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Irradiation Preservation of Korean Fishes

Part. II Radurization of Freshwater Species

by

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放射線 照射에 의한 韓國產 魚類의 品質保存에 關한 硏究

第 2 報 민물魚種(잉어 및 무지게 송어)의 放射線照射

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Abstract

The meat samples of carp (*Cyprinus carpio*, Linne) and rainbow trout (*Salmo gairdnerii*) packaged in aluminum pouches with polyethylene adjuvant were exposed to gamma radiation of doses up to 1.5 Mrad for the purpose of determining optimum dose range required to bring about a significant storage-life extension at refrigerated temperatures.

The maximum permissible dose for carp was determined to be 1.5 Mrad and that for rainbow trout 0.2 Mrad, while the optimum dose was 0.25 Mard and 0.05 Mrad, respectively. By irradiating them at each optimum dose, the practical storage-life of carp could be extended from one week to five at both 0° and 5°C and that of rainbow trout from one week to 3-4 weeks at 0°C and from 3 days to 14 days at 5°C.

The carp meat suffered from extensive drip loss during the post-irradiation storage and it could be reduced effectively by dipping the samples into 10% polyphosphate solution prior to the radurization treatment.

The rainbow trout was highly radiosensitive, while carp appeard to one of promising species to be radurization treated for the purpose of extending storage-life at refrigerated temperatures.

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Introduction

Much information has been compiled concerning the low dose application of radiation to marine fish species and the number of species that can be treated with the low dose of radiation for the purpose of extending storage-life at refrigerated temperatures is more or less well defined. Very limited information is available, however, on the applicability of such treatment to freshwater species[2].

Among Korean freshwater fish, the carp (*Cyprinus carpio*, Linne) and rainbow trout (*Salmo gairdnerii*) are commercially important, the former as a traditional species widely distributed in natural habitats and the latter being intensively farmed on commercial scale in the mountaineous areas. At present, these two species are sold mostly as live fish and the price is generally very high. With gradual implementation of long range national projects to put nations freshwater resources into multipurpose uses, the freshwater body that can support commercial scale fish farming shall be enlarged enormously in the future.

This study was undertaken to obtain basic information on the maximum and optimum dose range and to determine post-irradiation storage characteristics of the meat samples of carp and rainbow trout at 0° and 5°C after radurization treatments.

Experimental

1. General procedures

Prior to the determination of optimum dose range for each species, samples of carp and trout tissue were exposed to doses between 0.05 and 1.5 Mard. Immediately after the irradiation duplicate samples of each group were organoleptically evaluated by a panel to determine the dose above which irradiation induced undesirable changes to the extent that the panel member would be reluctant to buy as fresh fish. This dose limit was considered to be the maximum permissible dose for each species.

In order for the optmum dose for each species could be determined, the fish samples were irradiated at three dose levels arbitrarily chosen below the maximum permissible as previously determined and then the postirradiation characteristics were studied during 35 days of storage at 0° and 5°C.

2. Preparation of samples and irradiation

The carp and rainbow trout purchased from either the tank of local live fish dealers or fish farm directly were filleted and the fillets cuts into small cubes. Approximately 80g of the meats were packed in aluminum pouch with polyethylene adjuvant (0.03+0.03 mm in thickness) and the packages were heat sealed using a vacuum sealer (40 cm Hg by vacuum gauge). The packed fiish samples were well iced in insulated boxes and transported to the Korea Atomic Energy Research Institute to be irradiated using Brookheaven Natonal Laboratory Mark II. Shipboard Irradiator which is charged with about 20,000 Ci of cobalt-60. It required 10 min 25 sec to irradiate the samples at 0.1 Mrad. No effort was made to maintain samples at ice temperature during the time of irradiation. After irradiation all samples were stored at 0°C and 5°C for subsequent studies.

3. Sensory evaluation

Duplicate sample packages of each group were withdrawn at storage intervals of 0, 7, 14, 21, 28 and 35th day and a portion was presented to a taste panel of 5-7 judges for organoleptic rating, employing the 9-point scale system as described previously.[3] The average score of 5 was considered to be the borderline of acceptability.

4. Objective tests

Total bacterial counts, total volatile bases (TVB), trimethylamine (TMA) and pH were measured at each sampling interval by the same methods as reported previously.[3] The TVB and TMA contents, however, were estimated from clear filtrate prepared by blending fish tissue with equal weight of 10% trichloroacetic acid and filtering the homogenate. In addition tyrosine content of the filteate was estimated using phenol reagent.[1] The method of Spinelli, *et al*[14,15] were used for drip loss measurement.

Results and discussion

1. Maximum Permissible dose range

At an early stage of determining the maximum

permissible dose range for the carp and trout samples, it was clearly demonstrated that the carp could stand the irradiation very well whereas the trout was very radiosensitive.

The carp tissue samples were irradiated at the doses of 0, 0.1, 0.2, 0.3, 0.7, 1.0 and 1.5 Mrad. Although the samples irradiated at doses above 0.5 Mrad suffered from color bleaching and a fresh shell fish like odor became apparent, the samples irradiated at doses as high as 1.5 Mrad were still considered acceptable by majority of the panel members.

On the other hand, the samples of trout tissue irradiated at 0.1 Mrad had a rather strong, typical irradiation induced odor that can be best described as burnt metal (dry metal grinding on a high speed grinder) or burnt feather like. At doses above 0.2 Mrad, the irradiated samples were clearly unacceptable.

Kardashev[8] reported the maximum permissible dose for Russian carp to be at 0.5 Mrad and that could be increased up to 1.5 Mrad by frying or baking the irradiated samples. The results on German carp showed, on the contrary, that no undesirable changes occured up to 1.5 Mrad and the high dose irradiation enhanced the organoleptic quality peculiar to the fresh carp.[5]

From the results of present study, it was concluded therefore that the dose of 1.5 and 0.2 Mrad was considered to be the maximum permissible for the carp and rainbow trout respectively and the doses of 0.25, 0.5 and 1.0 Mrad for the carp and those of 0.05, 0.1 and 0.2 Mrad for the trout were selected in order to determine the optimum dose range during extended postirradiation study period at 0° and 5°C.

2. Postirradiation storage characteristics

Carp : Judging from the sensory evaluation data of the carp samples irradiated at three dose levels and stored at 0° and 5°C for up to 35 days, all the irratiated samples were in acceptable conditions for the entire storage period whereas the unirradiated control became unacceptable after one week at 0°C and before one week at 5°C of storage (Fig. 1-a and b). After the 3rd week, a slight color bleaching and texture softening started to develope in the irradiated samples and these changes appeared to be dose dependent and became more pronounced as storage period progressed. However, the organoleptic quality of the unirradiated control became deteriorated so rapidly within one week of storage at both 0° and 5°C that the benefit of radiation pasteurization treatment of carp samples could be very clearly demonstrated.

As shown in Fig. 1-a and b, the rate of organo-

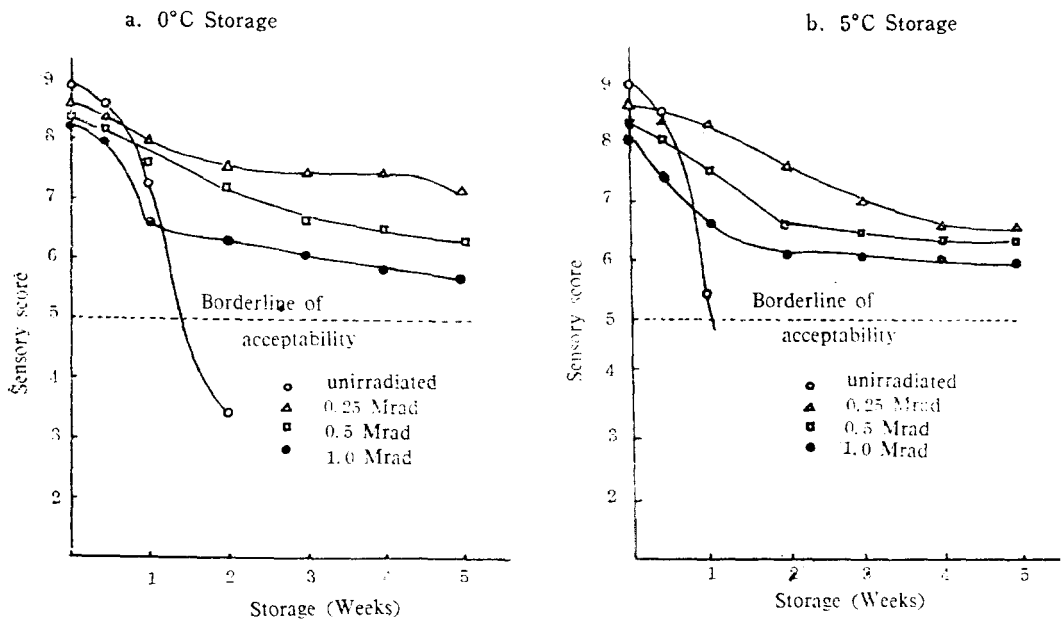

Fig. 1. Difference in sensory score of carp fillet

leptic quality deterioration of the irradiated carp samples stored at 5°C was not noticeably greater than that of the samples stored at 0°C.

In previous studies with Pacific oyster, hard clam and mussel[3] and with croaker, yellow corvenia and round nose flounder[4] the organoleptic quality of radurized samples became deteriorated also much faster at 5°C of storage than it did at 0°C and this was more pronounced with samples treated with lower doses of radiation.

Therefore, based on the sensory scores, the storage life of carp samples irradiated at doses below 0.5 Mrad could be extended from one week for the unirradiated to 5 weeks at both 0° and 5°C. Among the three dose levels tested (i. e., 0.25, 0.5 and 1.0 Mrad), the dose of 0.25 Mrad brought about the highest organoleptic quality retention throughout 35 days of storage period, thus the optimum dose to effect practical storage life extension of radurized carp under the conditions was consdiered to be 0.25 Mrad.

Irradiating the samples at 0.25, 0.5 and 1.0 Mrad reduced total microflora from the initial levels of 2,300 to 3,400 bacteria per gram fish flesh to less than 30, the minimum detectable level. The total bacterial counts of all the irradiated did not increase to a detectable level (above 30 bacteria per gm fish flesh) throughout 35 days of storage at both 0° and 5°C, although in the samples irradiated at 0.25 Mrad, the counts increased to 360 and 510 bacteria per gm fish flesh on the 28th day at 0° and 5°C respectively and by the 35th day the counts started to exceed the initial levels of the unirradiated control (Table 1). The bacterial counts of the unirradiated control samples on the other hand increased very rapidly, reaching the level above 10^7 bacteria per fish flesh by the 21st day of storage at 0°C and by the 7th day at 5°C.

These differences in microbiological quality were reflected in the total volatile bases (TVB) and tyrosine nitrogen content of the samples. The TVB content of the irradiated samples remained more or less unchanged at the initial level of 10mg N per 100g fish flesh throughout 35 days of storage period while that of the unirradiated increased rather slowly until the 3rd week and then it started to increase rapidly thereafter, reaching the level above 30mg N per 100g fish flesh by the 4th week. The TVB content of the unirradiaged was higher at 5°C than that at 0°C at all sampling intervals (Fig. 2-a and b). This suppression of TVB production in the irradiated samples under negligible influence of bacterial activities is in agreement with the work by Ehermann and Münzner[5] that no development of TVB accumulation occurred in German carp samples during storage after irradiating at doses between 0.1 and 1.5 Mrad. This phenomenon of TVB suppression during postirradiation storage of marine products has been well established and the unsuitability of TVB measurement as a chemical index for assessing the quality of irradiated marine products has been pointed out. [3,10,11,12,13,14,15]

The tyrosine content of the irradiated gradually increased from initial levels less than 100μg per 100g fish flesh to above 200μg per 100g fish flesh by the 5th week of storage at both 0° and 5°C. The differences between the doses in the tyrosine content accumulation during postirradiation storage period were not also significant. The tyrosine content of the unirradi-

Table 1. Total bacterial counts of carp fillets (No. cell/g·fish flesh)

a. 0°C storage

Storage (days)	Irradiated (Mrad) 0	0.25	0.5	1.0
0	3,400	N.C.	N.C.	N.C.
3	1,450	N.C.	N.C.	N.C.
7	18,500	N.C.	N.C.	N.C.
14	54,500	N.C.	N.C.	N.C.
21	12,500,000	360	N.C.	N.C.
35	87,000,000	3,000	N.C.	N.C.

N.C. : counts less than 30/g

b. 5°C storage

Storage (days)	Irradiated (Mrad) 0	0.25	0.5	1.0
0	2,300	N.C.	N.C.	N.C.
3	785,000	N.C.	N.C.	N.C.
7	71,000,000	N.C.	N.C.	N.C.
14	170,000,000	N.C.	N.C.	N.C.
21	373,000,000	N.C.	N.C.	N.C.
28	200,000,000	510	N.C.	N.C.
35	180,000,000	83,000	N.C.	N.C.

a. 0°C Storage b. 5°C Storage

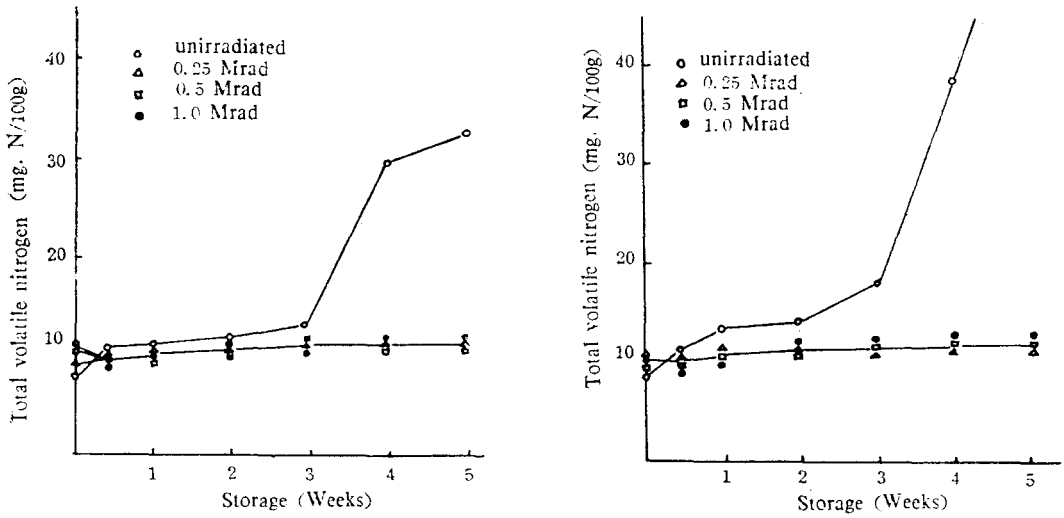

Fig. 2. Total volatile nitrogen of irradiated carp fillet

ated increased faster than that of the irradiated (Fig. 3-a and b).

The drip loss in the unirradiated samples increased from 1.2ml per 100g fish flesh on the 3rd day to 3.5—5.2ml by the end of 35 days of storage. Irradiation brought about increased amount of drip loss and in general it was observed that at higher the dose more drip loss occurred during postirradiation storage (Table 2-a and b). The drip loss values were not consistent enough to draw a generalization, however, it appeared

a. 0°C Storage b. 5°C Storage

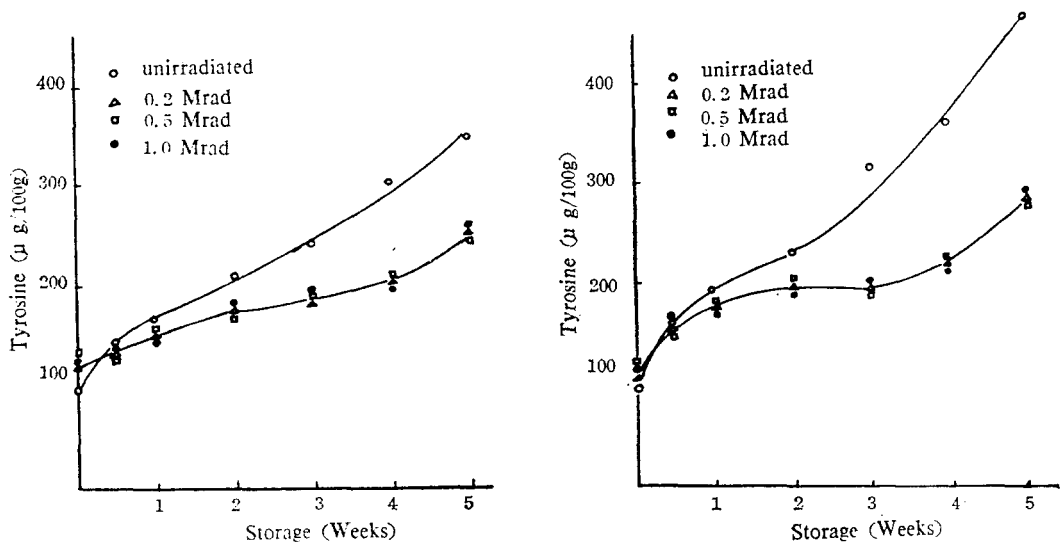

Fig. 3. Tyrosine contents in irradiated carp fillet

Table 2. Drip loss in carp fillets (ml/100g fish flesh)

a. 0°C storage

Irradiation (Mrad)	Storage days 3	7	14	21	28	35
0	1.0	3.2	2.8	3.3	4.5	5.2
0.25	2.3	6.1	4.5	5.1	7.1	4.6
0.5	2.3	5.5	5.0	5.7	8.0	6.6
1.0	2.2	4.5	6.1	6.7	10.0	6.6

b. 5°C storage

Irradiation (Mrad)	Storage days 3	7	14	21	28	35
0	1.2	2	3.5	3.8	4.8	3.5
0.25	2.0	3.6	4.2	3.3	4.8	4.7
0.5	2.2	3.5	3.7	3.4	4.4	6.2
1.0	2.4	4.0	4.4	4.7	4.6	5.0

th at the drip loss was more extensive in the samples irradiated at 0.25 Mrad, particularly during early period of postirradiation storage at both 0° and 5°C.

The pH changes during postirradiation storage as shown in Table 2 were negligible with exception of the unirradiated samples in which the initial value of 6.8 decreased to 6.4 to 6.6 by the end of 35 days of storage.

Rainbow trout : Because of the high radiosensitivity, the post-irradiation storage characteristics of the rainbow trout were very different from those of the carp. As revealed in the course of determining the maximum permissible dose, the dose of 0.1 Mrad imparted a slight, but unmistakably a burnt metal odor to the trout samples and this undesirable odor change was clearly dose dependent. However, at dose of 0.05 Mrad the odor change was negligible not only immediately after the irradiation but also throughout the 35 days of postirradiation storage period.

For the samples stored at 0°C, the unirradiated control became unacceptable by the 2nd week while the irradiated groups of 0.2, 0.1 and 0.05 Mrad became unacceptable successively by the 3rd, 4th and 5th week, respectively. For all practical purposes the samples irradiated at 0.1 and 0.2 Mrad could be stored for only up to 3 weeks at 0°C and those of 0.05 Mrad up to 4 weeks in acceptable organoleptic conditions (Fig. 4-a).

The rate of the organoleptic quality deterioration was much faster at 5°C than at 0°C as most of other marine products during postmortem; the storage-life of the unirradiated control was judged to be limited

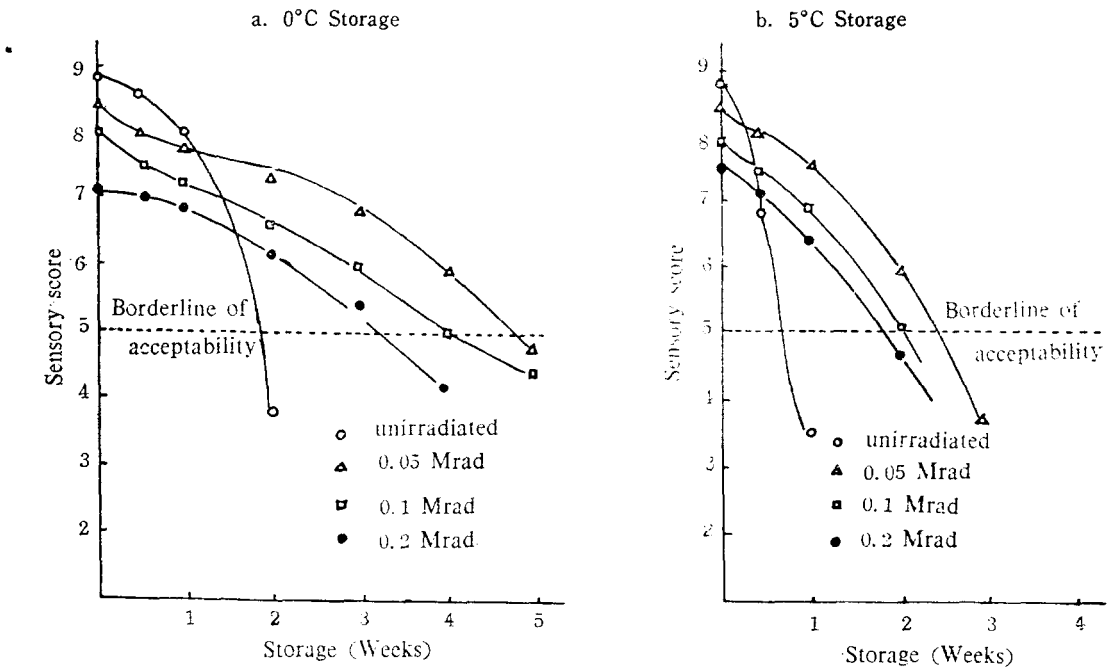

Fig. 4. Difference in sensory score of rainbow trout fillet

only to 4 days at 5°C, that of 0.05 Mard irradiated only to 2 weeks and that of 0.1 and 0.2 Mard only to one week (Fig. 4-b). This faster rate of organoleptic quality deterioration of both unirradiated and irradiated trout samples during storage at 5°C was reflected by the faster rate of microbial growth and TVB and tyrosine content accumulation.

The initial microflora was again significantly reduced as a result of irradiating the trout samples. However, with the exception of the 0.2 Mrad group, the total bacterial counts in the irradiated groups (i.e. 0.05 and 0.1 Mrad) started to increase during storage and by the 5th week the counts either reached or approached the maximum level of the unirradiated control (Fig. 5-a). At 5°C storage not only the gap of the microbial growth between the unirradiated and irradiated groups at each storage interval was narrower but the counts of the 0.2 Mrad group also started increase rapidly by the 2nd week, approaching the maximum level of the unirradiated control by the 4th week (Fig. 5-b).

It is important to note that being low dose irradiation below 0.2 Mrad, the organoleptic quality deterioration was closely correlated to the activities of surviving bacteria during postirradiation storage, thus undergoing a series of similar sequences of deterioration as the unirradiated control with only the necessary time lag.

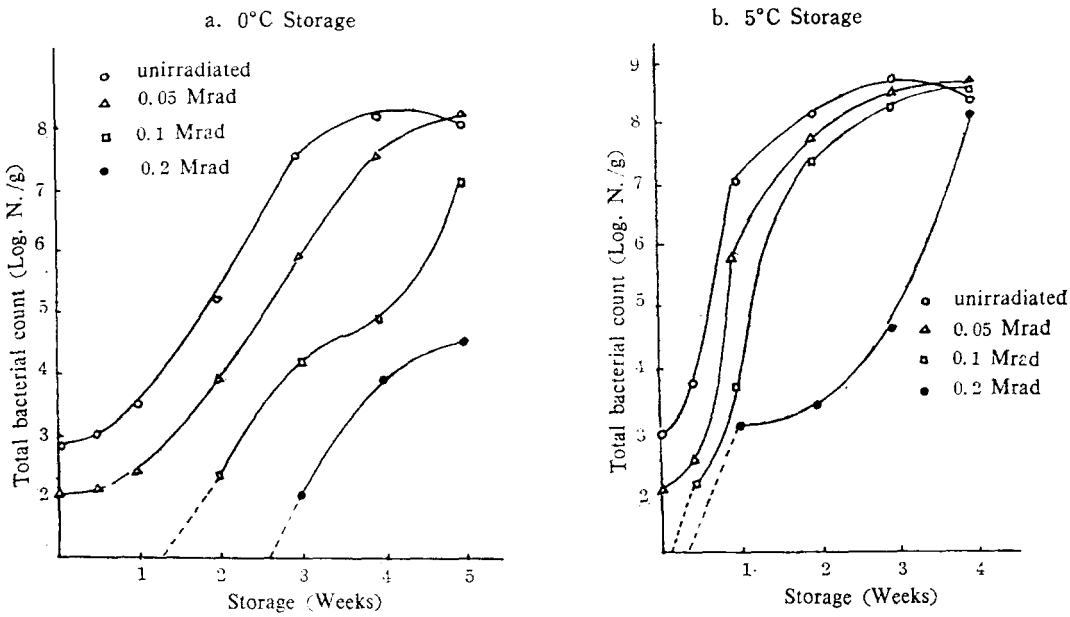

Fig. 5. Total bacterial counts of rainbow trout fillets

The TVB content accumulation was similarly suppressed in the irradiated groups; at 0°C the content started to increase rather rapidly only after the 4th week for the 0.05 Mrad group while that of the 0.1 and 0.2 Mrad group remained more or less unchanged at the level below 20mg N per 100g fish flesh. The

Table 3. pH Changes of carp fillets

a. 0°C storage

Irradiation (Mrad)	Storage days 0	3	7	14	21	28	35
0	6.8	6.8	6.9	6.8	6.4	6.6	6.6
0.25	6.8	6.8	6.9	6.9	6.9	6.8	6.8
0.5	6.8	6.8	6.9	6.9	6.9	6.9	6.9
1.0	6.8	6.8	6.9	6.9	6.9	6.9	6.9

b. 5°C storage

Irradiation (Mrad)	Storage days 0	3	7	14	21	28	35
0	6.8	6.8	6.4	6.2	6.3	6.5	6.4
0.25	6.8	6.8	6.7	9.7	6.8	6.9	6.9
0.5	6.8	6.8	6.7	6.7	6.8	6.9	6.9
1.0	6.8	6.8	6.7	6.7	6.8	6.9	6.9

TVB content of the unirradiated control rose above 30mg N per 100g fish flesh by the 5th week of storage at both 0°C. and 5°C. (Fig. 6-a) The TVB accumulation in the irradiated groups at 5°C became pronounced during the late storage period approaching that of the unirradiated (Fig. 6-b).

The tyrosine content accumulation in general followed a similar pattern to the TVB; the rate of accumulation at 5°C was much faster in all groups, irradiated and unirradiated, as compared to that of the same group stored at 0°C (Fig. 7-a and b).

The drip loss of the unirradiated trout samples during storage at 0°C was not consistent, but at 5°C the amount of drip loss increased gradually from 0.7 ml per 100 g fish flesh on the 4th day to 2.1 ml by the 19th day. Irradiation treatment resulted in more

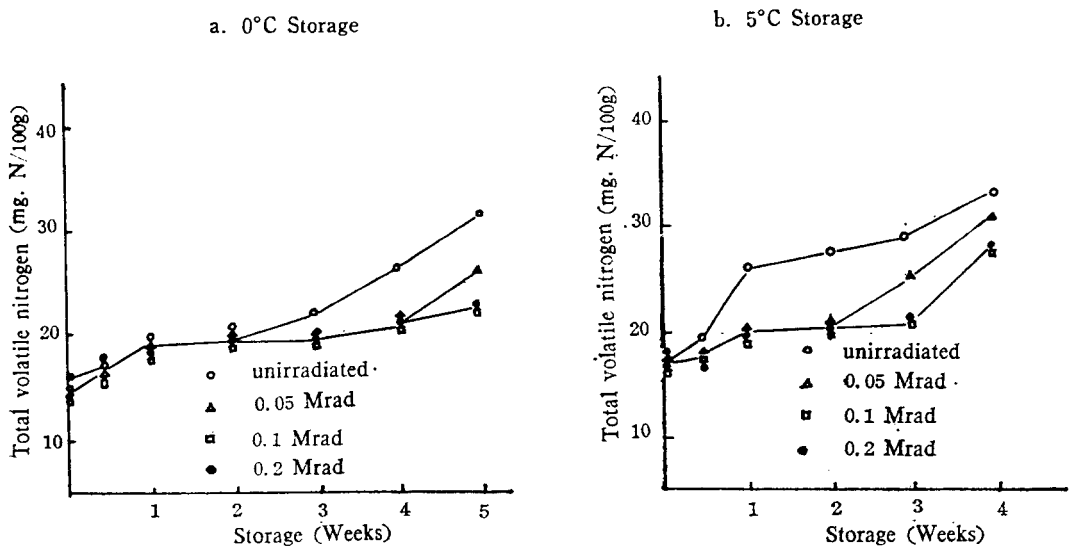

Fig. 6. Total volatile nitrogen of rainbow trout fillet

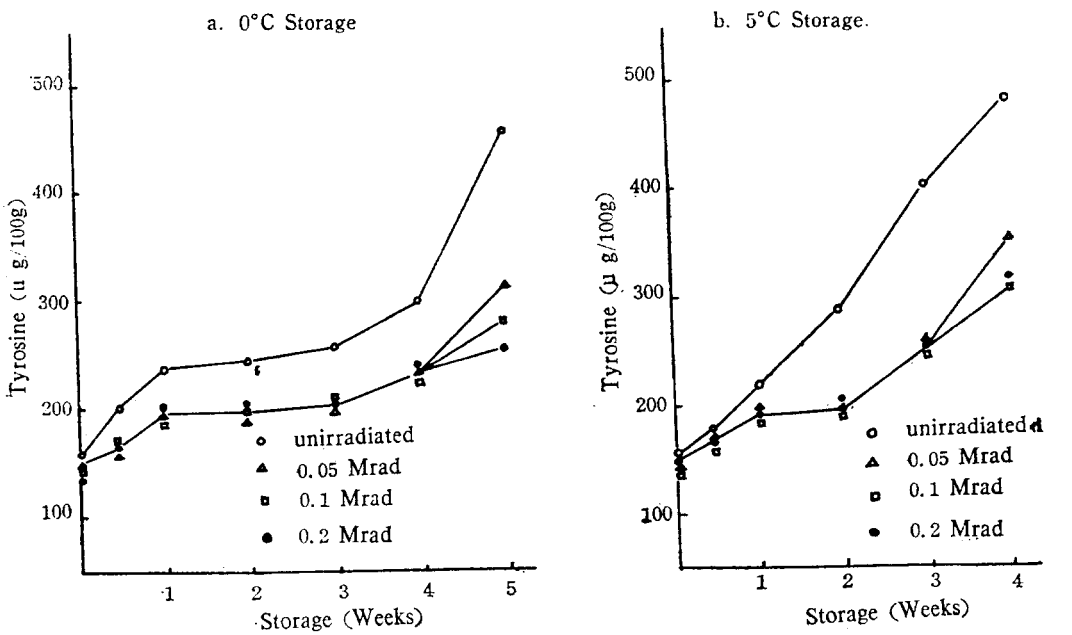

Fig. 7. Tyrosine content in rainbow trout fillet

Table 4. Drip loss in rainbow trout fillet (ml/100g fish flesh)

a. 0°C storage

Irradiation	Storage days 3	7	14	21	28
0	2.0	1.3	1.9	1.4	—
0.05	1.1	1.3	2.1	2.1	2.5
0.1	1.5	1.4	2.3	2.1	2.4
0.2	1.2	1.3	2.1	2.4	2.7

b. 5°C storage

Irradiation	Storage days 3	7	14	21	28
0	1.7	1.4	2.1	2.1	—
0.05	1.3	2.1	2.1	2.3	—
0.1	1.7	2.4	2.3	2.6	—
0.2	1.8	2.4	2.4	2.8	—

drip loss and its amount increasd with storage also (Table 4-a and b). This amount of drip loss in the trout tissue during storage, however, appeared to be normal as compared to that occurred in the carp tissue.

It is known the rancidity development of irradiated trout to be another limiting factor for the irradiation preservation of trout. Jorgensen *et al.*[7] reported that the keeping quality of rainbow trout irradiated at 0.1 Mrad could be greatly improved for the first three weeks of storage in ice by pretreating with ascorbic acid solution prior to the irradiation. They described the radiation induced odor of the rainbow trout as being wet fur like.

In this present study with Korean rainbow trout, the single predomineering component of irradiated odor spectrum at dose range up 0.5 Mrad was unmistakably of the burnt metal odor (the odor produced as a result of dry grinding steel on grinder), which was clearly dose dependent. It is, therefore, apparent that the main limiting factor for radurization of the rainbow trout appears to lie in its high radiosensitivity.

3. Pretreatment of carp tissue with polyphosphate solutions:

Since the carp tissue samples suffered from an extensive drip loss and irradiation at 0.25 Mard resulted in a higher drip loss, especially during the early storage, an attempt was made to test the possibility of significantly reducing the drip loss in the carp tissue samples irradiated at 0.25 Mrad. The drip loss in both irradiated and unirradiated rainbow trout samples appeared to be normal as compared to the carp samples. For this reason the rainbow trout was not tested in this pretreatment study.

The carp tissue samples were dipped for approximately 30 seconds in 10% solutions of sodium triphosphate and polyphosphate containing 2% NaCl. Then the carp tissue samples were drained on screen for 15 seconds, packed and irradiated at 0.25 Mrad. The control samples were processed similarly using distilled water as the dipping solution. All samples were prepard in duplicate and stored at 0°C.

As shown in Table 5, as expected, the drip loss of the untreated control was approximately as the same as that occurred in the carp samples irradiated at 0.25 Mard at each comparable storage interval (Table 2-a), whereas the drip loss in the samples pretreated with both phosphate solutions was negligible until the 28th day and a slight amount was detected thereafter.

It was also noticed that the pretreating the carp samples with phosphate solutions afforded a marked improvement in color and texture retension as compared to the untreated control. Therefore it is apparent that pretreatment of the carp samples with polyphosphate solution prior to a low dose irradiation is very effective in enhancing the keeping quality at refrigerated temperatures.

Table. 5. Drip in the carp fillet pretreated with polyphosphate salt and irradiated at 0.25 Mrad.

(ml/100g fish flesh)

Samples \ Storage days	7	14	21	28	35	42
Untreated control	3.8	4.3	5.1	5.7	6.2	6.8
Sodium triphosphate	0	0	0	0.4	0.4	0.4
Sodium polyphosphate	0	0	0	0.4	0.4	0.4

Conclusions

From the results obtained from this study, following conclusions may be drawn:

Optimum dose range : The carp tissue irradiated at doses as high as 1.5 Mrad was still acceptable while

the dose of 0.2 Mrad was considered to be the maximum for rainbow trout; irradiation at dose above the limit brought about undesirable changes in organoleptic quality that the panel would be reluctant to buy the irradiated samples as fresh fish. The optimum dose range sought for in this study may be defined as the minimum dose necessary for each species of fish to bring about a practical storage-life extension at refrigerated temperatures.

Based on the results of postirradiation storage characteristics the optimum dose range for the carp and rainbow trout was determined to be 0.25 and 0.05 Mrad respectively.

Storage-life extension : The carp tissue irradiated at dose of 0.25, 0.5 and 1.0 Mrad could be stored for up to 5weeks in acceptable condition at both 0° and 5°C, whereas the unirradiated control for only one week; thus 5 fold extension of storage-life was achieved. The rate of organoleptic quality deterioration was almost identical between the 0° and 5°C storage. Also the organoleptic quality of samples irradiated at 0.25 Mrad was superior to those receiving higher doses. Therefore, carp was considered to be one of the most promising species of fish for preservation by low dose irradiation.

On the other hand, the rainbow trout was highly radiosensitive and this high radiosensitivity was considered to be the factor limiting the application of a low dose radiation to effect a significant storage-life extension of fresh, untreated trout. Like most of other marine product, the keeping quality of radurized trout was improved by storing them at lower temperatures. Thus the storage-life of trout samples irradiated at 0.05 Mrad could be extended from one week for the unirradiated control to 4 weeks at 0°C --- a four fold extension of storage-life, while the acceptability was limited to less than one week for the unirradiated and the samples irradiated at 0.05 Mrad could be stored for two weeks at 5°C.

Postirradiation storage characteristics : Irradiation invariably resulted in a significant reduction of microflora af both species of fish and the dose above 0.2 Mrad appeared to be adequate for more or less completely inactivating the initial microflora normally carried by freshly killed fish.

For the trout samples receiving doses below 0.2 Mrad, almost ten fold reduction at 0.05 Mrad and nearly 100 fold reduction at 0.1 Mrad was achieved. TVB accumulation during subsequent storage was suppressed in all irradiated samples, despite the high total bacterial counts that were measured in late storage. Thus the TVB contents were significantly lower than those of the unirradiated at identical cell density. The protein breakdown as measured by tyrosine accumulation in the tissue samples also followed a similar pattern of TVB.

The rate of quality deterioration of the irradiated carp samples at 5°C was not faster than that at 0°C. This can be explained from the facts that the radiation doses applied were high enough to render the samples more or less completely free from microbial activities throughout the storage period.

Polyphosphate treatment : The drip loss in the carp samples during storage at refrigerated temperatures was quite extensive, and progressively increased with storage, approaching nearly 5% of wet weight by the 21st day. Irradiation increased the amount of drip due probably to corresponding decrease in water holding capacity. The carp samples irradiated at 0.25 Mrad, which is determined to be the optimum dose, suffered from more extensive drip loss during the first week of storage at both 0°and 5°C.

Irradiation had a similar effect of increasing the drip loss in the trout samples also. However, the drip loss of the unirradiated control samples was considered to be normal and the dose applied was below 0.2 Mrad.

By dipping the carp samples into 10% polyphosphate solution for 30 seconds prior to irradiation, the drip loss of the samples irradiated at 0.25 Mrad could be completely reduced during the practical storage period.

요 약

잉어(carp, *Cyprinus carpio*, Linne)와 무지개송어(rainbow trout, *Salmo grairdnerii*) 육편을 알미늄-폴리에치렌 봉지에 포장하여 1.5 Mrad까지의 감마선에 조사처리하여 냉장온도에서의 저장기간을 현저히 연장시킬수 있는 최적선량을 조사하였다. 잉어의 최고 허용선량은 1.5 Mrad 그리고 무지개송어는 0.2 Mrad 이었

으며 최적선량은 각각 0.25 Mrad와 0.05 Mrad이었다. 이 최적선량에 조사처리 하므로써 잉어의 저장기간은 0°C와 5°C에서 공히 1주에서 5주로 연장될 수 있었으며 두지개 송어는 0°C에서는 1주에서 3-4주로, 5°C에서는 3일에서 14일로 각각 연장될 수 있었다. 조사후 저장기간중 잉어는 체액유출(drip loss)이 심했으므로 조사전에 육편을 10% 나토륨 포리인산염액에 침지 처리한 다음 조사한 결과 거의 완전히 방지할 수 있었다. 무지개 송어는 방사선조사에 대단히 민감하였으나 잉어는 조사후 냉장온도에서의 저장성 연장을 목적으로 하는 저선량 조사처리에 매우 적합한 어종임이 규명되었다.

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