Fisheries Utilization Research—50 Years in Retrospect, Part III: Processing and Engineering Research

JOHN A. DASSOW

Introduction

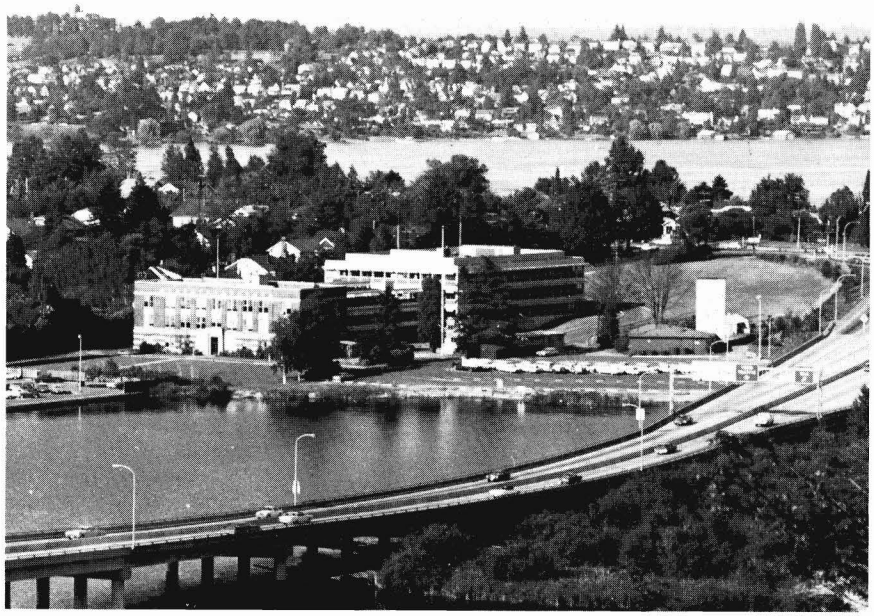
Fishery utilization research by definition is primarily applied research, and achieves its fullest expression in processing and engineering studies in which the objective is product and process development or improvement. I have selected for review four major research areas in which two or more laboratories participated in various phases of each program during a long period. These are: 1) Radiation pasteurization of fresh fish, from about 1960 to 1970; 2) freezing fish at sea, from 1948 to 1955, with intermittent studies later; 3) fish protein concentrate, from about 1958 to 1972; and 4) the surimi process, from about 1968 to the present.

Typically, in long-term processing studies, each laboratory developed its research program around a product and species mix of importance to the region. The Boston Technological Laboratory (1947-59) emphasized studies of fresh and frozen trawl fish and, in 1948, initiated a major study of freezing fish at sea. In 1959, with the move to the new laboratory in Gloucester, the research on fresh and frozen fish expanded to include major investigations of fish freezing and storage variables and engineering applications.

The College Park Laboratory, from its inception, emphasized fish meal and oil research and the nutritive value of fishery products in foods and animal feeds. In 1958 the laboratory undertook a major investigation into potential production of food-grade fish protein concentrate from hake, menhaden, and other fishery resources little used for food. After 1978, with the move to a new laboratory in Charleston, S.C., research emphasis shifted to menhaden as a potential source for processed foods and purified fish oil in nutritional supplements.

The Seattle Technological Laboratory in the 1930's emphasized fishery by-products, analytical methodology, and fresh fish quality measurement. Participation in the Alaska king crab expedition in 1940-41 and the establishment of the Ketchikan laboratory (in cooperation with the Fisheries Experimental Commission of Alaska but supervised by Seattle) rapidly expanded the program into fishery development. Processing research became a major program, with emphasis on freezing and storage of salmon, bottomfish, and shellfish.

After World War II ended, there was a surge of fishery development in Alaska, and a new division was formed in Seattle in 1949 for exploratory fishing and gear research. This established a continuing need for processing research at the Seattle and Ketchikan laboratories. In later years, the center of Alaska fisheries moved north and westward, and



The Northwest and Alaska Fisheries Research Center on Portage Bay in Seattle. The original fisheries research building, opened in 1931, is to the left; the second research building and the connecting library and conference building were completed in 1965.

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the Alaskan laboratory was moved in 1971 to Kodiak. The Kodiak laboratory began major studies on preservation and processing of walleye or Alaska pollock and other trawl fish. The trawl fishery in Alaska developed steadily after the 200-mile fishery conservation zone was established in 1976. By the early 1980's, industry, with government support, and the Seattle and Kodiak laboratories moved into evaluation of pollock surimi technology and the expanded utilization of other trawl fish species.

This brief history of program developments of the laboratories is important in understanding the factors that determined the direction of processing research. Regional interests and industry developments primarily determined the priorities for processing and engineering research in each laboratory.

Before turning to our major research topics, I would like to comment briefly on the importance of short-term processing studies at each laboratory. These were undertaken usually in response to an industry processing or quality problem and were frequently conducted in collaboration with one or more processors or an industry association. For example, at the Seattle and Ketchikan laboratories, we did collaborative studies with the Seattle laboratory of the National Canners Association (later, the National Food Processor's Association) in the 1950's on quality problems in the canning of king crab, canning of mechanically peeled pink shrimp, salmon frozen in Alaska for later canning in Seattle, and process recommendations for various canned smoked fishery products. The Gloucester laboratory studied improved salting and drying techniques for fish and the utilization of quahog clams.

In the 1960's the Seattle and College Park laboratories, in cooperation with the U.S. Food and Drug Administration, conducted studies on fresh oyster preservation and quality determination to assist industry in product improvement. In the early 1970's pollution control legislation was enacted to require treatment of fishery processing effluents before discharge. The Seattle laboratory conducted collaborative plant tests of effluent treatment techniques in Alaska and Washington to provide engineering data on the efficiency of solids recovery from fishery waste streams. Collaborative research on use of fish silage for animal feeding was undertaken to provide alternate technology for utilization of solid wastes from fish processing. More examples could be cited; however, I believe these are sufficient to indicate that not all processing and engineering research in fisheries involved long, costly programs.

J. M. Lemon, Director, Technological Laboratory, College Park, Md., in about 1939. In later years, he was chief of the technological section, Division of Commercial Fisheries, Washington, D.C. Mr. Lemon did early research on refrigeration of fish and was responsible for the early research on freezing fish at sea.

One question frequently came up in the orientation period for scientific personnel who were assigned to processing research: "How do I learn about fish and the industry?" The answer is simple. One learns from persons experienced in the fishing and processing business. If you are going to study fresh fish, get acquainted with the commercial fishermen. Make a trip on a fishing vessel to obtain fish for study. Observe the operations on the fish docks and in the plants. Ask the plant workers and supervisors. Many have grown up in the fish business and are glad to explain how or why things are done a certain way.

One factor that makes working in

fishery utilization research endlessly fascinating is the enormous variation in the raw material in terms of species, condition, and environment. For example, in the 1960's we did a cooperative study of halibut quality and the effects of handling and preservation at sea. In the beginning we were told by our fishery advisers that, contrary to our belief, we would find that halibut fresh from the water were not equal in their initial quality, nor in their keeping quality. True to their advice, we found that initial halibut quality varied greatly depending on the catch location, time of the year, feed, and stock variation.

In the first decades of our 50-year period, there were few technically or scientifically trained personnel in the fishing industry. Not any more. Quality control managers, production engineers, and research personnel are common in fish processing plants and aboard the larger trawler processors. Another change has been the growth of the number of fishery scientists and engineers in university food science departments. Credit for this development goes to the U.S. Congress for the passage in 1968 of the University Sea Grant Act which provides funds for university teaching and research programs in fisheries. Sea Grant and the earlier Saltonstall-Kennedy Act (1954) provide funds to universities and industry for research and processing studies that have helped substantially in the expansion of the modern fishing industry.

Radiation Pasteurization of Fresh Fish

If you obtained your fresh fish at the neighborhood fish market in past years, you soon figured out that the term "fresh" covered a lot of sins. Fresh, of course, has three meanings: 1) Newly obtained, 2) without any deterioration, and 3) unprocessed, i.e., not canned, frozen, or salted. The truth of the second definition is always the problem. Once caught, fish and shellfish remain truly fresh at room temperature for only a few hours. If dressed and iced carefully, they are truly fresh for only a few days. If one stretches the definition "without deterioration," most iced fish remain quite acceptable for 10 days or more depending on how fussy one is.

If you are a sport fisherman in the Pacific Northwest for salmon, trout, halibut, and bottom fish, you know that keeping and eating quality vary a lot depending on the condition and species of fish. Iced halibut store better than iced sole and flounder. Silver or coho salmon keep better than pink salmon. Some species of rockfish keep better than others. Pacific cod keeps better than Alaska pollock. Since we value the quality of fresh fish, everyone in the fish business has long been interested in treatments to keep the fish fresh longer. The key objective in all treatments is to inhibit the growth of the fish spoilage bacteria that proliferate after several days in iced fish. This was the concept of fresh fish pasteurization with ionizing gamma rays produced by radioactive isotopes.

The research on radiation of fresh food with gamma rays from cobalt-60 isotopes was an outgrowth of the Atoms For Peace programs of the U.S. Atomic Energy Commission (AEC) in the 1950's. The power of ionizing radiation to destroy bacteria was demonstrated many years earlier with X-rays, but it was not until a powerful and stable gamma ray source, cobalt-60 isotope, became available as a by-product of atomic reactor operation that potential uses in food preservation were seriously considered. Pioneer studies by the U.S. Army Natick Laboratories in Massachusetts established in the 1950's that the killing power of gamma rays depended on the dosage and could be used to destroy all or part of the normal spoilage bacteria present on fresh meats or fish and preserved meats like ham and bacon. The keeping quality of radiation sterilized ham, for example, could be extended for months or years, and would have obvious potential for Army rations if gamma-radiated foods were determined to be acceptable and safe.

During this period, the AEC became interested in the applications for civilian foods, particularly if lower doses of the gamma irradiation could be used to pasteurize packaged fresh foods that could then be refrigerated with a great increase in their market shelf life. Strawberries, potatoes, and fishery products were among early candidates.

Research on the application of low doses of irradiation to fish and shellfish were initiated at the Gloucester and Seattle laboratories under contract to the Atomic Energy Commission in 1961. The scope of the work included extensive preparation and examination of irradiated and control lots of fresh chilled fish and crabmeat. Later studies included large-scale shipping and acceptability tests and studies of irradiation at sea, using AEC experimental shipboard irradiators. Sensory, chemical, and microbiological methods were used to determine the effects of time and temperature changes, acceptability, and product safety. Microbiological research at Seattle was expanded to determine the potential health hazards from the bacteria *Clostridium botulinum*, which survive the radiation pasteurization process. Because of the importance of these studies to the future applications of the radiation preservation process, the contract research continued several years after the processing and acceptability studies were completed.

A research model of a cobalt-60 irradiator was installed in Seattle at the University of Washington for use by AEC contractors, and for larger scale studies a pilot plant irradiator was constructed in 1964 adjacent to the Gloucester Utilization Laboratory. The substantial extent of the research required major staff expansion at both laboratories during the 8 years of contract research with the AEC. At the Technological Laboratory, Ann Arbor, Mich., research on radiation pasteurization of Great Lakes fish emphasized shelf-life extension of fresh yellow perch fillets in conjunction with potential use of controlled atmospheres. The AEC, in addition, supported research on fishery and other food applications at several state universities—Washington, Oregon, California, Hawaii, Massachusetts, Louisiana, and others. Without a doubt the AEC support of research on radiation preservation of foods in the 1960's was the largest and most comprehensive contract research program in which the BCF-NMFS laboratories have participated.

A brief answer to the question of what did it all accomplish is not easy for me. Three major thoughts occur. The first and the most disappointing is that large-scale application of radiation pasteur-

ization to fish and shellfish was not achieved despite thorough research and long and magnificent support by the AEC. There were technical and economic reservations about industry application of fresh fish, but as indicated in Part II of this review, the unresolved questions of product safety were the main factor.

The second thought is that as a result of our intensive studies of the qualities of fresh and irradiated fish, we answered questions and added more to the published record on the enzymatic, chemical, physical, and microbiological characteristics of fresh fish than our laboratories had in the previous 20 years.

The third thought is that, owing to much needed additions to our scientific staff and laboratory facilities during the long contract support, our scientific and research capability was improved substantially. This yielded dividends in other research areas in later years.

A final comment seems appropriate on developments since our radiation pasteurization research was terminated almost 20 years ago. In the last few years there has been a rebirth of interest in irradiation of fish as well as fruits; however, in my view, the economic and product safety reservations are still evident for commercial application to fresh fish. Possibly more important, I wonder if we need it with the improved handling and air transport facilities for marketing good quality fresh and frozen fish from just about anywhere in the world. Availability of a wide variety of fish has increased substantially with the greater demand for fish on the basis of quality and nutritional value. At this time I can't believe that radiation-pasteurized fish and shellfish would be cheaper or more acceptable than what is already available.

Freezing Fish at Sea and Ashore

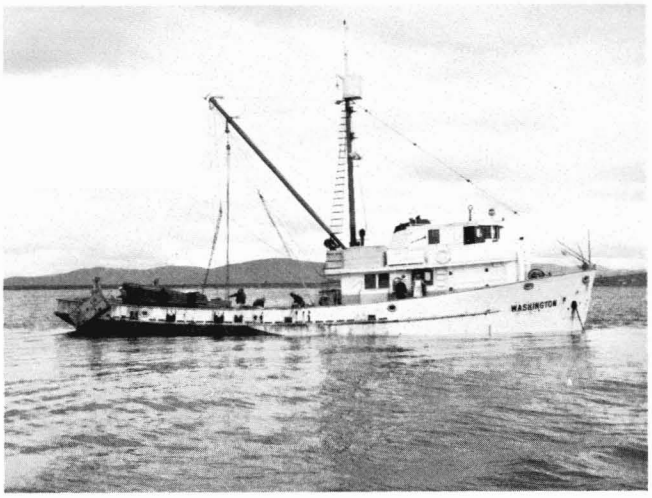
Freezing fish at sea is essential if the fisherman must stay out so long for a payload that the fresh or iced fish can not be delivered in good marketable condition. On the Pacific coast the tuna industry began to develop freezing at sea during the 1930's as the fishermen roamed farther south from California ports in search of larger payloads of yellowfin and skipjack tuna. At first the holds were lined with refrigerated coils to hold the iced fish; then, watertight holds lined with coils were used to hold the tuna in chilled sea water. Neither system was adequate, and the next step was to chill the tuna in the refrigerated seawater holds, then add salt to form brine, and lower the temperature of the brine and the tuna to about 10°F. After the tuna were frozen, the brine was pumped out and discarded.

The refrigeration control panel in the new Gloucester Technological Laboratory in 1962, with John Peters, chemist (left), and Joseph Slavin, laboratory director.

The method was efficient for the fishermen, but caused problems because of quality variation and the high salt content of the frozen tuna. Detailed research on the problem of brine freezing tuna was conducted by the Fisheries Research Laboratory of the Hooper Foundation of the University of California at San Francisco (Lang and Farber, 1939). By 1939, their research had shown that by prechilling tuna to 30°F in chilled sea water and then freezing the tuna by circulating dense brine precooled to −5°F, the salt absorption was limited primarily to the surface layer (¼-inch). The key to the method was that the wells were pumped dry before circulating the freezing brine. This limited the salt uptake to the freezing period, since the brine was pumped out after the fish were frozen.

As it turned out, the fishermen found it much more convenient to make up the brine in the well after prechilling, then drop the temperature to freezing. During prechilling, the wells were packed tightly with tuna to increase the payload. During the following years, the problems of quality, salt uptake, and physical damage to the tuna gradually worsened. As a result, the Seattle laboratory undertook cooperative studies with the industry and the California Department of Fish and Game in the mid 1950's. Substantial research under contract was conducted and included study of the tuna temperatures during prechilling and brine freezing aboard commercial vessels, and thawing procedures with dense brine prior to unloading at a cannery in Terminal Island, Calif. (Lassen, 1965).

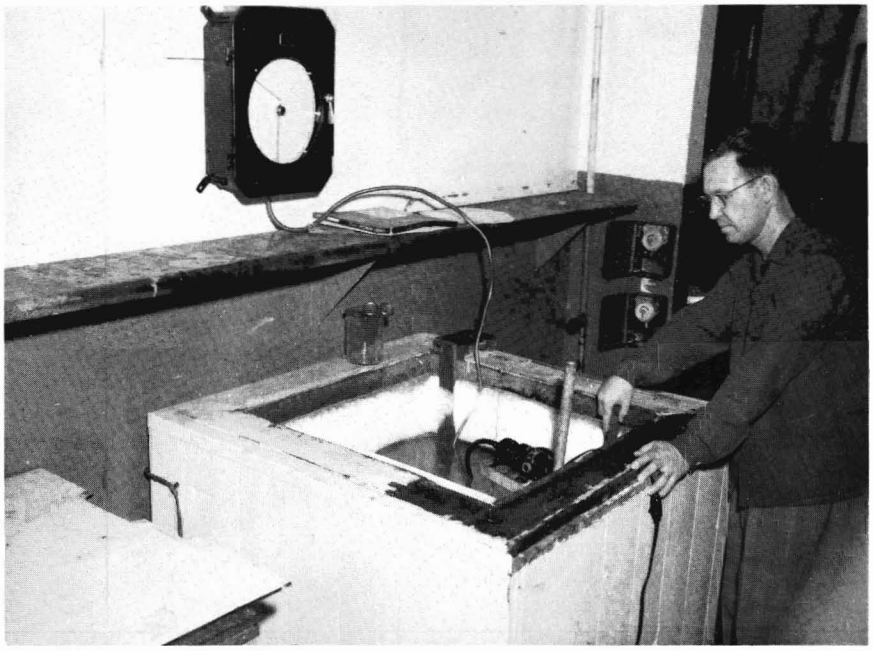
Sampling of the thawed and canned tuna from the test lots demonstrated that the problem was inadequate chilling and freezing of the tuna under tight packing conditions, resulting in poor heat transfer and highly variable salt uptake from the dense brine. The advantages of the old method for the fishermen were convenience in brine makeup after fishing started and additional payload obtained by packing tuna tightly in the wells. The primary problems for the processor were the economic losses in yield and



At left is the fishery research vessel *Washington*, a 100-foot steel trawler, anchored off Nome, Alaska, in September 1948 during exploratory fishing operations in the Bering Sea. Right, bringing in the trawl net on the *Washington* during operations north of Dutch Harbor. In the foreground is the hatch cover for one of the refrigerated wells used in brine freezing tests.

higher costs of quality control. It was obvious during our collaborative studies that the improved brine freezing method was overshadowed by the economic advantages of the old method. In a fishery that probably covers greater distance for its catch than any other fishery, it seemed likely that fleet economics would win.

During the late 1940's, the Seattle laboratory did limited investigations in brine freezing of salmon and groundfish at sea for later thawing and processing ashore. In 1948 tests were conducted aboard the exploratory fishing vessel *Washington* in Alaska. Red and silver (coho) salmon and five species of sole and flounder were frozen in dense brine at 5°F, stored in the brine for 3 weeks aboard vessel, and transferred at Seattle to dry storage at 0°F. The salmon were thawed and canned at the Seattle laboratory. The sole and flounder were thawed, filleted, packaged, and refrozen in commercial facilities in Seattle. Evaluations with industry representatives indicated that the products from brine frozen fish were of marketable quality. In 1952, I made a brief study of brine freezing Gulf of Mexico shrimp at sea to demonstrate the feasibility, but only limited applications developed (Dassow, 1954).



Experimental brine freezing tank in the Boston Technological Laboratory, November 1958, with H. W. Magnusson, research chemist.

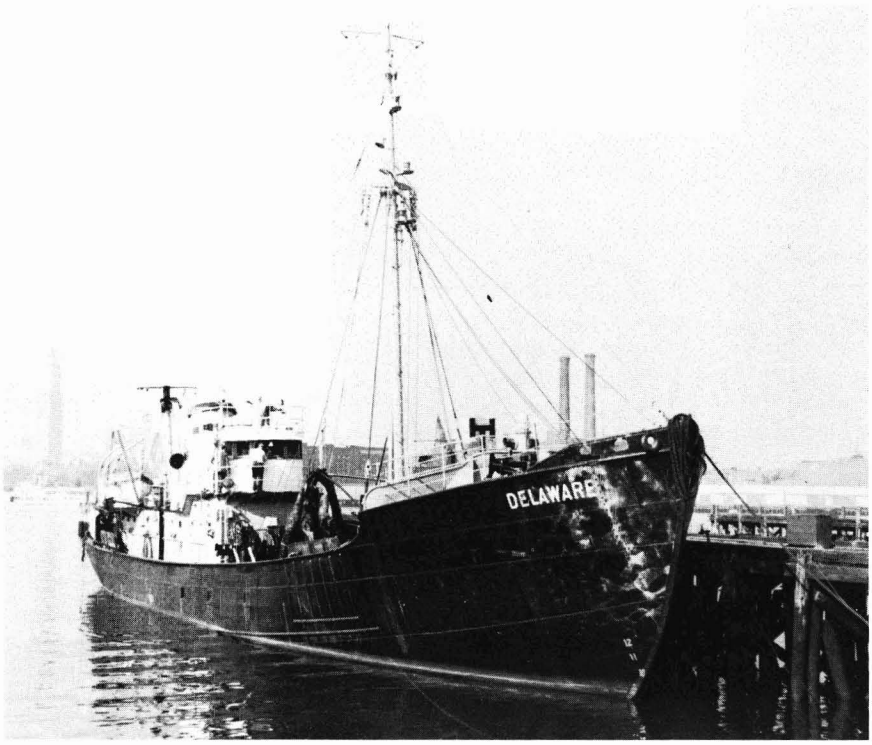
Additional samples of fish frozen at sea were received by the Seattle laboratory in 1948 from the Bering Sea operations of the government-subsidized factory ship, *S.S. Pacific Explorer*, and included frozen whole fish and packaged fillets of pollock, sole, and flounders. The whole fish were thawed, filleted, packaged, and refrozen. The refrozen fillets and the control fillets frozen at sea were then thawed, cooked, and compared. The control fillets had been processed aboard vessel under difficult conditions, and their poor quality made the comparison unfair with the refrozen

fillets, which were consistently judged superior. At best, we concluded that freezing whole fish at sea, then thawing, filleting, and refreezing ashore had no significant adverse effects.

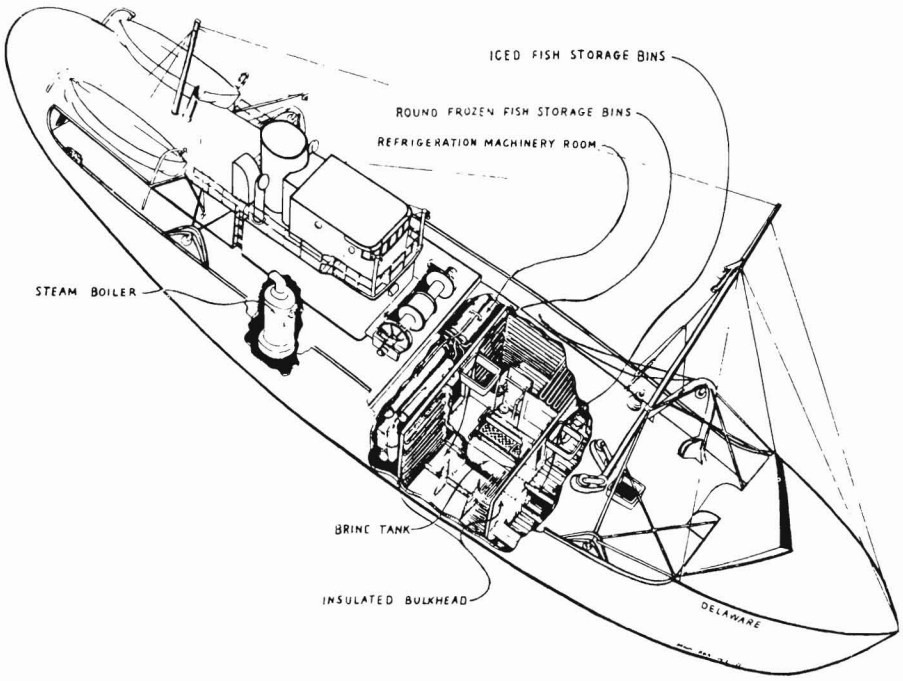
In late 1948 the Boston Technological Laboratory initiated a long-range, definitive study of freezing fish at sea in the North Atlantic. Initially, four species of fish (cod, haddock, ocean perch, and pollock) were frozen in the round aboard the research vessel *Albatross III*, and later thawed, filleted, and refrozen ashore. The laboratory tests showed no adverse effect on the quality of the refrozen fillets, compared with the fillets from commercially iced fish. At this point, industry was interested in the outlook for freezing at sea, but larger scale freezing, engineering, and quality studies were needed.

In 1950 the Boston laboratory acquired a well used but serviceable New England trawler, *Delaware*. Extensive alterations were made in the vessel, as well as in the laboratory facilities, for full-scale studies of brine freezing whole fish at sea with later processing ashore. The brine freezer was designed for continuous freezing in baskets with a capacity of about 3,000 pounds of fish per freezing cycle of 1-3 hours, depending on fish size. Frozen whole fish were transferred to frozen storage at 5°F, and iced gutted fish were prepared for use as controls in quality evaluations. Shore facilities included controlled thawing and processing equipment. During the next 5 years, the experimental studies included numerous trials and modification of equipment. Finally, commercial-scale trips were made in which more than 60,000 pounds of cod, haddock, and pollock were brine-frozen at sea, processed ashore, and evaluated. By 1955, the results demonstrated that the refrozen fillets were superior in quality and acceptability to the fresh fillets from commercially iced fish of the same species.

Despite the favorable results and the extensive documentation of the studies, including designs for a freezer-trawler, the New England fishing industry did not convert to freezing at sea. The major reasons were the economics of conversion and the increasing competition



The trawler *Delaware* in about 1950 prior to conversion for research on freezing fish at sea.



The trawler *Delaware*, showing location of the continuous brine freezer and the refrigerated storage holds.

for the North Atlantic trawl fishery resource in the 1950's and 1960's. The technical and engineering research by the laboratory was important to the industry, however, in evaluating the systems and costs for possible conversion to freezing at sea.

In the late 1960's, two factory freezer-trawlers, one for Atlantic and one for Pacific operation, were built under the U.S. fishing vessel construction subsidy. The vessels were tested and performed reasonably well, but did not prove financially successful. In Europe, numerous factory and freezer-trawlers were built and operated during the 1960's, but became financial liabilities in the 1970's as fishery restrictions imposed by nations limited availability to productive fishing grounds in the North Atlantic and elsewhere. Profitable operation of freezer-trawlers required an assured fishery supply.

On the Pacific coast, the rise of bottomfish trawling began in the Kodiak, Alaska, area and later in the Bering Sea, as the king crab fishery declined during the early 1980's. With a huge resource under American jurisdiction, the major trend in the Bering Sea trawl fishery has been to the freezer-processor vessel that delivers frozen fillets or, in the new pollock fishery, frozen surimi blocks. One major factor in the trend to large trawler processors is the improved, highly efficient machinery for filleting, skinning, and freezing the fish. A second factor is the economics of modern vessel operation that favor a greater return with a more costly but mechanized vessel, compared with operation of smaller trawlers and shoreside plants in a remote area like the Bering Sea.

Fish Protein Concentrate (FPC)

The concept of a dry protein concentrate prepared from whole fish, a product that is nutritous, stable, and useful as a protein supplement, was not new when the research began at the College Park laboratory in 1961. By some accounts, a similar concept existed in Rome in the first century A.D. in the preparation of liquamen, a dried stable product prepared from small whole fish, fish entrails (a natural source of enzymes), and salt. In the latter part of the 19th century, the Norwegians prepared a dry stable fish powder from lean fish for use as an emergency food.

The Gloucester laboratory experimented with fish flour in the early 1930's, and then, in the 1950's, the enormity of the global hunger problem was brought to the world's attention by various agencies of the United Nations. Accordingly, many government agencies and private ventures in the United States and other countries organized to meet the need. Several programs of other countries involved the production of a "food grade" fish meal that was solvent-extracted to reduce oil content. The resulting "fish flour" was recommended as a protein supplement in bread and cereals or for use with vegetables to make a protein-enriched stew.

One problem with several of these FPC-type products was that they were not acceptable for food by the U.S. Food and Drug Administration regulations, a requirement for the national FPC program. In addition most products were quite dark, had a strong odor and flavor, and were difficult to blend with other food ingredients.

Inasmuch as several species of lean fish, such as Atlantic and Pacific hake (whiting), were available in large amounts, one might wonder why the fish could not be simply filleted, minced, and dried. Experiments in dehydrating food fish at the Seattle laboratory during the early 1940's showed that precooking, close control of drying conditions, and subsequent storage in hermetically sealed containers were required to produce an acceptable product. Dehydration of oily fish like pilchard requires precooking and pressing to remove excess oil. Although satisfactory for some products, such as a dehydrated fish chowder, the dehydration process does not produce a highly stable product suitable for storage under the adverse conditions encountered in most emergency and long-range food distribution programs.

The chief objective of the new FPC research at College Park was challenging: To develop a process for producing a stable, nutritious, and convenient powdered fish that could be produced on a large scale from whole fish of a variety of species at a low cost compared with other dry food protein sources. In addition, the product should have a light color and little odor and flavor and be acceptable for food under U.S. Food and Drug Administration regulations. The initial laboratory studies and surveys produced several processes recommended for pilot plant study. The government's urgent timetable, however, mandated an accelerated program using a single process, one suitable for scaling up for construction of one or more large demonstration plants.

The researchers' problem was that they realized after the initial laboratory studies that FPC, as a practical concept, included a variety of processes and products. The basic solvent-extracted FPC is an inert nonfunctional product that is difficult to incorporate in many foods. Process modifications can produce a far more useful functional protein. Rather than pick one process at that stage, the long-range need was to diversify and determine the potentials and problems of several processes. But it was not to be. So much rhetoric had been expended on the need and virtues of FPC in a hungry world that politics dictated fast action.

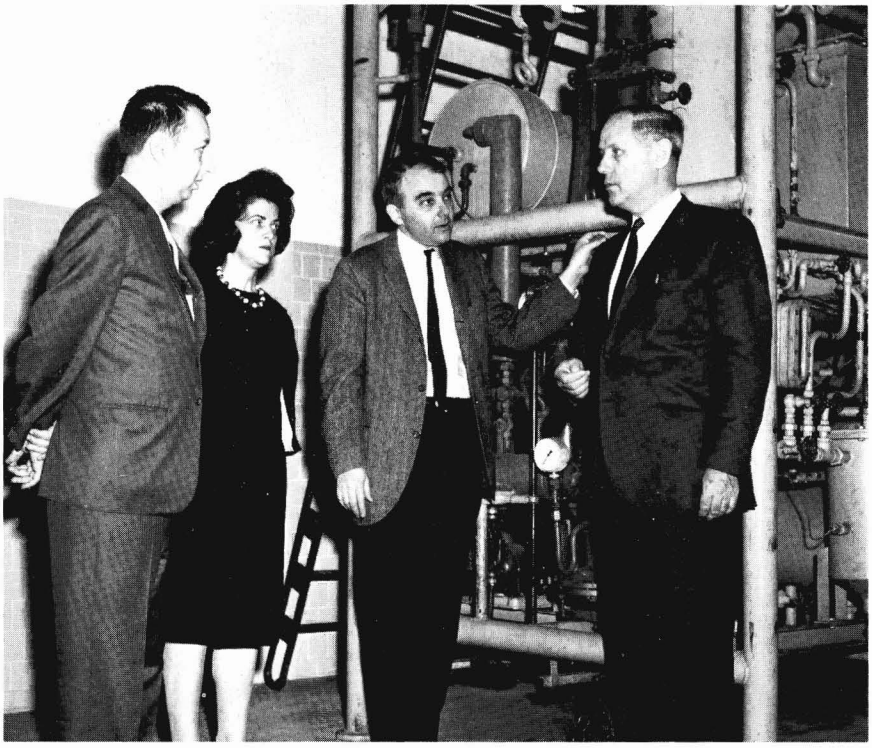
As a result, the best understood process, the counter-current extraction of minced whole fish with isopropyl alcohol, was selected, and all other great process ideas were shelved. The accelerated pilot research on the isopropyl process proceeded with the emphasis on the application to the leaner fish, the Pacific and Atlantic hakes, rather than on the oily species like menhaden and herring. After a 2-year delay in funding the experiment and demonstration plants, Congress decided only one plant would be built. After a long interval of technical and political review for the best location, Aberdeen, Wash., was selected, the favored site of Washington's Congressional sponsors and the one closest to the Pacific hake resource. The plant was designed, constructed, and operated by Ocean Harvesters, Inc., a joint enterprise of a tuna packer and an equipment manufacturer. Both the College Park and Seattle laboratories were

active in technical and engineering liaison during construction and the operation of the plant from March 1971 to mid-1972.

Production of FPC from Pacific hake provided numerous but solvable problems, and the quality of the product from the trouble-free runs was close to the specification. Production cost of hake FPC was estimated from the longest continuous operation, about 3 days. It was much too high compared with our expectations because of low product yield, excessive losses of solubles and fines during extraction, and equipment difficulties, such as proper separation of solids in the large vibrating screens. Time was running out because of the initial funding delays and the time limit imposed by the plant authorization bill (Public Law 89-701 of 1966). Therefore, late in 1971 the plant was modified for the trial runs of two oily species, menhaden and anchovy. The runs were made in early 1972 and were a disaster, although not an unmitigated one. The process and line equipment were completely inadequate to handle the problems of the oily sludges from either species; nevertheless, the runs on oily species provided the basic experience for engineering modifications of the process if plant trials on menhaden were to continue.

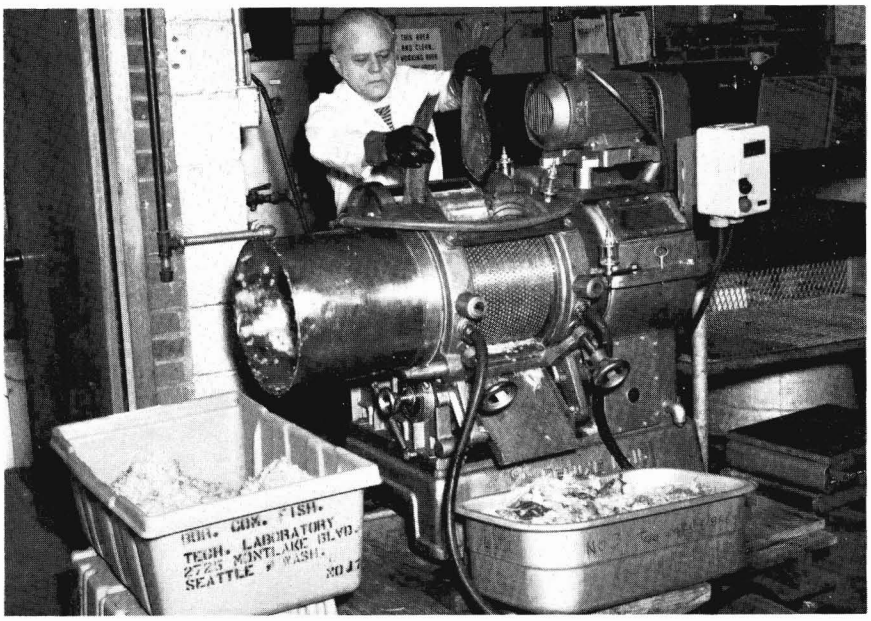
More money and the authorization for continuing operation were requested, but somehow the magic had gone out of the program, the authorization faded away, and the plant was closed in late 1972. Some months later the U.S. government sold at auction the 200,000 pounds of hake FPC produced at the plant for 24 cents per pound, a reasonable price for a one-time product. The plant and equipment were sold in later months and that ended the brief era of Federal FPC production. The momentum of research and interest in modified and more functional proteins continued at both the College Park and Seattle laboratories.

Looking back, it seems that it was worthwhile, considering the national interest in the idea of the United States producing packets of fish proteins to help balance the world's diet. As a protein supplement for hungry people in the



From left to right, Dr. Donald G. Snyder, director of College Park Technological Laboratory, and Dr. Olivia A. Hammerle and Dr. E. R. Pariser, research chemists, discuss the pilot research on fish protein concentrate with Rep. Hastings Keith, 1965.

Dedication day for the experimental demonstration plant for fish protein concentrate, 17 April 1971, in Aberdeen, Wash.



Max Patashnik, chemical engineer, prepares minced flesh from Pacific whiting, using the mechanical flesh separator at the Seattle Technological Laboratory, 1976. The minced fish is in the container to the left and the skin and bone waste are in the one to the right.

undeveloped countries, however, there was always the nagging problem of the poor financial outlook for a big industry investment. In addition, as a nonfunctional protein, FPC's future in the United States was bleak, considering that by 1970 the food industry was demanding more and more that food proteins add functionality for production of new foods and new appeal to old foods.

A functional FPC would not only have greater market appeal in the developed countries but, judging from our fish protein isolate research, would be much more valuable. Also, our research at Seattle had already indicated in the early 1970's that, for major species like pollock and possibly Pacific whiting (hake), the production of the frozen stabilized surimi-type product had more potential in the food world than we knew. Maybe for that reason I wasn't sorry to see FPC go back on the shelf.

The Surimi Process

Our interest at the Seattle laboratory in Japanese surimi production was an outgrowth of our research during the 1960's on utilizing the vast Alaska pollock and Pacific whiting resources. I have told part of that story in the fisheries development review in Part I, but would like to review the importance of the surimi potential as we began to see it in our cooperative studies in 1968-69 with the Japanese biochemist, Minoru Okada. During that year, our research group not only learned the technology of surimi from a world expert, we gradually appreciated the significance of the basic techniques for a broader application to utilizing fishery resources of every variety.

Keep in mind that surimi is an intermediate product and is the washed, mechanically separated fish flesh, in which well-known food additives such as salt, sodium phosphates, modified starches, sugar, antioxidants, and a wide variety of food modifiers can be added to improve color, texture, freezer stability, and protein elasticity. This latter property varies greatly in various fish species and is affected by factors such as freshness, freezing, temperature, and physiological conditions of the fish. By use of the washing and dewatering techniques and appropriate additives and blending, the surimi block is stabilized and frozen for later processing. The surimi process can be modified according to the problems of the species on hand and the desired end products.

The basic surimi product characteristic is a high quality wet fish protein with good elasticity for later binding and blending with other ingredients. With the proper forming or extrusion equipment, one can produce a variety of ready-to-eat and heat-and-eat products that can vary from simple fish-flavored products to simulated crab, shrimp, scallop, lobster, and you-name-it analogs of the original. The nutritive value rests on the high biological value of fish protein since much of the water-soluble nutrients in fish flesh are lost in the washing process. The product analog can be a low-fat product with minimal use of salt and sugar if deemed desirable. Since the washed separated protein loses its identify as a species, almost any species of fish can be used as long as it is suitable for mechanized evisceration and flesh separation.

Research is still needed to reach this goal with some oily or stronger flavored species like, for example, menhaden and certain herrings and mackerels. As a process, surimi production must be a large-scale operation for best economics and close to the fishing grounds, as either a shore or factory vessel operation. The final production of the surimi analog products, imitation crab or shrimp, can be either a small or large operation depending on the desired product and market potential. One final part of the outlook, surimi can be used as a protein ingredient in a wide variety of sausage and cured meat products, pizza toppings, and flavored snack foods.

Continuing research by utilization research laboratories is needed on the basic chemistry of flesh of various fish species and its stabilization and also on nutritional and microbiological aspects of derived food products from surimi. Food science laboratories in a number of universities and food processing firms have already contributed much knowledge to the new science of surimi and surimi product analogs. It appears that surimi technology is here to stay.

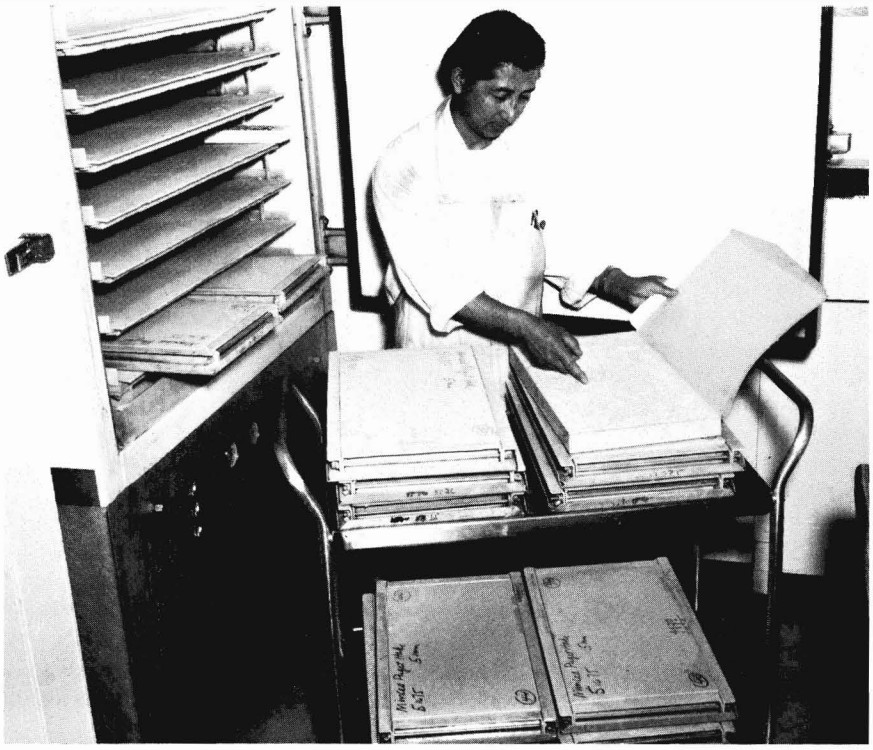
Afterword

Looking back through this retrospect of 50 years, I am keenly aware that much was left out. Obviously, my experience dictated a selection that may appear to others as a somewhat biased review of project accomplishments and, in some cases, failures to achieve our goals. Nevertheless, even in the latter cases, the knowledge gained was significant and proved to be essential in setting priorities for future research and developments in related fields.

Take the story of fish protein concentrate (FPC), a long and expensive (by our laboratory standards, anyway) investigation and engineering study. The goal, developing a cheap and nutritious protein supplement that could be produced from underutilized stocks of fish and distributed at low cost anywhere in the world, was certainly worthy. In the early 1960's the desirability of the nutritional and socio-political goals in FPC development was unquestioned.

If one compares the reports in two international symposia on fishery products, one in 1962 and one in 1974, the evolution of the fish protein in product concept is apparent during the period of the FPC's rise and fall (Heen and Kreuzer, 1962; Kreuzer, 1974). In 1962 the symposium had numerous papers from various countries describing the process and potential for fish flour and FPC. In the 1974 symposium, fish flour and FPC were hardly mentioned, but the meeting overflowed with papers on new and old product concepts for better utilization of fishery resources throughout the world. Reports on surimi and kamoboko developments in Japan (Okada and Noguchi, 1974) and the potential of new functional protein isolates in the United States (Spinelli et al., 1974) indicated the trend. In 12 years the world of fishery utilization moved from fish flour/FPC, after finding it to be neither cheap to produce nor universally accepted as a food supplement, to a diversified view of processed fishery foods better adapted to international tastes and market demands.

This cycle of change is not uncommon in processing research in which engineering applications are essential. We learned much from the failures to reach program goals, possibly more than from successes, because the changes in product concept and research direction reflected the immensity of the problem.



George Kudo, chemist, shows blocks of frozen minced flesh of Pacific whiting, prepared for product research at the Seattle Technological Laboratory, 1976.

For another example, let's take radiation pasteurization of fresh fish. The jury is still out on the industry application and product safety assurance for gamma radiation of fresh foods. Nevertheless, the goal of seeking peaceful uses for atomic energy and its isotopes is still worthy. True, we may have been overly optomistic about the potential of radiation pasteurization of fresh fish during the research in the 1960's. Yet it was definitive research, and much knowledge was gained and shared with the technological community on the chemistry and microbiology of fish quality changes and the effects of low levels of irradiation. Applications of this research may well develop for irradiated products and markets which we and the Atomic Energy Commission never anticipated 20 years ago.

I believe we achieved success in our research on the quality, nutritive value, and safety of fishery products. This view is tempered, however, by the fact that these are areas of changing technology, and new problems in the fishery supply and environment lie ahead. Research to assess and assure the quality and safety of fishery products is never completed.

Technical challenges lie ahead in developments now underway but still incomplete in the knowledge base. For example, current research on health and nutritional benefits of increased consumption of fish and the use of nutritional supplements of fish oils rich in omega-3 fatty acids may well expand the ways in which fish are processed and marketed.

The rapid development of freshwater and marine aquaculture for food fish production in the past 25 years has brought a host of problems and prospects for technological development. In the 1970's the Seattle laboratory studied methods for utilizing low-cost food fish

from freshwater culture (Dassow and Steinberg, 1973). New research was undertaken at Seattle on effects of aquaculture feed components on growth and flesh quality of salmonids (Spinelli and Mahnken, 1978). Development of improved feeds with optimum nutritive value is essential to the success of marine aquaculture and will continue to be an important research area. Turning to surimi technology, continued research into the process chemistry of fish flesh stabilization is essential if the industry is to utilize a wider variety of fish species. Alternate species sources are needed if the industry is to meet the vast market potential for surimi-based products on a long-term basis.

In conclusion, I must admit that this retrospect of 50 years has reminded me frequently that the future seldom developed as we thought it would during our research planning. The timing and rate of research and development generally were different, and usually longer than we projected. Optimism in research planning is important to funding; therefore, our errors were usually on the optimistic side. Looking ahead, there is little question that human management and protection of the essential water environment is basic to maintaining a healthy fishery resource—an issue that hardly occurred to anyone in fisheries in 1937. Given a healthy fishery resource, consumer tastes and market economics will dictate continued diversification of fresh and processed fishery products, with more demanding requirements for quality assurance, nutritional value, and product safety. In my projection, the future of fishery utilization research is secure.

Finally, a personal note to all the former colleagues whose names appear in the numerous references and literature cited in these articles. Time and again during my review, I was impressed with the excellent research and careful presentations. Space permitted only a small part of the 50-year record, but I believe the breadth of research listed is a tribute to all who participated.

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