A PROTOTYPE SEAFOOD IRRADIATOR

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INTRODUCTION

The Marine Products Development Irradiator (MPDI) is one of a family of irradiators built or funded by the Atomic Energy Commission (AEC) in the early to mid 1960's. It differed from its predecessors in that it was designed to be a development rather than research irradiator, and it was the first of its kind. The distinction between development and research irradiators is one of size and purpose. The development irradiator is of semicommercial size and can irradiate 2000 pounds of product per hour at a dose of 200,000 rads. The ability of the research irradiator at the same dose level is only about 375 pounds.

The purpose of the MPDI was to determine if it was commercially feasible to irradiate fresh seafoods on a large scale and ship them by common carrier under prevailing conditions of transportation to distant markets and still retain a high degree of freshness. Equally important was the desire to determine the reliability of extrapolating the cost per pound of product to a full scale irradiator. On the other hand, the purpose of a research irradiator was that being small, it could be established at any of several universities to provide radiation services of a strictly research nature in the very early part of the AEC program on low dose treatment of foods.

The first part of this report describes the prototype irradiator and its main objectives. The second describes a cooperative international fish irradiation program and the current status of irradiated seafoods. The last describes the versatility of the MPDI with respect not only for irradiating seafoods but also for low dose irradiation of fresh and processed chicken and meat.

DESCRIPTION AND OPERATIONS OF THE MPDI

Operative since 1965, the Marine Products Development Irradiator (MPDI) is a one-story building which features three principal areas--a refrigerated storage room, a product conveyor, and gamma radiation cell. In addition to these are the auxiliary supporting features consisting of office, health physics, dosimetry laboratory, and general work and storage areas.

Upon receipt of commercially prepared fillets packed in 4.54, 9, 13.62 kg (10, 20, or 30-lb.) capacity conventional fillet cans, they are immediately placed in the refrigerated storage room which is held at 0^{o} to $1^{o}C$ (32^{o} to $33.8^{o}F$). Before processing, each fillet can is tagged with an indicator that changes color when irradiated. The cans are fed into the irradiation cell by a fast conveyor which transfers them to a slow conveyor for the actual irradiation. To ensure correct dose uniformity, each can makes two complete round trips through the irradiation cell on each of both sides of the source center line. The source itself originally consisted of 235,000 curies of cobalt-60 and is made of six replaceable units, each containing 16 Brookhaven National Laboratory Mark I strips of cobalt-60. The rated source utilization is about 21% using target overlap for maximum efficiency. The normal dose for fillets is about 200,000 rads at a production rate of one ton/hr. with a maximum to minimum dose ratio of 1.3 (Miller and Herbert, 1964).

The MPDI programs were based upon the assumption that irradiation of fresh seafoods significantly extends the shelf life of the food under laboratory controlled conditions (Proctor et al., 1960). The first question then, to be studied was whether fresh fillets irradiated on a commercial scale at low-dose levels of irradiation and shipped under commercial conditions would exhibit a commercially significant extension of shelf life.

We carried out this work in three investigations. The studies were of such nature that if the first had turned out to be unsuccessful, we would not have undertaken the second, and if the second had turned out to be unsuccessful, we would not have undertaken the third.

In order to operate successfully, any industry needs a supply of suitable raw material. Irradiation, like other means of preservation, such as freezing, does not improve the freshness of food. It merely helps to preserve whatever freshness is present. Accordingly, a purpose of the first study was to determine the freshness level of haddock and cod.

We were able to simplify the study because haddock and cod are handled similarly so that general conclusions concerning the freshness of one species will apply to that of the other. Boston was the port of greatest landings of haddock and cod, and therefore we chose haddock as the species to be studied.

Quality of Fresh Haddock

The survey was made during the winter, summer, and autumn so as to reflect the effect of temperature differences of the principal seasons, with spring and autumn being considered equivalent. Criteria for subjective measurements of freshness were developed and applied to over 4,500 individual samples of haddock. Objective measurements of fish temperature were made by a carefully calibrated electronic thermometer.

All data were fed into a computer that was programmed to give correlations among the temperature measurements and the expert subjective judgments. The computer showed that subjective examinations had significant to highly significant correlations at the 1-percent level of probability. Our data showed that 78.6 percent of the haddock examined by us at the Boston Fish Pier was fresh enough to justify the use of irradiation (Kaylor and Murphy, 1970a).

Distribution Survey

Having satisfied ourselves that there was an ample supply of haddock and cod of a high enough freshness to justify irradiation, we turned our attention to fillet temperatures during distribution. We were concerned whether the temperature of the fillets when shipped by common carrier was sufficiently low to ensure that irradiated fillets would arrive at distant points in the nation in a fresh condition. We investigated, during all seasons of the year, the temperature of fresh fillets shipped by two means of transportation: truck and train. We found that shipments by truck could be divided into four categories: 1) processor-distributor shipments, 2) frozen-food shipments, 3) refrigerated fresh-fish shipments, and 4) nitrogen-gas refrigerated shipments.

One method of shipping by truck for short distances by processors was found to be too short in duration to achieve the maximum cooling of fresh fillets under the conditions of shipment. Shipment by refrigerated trucks designed for transportation of frozen foods resulted in partial freezing of the fresh fillets. The most common method of shipping fresh fishery products using a combination of ice and mechanical refrigeration maintained the fresh fillets at optimum temperature. One study of a more recent method of truck refrigeration using nitrogen gas showed that it had no advantage over the dominant method of mechanical refrigeration and ice.

Three studies of shipment by rail showed that fresh fillet temperatures were maintained at optimum temperatures by a method of refrigeration that was in long use (now unavailable)--namely, shipment of the fresh fillets in cans packed in ice in wooden barrels, which were re-iced in transit when needed.

The survey showed that all the common commercial methods of transporting fresh fish fillets interstate ensure fillet temperatures of 4.5°C (40°F) or lower. This temperature would be sufficiently low to permit shipment of irradiated fresh fillets in good condition to the most distant parts of the continental United States (Kaylor and Murphy, 1970b).

Commercial Benefit Study

Having shown that there was an ample supply of high quality of fish and that the present commercial interstate movements of fresh fish would not be a limiting factor for irradiated fresh fillets, we turned our attention to the commercial benefits to be derived, if any. With U.S. Food and Drug Administration (FDA) consent, we furnished commercial size samples of irradiated and nonirradiated haddock fillets to several of the largest supermarket chains for laboratory testing (not for sale to the public). Spokesmen for eight of the largest chain supermarkets in the nation stated that they could and would sell irradiated fresh seafoods in areas where fresh seafoods were not then sold.

Producers who followed our work indicated that irradiation processing would help to smooth out the highs and lows of availability of fresh fish supplies and would help to ensure a steadier market. Retailers claimed that using irradiated seafoods would permit holding of the fillets after the peak demand day in the week had passed rather than having to mark down the price or discard the fish due to spoilage. The process would enable retailers to offer fresh fish throughout the week to a degree greater than was then possible. Producers also claimed that these savings could be passed along to consumers. Another advantage to all segments was the obvious expansion of sales of fresh seafoods to areas not then available.

The results of the foregoing tests involving irradiating on a commercial scale, shipping by already established interstate carriers including cross-country shipments, indicated that the process was definitely efficacious and that many economic benefits could accrue to the consuming public and industry as the cost of low dose irradiation was estimated to be about two cents per pound (Ronsivalli et al., 1970).

INTERNATIONAL FEEDING STUDY

In 1972, MPDI personnel became involved with the International Project in the Field of Food Irradiation with respect to irradiation of fish. At a meeting in Paris in that year, it was agreed that cod Gadus morhua morhua, ocean perch (redfish) Sebastes marinus, European plaice Pleuronectes platessa, and an unspecified species of flounder should be the species of fish given priority in the feeding studies of irradiated fish.

Members of the MPDI were instrumental in establishing the specifications for fish caught at sea, processing on land, packing, and randomization into "control" and "irradiated" lots prior to irradiation. Strict procedures were established for temperature control from trawler to the point of irradiation and beyond. Rigid irradiation procedures were established for the expected irradiation series. These guaranteed identical conditions of Co-60 source configuration, size of container, mass of fish, dwell time correction for decay of Co-60, dosimetry, and maintenance of records covering each irradiation series.

Following irradiation or sham treatment of control samples, both lots were held under refrigeration for the prescribed length of time and then frozen and shipped via interstate carriers of frozen foods to the appropriate organization conducting the feeding studies.

The fish involved in the long term feeding studies were cod and ocean perch (redfish). A short term feeding study was conducted on yellowtail flounder, Limanda ferruginea. All fish were irradiated at a dose level of 175 kilorads.

MPDI personnel performed the above services for a period of over three years and in that time irradiated 7 tons of fish and prepared an equal amount of control samples. All services were freely given by the National Marine Fisheries Service. All costs for the 14 tons of fish were borne by the U.S. Atomic Energy Commission and its successor agency, the Energy Research and Development Administration. The value of the fish purchases and irradiation series well exceeded $50,000 thus reducing the cost to the 24 member nations of International Project in the Field of Food Irradiation.

The final results of the wholesomeness feeding studies may best be judged in the light of the recommendations made by the FAO/IAEA/WHO Joint Expert Committee on Food Irradiation (JECFI). This international committee does not and cannot speak for any particular country. It makes its recommendations after careful review of the wholesomeness data. In the case of cod and ocean perch (redfish), it has placed these fish in the category of "provisional acceptance." This means that some more wholesomeness test data are required.

Even if the required wholesomeness data are eventually supplied to the complete satisfaction of JEFCI so as to result in unconditional acceptance of irradiated cod and ocean perch (redfish), it does not mean that FDA would hold the same view. The difficulty is that other countries properly regard irradiation of foods simply as another form of food processing such as canning, freezing, etc. The United States is the only country in the world with a law that defines any source of radiation as an added substance within the meaning of the 1958 Delaney Amendment to the Federal Food, Drug, and Cosmetic Act.

At present, the seafood industry in the United States is not prepared to present a petition to the FDA for exempting irradiated seafoods. The organization of a petition involving such studies as mutagenicity, teratology, multigeneration reproduction, toxicity, and all other studies required by FDA, is too formidable for the small fresh fish industry to prepare.

Great advances have been made in the chemistry of irradiated foods. This is particularly so with the possible validity of extrapolating data from high dose levels to low dose levels. The research data gathered from many animal feeding studies apparently are convincing enough to suggest new approaches to toxicological evaluation that were not worthy of consideration a decade ago. Yet, despite these advances, no irradiated food of any kind has received FDA approval in over 15 years.

In view of the complete lack of progress in the United States in the last 15 years and the fact that in that same period, 18 other countries have given restricted or unlimited clearance to over 20 different foods, it would seem that recent reports to the effect that FDA is to review its policy on the food additive aspects of the Delaney Amendment is indeed encouraging.

VERSATILITY

The MPDI proved to be a versatile irradiator because of its unusual design requiring a vertical labyrinth. As an example, commercial irradiators use a horizontal labyrinth for the transport of material from the loading area to the radioactive source. The undeniable advantage of this type of labyrinth is that standard conveying equipment can be used as purchased or with slight modification. The MPDI design that called for a vertical labyrinth was based on the desire to economize on expensive floor area.

This design resulted in storing the radiation source in a vertical position at the bottom of a 15-foot pool of water. It is raised by an elevator which positions the source in a final horizontal plane between the lower and upper halves of the conveyor system. The horizontal position of the radiation source introduced a new element in irradiators because paired containers are carried side by side under and over the source rather than to approach it in a series of passes required by conventional irradiators.

In low dose irradiation of dressed chickens, ice was used in the twin containers to keep the chickens refrigerated and to fill the voids in the containers. The chilling effect of the ice caused condensation to form on the outside of the containers. The drip from the condensate as it falls is more thoroughly irradiated than the package it falls on. Irradiation of dressed chickens in this fashion was very successful and posed no problem to normal operating procedures.

Conversely, the MPDI was able to irradiate one pound cans of bacon and No. 10 size cans of ham in the megarad range for sterilization studies. Naturally, the processing time was much longer than the low dose irradiation treatment normally used for seafoods. No difficulties were experienced in irradiating either of these two meat items despite the disparity in size of the units.

Perhaps the most outstanding versatile use of the MPDI is the ability to manipulate the six sub-units of the radiation source underwater to change it from a production unit to a research irradiator with a higher production rate than is normally possible with a research irradiator. In this mode of operation, a special weighted, sealed, container lowered into the source pool by means of a metal chain affixed to an overhead electric motor can be used. When fully lowered into position, the sealed container is positioned precisely at a point equidistant from three sets of two radiation source plaques so arranged as to form an equilateral triangle. The container is rotated by the low speed motor at two revolutions per minute so as to obtain a very uniform dose distribution.

Irradiation studies have been carried out in this mode at very low dose levels on living plants such as cranberries and seedlings by the thousands. The sterile male technique for insects has been performed on gypsy moth pupae also by the thousands. Conversely, it has been used to continuously bombard precious gems such as diamonds and emeralds over a long period of time (months) so as to accumulate a dose of about half a billion rads.

All in all, our experience indicates that this type of irradiator can be used for low dose treatment of meats and chicken just as easily as for seafoods and fruits which we have irradiated by the ton.

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