PASTEURIZED FRESH WHOLE PICKLES

A series of three articles, based on original research, discussing heat penetration, peroxidase activity and other factors in the pasteurization of fresh pack pickles.

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III Heat Penetration in Fresh Pack Pickles

New studies present heating rates for whole fresh pack, genuine dill and bread and butter pickles . . . .

By W. B. ESSELEN, I. S. FAGERSON, I. J. PFLUG, and E. E. ANDERSON*

IN A PREVIOUS REPORT[4] heat penetration studies for quart jars of fresh pack whole pickles pasteurized in a water bath were presented and have been continued. Heating rates under spray and tank pasteurization methods have been compared, and heat penetration data for fresh sliced pickles and genuine dill pickles in quart jars have also been obtained. These data provide a better understanding of the pasteurization requirements of fresh pack pickles.

Review of Literature

Work dealing with the pasteurization of fresh pack pickles has been reviewed by Esselen *et al.*[1, 4]. Fabian and Switzer[8] recommended pasteurization at 165 degrees F. for 30 minutes for fresh or pasteurized unfermented dill pickles. Etchells and Goresline[5] and Etchells and Jones[6, 7] have described a controlled pasteurization procedure whereby the jars of fresh pack pickles are heated in a water bath until the temperature at the center of the container reaches 165 degrees F. This temperature is maintained in the container for 15 minutes; the jars are then rapidly cooled to 100 degrees F.

Esselen *et al.*[4] pointed out that the rate of heat penetration into quart jars of fresh whole pasteurized pickles is subject to considerable variation. Important causes of this variation are the nonuniformity of the product and the manner in which it is packed. The pasteurization procedure should be adequate to destroy potential spoilage organisms, which might be present in localized zones that heat slowly.

Experimental Procedures

Spray Pasteurization. A 2 by 3-foot rectangular tank, 2½ feet high, equipped with a 5-nozzle spray head, was used as a spray pasteurizer. The nozzles, spaced in an X pattern, 11 inches between centers, delivered a full cone spray at a 65-degree angle. The capacity of the 5-nozzle head varied from 0.42 gallon per minute per square foot at 20 p.s.i.g. to 0.83 gallon per minute per square foot at 80 p.s.i.g. The distance from the nozzles to the tops of the jars was approximately 20 inches and provided more than adequate spray overlapping.

To permit accurate temperature control of the spray, water was passed through a tubular heat exchanger equipped with a recording controller.

Preliminary runs to determine uniformity of heat distribution in the spray tank indicated that each jar would receive a uniform heat treatment. To obtain the desired temperature around the jars and achieve uniform heat distribution, it was necessary to cover the pasteurizer.

Water Bath Pasteurization. A tank of water heated by steam and equipped with an automatic temperature controller was employed. At the end of the pasteurization times, the jars of pickles were removed and cooled under a fine cold water spray.

Heat Penetration Measurement. Copper-constantan thermocouples were introduced into jars of pickles through a stuffing box on the jar lid. For whole fresh and for fermented dill pickles four thermocouples per jar were placed between pickles at points where the pickles were pressed tightly together as they were packed. Such locations had been found to be the points of slowest heating in the jars. The thermocouples were set in place as the pickles were packed. The jars were then brined and sealed. Depending upon the location and nature of the tests, the temperature measurements were made with either a Leeds and Northrup portable indicating potentiometer or with a Brown Electronik recording potentiometer. At the end of each heat penetration test the pickle count and brine volume of each jar were ascertained.

Whole Fresh Pack Pickles. Whole pickles were prepared and packed in the usual manner. From 10 to 15 pickles (depending upon their size) were hand packed in each jar. The jars were then brined and sealed. The brine contained 16 grains of acetic acid, 5 per cent salt, and an emulsized Kosher Dill essential oil mixture.* Heat penetration data were obtained for 14 different runs of quart jars of whole pickles in the spray pasteurizer operated at 185 degrees F. and for 10 different runs of quart jars of whole pickles pasteurized in a water tank under commercial conditions. To reduce the time of pasteurization, the jars may be heated rapidly at a relatively high temperature for the first few minutes in a continuous pasteurizer; the temperature is then reduced as the jars proceed through the pasteurizer. The following cycle

• This is the first of three papers on fresh pickle pasteurization presented February 19-21, 1952 at Michigan State College technical school for pickle and kraut packers. They are based on research by Professor W. B. Esselen and his associates, conducted under the sponsorship of the Glass Container Manufacturers Institute. The first two in the series (parts I and II) appeared last year. Parts IV and V will appear in the April and May issues of THE GLASS PACKER.

* Members of the University of Massachusetts faculty. This is Contribution No. 833 Mass. Agr. Exp. Sta.

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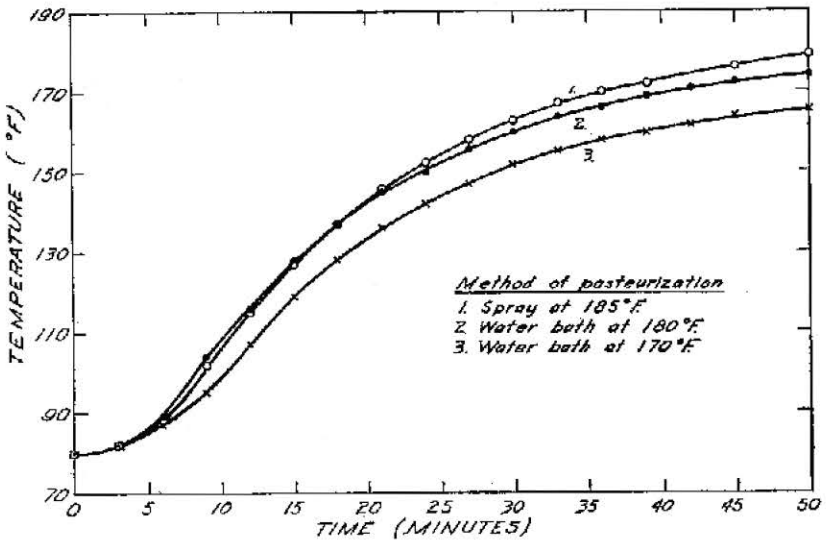

Fig. 1. Heat penetration curves for slowest heating quart jars of whole fresh pack pickles during pasteurization.

is typical of some procedures that have been suggested or employed: 5 minutes at 200 degrees F.; 10 minutes at 190 degrees F., and 15 minutes at 180 degrees F.; each procedure is followed by spray cooling. Heat penetration data were obtained on 15 runs of quart jars of whole pickles pasteurized under these conditions.

Bread and Butter Pickles. Sliced cucumbers were held overnight in a 30 degree salometer brine, containing tumeric for color. They were then drained and packed in jars containing a teaspoonful of a mixture of two parts mustard seed and one part celery seed. A pickle liquor containing vinegar and sugar (45 grains acid, 30 degrees Brix) was added, and the jars were sealed. Heat penetration data were obtained on 25 jars to which *hot* pickle liquor was added and on 24 jars to which pickle liquor at room temperature was added. The jars were pasteurized in a water bath at 180 degrees F. and then spray cooled.

Genuine Dill Pickles. Genuine dill pickles were fermented and prepared in barrels following commercial practice. Three- to four-inch pickles were used as they were to be packed in quart jars. The pickles were packed in the same manner as fresh pack whole pickles, and the original brine was added. The brine contained 1.14 per cent acid as lactic. Sixteen heat penetration runs were made on quart jars of dill pickles pasteurized in a water bath at 180 degrees F.

Analysis of Heat Penetration Data. The heat penetration data were analyzed to determine the fastest and slowest heating rates found. On a basis of the slowest heating jars, the lethal or sterilizing value of various pasteurization treatments was calculated by the graphical method in terms of holding time at 160 degrees F. This lethal or sterilizing value is given in terms of "F_{160}" with an assumed "z" value of 18 degrees F. F_{160} is the time in minutes required to destroy the spoilage organism and enzymes at 160 degrees F., and z is the slope of the thermal destruction time curve of the organism.

The heat penetration data for each jar when applicable were plotted on semilogarithmic paper and defined in terms of "j" and "f_h" values according to Ball[2]. In some cases 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 per cent level according to Snedecor.[10]

Test Process Results

Whole Fresh Pack Pickles. Heat penetration data, based on the slowest heating jar found in 14 runs of quart jars of whole fresh pack pickles spray pasteurized at 185 degrees F. are presented in Figure 1 and Tables 1 and 2. When compared with heat penetration data for this product pasteurized under water, it may be seen that under the conditions employed the heating rates are quite similar for spray and water bath pasteurization methods.

A 30-minute spray pasteurization procedure consisting of 5 minutes at 200 degrees F., 10 minutes at 190 degrees F., and 15 minutes at 180 degrees F. (Figure 2)

Table 1. SUMMARY OF HEAT PENETRATION RATES

Quart jars of whole fresh pack, bread and butter, and genuine dill pickles, during pasteurization.

Product and Method of Pasteurization	No. of Runs	Initial Temperature °F.	Heating Characteristics Average		Fastest Heating		Slowest Heating	
			j	f_h	j	f_h	j	f_h
Whole pickles, water bath at 180°F. (1948, 1949, 1950)	28	84	0.89	26.0	0.43	15.6	1.35	36.4
Whole pickles, water bath at 170°F.	10	100	1.87	28.7	1.41	19.8	1.58	34.3
Whole pickles, spray pasteurized at 185°F.	14	85	1.17	29.1	1.20	21.3	1.43	36.6
Genuine dill pickles, water bath at 180°F.	16	75	1.54	23.8	1.33	16.8	1.41	31.8
Bread and butter pickles, water bath at 180°F., brine at room temperature	24	75	1.27	20.6	1.11	18.7	1.40	23.0
Bread and butter pickles, water bath at 180°F., hot brine	25	95	1.10	23.3	1.00	20.4	1.13	25.8

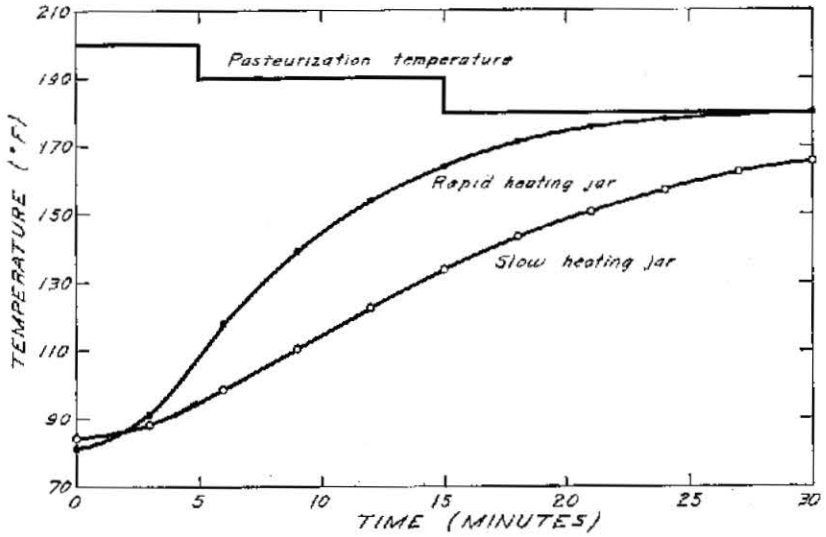

Fig. 2. Heat penetration curves for quart jars of whole fresh pack pickles pasteurized by water sprays in which the temperature was reduced during the pasteurization cycle.

resulted in a little more rapid heating rate than pasteurization at 180 degrees F. to 185 degrees F., based on the slowest heating jar; however, this method of pasteurization provided quite rapid heating in many jars. A limited number of tests with this pasteurization procedure were carried out with vacuum sealed quart jars of pickles that were packed and brined at room temperature under commercial conditions. A high percentage of the closures were displaced as a result of excessive internal pressure developed within the jar. It would appear that the caps were retained only on the slower heating jars or jars with larger head spaces. Such pasteurization procedures must be carefully controlled when vacuum sealed jars are used. The use of a hot brine and an adequate head space are measures that will help prevent the development of excessive internal pressures within the container during pasteurization.

As has been previously observed, zones of slow heating in jars of whole fresh pack pickles are usually located where two or more pickles are pressed tightly together.

A series of 10 heat penetration runs were also made under commercial conditions in which two standard retort crates of pickles were pasteurized in a tank of water in which the average temperatures ranged from 165 to 170 degrees F. The pickles were given a 30-minute process or holding time after the temperature in the center of the control jar reached 165 degrees F. as measured by a thermometer. Representative data are presented in Figure 3 and Tables 1 and 2. Additional heat penetration measurements made with jars placed on their sides indicated that jar position during pasteurization had no significant effect on the rate of heat penetration.

Bread and Butter Pickles. Heat penetration data for bread and butter pickles are presented in Figure 4 and Tables 1 and 2. The zone of slowest heating for the product was found to be one inch above the bottom of the jar on the vertical axis, at which point were located the thermocouples. Bread and butter pickles, as might be expected, exhibited much more uniform heating rates, from jar to jar, than did whole fresh pack pickles. The rate of heating was more rapid in the bread and butter pickles. Hot brine increased the sterilizing effect achieved during pasteurization.

Genuine Dill Pickles. As may be seen in Figure 5 and Tables 1 and 2, the heat penetration rate in quart jars of genuine dill pickles was quite similar to that in jars of whole fresh pack pickles. Here again the zones of slowest heating were located at points where pickles were pressed tightly together. Heat penetration rates in different jars of genuine dill pickles as well as fresh whole pickles varied widely. This variation is difficult to control because of the nature of the product and the method by which it is packed.

Table 2. STERILIZING VALUE (F_{100}) RECEIVED BY SLOWEST HEATING JARS

Quart jars of whole fresh pack, bread and butter, and genuine dill pickles during pasteurization.

Product and Method of Pasteurization	No. of Runs	Initial Temperature °F.	Pasteurization Time and Sterilizing Value (F_{100}) 15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.
Whole pickles, water bath at 180°F. (1948, 1949, 1950)	28	84	0.0	0.7	2.8	9.3	21.0	36.0	—	—
Whole pickles, water bath at 170°F.	10	100	0.0	0.7	2.7	8.3	13.7	19.4	27.6	42.8
Whole pickles, spray at 185°F.	14	85	0.0	0.9	3.0	9.9	23.9	48.7	83.5	126.0
Whole pickles, spray 5 min. at 200°F., 10 min. at 190°F., 15 min. at 180°F.	15	85	0.2	1.5	5.5	18.2	—	—	—	—
Genuine dill pickles, water bath at 180°F.	16	75	0.0	0.5	2.5	10.5	21.3	44.0	66.0	102.0
Bread and butter pickles, water bath at 180°F., brine at room temperature	24	75	1.1	6.4	20.3	40.8	67.9	101.9	—	—
Bread and butter pickles, water bath at 180°F., hot brine	25	95	2.0	6.6	24.0	47.0	78.0	100.0	—	—

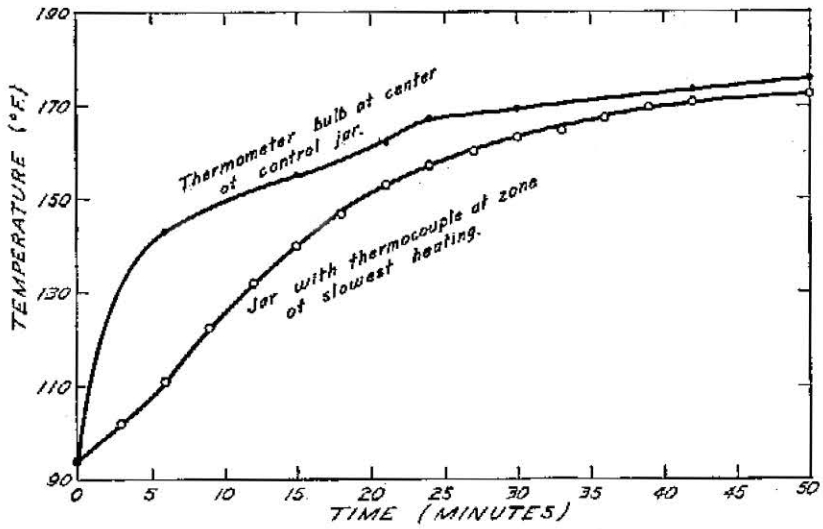

Fig. 3. Comparison of heating rate in quart jars of whole fresh pack pickles pasteurized in water bath at 175 degrees F. as indicated by a thermocouple at zone of slowest heating in one jar and by control thermometer in center of another jar. Data obtained during a commercial run.

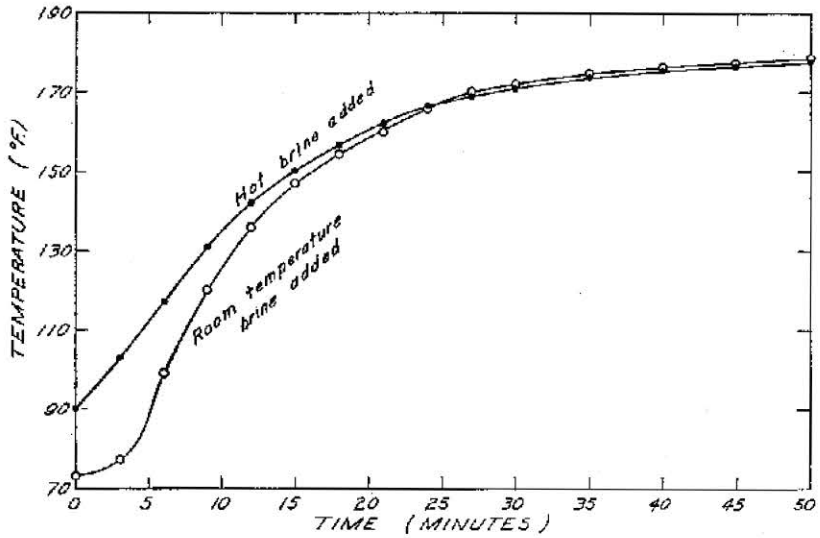

Fig. 4. Heat penetration curves for slowest heating quart jars of bread and butter pickles pasteurized in water bath at 180 degrees F.

Discussion

Heat penetration data during pasteurization for whole fresh pack pickles in quart jars obtained under laboratory and commercial conditions in 1951 were in good agreement with such data obtained during the past three years as previously reported by Esselen *et al.*[4] Because of variations in the heating rates of this type of pickle, pasteurization procedures should be set up to insure adequate pasteurization of the slowest heating jars. Many commercial pasteurization operations that have been observed and reported appear to provide the necessary heat treatment that has been indicated. Failure to observe these precautions can result in spoilage and the development of off flavors in the product during storage.

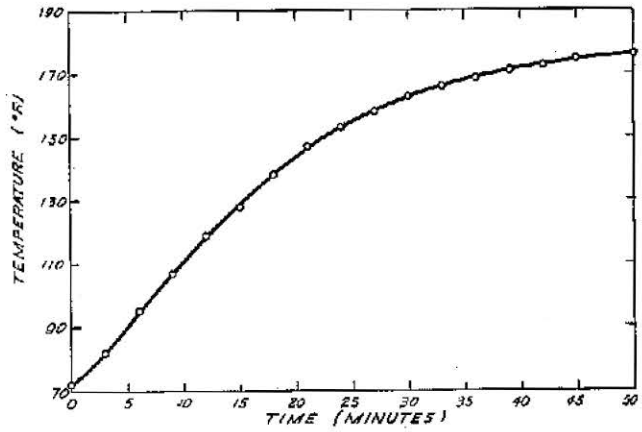

Fig. 5. Heat penetration curve for slowest heating quart jars of genuine dill pickles pasteurized in water bath at 180 degrees F.

On a basis of available data it would appear that spray pasteurization and tank methods of pasteurization are equally effective. In using spray pasteurization procedures, it is important that a uniform spray and temperature distribution be maintained. An adequate volume of spray water is also necessary to achieve the desired results.

The rate of heat penetration and variations in heating of quart jars of genuine dill pickles were similar to those of whole fresh pack pickles. It would appear that a pasteurization treatment for dill pickles should be adequate to destroy spoilage microorganisms and pectolytic enzymes that may cause softening during storage (Jones, Etchells, Veldhuis, and Veerhoff,[9]; Bell, Etchells, and Jones[3]) and yet not cause excessive softening because of overheating. Available evidence would indicate that such a pasteurization requirement may be somewhat difficult to achieve in practice.

Sliced bread and butter pickles are characterized by more rapid and uniform heating rates than are whole pickles. The pasteurization treatment should be adequate

to destroy potential spoilage microorganisms and enzymes that might cause deterioration during storage. Such a degree of pasteurization is more readily achieved with this type of pickle than with whole fresh pack pickles because of the higher acidity of the former.

Heating rates of quart jars of whole fresh pack pickles, genuine dill pickles, and sliced bread and butter pickles during pasteurization are presented. Heating rates of whole fresh pack pickles were essentially the same with either water spray or tank pasteurization methods. Sliced bread and butter pickles heat more rapidly and uniformly than do whole pickles.

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PASTEURIZED FRESH WHOLE PICKLES

IV Enzymes and Off-flavor in Fresh Pack Pickles

Proper time-temperature pasteurization formula will reduce peroxidase activity that causes off-flavor . . . . . By M. LABBEE, W. B. ESSELEN, and E. E. ANDERSON*

IT IS WELL KNOWN that enzymes, unless inactivated or controlled during processing, can be an important cause of food deterioration. For example, oxidative enzymes destroy vitamin C in freshly expressed apple juice and cause apples to turn brown when the cut surface is exposed to the air. They may also cause undesirable changes in flavor and odors in frozen fruits and vegetables. The problem of maintaining high quality in foods necessitates the destruction of those enzymes which may cause deterioration.

The present discussion is concerned with the thermal destruction of enzymes, particularly peroxidase, in relation to the quality of fresh pack pickles. Work on fresh pack pickles has been carried on at this laboratory during the past five years.

Studies by Kaplan, Esselen, and Fellers[5] and by Nebesky, Esselen, Kaplan, and Fellers[8] as well as work by others, have indicated that peroxidase is one of the most heat-resistant of the enzymes that are normally found in fruits and vegetables. Its inactivation has frequently been assumed to assure the destruction of other less heat-resistant detrimental enzymes which might be present in the raw material. Problems involved in the destruction of enzymes activity by heat have been summarized by Balls [2, 3], who stressed the difficulty of complete destruction, the possibility that the products of decomposition by heat might exert slight catalytic action, and the possibility of regeneration of activity after destruction. Such regeneration is well recognized and has been known to occur with proteolytic enzymes and with peroxidase.

Nebesky, Esselen, Kaplan, and Fellers[8] observed that the addition of sugar or vinegar to fruit and pickle substrates increased and decreased, respectively, the thermal stability of peroxidase, whereas the addition of small amounts of salt had no effect. Increasing the concentration of peroxidase increased its thermal stability. Peroxidase that was not inactivated in fresh cucumber pickles during processing was not destroyed during storage for one year. The peroxidase of fresh cucumbers obtained from the same location at different times during the harvesting season varied considerably in concentration and thermal resistance.

Nebesky, Esselen, and Fellers[7] pointed out that the presence of a concentrated preparation of peroxidase had some influence in lowering the quality of the color, flavor, and aroma of fresh pack pickles. The effect on quality was recognized by the development of a distinct flat or hay-like aroma and flavor together with a bleaching or fading of color. This deterioration was more noticeable in samples containing higher concentrations of peroxidase and in samples stored at 35 deg. F. The peroxidase activity of a variety of canned fruits and a number of pickle products (Kosher style dill, processed dill, sweet mixed, mustard, midget, chow chow, candied sticks, picklestix, and piccalilli) obtained from local markets and representing various manufacturers, was determined. Most packs of Kosher style dill pickles showed a high degree of peroxidase activity, whereas processed dill pickles showed a moderate degree of activity. The other products tested were negative. It was concluded that a high degree of peroxidase activity in a pickle product might act as a potential spoilage agent. Anderson *et al*,[1] in studies on pasteurized whole fresh pack pickles found a definite relationship between the development of off-flavor during storage and peroxidase activity. Adequate processing to reduce the original peroxidase concentration to a certain critical level yielded pickles that did not develop off-flavor during storage.

Experimental Pack Studies

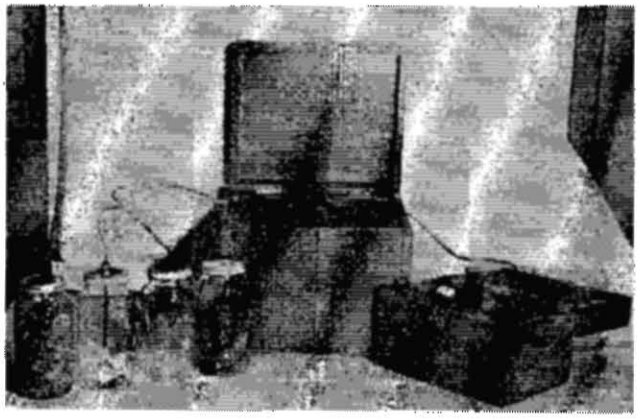
Effect of Various Process Times and Acidities on Peroxidase Activity and the Development of Off-Flavor.

The peroxidase activity of fresh pickling type cucumbers was found to be approximately 13 per cent of that of young horseradish roots. Since horseradish is considered one of the better sources of peroxidase, the cucumber should be considered accordingly as having substantial amounts of this enzyme.

During the 1950 season, 34 experimental packs of cucumber pickles, in quart jars, were put up in the usual manner. Acidities of the ingoing brine varied from 8 to 30 grains (0.8 to 3.0 per cent) acetic acid. The jars were pasteurized for time intervals of 5, 10, 15, 20, 25, 30, 35, and 40 minutes, respectively, at a temperature of 180 deg. F. in a water bath. Immediately after removal from the pasteurizer, the jars were cooled under a fine cold-water spray. The jars were then stored at room temperature for five to eight months, subsequently evaluated for quality, and then quantitatively analyzed for peroxidase activity.

On testing these packs at the end of the storage period, it was noted that in each pack of pickles, those pasteurized for the longer lengths of time were of acceptable quality. This was true even though in these acceptable packs there was a definite residual level of peroxidase activity after an eight-month storage period. At this time, the residual peroxidase activity amounted to 0.10 to 0.17 per cent of

* Members of the University of Massachusetts faculty. This is Contribution 833 of the Mass. Agr. Exp. Sta., and was presented at Michigan State College technical school for pickle and kraut packers, February 19-21, 1952.



• *Apparatus for heat penetration studies of fresh pack pickles at University of Massachusetts. Rigid and non-rigid thermocouples in jars are connected through selection switch box (center) to portable indicating potentiometer.*

that contained in the original product. This figure was based on standard curves for cucumber peroxidase activity prepared for the 1951 season. Further, it is realized that this value is not of the same order as that of the residual peroxidase after processing, since, as indicated later, peroxidase activity decreases during storage.

Further work was carried out during the 1951 season to determine the precise residual peroxidase content that can be tolerated immediately after processing without the development of off-flavors or off-odors during subsequent storage at room temperature. Packs prepared for this purpose were assayed quantitatively for peroxidase 72 hours after processing. A sample of the brine was removed aseptically from each of the packs at the various time intervals. The containers were resealed, stored for six months, then evaluated for quality, and again subjected to quantitative peroxidase determinations.

Data obtained from these tests indicated that the residual peroxidase activity tolerated without deterioration in quality during storage ranged from 0.17 to 0.28 per cent. By the sixth month of storage at room temperature, the residual had dropped to approximately that reported for the 1950 season, 0.10 to 0.17 per cent. Thus, approximately 40 per cent of the peroxidase activity present shortly after processing is destroyed during six months of storage.

There was no apparent relation between acidity and length of process necessary to prevent reduction in quality as a result of enzyme action. The experimental times to accomplish this result varied from 15 to 35 minutes at 180 deg. F. The factors found necessary from pack to pack to reduce the peroxidase concentration to the critical level are size of cucumbers, cucumber-brine ratio, and tightness of pack. Nevertheless, a process time of 35 minutes at 180 deg. F. has appeared to be adequate to prevent development of off-flavors in subsequent storage.

Effect of Storage Temperature on the Development of Off-Flavor. Packs were prepared in the usual manner and pasteurized at the times indicated. However, packs at this time were put up in triplicate, one of each being subsequently stored at 40, 70, and 100 deg. F. At the end of a six-month storage period, they were subjected to quality evaluation and quantitative peroxidase analysis.

In general, the intensity of off-flavor for any given process time decreased with increasing storage temperature for the six-month period involved. This increase is probably due to the balance between acceleration of peroxidase activity as a result of increased storage temperature and the increased inactivation of the enzyme itself as a result of this higher temperature, that is, the increased activity cannot counterbalance increased enzyme decomposition.

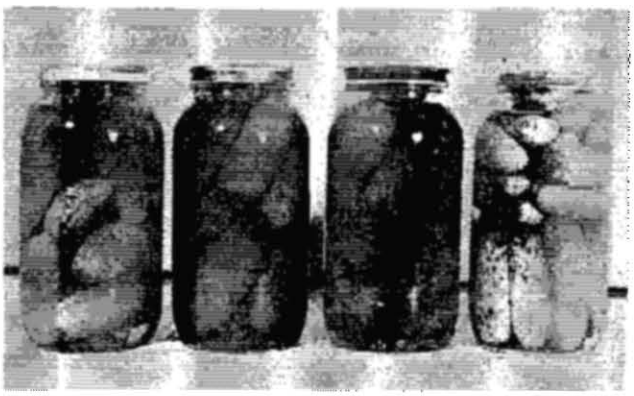
In this experiment the destruction of residual enzyme during a six-month storage period was approximately 1, 40, and 83 per cent for storage temperatures of 40, 70, and 100 deg. F. respectively.

Pickle Packs with Added Enzyme Preparations. Purified peroxidase suspensions were prepared from pickling type cucumbers and young horseradish roots. These were subsequently added aseptically in varying proportions into quart jars of fresh pack pickles previously rendered enzyme free by processing for 120 minutes at 180 deg. F. The results confirmed previous observations. As the level of peroxidase activity was increased, the off-flavor was also increased. This was not the case in controls where the added enzyme preparation was previously inactivated by heat treatment. Some of the samples of pickles that contained high levels of peroxidase activity had a marked bitter flavor, which was evident as an after-flavor.

It is interesting to note that purified preparations of horseradish peroxidase, when inoculated into pickle packs under the conditions previously described, resulted in the development of off-flavors indistinguishable from those of cucumber peroxidase. The activity of horseradish peroxidase required to produce a given off-flavor corresponds very well with the cucumber peroxidase activity necessary to create the same intensity of off-flavor.

When purified catalase preparations are inoculated into containers of pickles high in peroxidase activity, they tend to diminish the characteristic off-flavor caused by the peroxidase. Catalase preparations inoculated into pickle packs free of other enzyme systems produced characteristic off-flavors and off-odors different from the hay-like odor produced as a result of peroxidase activity.

Puréed Pickle Packs Cucumbers were puréed in a Waring Blendor and combined with pickle brine in a 5 to 3 ratio. Twenty milliliters of this suspension was pipetted into rubber-stoppered serum-bottles. With the aid of a hypodermic needle, samples could be readily removed aseptic-



• *These quart jars of whole fresh pack pickles show variations in pack which influence heating rate during pasteurization.*

ally or inoculums easily added. Furthermore, the small size of the serum-bottles presented more extensive inoculation of the small quantity of the purified enzyme preparations available.

Earlier experiments on whole fresh pack pickles were repeated, substituting the puréed pack. Process time intervals were of necessity shortened.

In general, the correlation between enzyme activity and off-flavor was very good. Slight differences were noted in several phases; for example, the samples of puréed pack stored at 100 deg. F. showed a definite odor and flavor attributed to warm storage conditions whereas traces of this flavor and odor could not be detected even in whole fresh pack pickles stored at 100 deg. F. Of interest were the color changes which the puréed packs underwent during processing at 180 deg. F. An olive color was seen to develop after a few minutes of processing in brines containing 0.8, 1.6, and 3.0 per cent acetic acid. This continued for about 20 minutes of heating at which time the characteristic green color originally present in the purée was seen to return. Further heating caused little change in color.

Cold Storage Color Changes Noted

In cold storage, samples that had been removed early in the process maintained their olive color. In certain instances the olive color faded to an even greater extent; however, comparative samples stored at room temperature or at 100 deg. F. soon developed a green color similar to that originally present. The formation of the olive-green color from the green in vegetables has been described by Campbell[4]. He demonstrated that the magnesium from chlorophyll is replaced by hydrogen to produce the yellowish product pheophytin. This has been demonstrated in improperly stored frozen peas in which the acids of the cell sap caused a color change. However, the reappearance of the green color might be attributed to the hydrolysis of pheophytin. The possibility that the acid subsequently hydrolyzes pheophytin, releasing the phytyl group and giving rise to free carboxylic pheophorbide, has been suggested by Lingelsheim.[6] He found the final green coloring matter of chlorophyll breakdown to be soluble in chloroform but, unlike chlorophyll, insoluble in benzene. This property was observed in the present investigation. It will be noted from this discussion, that decreasing temperatures tend to slow down the reappearance of green color. This agrees with Lingelsheim's proposal.

Peroxidase activity in fresh pack pickles appears to be associated with the development of off-flavor and odor during storage. High degrees of peroxidase activity appear to intensify the development of stale and bitter flavors in this product. The development of such off-flavors in pickles containing active peroxidase is markedly increased during storage at 35 deg. F. as compared with room temperature storage. These off-flavors were prevented by a pasteurization treatment sufficient to reduce the peroxidase activity to a low level. Pasteurization of quart jars of whole fresh pack pickles for 40 minutes at 180 deg. F. or for other time and temperature cycles to provide an equivalent degree of thermal destruction has been found to be adequate to prevent such off-flavor.

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PASTEURIZED FRESH WHOLE PICKLES

V Factors Influencing Pasteurization Requirements

Heat penetration is the chief influence on pasteurization though brine volume and spices are factors . . . .

W. B. ESSELEN, E. E. ANDERSON, I. S. FAGERSON, and M. LABBEE*

IN THE PASTEURIZATION of fresh pack pickles the ultimate objective is to expose the product to sufficient heat to prevent subsequent spoilage. On the other hand, excessively long pasteurization treatments are undesirable because they reduce the hourly capacity of the pasteurizing equipment and may result in overcooking the product. In the present discussion, some of the conditions that influence the pasteurization requirements of fresh pack pickles will be considered. An appreciation of these conditions should lead to a better understanding of the functions of pasteurization.

Experimental

Variation in Heating Rates and Tightness of Pack. The number and heat resistance of spoilage microorganisms vary so greatly from time to time that the packer has no way of ascertaining in advance either the microbial condition of the product or the time when it may change. The total number of spoilage organisms is important as is the heat resistance of those organisms present. The heat treatment in pasteurization, therefore, should be based on the worst conditions that may be encountered.

Esselen *et al*[3] and others have pointed out that the rate of heat penetration in whole fresh pack pickles may vary considerably from jar to jar and from batch to batch. This variation in heating rates may be attributed to the tightness of pack and the way in which individual pickles are pressed together in the jar. The zones of slowest heating are located between pickles where they are pressed together, usually in the central or lower section of the jar. The pasteurization treatment must provide adequate heat treatment at the points of slow heating. These localized zones are readily apparent by an inspection of the jar immediately after pasteurization and are characterized by a bright green color as contrasted with the straw or olive-green color of most of the pickle surface. Such zones are caused by a lack of heat and contact with the acid brine during pasteurization.

Within limits, the tightness of pack and rate of heating may be influenced by the size of the pickles and the manner in which they are packed. However, in apparently loosely packed jars, two pickles may be pressed together tightly enough to produce a definitely slow heating zone. It would appear that such conditions are common to whole fresh pack pickles. Such extremes in rates of heating, illustrated in Figure 1, are based on a large number of heat penetration tests made in commercial pickle plants and in the laboratory over a four-year period. The rates of heat penetration in the majority of jars were intermediate between these extremes.

Obviously, if pasteurization treatment is based on the slowest heating jars, many jars will be heated somewhat more than necessary; however, the treatment should prevent later spoilage. Moreover it would not appear that the extra heat received by the more rapid heating jars is sufficient to impair the quality of the product. On the other hand, if the pasteurization treatment is reduced in intensity and is based on jars that heat more rapidly, there is an ever-present danger of understerilization and subsequent spoilage of at least a small percentage of the jars. The desirability of basing the pasteurization treatment on the slowest heating rates is therefore apparent.

* Members of the University of Massachusetts faculty. This is Contribution 831 of the Mass. Agr. Exp. Sta., and was presented at Michigan State College technical school for pickle and kraut packers, February 19-21, 1952.

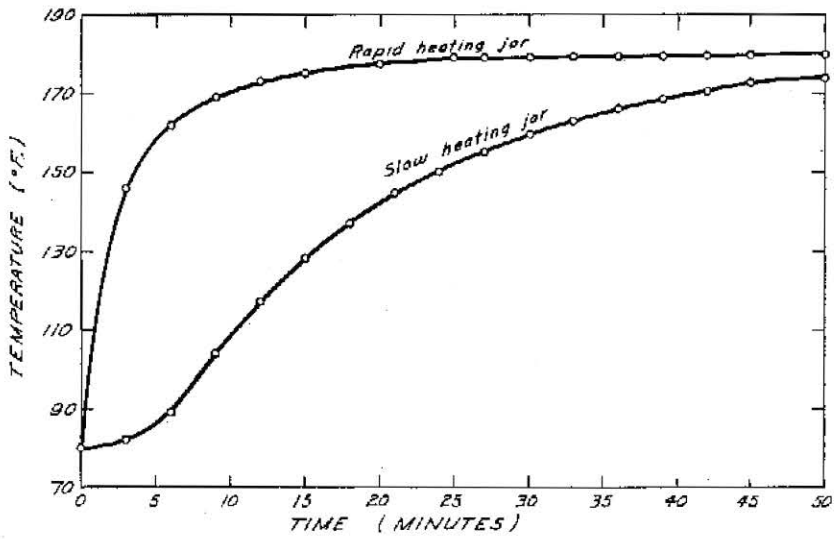

Fig. 1. Heat penetration curves for most rapid and slowest heating jars of whole fresh pickles pasteurized in water bath at 180 deg. F.

The canning industry has made an outstanding record in preventing spoilage by the use of controlled processing times and temperatures set up and based on the most severe conditions that might exist in good cannery practice. The adoption of such practices in the pasteurization of fresh pack pickles would undoubtedly help prevent some of the occasional problems reported and would contribute to a greater uniformity of the product. Progress is being made in this direction by the increasing use of properly controlled continuous pasteurizers.

Container Size Influences Heat and Time. Other factors being equal, the heating rates and pasteurization requirements of fresh pack pickles are influenced by the size of the container. Heating rates became slower as the size of the container was increased. Thus at a given temperature, the pasteurization time for a gallon jar would be somewhat longer than that for a quart jar. For example, preliminary heat penetration data obtained for whole fresh pack pickles in gallon jars would indicate that at 180 deg. F. gallon jars of these pickles should be pasteurized for 55 minutes to provide the same amount of effective heating that is given in quart jars in 40 minutes.

Acidity Acts as Preservative: It is well known that when acids, particularly acetic, are added to foods, they increase the ease with which spoilage microorganisms are destroyed by heating. Likewise, if present in sufficient concentrations, the acid itself exerts a preservative action. Etchells and Jones[4] investigated the effect of reducing simultaneously both the acid and sugar contents of pickling liquor on the destruction of test organisms after 15 minute processes at temperatures up to 160 deg. F. A definite correlation was found between the number of survivors and the acid content of the liquors.

Anderson *et al* [2], in studies of the effect of various concentrations of acetic acid on the heat resistance of a yeast that had caused spoilage in fresh pack pickles, found that the thermal death time decreased with increasing amounts of acid. It was pointed out that during pasteurization the initial acid concentration of the brine begins to decrease in the first few minutes as it equalizes into the pickles. In one experiment it was observed that the acid content of the brine was reduced 42 per cent during a pasteurization period of 40 minutes at 180 deg. F.

Table 1. EFFECT OF ADDED MUSTARD OIL (20 ppm) ON BACTERIA COUNT AND SPOILAGE

Quart jars of whole fresh pack pickles pasteurized at 180 deg. F.

Pasteurization Time min.	Bacteria Count per ml of Brine	No. Jars	No. Jars Spoiled	Per Cent Spoilage
	Control — no added mustard oil			
0	45,940,000	—	—	—
5	426,270	23	19	82.6
10	314,460	28	19	67.9
15	2,980	26	12	46.2
20	530	27	8	29.6
25	370	28	8	28.5
30	610	27	6	22.2
35	220	28	3	10.7
40	120	27	2	7.4
	20 ppm added mustard oil			
0	45,940,000	—	—	—
5	75,440	24	18	75.0
10	1,790	30	20	66.6
15	1,370	30	7	23.3
20	580	30	5	16.7
25	400	30	5	16.7
30	260	29	3	10.3
35	410	30	3	10.0
40	70	29	1	3.5

As pointed out previously, in many experimental and commercial packs it has been observed that the whole pickles were often pressed either firmly together or tightly against the jar. In such cases, not only may the rate of heat penetration be considerably retarded, but as the brine may not come in contact with these localized areas, much of the apparent lethal effect of the acid may be lost. Esselen *et al*[3] found that the application of heat equivalent to a sterilizing value of 36 minutes at 160 deg. F. based on the slowest heating jars found appeared to provide sufficient heat treatment to supply the degree of sterilization necessary to take care of these variables. It would appear that within the limits of acidity normally employed in whole fresh pack pickles that these other variables might tend to offset a favorable effect of brines with higher acid contents. Thus, it would not be safe to attempt to vary the pasteurizing time or temperature with variations in the acidity. However, brines with a higher acid content offer an enhanced margin of protection.

The normal range of acidity in whole fresh pack pickles

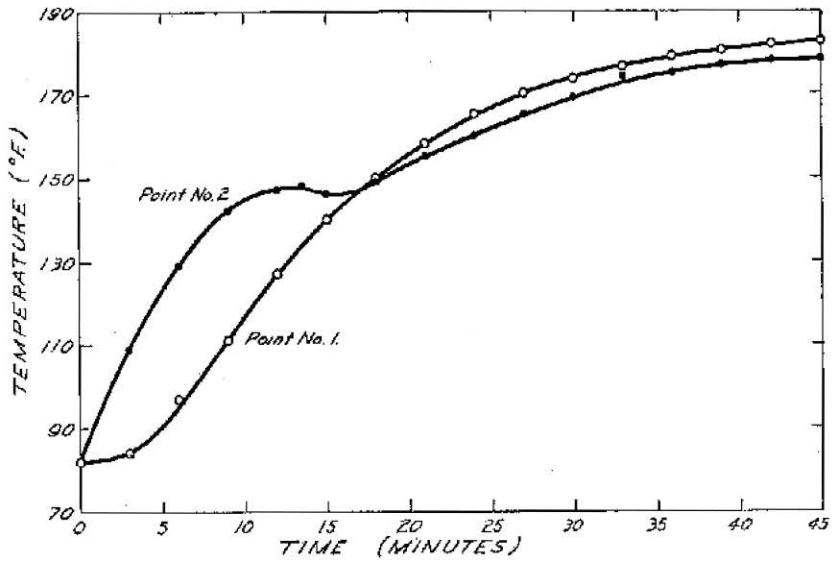

Fig. 2. Change in zone of slowest heating in quart jar of whole fresh pack pickles during spray pasteurization at 185 deg. F.

is not high enough to prevent the growth of some spoilage organisms. A yeast and two strains of *Lactobacilli*, isolated from spoiled jars of fresh pack pickles, grew in pickle brines containing 6.0 per cent but not 6.5 per cent salt and in pickle brines containing 1.4 per cent but not 1.6 per cent or more of acetic acid. Thus, pickle brine, which usually contains from 0.4 to 0.8 per cent acetic acid and about 2.5 per cent salt, could not be expected to prevent the growth of spoilage organisms. Moreover, because of the acid and salt tolerance of these organisms, it would not be practical to control spoilage in pickles by increasing the acid or salt content of the brine.

Ratio of Pickles to Brine. An analysis of heat penetration data for quart jars of whole fresh pack pickles and their correlation with the ratio of pickles to brine indicated 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 influence in the rate of heating. The method of packing and the tightness of pack of individual pickles also have an important influence on the rate of heating in the slowest heating area of the jar. In the spoilage of pickles in experimental packs, there was a general trend towards a higher incidence of spoilage in jars with smaller brine volumes; however, occasionally spoilage was found in jars with relatively large brine volumes. The tightness of pack of individual pickles together with an accompanying slow rate of heating in localized areas was regarded as a contributing cause.

Salt and Essential Oils Effects Vary. Concentrations of salt up to 10 and 15 per cent in pickle brines had little or no effect on the thermal resistance of a yeast that had caused spoilage in fresh pack pickles. From these and other observations, it would appear that the salt concentration, within the limits normally employed, would not influence the degree of heat treatment required for the pasteurization of fresh pack pickles.

Because of the bacteriostatic and bactericidal properties attributed to certain spices and essential oils, it would seem possible that these ingredients might influence the pasteurization requirements of fresh pack pickles. Anderson *et al*[2] reported that a Kosher dill spice oil flavoring (258 ppm.) and mustard oil (20 ppm.) reduced the thermal resistance of a yeast in pickle brine. Anderson, Esselen, and Fellers[1] in studies on the thermal resistance of *Bacillus thermoacidurans* found that clove oil and black pepper exerted a slight action in lowering the heat resistance of this organism in tomato juice. In five experimental packs of whole fresh pack pickles put up in this laboratory, the addition of 20 ppm. of mustard oil appeared to exert an influence in enhancing the effect of a given pasteurization treatment. The results of these tests, summarized in Table 1, are based on only a limited amount of data and are not considered as being conclusive because of the variables in heat penetration rates that may exist with this product. Although the data do not indicate that the addition of the mustard oil was significantly effective in reducing the pasteurization requirements, it would appear that its presence does provide an added safety factor of importance, especially under borderline conditions.

Kosker, Esselen and Fellers[5] have studied the effect of mustard oil (allylisothiocyanate), oil of garlic and oil of onion on the thermal resistance of *Aspergillus niger*, *Saccharomyces ellipsoideus*, and *Bacillus thermoacidurans*. The presence of 10 ppm. of mustard oil in buffer reduction and in apple and grape juices caused a marked reduction in the thermal resistance of *Aspergillus niger* and *Saccharomyces ellipsoideus*, but *Bacillus thermoacidurans* was much less sensitive to this compound. Oil of garlic and oil of onion had less effect on the thermal resistance of the latter organisms than did mustard oil.

Movement of Pickles During Pasteurization. In the course of investigations on heat penetration rates in jars of whole fresh pack pickles, data were occasionally obtained which indicated that during pasteurization the pickles in a jar or in certain areas of a jar may move sufficiently to alter the rate of heating at points where they are pressed together. These jars were not shaken, and it is assumed that any movement of the product was due to its expansion during heating. As a result of such movement, the rate of heating may be increased or decreased at a given point during pasteurization as illustrated in Figure 2.

The pasteurization or heat treatment requirement of whole fresh pack pickles is influenced to a considerable degree by the rate of heat penetration into the product. Because of the nonuniformity of the product and the way it is packed into jars the rate of heat penetration varies greatly. Pasteurization procedures therefore, should be based on these considerations. Although such factors as acidity (within the limits normally used), ratio of pickles to brine volume, and essential oils and spices may not be of major importance in influencing the effectiveness of pasteurization, they may exert a definite influence, the magnitude of which is governed by the rate of heat penetration and other conditions.

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