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Influence of Various Acidities and Pasteurizing Temperatures on the Keeping Quality of Fresh-Pack Dill Pickles

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SUMMARY

A series of experiments was conducted in commercial pickle plants involving the pasteurization of fresh-pack dill pickles. The various combinations of temperature and equilibrated acidity tested spanned ranges of 120–200°F and 0.20–1.00% acetic acid. The influence of these initial conditions was determined for physical and chemical characteristics of the equilibrated brine and pickles, and supplementary data was obtained on microbial activity in the stored product. A separate experiment was carried out in which heating rates and insulation of the jar caps were investigated. Another experiment was conducted to study the influence of tightness of pack on the heating rates of brine and pickles.

Internal-product temperatures in the range of 160–170°F with an equilibrated acidity of 0.60% acetic acid or greater, prevented spoilage by natural fermentation and produced pickles of good quality. At temperatures less than 160°F, acidities of up to 1.00% acetic acid did not prevent spoilage.

Increasingly higher internal-product temperatures, from 170 through 200°F, resulted in correspondingly increased amounts of bloater damage to the internal structure of the cucumber.

Faster heating rates decreased pickle firmness, particularly for those located in the upper part of the jar. Insulation of the top of the jar cap did not protect the pickles against this loss in texture.

Tightness of pack greatly influenced the heating rate of the fresh-pack dill pickles. Here, use of the lower brine percentage (25%) resulted in failure to attain the desired internal-product temperature, while the higher brine percentage (45%) caused the internal-product temperature to rise slightly above that of the standard pack (33%). Chemical composition of the finished product was also markedly affected.

INTRODUCTION

During the past 30 years, the amount of pickling cucumbers used in producing pasteurized pickle products has increased from about 200,000 bu to nearly 9,000,000; the latter figure represents almost 40% of the current national crop. Pasteurized pickle items have greatly expanded the cucumber market by making new types of pickles available. Such products have proven very popular with the consumer because they retain much of the characteristic crispness and attractive appearance of the natural cucumber (Etchells *et al.*, 1951).

Since one of our early publications (Etchells, 1938), a number of papers dealing with various aspects of the pickle pasteurization procedure have been reported (Cook *et al.*, 1957; Nicholas *et al.*, 1957; Nicholas *et al.*, 1961a, 1961b; Pflug *et al.*, 1960) including a recommended internal-product pasteurizing temperature of 165°F for 15 min followed by prompt cooling (Etchells *et al.*, 1940; Etchells *et al.*, 1941; Etchells *et al.*, 1942, 1943, 1944a, 1944b).

Although the above procedure has been in general use for many years, there appears to have been no study conducted under commercial conditions designed to give consideration to the influence of different acidities and temperatures on the physical, chemical and microbiological changes in fresh-pack dill pickles as related to the keeping quality of the product.

EXPERIMENTAL

Temperature and acidity study. Thirteen treatments with respect to initial conditions were selected; these constituted a trial. Each treatment within a trial contained 48 jars. Three trials were made during the first season's work—the first on August 5–9 (Trial 1-G), the second on September 5–7 (Trial 2-G) in the same plant, and the third September 4–12 (Trial 1-MW) in another plant. The 15 treatments, including a duplicate and a control, and certain physical and chemical properties of the packed material are identified in Table 1. All trials were

Table 1. Identification and properties of treatments for a single trial.

Code	Initial conditions: Temp.	Initial conditions: Desired equilibrated acidity as acetic acid	Headspace	Cover brine: Acidity as acetic acid[1]	Cover brine: Salt content	pH of blended material
	°F	%	cc	%	%	
M	120	0.60	20	1.54	2.80	3.99
E	140	0.35	20	0.90	2.70	3.99
D	140	0.85	20	2.18	3.00	3.77
G	150	0.50	20	1.28	2.95	3.94
F	150	0.70	20	1.80	2.95	3.80
C	160	0.20	20	0.51	2.75	4.16
A-1	160	0.60	20	1.54	2.85	3.98
A-2	160	0.60	20	1.54	2.95	3.98
B	160	1.00	20	2.57	2.90	3.81
X	165	0.60	20	1.54	2.90	3.98
I	170	0.50	20	1.28	3.00	3.90
H	170	0.70	20	1.80	3.00	3.82
J	180	0.35	25	0.90	2.80	4.07
K	180	0.85	25	2.18	3.10	3.97
L	200	0.60	35	1.54	2.85	3.99

[1] % acetic acid × 10 = grains vinegar.

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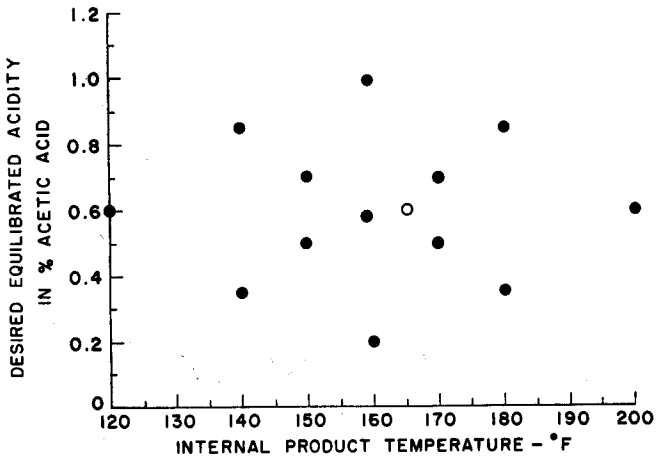

Fig. 1. Experimental plan used in the study of the influence of various acidities and pasteurizing temperatures on the quality of fresh-pack dill pickles shown in the configuration of the treatment combinations. The open circle represents the control treatment (165°F at 0.60% acetic acid).

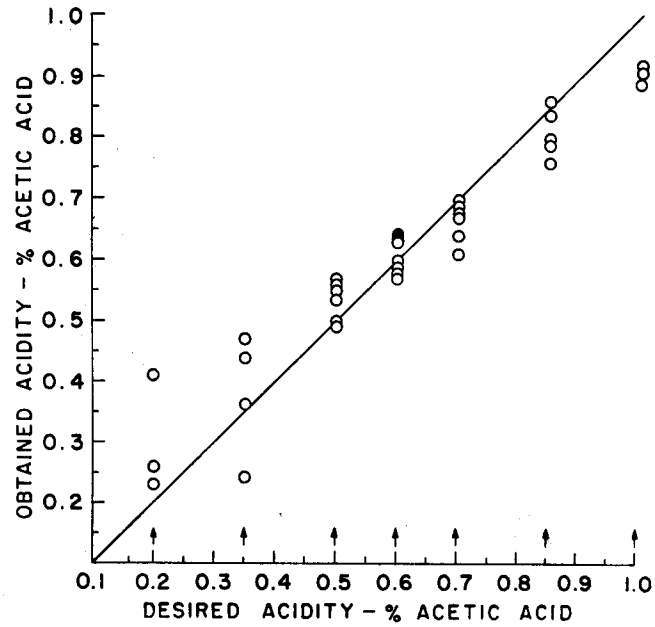

Fig. 2. Degree of success in obtaining the seven desired levels of equilibrated acidity included in the initial design of the experiment. Arrows on the abscissa mark the desired levels, and each point shown for an obtained acidity represents an average of three jars from one experimental run.

essentially the same except for the cucumber variety used. The first trial consisted of variety SMR-12 and the second of variety SR-6. The third was mixed stock of variety Maine No. 2 and another, probably SR-6. A second order statistical design was used to permit the characterization of the relationship between temperature and acidity. The configuration of the treatments in the temperature-acidity ranges is shown in Fig. 1. The extent to which the desired equilibrated acidities were achieved from the calculated brine acidities (Table 1) can be seen in Fig. 2.

Preparation of Pickles. The 32-oz. jars were first spiced with chopped dill weed and emulsified essential oil spices. Next, 10½ oz of brine, containing sufficient vinegar to equilibrate at the desired acidity levels, was poured into each of the 50 jars that constituted a run. Each jar was then hand-packed with washed, unblanched, fresh cucumbers to an accurate headspace level. All jars were packed to maintain 33% brine and 67% pickles by volume. By exercising careful control, a constant tightness of pack was obtained. One jar was blended for pH testing and another was used for temperature control. The remaining 48 jars were available for storage and future evaluation. The jars in each run were capped with 70 mm "twist-off" vacuum caps (White Cap Company, Chicago, Illinois) and pasteurized.

Pasteurizer description. This unit was designed to accommodate fifty, 32-oz jars. Two expanded-metal removable trays were employed to facilitate loading and unloading through a hinged end door. Live steam, regulated by manually operated valves, was introduced into the enclosed chamber through two manifolds located above and below the trays. Jars were cooled by a water spraying system positioned above them. Cooling water could be tempered with steam for initial cooling to prevent thermal shock.

Pasteurizer procedure. The first run contained a maximum thermometer located in the center of a cucumber and placed in the center of a jar. This thermometer checked the internal pickle temperature against the potentiometer readings. The readings were identical. Another jar was wired with five thermocouple leads to the potentiometer. The sensing ends of the leads were placed as follows:

1. Inside the center cucumber.
2. Center of the jar brine.
3. Inside the jar in the brine near the glass.
4. Pasteurizer temperature outside the jar.
5. Pasteurizer temperature outside the jar.

A four degree temperature difference was measured within individual jars during the heating process. Heat treatment refers to a given internal-product temperature without any holding time. In the pasteurizing cycle the coldest area was heated to the test temperature.

Cooling of pickles. As soon as the contents of the jars reached the desired temperature, tempered cooling water was introduced into the pasteurizer. The internal-product temperature of the jar was reduced to 100°F. The cases were stored in an area where temperature remained at approximately 70°F.

Measurements recorded on brine and pickles. Each treatment was inspected visually for signs of spoilage as indicated by turbidity of the brine.

After 6 months storage, three jars from each treatment were selected at random for analysis of brine and evaluation of the stock. In treatments which had both good and spoiled jars, three jars were selected from each kind.

On each jar the following physical measurements were taken:

1. Vacuum in inches.
2. Headspace in cubic centimeters.
3. Brine volume in ounces.
4. Refractometer readings on the brine in degrees Brix.

Chemical analyses for brine acidity (calculated as percent acetic acid), and for salt in percent were measured by the methods of Richardson *et al.* (1939). Measurement of pH was done with a glass electrode pH meter.

Microbial counts were made microscopically on the brine samples by the following methods:

1. Bacteria by smears as outlined by Wang (1941), and the Gram stain (Kopeloff *et al.*, 1928).
2. Yeasts were counted for viable and non-viable cells as described by

Table 2. Data from physical, chemical, and microscopic examination made at the end of 6 month's storage period.[1]

Trial	Temp. in °F	Desired equilibrated acidity %	Vacuum in inches	Head-space cc	Brine vol. oz	Acidity %	pH	Salt %	Spoilage %	Yeast[2] count in cells/ml	Bacterial[2] count in cells/ml
1-G	120	0.60(S)	−13.3	13	11.2	1.32	3.41	2.38	100.0	73 T	377 M
	140	0.35	4.0	48	11.0	0.47	4.03	2.45	16.7	140 T	19 T
	140	0.35(S)	−15.5	26	10.7	0.92	3.57	2.43	—	7 T	385 M
	140	0.85	5.8	42	10.9	0.86	3.78	2.68	16.7	0	65 T
	140	0.85(S)	−7.3	38	11.0	1.33	3.40	2.67	—	13 T	673 M
	150	0.50	5.5	44	10.7	0.56	4.02	1.73	4.8	0	52 T
	150	0.50(S)	2.5	44	10.7	1.02	—	1.75	—	0	>2000 M
	150	0.70	5.3	46	10.6	0.70	3.84	2.67	0.0	0	50 T
	160	0.20	5.0	45	10.9	0.41	4.25	2.53	0.0	8 T	60 T
	160	0.60	5.3	45	10.4	0.63	3.99	2.40	0.0	423 T	41 T
	160	0.60	6.5	44	10.6	0.64	4.00	2.07	0.0	206 T	75 T
	160	1.00	6.0	45	10.7	0.92	3.81	2.52	0.0	1623 T	7 T
	165	0.60	6.5	42	10.9	0.64	3.71	2.33	0.0	0	0
	170	0.50	8.5	51	10.3	0.57	3.94	2.50	0.0	12 T	32 T
	170	0.70	7.2	44	10.5	0.68	3.88	2.62	0.0	0	26 T
	180	0.35	6.9	50	10.4	0.44	4.06	2.55	0.0	8 T	140 T
	180	0.85	8.4	46	10.3	0.84	3.84	2.63	0.0	0	21 T
	200	0.60	12.3	54	10.2	0.63	3.97	2.37	0.0	266 T	63 T
2-G	120	0.60(S)	−19.3	0	11.6	1.18	3.32	2.65	100.0	163 T	368 M
	140	0.35(S)	−20.7	2	11.0	0.85	3.76	2.52	100.0	27 T	1237 M
	140	0.85	3.5	44	10.9	0.79	3.68	2.88	88.1	103 T	752 T
	140	0.85(S)	−15.3	0	11.4	1.08	3.56	2.80	—	250 T	350 M
	150	0.50	5.8	36	11.4	0.53	3.97	2.60	31.0	256 T	112 T
	150	0.50(S)	−18.7	3	10.9	0.86	3.75	2.67	—	47 T	1316 M
	150	0.70	5.5	40	11.3	0.69	3.87	2.93	42.9	80 T	656 T
	150	0.70(S)	−21.0	5	11.5	0.97	3.67	2.92	—	107 T	788 M
	160	0.20	4.5	40	11.2	0.26	4.17	2.42	0.0	0	1 M
	160	0.60	5.0	42	11.3	0.60	3.85	2.62	0.0	0	54 T
	160	0.60	5.7	40	11.8	0.57	3.94	2.62	0.0	120 T	9 T
	160	1.00	5.3	43	10.9	0.92	3.71	2.77	0.0	0	22 T
	170	0 50	6.0	40	11.2	0.55	3.92	2.70	0.0	0	97 T
	170	0.70	7.7	43	11.4	0.67	3.90	2.93	0.0	35 T	127 T
	180	0.35	7.6	43	11.3	0.36	4.04	2.60	0.0	0	106 T
	180	0.85	7.2	45	11.1	0.80	3.76	2.87	0.0	0	60 T
	200	0.60	11.5	57	10.8	0.58	3.91	2.63	0.0	0	97 T
1-MW	120	0.60(S)	−0.7	50	8.2	1.16	3.14	2.56	96.0	63 T	453 M
	140	0.35(S)	−7.3	51	10.7	0.90	3.49	1.90	100.0	27 T	3398 M
	140	0.85(S)	−5.7	31	10.5	1.69	3.14	3.03	100.0	28 T	1110 M
	150	0.50	7.8	47	10.1	0.50	3.89	0.92	13.0	0	22 T
	150	0.50(S)	2.8	72	8.9	0.49	3.97	2.20	—	15 M	36 M
	150	0.70	5.8	46	10.3	0.64	3.81	2.52	47.0	0	11 T
	150	0.70(S)	−2.0	68	8.2	1.15	3.39	2.32	—	47 T	1688 M
	160	0.20	8.7	55	9.3	0.23	4.33	1.50	45.5	3 T	90 T
	160	0.20(S)	3.7	57	9.2	0.53	3.78	1.50	—	60 T	750 M
	160	0.60	7.7	50	10.0	0.59	3.73	2.92	0.0	3 T	6 T
	160	1.00	7.8	49	10.0	0.89	3.66	2.65	0.0	236 T	14 T
	170	0.70	11.8	55	10.5	0.61	3.71	2.95	0.0	0	17 T
	180	0.35	10.7	73	9.9	0.24	4.28	1.62	4.2	0	22 T
	180	0.70	11.2	61	9.4	0.76	3.77	2.15	0.0	0	22 T
	180	0.85	16.2	66	10.3	0.87	3.62	2.55	0.0	0	0
	185	0.50	14.7	69	9.4	0.49	3.95	0.60	0.0	3 T	11 T
	200	0.60	18.8	83	7.8	0.64	3.54	2.47	0.0	0	442 T

[1] Data are for means of three jars. Lots showing spoilage shown as (S).
[2] T = Thousands, M = Millions.

Mills (1941).

Pickles from the three jars in each sample were pooled in a single lot and firmness determined with the USDA Fruit Pressure Tester (Magness *et al.*, 1925) using the procedure of Bell *et al.* (1955).

All pickles in each sample were cut and examined for evidence of bloating and other internal defects. Bloaters were classified as "balloon" or "lens" and reported as total bloaters (Etchells *et al.*, 1951).

An unusual condition associated only with high temperature treatments was observed. Here, the skin portion of the pickle separated from the fleshy part leaving thin, longitudinal cavity; this defect was recorded as a "skin split" (Fig. 3).

Additional samples were selected and analyzed for peroxidase and polyphenoloxidase activity in brine and pickles (Aurand *et al.*, 1956; Sisler *et al.*, 1958).

Heating rates. In a separate experiment, three rates of attaining a predetermined level of internal-product temperature were used 15 min, 30 min and 45 min. At the 15 min rate an additional treatment was included in which a pad of ¼ in. insulating cork was cemented to the top of the cap to protect the top pickles. The test temperature was 165°F with no holding period and 0.60% acetic acid was used. Twelve jars of each treatment were prepared and all other conditions of treatment were the same as used in the other experiments. Pressure tests were made separately on pickles from the top and bottom halves of four jars from each treatment.

Tightness of pack. In this experiment three different degrees of tightness of pack were specified. The tight pack (Treatment A) had 25% brine and 75% pickles; the standard pack (Treatment B) had 33% brine and 67% pickles; the loose pack (Treatment C) had 45% brine and 55% pickles.

RESULTS AND DISCUSSION

Temperature and acidity experiments. The measurements made at each trial are recorded in Tables 2 and 3. The reproducibility of the physical and chemical measurements, expressed as coefficients of variation, are shown in Table 4. While these coefficients

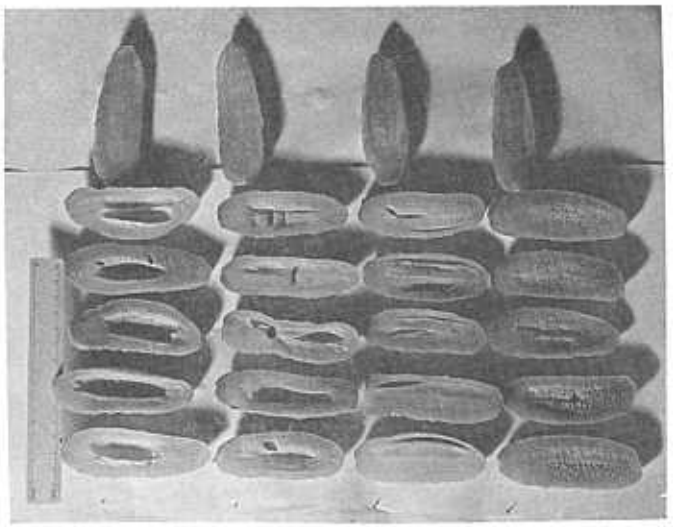

Fig. 3. Examples of undesirable changes in internal cucumber structure and appearance, classified as bloater damage, observed in unfermented, fresh-pack dill pickles pasteurized at temperatures of 170–200°F. The four types of bloater formation appear in the four columns of sliced pickles as follows (left to right): First column, balloon-type bloaters; second column, mostly lens-type bloaters; third column, skin-split-type bloaters; and, fourth column, honeycomb-type bloaters. Top row of pickles are free of bloater damage. Bloater damage similar to that illustrated above, has been reported earlier (Nagel and Vaughn, 1954; Nicholas and Pflug, 1962).

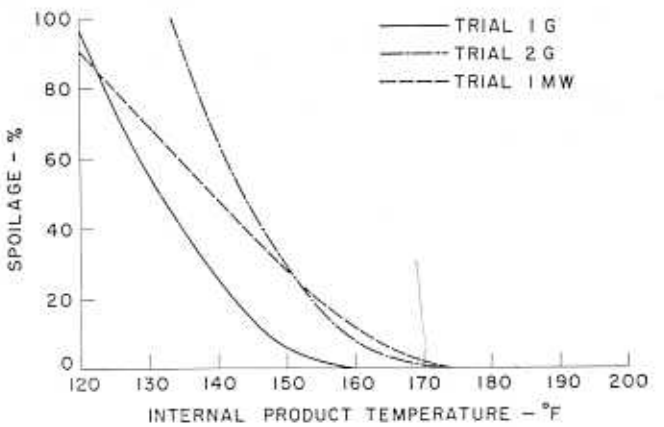

Fig. 4. Predicted spoilage of fresh-pack dill pickles(after six months' storage) as a function of pasteurizing temperature with an initial equilibrated acidity of 0.60% acetic acid.

varied somewhat from trial to trial, only the vacuum measurements were sufficiently variable to cast doubt on the efficiency of the three jar sample as representative on an entire treatment. The subsequent statistical analyses used the average of three jars.

A quadratic regression equation was fitted to each of the response variables where the independent variables were the initial conditions of pasteurizing temperature and the desired equilibrated acidity. A prediction equation was obtained for each response variable on each trial. Ability to predict response from the initial conditions is measured by the coefficient of determination given in Table 5. It must be emphasized that in computing the regression equation only the data from unspoiled jars were used unless the spoilage was 100% in that treatment. This procedure was adopted on the grounds that what was wanted was the effect of initial conditions on the jar contents apart from spoilage *unless* the condition was sure to lead to spoilage.

Table 3. Data from pickle stock. Examinations made after 6 months storage.[1]

Initial conditions		Trial 1-G			Trial 2-G			Trial 1-MW		
Temperature, °F	Desired equilibrated acidity as % acetic acid	Mean, pressure test, lbs	Mean, total bloaters %	Mean, "skin splits" %	Mean, pressure test, lbs	Mean, total bloaters %	Mean, "skin splits" %	Mean, pressure test, lbs	Mean, total bloaters %	Mean, "skin splits" %
120	0.60(S)	14.8	86.4	0	16.0	73.6	0	15.4	0	0
140	0.35	16.8	0	0	—	—	—	—	—	—
140	0.35(S)	15.3	48.6	0	15.5	96.7	0	16.5	57.8	—
140	0.85	15.8	0	0	13.1	0	0	—	—	—
140	0.85(S)	15.3	0	0	15.1	67.5	0	15.7	28.5	0
150	0.50	14.3	0	0	15.8	0	0	15.3	0	0
150	0.50(S)	15.1	0	0	15.5	76.9	0	17.6	27.0	0
150	0.70	15.0	0	0	17.0	5.0	0	16.5	0	0
150	0.70(S)	—	—	—	15.6	87.1	0	16.4	16.6	0
160	0.20	15.0	0	0	15.9	0	0	16.2	0	0
160	0.20(S)	—	—	—	—	—	—	16.6	16.2	0
160	0.60	13.5	2.6	0	17.1	0	0	15.8	0	0
160	0.60	15.6	0	0	16.6	0	0	—	—	—
160	1.00	14.0	0	20.5	16.1	0	0	15.7	0	0
165	0.60	13.9	0	0	—	—	—	—	—	—
170	0.50	12.9	0	2.3	16.9	0	0	—	—	—
170	0.70	14.2	6.2	9.3	16.0	11.1	0	14.2	0	9.1
180	0.35	14.3	19.2	0	15.4	0	13.8	13.9	31.0	0
180	0.70	—	—	—	—	—	—	15.6	7.6	5.1
180	0.85	13.3	0	35.1	16.4	0	13.5	11.6	29.6	7.4
185	0.50	—	—	—	—	—	—	13.6	0	11.7
200	0.60	10.8	0	20.5	13.0	0	69.5	13.1	91.6	0

[1] Lots having spoilage shown as (S).

Table 4. Reproducibility of physical and chemical determinations from jar to jar in the same lot (coefficient of variation expressed in percent of normal values).

Trial	Vacuum in inches	Headspace in cc	Brine vol, oz	Acidity %	pH	Salt %
1-G	32	7	3	7	1	4
2-G	19	9	2	3	2	3
1-MW	27	16	8	8	3	8

Table 5 shows that consistent predictions were obtained for vacuum, headspace, acidity, pH, spoilage, and total bacteria. For the other response variables at least one of the three trials showed no appreciable relationship to initial conditions. In the case of the refractometer readings there was so little variability in the response that the data were not presented.

The effects of temperature on spoilage are plotted in Fig. 4, again assuming an initial equilibrated acidity of 0.60%. These results are consistent with our previous commercial recommendations that the internal-product temperature should be 165°F with a 15 min holding period) with an equilibrated acidity sufficient to maintain a brine pH of 4.0 and below to assure protection from spoilage.

The results of the analyses for enzyme activity of the two oxidative enzyme systems can be summarized as follows: (1) all samples analyzed were negative for polyphenoloxidase activity; (2) peroxidase activities were highly variable below 180°F and absent above that temperature.

The discovery of skin-splits in the

Table 5. Predictability of final measurements (Y) from initial conditions of pasteurization temperature (X_1) and equilibrated finished acid strength (X_2) (expressed as % variability explainable by initial conditions).[1]

Trial	Vacuum in inches	Headspace cc	Brine vol, oz	Acidity %	pH	Salt %	Spoilage %	Yeast count per ml	Bacterial count per ml	Pressure test in lbs	Bloaters in %	Skin splits in %
1-G	79	71	84	86	79	23	93	11	75	74	56	95
2-G	86	87	33	92	88	73	82	67	68	49	76	93
1-MW	78	90	63	73	79	41	77	76	74	53	24	45

[1] The prediction equation has the form

$$y = b_0 + b_1X_1 + b_2X_2 + b_3X_1^2 + b_4X_2^2 + b_5X_1X_2$$

where X_1 = (Temperature − 160°)/5, X_2 = 2 (Acidity − 6.0 gr.), and the b's are constants calculated from the data. There is a separate set of b's for each Final Measurement (Y) and for each trial making 36 sets in all.

Table 6. Comparison of good (G) and spoiled (S) jars in lots of partial spoilage. Pressure tests and % bloaters measured on the pickle stock.

Trial	Initial conditions		Vac. in inches	Headspace in cc	Brine oz	Acidity %	pH	Salt %	Yeast[1] count in cells/ml	Bacterial[1] count in cells/ml	Pressure test in lbs	Bloaters %
	140°F	G	5.8	42.3	10.9	0.86	3.78	2.68	0	65 T	15.8	0
	0.85%[2]	S	−7.3	38.3	11.0	1.33	3.39	2.66	13 T	673 M	15.3	0
1-G	140°F	G	4.0	47.7	11.0	0.47	4.03	2.45	140 T	19 T	16.8	0
	0.35%	S	−15.0	26.0	10.7	0.92	3.57	2.43	7 T	385 M	15.3	49
	150°F	G	5.5	44.0	10.7	0.56	4.02	1.73	0	52 T	14.3	0
	0.50%	S	2.5	44.0	10.7	1.02	—	1.75	0	>2000 M	15.1	0
	140°F	G	3.5	44.0	10.9	0.79	3.68	2.88	103 T	752 T	13.1	0
	0.85%	S	−15.3	0.0	11.4	1.03	3.56	2.80	250 T	350 M	15.1	68
2-G	150°F	G	5.5	40.3	11.3	0.69	3.87	2.93	80 T	656 T	17.0	5
	0.70%	S	−21.0	4.7	11.5	0.97	3.67	2.92	106 T	788 M	15.6	87
	150°F	G	5.8	36.0	11.4	0.53	3.97	2.60	257 T	112 T	15.8	0
	0.50%	S	−18.7	3.0	10.9	0.86	3.75	2.67	47 T	1316 M	15.5	77
	160°F	G	8.7	54.7	9.3	0.23	4.33	1.50	3 T	90 T	16.2	0
	0.20%	S	3.7	56.7	9.2	0.53	3.78	1.50	60 T	750 M	16.6	16
1-MW	150°F	G	5.8	46.3	10.3	0.64	3.81	2.52	0	11 T	16.5	0
	0.70%	S	−2.0	67.9	8.2	1.15	3.39	2.32	47 T	1688 M	16.4	17
	150°F	G	7.8	47.0	10.1	0.50	3.89	0.92	0	22 T	15.3	0
	0.50%	S	2.8	72.3	8.9	0.49	3.97	2.20	15 M	36 M	17.6	27
	Average											
	Good		5.82	44.70	10.66	0.59	3.93	2.41	64 T	198 T	15.64	0.6
	Spoiled		−7.81	34.76	10.28	0.92	3.64	2.31	1725 T	887 M	15.83	87.9
	Difference		13.63	9.94	0.38	0.33	0.29	0.10	27:1	4480:1	0.19	87.3

[1] T = Thousands, M = Millions.
[2] Refers to desired equilibrated acidity as acetic acid.

pickles pasteurized at the higher temperatures was regarded as an unusual finding. The skin-split averages, plotted against temperature in Fig. 5, show a striking increase with increased pasteurization temperature. Examples of four different kinds of bloater damage at temperatures above 170°F are shown in Fig. 3.

Perhaps the most noticeable factor in all these results is the effect of spoilage in the jar. Direct comparisons between averages of the several response variables for both good and spoiled jars are shown in Table 6. These differences vary somewhat from trial to trial but worth noting are: loss in vacuum, marked increase in acidity (and lowering of pH), sharp increase in total bacteria, a moderate increase in yeasts, and a marked increase in the percentage of bloaters.

Heating rates. The relevant results of the evaluation made on the material from this experiment after 6 months' storage are presented in Fig. 6. There was no spoilage in any of the treatments.

The pickles in the bottom portion of the jars averaged 1.5 lb higher in pres-

Table 7. Studies on the influence of tightness of pack on the heating rate of fresh-pack dill pickles: Chemical and physical properties of the three experimental packs.[1]

Treatment		Final brine acidity	Final salt content	Pickles per jar
no.	% brine	%	%	number
A	25	0.60	1.90	15
B	33	0.73	2.75	13.5
C	45	1.05	3.75	11.5

[1] The pickles were first salt-brine blanched and then covered with a hot brine (140°F) having an acid content of 19.5 grains vinegar (= 1.95% acetic acid) and 7.2% salt.

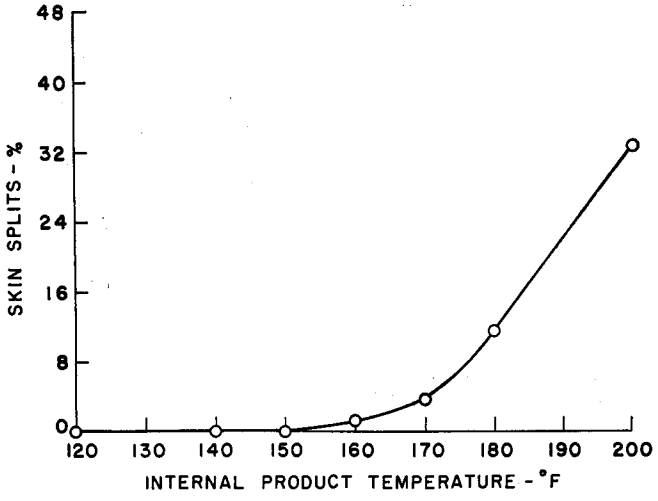

Fig. 5. Effect of pasteurizing temperature on the formation of skin-splits in fresh-pack dill pickles. The number of pickles cut to determine the percentage values shown ranged from 110 pickles for the 120°F treatment to 479 for 160°F.

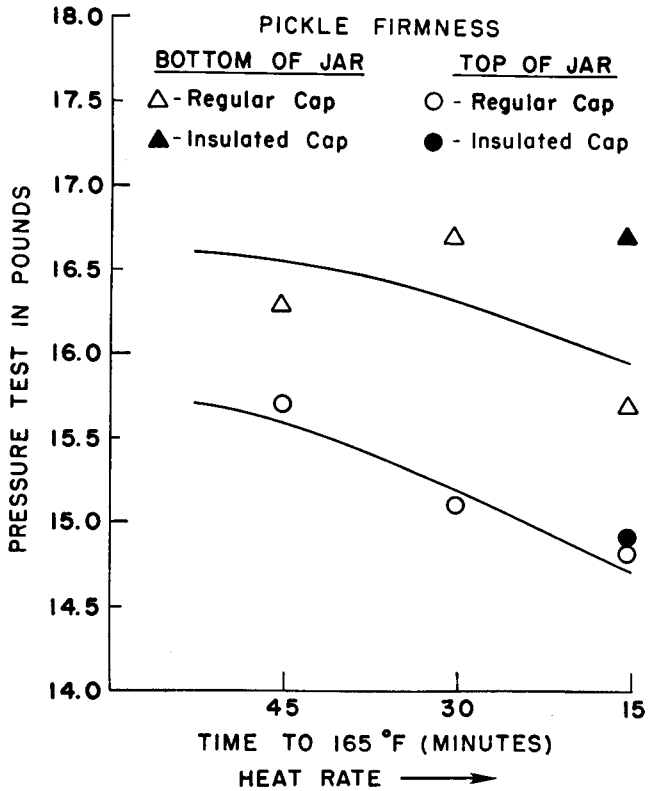

Fig. 6. Effect of rate of heating on the firmness of fresh-pack dill pickles according to location in the jar and, as influenced by insulation of the jar cap. Each point shown represents the average firmness of 20 pickles.

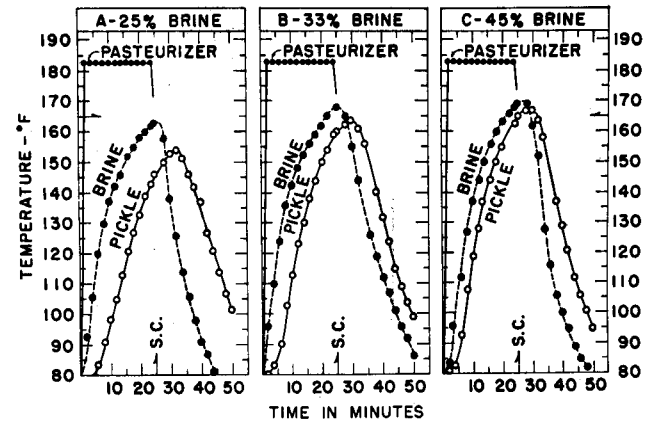

Fig. 7. Influence of tight and loose packs, compared with a standard pack, on the rate of heating of fresh-pack dill pickles. Treatment A (tight) refers to 25% brine and 75% pickles by volume; Treatment B (the standard), 33% brine and 67% pickles; Treatment C (loose), 45% brine and 55% pickles. The standard pack was heated to 165°F internal-product temperature and promptly cooled. The start of cooling (S.C.) began after 25 minutes of heating for all treatments.

sure test than those in the top portion. The faster rate of heating produced softer pickles and the difference between the top and bottom pickles was essentially the same for all three heating rates. The statistical analysis indicated that the difference between top and bottom pickles for the insulated cap treatment was not sufficiently larger than the same difference in uninsulated jars to be judged significant at the conventional 5% level. However, the analysis suggests that the insulated cap may afford some protection against thermal softening in the bottom portion of the jar.

Tightness of pack. The results of this experiment are summarized in Table 7 and Fig. 7. It is clear that the tight pack (75% pickles) results in underheating with respect to internal-product temperature whereas the looser pack (55% pickles) results in overshooting of the desired internal-product temperature. These results suggest that deviations from the standard pack in the direction of a tighter one would increase the probability of underheating and the likelihood of spoilage. A looser pack would be adequately preserved but the final levels of acidity, salt content, and spicing would be increased to the undesirable range for good product flavor.

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