MASTER

MIT - 3343 - 26

SIMULTANEOUS RADIATION - HEATING TREATMENT OF PRECOOKED MARINE PRODUCTS

Final Report, February 1, 1965 - February 28, 1966

By
S. A. Goldblith
J. T. R. Nickerson

May 1966
[DTIE Issuance Date]

Massachusetts Institute of Technology
Cambridge, Massachusetts

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

This report has been reproduced directly from the best available copy.

Printed in USA. Price \$3.00. Available from the Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U. S. Department of Commerce, Springfield, Virginia 22151.

MIT - 3343 - 26
ISOTOPES - INDUSTRIAL
TECHNOLOGY (TID - 4500)

CXSEI PRICES

H.C. \$ 3.00; MN .50

SIMULTANEOUS RADIATION-HEATING
TREATMENT OF PRECOOKED MARINE PRODUCTS

Prepared by:

S. A. Goldblith and J. T. R. Nickerson
Massachusetts Institute of Technology
Cambridge, Massachusetts

For:

Division of Isotopes Development
United States Atomic Energy Commission
Contract Number AT(30-1)-3343

Final Report
covering the period
February 1, 1965 to February 28, 1966

In order to evaluate the effect of irradiating cooked fish sticks and scallops while holding at 150°F and lobster meat and blue crab meat while holding at 140°F, it was necessary to prepare and evaluate a number of controls.

These controls for fish sticks consisted of the plain cooked fish sticks held at 150°F for 30 minutes and cooled; the cooked fish sticks held at 150°F for 30 minutes and cooled then irradiated at 150,000 or 250,000 rad while holding at 32°F; cooked fish sticks held at 150°F for 30 minutes and then held long enough at this temperature to irradiate at 150,000 rad then cooled; and cooked fish sticks held at 150°F for 30 minutes and then held long enough to irradiate at 250,000 rad then cooled.

With scallops the same types of controls were required however, cooked sample controls had to be held at 150°F for 30 minutes then held at this temperature for periods long enough to irradiate at 250,000 and 500,000 rad respectively, then cooled.

With crab meat and lobster meat it was necessary to have untreated controls; controls irradiated while holding at 32°F; controls heated to 140°F, cooled and irradiated at 125,000 and 250,000 rad while holding at

32°F; and controls heated to 140°F and held at this temperature for periods long enough to irradiate at 125,000 and 250,000 rad.

Samples of cooked fish sticks held at 150°F for 30 minutes, then irradiated at 125,000 and 250,000 rad while holding at 150°F; cooked scallops held at 150°F for 30 minutes, then irradiated at 250,000 and at 500,000 rad while holding at 150°F; and of lobster meat and crab meat heated to 140°F, held at 140°F for 20 minutes, then irradiated at 125,000 and 250,000 rad while holding at 140°F were also prepared.

All sample types were stored at 36 to 40°F and evaluated bacteriologically to determine the refrigerated storage life.

Only casual-type organoleptic tests were made on cooked fish stick and scallop samples. Consumer-type organoleptic tests were made on lobster meat and crab meat samples at the start and during storage at 36 to 40°F.

All types of cooked fish stick and scallop control samples were not spoiled bacteriologically after periods of 60 to 140 days at 36 to 40°F. However all types of fully cooked, irradiated and unirradiated samples became changed chemically during this storage period. It was, therefore, indicated that there would be no advantage in irradiating cooked products of this kind.

With lobster meat the fresh, untreated product had a storage life of 4 to 6 days at 36 to 40°F and heated controls had storage life times of between 14 and 19 days at 36 to 40°F, depending upon the time of heating to 140°F and holding at this temperature. Product irradiated at 125,000 rad while holding at 32°F had a storage life of about 16 days at 36 to 40°F while that irradiated at 125,000 rad while holding at 140°F had a storage life of approximately 42 days at 36 to 40°F.

Lobster meat irradiated at 250,000 rad while holding at 32°F had a storage life (bacteriological) greater than 80 days at 36 to 40°F, but at this time the product was chemically changed, the color having bleached.

It appears that irradiation at 250,000 rad while holding at 32°F would be sufficient to stabilize lobster meat bacteriologically for storage at 36 to 40°F for as long as might be required commercially and for as long as it would be stable chemically. However, consumer-type organoleptic tests have shown the product irradiated at this level to be sometimes significantly different from the control or from the product irradiated at 125,000 rad. Irradiating at 125,000 rad while holding at 140°F provides some extension of storage life at 36 to 40°F beyond that of product irradiated at the same dose level while holding at 32°F. There may, therefore, be commercial advantages in irradiating lobster meat at 125,000 rad while holding at 140°F, cooling and storing at 36 to 40°F.

While vacuum packed heated crab meat controls did not spoil during long periods of time at 36 to 40°F, air-packed heated controls spoiled in 26 to 37 days. Also product irradiated at 32°F after preheating and cooling has long storage life at 36 to 40°F. However, the material used in these tests was heated in small batches and at relatively low temperatures compared to those used in commercial pasteurization of crab meat, which heating is said to cause organoleptic changes. Also the bacteriological results on product irradiated at 125,000 rad at 32°F without preheating showed that spoilage occurred in 11 to 15 days at 36 to 40°F. These results indicate that there may be advantages in irradiation treatment of commercial crab meat while holding at 140°F.

Crab meat heated to 140°F and held at 140°F for 20 minutes, cooled then irradiated at 125,000 rad while holding at 32°F was not significantly different from the fresh control but crab meat heated to 140°F and held at that temperature for 20 minutes, cooled, then irradiated at 250,000 rad while holding at 32°F was significantly different from the fresh control. After holding these irradiated products for 43 days at 36 to 40°F (the control was held at -40°F) there were no significant differences among the samples. This appeared not to be due to the deterioration of the control during freezing and storage at -40°F since it received essentially the same score (6.3)

as did the fresh control in the original test (6.4).

Considering the results on blue crab meat and lobster meat, it is probable that irradiation at 125,000 rad is a suitable method of extending storage life at 36 to 40°F and that if some method of fast heating to 140°F, short time irradiation at low dose level and quick cooling could be devised, that irradiating while holding at the elevated temperature might be the best method of extending the storage life at 36 to 40°F.

Vacuum packing in hermetically sealed containers extended the storage life of all types of product but might not be suitable for holding at 36 to 40°F because of public health aspects.

Bacterial counts and organoleptic tests on already prepared sample of lobster meat and crab meat (controls, irradiated at 125,000 or 250,000 rad while holding at 32°F or at 140°F) will be continued as part of a thesis.

METHODS

Preparation of Cooked Scallop Samples

Breaded, uncooked frozen scallops obtained from a local producer, removed from a temperature of 0°F and cooked according to directions (4 minutes in deep fat at 350°F) were judged by taste panels not to be cooked. Further tests indicated that the product, handled in this manner, should be cooked for 6 minutes at 350°F.

In irradiating cooked scallops at 150°F the product had first to be heated to 150°F, held at this temperature for the time required to bring to and place in the source, then held at 150°F for the time required to irradiate at 250,000 or 500,000 rad. Due to the long holding times at 150°F it was necessary to find a different cooking time for product treated in this manner. This time was found to be 2 minutes at 375°F.

Also due to the holding times at 150°F used in irradiating at the two doses used at this temperature, it was necessary to prepare a number of controls to compare storage life at 36 to 40°F as determined by bacterial counts. Samples prepared were as follows:

<u>Sample Type</u>	<u>Treatment</u>
Cooked control A	Cooked 6 min @ 350°F, cooled immediately to 32°F, then stored at 36 to 40°F.
Cooked control B	Cooked 6 min @ 350°F, held 30 min @ 150°F, cooled to 32°F, then stored at 36 to 40°F.
Heated control A	Cooked 2 min @ 375°F, held 160 min @ 150°F (irradiation time plus 30 minutes), cooled 32°F, then stored @ 36 to 40°F.
Heated control B	Cooked 2 min @ 375°F, held 200 min @ 150°F (irradiation time plus 30 minutes), cooled to 32°F, then stored at 36 to 40°F.
Irradiated 250,000 rad @ 32°F	Cooked 2 min @ 375°F, held 30 min @ 150°F, cooled to 32°F, irradiated @ 32°F and stored at 36 to 40°F.

<u>Sample Type</u>	<u>Treatment</u>
Irradiated 500,000 rad @ 32°F	Cooked 2 min @ 375°F, held 30 min @ 150°F, cooled to 32°F, irradiated @ 32°F and stored at 36 to 40°F.
Irradiated 250,000 rad @ 150°F	Cooked 2 min @ 375°F, held 30 min @ 150°F, irradiated @ 150°F, cooled to 32°F and stored at 36 to 40°F.
Irradiated	Cooked 2 min @ 375°F, held 30 min @ 150°F, irradiated @ 150°F, cooled to 32°F and stored @ 36 to 40°F.

Samples were packed in hermetically sealed metal containers with and without vacuum. In order to facilitate bacterial counts, 50 gram portions were placed in each container.

Bacteriological Counts on Processed Scallops

The 50 gram portion of product was placed in a sterile blender container together with 450 ml of dilution water and blended for 3 minutes. All dilution water contained 0.1 per cent of trypticase and 1.82 g/liter of KH_2PO_4 and was regulated to pH 7.2. Only refrigerated dilution water was used.

Various dilutions were surface plated on Eugon agar and incubated for 5 days at 20°C prior to counting for aerobic counts.

For anaerobic counts various dilutions were cultured on Trypticase-Peptone-Glucose agar containing 0.2 per cent of sodium thioglycollate, 0.07 per cent of sodium sulfite

and 0.048 per cent iron citrate, in Miller-Prickett tubes. The medium was stratified with 2 per cent agar containing 0.2 per cent of sodium thioglycollate. Counts were made after incubating for 1, 2 and 3 days at 30°C.⁽¹⁾

Preparation of Cooked Fish Stick Samples

The same general procedures were used in the preparation of fish sticks as has been indicated for scallops. It was found that fish sticks could be fully cooked in 3.5 minutes at 325°F, while for product held at 150°F for irradiation times, cooking at 350°F for 2.5 minutes was found to be adequate.

According to the above requirements the following types of samples were prepared:

<u>Sample Type</u>	<u>Treatment</u>
Cooked control	Cooked 3.5 min @ 325°F, held 30 min @ 150°F, cooled to 32°F and stored at 36 to 40°F.
Heated control A	Cooked 2.5 min @ 350°F, held 90 min @ 150°F (irradiation time plus 30 min), cooled to 32°F and stored @ 36 to 40°F.
Heated control B	Cooked 2.5 min @ 350°F, held 130 min @ 150°F (irradiation time plus 30 min), cooled to 32°F and stored @ 36 to 40°F.
Irradiated 150,000 rad @ 32°F	Cooked 3.5 min @ 325°F, held 30 min @ 150°F, cooled to 32°F irradiated @ 32°F (60 min), then stored @ 36 to 40°F.
Irradiated 250,000 rad @ 32°F	Cooked 3.5 min @ 325°F, held 30 min @ 150°F, cooled to 32°F irradiated @ 32°F (100 min) then stored at 36 to 40°F.

<u>Sample Type</u>	<u>Treatment</u>
Irradiated 150,000 rad @ 150°F	Cooked 2.5 min @ 350°F, held 30 min @ 150°F, irradiated at 150°F (60 min), cooled to 32°F and stored @ 36 to 40°F.
Irradiated 250,000 rad @ 150°F	Cooked 2.5 min @ 350°F, held 30 min @ 150°F, irradiated at 150°F (100 min), cooled to 32°F and stored @ 36 to 40°F.

All samples were packed in hermetically sealed metal containers with and without vacuum.

Bacteriological Counts on Fish Sticks

Both aerobic plate counts and clostridial counts on fish sticks were made according to the methods described for scallops.

Preparation of Lobster Meat Samples

The lobster meat was purchased precooked from a local commercial lobster processing plant so that no cooking procedures were necessary. It was, however, necessary to determine the preheating time required to bring the product to 140°F. In the first series of tests the packaged product was heated in a bath at 155°F. It was finally concluded that the high bath temperature was having such a destructive effect, bacteriologically, that it was difficult to evaluate the effect of irradiation treatment. For this reason a new series of experiments were run in which preheating was carried out in a bath at 142°F.

The following types of lobster meat samples were prepared and evaluated:

<u>Sample Type</u>	<u>Treatment</u>
Fresh meat	No treatment, stored at 36 to 40°F
Irradiated 125,000 rad @ 32°F	Cooled to 32°F and irradiated at this temperature, stored @ 36 to 40°F.
Irradiated 250,000 rad @ 32°F	Cooled to 32°F and irradiated at this temperature, stored at 36 to 40°F.
Irradiated 125,000 rad @ 32°F	Preheated @ 155°F for 15 min or @ 142°F for 20 min, held for 20 min @ 140°F, cooled to 32°F, irradiated @ 32°F and stored @ 36 to 40°F.
Irradiated 250,000 rad @ 32°F	Preheated @ 155°F for 15 min or @ 142°F for 20 min, held @ 140°F for 20 min, cooled to 32°F, irradiated @ 32°F and stored @ 36 to 40°F.
Heated Control A	Preheated @ 155°F for 15 min or at 142°F for 20 min, held at 140°F for 20 min, cooled to 32°F and stored @ 36 to 40°F.
Heated Control B	Preheated @ 155°F for 15 min or @ 142°F for 20 min, held @ 140°F for 80 min (irradiation time 125,000 rad, plus time to carry to source), cooled to 32°F and stored @ 36 to 40°F.
Heated Control C	Preheated @ 155°F for 15 min or @ 142°F for 20 min, held @ 140°F for 120 min (time to carry to source and irradiate, 250,000 rad), cooled to 32°F and stored @ 36 to 40°F.

<u>Sample Type</u>	<u>Treatment</u>
Irradiated 125,000 rad @ 140°F	Heated @ 155°F for 15 min or @ 142°F for 20 min, held at 140°F for 20 min, irradiated (48 min) while holding @ 140°F, cooled to 32°F and stored @ 36 to 40°F
Irradiated 250,000 rad @ 140°F	Heated @ 155°F for 15 min or @ 142°F for 20 min, held @ 140°F for 20 min, irradiated (96 min) while holding at 140°F, cooled to 32°F and stored at 36 to 40°F.

All samples were packed in air and under vacuum in
hermetically sealed metal containers.

Bacteriological Counts on Lobster Meat

Aerobic plate counts and clostridial counts on lobster
meat were made by the methods described for scallops.

Preparation of Crab Meat Samples

Blue crab meat was obtained from a commercial shucking
plant in Maryland. The meat was flown in by air and picked
up at the airport on arrival. Since the meat was already
cooked, no preparation was necessary other than packaging,
preheating, holding at 140°F, when necessary, and applying the
irradiation dose used.

The following types of crab meat samples were prepared,
packed in air and in vacuum:

<u>Sample Type</u>	<u>Treatment</u>
Fresh meat	No treatment, held @ 36 to 40°F
Plain Control	Heated @ 142°F for 25 min, held @ 140°F for 20 min, cooled to 32°F and stored at 36 to 40°F
Heated Control A	Heated @ 142°F for 25 min, held @ 140°F for 70 min (20 min plus time to irradiate @ 125,000 rad) cooled to 32°F and stored @ 36 to 40°F

<u>Sample Type</u>	<u>Treatment</u>
Heated Control B	Heated @ 142°F for 25 min, held @ 140°F for 120 min (20 min plus time to irradiate at 250,000 rad) cooled to 32°F and stored @ 36 to 40°F.
Irradiated 125,000 rad @ 32°F	Cooled to 32°F, irradiated @ 32°F and stored at 36 to 40°F.
Irradiated 250,000 rad @ 32°F	Cooled to 32°F, irradiated @ 32°F and stored @ 36 to 40°F.
Irradiated 125,000 rad @ 32°F	Heated @ 142°F for 25 min, held 20 min @ 140°F, cooled to 32°F, irradiated @ 32°F and stored @ 36 to 40°F.
Irradiated 250,000 rad @ 32°F	Heated @ 142°F for 25 min, held 20 min @ 140°F, cooled to 32°F irradiated @ 32°F and stored @ 36 to 40°F.
Irradiated 125,000 rad @ 140°F	Heated @ 142°F for 25 min, held 20 min @ 140°F, irradiated @ 140°F (50 min), cooled to 32°F and stored @ 36 to 40°F.
Irradiated 250,000 rad @ 140°F	Heated @ 142°F for 25 min, held 20 min @ 140°F, irradiated @ 140°F (100 min), cooled to 32°F and stored @ 36 to 40°F.

Bacteriological Counts on Crab Meat

The procedures described for scallops were used for aerobic and anaerobic (clostridial) counts on crab meat.

Organoleptic Tests on Controls and Irradiated Lobster and Crab Meat

Organoleptic tests were made on these products or will be made according to the following groupings.

Group 1 (Air Packed)

1. Control - Fresh or frozen meat
2. Heated 25 min @ 143°F, held 20 min @ 140°F, cooled to 32°F and irradiated at 125,000 rad while holding at 32°F
3. Heated 25 min @ 142°F, held 20 min @ 140°F, cooled to 32°F and irradiated @ 250,000 rad while holding at 32°F

Group 2 (Air Packed)

1. Control - fresh or frozen meat
2. Heated 25 min @ 142°F, held 20 min @ 140°F, irradiated at 125,000 rad while holding at 140°F (50 min), cooled to 32°F
3. Heated 25 min @ 142°F, held 20 min @ 140°F, irradiated at 250,000 rad while holding at 140°F (100 min), and cooled to 32°F.

In addition to the above there were two others, groups 3 and 4, which had been vacuum packed but were otherwise the same as group 1 or group 2.

Fresh crab meat was used as the fresh control at the start but for stored samples frozen crab meat held at -40°F in hermetically sealed containers under vacuum was used for the fresh control. In the case of lobster meat the fresh, just purchased product was used as the fresh control.

In order to overcome the unlikely possibility of botulism, type E, all stored product to be tested organoleptically was held at 33°F.

It was decided to use a storage half-life of about 40 days and a full storage life of about 80 days for those types of samples which did not go bad, bacteriologically, for long periods of time at 36 to 40°F.

In testing, a consumer type panel of 20 untrained people were presented the three kinds of meat indicated in either of the groups 1 to 4 and were asked to score the product according to the following criteria: ⁽²⁾

<u>Description</u>	<u>Score</u>
like extremely	9
like very much	8
like moderately	7
like slightly	6
neither like nor dislike	5
dislike slightly	4
dislike moderately	3
dislike very much	2
dislike extremely	1

The tabulated scores in each case were subjected to analysis of variance calculations to obtain F values ⁽³⁾. If the F values were significant the means were subjected to further analysis according to Duncan's multiple range test ⁽⁴⁾ in order to obtain significant differences between the mean scores for the sample subjected to different treatments.

RESULTS AND DISCUSSION

The bacteriological counts made on cooked scallop controls held at 36 to 40°F are listed in Table 1 and the counts made on cooked fish stick controls during storage at 36 to 40°F are listed in Table 2. It can be seen that these products did not go bad bacteriologically during long periods of storage, 113 days for scallops and 72 to 160 days for fish sticks.

Since, when examined for color, texture and odor, without subjecting to the usual panel tast tests, these control scallops and fish sticks were spoiled chemically, regular organoleptic tests were not made on these products nor were complete bacteriological tests made on irradiated products of this kind even though they had been prepared and placed in storage at 36 to 40°F.

Bacterial counts on controls and irradiated, air packed, crab meat during storage at 36 to 40°F are listed in Table 3 and the same type of data for samples packed under vacuum are listed in Table 4.

It is evident that the fresh untreated meat, which was exceptionally low in bacterial count at the start, had a storage life of approximately 11 days at 36 to 40°F.

Tables 3 and 4 show that heated controls had storage life times at 36 to 40°F of less than 26 days to more than 92 days depending upon the time that it was held at 140°F.

Product irradiated during holding at 32°F which had been preheated and held at 140°F then cooled to 32°F prior to

irradiation had storage life times at 36 to 40°F of more than 60 days to more than 116 days depending on heating time and irradiation dose. However, product irradiated while holding at 32°F without preheating had a storage life of only about 18 days at 36 to 40°F.

While the bacteriological tests have not been completed, product irradiated at either 125,000 or 250,000 rad while holding at 140°F has still not spoiled bacteriologically after holding for 77 days at 36 to 40°F.

The bacteriological results on crab meat are not quite clear-cut due to the fact that a number of different treatments had to be evaluated. These included the holding of fresh meat; preheated and cooled meat; preheated, cooled and cold irradiated meat; and preheated, hot irradiated and cooled meat. In addition, all of these types of samples were evaluated as air packed and as vacuum packed products.

Some things are evident. Vacuum packed products of this kind are more stable bacteriologically at 36 to 40°F than are air packed products. Irradiation treatment alone seems not to provide extensive shelf life extension at 36 to 40°F beyond that of the fresh, untreated meat unless the bacteriological count on the fresh meat is very low. Both preheating and holding for long periods of time at 140°F and irradiation while holding at 140°F greatly extend the storage life of crab meat stored at 36 to 40°F.

It is unfortunate that some method of fast heating of

crab meat to 140°F was not available and that irradiation at 125,000 and 250,000 rad required so much time, making it necessary to hold heated controls for long periods of time at 140°F. Had this been otherwise, it is believed that a much clearer picture of the extension of the refrigerated storage life of crab meat obtainable by irradiation at 140°F might have been indicated.

Bacteriological counts on controls and on irradiated lobster meat, packed in air and under vacuum, during holding at 36 to 40°F are listed in Tables 5, 6, 7 and 8. It should be noted that, in general, two different lots were evaluated bacteriologically.

A somewhat clearer picture is possible with spoilage of lobster meat than with crab meat. To begin with, if the meat is near spoilage at the start (counts above 10,000,000 per gram) (Table 5 and 6), comparatively little storage life extension may be expected by any of the treatments employed (irradiation at 32°F without preheating; preheating to 140°F holding and cooling; preheating to 140°F, holding at this temperature; cooling and irradiating at 32°F or heating to 140°F, then irradiating at this temperature). Since this is the case, the conclusions have mostly been drawn from the results of data obtained from lobster meat which had a reasonably low count at the start (see Tables 7 and 8).

Even though the count is reasonably low at the start, the storage life of lobster meat at 36 to 40°F is short,

only 4 to 6 days. Some extension of storage life at 36 to 40°F is obtained by irradiating lobster meat at 125,000 or 250,000 rad while holding at 32°F without preheating, but this is not great (storage life of 8 to 13 days). Preheating and holding at 140°F alone also does not greatly extend the refrigerated storage life of lobster meat, the storage life time being 14 to 20 days depending upon the time of holding at 140°F.

When lobster meat was preheated to 140°F, held at this temperature for the time required to irradiate, cooled and irradiated at 32°F, the storage life extension for the 125,000 rad irradiation treatment was also not great (refrigerated storage life, 16 days); but, for product heated to 140°F, held at 140°F for the time required to irradiate at 250,000 rad, cooled and irradiated at 250,000 rad while holding at 32°F, the refrigerated storage life time was greater than 81 days.

It was indicated that irradiation of lobster meat at 125,000 rad while holding at 140°F gave a considerable extension of refrigerated storage life (42 days at 36 to 40°F). The product irradiated at 250,000 rad while holding at 140°F appeared to have a shorter storage life (34 days at 36 to 40°F), but this is believed to be an artifact due to a comparatively high count in the raw material. For this reason this type of product has been again prepared and is in the process of reevaluation.

Gross organoleptic tests have shown that lobster meat held for around 80 days at 36 to 40°F takes on off odors regardless of whether the bacterial count increases or not. This change seems not to be due to bacterial growth since aerobic counts cannot be obtained on such material and no anaerobic counts can be obtained either in stratified TPG agar with thioglycollate or in liver broth. The odor in this material was such as to suggest bacterial decomposition. Also the odor was more intense in product which had a high aerobic count at the start. It is believed that this change may be due to bacterial enzymes, the bacteria being destroyed by heating or by heating and irradiation, the enzymes remaining active after such treatment.

The results of organoleptic tests which have been made on controls (fresh at start and frozen and held at -40°F for tests on stored samples) and irradiated blue crab meat are listed in Table 9. It can be seen that the 125,000 rad treated crab meat, either irradiated in air or in vacuum, has not been found to be significantly different from the control at the start or during storage periods of 43 and 64 days respectively at 33°F. This appears not to be due to the fact that, for storage tests a frozen control was used, since the average score of the frozen control has been at least as high as that given the fresh, untreated meat. In any case, crab meat should be fairly stable when packed under vacuum in hermetically sealed metal containers, frozen and

stored at -40°F.

For blue crab meat irradiated at 250,000 rad while holding at 32°F it appears that, organoleptically, samples packed in air are significantly different (lower score) than controls or irradiated vacuum packed samples at the start or after 66 days at 32°F. Crab meat irradiated at 250,000 rad while holding at 140°F, in air or in vacuum, were not significantly different from controls at the start. Storage tests on the latter product have not yet been made.

The results of organoleptic tests on lobster meat are listed in Table 10. At the start in product irradiated at 32°F there were no significant differences among controls, 125,000 or 250,000 rad irradiated products packed under vacuum but in the same products packed in air both of the irradiated sample types were significantly different (lower scores) from the control.

In lobster meat irradiated while holding at 140°F, at the start there were no significant differences between controls and air packed 125,000 and 250,000 rad irradiated samples. Among the same samples packed in vacuum the 250,000 rad irradiated was significantly lower in score than the control or 125,000 rad irradiated.

After holding lobster meat irradiated at 125,000 rad while holding at 140°F for 21 or 39 days at 32°F the irradiated samples were not significantly different from fresh controls.

After 13 to 17 or after 21 days of storage of the irradiated

lobster meat at 32°F, the sample irradiated at 125,000 rad while holding at 32°F, air or vacuum packed, was not significantly different from the control. Since fresh lobster meat was always used as the control there can be no problem in changes during frozen storage.

Further organoleptic tests will be made on lobster meat.

CONCLUSIONS

(1) When very low count (aerobic bacterial count) lobster or crab meat is available, irradiation at 125,000 rad while holding at 32°F is a good method of extending the refrigerated storage life.

(2) Very good refrigerated storage life extension of lobster and crab meat, moderately contaminated with bacteria, may be obtained by irradiating at 125,000 rad while holding at 140°F.

(3) Organoleptic tests indicate that irradiation of lobster or crab meat at 125,000 rad, either while holding at 32 or 140°F, has little effect on the taste of these products, at the start or after refrigerated storage.

(4) Spoilage of lobster meat or crab meat because of the growth of anaerobic bacteria during refrigerated storage has never been observed during tests made on numerous samples and no significant increases in clostridia have been observed in these samples.

REFERENCES

- (1) 1963 Schmidt, C. F. and W. P. Segner
Packaging Development Report - Progress Report No. 1
Metal Division, Research and Development
Continental Can Company, Inc.
- (2) 1960 Peryam, D. R., B. W. Polemis, J. M. Kamin, J.
Endohoven and F. J. Pilgrim.
Food Preferences of Men in the U.S. Armed Forces.
Dept. of the Army, Quartermaster Research and
Engineering Command, Quartermaster Food and Container
Institute for the Armed Forces, Chicago, Illinois
- (3) 1939 Paterson, D. D.
STATISTICAL TECHNIQUE IN AGRICULTURAL RESEARCH
McGraw Hill Book Co., New York, New York
- (4) 1955 Duncan, D. B.
Multiple Range and Multiple F Tests
Biometrics 11, 42.

LIST OF DOCUMENTS

Monthly Progress Letter
Contract: AT(30-1)-3343 Simultaneous Radiation-Heating
Treatment of Haddock
Period Covered: February 1 to March 31, 1965

Monthly Progress Letter
Contract: AT(30-1)-3343 Simultaneous Radiation-Heating
Treatment of Haddock
Period Covered: May 1 to June 30, 1965

Monthly Progress Letter
Contract: AT(30-1)-3343 Simultaneous Radiation-Heating
Treatment of Haddock
Period Covered: July 1 to July 31, 1965

Monthly Progress Letter MIT Report No. SRH-23
Contract: AT(30-1)-3343 Simultaneous Radiation-Heating
Treatment of Haddock
Period Covered: August 1 to August 31, 1965

Monthly Progress Letter MIT Report No. SRH-24
Contract: AT(30-1)-3343 Simultaneous Radiation-Heating
Treatment of Haddock
Period Covered: September 1 to October 31, 1965

Monthly Progress Letter MIT Report No. SRH-25
Contract: AT(30-1)-3343 Simultaneous Radiation-Heating
Treatment of Precooked Marine Products.
Period Covered: November 1 to November 30, 1965

Final Report MIT Report No. SRH-26
Contract: AT(30-1)-3343 Simultaneous Radiation-Heating
Treatment of Precooked Marine Products.
Period Covered: February 1, 1965 to February 28, 1966

TABLE 1. Bacterial Counts on Controls for Irradiated, Cooked
Scallops during Storage at 36 to 40°F

Sample type	Days stored at 36 to 40°F	Aerobic count (per gram) average of two plates	Clostridial count (per gram)
Cooked control B	0	<300	<10
(cooked 6 min at	14	<300	<10
350°F, held 30	23	<300	<10
min at 150°F,	38	<300	<10
cooled to 32°F,	69	<300	<10
air packed)	113	<300	<10

TABLE 2. Bacterial Counts on Controls and Irradiated, Cooked Fish Sticks during Storage at 36 to 40°F.

Sample type	Days stored at 36 to 40°F	Aerobic count (per gram) Average of two plates	Clostridial count (per gram)
Cooked control	0	<300	<10
(Cooked 3.5 min at 325°F, held 30 min at 150°F, cooled to 32°F, air packed)	22	<300	<10
	53	>3,000,000	<10
	62	250,000,000	<10
	63	230,000	<10
	72	11,000,000	<10
	72	4,400,000	<10
	75	>3,000,000	<10
	88	340,000,000	<10
Cooked control	0	<300	<10
(as above, vacuum packed)	59	<300	<10
	94	<300	<10
	94	<300	<10
	160	<300	<10
Heated control A	0	<300	<10
(cooked 2.5 min at 350°F, held 88 min at 150°F, cooled to 32°F, air packed)	69	940,000	<10
	82	>30,000,000	<10
	97	6,600,000	<10
	97	<3,000,000	<10
Heated control B	0	<300	<10
(cooked 2.5 min at 350°F, held 127 min at 150°F, cooled to 32°F, air packed)	88	>30,000,000	<10
	91	250,000	<10
	104	32,000	<10
	119	9,400,000	<10

TABLE 2 (continued)

Sample type	Days stored at 36 to 40°F	Aerobic count (per gram) Average of two plates	Clostridial count (per gram)
Heated control C	0	<300	<10
(cooked 2.5 min at	91	<30,000	<10
350°F, held 225 min	104	<300	<10
at 150°F, cooled to	119	<30,000	<10
32°F, air packed)	127	>2,700,000	<10
Irradiated at	0	<300	<10
250,000 rad while	88	<300	<10
holding at 32°F	193	<300	<10
(cooked 3.5 min at			
325°F, held 30 min			
at 150°F, cooled to			
32°F and irradiated,			
air packed)			
Irradiated at	0	<300	<10
150,000 rad while	171	<300	<10
holding at 32°F			
(cooked 3.5 min at			
325°F, held 30 min			
at 150°F, cooled to			
32°F and irradiated,			
air packed)			

TABLE 3. Bacterial Counts on Controls and Irradiated Blue Crab Meat during Storage at 36 to 40°F -- Packed in Air

Sample type	Days stored at 36 to 40°F	Aerobic count Standard plate count (per gram)	Clostridial count (per gram)
Fresh meat (1)	0	10,000	<10
	7	2,900,000	<10
	8	30,000,000	<10
	8	13,000,000	<10
	11	<5,000,000	<10
	11	16,000,000	<10
Plain control (1)	0	<300	<10
(heated at 142°F	26	66,000,000	<10
for 25 min, held at	29	450,000,000	<10
140°F for 20 min)	29	230,000,000	<10
	35	480,000,000	<10
	35	670,000,000	<10
32°F irradiation (1)	0	<300	<10
125,000 R	29	<300	<10
(heated at 142°F for	46	<300	<10
25 min, held at 140°F	46	<300	<10
for 20 min, cooled to	57	13,000,000	<10
32°F, irradiated)	61	<30,000	<10
	61	<30,000	<10
	83	<300	<10
	83	<300	<10
	116	<300	<10

TABLE 3 (continued)

Sample type	Days stored at 36 to 40°F	Aerobic count Standard plate count (per gram)	Clostridial count (per gram)
32°F irradiation (1)	0	<300	<10
250,000 R	29	<300	<10
(heated at 142°F	61	<3,000	<10
for 25 min, held at	61	<3,000	<10
140°F for 20 min,	83	<300	<10
cooled to 32°F,	116	<300	<10
irradiated)			
Fresh meat (2)	0	5,600	<10
	0	2,800	<10
32°F irradiation (2)	0	<300	<10
125,000 R	11	>30,000,000	<10
cooled to 32°F,	13	2,900,000	<10
irradiated, no pre-	13	2,600,000	<10
warming, air	18	31,000,000	<10
packed			
32°F irradiation (2)	0	<300	<10
250,000 R	13	1,800,000	<10
cooled to 32°F,	13	2,400,000	<10
irradiated, no pre-	18	16,000,000	<10
warming, air			
packed			
Fresh meat (3)	0	160,000	<10
	0	84,000	<10
	9	1,000,000	<10
Heated control A (3)	0	<300	<10
heated at 142°F for	23	327,000	<10
25 min, held at 140°F	23	142,000	<10
for 70 min (20 min	30	9,200,000	<10
+ time to irradiate	30	15,000,000	<10
at 125,000 R) cooled	37	18,300,000	<10
to 32°F	94	550,000,000	<10

TABLE 3. (continued)

Sample type	Days stored at 36 to 40°F	Aerobic count Standard plate count (per gram)	Clostridial count (per gram)
Heated control B (3)	0	<300	<10
heated at 142°F for 25 min, held at	23	<300	<10
140°F for 120 min	23	220	<10
(20 min + time to irradiate at	29	<300	<10
250,000 R) cooled	30	<30,000	<10
to 32°F	37	<3,000,000	<10
	40	28,000,000	<10
	40	<300	<10
	94	15,900,000	<10
140°F irradiation (3)	0	<300	<10
125,000 R	0	<300	<10
heated at 142°F for	55	<300	<10
25 min, held at	56	<300	<10
140°F for 20 min +	77	<300	<10
50 min irradiation			
time, cooled to 32°F			
140°F irradiation (3)	0	<300	<10
250,000 R	56	<300	<10
heated at 142°F for	77	<300	<10
25 min, held at			
140°F for 20 min			
+ 100 min irradiation			
time, cooled to 32°F			

TABLE 4. Bacterial Counts on Controls and Irradiated Blue Crab Meat during Storage at 36 to 40°F--Packed Under Vacuum

Sample type	Days stored at 36 to 40°F	Aerobic count Standard plate count (per gram)	Clostridial count (per gram)
Fresh meat (4)	0	24,000	<10
	0	27,000	<10
	7	2,200,000	<10
	13	54,000,000	<10
	13	46,000,000	<10
Plain control (4)	0	<300	<10
heated at 142°F for 25 min, held at 140°F for 20 min.	24	55,000	<10
	27	84,000	<10
	27	<300	<10
	33	<300	<10
	33	>300,000	<10
	41	<300	<10
	55	>30,000,000	<10
	59	92,000,000	<10
	59	135,000,000	<10
32°F irradiation (4)	0	<300	<10
125,000 R	27	<300	<10
heated at 142°F for 25 min, held at 140°F for 20 min, cooled to 32°F, irradiated	60	<300	<10
	60	<300	<10
32°F irradiation (4)	0	<300	<10
250,000 R	60	<300	<10
heated at 142°F for 25 min, held at 140°F for 20 min, cooled to 32°F, irradiated			

TABLE 4. (continued)

Sample type	Days stored at 36 to 40°F	Aerobic count Standard plate count (per gram)	Clostridial count (per gram)
Fresh meat (2)	0	5,600	<10
	0	2,800	<10
32°F irradiation (2)	0	<300	<10
125,000 R	11	800	<10
cooled to 32°F, irradiated, no pre- warming	18	<3,000,000 (3 type cols- contaminated?)	<10
32°F irradiation (2)	0	<300	<10
250,000 R	18	<300	<10
cooled to 32°F, irradiated, no pre- warming			
Fresh meat (5)	0	110,000	>10
	0	19,000	<10
	7	11,000,000	<10
	7	13,000,000	<10
Heated Control A (5)	0	<300	<10
heated at 142°F for	21	<300	<10
25 min, held at 140°F	54	<3,000	<10
for 70 min (20 min	54	<3,000	<10
+ time to irradiate	75	<300	<10
at 125,000 R) cooled	92	37,000	<10
to 32°F		(bad odor)	
	92	<300	<10
Heated control B (5)	0	<300	<10
heated at 142°F for	21	<300	<10
25 min, held at 140°F	54	<300	<10
for 120 min (20 min	55	<300	<10
+ time to irradiate	75	<300	<10
at 250,000 R) cooled	92	<300	<10
to 32°F			

TABLE 4. (continued)

Sample type	Days stored at 36 to 40°F	Aerobic count Standard plate count (per gram)	Clostridial count (per gram)
140°F irradiation(5) 125,000R heated at 142°F for 25 min, held at 140°F for 20 min + 50 min, irradiation time cooled to 32°F	0 55	<300 <300	<10 <10
140°F irradiation(5) 250,000R heated at 142°F for 25 min, held at 140°F for 20 min + 100 min irradiation time, cooled to 32°F	0	<300	<10

TABLE 5. Bacterial Counts on Irradiated Lobster Meat and Controls during Storage at 36 to 40°F--First lot--
Air Packed

Sample type	Days stored at 36 to 40°F	Aerobic count (per gram) Average of two plates	Clostridial count (per gram)
Fresh meat	0	1,300,000	<100
no treatment	0	820,000	<100
	2	5,200,000	Didn't do
	2	8,600,000	Didn't do
	6	12,000,000	<10
	6	18,000,000	<10
	7	17,000,000	<10
	7	55,000,000	170
Fresh meat for below	0	9,300,000	<100
	0	18,000,000	<100
32°F irradiation	0	1,000,000	< 10
125,000 R	8	>30,000,000	< 10
cooled to 32°F and irradiated at this temperature	14	~200,000,000	==
Fresh meat for below	0	9,300,000	<100
	0	18,000,000	<100
32°F irradiation	0	120,000	<10
250,000 R	8	>30,000,000	<10
cooled to 32°F and irradiated at this temperature	14	~200,000,000	==
Fresh meat for below	0	9,600,000	<10
	0	9,800,000	<10
32°F irradiation	0	~300	<10
125,000 R	0	400	<10
heated at 155°F for 15 min, held for 20	28	~10,000,000	<10
min at 140°F, cooled to 32°F, irradiated at this temperature	32	220,000,000	==

TABLE 5. (continued)

Sample type	Days stored at 36 to 40°F	Aerobic count (per gram) Average of two plates	Clostridial count (per gram)
Fresh meat for below	0	9,600,000	<10
	0	9,800,000	<10
32°F irradiation	0	<300	<10
250,000 R	0	<300	<10
heated at 155°F for 15 min, held at 140°F for	38	<30,000	<10
20 min, cooled to	43	<30,000	<10
32°F	57	~3,000	<10
Fresh meat for below	0	9,600,000	<10
	0	9,800,000	<10
Heated control A	0	14,000	<10
heated at 155°F for	0	18,000	<10
15 min, held at 140°F	6	180,000	<10
for 20 min, cooled to	14	150,000,000	<10
32°F	21	1,200,000,000	==
Fresh meat for below	0	17,000,000	~10
	0	=====	<10
Heated control B*	0	300	<10
heated at 155°F for	0	<300	<10
15 min, held at 140°F	20	12,000,000	<10
for 70 min (irradia- tion time, 125,000 R, plus time to carry to source)			
cooled to 32°F			
Fresh meat for below	0	17,000,000	<10
	0	=====	<10
Heated control C*	0	<300	<10
heated at 155°F for	0	<300	<10
15 min, held at 140°F	24	~800,000,000	<10
for 120 min (irradia- tion time, 250,000 R, plus time to carry to source)			
cooled to 32°F			

TABLE 5: (continued)

Sample type	Days stored at 36 to 40°F	Aerobic count (per gram) Average of two plates	Clostridial count (per gram)
Fresh meat for below	0	17,000,000	~10
	0	=====	<10
140°F irradiation 125,000 R	0	<300	<10
heated at 155°F for 15 min, held at 140°F	0	<300	<10
for 20 min, irradiated for 50 min while hold- ing at 140°F, cooled to 32°F	30	>80,000,000	<10
Fresh meat for below	0	17,000,000	~10
	0	=====	<10
140° irradiation 250,000 R	0	<300	<10
heated at 155°F for 15 min, held at 140°F	0	<300	<10
for 20 min, irradiated for 100 min while hold- ing at 32°F	35 41	<30,000 30,000,000	<10 <10

*Overheated due to excess waterbath temperature

TABLE 6. Bacterial Counts on Irradiated Lobster Meat and Controls during Storage at 36 to 40°F--First lot--
Vacuum Packed

Sample type	Days stored at 36 to 40°F	Aerobic count (per gram) Average of two plates	Clostridial count (per gram)
Fresh meat no treatment		NOT DONE	
32°F irradiation 125,000 R cooled to 32°F and irradiated at this temperature		NOT DONE	
32°F irradiation 250,000 R cooled to 32°F and irradiated at this temperature		NOT DONE	
Fresh meat for below	0	18,000,000	<10
	0	28,000,000	<10
32°F irradiation*	0	<300	<10
125,000 R	0	380	<10
heated at 155°F for 15 min, held for 20	25	<3,000	<10
min at 140°F, cooled	29	<30,000	<10
to 32°F and irradiated	35	<30,000	<10
at 32°F	54 ⁺	14,000	<10
Fresh meat for below	0	18,000,000	<10
	0	28,000,000	<10
32°F irradiation*	0	<300	<10
250,000 R	0	<300	<10
heated at 155°F for 15 min, held at 140°F	54	<3,000	<10
for 20 min, cooled to 32°F, irradiated at 32°F			
Fresh meat for below	0	18,000,000	<10
	0	28,000,000	<10

TABLE 6. (continued)

Sample type	Days stored at 36 to 40°F	Aerobic count (per gram) Average of two plates	Clostridial count (per gram)
Heated control A*	0	~250	<10
heated at 155°F for	0	<300	<10
15 min, held at 140°F	18	1,900,000	<10
for 20 min, cooled to	25	<1,000,000	<10
32°F	29	520,000	<10
	35	<1,000,000	<10
	40	620,000	<10
Fresh meat for	0	20,000,000	<10
below	0	cont.	<10
Heated control B	0	8,000	<10
heated at 155°F for	0	14,000	<10
15 min, held at 140°F	11	~7,900	<10
for 80 min (irradia-	18	2,000,000	<10
tion time, 125,000 R,	22	14,000,000	<10
plus time to carry to			
source) cooled to			
32°F			
Fresh meat for	0	20,000,000	<10
below	0	cont.	<10
Heated control C	0	5,100	<10
heated at 155°F for	0	500	<10
15 min, held at 140°F	11	~2,500	<10
for 120 min (irradia-	22	680,000	<10
tion time, 250,000 R,	28	>3,000,000	<10
plus time to carry to	33	23,000,000	==
source) cooled to 32°F			
Fresh meat for	0	20,000,000	<10
below	0	cont.	<10
140°F irradiation	0	900	<10
125,000 R	0	<300	<10
heated at 155°F for	11	<3,000	<10
15 min, held at 140°F	28	<30,000	<10
20 min, irradiated 50	47+	<3,000	<10
min while holding at			
140°F, cooled to 32°F			

TABLE 6. (continued)

Sample type	Days stored at 36 to 40°F	Aerobic count (per gram) Average of two plates	Clostridial count (per gram)
Fresh meat for	0	20,000,000	<10
below	0	cont.	<10
140°F irradiation	0	<300	<10
250,000 R	0	<300	<10
heated at 155°F for	0	<300	<10
15 min, held at 140°F	39 ⁺	<30,000	<10
for 20 min, irradiated	47 ⁺	<3,000	<10
for 100 min while hold- ing at 140°F, cooled to 32°F			

⁺Spoiled organoleptically (chemically)

*Overheated due to excess waterbath temperature

TABLE 7. Bacterial Counts on Irradiated Lobster Meat and Controls
during Storage at 36 to 40°F--Second Lot--Air Packed

Second Run--Without Vacuum

Sample type	Days stored at 36 to 40°F	Aerobic count (per gram) Average of two plates	Clostridial count (per gram)
Fresh meat no treatment	0	64,000	==
	2	1,000,000	==
	3	3,600,000	==
	4+	9,800,000	==
	6	24,000,000	==
Fresh meat for below	0	36,000	==
32°F irradiation	0	~700 (<3,000)	==
125,000 R	8	35,000,000	==
cooled to 32°F and irradiated at this temperature			
Fresh meat for below	0	36,000	==
32°F irradiation	0	<300	==
250,000 R	13	~100,000,000	==
cooled to 32°F and irradiated at this temperature			
Fresh meat for below	0	1,100,000	<10
	0	500,000	<10
32°F irradiation	0	<300	<10
125,000 R	0	cont.	<10
heated at 142°F for 25 min, held for 20 min at 140°F, cooled to 32°F and irradiated at this temperature	16	24,000,000	<10
Fresh meat for below	0	580,000	<10
	0	520,000	<10

TABLE 7. (continued)

Sample type	Days stored at 36 to 40°F	Aerobic count (per gram) Average of two plates	Clostridial count (per gram)
32°F irradiation	0	3,800	<10
250,000 R	0	<3,000	<10
heated at 142°F for			
25 min, held at 140°F	25	<30,000	<10
for 20 min, cooled	30	<30,000	<10
to 32°F and irradiated	45	<300	<10
at this temperature	66	~3,000	==
	81+	500	==
Fresh meat for	0	1,100,000	<10
below	0	500,000	<10
Heated control A	0	16,000	<10
heated at 142°F for	0	17,000	<10
25 min, held at 140°F	14	~100,000,000	<10
for 20 min, cooled to			
32°F			
Fresh meat for	0	580,000	<10
below	0	520,000	<10
Heated control B	0	12,000	<10
heated at 142°F for	17	>30,000,000	<10
25 min, held at 140°F	22	150,000,000	==
for 72 min, (irradia-			
tion time, 125,000 R,			
plus time to carry to			
source) cooled to 32°F			
Fresh meat for	0	580,000	<10
below	0	520,000	<10
Heated control C	0	~7,500	<10
heated at 142°F for	16	>30,000,000	<10
25 min, held at 140°F	22	150,000,000	==
for 124 min (irradia-			
tion time, 250,000 R,			
plus time to carry to			
source) cooled to 32°F			

TABLE 7. (continued)

Sample type	Days stored at 36 to 40°F	Aerobic count (per gram) Average of two plates	Clostridial count (per gram)
Fresh meat for below	0	?	==
140°F irradiation	0	<300	<10
125,000 R	0	<300	<10
heated at 142°F for 25 min, irradiated	24	<30,000	<10
(52 min) while holding at 140°F, cooled to 32°F	32	<30,000	<10
	35	<300	==
	42	~5,000,000-6,000,000	==
	49	>100,000,000	==
Fresh meat for below	0	1,100,000	==
	0	1,900,000	==
140°F irradiation	0	<300	==
250,000 R	0	<300	==
heated at 142°F for 25 min, held at	34	>10,000,000	==
140°F for 20 min, irradiated (104 min)	37	>100,000,000	==
while holding at 140°F, cooled to 32°F	44	>100,000,000	==

⁺ Spoiled organoleptically (chemically)

TABLE 8. Bacterial Counts on Irradiated Lobster Meat and on
Controls--Second Lot--Vacuum Packed

Sample type	Days stored at 36 to 40°F	Aerobic count (per gram) Average of two plates	Clostridial count (per gram)
Fresh meat No treatment	0	64,000	==
	2	460,000	==
	3	1,200,000	==
	4	3,500,000	==
	6+	14,000,000	==
Fresh meat for below	0	36,000	==
32°F irradiation 125,000 R	0	2,600	==
cooled to 32°F	8	19,000,000	==
and irradiated at this tempera- ture	13	>150,000,000	==
Fresh meat for below	0	36,000	==
32°F irradiation 250,000 R	0	850	==
cooled to 32°F	13	25,000,000	==
and irradiated at this tempera- ture			
Fresh meat for below	0	580,000	<10
	0	520,000	<10
32°F irradiation 125,000 R	0	<3,000	<10
heated at 142°F for 25 min, held 27 min	0	<3,000	<10
at 140°F, cooled to 32°F and irradiated at this temperature	25	>200,000,000	==
	30	100,000,000	==

TABLE 8. (continued)

Sample type	Days stored at 36 to 40°F	Aerobic count (per gram) Average of two plates	Clostridial count (per gram)
Fresh meat for below	0	580,000	<10
	0	520,000	<10
32°F irradiation	0	630	<10
250,000 R	0	7,200	<10
heated at 142°F for	25	66,000	<10
25 min, held at 140°F	30	<30,000	==
for 20 min, cooled to	45	<30,000? -C	==
32°F and irradiated at	86+	<300	==
this temperature			
Fresh meat for	0	580,000	<10
below	0	520,000	<10
Heated control A	0	200,000? -C	<10
heated 142°F for 25	0	29,000	<10
min, held at 140°F	16	~100,000,000	<10
for 20 min, cooled	22	80,000,000	==
to 32°F			
Fresh meat for	0	1,100,000	==
below	0	1,900,000	==
Heated control B	0	2,700	==
heated at 142°F for 25	0	3,400	==
min, held at 140°F for	15	6,000,000	<10
72 min (irradiation			
time, 125,000 R, plus			
time to carry to source)			
cooled to 32°F			
Fresh meat for	0	47,000	<10
below			
Heated control C	0	<300	<10
heated at 142°F for 25	0	<300	<10
min, held at 140°F for	16	1,000,000	<10
124 min (irradiation	19	3,500,000	<10
time, 250,000 R, plus			
time to carry to source)			
cooled to 32°F			

TABLE 8. (continued)

Sample type	Days stored at 36 to 40°F	Aerobic count (per gram) Average of two plates	Clostridial count (per gram)
Fresh meat for below	0	230,000	==
	0	100,000	==
140°F irradiation	0	~1,000	==
125,000 R	0	~300	==
Heated at 142°F for			
25 min, irradiated (52	29	<30,000	==
min) while holding at			
140°F, cooled to 32°F	34	~30,000	==
Fresh meat for below	0	180,000	==
140°F irradiation	0	<300	==
250,000 R			
heated at 142°F for	37	<30,000	==
25 min, held at 140°F			
for 20 min, irradiated			
104 min, cooled to 32°F			

⁺Spoiled organoleptically (chemically)

TABLE 9. Organoleptic Tests on Controls and Irradiated Blue Crab Meat Stored at 32°F

Sample and Treatment	Storage time in days at 32°F	Aerobic count	Anaerobic count	Average score (20 people)	F* value for group	Significance *
Fresh-untreated control for all organoleptic crab	0	108,000	<10	--	--	--
	0	136,000	<10	--	--	--
Control-Fresh air packed	0	--	--	6.4		
32°F irradiation 125,000 R						
heated 25 min at 142°F, held 20 min at 140°F, cooled to 32°F, air packed	0	<300	<10	6.6	8.0	Difference in control & 32°F 250,000 R irradiation is significant at 1% level
32°F irradiation 250,000 R						
heated 25 min at 142°F, held 20 min at 140°F, cooled to 32°F, air packed	0	<300	<10	4.4		Difference in 32°F 125,000 R irradiation and 32°F, 250,000 R irradiation is significant at 1% level
Control-Fresh air packed	0	--	--	5.8		
140°F irradiation 125,000 R						
heated 25 min at 142°F, held 71 min at 140°F, air packed	0	<300 (done on day 5)	<10	5.2		
140°F irradiation 250,000 R						
heated 25 min at 142°F, held 2 hrs at 140°F, air packed	0	<300	<10	5.5	0.45	No significant differences

TABLE 9. (continued)

Sample and treatment	Storage time in days at 32°F	Aerobic count	Anaerobic count	Average score (20 people)	F value for group	Significance
Control-Fresh air packed	0	--	--	5.8		
32°F irradiation 125,000 R, heated 25 min at 142°F, held 20 min at 140°F, cooled to 32°F, vacuum packed	0	<300	<10	5.8	2.2	No significant differences
32°F irradiation 250,000 R, heated 25 min at 142°F, held 20 min at 140°F, cooled to 32°F, vacuum packed	0	<300	<10	5.4		
<hr/>						
Control-Fresh air packed	0	--	--	6.5		
140°F irradiation 125,000 R, heated 25 min at 142°F, held 70 min at 140°F, vacuum packed	0	<300	<10	5.8	1.71	No significant differences
140°F irradiation 250,000 R, heated 25 min at 142°F, held 2 hrs at 140°F, vacuum packed	0	<300	<10	5.4		

TABLE 9. (continued)

Sample and treatment	Storage time in days at 32°F	Aerobic count	Anaerobic count	Average score (20 people)	F value for group	Significance
Control-Frozen air packed	43	--	--	6.3		
32°F irradiation 125,000 R heated 25 min at 142°F, held 20 min at 140°F, air packed	43	--	--	5.8	1.10	No significant differences
32°F irradiation 125,000 R heated 25 min at 142°F, held 20 min at 140°F, vacuum packed	43	<300	<10	5.5		
Control-Frozen air packed	64	--	--	5.8		
140°F irradiation 125,000 R heated 25 min at 142°F, held 70 min at 140°F, air packed	64	--	--	5.8	1.58	No significant differences
140°F irradiation 125,000 R heated 25 min at 142°F, held 2 hrs at 140°F, vacuum packed	64	--	--	6.1		

TABLE 9. (continued)

Sample and treatment	Storage time in days at 32°F	Aerobic count	Anaerobic count	Average score (20 people)	F value for group	Significance
Control-Frozen air packed	64	--	--	6.6	6.35	Difference in Control vs. 140°F, 250,000 R irradiation, air is (2.1) significant at 1% level
140°F irradiation 250,000 R						
heated 25 min at 142°F, held 2 hrs at 140°F, air packed	64	--	--	4.5		
140°F irradiation 250,000 R					6.35	Difference in 140°F, 250,000 R, vacuum, vs. 140°F, 250,000 R irradiation, air is (1.3) significant at 5% level
heated 25 min at 142°F, held 2 hrs at 140°F, vacuum packed	64	--	--	5.8		
Control-Frozen air packed	66	--	--	7.0	3.41	Difference in control vs. 32°F, 250,000 R irradiation, air is (1.6) significant at 5% level
32°F irradiation 250,000 R						
heated 25 min at 142°F, held 20 min at 140°F, cooled to 32°F, air packed	66	--	--	5.4		
32°F irradiation 250,000 R					3.41	Difference in control vs. 32°F, 250,000 R irradiation, air is (1.6) significant at 5% level
heated 25 min at 142°F, held 20 min at 140°F, cooled to 32°F, vacuum packed	66	--	--	6.1		

*Organoleptic tests

TABLE 10. Organoleptic Tests on Controls and Irradiated Lobster Meat Stored at 32°F

Sample and treatment	Storage time in days at 32°F	Aerobic count	Average* score	F * value for group	Significance*
Control-Fresh	1	1,600,000	6.45		
32°F irradiation 125,000 R heated 25 min at 142°F, held 20 min at 140°F, cooled to 32°F, vacuum packed	0	<300	6.80	0.2148	No significant differences
32°F irradiation 250,000 R heated 25 min at 142°F, held 20 min at 140°F, cooled to 32°F, vacuum packed	0	<300	6.55		
Control-Fresh	0	--	7.05		Fresh significantly different from both 125,000 R and 250,000 R at both 1% and 5% levels
32°F irradiation 125,000 R heated 25 min at 142°F, held 20 min at 140°F, cooled to 32°F, packed without vacuum	0	<300	5.65	6.81	
32°F irradiation 250,000 R heated 25 min at 142°F, held 20 min at 140°F, cooled to 32°F, packed without vacuum	0	<300	5.45		

TABLE 10. (continued)

Sample and treatment	Storage time in days at 32°F	Aerobic count	Average score	F value for group	Significance
Control-Fresh	0	150,000	6.55		
140°F irradiation 125,000 R heated 25 min at 142°F, held 20 min at 140°F, packed without vacuum	0	<300	6.15	0.274	No significant differences
140°F irradiation 250,000 R heated 25 min at 142°F, held 20 min at 140°F, packed without vacuum	0	<300	6.15		
Control-Fresh	0	58,000	7.45		
140°F irradiation 125,000 R heated 25 min at 142°F, held 20 min at 140°F, vacuum packed	0	<300	7.40	3.736	250,000 R significantly different from fresh and 125,000 R at 5% level
140°F irradiation 250,000 R heated 25 min at 142°F, held 20 min at 140°F, vacuum packed	0	<300	6.30		

TABLE 10. (continued)

Sample and treatment	Storage time in days at 32°F	Aerobic count	Average score	F value for group	Significance
Control-Fresh	0	16,000	6.55		
32°F irradiation 125,000 R heated 25 min at 142°F, held 20 min at 140°F, cooled to 32°F, vacuum packed	14	--	7.0	1.42	No significant differences
32°F irradiation 125,000 R heated 25 min at 142°F, held 20 min at 140°F, cooled to 32°F, packed without vacuum	17	--	6.1		
Control-Fresh	0	--	7.20		
32°F irradiation 125,000 R heated 25 min at 142°F, held 20 min at 140°F, cooled to 32°F vacuum packed	13	--	7.05	1.0	No significant differences
32°F irradiation 125,000 R heated 25 min at 142°F, held 20 min at 140°F, cooled to 32°F, packed without vacuum	13	--	6.55		

TABLE 10. (continued)

Sample and treatment	Storage time in days at 32°F	Aerobic count	Average score	F value for group	Significance
Control-Fresh	0	Not done	7.0		
140°F irradiation 125,000 R heated 25 min at 142°F, held 20 min at 140°F, vacuum packed	21	Not done	6.5	1.244	No significant differences
140°F irradiation 125,000 R heated 25 min at 142°F, held 20 min at 140°F, packed without vacuum	21	Not done	7.2		
Control-Fresh	0	Not done	6.65		
140°F irradiation 125,000 R heated 25 min at 142°F, held 20 min at 140°F, vacuum packed	39	Not done	5.75	1.43	No significant differences
140°F irradiation 125,000 R heated 25 min at 142°F, held 20 min at 140°F, packed without vacuum	39	Not done	5.95		
Control-Fresh	0	Not done	7.00	0.01	
32°F irradiation 125,000 R heated 25 min at 142°F, held 20 min at 140°F, cooled to 32°F, vacuum packed	22	Not done	6.95		No significant differences

*Organoleptic tests