TEXAS AGRICULTURAL EXPERIMENT STATION

A. B. CONNER, DIRECTOR
College Station, Texas

BULLETIN NO. 635 JULY 1943

DEVELOPMENT OF METHODS FOR SAFE PROCESSING OF HOME CANNED MEATS

SYLVIA COVER, R. D. TURK, AND A. H. KERNS

Division of Rural Home Research

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS
T. O. WALTON, President

B39—743—4M—L180

[Blank Page in Original Bulletin]

Since farm people are being urged to increase their supply of home produced meat, it is imperative that a canning procedure be recommended which not only is adequate to prevent danger from harmful bacteria but also is as economical of time as is consistent with safety. When spores of Clostridium botulinum develop in food they produce a toxin so potent that a minute amount if eaten is sufficient to cause death. While this seldom happens in canned meat, contamination with these spores from the soil may occur when animals are slaughtered even under the best of conditions found on Texas farms and ranches. This study was made to find the lowest processing periods which would destroy Clostridium botulinum in canned meat and make it a safe food.

The procedure recommended is as follows:

First: Pack cold meat into containers, leave unsealed and heat for a specified time in a cooker from which steam is escaping. The time at which steam starts to flow from the cooker in a steady stream marks the beginning of "Steaming time." "Steaming time" varies in length according to the size of container as follows:

No. 1 cans	30 minutes
No. 2 cans	60 minutes
No. 3 cans	90 minutes
Pint jars	60 minutes
Quart jars	80 minutes

Next: Immediately after "steaming time" is ended, seal the containers, return them quickly to the hot cooker, and begin processing at once. Process at 15 pounds according to size of container for the following periods of time:

No. 1 cans	50 minutes
No. 2 cans	60 minutes
No. 3 cans	85 minutes
Pint jars	60 minutes
Quart jars	75 minutes

Finally: As soon after processing as the pressure on the gauge returns to zero, remove tin cans and cool quickly and thoroughly in cold water. Leave the glass jars in the open cooker until the liquid inside stops bubbling, then remove them and allow to cool in air at room temperature.

CONTENTS

DEVELOPMENT OF METHODS FOR SAFE PROCESSING OF HOME CANNED MEAT

Sylvia Cover, Foods Specialist, R. D. Turk, Veterinarian, and A. H. Kerns, Electrical Engineer

During the war emergency, farm people are being urged to increase their preservation of home produced foods as much as possible in order to relieve the strain on processing and transportation facilities and yet be adequately fed. This report of safe processing periods is as timely as if it had been planned for war use. When the work was begun, tin cans only were used since they may be cooled much more quickly than glass jars, but when the shortage of tin developed, the plans were changed to include pint and quart glass jars.

When meat is canned at home on Texas farms and ranches, a whole carcass is frequently canned in one day. Under these circumstances, it becomes especially important to use the shortest processing time consistent with safety.

The Bureau of Home Economics, in 1936 and in 1943 (9) recommended that ground beef be processed at 15 pounds pressure for 90 minutes in No. 2 cans and pint jars and 120 minutes in quart jars. Texas homemakers had found that meat would "keep" perfectly with much shorter processes. The Texas Extension Service in 1940 (7) recommended 50 minutes for No. 1 cans, 65 minutes for No. 2 cans, 80 minutes for No. 3 cans, 75 minutes for pint, and 90 minutes for quart jars. In certain parts of Texas, however, objections to the meat canning program were encountered among a few physicians because of the fear of botulinus poisoning if inadequate processing periods were used.

Clostridium botulinum is widely distributed in nature. Meyer and Dubovsky (6) found this organism in virgin soil, in cultivated garden and field soils and their products, and on vegetables and fruits bought in various cities and towns in California where this study was made. The organism is a strict anaerobe, growing only in the absence of air and at temperatures from 20°C (68°F) to 37.5°C (99.5°F) on most ordinary media. According to Kelser (5) it is quite fastidious in its media reaction requirements, a neutral or alkaline medium being necessary for best luxuriant growth. It will not grow in highly acid media. Heat resistance of the spores is far from uniform. Esty and Meyer (3) found that the spores of Clostridium botulinum in juices of 17 varieties of canned food resisted heating at 100°C (212°F) for periods varying from less than 10 minutes to 230 minutes and that at 105°C (221°F, 3 pounds pressure) the heat resistance varied from 3 to 80 minutes for 109 strains of Clostridium botulinum. Thus there is always a chance that meat may become contaminated with a highly resistant strain. Acidification greatly lowers the thermal death point, the spores being

most heat resistant in media of neutral reaction. Young moist spores are the most resistant.

When animals are killed at home, even under the most favorable conditions, such as under a tree in the yard or pasture, there is a possibility of meat becoming contaminated with soil containing botulinus spores. Under less favorable conditions the possibility of such contamination is increased. Experimental work was needed to find the lowest processing periods which would kill these spores and thereby make the meat safe from the toxin produced by this organism.

Nelson and Knowles of North Dakota (8) used a sealing temperature of 86°F (30°C) but Texas people have been taught for years by their Extension Service workers to use a high sealing temperature followed by immediate processing. Using such directions, shorter processing periods are required. Thus any recommendation of processing periods must set up the conditions used in heating before sealing.

Plan of Work

Since the destruction by heat of the spores of Clostridium botulinum depends on the temperatures reached and the lengths of time they are maintained it becomes important to determine what temperatures are reached and for how long they are maintained. Heat penetration studies supplied this information. The heat penetration data were used for calculating processing times using a complicated mathematical formula which had previously been tested extensively in commercial canning plants.

Actual destruction of live spores was used as the final proof of safe processing.

In all of these tests the temperature of the meat in the cans at sealing time was as high as 180°F. This is an important point because lower sealing temperatures increase the time needed for processing. Several methods of obtaining this high sealing temperature were tested.

Heating Before Sealing

Heating before sealing drives air out of the container and reduces the chance of breaking the jars or of bulging the seams in tin cans during the processing under pressure. The higher the sealing temperature the shorter will be the time under pressure needed for the meat to reach a temperature high enough to make it safe.

Various methods have been recommended for obtaining a high temperature in the can before sealing: 1. boiling in a kettle and packing hot, 2. Cooking in an oven or in deep fat and packing hot, 3. packing cold and heating under pressure, and 4. packing cold and heating in flowing steam. The first three methods were found to have the following objections: When meat is boiled in a kettle or cooked in an oven or in deep fat before packing, it is somewhat difficult to pack and if the packing process is delayed to obtain a full even pack, the tem-

perature of the meat when sealed may be lower than 180°F. When cold meat is packed into containers and heated under pressure (7), the temperature of the meat inside is frequently raised above the boiling point of water. After the fire is turned out the meat temperature may be above that of the cooker for several minutes even after the pressure gauge has returned to zero (Fig. 1). If the petcock is opened and the

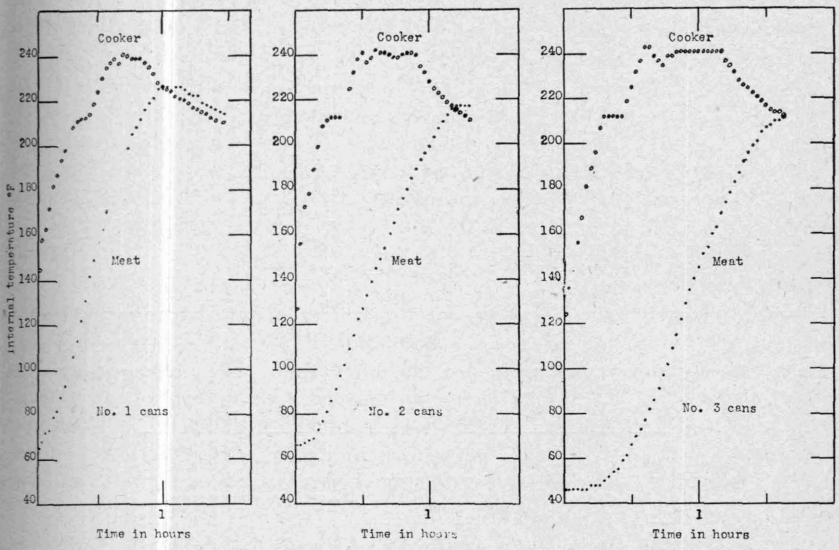

Chart 1. Heat penetration curves for No. 1, 2, and 3 cans during heating at 15 pounds pressure before sealing.

lid removed as soon as the gauge returns to zero, liquid is seen to have been drawn out of the containers so that frequently only a small amount is left. Without an elaborate set up for recording temperatures inside the containers, it is impossible to know just when to stop the heating process so that this condition will not occur.

The fourth method was found to be the most satisfactory. Cold or cool meat, which is easy to handle, is packed into jars or cans. The uncovered containers are placed on a rack in a cooker containing boiling water to within 2 inches of the top of the containers. (Glass jars must be set in cool water so that the temperature of the meat inside and the water outside does not differ enough to cause breakage.) The cooker lid is adjusted, tightening only one pair of clamps. The heat is turned on full and time is counted as soon as a continuous straight jet of steam escapes from the petcock ("flowing steam"). For No. 1 cans "flowing steam" should be maintained for 30 minutes, No. 2 cans 60 minutes, and No. 3 cans 90 minutes. For pint jars the time is 60 minutes, for quart jars 80 minutes. Tests have shown that by using this method the meat temparture is raised to around 200° F. (Figs. 2 and 3). This

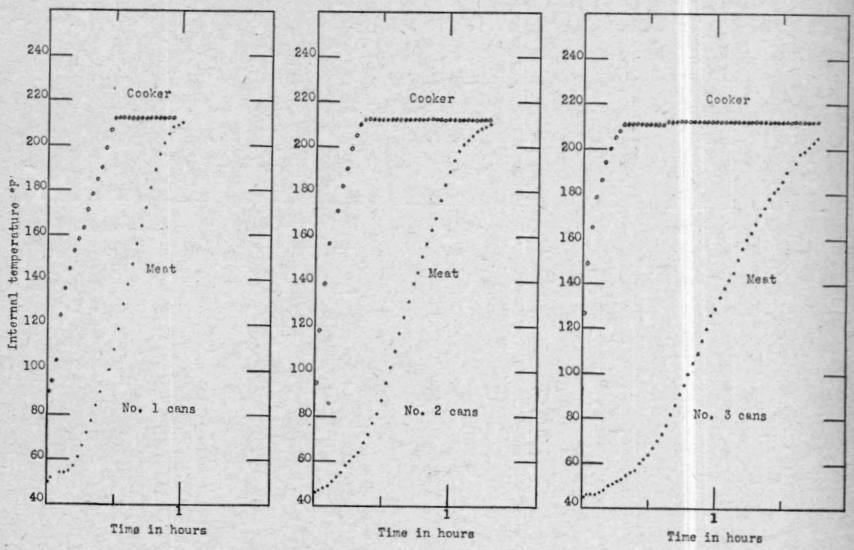

Chart 2. Heat penetration curves for No. 1, 2, and 3 cans during heating in steam before sealing.

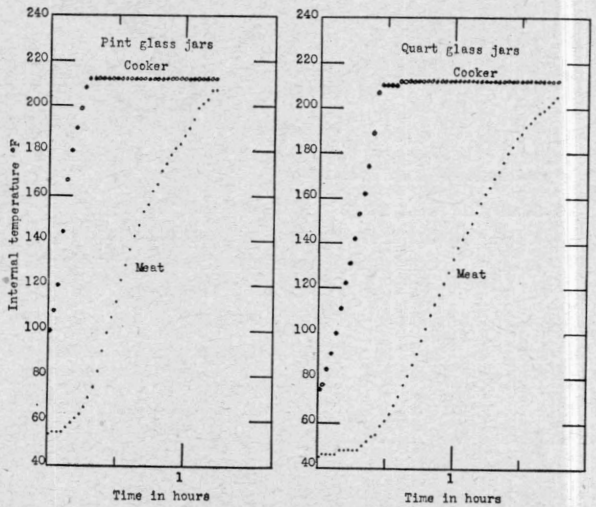

Chart 3. Heat penetration curves for pint and quart glass jars during heating in steam before sealing.

is high enough to insure an actual temparture as high as 180°F when processing is begun, if the meat is sealed quickly.

This method of heating before sealing has several advantages. After "flowing steam" is obtained, the cooker needs no attention until the time is up—a decided advantage over using pressure, as on many ranges

the flame needs frequent adjustment to maintain even pressure in the cooker and the pressure gauge must be watched constantly. The containers are always full of liquid when the lid is taken off the cooker. The total time required with "flowing steam" is about the same as when pressure is used since a fair comparison must include not only the time under pressure but the 7 minutes allowed before closing the petcock, the time to reach the desired pressure, and the time to return to zero (compare Figs. 1 and 2). The total time for No. 1 cans with pressure is 90 minutes, with "flowing steam" 60 minutes; for No. 2 cans with pressure or "flowing steam" 80 minutes; for No. 3 cans with pressure 100 minutes, with "flowing steam" 106 minutes.

When steaming is done over a low flame on a gas or on a kerosene stove, the time required to obtain "flowing steam" may be as much as 2 or 3 hours. In such cases the time after "flowing steam" may be reduced considerably (Figs. 4, 5, and 6). In fact, on an old model kerosene stove, the meat had reached the desired temperature by the time "flowing steam" was obtained (3 hours). However, the conditions vary so much among different stoves that no recommendations can be made.

A temperature of 180°F when processing begins is higher than is frequently recommended but is practical if this method of heating before sealing is used and the cans or jars are sealed **quickly** and replaced **immediately** in the **hot** cooker for processing so that the internal temperature of the containers does not drop below 180°F before processing begins. If the containers cannot be sealed as soon as "steaming time" is up, sealing within 30 minutes will still give a high enough sealing

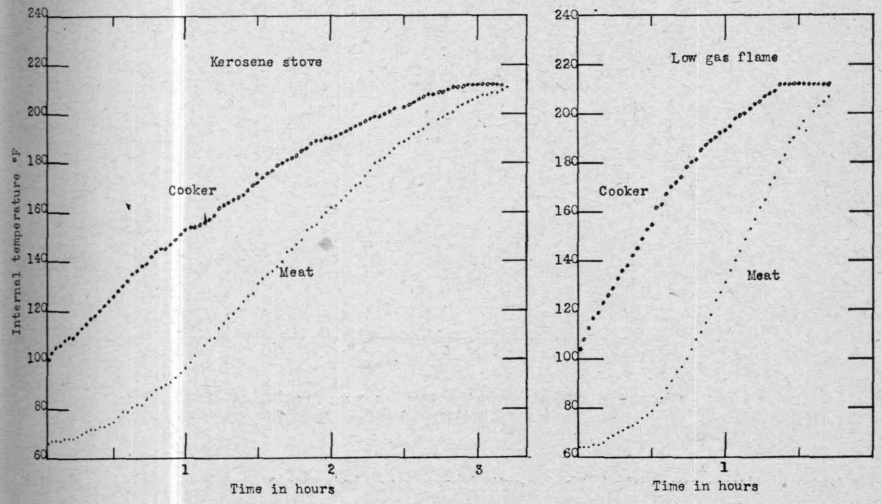

Chart 4. Heat penetration curves for No. 1 cans during heating before sealing on kerosene stove and over low gas flame.

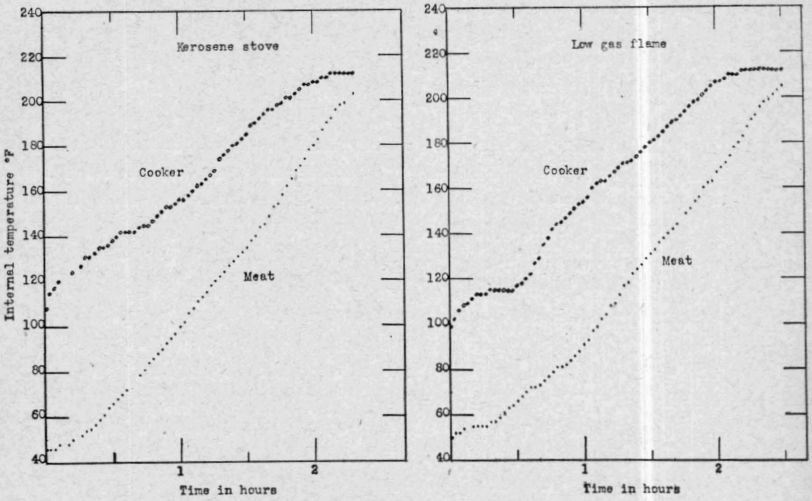

Chart 5. Heat penetration curves for No. 2 cans during heating before sealing on kerosene stove and over low gas flame.

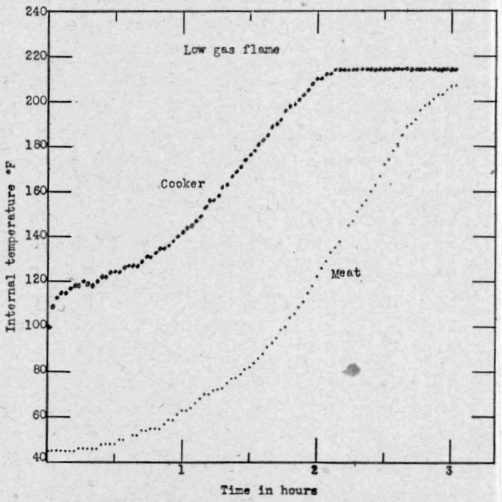

Chart 6. Heat penetration curves for No. 3 cans during heating before sealing on low gas flame.

temperature **provided** the containers are left undisturbed in the **closed cooker** (Fig. 7).

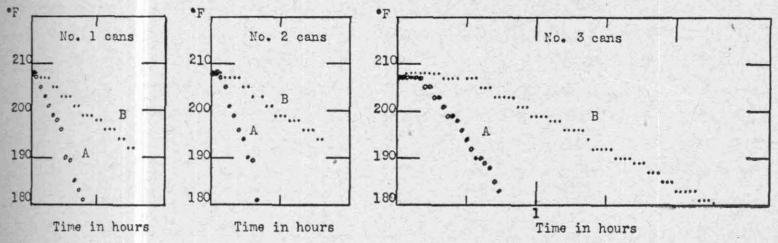

Chart 7. Cooling curves of cans under different conditions. A. On table at room temperature. B. Left undisturbed in closed cooker.

Heat Penetration Tests

The shortest safe processing period for ground meat in sealed cans was tested in two ways. In the first, now to be described, heat penetration data were obtained and used to calculate the time needed to destroy spores of Clostridium botulinum.

Thermocouples and stuffing boxes for the pressure cooker, cans, and jars, were constructed for use in measuring heat penetration. The directions given by Bigelow (2) were followed as closely as possible. At first, the thermocouple readings were made with a Leads Northrup potentiometer and the millivolt readings converted into degrees centigrade. Later, the work was speeded up greatly by substituting for the potentiometer a Celectray recording device equipped with four thermocouple lead wires which recorded the temperature on a chart. When this instrument was obtained, the thermolite rods through the stuffing boxes (recommended by Ball) were discarded because the asbestos covering on the wires of the new apparatus prevented injury during tightening of the stuffing boxes.

Two thermocouples were led into the pressure cooker by a shank type stuffing box attached to the lid. One of them was short for determining the temperature of the cooker, the other long and equipped with a flat type stuffing box for determining the temperature inside the can of meat. Since the lid on tin cans could not be sealed with the stuffing box in place, a small round hole was cut in the center of the lid of the test can to permit inserting the thermocouple after sealing. The flat type stuffing box could then be soldered to the lid, closing the hole completely. Soldering the stuffing box to the can of hot meat proved to be a very trying procedure. The heat from the soldering iron overheated the contents at the top of the can forcing the greasy broth through the liquid solder. Unless this was removed completely, the solder would not hold. Frequently a can, which seemed sealed when placed in the cooker, was leaking when removed from the cooker after processing. This necessitated many runs before data on a perfectly sealed can were obtained.

This difficulty was not present in the trials with glass jars. A square, wide mouth, glass jar having a glass top and screw band was used. A

hole was drilled in the glass top with emory dust and a shank type stuffing box was attached with gaskets and screwed tight, easily forming an airtight junction.

Heat penetration tests were made at 15 pounds pressure for No. 2 tin cans and pint and quart glass jars, and at 10 pounds pressure for No. 2 cans on a gas stove and on an old model kerosene stove.

Results from Heat Penetration Tests

Heat penetration data are given in Tables 1–3 inclusive. Safe processing periods were calculated from the heat penetration data by the National Canners Association, using the method developed by Ball (1). (Such calculations are made routinely by the National Canners Association from data collected on industrial packs but previous to the time this work was planned they had not had access to such data on packs made according to home canning procedures.)

With 15 pounds pressure. Heat penetration data for ground meat in No. 2 cans are given in Table 1. Calculations showed that the No. 2 cans would require processing at 15 pounds pressure for 50 minutes to destroy spores of Clostridium botulinum.

Heat penetration data were not obtained for No. 1 and No. 2 cans. Bigelow (2) gives a table of factors for estimating safe processing times

Table 1. Heat Penetration Data for No. 2 Cans at 15 Pounds Pressure

Time in minutes	Temperature °C	
	Pressure cooker	Center of can
2	99	97
3	101	--
4	102	86
5	107	86
7	113	88
9	120	92
10	121	94
11	121	94
13	121	96
15	121	97
17	121	98
19	121	100
22	121	102
25	121	105
28	121	107
31	121	109
34	121	111
37	121	112
41	121	114
45	121	116
50	121	117
55	121	118
60	121	119
65	121	119
70	121	120
75	116	120
80	110	120
85	106	119
89	101	117

Table 2. Heat Penetration Data for No. 2 Cans at 10 Pounds Pressure

Time in minutes	Temperature °C		Time in minutes	Temperature °C	
	Pressure cooker	Center of can		Pressure cooker	Center of can
0	52	89	64	116+	109
2	73	89	66	115	109
4	81	88+	68	115	109+
6	93	88−	70	116	110
8	100	87	72	116	110+
10	100+	87	74	116+	111
12	101−	87−	76	116−	111
14	101−	87+	78	116−	111+
16	103	88−	80	116−	112−
18	108	88	82	116−	112
20	112	89−	84	116−	112
22	116	90−	86	116−	112+
24	116−	90	88	116	113
26	---	92	90	116	113
28	116−	93	92	116	113
30	116−	94	94	116	113+
32	116−	95	96	116	114−
34	116	97	98	116	114−
36	116	98−	100	116	114−
38	116	99−	102	116−	114−
40	116	100−	104	116−	114
42	116	100+	106	115	114
44	116	102	108	115	114
46	116	103	110	115	114+
48	116	103	112	116	114+
50	116	104	114	116	114+
52	116	105	116	116	115−
54	116−	106−	118	116	115−
56	116−	107−	120	---	---
58	116−	107	122	116−	115+
60	116−	108−	124	101	105
62	116+	109−	126	---	100

for various sizes of cans, if the correct time for one size is known. Multiplying the Bigelow factor 1.5 by 50 (the processing time required for No. 2 cans) gives an estimated processing period of 75 minutes for No. 3 cans. The Bigelow factor 0.6 times 50 gives an estimated processing period of 30 minutes for No. 1 cans.

Heat penetration data for ground meat in pint and quart glass jars were obtained but the National Canners Association was swamped with emergency measures when these data were ready. Since the volumes of these jars are similar to No. 2 and No. 3 cans respectively, they were assumed to require similar processing times. Glass heats more slowly than tin but tin cans are cooled quickly and thoroughly in cold water immediately after processing, while glass jars are allowed to cool slowly in the cooker until bubbling stops then the cooling is continued in air at room temperature. Since the heat penetration tests showed that the temperature inside the glass jars when the pressure gauge returned to zero was 106°C or 107°C (corresponding to about 4 pounds pressure), the slow cooling would allow further sterilization to take place. This slow cooling is not practiced in commercial canning and the formula used for calculating safe processing times makes no provision for including this part of the sterilization period. Calculated processing peri-

Table 3. Heat Penetration Data for No. 2 Cans at 10 Pounds Pressure on an Old Model Kerosene Stove

Time in minutes	Temperature °C		Time in minutes	Temperature °C	
	Pressure cooker	Center of can		Pressure cooker	Center of can
0	60	84+	88	112	102+
2	73	84−	90	112+	103
4	77	83	92	113	104−
6	80	82	94	114−	104
8	82	81	96	114	105
10	84	81−	98	114+	105
12	86−	81−	100	115	106
14	87−	80+	102	115	107−
16	89	80+	104	116−	107
18	90−	80	106	116−	108
20	91	80+	108	116−	108
22	92	80+	110	116−	108+
24	93	81	112	116−	109
26	93	81	114	116	109+
28	93	82	116	116	110
30	94+	82+	118	116	111−
32	95	83	120	116+	111
34	96	84	122	116+	111
36	97	84	124	116	112−
38	98	84+	126	115	112
40	99	85	128	115	112+
42	99+	86	130	115+	113−
44	100	87	132	116−	113−
46	100	88−	134	116	113−
48	100+	88+	136	116	113
50	100+	89+	138	116	113
52	101	90	140	116	113+
54	102	--	142	116−	114
56	102+	91+	144	115	114−
58	104−	92	146	115	114
60	104	93	148	115	114
62	105	94−	150	115	---
64	105+	94+	152	115	114
66	106	95	154	115	114
68	107	96	156	116−	114
70	108−	97−	158	116−	114+
72	108	97	160	116	114+
74	109−	98	162	116	114+
76	109	98+	164	116	114+
78	110−	99	166	116	114+
80	110	100−	168	116	115−
82	111−	101−	170	116	115
84	111	101	172	100	115
86	112−	102			

ods based on heat penetration studies of meat canned in glass jars, therefore, would be somewhat higher than the minimum.

With 10 pounds pressure. Heat penetration data for ground meat in No. 2 cans are given in Table 2. Calculation showed that 100 minutes would be needed for safe processing.

Heat penetration data using an old model kerosene stove are given in Table 3. Such stoves are sometimes used on Texas farms and ranches to provide supplemental heating units when large amounts of canning must be done in one day. The laboratory experience was similar to that in the homes. It required 2½ hours to reach 10 pounds pressure even with the water in the cooker boiling when the sealed cans were set in. (On such a stove 15 pounds pressure is exceedingly difficult to

attain.) Although the slow rate of heating for the cooker was reflected in the rate of heat penetration into the meat in the sealed cans, yet at the time 10 pounds pressure (116°C) was reached in the cooker, the meat was actually at a higher temperature (109+°C) than when the gas stove (90−°C) had been used (compare Tables 2 and 3). This would seem to indicate that less than 100 minutes at 10 pounds pressure would destroy the spores of Clostridium botulinum when a kerosene stove is used. But when the data were submitted to the National Canners Association they reported that this method of processing was "impractical," and did not give any calculated processing time. Other reasons (given later) also caused the authors to agree that no recommendations should be made for this type of process.

Inoculation Tests

Since the deadly toxin of Clostridium botulinum is produced when viable spores grow inside the sealed cans, the processing time must be long enough to destroy the viable spores. Inoculation tests should give this information but it is difficult to produce spore crops of strains of Clostridium botulinum having a high resistance to heat, even a medium resistance being difficult of attainment. Esty and Meyer (3) reported the maximum heat resistance of spores artificially produced under the most favorable conditions for growth and heated in a phosphate solution at pH 7.0 was:

4 minutes at 120°C (248°F)
10 minutes at 115°C (239°F)
32 minutes at 110°C (230°F)
100 minutes at 105°C (221°F)
330 minutes at 100°C (212°F)

Yet the knowledge of the maximum resistance in meat of naturally occurring spores is of major importance in determining adequate sterilization processes. As a result another organism was needed similar in its growth requirements to Clostridium botulinum and at the same time having the ability more readily to produce spores of comparatively high heat resistance. Townsend, Esty, and Baselt (10) made heat resistance studies on spores of putrefactive anaerobes to determine safe processes in canned foods. They reported that P. A. No. 3679 was the most suitable organism yet found as a substitute for Clostridium botulinum and "processes for canned foods based on spoilage data obtained by the use of suspensions of No. 3679 of a resistance in phosphate equivalent to the maximum for Clostridium botulinum should be on the safe side for Clostridium botulinum." The organism has since been widely used by laboratories connected with the canning industry in experiments on canned foods. It was the organism used in this study. The spore suspension was obtained from the National Canners Association.

Four processing periods for each size of can or jar were used in the inoculation tests to provide at least one pack above and one below the lowest point at which viable spores would be found. (This point had been determined previously by calculation from heat penetration data or by other ways of estimation). Control cans or jars which were not inoculated were processed in each cooker with the inoculated ones. Inoculations were made with a suspension containing 10,000 spores per milliliter. For No. 1 cans 0.5 ml. was used, No. 2 cans and pint jars 1 ml., No. 3 cans and quart jars 1.5 ml. After heating but just before sealing the spores were placed in the center of the cans and jars with a pipette. Inoculation at this point made certain that all of the spores remained in the container. Inoculation before the steaming period would have raised the question of whether or how many spores were lost in the meat juices which spilled out of the full container during the handling necessary for sealing.

After processing, the tin cans were cooled quickly in cold water but the glass jars were allowed to cool in air at room temperature. All of the cans and jars after cooling over night to room temperature were stored at 95-98°F.

Those that showed no external evidence of spoilage (bulging or visible gas bubbles) after several months of storage were cultured in the laboratories of the Division of Veterinary Science to determine the presence of viable spores. The test for viable spores was carried out as follows: Dextrose-meat-mash media was placed in long narrow tubes (20 x 200 mm), heated just prior to inoculation to drive off any oxygen that might be present and cooled rapidly to 35°C. Control tubes of this medium, using unheated spores of P. A. No. 3679, showed luxuriant growth as evidenced by gas formation, clouding of the supernatant fluid, and a marked offensive odor. The containers of meat were opened aseptically. One milliliter of meat particles and broth was placed deep into the tubes containing the media, care being taken to introduce no air bubbles at the time of transfer. Short lengths of sterile glass tubing were used as pipettes in making the inoculations. All tubes were held in the incubator at 37°C for 7 days before being discarded. However, the positive cultures usually showed up within 24 to 48 hours, only one showed up as late as 72 hours.

Since the processing period at 10 pounds pressure as calculated by the National Canners Association was 100 minutes the method using 10 pounds pressure was considered impractical under home canning conditions and no inoculation tests were made.

No inoculation tests were made in cans processed on the kerosene stove. Each kerosene stove would present a different problem and it was deemed impossible to make recommendations which would apply to each.

Results from Inoculation Tests

When spores from P. A. No. 3679 were used, the data (Table 4) show that using a temperature as high as 180°F when processing begins and a processing pressure of 15 pounds, the lowest point at which viable spores were absent is: 40 minutes for No. 1 cans, 50 minutes for No. 2 cans, 75 minutes for No. 3 cans, 50 minutes for pint jars and 65 minutes for quart jars. These are the lowest safe processing times for canned ground meat as determined in this study.

Table 4. Spoilage Tests of Canned Meat Processed at 15 Pounds Pressure

Container size	No. of cookers full	Processing time minutes	No. of cans stored		Length of storage at 98°F (37°C)	No. of cans containing viable spores				
							Inoculated			
			Controls	Inoculated		Controls	Spo	Positive on culture	Total	Percentage
Tin Cans										
							Bulged			
1	1	20	12	24	1 wk.	0	24	--	24	100
	1	30	12	24	3 mo.	0	0	2	2	8
	1	40	12	24	3 mo.	0	0	0	0	0
	1	50	12	23	3 mo.	0	0	0	0	0
2	2	30	8	22	5 mo.	0	10	11	21	95
	2	40	8	24	5 mo.	0	0	5	5	21
	2	50	9	23	5 mo.	0	0	0	0	0
	2	60	10	22	5 mo.	0	0	0	0	0
3	3	55	9	21	2 mo.	0	4	9	13	62
	3	65	9	21	2 mo.	0	0	4	4	19
	3	75	9	21	2 mo.	0	0	0	0	0
	3	85	9	21	2 mo.	0	0	0	0	0
Glass Jars										
							Bubbles			
Pint	2	30	8	18	2 mo.	0	0	12	12	67
	2	40	9	20	2 mo.	0	0	2	2	10
	2	50	9	16	2 mo.	0	0	0	0	0
	2	60	10	16	2 mo.	0	0	0	0	0
Quart	3	55	6	15	3 mo.	0	0	2	2	13
	5	65	10	23	3 mo.	0	0	0	0	0
	5	75	9	22	3 mo.	0	0	0	0	0
	4	85	8	20	3 mo.	0	0	0	0	0

Discussion

Comparisons were made between the calculated processes and those determined by inoculation tests. For No. 2 cans the National Canners Association had calculated from heat pentration data that 50 minutes would be required to kill the spores of Clostridium botulinum, inoculation tests showed that 50 minutes was the lowest period at which no viable spores were found. For No. 3 cans the estimations using the

Bigelow factor gave 75 minutes and 75 minutes was the lowest processing period at which no viable spores were found in inoculation tests. However, for No. 1 cans the estimations using the Bigelow factor gave 30 minutes but the inoculation tests showed that 40 minutes was the lowest processing period at which no viable spores were found.

Experience showed that in some of the glass jars the seal was broken when the jars were removed from the cooker. Heat penetration tests showed that when the cooker was opened after processing, the temperature inside the glass jars corresponded to about 4 pounds pressure. This pressure, seemed sufficient for a sudden jar to cause the softened rubber to bulge outward and break the seal. For this reason it is recommended that the glass jars be allowed to remain undisturbed in the open cooker until the liquid inside stops bubbling. Then they may be removed and the cooling finished in air at room temperature.

When processing times are to be recommended to the homemakers the minimum periods necessary to destroy spores of Clostridium botulinum must be taken into consideration. However, since it is difficult under home conditions to know when slight inaccuracies occur in the pressure gauge, it seems wise to recommend the use of processing periods 10 minutes longer than those found to be the minimum.

The following factors of safety are present in the recommended processing times: 1. Heavy inoculation of viable spores. 2. Since spores were placed in cans or jars after steaming and just before sealing, they were not subjected to the heat treatment involved in "heating before sealing" which might have made them somewhat more susceptible to the higher temperature later. 3. Actual spoilage of meat in the cans was not found at a level twenty minutes under the recommended level. 4. Viable spores were not found at a level ten minutes under the recommended level.

It should be noted also that the toxin of Clostridium botulinum is thermolabile, the toxic properties being destroyed at 80°C (176°F) in 30 minutes. Thus if the canned meat is thoroughly heated just before it is eaten, any toxin present will be destroyed.

Hall (4) who reported details of several cases of botulism observed from his studies that there seem to be three distinct groups of housewives:

1. Those who are well grounded in the fundamental principles of bacteriology as applied to home canning; who intelligently use controlled steam pressure; who are ever conscious of the danger of botulism in spoiled canned foods; and who always recook all canned foods before serving them. These housewives and their families rarely, if ever, die from botulism.

2. A very large number of women who have little or no knowledge of bacteriology; who use antiquated "cold-pack" or other inadequate methods of canning; and who having much spoilage, are vaguely conscious of an ill-defined ele-

ment of danger which they attempt to avoid by tasting each jar of food before serving it. No doubt thousands of jars of perfectly harmless spoiled home canned foods are discarded as a result of this common practice, but from time to time a jar is encountered which contains botulinus toxin resulting in the death of the human guinea pig and often domestic fowls and other animals as well. In these cases the other members of the family generally do not suffer.

3. The third group consists of people who are at the bottom of the ladder educationally, socially, and economically; who use the crudest methods of home canning; who seem to be oblivious to the danger of eating spoiled foods; and who will apparently eat anything that looks like food if they can get it down. Such foods may be highly seasoned or flavored to mask spoilage. When botulism occurs under such conditions it usually takes a toll of several lives.

Research in home canning therefore must be aimed to benefit homemakers who are capable of following directions carefully, such as those in the first group mentioned by Hall. It would be impossible to make safe recommendations for the third group because of the uncertainty that any of them would be followed.

ACKNOWLEDGMENT

Grateful acknowledgment is made to the National Canners Association for calculating the processing times from the heat penetration data and for supplying the spore suspension of the test organism.

SUMMARY AND RECOMMENDATIONS

Two periods of heating are necessary in canning meat; the first before sealing, for driving the air out of the cans or jars to provide a partial vacuum inside the sealed cans and the second, after sealing, for destroying spoilage organism inside the sealed cans. The Texas Agricultural Extension Service has, heretofore, recommended that both periods of heating be under pressure. Because of certain difficulties, experiments were set up to determine 1. an adequate but simpler procedure for heating before sealing, 2. the shortest processing time which would destroy the spores of Clostridium botulinum. These tests were carried out by using heat penetration data and by placing live spores inside the containers of meat before processing.

If heating before sealing is done under pressure, the cooker needs to be watched constantly. Some liquid is always drawn out of the containers which then need to be refilled before sealing—a messy and time consuming duty. Meat heated in boiling broth, in deep fat, or in an oven must be packed while the meat is hot and difficult to handle. There is danger that the meat temperature will fall below 180°F before sealing. The method of heating in steam before sealing was found to be best. It has the following advantages: containers are packed with cold meat which is easy to handle, containers need only to be sealed after

heating so that it is easy to have the meat temperature as high as 180°F when processing begins, the cooker is not under pressure and therefore does not need constant watching.

The shortest safe processing period for the sealed cans was tested in several ways. 1. By using the heat penetration data to calculate the time needed to destroy the spores of Clostridium botulinum. These calculations were made by the National Canners Association according to a complicated mathematical formula previously worked out and tested under commercial canning conditions. 2. A short method of calculating was used after the safe processing period had been determined for one size of can. 3. The calculated processing periods were then checked by using cans of meat inoculated heavily with spores of P. A. 3679, an organism whose spores are similar to those of Clostridium botulinum in heat resistance but are more uniform in their high heat resistance. The containers were processed at four different time levels for each size of jar or can so that at least one pack would be above and at least one below the point at which no viable spores were present. Growth of the organism took place at the lowest level in the cans causing them to bulge. A foul odor which was unmistakable was present also. With a longer period of processing no spoilage took place but viable spores were present in a small percentage of the containers. No spoilage was observed in any of the glass jars but viable spores were found at the lowest levels. With the two or three still longer processing periods no viable spores were found. The lowest level at which no viable spores were found is considered the lowest safe processing period, but ten minutes is added to it as a factor of safety in making recommendations.

The two heating periods recommended are:

"Steaming time" (heating before sealing)

No. 1 cans	30 minutes
No. 2 cans	60 minutes
No. 3 cans	90 minutes
Pint jars	60 minutes
Quart jars	80 minutes

"Processing time" (in sealed containers at 15 pounds pressure)

No. 1 cans	50 minutes
No. 2 cans	60 minutes
No. 3 cans	85 minutes
Pint jars	60 minutes
Quart jars	75 minutes

When "steaming time" is over, seal **immediately,** put **hot** sealed containers **immediately** into a **hot** pressure cooker, and begin processing **as quickly as possible.** This assures a temperature of 180°F inside the containers when processing begins.

When the pressure on the gauge returns to zero, cool the tin cans quickly and thoroughly in cold water but allow the glass jars to remain undisturbed in the open cooker until the liquid inside stops bubbling, then finish cooling in the air at room temperature.

REFERENCES

1. Ball, C. O. 1928. Mathematical Solution of Problems on Thermal Processing of Canned Food. University of California Publications in Public Health 1:15-245.

2. Bigelow, W. D., Bohart, G. S., Richardson, A. C., and Ball C. O. 1920. Heat Penetration in Processing Canned Foods. National Canners Association Bulletin No. 16-L.

3. Esty, J. R., and Meyer, K. F. 1922. The Heat Resistance of the Spores of B. Botulinus and Allied Anaerobes. XI. Journal of Infectious Diseases 31:650-663.

4. Hall, Ivan C. 1936. New Outbreaks of Botulism in Western United States. Food Research 1:171-198.

5. Kelser, R. A. 1927. Manual of Veterinary Bacteriology. The William and Watkins Co., Baltimore, Md.

6. Meyer, K. F., and Dubovsky, B. J. 1922. The Distribution of B. Botulism in California. II. Journal of Infectious Diseases 31:541-555.

7. Neeley, Grace I. 1940. Canning Meat in the Home. Texas Extension Service Bulletin B-101.

8. Nelson, Casper I., and Knowles, Darlene. 1940. Effectiveness of Heat Penetration in Meat Canned in Glass Jars in a Pressure Cooker. Jour. Agri. Research 61:753-759.

9. Stanley, L. and Stienbarger, M. C. 1936. (New edition 1942.) Home Canning of Fruits, Vegetables, and Meats. Farmers' Bulletin 1762.

10. Townsend, C. T., Esty, J. R., and Baselt, F. C. 1938. Heat Resistance Studies on Spores of Putrefactive Anaerobes in Relation to Determination of Safe Processes for Canned Foods. Food Research 3:323-346.