The business and scientific aspects of the fishing industry are now so closely related that the businessman cannot afford to neglect scientific advances. Here are some basic ideas and terminology in fishery science he may find helpful.

BASIC IDEAS IN FISHERY SCIENCE

In the last half century, changes in the fishing industry have come about rapidly. The design of fishing vessels and gear; the methods of locating, capturing, handling, and preserving fish at sea; the techniques of processing, packaging, and distributing fish ashore--all differ markedly now from the old designs and ways of doing things.

What has caused this rapidly accelerated rate of change in the modern fishing industry? The answer: adoption of scientific methods. Once research is started, new ideas develop and new products and better methods ensue. The gear manufacturer alters his product so that newly available species can be used efficiently; the processor adapts his methods to changes in types of fish caught; the researcher expands his field of study to encompass changes in fish types and product usage. All these interlocking and interrelated aspects of the industry progress together.

One obvious result is better, more varied product--often at a lower price. Still another result is an increasingly rapid rate of obsolescence. And the price of obsolescence is high.

It is obviously difficult for even the specialist to keep abreast of all new developments in his field. It is impossible for any one person to be familiar with developments in all fields. But to stay in business in the modern fishing industry, we must recognize that changes are occurring rapidly and that we must be aware at least of the areas in which major changes occur.

--F. Bruce Sanford

I - PRESERVATION OF FISH BY THE USE OF GAMMA RAYS

By Louis J. Ronsivalli,* Lena Baldwin,** and F. Bruce Sanford***

Fresh fish, both finfish and shellfish, have excellent flavor qualities, but maintaining freshness has always been a problem because fish spoil rapidly if left untreated. Since early times, fish have been salted, smoked, pickled, or fermented. Although these treatments impede the advance of spoilage, they change the flavor appreciably.

More recently, fish have been canned, frozen, or chilled. The tastes of these newer products, particularly those chilled, come closer to the goal of freshness, but they, too, may lack something of the natural fresh flavor. For a few days, chilled fish retain the taste of freshly caught fish. Beyond that time, however, spoilage becomes noticeable and the product begins to lose its quality of freshness. Since canned and frozen fish lose their fresh taste either during processing or subsequent storage--and since chilling has such a short period of effectiveness--truly fresh-tasting fish ordinarily have been available only to people within easy transportation range of the capture areas.

Now, however, many people who live beyond that range also may enjoy the fresh-fish flavor. When chilling is combined with a gamma-radiation treatment, the period of freshness is extended markedly, long enough to permit fish to be shipped great distances.

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U. S. DEPARTMENT OF THE INTERIOR
Fish and Wildlife Service
Sep. No. 794

Because the novelty of the method might iscourage its use, we will describe it, re- ew briefly the general attributes of radia- on--what it is and how it preserves food-- nd then show in particular how radiation eatment can be used to preserve fish.

RADIATION

What Is Radiation? The radiation we are imarily concerned with is the energy that sses in invisible waves through space. A miliar kind is the energy that flows con- antly from the sun and reaches the earth incipally as light rays and heat rays. We n see and feel the presence of this energy. s a matter of fact, we need it for life. ltraviolet rays, X-rays, and gamma rays re other kinds of radiation energy.

Except that gamma rays are of shorter avelength and more energetic, they are ery similar to X-rays, ultraviolet rays, nd other forms of electromagnetic radia- on. Our interest in radiation is centered on ese energetic, invisible gamma rays--for, roperly controlled, they can be used to de- troy bacteria. And the preservation of food epends primarily on the controlled destruc- on of bacteria.

How Does Radiation Preserve Food? oods normally are spoiled by bacteria, esent by the millions in the meat and fresh sh we buy. To understand how our foods n be protected from these food-spoiling ents requires a close look at what goes n when the bacteria are exposed to a given nount of gamma radiation at some prede- rmined rate.

How Does Gamma Radiation Destroy Bac- ria? Using gamma radiation to destroy cteria can be direct, much like using a achine gun on them would be direct. The dioactive source is the gun, the gamma ys are the bullets, and the result of a di- ect hit is relatively instantaneous. De- troying bacteria with radiation can also be direct, the result of secondary chemical ffects set in motion within the environ- ent of the bacteria. One such effect is roduced as follows: When bacteria are rradiated, hydrogen peroxide (H_2O_2) is rmed from the water (H_2O) that makes up large part of the bacterial cell. Hydrogen eroxide destroys cytochrome oxidase, an nzyme vital to regeneration and growth, oth in man and in bacteria. Once this enzyme is destroyed and protein synthesis prevented, the bacteria die.

What Determines the Amount of Radiation To Be Used? Evidently, we would not expose food to these powerful rays without regard to amount or time of exposure any more than we would expose our skin willy-nilly to the sun's rays. By the same token, food that is being irradiated is exposed to some measured radiation dose at some determined dose rate. But what is a "radiation dose"? And what is meant by "dose rate"?

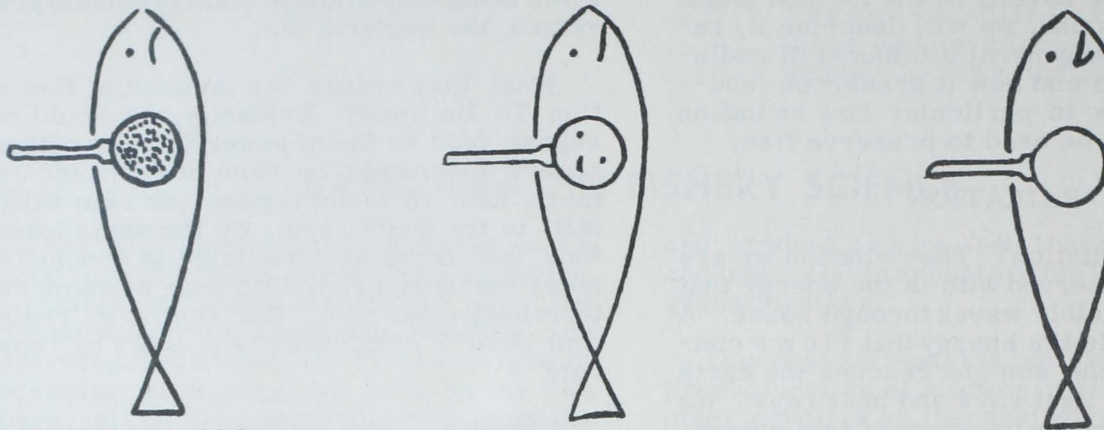
Radiation dose is simply the amount of radiant energy absorbed by a unit mass (usually 1 gram) of the material being irradiated. Radiation dose is expressed in "rads." A rad is to gamma radiation what a calorie is to heat; however, since the rad is such a small unit of energy, it is usually multiplied by a million for practical purposes of measurement. The million-rad unit is commonly called a "megarad."

The dose rate includes a time factor. It is the amount of gamma radiation absorbed in a given time by a unit mass of the material being irradiated. Mathematically, this relation can be simply expressed as $R = \frac{D}{t}$, where R is the radiation dose rate, D the radiation dose, and t the time. Usually dose rate is expressed in megarads per second, megarads per minute, or megarads per hour.

PRESERVATION BY RADIATION

Is Radiation Preservation Suited to Fish? When we think of preserving or prolonging the life of foods, we often think in terms of either sterilization or pasteurization. In common practice, either process requires heat; however, some fish tend to become mushy when treated with heat. Since a food does not become heated during radiation processing, the radiation technique offers an attractive alternative for preserving fish.

What Types of Radiation Preservation Have Been Tried On Fish? Both radiation sterilization and radiation pasteurization have been used. The shelf-life of the resulting products has not been equally long, however, largely because of the difference in number of bacteria destroyed by the two processes (figure).



Bacteria on normal fish as seen by high power magnification.

Only a small number of bacteria remain after pasteurization.

No bacteria remain after sterilization.

The effect of pasteurization and sterilization on bacteria in fish.

Radiation sterilization is the process of destroying all bacteria in the fish. Once these bacteria have been eliminated, no others must be allowed to reach the fish; that is why fish are packed in bacteria-tight containers before they are irradiated.

Canned fish (salmon or tuna, for example) sterilized by heat have one decided advantage over fish preserved by other methods: they can be kept unrefrigerated for months, or even years, without spoiling. The reason they last so long is that all the bacteria and enzymes that might cause spoilage have been destroyed. (Enzymes catalyze chemical change even after the bacteria are killed.) Radiation-sterilized fish have an additional advantage over fish that have been heat sterilized: they retain a firmness that heat sterilizing tends to destroy.

Despite these advantages, radiation sterilization of fish has not been too successful. The amount of radiation needed to destroy all bacteria is so high that it ordinarily causes the fish to smell and taste overcooked--or even burned. Still higher radiation doses are needed to destroy the enzymes. Yet the idea of preserving fish by radiation sterilization has not been abandoned. Recent developments have led investigators to believe that radiation at an extremely low temperature will not be accompanied by the off-flavors and off-odors that, up to now, have characterized sterilized fish.

Radiation pasteurization is the process whereby most bacteria--not all--are destroyed. In other words, the bacteria in radiation-pasteurized fish are not eliminated; they are simply reduced in number by subjection to a low level of radiation; thus it is necessary to refrigerate the product. Yet even with refrigeration, pasteurized foods have a relatively short shelf life (a few weeks).

Scientists at the BCF Technological Laboratories at Gloucester, Mass., Seattle, Wash., and Ann Arbor, Mich., have determined the amount of radiation needed to pasteurize many fish caught by commercial fishermen. For example, radiation-pasteurized haddock fillets require about 250,000 rads of gamma radiation. Since radiation-sterilized haddock fillets require about 4,500,000 rads, the term "low level" is used to describe the pasteurizing radiation dose. This 250,000-rad dose, nevertheless, will kill about 99 percent of the bacteria. But the remaining 1 percent can multiply rapidly if the irradiated fillets are not refrigerated, and so the fillets are kept at near-freezing temperatures following pasteurization.

To appreciate how rapidly bacteria can multiply, one need only consider how tremendously the multiplication process accelerates with rising temperature. For example, at 33° F., some bacteria take 10 hours to split in two; at 42° F., each bacterium will split in two in only 2 hours, giving rise to 32 bacteria by the end of 10 hours; and at 70° F., 1 bacterium could generate a million bacteria in 10 hours.

Why are only some bacteria killed at low radiation levels? The answer lies in the nature of gamma rays--the "bullets" ejected by the radiation source--and of the bacteria exposed. Gamma rays are small and travel in a straight line; bacteria are small and scattered throughout the product. As the gamma rays pass through the food being irradiated, they hit only those bacteria that chance to be in their path. If the rays are intense enough and last long enough, the chances are that all bacteria will eventually be hit. But some types of bacteria are more resistant than others and may require several hits before they are destroyed. If some escape this bombardment, they will continue to survive, grow, and reproduce. Thus radiation-pasteurized fish, unlike radiation-sterilized fish, must be refrigerated so that the growth of the few remaining spoilage organisms will be retarded.

Normally, fresh fish last about 1 or 2 weeks when they are stored at temperatures between 33° and 25° F. The 250,000-rad dose used at Gloucester has extended this storage life by at least 2 weeks. In general, the life of these irradiated fish is 2 to 3 times as long as the life of unirradiated fish kept at the same temperature. Expert panels of scientists have judged that the appearance, flavor, odor, and texture of the irradiated fish stored for 30 days are of good quality.

Is Irradiated Fish Safe for the Consumer? When properly controlled, gamma rays pass through the fish and kill the bacteria without causing the food itself to become radioactive. Tests for radioactivity are relatively simple with geiger-counter-type instruments. Repeated tests with sensitive radiation-detection devices have revealed no instance of the presence of radioactivity in irradiated fish. The destructive force of the radiation is confined to the radiation chamber. Needless to say, it is not healthful to enter the radiation chamber while fish are being processed there--any more than it would be to enter an oven where bread is being baked.

Scientists have carried the safety investigation beyond the areas concerned with the primary effect (radioactivity) into several secondary areas. These investigations have revealed no instance of toxic substances in irradiated foods. The available evidence indicates that irradiated foods, properly handled, are perfectly safe to eat. Even now, irradiated potatoes are being sold in Canada (radiation prevents sprouting), and grains are being irradiated to destroy insects and insect eggs that commonly occur in grain.

What Are the Prospects for Radiation Pasteurized Fish? The Food and Drug Administration has been petitioned to approve the use of irradiated fish. This petition resulted from years of cooperative study by scientists in BCF technological laboratories and those associated with the U. S. Atomic Energy Commission (AEC). The studies have included not only the possibility of radiation pasteurizing fish at the commercial level, but the cost of producing the product, the problems of distributing it, and the likelihood of consumers accepting it. As a vehicle for these studies, AEC has built a large cobalt 60 fish-processing plant at BCF's technological laboratory in Gloucester, Mass.

What Is the Role of Cobalt 60 in the Future of Commercially Irradiated Fish? Cobalt 60, one of the most promising radioactive sources that emit gamma rays, is being used in the present fish-preservation program. Other radioactive elements could be used as the gamma-ray source, but cobalt 60 has a major advantage over many of the others; it has a reasonably long half-life.

"Half-life" is the unit used to measure the length of time a radio-active substance emits radiation. For example, the half-life of cobalt 60 is 5.2 years--that is, after every 5.2 years, one-half of the radioactivity present at the beginning of the 5.2-year period has been lost. In contrast, uranium Y has a half-life of about 24 hours, and some radio-active elements in the actinium and thorium families have a half-life of a few microseconds. When the processor must pay several thousand dollars for his radiation source, half-life can take on real economic significance.

What Long-Range Effects Can Radiation Pasteurization of Fish Promise? If studies on radiation pasteurizing yield the expected results, pasteurized fish will be available to any part of the world where demand for fresh fish exists. For the consumer, the availability of radiation-pasteurized fish will be more than a taste treat--it will mean the availability of a product whose nutrients are virtually unchanged. The result can hardly be less than increased demand for the product.

With increased demand for fresh seafoods will come increased incentive to accelerate the production rate. And with this increase will come a vigorous demand for newer and more effective fishing vessels to harvest the seafoods. Thus, all parts of the fishing industry will benefit, along with the consumer.

Where Can We Get More Information on Preservation of Fish by Radiation?

Subject	Source
Atlantic fisheries	Laboratory Director Bureau of Commercial Fisheries Technological Laboratory Emerson Avenue Gloucester, Mass. 09131
Pacific fisheries	Laboratory Director Bureau of Commercial Fisheries Technological Laboratory 2725 Montlake Boulevard East Seattle, Wash. 98102

(Listing continued on next column.)

Subject	Source
Great Lakes fisheries	Laboratory Director Bureau of Commercial Fisheries Technological Laboratory 5 Research Drive Ann Arbor, Mich. 48103
Gulf fisheries	Head of the Department of Food Science and Technology Louisiana State University Baton Rouge, La. 70803
Food Preservation by Irradiation," a free booklet by Grace M. Urrows	U. S. Atomic Energy Commissio P. O. Box 62 Oak Ridge, Tenn. 37830

Acknowledgment: John Spinelli, Research Chemist, BCF Technological Laboratory, Seattle, Wash., and Francis Joseph Weiss, Science Specialist, Library of Congress, Washington, D. C., contributed many helpful suggestions in the writing of this article; Mary Fukuyama, Editor, BCF Branch of Reports, Seattle, Wash., assembled the bibliography (available in Separate No. 794). For a free copy of the Separate, write to Office of Information, U. S. Department of the Interior, Fish and Wildlife Service, BCF, Washington, D. C. 20240.

A FISH FOOD CHAIN