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Pasteurized Fresh Whole Pickles. I. Pasteurization Studies[a,b]

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Heat penetration and spoilage data were obtained on 24 laboratory and 30 commercial packs of pasteurized fresh whole pickles.

During the past three years heat penetration, spoilage, bacteriological, and other pertinent data were obtained on 54 experimental packs of pasteurized fresh whole cucumber pickles. Twenty-four of the packs of pickles were made in the laboratory and 30 were made in the plants of various commercial pickle packers. The purpose of this investigation was to obtain information on factors which influence the process requirements and quality of this product. The data so obtained have provided a basis for evaluating variations in heating rates, processing values, brine volume to acidity ratios, firmness, and process requirements to prevent spoilage.

According to Fabian and Switzer *(11)*, fresh or pasteurized dill pickles are unfermented pickles made by placing fresh cucumbers in a weak brine, 20° salometer, containing 5.3% salt and about 10 to 15 grains of acetic acid. The desired flavoring is provided by the addition of essential oils, dill weed, garlic, etc. Pasteurization at 73° C. (165° F.) for 30 minutes was recommended. Emphasis was placed on the importance of maintaining an approximately constant ratio of brine to cucumbers, in the jar, in order to maintain a uniform flavor and acidity.

Etchells and Goresline *(5)* reported that controlled pasteurization carried out at 71° C. (160° F.) for 20 minutes or 73° C. (165° F.) for 15 minutes was adequate to kill the bacteria, yeasts, and molds which might cause spoilage in fresh cucumber pickle. According to this pasteurization procedure *(4)*, the jars of pickles are sealed and heated in a water bath until the temperature at the center of the container reaches 73° C. (165° F.). This temperature is maintained in the container for 15 minutes, after which the jars are rapidly cooled to 38° C. (100° F.) by cooling with water. Pasteurization by the above method so reduced the microbial content of the pickles that only the more resistant types of organisms survived, and these tended to decrease during storage. Methods for the bacteriological analyses of pasteurized and unpasteurized pickles and for the determination of keeping quality were outlined. It was concluded that the bacteriological methods described are suitable for determining the correct pasteurizing temperatures and holding period to employ for the preservation of fresh cucumber pickles. Etchells and Jones *(6)* reported that the controlled pasteurization procedure at 73° C. (165° F.) for 15 minutes was adequate for pickle products in classes covering an acid content range of from 4.0 to 17.0 grains acetic acid. It was pointed out that in pasteurizing fresh pickles care should be taken to avoid overheating since this will result in a marked loss in firmness and the possible development of cooked flavors. Pasteurization caused a marked reduction in the number of acid-forming bacteria and yeasts. The surviving organisms were of the heat-resistant spore-forming types.

Etchells and Jones *(7)* showed with pasteurization procedures using temperatures of 49, 54, 60, 66, and 71° C. (120, 130, 140, 150, and 160° F.) applied for 15 minutes, that increasing pasteurizing temperatures brought about corresponding decreases in the number of surviving organisms. Pasteurization at 71° C. (160° F.) was sufficient to destroy both acid-forming bacteria and yeasts in sliced cucumber pickle in 25 ounce jars. Heat penetration data presented by the above authors for pasteurization at 71° C. (160° F.) for 15 minutes when evaluated by the present authors according to the graphical method *(2)* of process calculation were found to have a sterilizing value equivalent to a holding time of 26.8 minutes at 71° C. (160° F.). Etchells and Jones *(8)* presented detailed procedures for the pasteurization of pickles. The importance of controlled pasteurization at 73° C. (165° F.) for 15 minutes was stressed. It was also pointed out that spoilage of improperly pasteurized pickles sometimes does not appear until some weeks after the pickles have been packed.

Procedures for the bacteriological examination of pickles have been described by Etchells and Jones *(9)*. They stated that spoilage of improperly pasteurized pickles is due chiefly to yeasts and/or acid-forming bacteria that survive the faulty heat treatment. Molds and mycoderma scum are factors principally in cases of poor jar closures.

Altenburger and Herold *(1)* described the use of a steam exhaust box for the pasteurization of fresh cucumber pickles. The jars of pickles were brined and put through an exhaust box at a temperature of 99° C. (210° F.). The brine temperature in jars reached at least 66° C. (150° F.). The jars were then capped, pasteurized, and cooled. The authors indicated that if the jars had a brine temperature of 76° C. (169° F.) and a center pickle temperature of 62° C. (144° F.) at the end of the pasteurization treatment the pickles would not spoil. Spoilage to the extent of 39.5% was encountered in jars which had a maximum brine temperature of 73° C. (165° F.).

Bernstein and Epstein *(3)* reported that the use of a quarternary ammonium detergent germicide in washing

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cucumbers was more effective in reducing the number of microorganisms than was washing in tap water. In terms of pasteurization time at 82° C. (180° F.) the cucumber pickles treated with the germicidal wash required only 15 minutes as compared with 20 minutes for those from the same lot washed only in tap water. On the other hand Fabian and Orloff *(10)* found that tap water or 30 degree salometer brine gave as effective results for washing pickles as did water containing quarternary ammonium compounds.

EXPERIMENTAL

Experimental Packs. During the 1949 season 10 experimental packs of fresh cucumber pickles, in quart jars, were put up in the laboratory, and 9 packs were put up under commercial conditions in three different pickle plants in this area. In 1950 a total of 34 experimental packs were put up as follows: 13 in the laboratory, 14 at two different pickle plants in the New England area, and 7 from various pickle packers in the South and Midwest were put up through arrangements made with the cooperating packers.

The general procedure in making the experimental packs was as follows: The pickles were packed into quart jars in the usual manner. From 10 to 15 pickles (depending upon their size) were placed in each jar. The jars were then brined and sealed. The brine used in the laboratory packs and some of the commercial packs was made up to approximate that used in commercial practice. Variations in acidity of from 12 to 30 grains acetic acid were employed plus 5% salt plus an emulsified Kosher Dill essential oil mixture.[c] From 6 to 8 quart jars of pickles were pasteurized for time intervals of 5, 10, 15, 20, 25, 30, 35, and 40 minutes, respectively, at a temperature of 82° C. (180° F.) in a water bath, unless otherwise indicated. In some cases other pasteurization time schedules and temperatures were used in order to correlate the sterilizing values obtained under various conditions. Immediately after removal from the pasteurizer the jars were cooled under a fine cold water spray.

Within a few hours after being processed one jar from each processing level was examined bacteriologically. The brine was plated out on Difco Nutritive Caseinate Agar. The plates were counted after 72 hours incubation. Counts of acid-forming and peptonizing bacteria as well as total counts were obtained.

The remaining jars were stored at room temperature and examined for spoilage at frequent intervals. Spoiled jars from each process level of each pack were subcultured in an attempt to recover the spoilage organisms.

Heat penetration data were also obtained on jars processed in each run. Two to four thermocouples were placed in the brine in the zone of slowest heating (¾ inch above the bottom of the jar on the vertical axis). In some packs thermocouples were placed in the approximate center of pickles located in the zone of slowest heating. The heat penetration data obtained during this investigation were analyzed to determine the fastest and slowest heating rates encountered. On a basis of the slowest heating jars the lethal or sterilizing value of the process level necessary to prevent spoilage was calculated by the graphical method in terms of holding time at 71° C. (160° F.). With 71° C. (160° F.) as the base temperature, the sterilizing value of process times at other temperatures was calculated and compared in terms of actual holding time at 71° C. (160° F.). This lethal or sterilizing value is given in terms of "F_{160}," with an assumed "z" value of 18° F. F_{160} is the time in minutes required to destroy the spoilage organisms at 71° C. (160° F.), and z is the slope of the thermal death time curve of the organism.

As will be shown later, a holding time (F_{160}) of 36 minutes at 71° C. (160° F.) or its equivalent at other temperatures was necessary to prevent spoilage in some of the experimental packs of pickles. Holding times at other temperatures, which are equivalent to 36 minutes at 71° C. (160° F.) under the above conditions are as follows:

Temperature ° F.	Holding time equivalent to 36 minutes at 160° F.
160	36.000
165	19.100
170	10.080
175	5.330
180	2.740
185	1.460
190	0.792
195	0.414
200	0.218
205	0.115
211	0.054

An indicated equivalent holding time of 2.74 minutes at 82° C. (180° F.), for example, does not mean that a 2.74 minute process at 82° C. (180° F.) is required for a jar of pickles. The derivation of the actual required process time involves an integration of the sterilizing values of the temperature in the jar as it heats up and approaches the pasteurization temperature. Under these conditions, the process or pasteurization time is extended until the integrated sterilizing values are equal and equivalent to 2.74 minutes actual holding time at 82° C. (180° F.) As will be shown later, a pasteurization time of 40 minutes at 82° C. (180° F.) was required to provide this degree of sterilization.

In some of the laboratory packs the pickles were not washed or soaked but were packed just as they came from the field to provide a high bacteria load in the product.

Pickles from each process level of a number of the packs were tested for the presence of the enzyme peroxidase, using guaiacol as a substrate.

Reports have been received from some pickle packers that off or stale flavors may develop in pasteurized fresh cucumber pickles during storage. In order to observe the tendency of these pickles to develop off flavors, taste tests were conducted on all of the packs of pickles after seven to eight months storage. In the 1950 packs the results of these taste tests were correlated with quantitative tests for peroxidase activity.

After seven to eight months storage firmness tests were made on the various packs of pickles with a penetrometer-type jelly-strength tester made by the Chatillon Company, New York, N. Y. For these tests the penetrometer was equipped with a 7/16-inch diameter plunger. In making the firmness test ¼-inch thick cross slices were taken from the center and one inch from each end of the pickle. The firmness in terms of grams pressure to penetrate the slices was determined at three points around the slice, midway between the skin and the central seed core area. Such tests were made on each pickle from one jar, and an average of the results was taken as the representative firmness of the pickles.

Packs were also made in which 20 p.p.m. of mustard oil (allyl isothiocyanate) were added to each jar to see if this compound would decrease the process time required to prevent spoilage.

RESULTS

Pasteurization Time and Temperature Requirements. The results obtained in the experimental packs of pickles are summarized in Table 1. The process time required to prevent spoilage and off-flavors is taken as the next longest process time above the longest process time at which spoilage was encountered. In most cases spoilage occurring within three weeks after packing was characterized by vigorous gas production and cloudiness. Much of the spoilage that developed after this time was characterized by the formation of a white sediment on the pickles and at the bottom of the

[c] Provided by the Magnus, Maybee and Reynard Company.

TABLE 1

Summary of experimental packs of pasteurized fresh whole pickles put up in 1948, 1949 and 1950

Pack no.	Plant [a]	Date	Pasteurization temperature	Pasteurization time and F_{180} value to prevent spoilage		Pasteurization time and F_{180} value to prevent off-flavor on storage		Acidity of ingoing brine
				Time	F_{180}	Time	F_{180}	
			° F.	*Min.*	*Min.*	*Min.*	*Min.*	%
1	A	8/10/48	187	20	1.1	....	....	....
2	M	8/1/49	180	40	36.0	20	0.7	....
3	M	8/4/49	180	35	21.0	25	2.8	....
4	M	8/8/49	180	35	21.0	20	0.7	....
5	A	8/9/49	180	20	0.7	25	2.8	....
6	A	8/9/49	180	20	0.7	30	9.3	....
7	M	8/12/49	180	40	36.0	30	9.3	....
8	M	8/12/49	180	40	36.0	30	9.3	....
9	B	8/16/49	185	15	0.4	25	4.8	....
10	B	8/16/49	185	15	0.4	25	4.8	....
11	C	8/18/49	180	40	36.0	25	2.8	....
12	C	8/18/49	180	40	36.0	20	0.7	....
13	M	8/19/49	180	40	36.0	40	36.0	....
14	M	8/19/49	180	40	36.0	30	9.3	....
15	M	8/23/49	180	40	36.0	30	9.3	....
16	M	8/23/49	200	20	5.0	21	6.0	....
17	A	8/24/49	180	35	21.0	25	2.8	....
18	A	8/24/49	200	15	2.0	18	3.0	....
19	A	8/24/49	180	40	36.0	....	....	....
20	M	8/30/49	200	15	2.0	24	13.4	....
21	D	5/31/50	165-185	14	....	35	....	....
22	E	6/7/50	185	20	1.1	35	35.2	....
23	F	6/10/50	175	15	0.2	35	12.2	....
24	G	6/9/50	190-200	15	....	30	....	....
25	M	8/8/50	180	40	36.0	30	9.3	0.80
26	M	8/8/50	180	40	36.0	30	9.3	1.20
27	M	8/8/50	180	35	21.0	35	21.0	1.60
28	A	8/10/50	180	25	2.8	30	9.3	1.14
29	A	8/10/50	180	25	2.8	30	9.3	1.54
30	A	8/10/50	180	40	36.0	20	0.7	1.77
31	A	8/10/50	180	25	2.8	15	....	2.93
32	M	8/14/50	180	30	9.3	35	21.0	1.57
33	M	8/14/50	180	35	21.0	20	0.7	1.90
34	M	8/14/50	180	30	9.3	25	2.8	3.00
35	M	8/16/50	180	35	21.0	25	2.8	1.60
36	M	8/16/50	212	18	9.7	15	6.9	1.60
37	A	8/17/50	180	20	0.7	25	2.8	1.99
38	A	8/17/50	180	20	0.7	25	2.8	1.67
39	A	8/17/50	180	20	0.7	20	0.7	1.81
40	A	8/17/50	180	20	0.7	20	0.7	2.94
41	M	8/21/50	180	40	36.0	35	21.0	1.59
42	M	8/21/50	196	28	24.0	28	24.0	1.59
43	G	8/21/50	190-200	10	....	30	....	1.73
44	M	8/22/50	168	55	23.7	40	7.7	1.71
45	M	8/22/50	180	30	9.3	35	21.0	1.71
46	M	8/22/50	211	13	3.5	21	20.2	1.71
47	A	8/29/50	180	35	21.0	35	21.0	1.15
48	A	8/29/50	180	20	0.7	35	21.0	1.54
49	A	8/29/50	180	15	....	30	9.3	2.04
50	A	8/29/50	180	20	0.7	30	9.3	2.94
51	C	9/18/50	180	10	....	40	36.0	....
52	C	9/18/50	195	12	0.7	36	....	....
53	H	9/10/50	185	10	....	25	4.8	....
54	I	9/19/50	180	30	9.3	10	....	....

[a] The various letters designate different packers. Packs put up at the University of Massachusetts are designated by "M".

jar and by occasional clouding of the brine. Jars of pickles showing this type of spoilage have been found from time to time on stored shelves.

Considerable variation in the rates of heat penetration in different jars of pickles was observed. In order to obtain a basis upon which to evaluate the time and temperature requirements for pasteurization, the heat penetration data of jars of pickles from 28 different packs processed at 82° C. (180° F.) were treated statistically in order to arrive at the slowest rate of heating that might be expected. The heat penetration data for each jar were plotted on semilogarithmic paper and defined in terms of "j" and "f_h" values according to Ball *(2)*. Here "j" is an arbitrary factor which, when multiplied by the differences in degrees (° F.) between the temperature of the pasteurizer and the initial temperature of the jar, designates a point of intersection of the vertical line representing the beginning of a process with the extension of the straight portion of the semi-log heating curve, when no time is consumed in bringing the pasteurizing bath to pasteurizing temperature, and f_h is the slope of semi-log heating curve expressed as time in minutes required to traverse one complete log cycle on the temperature ordinate.

The standard error and deviations of the "f_h" and "j" values were determined, and the upper and lower limits taken were based on the "t" value for the 1% level according to Snedecor *(14)*. The average and upper and lower limits of the heat penetration data thus indicated are shown in Figure 1. These data are described as follows:

	j	f_h
Average	0.89	26.0
Fastest heating	0.43	15.6
Slowest heating	1.35	36.4

The above data were in good agreement with the actual data obtained for the slowest and fastest heating jars and exceeded the actual limits by only a small degree.

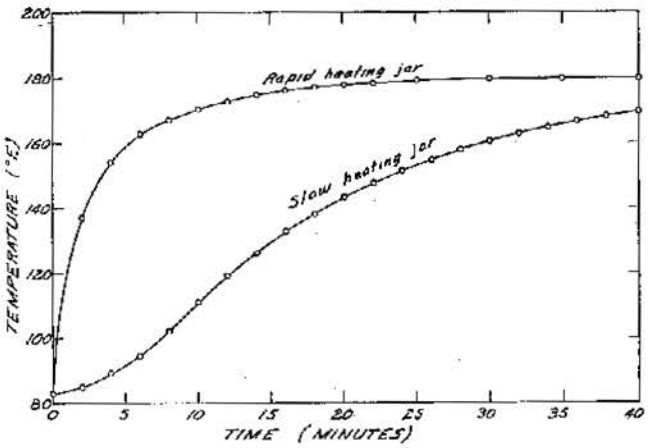

FIG. 1. Heat penetration curves for most rapid and slowest heating jars of fresh whole pickles pasteurized in a water bath at 82° C. (180° F.).

Data based on the slowest heating rates to be expected were used to calculate the sterilizing value (F_{300}) required to prevent spoilage and off-flavor development in the experimental packs as shown in Table 1. On a basis of the available data and the actual spoilage encountered it would appear that a sterilizing value equivalent to 36 minutes at 71° C. (160° F.) with an assumed "z" value of 18 was required to prevent spoilage. On this basis pasteurization times required to provide an equivalent degree of sterilization at pasteurization temperatures ranging from 165 to 211° F. were derived by applying mathematical methods *(2)* and are listed in Table 2. These pasteurization times were adequate

TABLE 2

Equivalent pasteurization times for quart jars of fresh whole pasteurized pickles at different temperatures to provide sterilizing values equal to F_{180} of 36 minutes achieved with 40 minutes process at 180° F.

Pasteurizing temperature	Pasteurizing Time
° F.	*Min.*
165	63.4
170	52.3
175	44.8
180	40.0
185	35.2
190	32.2
195	29.7
200	27.7
205	25.8
211	24.3

to prevent spoilage in the experimental packs pasteurized at different temperatures as may be seen from Table 1. These pasteurization times are based upon a procedure wherein the jars are placed in a processing tank at the indicated pasteurization temperature, the temperature is maintained constant during the pasteurization time, and then the jars are cooled. This procedure differs from the controlled pasteurization procedure as described by Etchells and Jones in which the jars of pickles are heated in a water bath until the temperature at the center of the container reached 73° C. (165° F.). This temperature is maintained in the container for 15 minutes, after which the jars are rapidly cooled to 38° C. (100° F.).

Brine Volume. Data on the brine volumes of 592 quart jars of pickles representing both commercial and laboratory packs were obtained. The results are summarized as follows:

Brine Volume, fl. oz.	Percentage of Jars
8 to 9	5.4
9 to 10	22.8
10 to 11	31.4
11 to 12	27.5
12 to 13	10.6
13 to 14.5	2.3

The above data indicate extremes in ratios (from 3:1 to 9:7) of pickles to brine by volume in the jars. Such variations are difficult to control in practice; yet they can have an important influence on the acidity and flavor of the finished product. Likewise, these variations are a complicating factor in attempting to arrive at minimum pasteurization requirements for this product.

A correlation of the rate of heating (f_h) with the brine volume gave a correlation coefficient of —0.500. Such a correlation is taken to indicate that although there was a tendency for the jars with a large volume of brine to heat more rapidly, the brine volume was not the only factor influencing the rate of heating. The method of packing and the tightness of individual pickles also have an important influence on the rate of heating in the slowest heating portion of the jar.

An analysis of the brine volumes of jars of pickles which spoiled in the experimental packs indicated a general trend towards a higher incidence of spoilage in jars with lower brine volumes. However, occasionally spoilage was encountered in jars with relatively large brine volumes. The tightness of packs of individual pickles with an accompanying slow rate of heating in localized areas was taken as a contributing factor.

Firmness. Pasteurization times up to 40 minutes at 82° C. (180° F.) appeared to have no significant effect on the firmness of the pickles. One series of tests was conducted in a commercial plant in which lots of pickles were pasteurized one, two, and three times, respectively, in a continuous pasteurizer. One pass through the pasteurizer provided a degree of heating approximating 40 minutes at 82° C. (180° F.). The pickles pasteurized two and three times had about the same degree of firmness as those pasteurized once in the usual manner.

The penetrometer method of measuring firmness gave results which were in agreement with subjective biting and chewing tests.

Cooked Flavor. No evidence of so-called "cooked flavors" was observed in any of the packs of pickles. It was concluded that pasteurization treatments within the limits used in this investigation did not overcook the product to the extent of producing adverse flavors. Likewise, in one test where lots of pickles were pasteurized one, two, and three times, respectively, in a

continuous pasteurizer, no cooked flavors caused by over-pasteurization could be detected.

Enzymes and Off Flavors. Reports have been received from some pickle packers that off or stale flavors may develop in pasteurized fresh cucumber pickles during storage. Taste tests were made on the experimental packs of pickles after seven to eight months of storage at room temperature. As indicated in Table 1, the development of such a flavor was prevented or retarded if the pickles were pasteurized long enough. The tendency of the pickles, if not pasteurized sufficiently, to develop an offor stale flavor during storage appears to be related to the destruction of peroxidase and related enzymes. The off flavor is similar to that which is caused by adding a peroxidase preparation to pickles *(12)*. The presence of peroxidase was found to play a role in lowering the quality of the color, flavor, and aroma of processed cucumbers. The effect on quality was more noticeable with samples containing the greater concentration of peroxidase.

Effect of Acidity. The range of acidity normally employed in packing pasteurized fresh whole pickles did not appear to have a significant effect on the pasteurization requirements of this product on a basis of practical observations. Other factors such as tightness of pack, etc., appear to be of greater importance. However, the use of as high a degree of acidity as practical should provide an added safety factor in contributing to a more effective rate of destruction of spoilage organisms during pasteurization as well as in preventing the growth of microorganisms in the product during storage. The observed relationship between the original and equalized acidity and its variation with brine volume is shown in Figure 2.

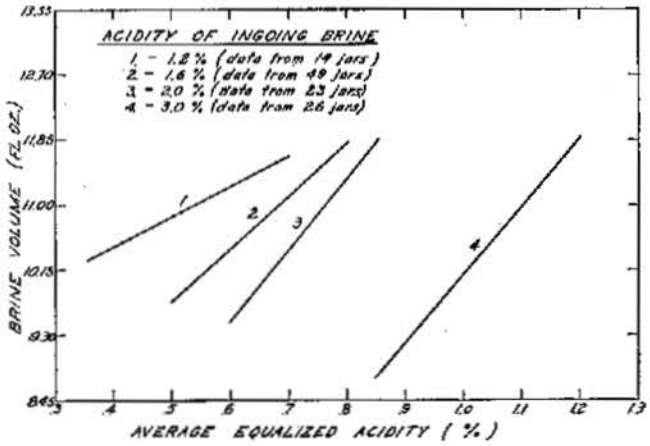

FIG. 2. Observed relationship between original and equalized acidity in brine of quart jars of pasteurized fresh whole pickles.

Relationship of Present Results to Those of Etchells and Jones. The controlled pasteurization procedure as described by Etchells and Jones, which is based on heating the jars of pickles for 15 minutes after the center has reached 73° C. (165° F.) has been followed as standard practice by many pickle packers. The results of the present investigation are in general agreement with the above method so far as the sterilizing value required is concerned, and variations in the product are considered. Data on variables encountered in this product and their effect on quality and pasteurization requirements have been presented.

DISCUSSION

The rate of heat penetration into quart jars of fresh whole pasteurized pickles is subject to considerable variation. An important cause of this variation is the nonuniformity of the product and the way it is packed into the jars. In some jars the nature of the pack may be such as to permit considerable free circulation of the brine, by convection currents during pasteurization, while in others the circulation may be greatly impeded. Also, frequently two or more pickles may be pressed tightly together, thus forming pockets or zones which heat relatively slowly. In order to prevent spoilage the pasteurization procedure should be adequate to destroy potential spoilage organisms which might be present in the localized zones which heat slowly. In determining the rate of heat penetration in this product, every effort was made to take the above variables into consideration.

The equivalent holding time or sterilizing value (F_{160}) at 71° C. (160° F.) was taken as a basis for evaluating the pasteurization requirements for each pack and for calculating equivalent pasteurization time at various temperatures. Such calculations were based upon the conditions of slowest heating as indicated by the data obtained. It is recognized that in a product of this type the indicated sterilizing value may be more severe than that indicated by the heat resistance of the spoilage organisms themselves. However, this apparent discrepancy is necessary in order to provide adequate pasteurization under the variable conditions of heating which were encountered in the packs of pickles under consideration.

Within limits the proportion of brine to pickles affected the rate of heating and the incidence of spoilage encountered. As the proportion of brine to pickles by volume, in a jar, was increased, the rate of heating tended to increase. However, from a consideration of the nature of the product and method of packing it is obvious that the tightness of pack and the placement of individual pickles in the jar may also have an important bearing on heating rates. These factors are important variables that must be considered in the pasteurization of this type of product.

Heat penetration data presented by Etchells and Jones *(7)* for fresh sliced cucumber pickle in 25-ounce jars, pasteurized according to their controlled procedure [center temperature of the jars maintained at 71° C. (160° F.) for 15 minutes], were evaluated in terms of F_{160}. The total heating on pasteurization treatment was found to provide an F_{160} value of about 27 minutes. In the present investigation the required F_{160} value of 36 minutes for quart jars of whole pickles takes into account the greater variation in heating to be expected with whole pickles.

The time and temperatures for pasteurization employed in this study had no significant effect on the firmness or flavor of the pickles.

CONCLUSIONS

Heat penetration and spoilage data were obtained on 24 laboratory and 30 commercial packs of pasteurized fresh whole pickles. As represented by the data obtained a sterilizing value equivalent to an actual holding time of 36 minutes at 71° C. (160° F.) was required to prevent spoilage and the development of off flavors due to enzyme action. Insofar as could be determined by flavor, firmness, and color this degree of sterilization had no deleterious effect on the quality of the pickles.

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