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Effects of Jar Size, Liquor, and Product-to-Liquor Ratio on Heating Characteristics of Fresh-Packed Pickle Products[a, b]

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DETERMINATION OF THE CORRECT PROCESS for fresh cucumber pickle pasteurization has two distinct aspects; first, a determination of the amount of heat necessary to inactivate the spoilage agent, and, second, a solution of the physical problem of delivering that heat. Considerable work has been done to determine the amount of heat required for pasteurization *(2, 3)*; however, the physical aspect of the problem has not been examined in detail. This paper describes some of the physical factors that influence the rate and amount of heat received by the fresh packs. The data of this study will aid the pickle packer in the evaluation of these factors so that he may scientifically adjust his process to different packs.

EXPERIMENTAL

Two cucumber shapes, 2 liquors, 6 jar geometries, and 4 pickle-to-liquor ratios were studied. The 2 cucumber shapes used were slices cut 7/32 in. thick from No. 3 variety SR-6 pickling cucumber, and spears made by slicing the No. 3 cucumbers lengthwise into 5 equal wedges. Brine containing 14-grain (1.4%) acetic acid and 5.0% salt and a syrup containing 50% sucrose were used as covering liquors. Jar data are given in Table 1. Spear weights of 10.00, 11.25, 12.00, and 13.50 oz. in 16-oz. jars were studied.

TABLE 1
Jar dimensions

Name	Normal fill (oz.)[1]	Outside dia. (in.)	Height to top of finish (in.)	Jar weight (gm.)
Vegetable	16	3	4 3/4	202
Cylinder	16	2 7/8	5 1/2	259
Cylinder	22	3	7 1/4	366
Novelty	24	3 3/4 [2]	7 1/8	365
Icebox	28	4	5	346
Regular	32	3 5/8	7 1/8	370

[1] Overflow capacity is about 1/2 oz. more.
[2] Largest diameter.

The cucumber products were weighed into the jars to the nearest 0.25 oz. and the liquor at 135 ± 10° F. was added just prior to placing the jars in the water bath.

Temperatures in the jars were sensed with pencil-type copper-constantan thermocouples similar to those described in *(5)* and were measured with a 12-point recording potentiometer. Thermocouples were located in the neighborhood of the slowest heating point along the central axes of the jars at 0.2h from the jar bottom, where h is the liquid height. Jars were heated in a constant temperature water bath in which the point-to-point variation in the region where the jars were placed was less than 1 1/4° F., and in which the temperature at any particular point varied about its mean with a standard deviation of 1/4° F.

ANALYSIS

Time-temperature plots of the experimental data were made according to Ball *(1)*, and the heating rate, f_h, and lag factor, j, were determined. Sterilizing values were computed at the end of various times using the fundamental equation defined by Ball *(1)*, in which are implicit the assumptions that heating rate is proportional to temperature difference, and that the destruction rate of the system critical in proper pickle pasteurization is logarithmic with an F_{160} of 36 minutes and a *z* of 18° F. *(2)*. Values of the F-integral were obtained from the Jahnke-Emde tables *(4)*. Significant differences, where investigated, were obtained from an analysis of variance of the data; any significant differences listed below are at the 5% level.

DISCUSSION AND RESULTS

Jar geomtery. The effect of jar geometry on heating characteristics of slices in both brine and syrup was studied for the 6 jar types. Table 2 gives the mean values of the heating characteristics. The 22-oz. and 24-oz. jars, although of larger capacity than the 16-oz. jars, do not have a correspondingly larger j or f_h. The 28-oz. jars with syrup have a much larger f_h than the 32-oz. jars. These facts reflect the more favorable geometry of the 22-oz. and 24-oz. jars; namely, a larger surface-to-volume ratio and a smaller diameter. By contrast, the 28-oz. jars have a low surface-to-volume ratio.

Liquor. Results of the studies of cucumber slices are summarized in Table 2. The lag factor, j, was not significantly different between liquors in all jar types studied. The f_h values for jars containing syrup were significantly higher than the f_h values for jars containing brine. The increase was not the same for each jar type. In brine packs, the f_h of the 22-oz., 24-oz., 28-oz., and 32-oz. jars is significantly higher than the f_h of the 16-oz. jars. In syrup packs, the 28-oz. and 32-oz. jars have significantly higher f_h values than the other four jar types. These data indicate the existence of a jar-liquor interaction, because the order of increasing f_h among jars changes with a change in liquor. The following comparisons refer to brine and syrup. When brine packs were compared with syrup packs, the syrup packs showed an increase in the f_h of about 60% in the case of the

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TABLE 2

Jar geometry: mean values of heating characteristics of slices

Jar	Brine				Syrup			
	No. of runs	j	f_h	F_{160} at 25 min.	No. of runs	j	f_h	F_{160} at 25 min.
16 oz. VEG	4	1.32	19.2	32.9	6	1.45	31.4	4.6
16 oz. CYL	4	1.34	19.6	30.5	6	1.42	32.7	3.4
22 oz. CYL	4	1.36	23.3	19.1	6	1.24	34.5	3.4
24 oz. NOV	4	1.37	21.9	19.4	6	1.31	34.8	3.6
28 oz. ICE	4	1.23	21.2	29.8	6	1.32	50.8	0.4
32 oz. REG	4	1.24	28.5	18.1	6	1.37	44.8	0.8

16-oz., 22-oz., and 24-oz. jars, and an increase of about 100% in the case of the 28-oz. and 32-oz. jars. The sterilizing value at 25 minutes was reduced to about 14% and 3% respectively for these two groups of jars.

Cucumber spears are normally packed in 16-oz. vegetable and 28-oz. jars; therefore, this study was restricted to these 2 sizes. Results are summarized in Table 3. The lag factor, j, was significantly increased by about 40% and the heating rate, f_h, was increased by 100% in both cases.

Pickle-to-liquor ratio. The effect of increased pickle-to-liquor ratio was studied in spear products in syrup in 16-oz. vegetable jars and the results are given in Figure 1. The points circled represent the individual data and the vertical lines indicate the mean values. An analysis of variance of the data from these 34 jars showed no significant difference in the lag factor, j, and a significant difference in the sterilizing value, F_{160}. The change in f_h was not statistically different; however, there may be a real decrease in f_h with increased ratio that is masked by the large variation among jars for a given ratio. The increased pickle-to-liquor ratio resulted in an increased lag factor. The 10-oz. and 11¼-oz. packs were not different, but all other comparisons were statistically different. The increased ratio resulted in a decreased sterilizing value. The 10-oz. pack was different from the 12-oz. and 13½-oz. packs; the 11¼-oz. pack was different from the 13½-oz. pack. Results indicate that under these conditions the lag factor, j, and not the f_h value is responsible for the decrease in the sterilizing value of pickle spears in syrup.

A large coefficient of variation was associated with the f_h, and j values in all tests where pickle products were involved. These values were consistently of the order of magnitude of 10%; whereas, when brine or syrup alone was used, the coefficient of variation was 3%. The f_h and j values with a coefficient of variation of 10% produce a corresponding variation in sterilizing value, F_{160}, of about 50%.

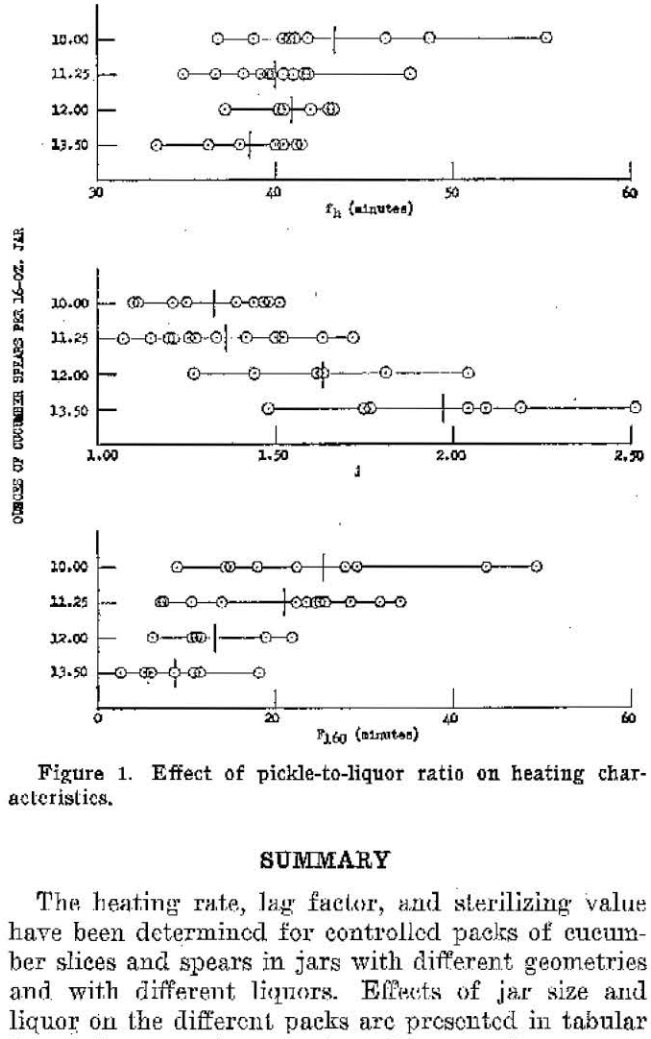

Figure 1. Effect of pickle-to-liquor ratio on heating characteristics.

SUMMARY

The heating rate, lag factor, and sterilizing value have been determined for controlled packs of cucumber slices and spears in jars with different geometries and with different liquors. Effects of jar size and liquor on the different packs are presented in tabular form. In general, a product in syrup heats more slowly than the same product packed in brine. Increasing the product-to-liquor ratio, while it does not significantly change the rate at which the jar heats, does increase the lag factor; the net result is a decrease in the sterilizing value.

TABLE 3

Mean values of heating characteristics of spears

Jars	Brine				Syrup			
	No. of runs	j	f_h	F_{160} at 25 min.	No. of runs	j	f_h	F_{160} at 30 min.
16 oz. VEG	21	1.21	21.0	32.5	12	1.52	40.8	3.2
28 oz. ICE	12	1.17	24.7	20.4	12	1.67	51.6	0.6

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