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Irradiation Preservation of Korean Shellfish

by

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放射線 照射에 의한 韓國產 貝類의 品質保存에 關한 硏究

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Abstract

Pacific oyster, hard clam and mussel were irradiated at doses up to 0.5 Mrad, the optimum dose rather than the maximum permissible was sought for in each species and post-irradiation storage characteristics studied at 0° and 5°C.

No shellfish meat irradited at doses as high as 0.5 Mrad produced any adverse odor. However the organoleptic quality of each sample irradiated at lower doses was superior to those irradiated at the higher during the early storage period. The optimum dose was determined to be 0.2 Mrad for Pacific oyster and mussel and 0.1 Mrad for hard clam. By irradiating at the optimum dose, the storage life of Pacific oyster cculd be extend from less than 14 days to 35 days at 0°C and from only 3 days to 21 days at 5°C. A similar storage extension was observed with mussel. The storage life of hard clam was extended from 7 days to 14 days at 0°C and from 3 days to 12 days at 5°C.

The hard clam meats were particularly susceptible to tissue softening by irradiation; an earlier onset and more extensive softening were observed with increasing dose.

Introduction

It is very well agreed that real promise of radiation preservation of foods lies in the low dose application to effect market life extension at refrigerated temperatures and the number of species of fish and shellfish that could be radiation pasteurized commercially is now more or less well established.[16] With Korean shellfish species, Choe and Chung[2] and Choe *et al*[3] have studied on common ark-shell, pink shrimp and squid for determining optimum dose and their shelf-life extension during postirradiation storage at refrigerated temperatures. Similar studies on Pacific oyster have been reported.[4,5] At present time, however, Korean shellfish species suitable for irradiation pasteurization are largely unknown.

Shellfish production comprises a significant portion

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of total marine out put in Korea (112,835 vs. 935,462 M/T in 1970) and it is expected to increase rapidly as a result of government's effort to expand shellfish culturing area for the last decade. Of the shellfish of economic importance in Korea, Pacific oyster, hard clam, and mussel are being cultured extensively along the west and south coast.

Since they are mostly marketed as fresh, their market life is very limited. Although hard clam and mussel are marketed as shell-on to take advantage of the fact that shellfish close themselves very tightly upon leaving the waters and remains alive for as long as a week at chill temperatures, it would be very convenient and econmical to market them without shell that constitutes major portion of total weight.

This study is the first of series of systematic investigations designed (1) to study on methodology and post-irradiation storage characteristics of fresh fish and shellfish of economic importance in Korea, (2) to determine the species suitable for low dose application of gamma-radiation to bring about a significant shelf-life extension at refrigerated temperatures from both scientific and practical point of views and (3) to evaluate the economics of low dose application to the species with particular reference to the cost/beniffit relationship.

Matrials and Methods

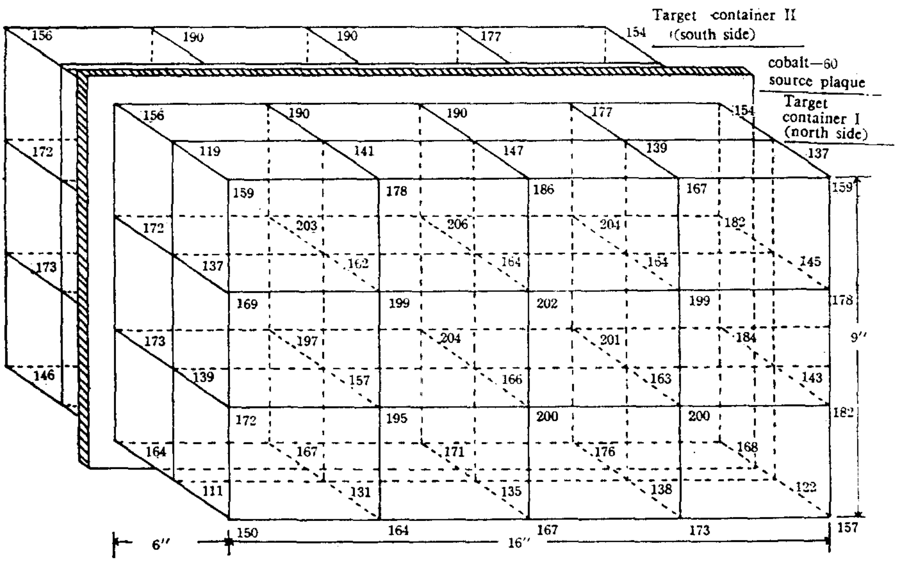
1. Raw materials

Three species of shellfish of economic importance in Korea, namely Pacific oyster (*Crassostrea gigas*, Thunberg), hard clam (*Meretrix lusoria*, Roading), and mussel (*Mytilus edulis*, Linne), were purchased during their prespawning season in early spring from commerical growers and transported to the laboratory in live condition. The samples were shucked in stainless steel containers, the meats washed once with tap water, drained, and packed in flexible film bags, and then heat-sealed with minimum of air space.

2. Dosimetry

The shipboard irrardiator (25,000 Ci strength of cobalt-60) used in this study was designed by the Brookheaven National Laboratory and it was loaned for a period of two years to the Korea Atomic Energy Research Institute by the U.S. Atomic Energy Commission in 1970. Slavin *et al*[17] reported in details on the description and the operational procedure of a similar type of shipboard irradiator.

For dosimetry the sample container box (9″×16″×6″w) was first fitted with a steeel wire fiame with



F.ig 1. **Dose rate pattern from both side exposure to source plaques (rad/sec) as of 10 February 1971.** After exposure to one side for 25 min. the box was moved to the opposite side without changing position in respect to the source and exposed for another 25 min prior to determining dose rate at each position.

dosimetry ampoules held in hooks at sixty different geometries and the box was filled with polished rice. The dosimetry box was then exposed at one side of source for 25 min followed by another 25 min at the other side and absorbed dose rate at each geometry was determined by ferrous sulfate-cupric sulfate method. The difference in dose rate between the highest (center position closest to the source) and the lowest absorbing position (mid position of four corners of box) was as great as 45% (Fig.1). Therefore, in order to avoid the excessive dose variation, mean value of dose rate at all geometries excluding those of both ends of the box was taken (0. 16 Krad/sec) and samples were exposed to the source for the period required to reach calculated dose rate. Thus for irradiating sample at dose of 0. 1 Mrad it required 10 min and 25 sec, 5 min $12^1/_2$ sec at one side of source palque and anther 5 min $12^1/_2$ sec at the other side without changing the position of container box in respect to source plaque.

3. Packaging material

Among the flexible film materials available in local market polyethylene L.D. of 0. 06 and 0. 1mm in thickness, polypropylene of 0. 05mm and aluminum with polyethylene adjuvant of 0. 03 and 0. 03mm in thickness respectively were chosen and their suitability as packaging material of irradiated Pacific oyster was determined at 5°C. The oyster meats packed in four different kinds of flexible film materials were exposed to 0. 2 Mrad and at intervals the quality of samples was assessed by sensory evaluation, total bacterial count, and pH measurement. The unirradiated oyster meats packed in the Al-PE pouch served as control.

4. Determination of optimum dose

The samples packed in Al+PE pouch were irradiated at dose of 0. 1, 0. 2, 0. 3, 0. 4, and 0. 5 Mrad and stored at 0°C. At intervals, duplicate samples of each group were withdraw and presented to an experienced taste panel of 5-7 judges for quality evaluation to determine irradiation-induced changes. The quality of irradiated samples was compared with that of fresh or frozen and thawed samples (Reference)on a 9-point scale (Table 2) and sensory evaluation was used to determine optimum radiation dose level for each species of shellfish.

5. Post-irradiation storage characteristics

Table 1. Storage changes of Pacific oyster packed in different flexible film materials

(Irradiated at 0. 2 Mrad and stored at 5°C)

Total Bacterial Count
(Log No. bacteria/g tissue)

Packaging material (thickness-mm)	Storage (days) 0	3	5	7	14
PE(0. 06mm)	4. 58	4. 32	5. 54	6. 74	8. 87
PE(0. 1mm)	4. 54	4. 85	5. 40	6. 26	8. 96
PP(0. 05mm)	4. 60	4. 18	4. 97	5. 71	8. 87
AI+PE(0. 03+0. 03)	4. 70	4. 18	5. 08	5. 68	6. 92
AI-PE(0. 03+0. 03) (Unirradiated)	5. 71	6. 71	7. 56	8. 71	9. 08

Organoleptic Scores(9 Point hedonic scale)

Packaging material (thikness-mm)	Storage (days) 0	3	5	7	14
PE(0. 06mm)	9	8	7	6. 5	4
PE(0. 1mm)	9	8	7. 5	7	5
PP(0. 05mm)	9	8	8	8	6
Al+PE(0. 03+0. 03)	9	8. 5	8. 5	8. 5	7
Al+PE(0. 3+0. 03) (Unirradiated)	9	6	4	1	1

pH Changes

Packaging material (thickness-mm)	Storage(ays) 0	3	5	7	14
PE(0. 06mm)	5. 8	5. 6	5. 6	5. 4	4. 8
PE(0. 1mm)	5. 8	5. 6	5. 6	5. 4	4. 8
PP(0. 5mm)	5. 8	5. 6	5. 6	5. 4	5. 2
Al+PE(0. 03+0. 03)	5. 8	5. 6	5. 6	5. 4	5. 2
Al+PE(0. 03+0. 03) (Unirradiatded)	5. 8	5. 4	5. 4	5. 0	4. 4

Table 2. Sensory score reflecting quality changes of irradiated samples.

Score	Comparative characteristics
9	Odor and appearance comparable to reference samples.
8	Loss, in part, of "fresh" odor and appearance but not distinguished by new characteristics.
6-7	First singnificant change; degree of odor and appearance change slight but still considered fresh.
5	Moderate degree of change but normal desirable chracterestics still apparent(Borderline of acceptability)
3-4	Strong degree of change; loss in palatability definite.
1-2	Extreme degree of change

The samples of each species were irradiated at dose determined previously (at 0.2 Mrad for Pacific oyster, at 0.1 Mard for hard clam, and at 0.2 Mrad for mussel) and stored at 0° and 5°C. At intervals, duplicate samples of each group were withdrawn and prepared for sensory evaluation, microbiological examination and chemical tests to assess post-irradiation storage characteristics of each species.

6. Sensory evaluation

A portion of each sample meats was presented to an experienced panel of 5-7 judges to compare the quality with that of unirradiated fresh or frozen and thawed reference sample. Each judge of the panel was asked to score the organoleptic quality of each sample employing 9-point hedonic rating scale (Table 2) in respect to its appearance, odor and texture. The average score of 5 was considered to be the borderline of acceptability.

7. Total plate count

Forty grams of meats were weighed into 2-oz glass blending jar presterilized and cooled and 3 volume of 0.1% peptone solution, sterilized and pre-chilled, was added and the meat homogenized at high speed for 30-60 seconds, using an Osterizer blender. The homogenate was made into a series of decimal dilutions and plates poured, allowed to solidify, and incubated at 20°C. Tryptone glucose yeast extract agar[15] and 0.1% peptone water were used as medium and diluent, respectively. Colonies were counted after 5 days of incubation and results expressed as logarithmic number of bacteria per gram meats,

8. Chemical tests

A portion of the homogenate was used for estimating total volatile bases (TVB) by microdiffusion method of Conway and Byrne[7] as modified for fish by Beatty and Gibbons.[1] An attempt to estimate trimethylamine (TMA) nitrogen content was made by the same microdiffuion method after fixing ammonia by addition of neutralized formaline prior to adding saturated K_2CO_3 solution. However, the quantity that could be determined by the method was insignificant and its reproducibility with shellfish meats was not good. Therefore. TMA content was not estimated in this work. Lartipue *et al*[10] reported on TMA estimation not recommendable for assessing the quality of Southern oyster.

9. pH measurement

pH was measured of homogenates electrometrically using a Beckman pH meter.

Results and Discussion

1. Selection of flexible film packaging materials

Since it is well established that, among the factors affecting the quality of irradiated foods during storage, the packaging is important in providing protection necessary for retaining the quality of irradiated foods. Ideally hermetic containers such as tin cans would be the choice as packaging material for the irradiated foods. However, the tin cans are too costly for radiation pasteurized foods intended only for a limited storage life, particulary so in countries like Korea. For this reason flexible film materials suitable for packaging seafood products was subject to study.

Based on physcical data such as impact strength and water vapor permeability of flexible film materials of various thickness that are available in local market, polyethylene, L.D. of 0.06 and 0.1 mm, polypropylene of 0.05mm, and aluminum with polyethylene adjuvant of 0.03 and 0.03 mm were chosen and a series of test pack studies were conducted at 5°C using Pacific oyster meats as testing sample. Unirra dia ted oyster meats packed in the aluminum pouch served as control.

As compared to the irradiated oyster meats packed in the aluminum pouch, the quality of those packed in the polyethylene and polypropylene deteriorated much faster and the oyster became inedible within 14 days of storage, evidenced by low organoleptic scores and high bacterial counts (Table 1).

Since other materials such as nylon and polyester are not as yet available commercially in Korea, it was decided to use the aluminum with polyethylene adjuvant (Al+PE) for subsequent postirradiation storage studies as packaging material.

2. Determination of optimum doses

In this work it was intended to determine the minimum doses that would bring about significant storagelife extension rather than the maximum permissible doses that may be difined as doses above which cause adverse changes in appearance and flavor to irradiated products.

No shellfish meats irradiated at doses as high as 0.5 Mrad produced an adverse odor that could be identified as irradiation odor. Gardner and Watts[8] reported on Eastern oyster that irradiation doses above 0.7 Mrad imparted an off-odor described as "grassy". On the other hand 0.2 Mrad was reported to be the maximum without producing undesirable side effects with Southern oyster.[14] Connors and Steinberg[6] indicated that soft-shelled clam meats irradiated at doses as high as 550 Krad extented shelf life by several folds but did not report on adverse effects caused by the dose levels during the 30 days of storage at 33° and 42°F. No published information is available in irradiated mussel as yet.

By judging form the sensory evaluation of each sample, the optimum dose for oyster and mussel were determined to be 0.2 Mrad; the dose levels above the

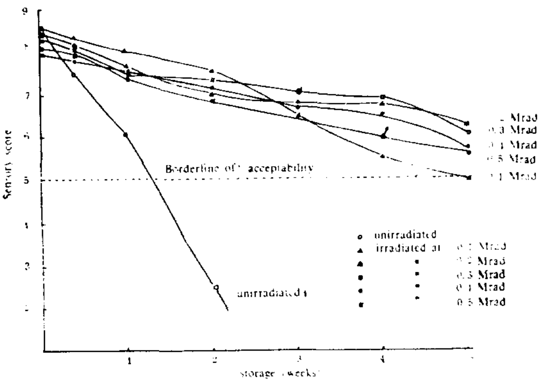


Fig. 2. Difference in sensory score of Pacific oyster meats stored at 0°C

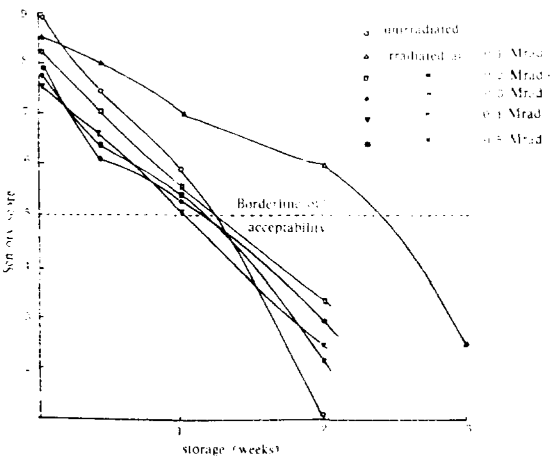


Fig. 3. Difference in sensory score of hard clam meats stored at 0°C

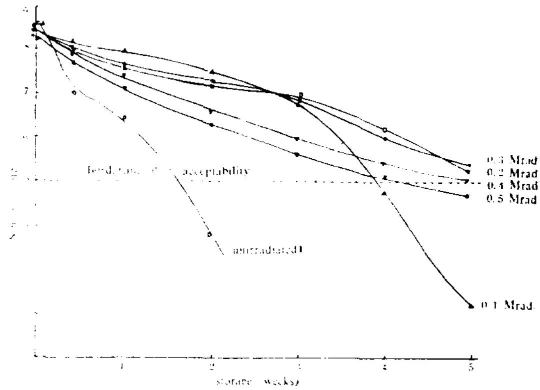


Fig. 4. Difference in sensory score of mussel meats stored at O°C

optimum dose produced inferior organoleptic quality due mainly to softening of tissue and more extensive darkening, particulary during late storage period(Fig. 2 and 4). The hard clam suffered from softening of meats at doses above 0.1 Mrad; and earlier onset and more extensive softening with increasing dose were observed. The effect of softening of hard clam meats appeared to be the singularly important factor contributing to the poor organoleptic quality of the irradiatedsample(Fig. 3). Therefore, the dose of 0.1 Mrad was considered to be the optimum for the hard clam.

3. Postirradiation storage characteristics of Pacific oyster

One of the immediate effects of irradiating Pacific oyster meats at 0.2 Mrad was the 10 fold reduction of total bacterial counts and the counts of the irradiated lagged behind those of the unirradiated throughout the storage period at both 0°C and 5°C. It was noted that the rate of increase in the total bacterial counts was much lower at 0°C as compared to that at 5°C. Also at 0°C, the gap of the counts between the irradiated and unirradiated remained more or less unchanged throughout the storage period (Fig. 5-a). while at 5°C that gap started to become narrow after the 3rd week, approaching to the level of the unirradiated by the 5th week (Fig. 5-b). It is apparent from the bacterial growth curves that for the samples stored at 5°C the microbial growth entered into the declining phase after the 2nd week in the unirradiated, whereas such maximum level was delayed until after the 5th week for the irradited, stored at the same temperature (Fig. 5-b).

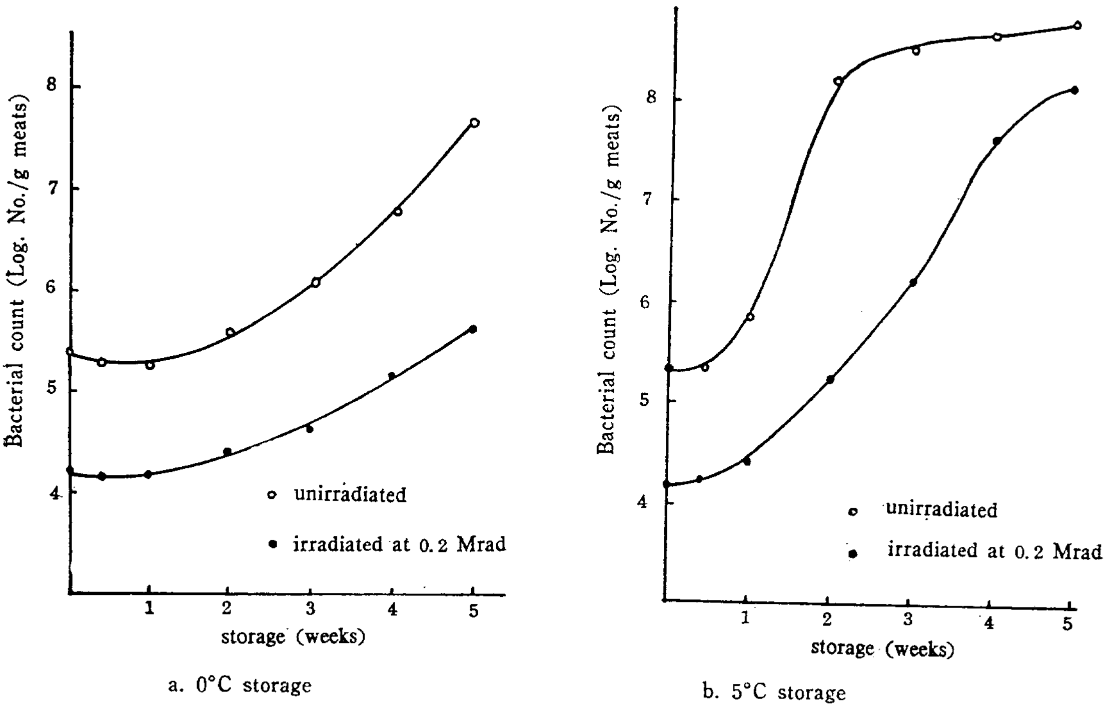
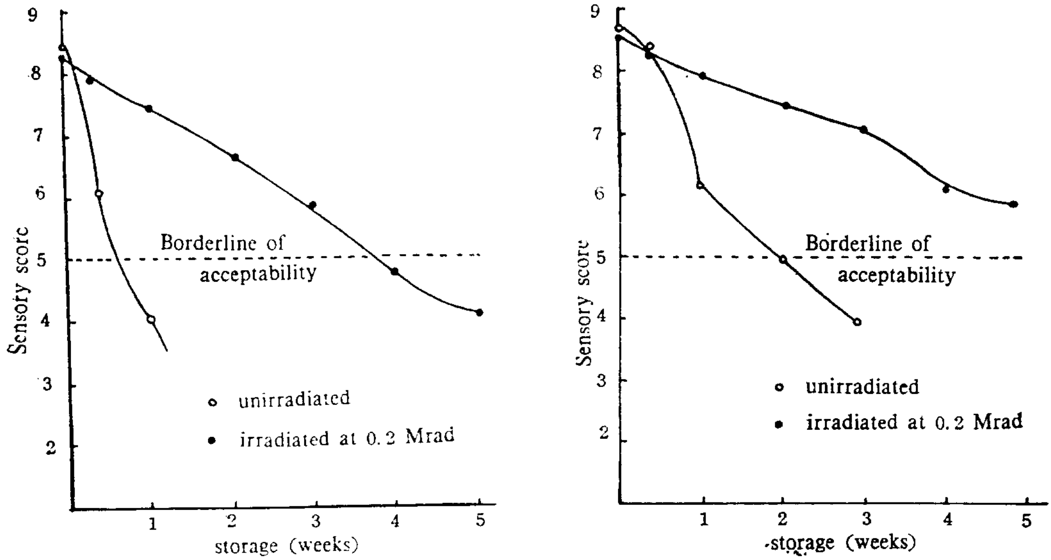


Fig. 5. Total bacterial count of Pacific oyster meats

These differences in microbiological quantity were reflected in the sensory scores of the samples stored at 0° and 5°C. For the 0°C samples, the unirradiated became inedible by the 2nd week while the irradiated were still in edible conditions until the 5th week 4 to 5 fold storage life extension was possible by irradiating at 0.2 Mrad and storing at 0°C (Fig. 6-a). The storage life of the irradiated, stored at 5°C was 3 weeks and that of the unirradiated only 3 days (Fig. 6-b), indicating 6 to 7 fold extenion of storage-life.

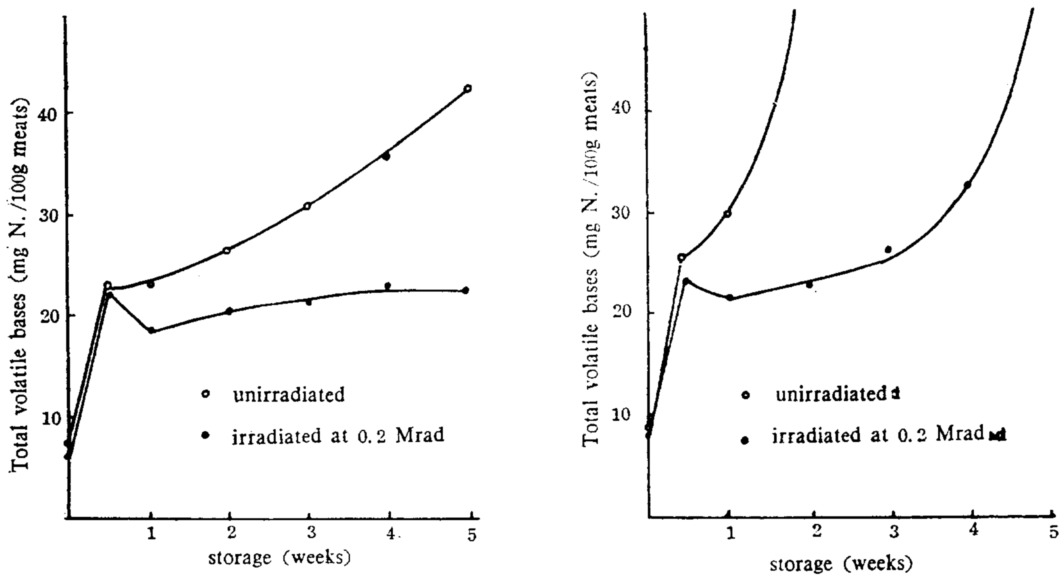
The rapid quality deterioration in the 5°C stored samples of the both irradiated and unirradiated was also reflected by greater rate of TVB accumulation (Fig. 7-a andb). Although the TVB content in all samples increased rather rapidly from the initial levels below 100 mg% to those above 20 mg% during the first 3 days of storage at both 0° and 5°C, the rate of TVB accumulation in the unirradiated stored at 5°C was much greater than that of the same samples stored at 0°C, reaching 120.38 mg% at the end of 35 days of storage. Despite the irradiation treatment, the TVB content in the irradiated, stored at 5°C started to increase more rapidly as compared to that in the unirradiated, stored at 0oC, during the 2nd week, reaching the value above that of the irradiated, stored at 0°C by the 4th week. This is reflected by a rapid rate of microbial activities in the former as evidenced by higher total bacterial counts than that of the latter during the period. (Fig. 5-a and b)

TVB as a useful measure for assessing freshness of various marine products has been established and it is generally accepted the TVB content of 30mg% being the upper limit for acceptability of marine products [9,11,18,19]. However, the results of this study very clearly indicate that the levels of TVB content as related to the quality of marine products undergoing normal spoilage can not be applied to the irradiated because radiation treatment brought about reduction of microflora, thus disrupting the spoilage pattern. One of the effects of microflora redution in the irradiated Pacific oyster was indicated by the suppression of TVB accumulation during the storage. It is interesting to note that the TVB content for a given density of microflora in the Pacific oyster meats of the irradiated samples was much less as compared to that in the unirradiated. This fact may suggest that irradiation inactivated more or less selectively the TVB producing bacteria of the



a. 0°C storage b. 5°C storage

Fig. 6. Difference in sensory score of Pacific oyster meats



a. 0°C storage b. 5°C storage

Fig. 7. Total volatile bases in Pacific oyster meats

total microflora.

The irradiated oyster meats suffered from softening after the 3rd week, this phenomenon being more pronounced for the samples stored 5°C.. By this time these samples became sour and stale with darkening on the surface that progressed during the ensuing storage period.

There was no difference in the initial pH value of the both irradiated and unirradiated. During the strage, the value of all samples decreased gradually, reaching 4.4 from the initial value of 6.0 by the 5th week for the unirradiated, stored at 5°C (Table 3-a). In general

Table 3. pH changes in shellfish meats during storage

a. Pacific oyster

Irradiation (Mrad)	Storage temperature	Storage (days)						
		0	3	7	14	21	28	35
0	0°C	6.0	5.8	5.6	5.4	5.6	5.6	5.6
	5°C	6.0	5.6	5.4	4.8	4.8	4.6	4.4
0.2	0°C	6.0	5.8	5.8	5.6	5.6	5.6	5.6
	5°C	6.0	5.8	5.8	5.6	5.6	5.4	5.2

b. Hard clam

Irradiation (Mrad)	Storage temperatures	Storage (days)						
		0	3	7	10	12	14	21
0	0°C	6.4	6.4	6.4	6.0	6.1	6.0	5.4
	5°C	6.4	6.2	5.6	5.4	5.2	5.2	4.8
0.1	0°C	6.4	6.4	6.2	6.2	6.1	6.0	6.0
	5°C	6.4	6.2	6.0	6.0	6.1	5.4	5.0
0.2	5°C	6.4	6.2	6.0	6.1	6.1	5.6	5.0

c. Mussel

Irradiation (Mrad)	Storage temperature	Storage (days)						
		0	3	7	14	21	28	35
0	0°C	6.0	6.0	6.0	5.6	5.4	5.2	4.8
	5°C	6.0	5.8	5.6	4.8	4.4	4.0	4.0
0.2	0₀C	6.0	6.1	6.1	6.1	6.2	6.2	6.0
	5°C	6.0	6.1	6.0	6.0	5.0	4.0	4.0
0.3	5°C	6.0	6.1	6.1	6.1	5.8	4.4	4.2

pH value below 5.4 appeared to be related to the state of inedibility for the unirradiated only. Otherwise the pH measurement did not seem to be useful for assessing quality of the irradiated Pacific oyster.

4. Postirradiation storage characteristics of hard clam

As it was with the Pacific oyster meats, irradiation treament of hard clam meats resulted in reduction of initial microflora. However the dose of 0.1 Mrad brought about almost 10 fold and 0.2 Mrad irradiation 100 fold reduction of the microflora of the hard clam (Fig. 8-a and b). The pattern of microbial growth in the irradiated samples during storage at 0° and 5°C was essentially similar to that observed with the Pacific oyster samples.

The time required for the microbial growth to reach the initial level of the unirradiated was approximately 21 days for the 0.1 Mrad irradiated, stored at 0°C whereas it required only 10 days at 5°C. Fourteen days were required for the samples irradiated at 0.2 Mrad, stored at 5°C.

The data on the sensory quality of irradiated hard clam samples indicated that at 0°C the storage life of the unirradiated was little over 7 days and by irradiating at 0.1 Mard two fold extension of storage life was possible. For the samples stored at 5°C, irradiation treatment resulted in the storage life extension from 3days to 12 days approximately 4 fold extension (Fig. 9-b). In spite of significantly lower total bacterial counts of the 0.2 Mard irradiated

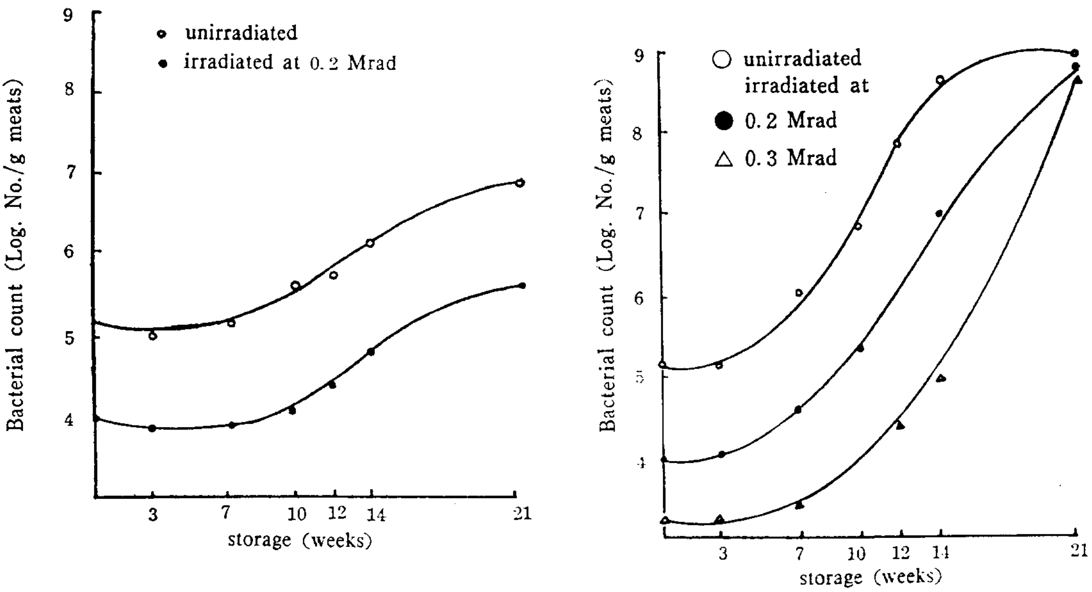


Fig. 8. Total bacterial count of hard clam meats

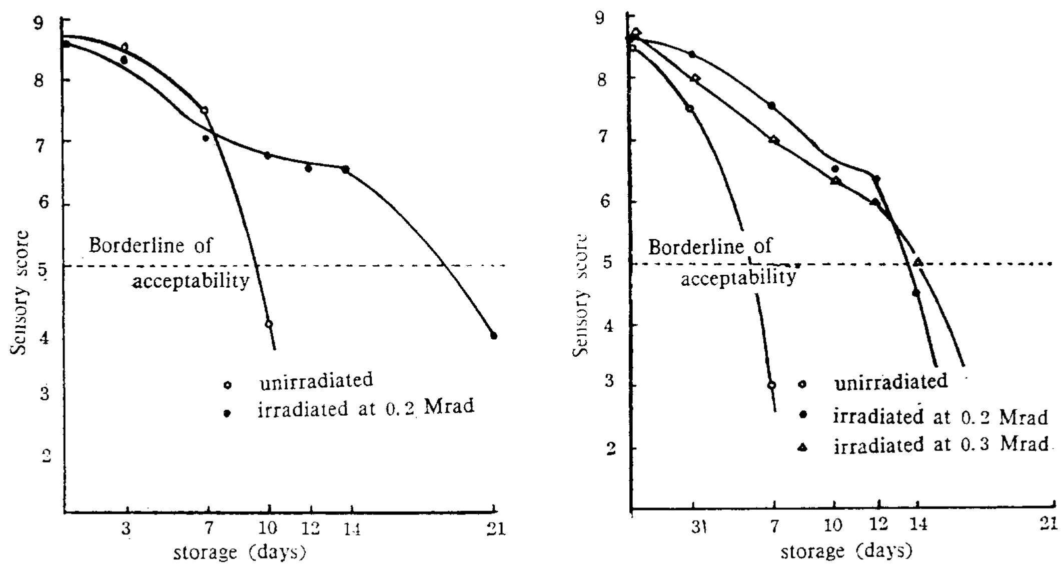


Fig. 9. Difference in sensory score of hard clam meats

samples (Fig. 8-b), the sensory scores were not noticeablly better than those of the 0.1 Mrad irradiated. As indicated previously the hard clam was particularly susceptible to tissue softening resulting in poor organoleptic quality during postirradiation storage. For the 5°C stored samples, the sensory rating of the 0.2 Mrad irradiated was consistantly lower than that of the 0.1 Mrad samples at all sampling intervals(Fig. 9-b).

Masurosky *et al*[12] reported on soft-shelled clam meats irradiated at 0.05 to 0.8 Mrad of gamma radiation that no essential differences in texture and odor were observed when compared to the fresh controls and that the color of the irradiated clams seemed somewhat lighter than the fresh, unirradiated clams at high doses of radiation. Irradiation of hard clam meats however, caused pale pinkish coloration in the viscera region between the foot and stomach beneath the gills. The coloration appeared more extensive at higher doses and became more intense during strage, thereafter became more or less the same among samples as their organoleptic quality deteriorated below the acceptability. Masurousky *et al*[13] indicated in another report on the same soft-shelled clam meats, that the storage-life extension was apparently dose dependent in the range from 400 to 800 Krad.

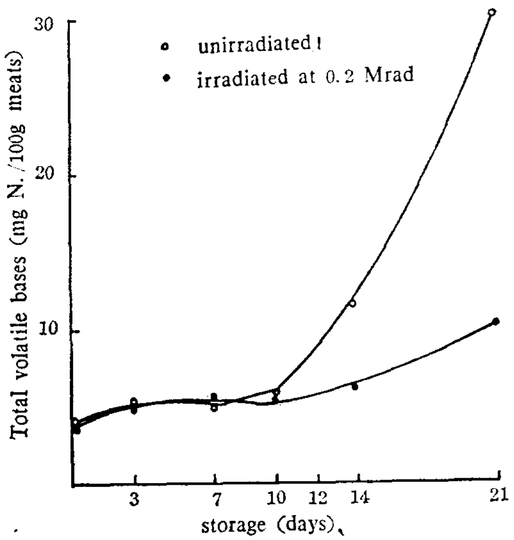
It is interesting to note that as far as the storage-life extension of irradiated hard clam meats is concerned, the sofening of tissue due to irradiation appeared to be an important factor contributing to the rapid deterioration of quality during postirradiation strage. Since the organoleptic quality of the irradiated hard clam meats deteriorated in the early period of storage (Fig. 9 a and b), microbiological activities should have had a very negligible contribution if any, to the deteriorative changes in organolieptic quality of irradiated hard clam meats.

Total volatile base contents of fresh hard clam meats ranged from 3.5 to 4.1 mg%, approximately one half that of Pacific oyster meats. The contents increased with storage in all samples (Fig. 10 a and b), reaching 30.1 and 55.18 mg% at the end of 21 days of storage of the unirradiated stored at 0° and 5°C, respectively. Depression of TVB accumulation in the irradiated hard clam meats may also be attributed to the removal of TVB producing microflora initially present in fresh hard clam meats.

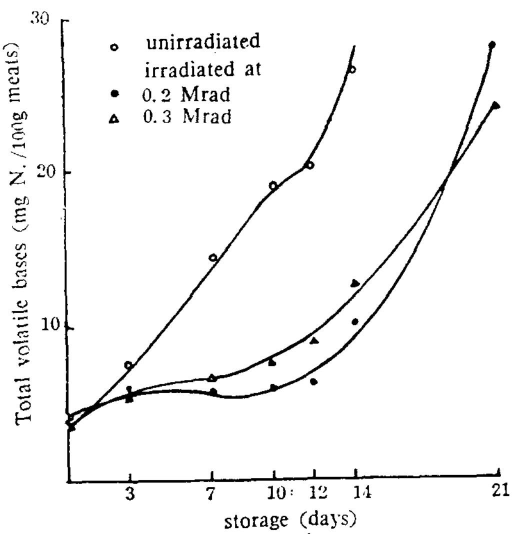
The pattern of changes in pH value of hard clam meats was similar to that of Pacific oyster and pH measurement is even more remotely related to the assessment of organoleptic quality of irradiated hard clam meats (Table 3-b).

5. Postirradiation storage characteristics of mussel

The total bacterial count of fresh mussel meats was also over 10^5 per g meats and there occured a little over 10 fold reduction in number as a result of irradiation at 0.2 Mrad. Almost another ten fold reduction was realized at 0.3 Mrad(Fig. 11-a and b). The changes during storage at 0° and 5°C underwent essentially an identical pattern as observed in Pacific oyster and hard clam meats. For the samples stored at 0°C, however the gap of microbial counts between the irradiated and unirradiated became wider with storage and it required for the count of the irradiated almost 5 weeks to reach the initial level of microflora present in the fresh, unirradiated (Fig. 11-a). This come-

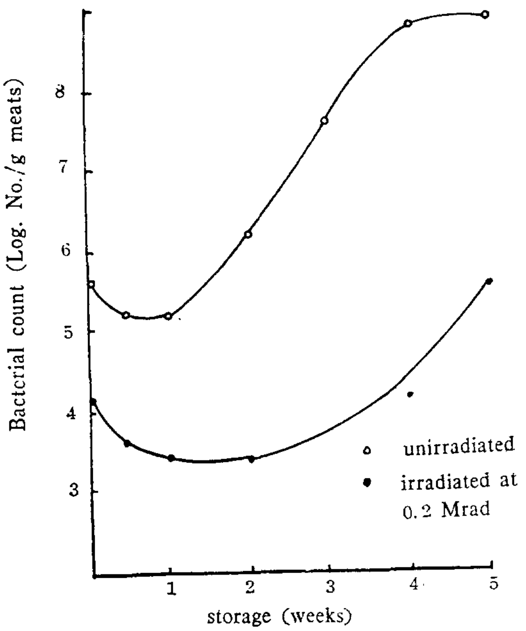


a. 0°C storage

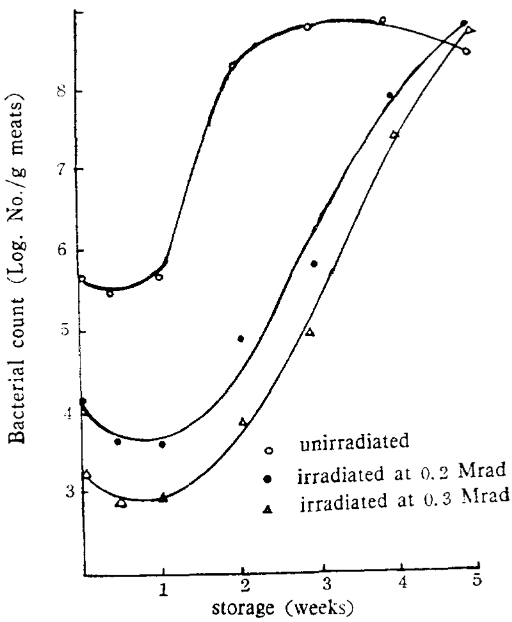


b. 5°C storage

Fig. 10. Total volatile bases in hard clam meats



a. 0°C storage



b. 0°C storage

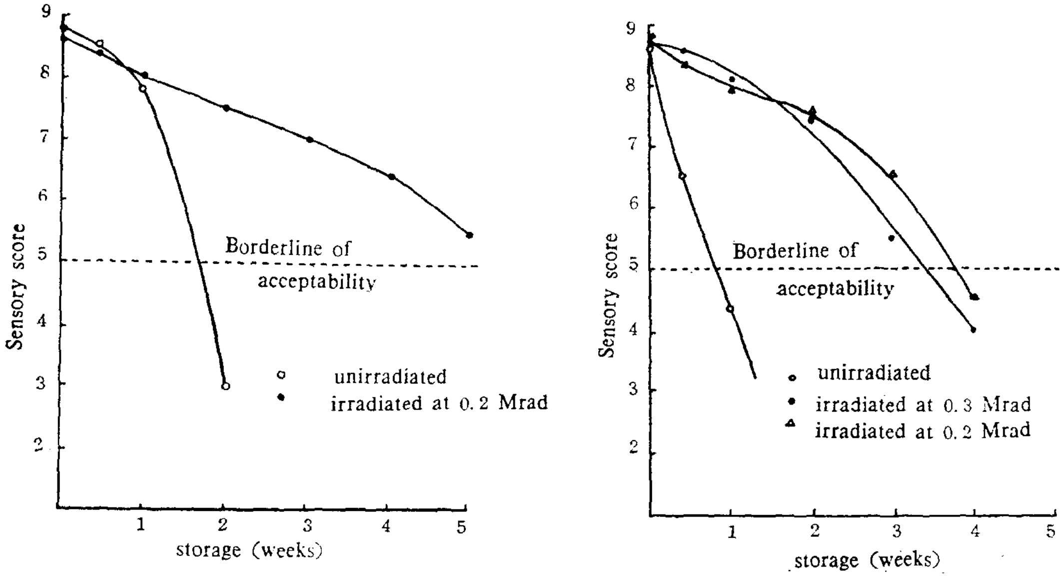
Fig 11. Total bacterial count of mussel meats

up period for the irradiated, stored at 5₀C was reduced to 3 weeks; the 0.3 Mard irradiated little over 3 weeks. The rate of increase in the total bacterial counts between the 0.1 and 0.3 irradiated samples was not significantly different particularly after the 3rd week of storage at 5°C (Fig. 11-b).

The uncooked fresh mussel is in general not very attractive because of dark coloration in mantle and gills covering viscera mass. Also the odor of even very fresh mussel meats is somewhat unpleasant. These may account for the fact that mussel meats are not consumed fresh to a large extent in Korea. However, when cooked, it can be as palatable as any other high quality shellfish. The unirradiated fresh mussel meats became dark due mainly to the diffusion of pigments from the mantle and gill regions and, with concurrent softening after resolution of rigor state, the appearance soon became unattractive. These quality deterioration of mussel during early phase of storage at refrigerated temperatures apparently are not directly ralated to the microbial activities as evidenced by the microbial growth still in the lag phase at the time when the unirradiated samples were rated organoleptically unacceptable on the 14th day at 0°C (Fig. 12-a and b). On the other hand, judging from the organoleptic rating the 0.2 Mrad irradiated samples could be held for 3 weeks at 5°C (7 fold extension of storage life) and for 4 to 5 weeks at 0°C (4-5 fold extension). The 0.3 Mrad irradiated gave a noticeablly higher rating in the 3rd week as compared to the 0.2 Mrad irradiated and stored at 5°C. However, the both became unacceptable before the 4th week(Fig. 12-b).

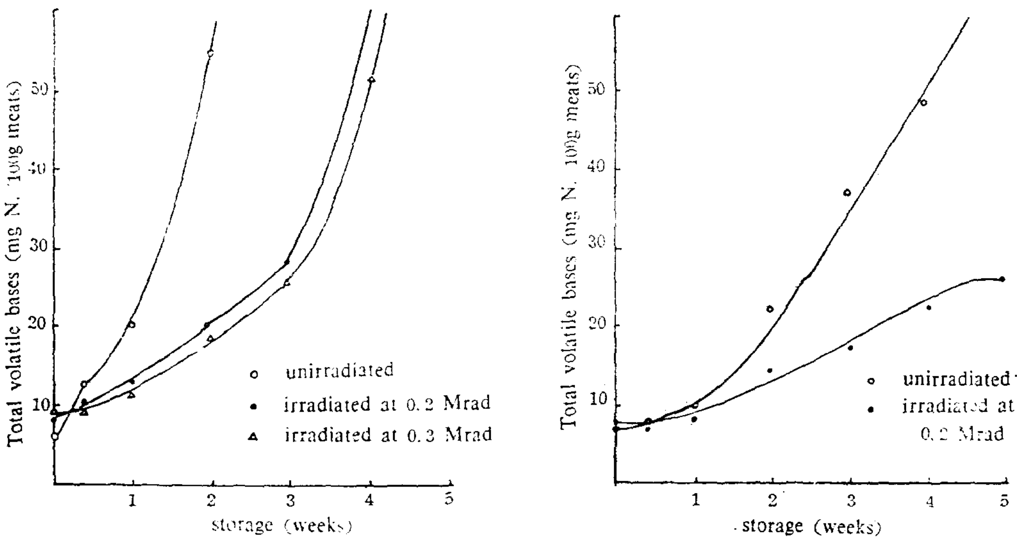
It was noted that drip from mussel meats increased in amount and in turbidity with storage at both 0° and 5°C and the drip from the irradiated in general was much less and less turbid.

The general pattern of TVB accumulation in mussel meats during storage was essentially similar to that observed in Pacific oyster and hard clam meats. However, unlike in the Pacific oyster, the level of TVB as related to the organoleptic acceptability was a little over 10 mg%, whereas the values of the irradiated



a. 0°C storage b. 5°C storage

Fig. 12. Difference in sensory score of mussel meats



a. 0°C storage b. 5°C storage

Fig. 13. Total volatile bases in mussel meats

were approaching 30 mg% in the 3rd week and in the 5th week at 5° and 0°C storage, respectively (Fig. 13-a and b).

The pH changes likewise were quite similar to those of Pacific oyster and hard clam the values decreased gradually during storage. However, differences among samples were not significant enough to directly correlate the organoleptic qualty rating of each sample (Table 3-c).

Summary

1) Packaging material

Shellfish meats packaged in pouches of polyethylene

(0.06 and 0.1mm thickness) and polypropylene (0.05 mm thickness) and irradiated at 0.2 Mrad spoiled and became unacceptable within 14 days of storage at 5°C. Therefore, for the lack of better ones in terms of the cost, etc., alumimum pouch with polyethylene adjuvant (0.03+0.03mm thickess) was chosen as packaging material for this study.

2) Optimum doses

The minimum doses of radiation that would bring about a significant storage-life extension at refrigerated temperatures varied with species of shellfish; 0.2 Mrad was considered to be the optimum for Pacific oyster and mussel,and 0.1 Mrad for hard clam. No shellfish meats irradiated at doses as high as 0.5 Mrad produced any irradiation odor. The hard clam meats suffered from softening of tissue within 3 days of storage when irradiated at doses above 0.1 Mrad, this softening appeared to be the most important factor limiting the storage-life.

3) Storage-life extension

The Pacific oyster meats irradiated at 0.2 Mrad could be held at 0°C for as long as 35 days in acceptable conditions, while the unirradiated became inedible within 14 days —4 to 5 fold extension. The storage life at 5°C was 3 weeks and that of the unirradiated was only 3 days —6 to 7 fold extension was possible at 5°C.

The storage life of hard clam irradiated at 0.1 Mrad was extended from 7 days of the unirradiated control to 14 days at 0°C —2 fold extension could be realized. The storage life of the same samples at 5°C was extended from only 3 days to 12 days. Although total bacterial counts were much less at each storage interval, irradiation of hard clam meats at 0.2 Mrad, twice the optimum, did not bring about any noticeable advantage over the 0.1 Mrad irradiation in extending storage life.

The storagelife extension of mussel irradiated at 0.2 Mrad was similar to what was observed with Pacific oyster at each temperature. The 0.3 Mrad irradiated gave higher organoleptic ratings than the 0.2 Mrad irradiated during storage at 5°C, but both became unacceptable prior to the 4th week.

4) Postmortem changes of irradiated shellfish meats

Irradiation of shellfish meats invariably resulted in the reduction of microflora by 10 fold in 0.2 Mrad irradiated Pacific oyster, 10 fold in 0.1 Mrad and 100 fold in 0.2 Mrad irradiated hard clam, and 10 fold and 100 fold in 0.2 Mrad and 0.3 Mrad irradiated mussel, respectively. TVB accumlation during subsequent storage was suppressed in all irradiated samples and, despite the high total bacterial counts that the irradiated samples had in late storage, the TVB contents were significantly lower than those of unirradiated at identical cell density. This suggests that irradiation treatment caused both quantitative and qualitative changes of microflora initially present.

요 약

한국에서 경제적으로 중요한 3종의 패류인 참굴, 백합 그리고 홍합 근육을 0.5 Mrad이하의 감마선량에 조사하여 냉장온도에서 현저한 선도 연장을 가져오게 하는 최적 선량을 구했으며 0°와 5°C에서 조사후 저장기간중의 변화과정의 특성을 규명하였다.

0.5Mrad의 감마선조사로서는 어느 패류도 방사취를 발생치 않았다. 그러나 처음 2-3주간의 저장기간중의 관능 특질은 저선량 조사구(0.1과 0.2Mrad)의 경우 고선량 조사구(0.3 Mrad이상)보다 우수하였다. 참굴과 홍합을 위한 최적조사선량은 0.2 Mrad, 백합은 0.1 Mrad임이 밝혀졌다. 이 최적 조사선량에 처리된 패류의 선도 연장은 참굴의 경우 0°C에서는 비조사구의 14일 내외로부터 35일까지, 5°C에선 3일에서 21일로 각각 연장이 가능했다. 홍합도 비슷한 선도연장을 가져왔다. 백합의 경우 0°C에선 7일에서 14일로, 5°C에선 3일에서 12일로 각각 연장되었다.

방사선 조사로 인한 근육 조직의 연약 현상은 백합에 있어서 가장 두드러지게 나타났다. 조사선량이 높을수록 조사후 저장 기간중 연약현상이 빨리 일어났으며 연약도도 높았다. 저선량 조사에 의한 패류의 선도 연장을 꾀하는데 있어서 조사후 저장기간중에 일어나는 근육의 연약화는 중요한 제한점인 것으로 사려된다.

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References

(1) Beatty, S.A. and Gibbons, N.E.: *J.Biol. Bd. Canada* **3**, 77 (1936)

(2) Choe, S. and Chung, T.W.: *Bull. Atomic Energy Korea*, **3**(2), 26 (1966)

(3) Choe, S., Chung, T.W. and Kwak, H.S.: *J.Korean Nucl. Soc.*, **1**, 23(1969)

(4) Chung, J.R.: *Bull.Korean Fish. Soc.*, **2**, 41(1969)

(5) Chung, J.R.: *Bull.Korean Fish. Soc.*, **7**, 221(1974)

(6) Connors, T.J. and Steinberg, M.A.: *Food Technol.*, **18**, 113(1964)

(7) Conway, E.J. and Byrne, A.: *Biochem. J.*, 27, 419(1933)

(8) Gardner, E.A. and Watts, B.M.: *Food Technol.*, **11**, 329(1957)

(9) Kimura, K. and Kiamakura, S.: *Proc. 5th Pacific Sci. Congr.* **5**, 3709(1934)

(10) Lartigue,D., Novak, A.F. and Fieger, E.A.: *Food Technol.*, **14**, 109(1960)

(11) Lucke, F. and Geidel, W.: *Z. Untersuch. Lebensm*, **70**, 441(1935)

(12) Masurovsky, E.B., Voss, J.S. and Goldblith, S.A.: *Appl. Microbiol.*, **11**, 229(1963)

(13) Masurovsky, E.B., Goldblith, S.A. and Nickerson, J.T.R.: *Appl. Microbiol.*, **11**, 220(1963)

(14) Novak, A.F., Liuzzo, J.A, Gronder, R.M. and Lovell, R.T.: *Food Technol.*, **20**, 201(1966)

(15) Scholz, D.J., Sinnhuber, R.O. East, D.M. and Anderson, A.W.: *Food Technol.*, **16**, 118(1962)

(16) Shewan, J.M.: *Proc. International Symp. Food Irradiation* IAEA, Vienna, P. 489(1966)

(17) Slavin, J.W., Carver, J.H. Connors, T.J. and Ronsivalli, L.J.: Shipboard irradiator studies. Annual Report; May 15, 1965 to May 14, 1966, TID-23398 *Isotopes-Industrial Technology*, 82 pp (1966)

(18) Tanikawa, E.: *J.Soc. Ind. Fish.*, **3**, 267(1935)

(19) Yamamura, Y.: *Bull. Japan. Soc. Sci. Fish.*, **2**, 101 (1933)