-day-old culture medium contained a considerable amount of lactic acid, probably in the neighborhood of .8 to 1 per cent, and this presumably contributed in part to the rapid destruction of the bacteria. The results for the two strains of yeasts used showed that one strain (No. V-13) survived the 150°F. maximum temperature while the other (No. F C) may be considered to have been killed by exposure to 140°F. The room-temperature controls showed slight increases for all three organisms during the two hours required for the experiment.

SUMMARY AND CONCLUSION

The results of a series of experiments dealing with the mortality of microorganisms during the pasteurization of cucumber pickle have been presented. Pasteurization procedures using temperatures of 120, 130, 140, 150, and 160°F. applied for 15 minutes were carried out on three lots of inoculated cucumber pickle which varied with respect to acid and sugar contents of the liquor (full-strength, one-half strength, and one-quarter strength). One strain of an acid-forming bacterium and two strains of yeast were used as the test organisms.

In general, the results show that increasing pasteurizing temperatures beginning with 120°F. brought about corresponding decreases in the numbers of surviving organisms up to 160°F. The latter pasteurizing temperature was sufficient to destroy both acid-forming bacteria and yeasts in all liquor treatments used irrespective of the quantity of inoculum employed. Furthermore, it was noted that with the lower temperature treatments (120 and 130°F.) there was a definite correlation between the number of surviving acid-forming bacteria and yeasts and the acid contents of the three liquors used. Results for the 140 and 150°F. treatments indicated that the organisms added as inoculum were killed in the most-acid liquor, that some survived in the two less-acid liquors, and that the numbers surviving in these were about equal. In addition, the results show that with the inoculated, unpasteurized lots (room-temperature controls) a marked reduction in the number of surviving organisms occurred within one and three-quarters to two and one-half hours, the time required to complete a series

of pasteurization treatments. This effect is due presumably to the acid content of the liquors.

ACKNOWLEDGMENT

We wish to thank the Charles F. Cates Company, Faison, N. C., for the fresh cucumber pickle and for other facilities provided. Furthermore, we are sincerely indebted to Mr. Harvey B. Ohmer of the Charles F. Cates Company and Mr. William M. Lewis of the Agricultural Chemical Research Division (Bureau of Agricultural Chemistry and Engineering, U. S. Department of Agriculture) for their assistance in this study.

REFERENCES

ETCHELLS, JOHN L., 1938. Rate of heat penetration during the pasteurization of cucumber pickle. Fruit Prod. J. 18, 68-70.

———, AND GORESLINE, HARRY E., 1940. Methods of examination of fresh cucumber pickle. Fruit Prod. J. 19, 331-335.

———, AND OHMER, HARVEY B., 1941. A bacteriological study of the manufacture of fresh cucumber pickle. Fruit Prod. J. 20, 334-337; 357.