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Progress Report No. 9

COMBINED USE OF HEAT AND RADIATION  
TREATMENT FOR STERILIZATION OF FOODS

Period: 30 September 1956 to 30 November 1956

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Official Investigator

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Collaborator

Project 2391

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for Sterilization of Foods

SUMMARY

Tests of the combined irradiation-heat processing of canned ground beef inoculated with approximately 10,000 PA-3679 spores per can are in progress. Present data indicate the following for these conditions:

1. Approximately 1.0 megarep preirradiation is required before a significant effect of irradiation is noted on the  $F_0$  value required for subsequent heat sterilization of the canned meat.

2. Following irradiation with 1.7 megarep of gamma radiation, an  $F_0$  between 1.1 and 3.2 is required for sterilization; an  $F_0$  between 6.5 and 8.4 was required with heat processing alone.

These studies are being extended to include slightly higher preirradiation levels.

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EFFECT OF PREIRRADIATION OF CANNED GROUND BEEF INOCULATED  
WITH PA-3679 SPORES ON THE  $F_0$   
SUBSEQUENTLY REQUIRED FOR STERILIZATION

Data have been presented in previous reports to show that the  $F_0$  required to sterilize canned ground beef inoculated with C. botulinum 213B spores can be considerably reduced when heat processing follows irradiation of the canned meat with gamma rays. This study is now being extended to include packs inoculated with PA-3679 spores. Up to the present time, all the work has been carried out on previously heat-sterilized meat.

The techniques in use are similar to those previously described in the annual report for this project dated September, 1956, except that PA-3679 spores are presently being used. The previous work was done with C. botulinum 213B spores. Briefly these techniques involve preparation of inoculated packs of lean ground beef in No. 1 picnic tin cans which are closed while hot in order to develop vacua. The cans are then irradiated in the large cobalt-60 gamma-radiation source in the Fission Products Laboratory, at The University of Michigan. They are next processed in a steam autoclave and finally incubated at 29°C. Sufficient  $F_0$  values are used to permit bracketing that  $F_0$  value which is required to sterilize all four cans. Sterility is determined by observation of swelling during incubation.

One variation, namely the use of a 250°F processing temperature instead of 230°F, was tried for Runs PA-2 through PA-9. This was revised because of operating difficulties and also because 230°F is more commonly used industrially. Runs following PA-9 were conducted with the processing temperature of 230°F, the temperature previously used with C. botulinum 213B spore packs.

The PA-3679 spores are grown, prepared, counted, and used according to techniques described in previously published work from this laboratory.<sup>1</sup>

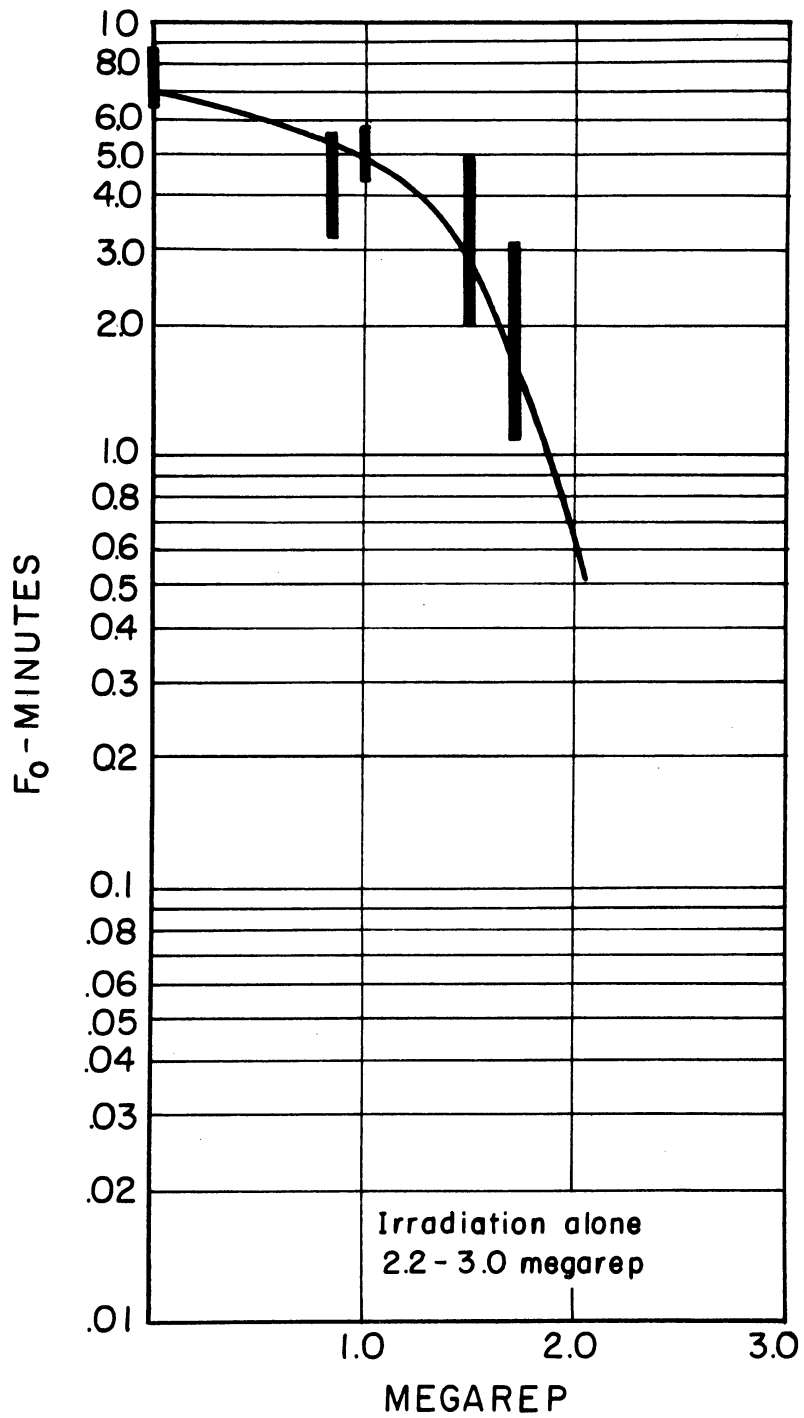
Data from the early runs are included in Table I. The steam temperatures for the combined heat and irradiation processing experiments reported in this table was 250°F. This temperature was lowered to 230°F for runs following PA-9. Two runs PA-4 and PA-7, included in this table are useful in establishing the level of irradiation required to sterilize canned ground beef when irradiation is used alone.

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<sup>1</sup>"Gamma-ray sterilization of canned meat previously inoculated with anaerobic bacterial spores," by Kempe et al., Applied Microbiology, 2, 330 (1954).

Table II and the accompanying figure show that preirradiation reduces the severity of the heat processing required to sterilize canned ground beef inoculated with approximately 10,000 PA-3679 spores per can. The present data indicate that preirradiation with approximately 1.0 megarep is required before a significant reduction in the  $F_0$  value, subsequently needed for sterilization, occurs under these conditions. Also, preirradiation with 1.7 megarep reduced the  $F_0$  value, subsequently required, to a value between 1.1 and 3.2. This compares with an  $F_0$  value between 6.5 and 8.4 that is needed to produce sterility when no preirradiation is used.

These studies are being extended to include slightly higher preirradiation levels before work is begun on inoculated packs of raw meat.



$F_0$  required to sterilize ground beef packed in No. 1 picnic tin cans, inoculated with approximately 10,000 PA-3679 spores per can and irradiated with gamma rays from cobalt-60 before heat processing at 230°F.

TABLE I -  $F_0$  Value Required to Sterilize Ground Beef in No. 1 Picnic Tin Cans, Previously Inoculated with Approximately 10,000 PA-3679 Spores per Can and Then Processed at 250°F.

Run No. PA-2—Can Size	- No. 1 Picnic (211 x 400)
Product	- Ground Beef
Inoculum	- 10,000 PA-3679 spores per can
Preirradiation	- none
Processing Temperature	- 250°F
Incubation Temperature	- 29°C

$F_0$	Can No.	Days to Gas Formation
Noninoculated Controls	NI 1	-
	NI 2	-
	NI 3	-
	NI 4	-
Inoculated Controls	26	3
	27	3
	28	3
	29	3
Can 1, 2.5	1	-
Can 2, 2.5	3	5
	4	4
	7	5
Can 1, 4.1	2	6
Can 2, 4.1	5	-
Can 3, 3.7 (disregard)	6	-
	8	-
Can 1, 1.1	9	4
Can 2, 1.1	10	4
Can 3, 1.3	11	4
	12	4
Can 1, 3.7	13	4
Can 2, 3.7	14	-
Can 3, 2.8 (disregard)	15	5
	16	5
Can 1, 6.2	18	-
Can 2, 3.3	19	4
	20	-
	21	-
	25	-
Can 1, 8.8	22	-
Can 2, 8.8	23	-
	24	-
	25	-

Conclusion: Ground beef, packed in No. 1 picnic tin cans, and inoculated with 10,000 PA-3679 spores per can, required an  $F_0$  value between 3.7 and 8.8 for sterilization when processed at 250°F.

TABLE I (Continued)

Run No. PA-3—Can Size	- No. 1 Picnic (211 x 400)
Product	- Ground Beef
Inoculum	- 600,000 PA-3679 spores per can
Preirradiation	- none
Processing Temperature	- 250°F (except cans 1, 2, 3, and 4
Incubation Temperature	- 29°C at 230°F)

F <sub>0</sub>	Can No.	Days to Gas Formation
Noninoculated Controls	NI 1	-
	NI 2	-
Inoculated Controls	I 1	3
	I 2	+*
Can 1, 2.3	1	4
	2	4
	3	4
	4	4
Can 1, 6.1	5	4
	6	6
	7	4
	8	5
Can 1, 9.4	9	9
	10	8
	11	6
	12	9
Can 1, 12.4	13	9
	14	13
	15	13
	16	16
Can 2, 2.3		
Can 2, 6.1		
Can 2, 9.4		
Can 2, 12.4		
Can 3, 2.3		
Can 3, 3.8 (disregard)		
Can 3, 8.3		
Can 3, 8.7		
Can 3, 11.6 (disregard)		

\*Date not recorded.

Conclusion: With 600,000 PA-3679 spores per can and a processing temperature of 250°F, the F<sub>0</sub> value required for sterilization of the canned meat exceeds 12.4.

TABLE I (Continued)

Run No. PA-4—Can Size - No. 1 Picnic (211 x 400)  
 Product - Ground Beef  
 Inoculum - 200 PA-3679 spores per can  
 Preirradiation - as indicated  
 Processing Temperature - not heat processed  
 Incubation Temperature - 29°C

Irradiation Dosage, megarep	Can No.	Days to Gas Formation
Noninoculated Controls	See Run 5	
Inoculated Controls	See Run 5	
4.100	1	-
	2	-
	3	-
	4	-
3.700	5	-
	6	-
	7	-
	8	-
1.600	9	-
	10	-
	11	6
	12	-
2.100	13	-
	14	-
	15	-
	16	-

Conclusion: Under the above conditions canned ground beef was sterilized with between 1.600 and 2.100 megarep of gamma irradiation.



TABLE I (Continued)

Run No. PA-5	Can Size	- No. 1 Picnic (211 x 400)
	Product	- Ground Beef
	Inoculum	- 200 PA-3679 spores per can
	Preirradiation	- none
	Processing Temperature	- 250°F
	Incubation Temperature	- 29°C

$F_0$	Can No.	Days to Gas Formation
Noninoculated Controls	NI 1	-
	NI 2	-
	NI 3	-
	NI 4	-
Inoculated Controls	INC 1	3
	INC 2	3
	INC 3	3
	INC 4	3
Can 1, 2.7	1	-
Can 2, 2.7	2	-
	3	-
	4	-
	5	-
Can 1, 3.6	5	-
Can 2, 6.8	6	-
Can 3, 8.3	8	-
	9	-
Can 1, 12.3	10	-
Can 2, 12.3	11	-
Can 3, 15.3 (disregard)	12	-
	13	-
Can 1, 9.0	14	-
Can 2, 8.0	15	-
Can 3, 8.1 (disregard)	16	-
	17	-
Can 1, 4.9	18	-
Can 2, 2.7	19	-
Can 3, 6.8	20	-
	21	-
Can 1, 4.4	23	-
Can 2, 4.4	24	-
	25	-
	26	-
	27	-
Can 1, 14.1	7	-
Can 2, 12.6	22	-
	27	-
	28	-

Conclusion: Under the above conditions an  $F_0$  value less than 2.7 was needed to sterilize ground beef.

TABLE I (Continued)

Run No. PA-6—Can Size	- No. 1 Picnic (211 x 400)
Product	- Ground Beef
Inoculum	- 54,000 spores per can
Preirradiation	- 1.200 megarep
Processing Temperature	- 250°F
Incubation Temperature	- 29°C

F <sub>0</sub>	Can No.	Days to Gas Formation
Noninoculated Controls	NI 1	-
	NI 2	-
Inoculated Controls	17	4
	18	4
	19	4
	20	4
Can 1, 3.1	1	-
Can 2, 3.1	2	10
Can 3, 2.7 (disregard)	3	-
	4	-
Can 1, 3.8	5	8
Can 2, 3.5	6	-
Can 3, 4.1	7	-
	8	-
Can 1, 1.0	9	5
Can 2, 1.2	10	7
Can 3, 1.7	11	9
	12	7
Can 1, 8.6	13	-
Can 2, 6.2	14	-
Can 3, 5.5	15	-
	16	-

Conclusion: Under these conditions sterilization of canned ground beef is obtained by irradiation with 1.2 megarep of gamma rays followed by an F<sub>0</sub> value between 3.5 and 8.6.

TABLE I (Continued)

Run No. PA-7—Can Size	- No. 1 Picnic (211 x 400)
Product	- Ground Beef
Inoculum	- 13,500 PA-3679 spores per can
Irradiation	- as indicated
Processing Temperature	- not processed
Incubation Temperature	- 29°C

Megarep	Can No.	Days to Gas Formation
Noninoculated Controls	See Run 8	
Inoculated Controls	35	3
	36	3
	37	3
	38	3
1.000	1	4
	2	4
	3	4
	4	4
2.200	13	6
	14	-
	15	-
	16	4
1.900	31	4
	32	4
	33	4
	34	4
3.000	9	-
	10	-
	11	-
	12	-
3.900	5	-
	6	-
	7	-
	8	-

Conclusion: Irradiation-sterilization dosage for canned ground beef under these conditions lies between 2.2 and 3.0 megarep.

TABLE I (Continued)

Run No. PA-8—Can Size	- No. 1 Picnic (211 x 400)
Product	- Ground Beef
Inoculum	- 13,500 PA-3679 spores per can
Preirradiation	- none
Processing Temperature	- 250°F
Incubation Temperature	- 29°C

F <sub>0</sub>	Can No.	Days to Gas Formation
Noninoculated Controls	NI 1	-
	NI 2	-
	NI 3	-
	NI 4	-
Inoculated Controls	35	4
	36	4
	37	4
	38	4
Can 1, 3.1	1	-
Can 2, 2.5	2	13
	3	6
	4	-
Can 1, 9.6	5	-
Can 2, 9.6	6	-
	7	-
	8	-
	9	-
Can 1, 5.6	10	-
Can 2, 5.6	11	-
	12	-
Can 1, 3.8	13	-
Can 2, 2.9	14	9
	15	6
	16	-
Can 1, 7.9	17	-
Can 2, 10.7	18	-
Can 3, 12.8	19	-
	20	-
Can 1, 7.0	21	-
Can 2, 7.0	22	-
	23	-
	24	-
Can 1, 11.6	25	-
Can 2, 9.2	26	-
	27	-
	28	-

Conclusion: Under these conditions canned ground beef was sterilized with heat processing at 250°F, having an F<sub>0</sub> value between 2.5 and 5.6.

TABLE I (Concluded)

Run No. PA-9—Can Size	- No. 1 Picnic (211 x 400)
Product	- Ground Beef
Inoculum	- 16,000 PA-3679 spores per can
Preirradiation	- 1.000 megarep
Processing Temperature	- 250°F
Incubation Temperature	- 29°C

$F_0$	Can No.	Days to Gas Formation
Inoculated Controls	21	3
	23	3
	24	3
Irradiation Controls, 1.340 megarep	17	3
	18	3
	19	3
	20	3
Can 1, 2.3	1	4
Can 2, 2.3	2	5
Can 3, 0.6 (disregard)	3	4
	4	5
Can 1, 3.8	5	6
Can 2, 3.8	6	-
Can 3, 4.2	7	-
	8	7
Can 1, 0.5	9	5
Can 2, 0.5	10	4
	11	4
	12	4
Can 1, 6.5	13	-
Can 2, 9.0	14	-
Can 3, 11.7	15	-
	16	-

Conclusion: Under these conditions canned ground beef was sterilized by irradiation with 1.500 megarep of gamma irradiation followed by heat processing to an  $F_0$  value of between 6.3 and 11.7.

TABLE II -  $F_0$  Value Required to Sterilize Ground Beef in No. 1 Picnic Tin Cans, Previously Inoculated with Approximately 10,000 PA-3679 Spores per Can and Then Processed at 230°F.

Run No. PA-10—Can Size - No. 1 Picnic (211 x 400)  
 Product - Ground Beef  
 Inoculum - 10,000 PA-3679 spores per can  
 Preirradiation - none  
 Processing Temperature - 230°F  
 Incubation Temperature - 29°C

$F_0$	Can No.	Days to Gas Formation
Noninoculated Controls		
	NI 1	-
	NI 2	-
	NI 3	-
	NI 4	-
Inoculated Controls		
	17	3
	18	3
	19	3
	20	3
Can 1, 6.0	1	9
Can 2, 6.0	2	11
Can 3, 5.2	3	8
	4	11
Can 1, 3.8	5	5
Can 2, 3.8	6	6
Can 3, 3.8	7	5
	8	5
Can 1, 3.0	9	6
Can 2, 3.0	10	5
Can 3, 3.0	11	5
	12	5
Can 1, 2.0	13	4
Can 2, 2.0	14	4
Can 3, 2.0	15	4
	16	4

Conclusion: Under these conditions the  $F_0$  value required to sterilize canned ground beef exceeds 6.0.

TABLE II (Continued)

Run No. PA-11—Can Size	- No. 1 Picnic (211 x 400)
Product	- Ground Beef
Inoculum	- 10,000 PA-3679 spores per can
Preirradiation	- 1.500 megarep
Processing Temperature	- 230°F
Incubation Temperature	- 29°C

$F_0$	Can No.	Days to Gas Formation
Noninoculated Controls	NI 1	-
	NI 2	-
	NI 3	-
	NI 4	-
Inoculated Controls	17	3
	18	3
	19	3
	20	3
Can 1, 1.0 Can 2, 0.8 Can 3, 0.4	1	5
	2	5
	3	5
	4	5
Can 1, 1.6 Can 2, 1.0 Can 3, 0.8	5	6
	6	5
	7	5
	8	6
Can 1, 2.0 Can 2, 2.0 Can 3, 3.0 (disregard)	9	9
	10	6
	11	9
	12	-
Can 1, 3.9 Can 2, 3.9 Can 3, 4.9 (disregard)	13	-
	14	-
	15	-
	16	-

Conclusion: Canned ground beef was sterilized under these conditions by 1.500 megarep of preirradiation followed by heat processing with an  $F_0$  value between 2.0 and 3.9.

TABLE II (Continued)

Run No. PA-12--Can Size - No. 1 Picnic (211 x 400)  
 Product - Ground Beef  
 Inoculum - 10,000 PA-3679 spores per can  
 Preirradiation - None  
 Processing Temperature - 230°F  
 Incubation Temperature - 29°C

F <sub>0</sub>	Can No.	Days to Gas Formation	
Noninoculated Controls	NI 1	-	
	NI 2	-	
	NI 3	-	
Inoculated Controls	INOC	3	
	1	4	
	2	4	
	3	3	
Can 1, 2.9	4	5	
	Can 2, 2.9	5	14
		6	-
	Can 1, 5.8	7	11
8		14	
Can 2, 5.8	9	6	
	10	7	
	11	6	
	12	6	

Conclusion: Canned ground beef requires an F<sub>0</sub> value of more than 5.8 for sterilization under these conditions.



TABLE II (Continued)

Run No. PA-13—Can Size	- No. 1 Picnic (211 x 400)
Product	- Ground Beef
Inoculum	- 10,000 PA-3679 spores per can
Preirradiation	- 1.000 megarep
Processing Temperature	- 230°F
Incubation Temperature	- 29°C

F <sub>0</sub>	Can No.	Days to Gas Formation
Can 1, 4.4*	1	-
Can 2, 4.4	2	7
	3	-
	4	-
Can 1, 0.7	5	4
Can 2, 0.5	6	3
	7	4
	8	4
Can 1, 2.3	9	7
Can 2, 2.3	10	4
	11	5
	12	5
Can 1, 5.7	13	-
Can 2, 5.7	14	-
	15	-
	16	-

Conclusion: Canned ground beef was sterilized under these conditions by 1.000 megarep of preirradiation followed by heat processing with an F<sub>0</sub> value between 4.4 and 5.7.

\*Same controls as used for Run 12.

TABLE II (Continued)

Run No. PA-14—Can Size - No. 1 Picnic (211 x 400)  
 Product - Ground Beef  
 Inoculum - 10,000 PA-3679 spores per can  
 Preirradiation - 1.700 megarep  
 Processing Temperature - 230°F  
 Incubation Temperature - 29°C

$F_0$	Can No.	Days to Gas Formation
Noninoculated Controls	NI 1	-
	NI 2	-
	NI 3	-
	NI 4	-
Inoculated Controls	17	3
	18	3
	19	3
	20	3
Can 1, 5.6 Can 2, 4.9	1	-
	2	-
	3	-
	4	-
Can 1, 6.5 Can 2, 5.6	5	-
	6	-
	7	-
	8	-
Can 1, 1.1 Can 2, 1.1	9	9
	10	-
	11	9
	12	-
Can 1, 3.2 Can 2, 3.2 Can 3, 3.2	13	-
	14	-
	15	-
	16	-

Conclusion: Canned ground beef was sterilized under these conditions by 1.700 megarep of gamma irradiation followed by heat processing with an  $F_0$  value between 1.1 and 3.2.

TABLE II (Continued)

Run No. PA-15—Can Size	- No. 1 Picnic (211 x 400)
Product	- Ground Beef
Inoculum	- 10,000 PA-3679 spores per can
Preirradiation	- None
Processing Temperature	- 230°F
Incubation Temperature	- 29°C

$F_0$	Can No.	Days to Gas Formation
Noninoculated Controls	NI 1	-
	NI 2	-
	NI 3	-
	NI 4	-
Inoculated Controls	17	3
	18	3
	19	3
	20	3
Can 1, 6.5	1	21
Can 2, 7.0	2	17
Can 3, 7.0	3	-
	4	13
Can 1, 8.4	5	-
Can 2, 7.3	6	-
	7	-
	8	-
Can 1, 6.0	9	8
Can 2, 6.0	10	8
Can 3, 6.0	11	7
	12	7
Can 1, 5.0	13	11
Can 2, 5.0	14	11
Can 3, 5.0	15	11
	16	8

Conclusion: Under these conditions, canned ground beef was sterilized with an  $F_0$  value between 6.5 and 8.4.

TABLE II (Continued)

Run No. PA-16—Can Size - No. 1 Picnic (211 x 400)  
 Product - Ground Beef  
 Inoculum - 10,000 PA-3679 spores per can  
 Preirradiation - None  
 Processing Temperature - 230°F  
 Incubation Temperature - 29°C

$F_0$	Can No.	Days to Gas Formation
Noninoculated Controls	NI 1	-
	NI 2	-
	NI 3	-
	NI 4	-
Inoculated Controls	13	3
	14	3
	15	3
	INOC	4
Can 1, 7.1 Can 2, 7.1 Can 3, 7.1	1	-
	2	-
	3	-
	4	-
Can 1, 8.7 Can 2, 8.7	5	-
	6	-
	7	-
	8	-
Can 1, 4.1 Can 2, 4.6	9	7
	10	7
	11	7
	12	7

Conclusion: Under these conditions canned ground beef was sterilized with an  $F_0$  value between 4.1 and 7.1.

TABLE II (Concluded)

Run No. PA-17—Can Size	- No. 1 Picnic (211 x 400)
Product	- Ground Beef
Inoculum	- 10,000 PA-3679 spores per can
Preirradiation	- 0.850 megarep
Processing Temperature	- 230°F
Incubation Temperature	- 29°C

$F_0$	Can No.	Days to Gas Formation
Noninoculated Controls	NI 1	-
	NI 2	-
	NI 3	-
	NI 4	-
Inoculated Controls	13	3
	14	3
	15	3
	INOC	4
Can 1, 10.2 Can 2, 10.2 Can 3, 10.2	1	-
	2	-
	3	-
	4	-
Can 1, 5.5 Can 2, 4.9	5	-
	6	-
	7	-
	8	-
Can 1, 6.9 Can 2, 6.6	9	-
	10	-
	11	-
	12	-
Can 1, 3.7 Can 2, 3.1	13	-
	14	17
	15	12
	16	12

Conclusion (tentative because of insufficient incubation time at the time of this report): Canned ground beef was sterilized under these conditions by 0.850 megarep irradiation followed by heat processing with an  $F_0$  value between 3.1 and 5.5.