ULLETIN 707 DECEMBER 1948

Development of Safe Methods for Canning *Blackeye Peas* at Home

TEXAS AGRICULTURAL EXPERIMENT STATION

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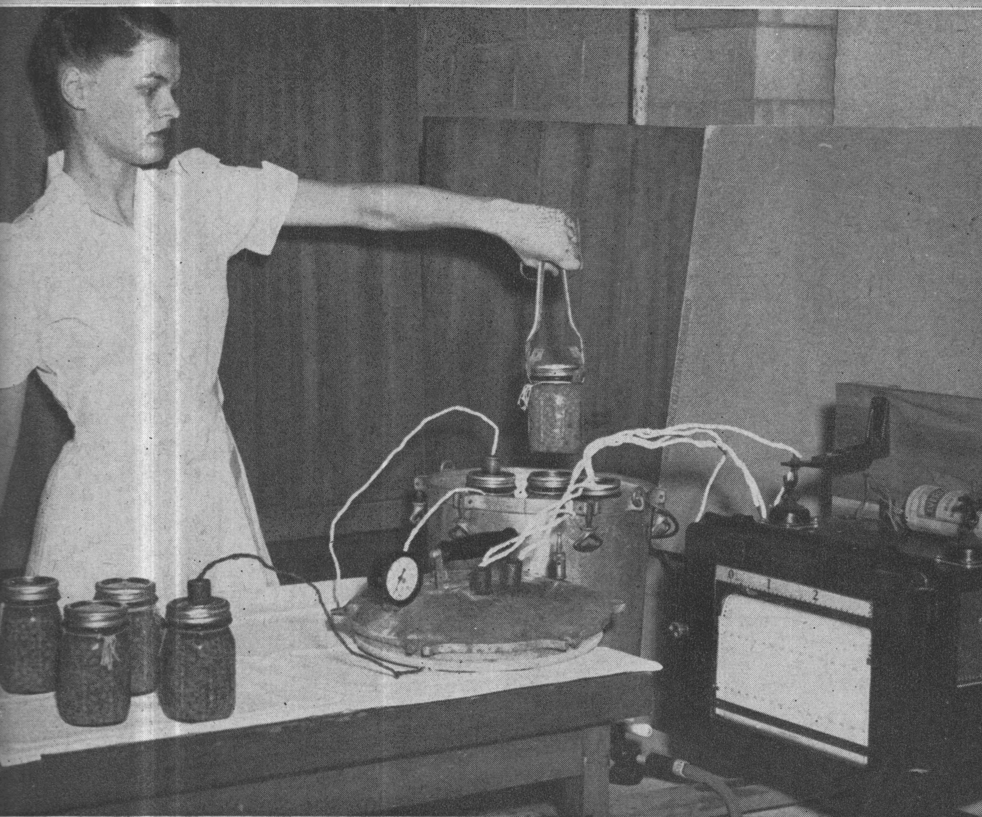

The TEXAS AGRICULTURAL AND MECHANICAL COLLEGE SYSTEM

GIBB GILCHRIST, Chancellor

The Cover Picture

A load of pint jars of blackeye peas is being removed from the canner. Three of the 16 jars were used for heat penetration tests.

The thermocouple wires were inserted in the jars by means of the flat type stuffing box soldered to the lid. One jar with a thermocouple attached is on the table, another may be seen in the top layer in the canner and the third is in the bottom layer of the canner with only the thermocouple wire visible.

The temperature inside each jar was recorded at two-minute intervals by the instrument seen at the right.

Preface

Blackeye peas are one of the favorite foods of Texans and many are canned at home. The canning procedure used should prevent the growth of harmful bacteria and be carried out as quickly as is consistent with safety.

This study was made to find the shortest safe processing periods which would destroy the harmful bacteria and make home canned blackeye peas a safe food. The recommended procedure involves two steps: processing and cooling.

Processing: Place sealed containers in a pressure canner containing one to two inches of boiling water. Process at 10 pounds pressure for the times required by size and kind of container.

Processing times for glass jars (hot or cold pack):

Pints . . . . 35 minutes
Quarts . . . . 40 minutes

Processing times for tin cans (hot pack only, sealing temperature 170° F. or above):

No. 2 . . . . 30 minutes
No. 2½ . . . . 35 minutes
No. 3 . . . . 35 minutes

Cooling: *For glass jars,* allow the petcock to remain closed until the pressure returns to zero. Then open the petcock and remove the canner lid. Cool glass jars at room temperature away from drafts.

For tin cans, open the petcock as soon as the fire is turned out. When the pressure returns to zero, remove the lid of the canner. Cool tin cans in several changes of cold water.

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CONSIDERABLE research has been done in recent years on developing safe methods for home canning of foods (Toepfer *et al.*, 1946; Nelson and Knowles, 1940; Cover *et al.*, 1943). The Bureau of Human Nutrition and Home Economics, in cooperation with various agricultural experiment stations and departments of home economics, is now engaged in a comprehensive study of home canning problems. The Texas Station is cooperating with the Bureau in the work on vegetables.

Vegetables are receiving attention because many of them are in the low-acid group of foods. If spores of *Clostridium botulinum* are present, and the heat treatment during canning is not sufficient to destroy them, these spores may grow in sealed containers of canned low-acid foods and produce a toxin so poisonous that a tiny amount is sufficient to cause death. The deadliness of this toxin may be more clearly understood when it is compared with that of other poisons. Hull (1943) reported that the pure toxin of *Cl. botulinum* is 20 times as strong as cobra venom, 300 times as strong as strychnine and 10,000 times as strong as potassium cyanide.

The toxin of *Cl. botulinum* may be present in a canned product which shows only slight indications of spoilage or decomposition. This is indicated in a striking manner in the detailed reports of case histories from outbreaks of botulism. The habit of tasting food suspected of incipient spoilage has caused many women to die of botulism. A list of some foods which have caused outbreaks of botulism and references to the original articles are given in Table 1. As a result of these and other studies, commercial canners were forced to adopt processing times which are adequate to destroy *Cl. botulinum*.

Table 1. Foods which have caused outbreaks of botulism

Food	Number of outbreaks	Bacteriologically proven	Reference
String beans	21	6	Schoenholz, et al. 1923; Geiger, et al. 1922; Dickson 1918
Corn	12	6	Schoenholz, et al. 1923; Geiger, et al. 1922
Asparagus	5	3	Schoenholz, et al. 1923; Dickson 1918; Geiger, et al. 1922
Spinach	4	1	Schoenholz, et al. 1923; Geiger, et al. 1922
Apricots	3	1	Schoenholz, et al. 1923; Dickson 1918
Pears	3	1	Schoenholz, et al. 1923; Dickson 1918; Meyer and Gunnison 1929
Chili sauce	1	1	Schoenholz, et al. 1923
Chili peppers	1	1	Hall 1936
Cauliflower	1	1	Hall 1936
Tomato-onion-chili sauce	1	1	Cutter 1922
Tomatoes	1	1	Slocum, et al. 1941
Okra	1	1	Tucker and Swanson 1939
Beets	1	0	Schoenholz, et al. 1923; Geiger, et al. 1922
Beets and turnip tops	1	0	Schoenholz, et al. 1923
Pimento	1	Not tested	Geiger 1924a
Figs	1	Not tested	Geiger 1924a

Home canners in many parts of the United States, however, have not been as aware of this danger as have the commercial canners, nor have all of them been conscientious about using only those processing times which were known to be safe. Scarcity of recognized outbreaks and lack of familiarity with known cases of botulism may have given home canners an unwarranted feeling of security which the commercial canners were forced to abandon long ago.

The wide geographic distribution of *Cl. botulinum* is indicated by its isolation in 44 of the 48 states either from soil samples or from outbreaks of botulism. Texas is among the 44. Much of this work was done by Meyer and Dubovsky (1922a and 1922b) but some reports were made also by Thom *et al.* (1919), Nevin (1921), Cutter (1922), Geiger (1924b), Damon and Payabal (1926), Hayhurst (1926), Meyer and Gunnison (1929), Hall (1933 and 1936), Slocum *et al.* (1941) and Parry (1946). Although the spores have been found most frequently in the Western States, they are so widely distributed in nature that no area may safely be assumed to be free of them.

With these facts in mind, it is a wise precaution to use only those canning methods which provide heat treatments sufficient to destroy the spores of *Cl. botulinum.* Low-acid foods, for this reason, should be processed only under steam pressure, never in an oven or boiling water bath. This makes the pressure canner indispensable to the safe processing of home canned low-acid foods.

Other losses from spoiled food are also important. The time and labor involved in preparing and preserving the food are too great to risk spoilage by using inadequate processing times. In times of food scarcity or high prices, the loss of the food itself is an important consideration.

Because of the lack of information on adequate heat treatments under home conditions, quite long processing periods in the pressure canner were recommended in the past.

Many factors must be considered in determining the lowest safe processing periods. The heat resistance of the spores is not the same in all foods. Differences in composition and acid reaction cause some foods to need longer heat treatments than others. Heat penetration, moreover, varies with the size of the container and also with the consistency of the food; thick or solid packs need longer processes than watery or loose packs. Thus, the processing time of each food must be studied separately in each of the various sizes and kinds of containers.

The present cooperative study between the Texas Agricultural Experiment Station and the Bureau of Human Nutrition and Home Economics reports the development of a safe home canning method for blackeye peas, a popular variety of Southern peas (edible cowpeas).

Experimental Procedure

The lowest safe processing times for blackeye peas were determined by procedures essentially the same as those described by Toepfer, Reynolds, Gilpin and Taube (1946) for other vegetables. These procedures made use of heat penetration records and inoculated jars.

Peas Used

Fresh blackeye peas were obtained from a wholesale produce company, grocery stores and local farms and gardens. The size and maturity of the peas used in the study were:

1. *Immature green*—The entire pods were green. The shelled peas were small, immature and green in color; they were very difficult to shell, but the quality and flavor of the canned product were excellent.
2. *Fresh mature*—The pods were either yellowish green or had yellow streaks. The peas were fully grown but were a mixture of green and white; they were easier to shell than the smaller ones.
3. *Fresh white mature*—The pods were yellow. These peas were fresh (not dry), large, very mature and white; they were quite easy to shell.

The peas were kept under refrigeration both before and after shelling until they were used. Every effort was made to use only firm, sound peas of good color and of the desired maturity.

Hot Pack Method

The canning procedure used in this study followed the recommendations given in the USDA leaflet AWI-93, "Home Canning of Fruits and Vegetables" (1944), with a few exceptions. The most important exceptions were the method of standardizing the fill of the containers and the amount of headspace above the liquid level.

Because the fill of the container and the level of the liquid inside it may influence the rate of heat penetration, preliminary runs were made to learn what weight of peas, in grams, would give the most desirable fill after processing. The weight of peas used for each maturity and for each size and kind of container is given in Table 2. The desirable fill obtained is shown in Figure 1.

Just before canning, the peas were thoroughly washed in small lots, drained and combined into one large lot. The peas for each

Table 2. Weight of blackeye peas in each container

Container	Weight of peas packed, grams			
	Hot pack			Cold pack
	Immature green	Fresh mature	Fresh white mature	Fresh mature
Pint glass jars	255	245	240	210
Quart glass jars	570	540	....	510
No. 2 tin cans	320	....	....	....
No. 2½ tin cans	....	470	....	....
No. 3 tin cans	....	540	535	....

container were then weighed, placed in individual two-quart saucepans and precooked separately by covering with boiling water and bringing to a rolling boil. Next, they were drained and placed in clean, numbered, hot glass jars or clean, numbered tin cans. Fresh, boiling water was added to the containers in accordance with the Bureau's directions. (Certain bacteriologists insist that the precooking water be discarded because this reduces the spore load.) The headspace above the liquid level was one-half inch for jars and one-fourth inch for tin cans. Air bubbles were worked out with a knife blade. The mouth of each container was wiped with a clean, damp cloth. The jars were sealed with two-piece metal closures which had been given the recommended hot water treatment. The recorded sealing temperatures for tin cans ranged from 177° to 195° F., well above the minimum of 170° F. specified for tin cans by Toepfer, Reynolds, Gilpin and Taube (1946). Each container, as soon as it was packed and sealed, was placed in the hot pressure canner containing 1 to 2 inches of boiling water. Placing the containers in accordance with a prearranged diagram insured that the containers with the thermocouples, the inoculated containers and the controls were arranged differently in each canner load. Two

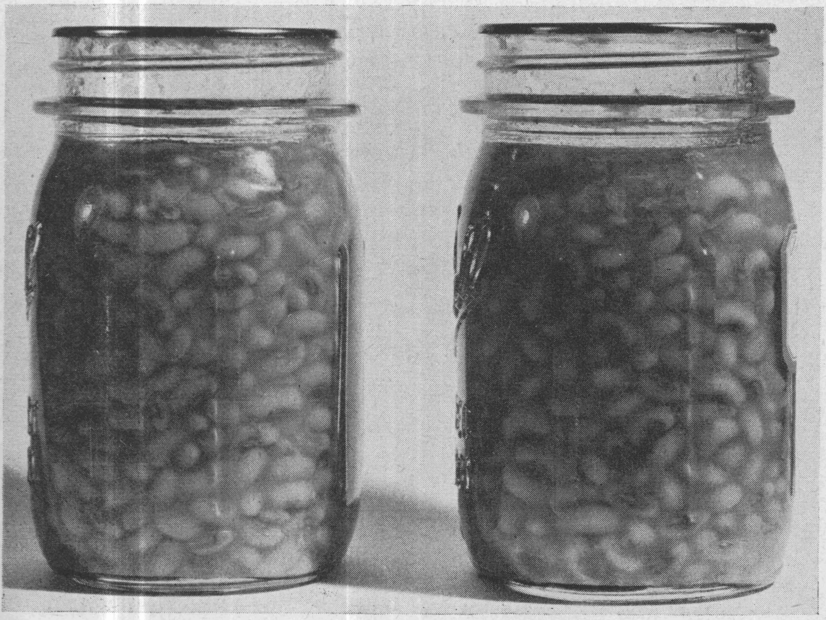

Figure 1. Desirable fill of jar. The peas come to the neck of the jar and the liquid covers them slightly.

persons working together completed the procedure from the start of the precooking to the sealing of the last container for a full canner load in approximately 20 minutes.

Frequently, steam was issuing from the petcock by the time the canner lid was fastened. After steam appeared, the petcock was left open for a 10-minute steaming period, during which the amount of issuing steam was kept steady. When the petcock was closed, the flame was turned up until it covered the bottom of the pressure canner, and an effort was made to bring the temperature of the pressure canner up to 115.5° C. (240° F., 10 pounds pressure) in approximately 10 minutes. Processing time was counted from the time the pressure canner reached 10 pounds pressure. At the end of the processing time, the fire was turned out and the canner left to cool on the open ring of the gas hot plate. When pint and quart jars were processed, the petcock was left closed until the temperature of the pressure canner reached 100° C. (212° F., 0 pounds pressure). At that time the petcock was opened and the lid was removed. When No. 2, No. 2½ and No. 3 tin cans were processed, the petcock was opened immediately after the fire was turned out, and the lid of the pressure canner was removed when the temperature of the canner reached 100° C. (212° F.). The glass jars were allowed to cool at room temperature, away from drafts. The tin cans were cooled by being moved about in a sink filled and refilled with cold water.

A continuous record of the internal temperature of the pressure canner and the three jars (or cans) containing the thermocouples was secured at 2-minute intervals throughout the entire processing period. This record was continued for the containers until the temperature of the slowest cooling one reached 87.5° C. (189.5° F.). After cooling, the bands were removed from the jars, and both jars and cans were cleaned, labeled and stored.

A full canner load was processed each time. For pint jars and No. 2 tin cans, there were 16 containers in each canner load, but there were only 11 No. 2½ tin cans, 10 No. 3 tin cans and 7 quart jars.

Cold Pack Method

Cold pack methods are easier to use than hot pack methods, but they may not produce as good a product because of inadequate venting of entrapped air. However, Esselen and Fellers (1948) reported that glass jars, if tightly sealed with two-piece metal closures and processed at 10 pounds pressure, will vent satisfactorily and will permit most of the entrapped air to be exhausted from the jars during the processing. This venting characteristic makes glass jars suitable for cold pack canning. The determination of safe processing times for blackeye peas in glass jars using the cold pack method is, therefore, desirable.

The cold pack method used with the blackeye peas followed closely the previously described hot pack method. The only difference in the two methods was that, in the cold pack method, the peas were not precooked; they were placed in the clean containers immediately after weighing, and fresh, boiling water was added to within one-half inch of the top of the jars. Preliminary runs were made, as before, to determine what weight of peas, in grams, would give the most desirable fill after processing. The weights selected are given in Table 2.

Heat Penetration Tests

The heat penetration tests were made by passing four thermocouple leads from a recording potentiometer through the lid of the pressure canner. One was used to record the temperature in the canner and one in each of the three containers of canned food. To prevent loss of steam, the thermocouple wires were passed through stuffing boxes attached to the lid of the canner and the lids of the containers of food. Two types of stuffing boxes were used, as shown in Figure 2. The shank type (in the foreground) was attached to

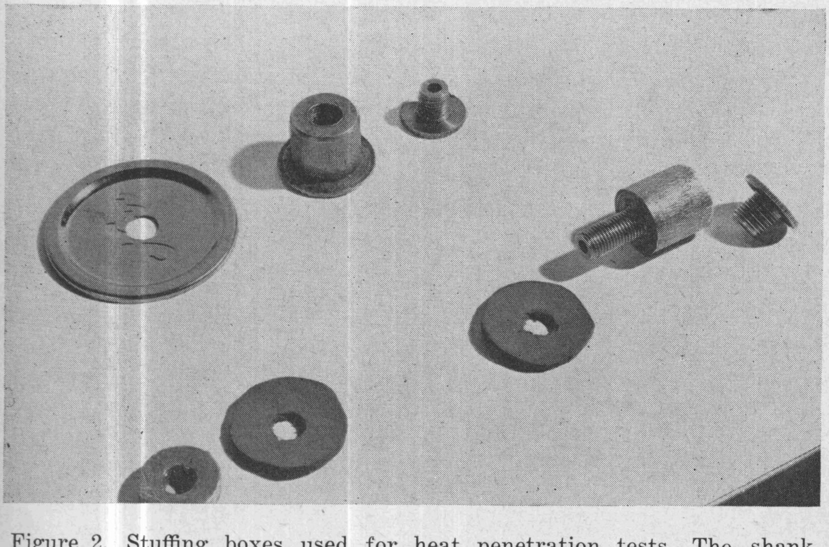

Figure 2. Stuffing boxes used for heat penetration tests. The shank type, in the foreground, was used on the lid of the pressure canner. The flat type, in the background, was soldered to the lid of the container.

the pressure canner by means of two gaskets and a nut. A hole had been drilled in the canner lid to allow passage of the shank containing the wires. One gasket was placed between the stuffing box and the outside of the lid, the other between the inside of the lid and the nut. The flat type (in the background) was soldered directly to the lid of the containers; a small hole had been cut in the lid to allow passage of the thermocouple wire. With the lids for the glass jars, the soldering could be done before the hot food was placed in the container, but for the tin cans, the soldering had to be done after the container was sealed. Temperatures of canner and containers were recorded automatically on the instrument chart. This equipment is shown in the front cover picture with a load of pint jars being removed from the canner.

Because the place in the container which heats most slowly is the spot most desirable for the thermocouple, preliminary runs were made to determine the location of the "cold spot" in each of the different containers. This was done by inserting two or three thermocouple wires of different lengths along a vertical axis in the center of the same container filled with peas and noting the differences in heat penetration. The "cold spot" was found to be near the bottom of the container. The length of the thermocouple wire was then adjusted to secure readings at that spot in each container.

Inoculation Tests

Spore preparations of *Cl. botulinum* fail to exhibit uniform heat resistance. For this reason, laboratories interested in commercial canning problems found that they needed an organism whose spores were similar to *Cl. botulinum* in their growth requirements, were near or slightly higher than the maximum of *Cl. botulinum* for heat ressistance, but were of uniform heat resistance. Putrefactive Anaerobe No. 3679 was reported by Townsend, Esty and Baselt (1938) to meet these conditions. This organism has been and is widely used by the canning industry in place of *Cl. botulinum* for determining safe processing times. Since outbreaks of botulism from eating commercially canned food have not occurred in recent years, P. A. No. 3679 was considered a satisfactory test organism and was used in this study.

Inoculation tests were made only in hot pack pint jars. Only one size and kind of container and method of packing was needed because the inoculation tests were made to determine the heat resistance of the spores. The heat resistance is affected by the composition and acid reaction of the food, not by the rate of heat penetration.

The 13 jars in each canner load not needed for heat penetration tests, were utilized for the inoculation tests. Four or 5 were kept as controls, and the remaining 8 or 9 were each inoculated with 10,000 spores of P. A. No. 3679. Because no spoilage occurred the first year even with short processing times, the precaution was taken the second year to test the viability and resistance of the spores at intervals during the canning period. The dilution of the spore suspension was adjusted to secure 10,000 viable spores per milliliter of inoculum. Inoculation was made into the filled container just before it was sealed. Spoilage in the inoculated jars was shown by broken seals, gas bubbles, frothing and foul odor.

The inoculated and control jars were stored in a constant temperature room in which the temperature varied normally between 78° and 80° F.

Actual Processing Times

Variation in process times for the hot pack pint jars were planned in accordance with expected spoilage: complete spoilage with the lowest process time, partial spoilage with the next, and none with the highest. Because quart jars, tin cans and cold pack pint jars were not inoculated, only one processing time was used. The time selected was estimated to be long enough to prevent spoilage. The reasons for this will be given later in the bulletin.

Results and Discussion

Inoculation Tests

Complete spoilage data were obtained for immature green blackeye peas and some data were secured with the other maturities. Data from the spoilage tests are given in Table 3.

Immature green blackeye peas: With the 10-minute processing, complete spoilage of the inoculated jars had been expected. In the 5 canner loads processed, 40 of the 41 inoculated jars had spoiled after 6 months' storage, but none of the 22 control jars spoiled. The one unspoiled, inoculated jar contained no viable spores of P. A. No. 3679 when tested bacteriologically in the laboratories of the Bureau of Human Nutrition and Home Economics.

With the 20 minute processing, some spoilage was expected. Four canner loads were processed. Of the 33 inoculated jars stored, only 1 spoiled within 6 months, and no viable spores were found in any of the other 32 when bacteriological tests were made by the Bureau. None of the control jars spoiled.

Table 3. Spoilage in inoculated pint jars of blackeye peas after processing at 240° and incubation at 78-80° F., 1947 data (hot pack)

Date of processing	No. of canner loads	Process time, min.	Mean process value F_0	No. of jars stored		Spoilage in inoculated jars		Length storag month
				Control*	Inoculated	Number	%	
Immature green								
May 13, 14, 15, 16, and 19	5	10	4.68	22	41	24 37 38 39 40	59 90 93 95 98	1 2 4 5 6
May 17, 21, 22, and 23	4	20	7.87	17	33	1	3	6
May 24, 26, 27, and 28	4	30	10.51	17	34	0	0	6
Fresh mature								
June 12, 13, 14, 16, and 17	5	10	4.30	22	41	38 39 41	93 95 100	1 2 3
Fresh white mature								
May 28	1	10	3.79	4	9	9	100	1

*None spoiled.

No spoilage was expected with the 30 minute processing. Four canner loads were processed for 30 minutes, and no spoilage occurred in either the control or the inoculated jars after 6 months' storage.

Fresh mature blackeye peas: Five canner loads were processed for 10 minutes. All of the 41 inoculated jars spoiled within the first 3 months of storage. No other packs of this maturity were inoculated.

Fresh white mature blackeye peas: Only one canner load of peas of this maturity was available when the inoculation tests were made. They were processed for 10 minutes. All of the nine inoculated jars spoiled within the first month of storage.

Calculation of Actual Process Values From Heat Penetration Data

The heat penetration records, consisting of the internal temperatures of the containers, were used to calculate safe process times. As the first step in these calculations, the time and temperature data for each container of food must be converted into terms of their destructive effect on the spores of the spoilage organism. The destructive effect of each temperature for each minute of time it is maintained represents a definite fraction of the total destruction. This fraction may be expressed as the lethal rate.

The lethal rate at any given temperature is the ratio of the time in minutes needed to destroy the organism at 250° F. to the time in minutes needed to destroy it at the given temperature. This ratio is known as F/t. The equation for calculating F/t is usually given

as $\log t/F = \dfrac{250 - T}{z}$, where

F is the time in minutes needed to destroy the organism at 250° F.

t is the time in minutes needed to destroy the organism at the given temperature.

z is the slope of the thermal-death-time curve. ($z = 18$ was used for the calculations in this study.)

250 is degrees Fahrenheit.

T is the observed can or jar temperature in ° F.

Using a table of logarithms, the antilog for $\log t/F$ is obtained. The reciprocal of this antilog is F/t.

A table of lethality values was prepared from these calculations. Since the temperatures were recorded in degrees Centigrade, the table was made for the Centigrade readings and their equivalents in degrees Fahrenheit. As an illustration, the time and temperature data and the F/t values for one pint jar (hot pack) in one canner load are given in Table 4.

A lethality curve was then constructed for each jar containing a thermocouple. This was done by plotting lethal value against time on accordinate paper. Such a lethality curve is shown in Figure 3 using the data given in Table 4. The area under the lethality curve was then measured in square inches with a planimeter (Figure 4). This area represents the total lethal value of the heating-cooling period and is referred to as the process value, or F_0. The heating part of the area is referred to as F_H and the cooling part of the area as F_C. In order for the area under the lethality curve, in square inches, to represent the lethal value of the process directly in terms of F_0, the scale of the figure was purposely designed so that, in one square inch, the product of the time and the sterilizing value (F/t) would equal 1, as, for example, 20 minutes x .05 = 1.0 in Figure 3. A summary of the heating and cooling data and the sterilizing value of the processes for blackeye peas is given in Table 5.

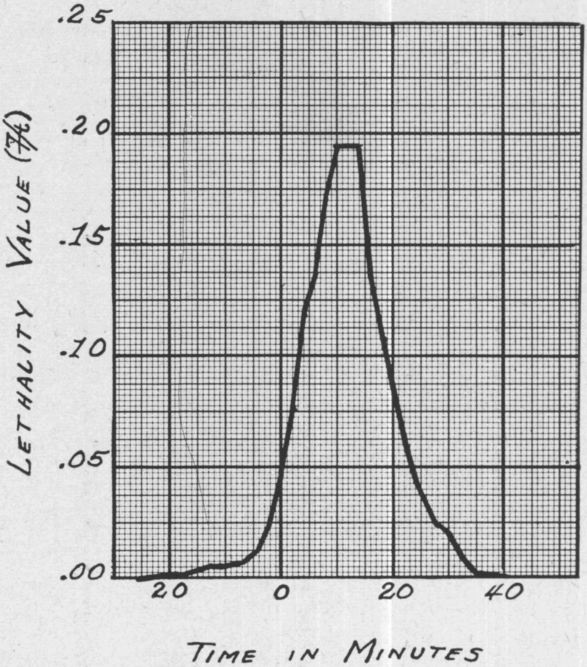

Figure 3. A lethality curve constructed from the data for a pint jar given in Table 4.

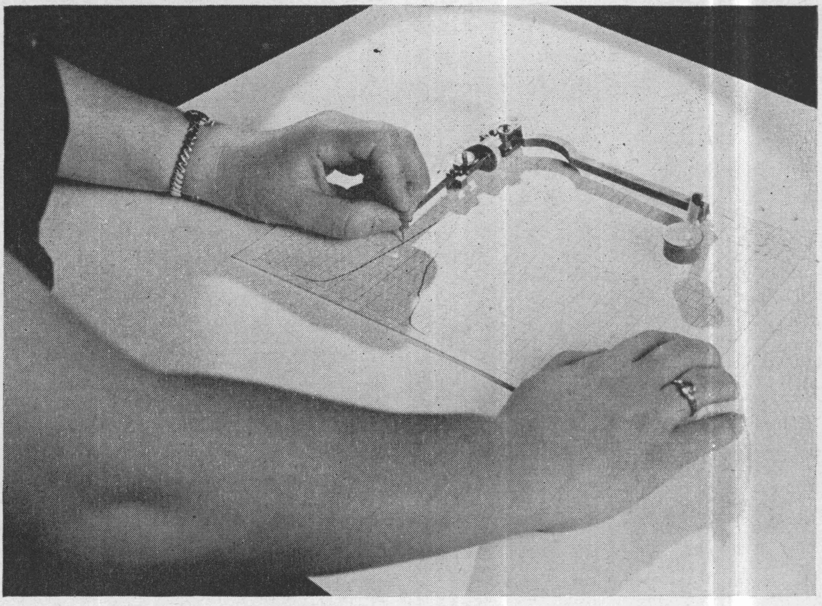

Figure 4. The area under the lethality curve is being measured with a planimeter.

Table 4. Times, temperatures, and lethality values for one pint jar of blackeye peas during processing at 240° F. (hot pack)

Minutes from fastening of pressure canner lid	Minutes from start of processing time	Temperature inside pressure canner		Jar 6B		
				Jar temperature		F/t
		°C	°F	°C	°F	
				82.5*	180.5*	
0	—28			86.0	186.8	
2	—26			88.0	190.4	.00049
4	—24			90.0	194.0	.00077
6	—22	91.0	195.8	91.5	196.7	.00109
8 (S)	—20	99.5	211.1	93.5	200.3	.00173
10	—18	100.5	212.9	95.5	203.9	.00275
12	—16	100.0	212.0	97.5	207.5	.00436
14	—14	100.5	212.9	98.5	209.3	.00548
16	—12	100.0	212.0	99.5	211.1	.00690
18 (D)	—10	100.5	212.9	99.5	211.1	.00690
20	— 8	103.5	218.3	100.0	212.0	.00774
22	— 6	106.5	223.7	101.0	213.8	.00975
24	— 4	108.5	227.3	103.0	217.4	.0155
26	— 2	113.0	235.4	105.5	221.9	.0275
28 (P)	0	116.0	240.8	108.0	226.4	.0489
30	2	115.5	239.9	110.5	230.9	.0869
32	4	115.5	239.9	112.0	233.6	.1227
34	6	115.5	239.9	112.5	234.5	.1377
36	8	115.0	239.0	113.5	236.3	.1734
38 (O)	10	116.0	240.8	114.0	237.2	.1945
40	12	114.0	237.2	114.0	237.2	.1945
42	14	112.0	233.6	114.0	237.2	.1945
44	16	111.0	231.8	112.5	234.5	.1377
46	18			111.5	232.7	.1094
48	20	107.0	224.6	110.5	230.9	.0869
50	22	106.0	222.8	109.0	228.2	.0615
52	24	104.5	220.1	107.5	225.2	.0436
54	26	103.0	217.4	106.5	223.7	.0346
56	28	102.0	215.6	105.0	221.0	.0245
58 (R)	30	100.5	212.9	104.5	220.1	.0218
60	32			101.5	214.7	.0109
62	34			98.0	208.4	.00489
64	36			93.5	200.3	.00173
66	38			91.5	196.7	.00109
68	40			88.0	190.4	.00049

*Sealing temperature.
Symbols
S—Steam
D—Petcock down
P—Processing time begun
O—Fire out
R—Jars removed

Estimated process values are sometimes necessary. In those tests which were run for heat penetration only, the processing time was continued for a period considerably beyond that at which spoilage would develop, thus permitting estimations of process values to be made for shorter times. First, the lethality curve was constructed as before, and the process value for the entire time was obtained in the usual way. Then, to obtain the process value of the shorter time, a vertical line was erected at the new process time until it intersected the heating curve. A second line was drawn horizontally from that point until it intersected the cooling curve. A third line was drawn perpendicularly between that intersection and the base line. The area to the left of the first new line is the new F_H, and the area to the right of the third new line is the new F_C. The sum of the two areas is the estimated F_0 for the new process time. The estimated process value for a still shorter process time may be

Table 5. Heating and cooling data and sterilizing values of processes for blackeye peas

Container	Product	Year	Process time	No. of containers	Container temperature: When sealed	Container temperature: When canner reached 240° F	Mean process values: Heating	Mean process values: Cooling	Mean process values: Total	Standard deviation of F_O
Hot pack										
			Min.		°F	°F	F_H	F_C	F_O	S. D.
Pints........	Immature green.....	1946	10	12	187	231	1.56	1.10	2.66	0.59
			20	12	187	223	3.70	1.57	5.27	0.78
			35	12	185	225	8.43	1.49	9.92	0.97
		1947	10	15	177	228	2.35	2.33	4.68	0.56
			20	12	175	229	4.93	2.94	7.87	0.72
			30	12	177	229	7.82	2.69	10.51	0.64
	Fresh mature.......	1947	10	15	180	226	2.30	2.00	4.30	0.85
			45	13	182	228	10.99	2.60	13.59	0.46
	Fresh white mature..	1947	10	3	185	226	2.25	1.50	3.75	....
Quarts.......	Immature green.....	1946	60	12	190	221	13.62	1.47	15.09	0.62
	Fresh mature.......	1947	60	14	182	225	13.68	2.35	16.03	0.62
No. 2 cans....	Immature green.....	1946	40	11	187	232	10.75	0.76	11.51	0.95
No. 2½ cans..	Fresh mature.......	1947	60	12	181	229	15.19	0.74	15.93	0.81
No. 3 cans....	Fresh mature.......	1947	60	12	184	233	16.05	0.63	16.68	0.51
	Fresh white mature..	1948	40	12	190	230	9.72	0.88	10.60	0.61
Cold pack										
Pints........	Fresh mature.......	1948	36	15	147	228	8.99	2.43	11.42	1.07
Quarts.......	Fresh mature.......	1948	35	12	132	221	7.38	2.61	10.00	0.35

Table 6. Actual and estimated process values for immature green blackeye peas in quart jars (hot pack)

Actual process values		Estimated process values	
Number of canner loads	60 minutes	35 minutes	10 minutes
	F_0	F_0	F_0
1	15.56	8.61	1.44
	15.48	8.53	1.59
	15.32	8.37	1.54
1	14.46	8.06	1.53
	14.41	8.57	1.86
	14.92	8.52	1.60
1	16.54	8.48	1.77
	15.32	7.25	1.42
	15.23	8.28	1.61
1	14.72	7.77	1.21
	14.73	7.23	1.10
	14.39	7.99	1.28

obtained in a similar way. An illustration of how an estimated process value was obtained is given in Figure 5, using data for a hot pack quart jar. Actual and estimated processes for one series of quart jars are given in Table 6. Thus, by using two estimated processes, the number of process times needed for calculating the regression line may be obtained from the heat penetration data for only one long actual processing time.

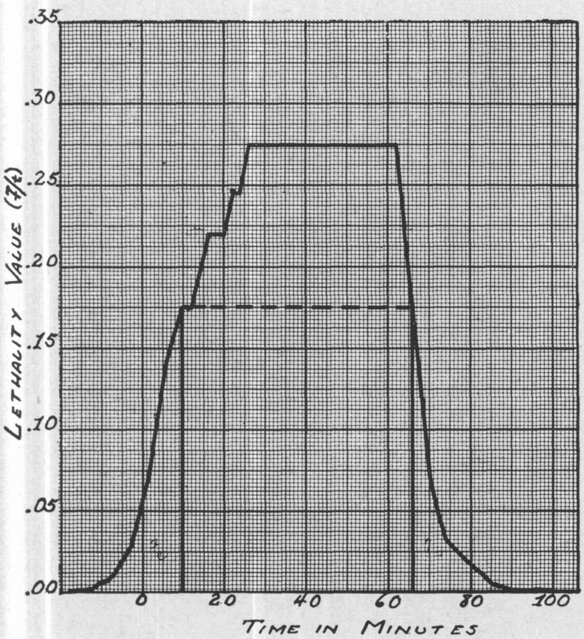

Figure 5. A lethality curve, showing how an estimated process value was obtained for a process time of 10 minutes.

Estimated process values may be slightly in error when they are obtained for very short process times. In experimentally obtained curves for short process times, the temperature of the food may remain constant at the process temperature for a few minutes, or even rise slightly, before cooling. This would increase the area under the curve and so increase the process value. Thus, an estimated process value, which does not take this increase into account, may be slightly lower than one obtained experimentally. The error, however, has the effect of increasing the margin of safety.

Calculation of Representative Process Values for Corresponding Process Times

The next step was to determine, from the many individual process values, processing times which will yield adequate sterilizing values for each size of container and method of packing. Uusually 12 separate process values were secured for each process time, and usually each one was a different value. The mean of these F_0 values could not be used as the representative value because it would be greater than several of the determinations for the same process times, and the containers showing these lower F_0 values would require longer process times to reach that mean F_0. On the other hand, to use the lowest process value obtained in a series of 12 would not mean that the lowest value in that series is the lowest one possible for the given process time. In view of these objections to using either the mean or the lowest process value, statistics were employed to obtain the lower limit of process value. This makes use of a line of regression and its standard error of estimate.

The line of regression shows the change of process value with process time. F_0 values from at least three different process times must be obtained. The 12 F_0 values for each of the 3 different process times for blackeye peas were obtained experimentally in some instances, but in others only the highest level was obtained experimentally while the 2 lower ones were obtained by estimation, as previously described. The 12 individual F_0 values at each time level were used to calculate the regression line and its standard error of estimate. The equation for the line of regression is $y_r = a + bx$, in which x equals the process time; y, the process value; a, the ordinate of the point where the line crosses the y axis $(x = o)$; and b, the slope of the line. The values for constructing the lines of regression for each size of container, maturity of peas and method of packing are given in Table 7.

The standard error of estimate is a measure of the variation among all the different process values used for calculating the line

Table 7. Regression equation and standard error of estimate of process value on process time

Container size	Maturity of peas	Year	Regression equation $y_r = a + bx$			
			a	b	Standard error of estimate	2.6 x St. E. of Est.
Hot pack						
Pints.	Immature green	1946	—0.377	0.292	0.795	2.07
		1947	1.841	0.292	0.641	1.67
	Fresh mature. . .	1947	1.371	0.269	0.770	2.00
	All 1947 pints. . .	. . . .	1.861	0.267	0.849	2.21
	All pints.	. . . .	1.203	0.273	1.150	2.99
Quarts.	Immature green	1946	—1.279	0.272	0.474	1.23
	Fresh mature. . .	1947	—0.872	0.280	0.671	1.74
	All quarts.	. . . .	—1.039	0.276	0.680	1.77
No. 2 cans. . .	Immature green	1946	0.488	0.276	0.401	1.04
No. 2½ cans	Fresh mature. . .	1947	—0.538	0.275	0.544	1.41
No. 3 cans. . .	Fresh mature. . .	1947	0.304	0.273	0.591	1.54
	Fresh white mature.	1948	—0.604	0.281	0.680	1.77
	All No. 3 cans . .	. . . .	0.254	0.280	0.715	1.86
Cold pack						
Pints.	Fresh mature. . .	1948	0.481	0.302	0.883	2.30
Quarts.	Fresh mature. . .	1948	—0.897	0.312	0.460	1.20

of regression. The value to be assigned to each standard error of estimate is also arrived at by statistical calculations. The values for the standard errors of estimate are given in Table 7.

Each regression line was then drawn on coordinate paper, and a broken parallel line was constructed below it at a distance of 2.6 times the standard error of estimate. This lower line was the one used in determining adequate process times, because it is assumed that, with normal distribution of process values, the F_0 values for a given process time would not fall below this lower limit more than once out of every 200 times. This was the method used by Toepfer, Reynolds, Gilpin and Taube (1946). As an illustration, the regression line and its lower limit are given for hot pack pint jars in Figure 6.

Calculation of Safe Process Times

A safe process is one in which the heat treatment is adequate to destroy completely the most heat-resistant food poisoning organisms likely to be present in the raw product. Since the F value of the organism (the process value causing complete destruction) is not the same in all foods, it must be determined by relating inocu-

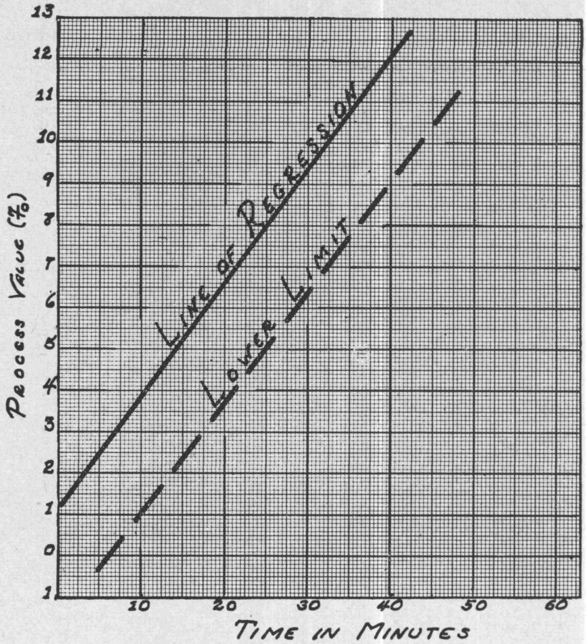

Figure 6. A regression line and its lower limit. The lower limit is drawn at a distance of 2.6 times the standard error of estimate, and is used to determine adequate process times.

lated pack data to heat penetration data. The process values (F_0) for a series of inoculated packs are given in Table 8 together with the spoilage data. These data indicate that processes yielding F_0 values of 8.0 will be adequate to destroy spores of P. A. 3679 in blackeye peas. Since spores of this organism are one and a half to two times as resistant to heat as are those of *Cl. botulinum*, processes with minimum F_0 values of 8.0 may be expected to have good margins of safety. The processes recommended were chosen to provide such sterilizing values.

Table 8. Summary of heat penetration and inoculation tests in pint jars. 1947 data for immature green blackeye peas

Process time	Inoculated jars containing spores not killed		Process value	
	Spoiled within 6 months	Viable spores present after 6 months	Mean	Range
Minutes	%	%	F_0	F_0
10	98	0	4.68	3.71 to 5.63
20	3	0	7.87	6.81 to 9.47
30	0	Not tested	10.51	9.30 to 11.20

Table 9. Calculated and recommended process times for blackeye peas

Container size	Maturity of peas	Year	Process value	Processing time at 240° F		
				Calculated		Recommended
				Hot pack	Cold pack	
			F_0	Minutes	Minutes	Minutes
Pints	Immature green	1946	8.0	36	....	....
	Immature green	1947	8.0	27	....	....
	Fresh mature	1947	8.0	32	....	....
	Fresh mature	1948	8.0	....	33	....
	All 1947 pints		8.0	31	....	....
	All pints		8.0	36	33	35
Quarts	Immature green	1946	8.0	39	....	....
	Fresh mature	1947	8.0	38	....	....
	Fresh mature	1948	8.0	....	33	....
	All quarts		8.0	39	33	40
No. 2 cans	Immature green	1946	8.0	31	....	30
No. 2½ cans	Fresh mature	1947	8.0	36	....	35
No. 3 cans	Fresh mature	1947	8.0	34	....	....
	Fresh white mature	1948	8.0	37	....	....
	All No. 3 cans		8.0	36	....	35

Because the lower limits of the lines of regression indicate the minimum process values expected for specified processing times, the processing times required to give F_0 values of 8.0 or higher may be obtained from the lower limit of each regression line. This procedure is illustrated in Figure 7 where a processing time of 36 minutes was obtained for all hot pack pint jars. Safe processing times were calculated in this way from the individual lines of regression for each size of container, maturity of peas, year and method of packing. These times appear in Table 9.

It may be noted that the calculated processing times for hot packs were similar for any one size of container irrespective of maturity of peas or year the data were obtained, except in the 1946 pints. Nevertheless, separate calculations were made using the combined data for each container size. The safe processing times calculated in this way are also given in Table 9. These times were rounded off to the nearest 5-minute interval to give the recommended processing times for hot packs (Table 9). Thus, only one processing time is recommended for each container size.

Cold packs in glass jars gave calculated processes of 33 minutes for both pints and quarts (Table 9). The recommended processing times, therefore, could be 35 minutes for each. However, it seemed safest to recommend the same processing times for cold packs as for hot packs. This increased the recommended time for quarts to 40 minutes.

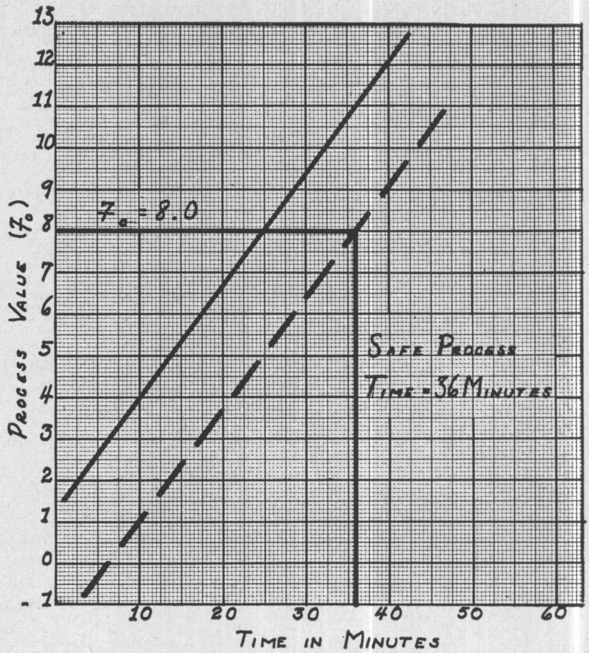

Figure 7. The regression line and its lower limit, showing how safe process times are read from the lower limits of the regression lines for an F_o of 8.0.

Conclusions

Recommended processing times for hot pack blackeye peas are: pints, 35 minutes; quarts, 40 minutes; No. 2 cans, 30 minutes; No. 2½ cans, 35 minutes, and No. 3 cans, 35 minutes. Cold packs in glass jars may be processed for the same times as hot packs.

It is convenient that maturity of peas does not influence the recommendations.

While the cold pack method of canning is much easier to do than the hot pack, there is no information yet as to which method gives the more palatable product or retains more of the vitamins. The hot pack method differs from the cold pack chiefly in its higher sealing temperature and the precooking in water which is discarded; therefore, flavor and vitamin retention may be affected. These problems need to be studied before either hot or cold pack can be recommended as the better method.

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