WITH SCIENCE WE DEFEND

TECHNICAL REPORT
NATICK/TR-99/002

AD_____

REDUCTION OF ADDED NITRITE IN CORNED BEEF PRESERVED BY IRRADIATION

by
Gary W. Shults
Eugen Wierbicki
John J. Howker
Joseph S. Cohen
and
R. A. Gates

October 1998

Final Report
August 1978

Approved for Public Release; Distribution Unlimited

U.S. ARMY SOLDIER AND BIOLOGICAL CHEMICAL COMMAND
SOLDIER SYSTEMS CENTER
NATICK, MASSACHUSETTS 01760-5018

DISCLAIMERS

The findings contained in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Citation of trade names in this report does not constitute an official endorsement or approval of the use of such items.

DESTRUCTION NOTICE

For Classified Documents:

Follow the procedures in DoD 5200.22-M, Industrial Security Manual, Section II-19 or DoD 5200.1-R, Information Security Program Regulation, Chapter IX.

For Unclassified/Limited Distribution Documents:

Destroy by any method that prevents disclosure of contents or reconstruction of the document.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 1998	FINAL August 1978

4. TITLE AND SUBTITLE

REDUCTION OF ADDED NITRITE IN CORNED BEEF PRESERVED BY IRRADIATION

5. FUNDING NUMBERS

C 8AB81A
N 3122

6. AUTHOR(S)

Gary W. Shults, Eugen Wierbicki, John J. Howker,
Joseph S. Cohen and R.A. Gates

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Soldier and Biological Chemical Command
Soldier Systems Center
ATTN: SBCCOM: W
Natick, MA 01760-5018

8. PERFORMING ORGANIZATION REPORT NUMBER

NATICK/TR-99/002

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for Public Release; Distribution Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report deals with consumer acceptance of irradiation sterilized flavored ground beef patties Flavorings used were salt, garlic salt, onion salt and pepper in various combinations. Textured soy protein (TSP) was also added at a 20 % level. A trained eight-member panel evaluated the products for flavor, odor, color, texture and appearance using an eight points intensity scale. The patties all received acceptable rating in the range of 5.7 to 7.1 This showed that highly acceptable, irradiation sterilized ground beef patties could be prepared for inclusion in the military feeding system.

14. SUBJECT TERMS

SODIUM NITRITE
NITRITES
REDUCTION
IRRADIATED FOOD
IRRADIATION
FOOD PRESERVATION
SHELF STABLE MEATS
CURED MEAT
COMBAT RATIONS

15. NUMBER OF PAGES 16

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

TABLE OF CONTENTS

LIST OF TABLES

REDUCTION OF ADDED NITRITE IN CORNED BEEF, PRESERVED BY IRRADIATION

PREFACE

The data for this report were collected by investigators from the US Army, Natick Research and Development Command during the 1970s.

It is being published now as the Army has expressed a need for irradiation sterilized meat products, Loveridge, 1994. The data is relevant.

Corned beef briskets processed with several levels of sodium nitrite ($NaNO_2$) (0, 25, 37.5, 50, 75, 150 ppm) and several levels of sodium nitrate ($NaNO_3$) (0, 25, 50, 37.5 ppm) in various combinations, were precooked, vacuum packed and irradiated with 27 kGy of gamma irradiation at -30°C (the 12-D) dose. They were evaluated for cured meat color intensities, sensory properties and nitrosamines. All the samples were found to be of acceptable quality. The color stability of the irradiated samples was best when the nitrite and nitrate were used in combination. Acceptable products can be produced without nitrate addition. Nitrosamines were not detected in any of the irradiated and nonirradiated samples.

The military requires this type of shelf-stable, whole muscle product to increase variety and quantity to the combat ration.

Citation of trade names in this report does not constitute an official endorsement or approval of the uSe of such item.

Introduction

Investigations on cured meat products have been directed toward reducing the amounts of sodium nitrate and sodium nitrite required for the production of cured meat products. These efforts have been motivated by the acknowledgement that nitrosamine formation in cured meats directly associated with the addition of curing salts. Research was conducted on the development of cured meats with the minimal amount of curing salts to determine which additive level produces a product with the characteristic color and microbiological safety. The US Department of Agriculture's (USDA) 1973 regulations eliminated the use of sodium nitrate ($NaNO_3$) as a curing ingredient in meats except for dry cured ham and fermented sausage. The approved level of sodium nitrite ($NaNO_2$) addition was also substantially lowered.

Wierbicki and Heiligman (1973) reported extensive investigations on the reduction of $NaNO_3$ and $NaNO_2$ in irradiated ham. They reported that the additive level of $NaNO_2$ could be reduced to 25 ppm when used in combination with 100 ppm of $NaNO_3$. Without the 100 ppm of $NaNO_3$, fading of the cured meat was detected and preference scores were lowered. Wasserman (1978) reported that no nitrosamines were found in irradiated cured meats when lower levels of $NaNO_2$ and $NaNO_3$ were used. Wierbicki et al. (1974) reported that the level of $NaNO_2$ addition could be reduced from 156 to 75 ppm in nonirradiated cured meats without affecting the quality. Wierbicki et al. (1976) reported that acceptable irradiated corned beef can be produced with an addition of 156 ppm $NaNO_2$ without $NaNO_3$. Shults et al. (1977) also showed that an addition level of 150 ppm $NaNO_2$ was sufficient to produce acceptable irradiated corned beef. An addition level of 25 ppm $NaNO_2$ also produced an acceptable product, but with decreased color intensity. Cohen et al. (1978) reported that an acceptable irradiated corned beef could be produced with the addition of 75 ppm $NaNO_2$ without the $NaNO_3$ addition.

This study was initiated to investigate the effects of low level additions of $NaNO_2$ and $NaNO_3$ on the color, acceptance and nitrosamine formation in irradiated and nonirradiated corned beef.

Materials and Methods

The raw material utilized for these studies was fresh beef brisket, pectoralis profundis muscle, excised from USDA choice grade carcasses. The briskets were trimmed of all surface fat and injecto-pumped with a Griffith #8 Big Boy™ meat pump (The Griffith Laboratories, Inc., Chicago, IL) operating at 90 Pa of pressure. The briskets were pumped to 15% added weight with the curing solutions. Each cure contained 3.0% NaCl, 275 ppm sodium ascorbate and 275 ppm sodium erythorbate. $NaNO_2$ levels evaluated were 150, 75, 50, 37.5, 25 and 0 ppm. $NaNO_3$ levels were 50, 37.5, 25 and 0 ppm. Various combinations were used. The briskets were held for 72 hours at +2 ^{o}C after pumping, prior to cooking.

The cured briskets were cooked in a water kettle at 97 $\pm$ 1 ^{o}C until an internal temperature of 80 $\pm$ 2 ^{o} C and then simmered at 75 ^{o}C for one hour. After cooking the briskets were cooled at 2 to 5 ^{o}C.

Packaging

The cooked briskets were cut into portions and packed in 404 x 202 cans, lined with an epoxy phenolic type interior enamel and closed under a pressure of 7 ± kPa. A mass of 330 ± 10 g was packed into each can. After closure, the cans were frozen to -40 ± 5 °C prior to irradiation.

Irradiation Processing

Irradiation of the corned beef was accomplished in the Cobalt 60 (Co^{60}) source at the US Army Research and Development Command, Natick, MA. The dose range was the minimum dose plus 18%; All samples received a dose of 27 to 33 kGy. The dose rate of the source was 14 kGy per kg per sec. Temperatures during irradiation were controlled at -30 ± 10 °C using liquid nitrogen. Samples were stored at 21 or 38 ± 2°C after irradiation. Non-irradiated samples were stored at -29 ± 2 ° C after irradiation.

Evaluation

The samples were evaluated by 10 to 12 member sensory panels for the sensory characteristics: odor, flavor, color and texture in which the following hedonic scale was used: 1 - extremely poor; 2 - very poor; 3 - poor; 4 - below fair, above poor; 5 - fair; 6 - below good, above fair; 7 - good; 8 - very good; 9 - excellent.

Preference ratings were obtained by 35 member consumer panels. Evaluations for preference were made using the scale of 1 to 9, with 1 being "dislike extremely," and 9 meaning "like extremely" (Peryam and Pilgrim, 1957). A rating of 5, "neither like nor dislike", is considered the base line in determining the acceptability of the product. Samples were served cold to the panelists.
Samples were evaluated over an 18 month storage period.

Data Analysis

All of the data reported in this paper were subject to statistical data analysis using an analysis of variance and least significant differences (LSD) methods (Steel and Torrie, 1960)

Color intensities were evaluated by 15 to 20 panelists at zero time and after two hours exposure to light at 21 ± 5 ° C. Samples were wrapped in clear plastic between the two evaluations to reduce the surface drying effects. All samples were compared to a color reference sample.

Nitrosamine Determination

Nitrosamine analyses were carried out using gas-liquid chromatographic techniques and mass spectrometry. The samples were shipped to the USDA Eastern Regional Center, ARS, Philadelphia, PA for the analyses.

Results and Discussion

Color intensities of irradiated cured meats have been reported to decrease upon exposure to room light (Wierbicki, et al. 1973 - 1976). The addition of a small amount of $NaNO_3$ reduced the degree of fading in the irradiated cured meat. To further study the color changes in irradiated cured beef, samples were prepared with various levels of $NaNO_2$ (150, 75, 50, 37.5 and 25 ppm) and $NaNO_3$ (50, 37.5, 25 and 0 ppm). The samples were irradiated and evaluated over an 18 month period.

Color intensity ratings for the samples are shown in Table 1. The samples were evaluated after one week of storage. Color ratings show that the irradiated samples

without $NaNO_3$ added were unacceptable (5.0 or below) after two hours of exposure. In nonirradiated samples, cured with 150 ppm $NaNO_2$ resulted in the highest color intensity. Evaluations for color after three months of storage showed the same trends that were noted on the initial evaluation. Samples without added $NaNO_3$ faded significantly more after irradiation than samples with added $NaNO_3$.

TABLE 1 - COLOR EVALUATION OF CORNED BEEF

Nitrite	Nitrate	Rating							
		Irradiated				Nonirradiated			
$NaNO_2$	$NaNO_3$	0 time		2 hours [1]		0 time		2 hours*	
ppm	ppm	mean	SD	mean	SD	mean	SD	mean	SD
A. One week storage [2]									
150.0	0.0	4.8[a]	1.4	4.7	0.9	7.6[c]	0.9	7.1[d]	0.9
75.0	0.0	5.5[a,b]	1.1	4.7	1.2	6.9[b]	1.2	6.5[d,e]	0.9
25.0	50.0	5.7[b]	1.0	5.2	0.8	6.7[b]	0.9	6.2[e]	0.9
50.0	25.0	5.6[b]	1.1	5.2	1.1	7.1[c,b]	0.9	6.5[d,e]	0.9
37.5	37.5	6.1[b]	1.0	5.4	1.1	6.6[b]	1.2	5.4	1.4
F		3.33		1.82		2.95		7.55	
significance		0.05		NSD		0.05		0.05	
B. Three months storage [3]									
150.0	0.0	5.3[a]	1.7	4.7[b]	1.4	6.0[d]	1.3	5.9[f]	1.1
75.0	0.0	5.1[a]	1.6	4.3[b]	1.3	6.8[d]	1.5	6.8[e]	1.4
25.0	50.0	6.1[a]	1.3	5.6[c]	1.2	6.4[d]	1.7	6.2[e,f]	1.4
50.0	25.0	6.0[a]	1.5	5.6[c]	1.4	7.1[d]	1.7	6.3[e,f]	1.2
37.5	37.5	6.4[a]	1.7	5.8[c]	1.4	6.4[d]	2.1	5.8[f]	1.8
F		2.0		3.8		1.0		3.2	
significance		NSD		0.05		NSD		0.05	

means in a column followed by the same letter are not significant

[1] 2 hours exposure to room light, [2] 19 panelists, [3] 16 panelists

Irradiation conditions - 27 kGy at -30 ± 10 °C

These samples were also evaluated by trained panelists (Table 2). When color was rated without standard reference, the ratings tended to be higher.

The panelists rated all samples highly acceptable for the sensory characteristics and no significant differences were found among the samples or among irradiated and nonirradiated samples for each of the factors tested.

TABLE 2 - SENSORY EVALUATION OF CORNED BEEF

$NaNO_2$ ppm	$NaNO_3$ ppm	Characteristic: Color mean	Color SD	Odor mean	Odor SD	Flavor mean	Flavor SD	Texture mean	Texture SD	
A. 1 week storage										
a. Nonirradiated										
150.0	0.0	7.1	0.5	7.2	0.8	6.4	1.2	6.5	1.0	
75.0	0.0	7.3	0.8	7.4	0.7	6.7	1.3	7.0	0.9	
25.0	50.0	7.5	0.7	6.9	1.0	7.1	1.3	7.2	0.9	
50.0	25.0	7.7	0.8	7.3	0.8	7.4	0.8	7.0	0.6	
37.5	37.5	7.4	0.8	7.2	0.9	7.4	0.7	6.6	1.4	
	F	0.9		0.5		1.2		1.1		all NSD
b. Irradiated										
150.0	0.0	7.4	0.9	7.2	1.1	6.8	1.4	6.9	1.3	
75.0	0.0	6.8	1.3	6.8	1.3	7.1	1.5	6.7	1.6	
25.0	50.0	7.2	1.0	6.5	1.4	6.5	1.3	7.1	1.0	
50.0	25.0	7.5	0.8	6.8	1.4	6.7	1.6	7.5	1.1	
37.5	37.5	7.8	0.8	6.7	1.7	6.6	1.4	6.5	1.2	
	F	1.3		0.3		0.2		0.8		all NSD
B. 3 month storage										
a. Nonirradiated										
150.0	0.0	7.0	0.6	6.5	0.8	5.8	1.5	6.7	0.6	
75.0	0.0	6.8	0.9	6.1	1.3	5.9	1.3	6.3	1.1	
25.0	50.0	7.0	0.9	6.7	0.8	6.2	1.1	6.6	0.9	
50.0	25.0	6.8	1.4	5.8	1.4	6.3	1.4	7.0	0.6	
37.5	37.5	6.9	0.8	6.1	0.9	6.2	1.4	6.7	0.9	
	F	0.4		0.9		0.7		0.7		all NSD
b. Irradiated										
150.0	0.0	6.6	1.6	6.4	1.4	5.7	1.8	6.4	1.2	
75.0	0.0	6.5	1.5	6.1	1.3	5.9	1.3	6.3	1.1	
25.0	50.0	6.5	1.1	6.8	0.9	6.3	1.2	7.1	1.1	
50.0	25.0	7.0	1.3	6.7	1.3	7.2	1.3	7.4	1.0	
37.5	37.5	6.3	1.4	6.5	0.9	6.2	1.4	7.1	1.0	
	F	0.3		0.6		1.2		1.1		all NSD

No significant difference between irradiated and nonirradiated sample

10 panelists per test.

Irradiation conditions - 27 kGy at -30 $\pm$ 10 ^{o}C

Also in Table 2, results of the trained panel evaluation for color, odor, flavor and texture shows that no significant effects were found among samples with various cure levels.

The samples were evaluated after 18 months of storage at 21 °C and the color intensity ratings are shown in Table 3.

TABLE 3 - COLOR EVALUATION OF CORNED BEEF AFTER 18 MONTH STORAGE

		Color Rating					
		Nonirradiated				Irradiated	
$NaNO_2$	$NaNO_3$	0 time		2 hours*		0 time		2 hour*	
ppm	ppm	mean	SD	mean	SD	mean	SD	mean	SD
150.0	0.0	$7.5^{a,b}$	0.8	$6.4^{c,d}$	1.2	7.9^{a}	0.8	6.6	1.3
75.0	0.0	7.1^{a}	1.0	6.1^{c}	1.1	$7.3^{a,b}$	0.6	6.4	1.2
25.0	50.0	7.8^{b}	0.7	$6.9^{d,e}$	1.1	$6.9^{b,c}$	1.0	5.9	1.2
50.0	25.0	7.9^{b}	0.5	7.1^{e}	1.0	6.3^{c}	1.1	5.7	1.2
37.5	37.5	7.8^{b}	0.7	7.3^{e}	1.0	6.4^{c}	1.3	6.1	0.6
	F	2.46		3.09		6.54		1.19	
significance		0.05		0.05		0.01		NSD	

* 2 hours exposure to room light

Means within a column followed by the same letter are not significantly different.

16 panelists Irradiation conditions - 27 kGy at -30 ± 10 °C

All the samples showed a decrease in color intensity after two hours exposure to light. Differences in the ratings for the irradiated samples after two hours of light exposure were not significant. Evaluation of the unexposed samples show that the irradiated samples without $NaNO_3$ were rated significantly higher in most cases than samples with $NaNO_3$. This did not hold true with the nonirradiated samples. Table 4 lists the sensory panel results for the irradiated and nonirradiated sample. No significant differences were found among the samples, both irradiated and nonirradiated. All the samples were rated highly acceptable for each of the characteristics.

Consumer ratings listed in Table 5 show no significant differences in the preference scores of the nonirradiated samples. In the irradiated group, the sample with 75 ppm $NaNO_2$ and the sample with 37.5 ppm $NaNO_2$ and $NaNO_3$ were rated significantly lower than the others. However, all samples rated within the acceptable range of 5.0 and above.

TABLE 4 - SENSORY EVALUATION OF CORNED BEEF AFTER 18 MONTH STORAGE

$NaNO_2$	$NaNO_3$	Sensory Characteristics								
		Color		Odor		Flavor		Texture		
ppm	ppm	mean	SD	mean	SD	mean	SD	mean	SD	
A. Nonirradiated frozen control										
150.0	0.0	7.0	0.6	6.5	0.8	5.8	1.5	6.7	0.6	
75.0	0.0	6.8	0.9	6.1	1.3	5.9	1.3	6.3	1.1	
25.0	50.0	7.0	0.9	6.7	0.8	6.2	1.1	6.6	0.9	
50.0	25.0	6.8	0.7	5.8	1.4	6.3	1.4	7.0	0.6	
37.5	37.5	6.9	0.8	6.1	0.9	6.2	1.4	6.7	0.9	
	F	0.4		0.9		0.7		0.7		all NSD
B. Irradiated										
150.0	0.0	7.4	0.9	7.0	1.3	7.2	1.0	7.1	0.9	
75.0	0.0	7.5	0.7	6.8	1.2	6.7	1.1	6.6	1.2	
25.0	50.0	7.6	0.7	7.4	1.3	1.0	1.0	7.4	0.7	
50.0	25.0	7.1	0.8	7.2	1.4	6.9	1.0	7.2	0.8	
37.5	37.5	7.5	0.8	7.2	1.1	6.9	1.0	6.6	1.4	
	F	0.5		0.3		0.3		1.2		all NSD

10 panelists per test Irradiation conditions - 27 kGy at -30 ± 10 °C

TABLE 5 - CONSUMER RATINGS FOR CORNED BEEF

$NaNO_2$	$NaNO_3$	Preference Rating			
		Nonirradiated		Irradiated	
ppm	ppm	mean	SD	mean	SD
150.0	0.0	6.1	1.7	6.2^{a}	1.7
75.0	0.0	6.4	1.6	5.5^{b}	1.6
25.0	50.0	6.7	1.5	6.2^{a}	1.6
50.0	25.0	6.5	1.5	$6.1^{a,b}$	1.3
37.5	37.5	6.5	1.6	$6.0^{a,b}$	1.6

means in a column followed by the same letter are not significantly different

35 panelists per test, 18 month storage

Irradiation conditions - 27 kGy at -30 ± 10 °C

Nitrosamine Analysis

Samples of the cured beef were subjected to nitrosamine analysis using mass spectrometry and gas-liquid chromatography (GLC). The analyses were done on samples thet were both hoth and served in a meal, and cold without further processing. None of the six nitrosamine compounds, DMNA, MENA, DEMA, ONMar, Onp/p and OnPyr were detected at a limit of 1 ppb in the irradiated and non irradiated cured beef samples.

Sensory evaluation of samples with and without NO_2 and NO_3

Samples of cured beef were prepared with $NaNO_2$ at concentrations of 0, 25, 37.5 and 75 ppm and $NaNO_3$ concentrations of 0, 25, 37.5 and 50 ppm in various combination. The samples were tested over a 6 month period. The results of the color analysis after 6 months of storage are shown in Table 7. The irradiated samples with 75 ppm $NaNO_2$ and with 25 ppm $NaNO_2$ - 25 ppm $NaNO_3$ had lower color intensity ratings at 0 and 2 hours exposure than the samples with 37.5 and 50 ppm $NaNO_2$. The sample without any addition did not develop the typical cured meat color and was rated unacceptable for both irradiated and nonirradiated products. No significant differences were found in the nonirradiated samples with additives.

TABLE 6 - COLOR EVALUATION OF CORNED BEEF

		Rating							
		Irradiated				Nonirradiated			
		Hours Exposure to room light							
$NaNO_2$	$NaNO_3$	0		2		0		2	
ppm	ppm	mean	SD	mean	SD	mean	SD	mean	SD
75.0	0.0	6.3	1.5	5.5	1.3	7.3	1.2	6.8	1.2
25.0	25.0	6.3	1.2	5.4	1.5	7.2	1.1	6.4	0.8
25.0	50.0	7.3	0.8	6.4	1.4	7.3	0.8	6.7	0.7
37.5	37.5	6.7	0.9	6.2	1.4	7.4	1.1	6.8	1.2
0.0	0.0	4.2	1.4	3.6	1.5	2.9	1.6	2.7	1.6
	F	13.2		8.7		32.0		28.6	
significance		0.01		0.01		0.01		0.01	

13 member panel

irradiation conditions - 27 kGy at -30 $\pm$ 10 ^{o} C

Table 8 shows the sesnsory evaluation of the samples. The samples without additive addition were rated significantly lower for color and flavor characteristics in the nonirradiated group and had signfificantly lower color intensity in the irradiated group. No significant differences were found between the additive samples for the other characterist

TABLE 7 - 6 MONTH SENSORY EVALUATION OF CORNED BEEF

$NaNO_2$ ppm	$NaNO_3$ ppm	Characteristic: Color mean	Color SD	Odor mean	Odor SD	Flavor mean	Flavor SD	Texture mean	Texture SD
A. Nonirradiated									
75.0	0.0	6.9[a]	1.3	7.3	1.6	7.2[b]	1.1	7.6	1.0
25.0	25.0	7.8[a]	0.8	8.1	0.5	8.0[b]	0.6	7.7	0.6
25.0	50.0	7.5[a]	0.8	8.1	0.7	7.6[b]	0.9	7.5	1.0
37.5	37.5	7.9[a]	0.8	7.8	0.6	7.6[b]	0.8	7.6	1.1
0.0	0.0	3.6	1.9	7.1	1.1	6.4	1.7	7.2	1.3
	F	20.7		2.0		2.9		0.3	
significance		0.01		NSD		0.05		NSD	
B. Irradiated									
75.0	0.0	7.2[c]	1.5	7.1	1.1	6.5	1.4	7.8	0.8
25.0	25.0	7.1[c]	1.6	7.3	1.2	7.3	1.2	7.0	1.1
25.0	50.0	7.3[c]	1.2	7.2	1.1	6.9	1.5	7.3	1.1
37.5	37.5	7.5[c]	0.8	7.5	0.8	7.2	1.2	7.4	1.1
0.0	0.0	5.1	0.9	7.4	1.3	6.8	1.3	7.5	0.9
	F	5.1		0.2		0.6		0.8	
significance		0.01		NSD		NSD		NSD	

means in a column followed by the same letter are not significantly different

10 member panel Irradiation dose - 27 kGy at -30 ± 10 °C

Conclusions

The results of these studies show that $NaNO_3$ addition reduces the degree of fading of the cured meat color on exposure to light. Color intensities of the unexposed samples were not increased with the addtion of $NaNO_3$.

Acceptable irradiated cured beef products can bes produced with $NaNO_2$ at a conentration lower than required by the USDA. Shults (1977) showed that the addition of 25 ppm $NaNO_2$ was sufficient to produce an acceptable irradiated product. Ionizing radiation eliminates the need for high amounts of $NaNO_2$ for the control of *C. boutlinum*. Therefore, it is concluded that irradiated corned beef can be safely produced with concentrations of 25 to 75 ppm $NaNO_2$ wihout any addition of $NaNO_3$.

This document reports research undertaken at the U.S. Army Soldier and Biological Chemical Command, Soldier Systems Center, and has been assigned No. NATICK/TR-99/002 in a series of reports approved for publication.

REFERENCES

Cohen, J.S., Shults, G.W., Howker, J.J. and Mason, V.C. (1978) Measurement of Color of Cured Beef and Pork Muscles Preserved by Freezing and Irradiation. Presentation 78-3552 at Am. Soc. Agric. Eng. Meeting, Chicago, 1978

Loveridge, V. (1994) Quality Assessment of Irradiated Foods AM94-18

Peryam, D.R. and Pilgrim, F.J. 1957. Hedonic scale method for measuring food preferences. Food Technol. 11 (9): Suppl. 9

Shults, G.W., Cohen, J.S., Howker, J.J., Mason, V.C. and Wierbicki, E. 1977. Effects of Sodium Nitrate and Sodium Nitrite Additions and Irradiation Processing Variables on the Color and Acceptability of Corned Beef Briskets. J. of Food Sci. 42, p. 1506

Steel, R.G. and Torrie, J.H. 1960. "Principles and Procedures of Statistics" McGraw-Hill Book Co., New York, NY

USDA. 1975. Meat and Poultry Inspection Regulations - Meat and Poultry Inspection Program. May 1975

Wasserman, A.E., Pensabene, J.W. and Piotrowski, E.G. 1978. Nitrosamine formation in home cooked bacon. J. of Food Sci. 43, p. 276

Wierbicki, E. and Heiligman, F. 1973. Shelf-stable cured ham with low nitrite-nitrate additions preserved by radappertization. Proceedings, Int. Symposium Nitrite in Meat Products. Zeist, the Netherlands, Sept. 10 -14, PUDOC, Wageningent: 189

Wierbicki, E., Heiligman, F. and Wasserman, A.E. 1974. Cured meat with reduced nitrite preserved by radappertization. Proceedings, 20th European Meeting of Meat Res. Workers. Dublin, Ireland, Sept 15 - 20