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Food irradiation, part 2

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1 October 2003 George J. Flick, Jr., Ph.D.

Fish, shellfish applications

Careful microbiological and chemical analyses of seafood before and after irradiation prove the effectiveness of this method.

Within the past five years, numerous reports have been published on safety hazards present in our food. While chemical contamination was reported on several occasions, most of the offending causes were of a biological origin, primarily microorganisms.

Several seafood products, especially those classified as ready-to-eat, have been identified by national and international health regulatory agencies as presenting an unacceptable health risks to consumers if improperly processed, packaged, or prepared. Such products included cooked crabmeat, crawfish, shrimp, lobster, smoked fish, raw molluscan shellfish, seafood salads and scombroid fish.

Ionizing radiation treatments can extend the shelf life of these and other foods by reducing pathogenic microorganisms and spoilage.

Effects on pathogenic microorganisms

Of special interest in food safety are the psychrotrophic microorganisms capable of growing in refrigerated foods at temperatures as low as 0 degrees-C, such as *Listeria monocytogenes*, *Yersinia enterocolitica* and *Aeromonas hydrophila*. Because these bacteria can grow in most refrigerated foods, procedures should be incorporated into food production to limit and inhibit their growth during distribution, retailing, and home storage.

Irradiation can be an effective intervention procedure to achieve significant reductions in psychrotrophic pathogens with minimal influence on the chemical and physical characteristics of food. In recent research, seven strains of *Listeria monocytogenes* were tested for their sensitivity to ionizing irradiation. A dose of 2 KGy (equivalent to 200,000 rads) was reported sufficient to destroy 4 $\log_{10}$ (99.99 percent) of the bacteria.

This reduction is significant, since *Listeria monocytogenes* contamination in processing facilities employing effective good manufacturing practices is usually less than 100 organisms per gram. Even if the full 99.99 percent reduction from irradiation is not always achieved, an adequate process was applied.

A 2-KGy dose is the maximum application amount requested by the National Fisheries Institute in its petition to the U.S. Food and Drug Administration. The dose has also been shown to destroy several *Salmonella* species. Therefore, two major food pathogens can be effectively controlled by one irradiation process.

Aeromonas hydrophila, *Escherichia coli*, and *Yersinia enterocolitica* are less resistant to irradiation than *Listeria monocytogenes*. A dose of 1 KGy was sufficient to eliminate *Yersinia enterocolitica* from fish fillets without affecting their organoleptic values. Since *E. coli*, *Y. enterocolitica*, *A. hydrophila*, and most species of *Salmonella* are among the most sensitive to ionizing energy, low-dose irradiation can be useful in reducing the potential risks to public health from seafoods that carry these bacteria.

Spore-forming bacteria

Irradiation at low doses, however, is not lethal to bacteria spores. Two spore-forming bacteria are of primary interest to seafood processors: *Clostridium botulinum* and *Bacillus cereus*. A dose of 3 KGy reduced *Clostridium botulinum* type E (Beluga) spores by only 90 percent. *Bacillus cereus* spores are expected to have equal resistance to irradiation.

It has been recommended that irradiated food products be packaged under air – but not vacuum – to prevent the germination of pathogenic bacteria spores and growth of vegetative cells. However, even when meat is packaged aerobically, the atmosphere can change during storage because oxygen is utilized by the muscle tissue and aerobic microorganisms. Some scientists have suggested that vacuum packaging should be allowed for foods pasteurized by low-dose irradiation.

Effects of irradiation on fish, shellfish

Anchovies

In tests, anchovies (*Stolephorus commersonii)* were irradiated at 2 KGy and held in ice storage. The quality of the fish was periodically evaluated by sensory, chemical, and microbiological parameters.

The irradiated fish had better quality attributes than control fish that did not receive irradiation. Irradiated fish were considered acceptable for up to 17 days, in comparison to a storage life of 13 days for the nonirradiated product. Although the fish had a shelf life of 20 days, drip accumulation and poor appearance resulted in a loss of product appeal.

Mackerel

Bluejack mackerel (*Trachurus picturatus)* were irradiated with 1, 2 and 3 KGy. The controls were rejected on day 5 for fish caught in December and day 11 for fish caught in May, whereas the irradiated samples would only be discarded after 20 and 25 days, respectively. As previously reported, irradiation did not have a negative effect on the sensory characteristics of the fish, in spite of their relatively high 4 percent fat content.

There was no improvement in quality when the higher radiation doses were used, so a 1-KGy dose could be considered sufficient to extend the shelf life by maintaining bacterial counts below the rejection level. A second study on *Rastrelliger kanagurta* mackerel showed that a dose of 1.5 KGy in combination with a 10 percent sodium polyphosphate treatment extended the shelf life up to three weeks and minimized drip loss during storage at 0 to 3 degrees-C.

Tilapia

In further research, aquacultured tilapia (*Oreochromis mossambicus)* and silver carp (*Hypophthalmichthys molitrix)*, were irradiated at 1 KGy and stored at 1 degree-C. There were no detectable nucleotide changes in either species, and no change in the thiamin content of the tilapia, but the loss of thiamin in the silver carp was significant. Irradiation caused a 90 percent reduction in bacteria populations.

In another study, aquacultured tilapia (*Tilapia nilotica* × *T. aurea)*, were irradiated at 1.5 and 3.0 KGy and stored at 2 degrees-C. A dose of 1.5 KGy reduced the levels of hydrogen sulfide bacteria and kept the level low throughout a 20-day storage period. Moreover, this dose also eliminated *Salmonella*, *Yersinia*, and *Campylobacter* species. The 3-KGy dose was able to extend the shelf life by up to eight days when compared to the nonirradiated fish in the test.

Bream and redfish

Black bream (*Acanthopagrus australis)* and redfish (*Centroberyx affinis)* were irradiated at 1 and 2 KGy and stored at 1 degree-C in additional research. There were no significant changes in fatty acid composition, but vitamin E loss was evident in some fillets – a finding that could not be correlated with the treatment dosage. Regardless, irradiated fillets had a vitamin E content well in excess of baseline levels recommended for human consumption.

Channel catfish

Further, aquacultured catfish (*Ictalurus punctatus)* were irradiated at 0.5 and 1 KGy in combination with modified atmosphere packaging (80:20 CO_2 per air, 100 percent CO_2) and stored at 0 to 2 degrees-C. No differences in color and 2-thiobarbituric acid values, a measure of fat rancidity, were observed between the microbial counts of packages flushed with the modified atmospheres or 100 percent air. Irradiation significantly reduced the microbial load and extended shelf life from 5-7 days to 20-30 days.

Striped bass

Aquacultured striped bass, (*Morone saxatilis* × *M. chrysops)*, were irradiated at 2 and 3 KGy in the presence of air or vacuum packaged and stored at 4 degrees-C. Irradiation did not influence the rate of nucleotide degradation, a measure of overall quality deterioration, in the treated fish compared with nonirradiated controls. Vacuum packaging resulted in a lower nucleotide degradation rate.

Scallops

Saucer scallops, (*Amusium balloti)*, were irradiated at 0.5, 1.5, and 3 KGy and stored at 0 degrees C. The storage life of 13 days for nonirradiated scallops was extended to 18, 23 and 42 days when the scallops were treated with 0.5, 1.5 and 3 KGy, respectively. Irradiation resulted in a 99 to 99.99 percent reduction in bacterial numbers with no induced off odors or flavors.

Other species

In additional testing, other species of fish and shellfish – including sweet-lip, red emperor, mackerel, whiting, mullet, barramundi, sand crab, Moreton Bay prawns and king prawns – were irradiated at 0, 1, and 3 KGy. A dose of 1 KGy resulted in a 95 to 99.99 percent reduction in total bacterial numbers, with further reduction in the samples treated at 3 KGy (Table 1). The effects of irradiation on the oily mackerel and mullet species were not markedly different from the others. All the species maintained high acceptability after the irradiation treatment and did not have adverse odors or flavors.

Flick, Effect of irradiation on bacterial counts in subtropical seafood, Table 1

Species	Mean Bacterial Count ($\log_{10}$ CFU/g0 kGy	Mean Bacterial Count ($\log_{10}$ CFU/g 1 kGy	Mean Bacterial Count ($\log_{10}$ CFU/g) 3 kGy
Sweetlip	6.0	4.1	2.8
Red emperor	6.7	4.6	3.2
Mackerel	8.0	5.9	5.0
Mullet	7.5	5.2	3.0
Whiting	6.7	4.0	2.5
Barramundi	6.7	2.7	1.5
Crabmeat	6.0	4.3	2.9
King prawn, green	5.5	3.4	2.1
King prawn, cooked	5.9	4.3	2.6
Bay prawn, cooked	8.0	5.8	4.9

Table 1. Effect of irradiation on bacterial counts in subtropical seafood.

Conclusion

Irradiation processes applied at 2 KGy or less have significant economic and food safety implications for the fish and shellfish industries. Low-dose ionizing irradiation does not form toxic compounds and is effective in reducing pathogenic and spoilage microorganisms and extending product shelf life. Most of the physical and chemical properties of irradiated products retain their original values with no production of off odors or flavors.

(Editor's Note: This article was originally published in the October 2003 print edition of the Global Aquaculture Advocate.*)*

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