Utilization Research, 1931-1981: A Historical Overview

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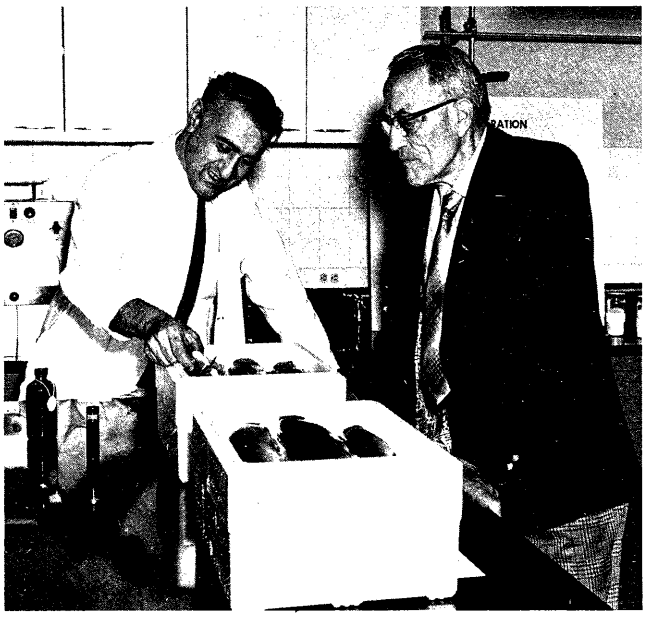
Preparation of trawl-caught fish for research on problems connected with processing (left to right, George Kudo and Fuad Teeny, chemists, and Herman Groninger, biochemist; Utilization Research Division in 1968).



John Spinelli, chemist, shows Dr. Lauren Donaldson, noted aquaculture expert of the University of Washington, the improved flesh color in pen-reared coho salmon that had natural carotenoid extract added to the diet. Photo taken at the Open House in 1974.

INTRODUCTION

Our review of Fishery Utilization research properly begins in May 1933 when Roger Harrison, chemical engineer, and Andrew W. Anderson, fishery technologist, arrived to initiate the technological research program in Seattle in the new Bureau of Fisheries Building. Before picking up the thread of the technological research at that time, however, I would like to refer briefly to the background from which Harrison and Anderson emerged.

Fishery technology or, as we refer to it now, fishery utilization, had been a federal research activity of considerable scope for many years prior to the opening of the Seattle laboratory in 1931. A compilation by Maurice E. Stansby records technological research at 17 locations in the United States starting in 1878 in Gloucester, Massachusetts, to four locations in 1931--Gloucester, Massachusetts; College Park, Maryland; San Diego, California; and Washington, D.C. The research facilities in most cases were temporary; however, it is significant that of the various locations, Gloucester and Seattle are the locations that as of 1981 have

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retained technological research facilities over the longest periods during the 103 years from 1878.

The scope of this technological research from 1878 to 1931 is even more significant because it demonstrates the continuity of problems associated with Utilization Research to the present day. This is not surprising to anyone who knows the scientific literature of fisheries chemistry and technology. What is dismaying to those of us who have been in utilization research for a few decades is a failing of many students of Fishery Food Science. They arrive on the scene convinced that all important findings on the chemistry, composition, nutritional value, spoilage, refrigeration, and waste utilization of fish and shellfish were accomplished in the last 5-10 years. Therefore, the conclusion is that the literature prior to that is ancient history, not science. Let me be specific on this matter of the enduring nature of good technological research. Consider the basic proximate composition of fish. Food composition tables today include analytical data that are still useful from Dr. W. O. Atwater's classical studies in the 1880's, Dr. Ernest Clark's and R. W. Clough's analyses in the National Canner's Association laboratory in the 1920's, and E. H. Coulson's mineral analyses from 1929 to 1935. Recently, for reply to a dietician, I found Coulson's iodine data of 45 years ago comparable on similar species to recent published data and more complete on the variation in salmon and shrimp. Other examples from the 1920's of the technological base prior to 1933 are the refrigeration and canning studies by Harden Taylor and Harry Beard, respectively, and research on the spoilage of fish and oysters by Ernest Clark, Donald Tressler, and others. Norman Jarvis' studies and compilations of canning and curing technology are still in demand after 40 years. The works of J. M. Lemon on chilling and freezing fish from 1930 to 1950 are still widely used for reviews and textbook presentations. The tools for research are sharper today and certainly far more costly; however, the use of good science of the past is important to utilization research today and tomorrow.

For our overview, I would like to divide our discussion into the five decades. In each period the backdrop of industrial developments and problems is appraised first because, without industry, utilization research is a biography of knowledge with little application. For this reason, the research direction and events of utilization research are summarized primarily by their relation to industry, not the research leaders or scientific staff. In the history section of this publication, the personal research recorded is more complete. The final and obvious topic for our review is the assessment of economic benefits. In my experience, estimation of benefit/cost ratios for government research has a large margin of error potential depending on one's skill in the science of reasonable assumptions; however, we will consider recent examples of research benefits.

UTLILIZATION RESEARCH DIRECTIONS AND ACCOMPLISHMENTS

By 1933, the scientific disciplines were established for fishery utilization research--chemistry, physics, biochemistry, microbiology, and engineering. The technological areas of the earlier studies are equally familiar--chemical composition;

nutritive value; spoilage of fish and shellfish; processing technology including handling, chilling, freezing, canning, salting, curing, drying; and waste utilization. These then were the basic research areas for the new Fisheries Technological Laboratory when Roger Harrison assumed direction in May 1933.

1931-1941

Looking back at the Pacific Coast Fisheries of the 1930's, salmon canning clearly was the dominant industry of the Northwest and Alaska with 115 operating canneries in Alaska during the 1931 season and 48 in the Puget Sound and Columbia River areas. Farther south, sardine canning was a major industry but showing the first signs of decline. Tuna had developed a firm base since 1927 of about 1.2 million cases but showed no signs of the spectacular growth ahead. In Alaska, halibut fishing and salmon trolling started in the spring for a 6-month season, and the codfish schooners with their stacks of dories headed for the Bering Sea. About the same time, shrimp, Dungeness crab, herring, and bottomfish were small but important fisheries in communities along the coast. The economic depression of the 30's handicapped fishermen and processors alike. The number of operating salmon canneries in Alaska dropped 30 percent in the early 30's. In Bristol Bay an excellent sockeye (red) salmon run glutted the canneries and prices to the fishermen sometimes dropped unbelievably low--some landings at one cent a pound.

At the new Seattle Fisheries laboratory, the first task for Harrison and Anderson was to finish the fish meal and oil studies and reports from the extensive research conducted at Gloucester, Massachusetts, and at Reedville, Virginia. Research on utilizing waste from the various salmon species was the first major study during the 1930's and included definitive studies of the chemical and physical properties of salmon oils including their vitamin A and D content and the production of edible quality oil for use in canned salmon. Interest in freezing foods, both commercially and for personal use, developed rapidly in this period and the small laboratory staff initiated major research on freezing and storage of various species of salmon and bottomfish. One pioneer study with private funding was the potential use of cereal antioxidants to inhibit the development of rancidity. With the arrival of Maurice Stansby in 1937, research was expanded to include chemical studies of rancidity development in frozen salmon and chemistry of freshness and spoilage changes in fresh salmon. In the fish meal and oil studies and frozen fish research, it is significant that the laboratory laid a firm base during these years for analytical methodology and improved measurement of chemical changes in fishery products. The results published by Harrison, Stansby, Anderson, and others established the reputation of the Seattle laboratory at an early date.

At the close of the decade, the technological laboratory undertook a prophetic assignment--an investigation of the feasibility of a king crab fishery in Alaska including methods for harvesting and processing king crab. The subsequent exploratory and technical studies were directed by Harrison with seven research specialists. The field investigations used experienced fishermen and chartered fishing vessels and provided the first systematic record of the Alaska king crab industry potential.

The report of the study, published in May 1942, noted another finding of interest, "Alaskan waters hold an enormous reserve of edible fish--notably sole and pollock--which is at present wholly unutilized." Another indication of the Federal interest in fishery development in Alaska occurred in the last year of this period when the new Fishery Products laboratory was completed in late 1940 in Ketchikan and Stansby transferred to Ketchikan as the first director. However, the logical course of these and other developments was interrupted by the events of December 7, 1941, and World War II.

1941-1951

Wartime priorities soon imposed changes and expansion of the research program at the technological laboratory and the new satellite laboratory at Ketchikan. Industry shortages of vital materials and resources for food production were anticipated and research was soon underway on the feasibility of substitute containers for fresh and canned fish to save on tinplate. A possible shortage of agar, the seaweed extractive, was feared and a project on possible use of substitute seaweeds was started. Vitamin A in fish livers and proper sampling and analytical methods became important. A major project was established to determine the requirements for production and storage of dehydrated fish. Pilot dehydrating equipment was designed and constructed to demonstrate engineering essentials and the production of a test product.

In Ketchikan, studies were undertaken early in the war to determine the potential use of a wide variety of marine resources for food. The fishing industry was beset with the highest demand for fishery products in its history at a time when wartime activities and restrictions made offshore fisheries expansion a hazardous undertaking. My introduction to exploratory fishing occurred during this time at the Ketchikan laboratory, when a Seattle trawlers' association sent several vessels to explore for bottomfish in southeast Alaska. I went aboard one of the trawlers to collect species for preservation studies. The trawlers found rough bottom along with a variety of flounders, rockfish, and walleye (Alaska) pollock but little real production. At the laboratory we tested a wide variety of the little used bottomfish and other species for potential food--pollock, skate, rockfishes, smelt, sharks, wolf fish, greenling, starry flounder, arrowtooth flounder, and similar dubious species. Probably our most interesting experience was the work with Pacific sleeper shark and Stellar sea lion. Both proved quite edible in proper form and disguise. Industry tried marketing frozen sleeper shark fillets from Alaska in Chicago with, it's not too surprising, disastrous results. Even in wartime with meat and fish shortages, the consumer still exercised the right to buy something different only once.

Most of the wartime projects terminated in 1946 or soon after; research on vitamin A in fish livers continued until the industry declined drastically in the late 40's with the introduction of synthetic vitamin A. The laboratory needed a research initiative providing funds, and a proposal for a detailed study on utilization of Alaska salmon cannery wastes was funded through the Fisheries Experimental Commission of Alaska. The studies during 1947-48 included sample and data collection, species waste composition, pharmaceutical potentials, food uses for edible portions, edible oil production, and use for salmon hatchery

diets. The reports still provide the basic analytical data for inquiries on salmon wastes after 33 years. The Ketchikan laboratory initiated research on the problem of paralytic shellfish toxin occurrence in butter clams after a problem of product safety developed in this small but important industry in 1946. The studies on freezing and storage of various species were broadened to include Pacific salmon species and a wider range of bottomfish. More emphasis was placed on the factors of pretreatment, packaging, antioxidants, and use of lower storage temperatures to improve keeping quality of frozen products.

In 1947 the laboratory inititated further investigations on the king crab and bottomfish industry in Alaska. Experimental and smallzscale commercial packs of frozen king crab meat and crab sections in the shell were prepared cooperatively aboard the exploratory vessel Alaska in 1947 and aboard the subsidized factory vessel Pacific Explorer in the Bering Sea in 1948. The production of the Pacific Explorer included canned and frozen king crab and frozen fillets of pollock and sole from the Bering Sea. The Explorer operations were hardly successful because of the mediocre quality of the products, the low production levels, and the indifferent market acceptance. Yet it must be counted as a worthwhile endeavor that demonstrated in our product evaluations the process problems and technological pitfalls in factory vessel operations in Alaska.

During the same post-war period, Lowell Wakefield, Bill Suryan, Harry Guffey, Ed Shields, and others were testing their ideas for harvesting and processing king crab aboard vessel. Who led the way most clearly? Certainly the government exploratory studies of the 1940-41 king crab expedition and our laboratory studies of 1947-49 helped sort out the production potentials, quality problems, and the need for process controls at every step. Nevertheless king crab worthy of the name was produced at a profit first and best by Wakefield's. How long did it take? An important question in benefit/cost analyses is always the time from experiment to assured commercial success. Lowell Wakefield once told me that for king crab it was 15 years. Returning to our work in the late 40's on processing frozen pollock and bottomfish of the Bering Sea, it is obvious 30 years later that major problems of using this resource for domestic industry expansion still remain, even though much knowledge of the resource and process alternatives is available.

1951-1961

In the early 1950's, there were several industry developments that were reflected in the technological research program. In the Pacific Northwest and Alaska, salmon canning and halibut freezing were still dominant.

The increased use of freezerships for freezing salmon in Alaska for later canning and the industry problems of increasing costs for Alaska operation indicated that economics and need for better production efficiency were dictating changes. King crab was still on the horizon with less than 1 million pounds frozen meat production as the industry struggled for recognition in eastern markets and higher prices. Frozen fillet production in the Pacific Northwest seemed static around 5 to 6 million pounds; however, the exploratory fishing findings of large stocks of Pacific ocean perch in deeper waters looked promising. Indications

of large populations of pink shrimp off Oregon seemed to point to future expansion of the Northwest shrimp industry.

The California tuna industry was still growing after the post-war expansion and was packing 8 to 9 million cases a year but pilchards (sardines) fell from the biggest production year of 5.3 million cases in 1950-51 to 65 thousand cases in 1953. Tuna was very competitive and striving for a quality image as production climbed.

Back at the Seattle Technological Laboratory, research on utilizing salmon cannery waste, the nutritional significance of fish meals, and freezing and storage studies for several species of fish and shellfish were completed. Studies of the quality changes in freezing and storing salmon for later canning were completed and reviewed with the National Canners' Association and processors. By this time, various studies on quality and processing problems had demonstrated the need to expand the basic data on proximate composition and food values of a wide variety of species of both marine and freshwater origin. This project from 1955 to 1961 provided analyses of most Pacific coast species and proved highly valuable to both industry and nutritionists.

At the Ketchikan laboratory, the 5-year study of the problem of paralytic shellfish poison in butter clams was completed. The results showed that the problem of producing frozen or canned clams in southeastern Alaska required close monitoring of toxin levels prior to processing because of the wide and frequently inconsistent variation in the toxicity of clams from many beaches. This, incidentally, is about where we are 30 years later; however, recent research by the University of Alaska and others suggest we may soon understand the mechanism that accounts for variable toxicity in adjacent clam beds.

A major expansion in the Seattle technological research arrived in 1954 with supplementary funds, from $63,000 initially to over $200,000 by 1960, allotted under the Saltonstall-Kennedy Act of 1954 for fishery development and quality research. Two new major research programs were inititated: (1) Chemical and nutritional characteristics of fish oil and development of new uses for fish oils and (2) Development of voluntary standards of quality for fresh and frozen fish and shellfish for use by the new voluntary inspection program and industry.

The fish oil research included both fundamental and applied research under contract to the top two universities in the fields--California and Minnesota. Industry liaison was a significant part of the research and included oil producers, users, and chemical manufacturers for the studies at the laboratory on chemical derivatives and intermediates. Other research emphasized the significance of the polyunsaturated fish oils and the role of the fatty acids for dietary use in lowering serum cholesterol. Substantial interest and support was shown by nutritionists and physicians in this research because of national concern of the American Heart Association for proper dietary control of the factors causing high serum cholesterol and atherosclerosis in an increasing number of Americans. The research included support of dietary studies with both animals and humans and demonstrated the value of seafoods and fish oils in the diet under long-term comparative conditions. In recent years, new controversies have arisen in

this field because of the complexities of individual health and dietary regimes. It is of special interest to note that pioneering studies of the Seattle heart specialist Dr. Averly Nelson, for whom the technological laboratory provided considerable assistance, showed in a 20-year study of heart patients that when high amounts of oily fish such as salmon were in the diets, 36% of the patients survived over the 20 years; only 8% of the patients who did not use the high fish diet survived. This early work published in 1972 provided the first evidence of the great value oily fish can be for heart patients. Recent workers during the past five years, unaware of Dr. Nelson's earlier results, are now substantiating this role of oily fish and fish oils in connection with heart disease.

The new quality standards program at Seattle emphasized frozen salmon, halibut, sole, cod, and Pacific ocean perch. The measurement of quality in each species was conducted in collaboration with industry groups and included many product cuttings. The validity of the voluntary grade standards and their application for consumer acceptance was thoroughly reviewed and, on occasion challenged, in industry cuttings. This work, for the first time, emphasized the difficulty of defining intrinsic quality in freshness, flavor, and texture of otherwise good quality fish.

The problem was best illustrated in our work with quality grading of frozen halibut steaks and, in a later study, the quality grading of the landed fresh iced halibut. Considerable work on this latter problem was conducted aboard fishing vessels, an interesting assignment that required, in the case of the halibut fishery, a chemist or technologist with good sea legs and a little Scandinavian blood. One of the first facts of fish life that expanded our laboratory views of fresh fish was the finding that halibut of various fishing grounds varied remarkably on occasion in keeping quality and intrinsic acceptability. For example, I can remember selecting in a taste panel a sample of an 18-day-old iced halibut as exemplifying a top quality fresh halibut (i.e., Grade A) in contrast with another sample of halibut from a different ground that was quite edible but appeared to have suffered much quality loss. The poorer sample of halibut was iced for only 5 days. Like melons and fine wines, the environment for fish must be also just right to produce the most desirable quality. In our current quality studies of the cod and pollock of Alaska, we are finding again that all fresh fish are not equal. Our experiments at sea and in the laboratory must recognize the natural variations that affect acceptability and keeping quality of the fish harvested at various times or from different fishing areas.

An important study of quite different problems in the 50's was the quality of canned tuna and the determination of the handling and brine chilling factors aboard vessel that resulted in high salt content, spoilage, and physical damage to yellowfin and skipjack tuna. Research and contract studies at sea were conducted on the quality differences, the problems of brine chilling and freezing tuna, and the factors that contributed to quality losses. The laboratory coordinated the research with the tuna industry technical committee and the National Canners' Association laboratory in California. Results and the final report recommendations emphasized the refrigeration requirements and pinpointed the problem areas. We

recognized, however, that the basic economics dictated a number of the poor practices aboard vessel and this we could not solve.

1961-1971

The 1960's brought some good and poor years for the salmon industry and a feeling of uncertainty about the future as the industry observed the problems of international competition for the prime fishing grounds of the North Pacific. Japanese bottomfish operations appeared in the Bering Sea in 1960 and expanded in 1961. King crab freezing and canning plants at points from the Shumagin Islands to Kodiak and Cordova and southeast Alaska were producing at highest production levels to date in 1961.

By 1966 production of both canned and frozen king crab had tripled in volume from 1961 with landings of 159 million pounds. Pacific shrimp production got off the ground in the late 50's and was producing 155 thousand cases worth $2.5 million by 1961. Alaska bottomfish was still in wraps but halibut and salmon from Alaska and frozen fillets from Puget Sound were tops in the frozen fish business at 72 million pounds total for the Northwest and Alaska. In California, tuna at the beginning of the decade produced a new high of over 15 million cases and continued to grow.

Research on chemistry and nutritional properties of fish oils, development of quality criteria and measurement in fresh and frozen fish and shellfish, and development of voluntary standards for product inspection were major activities as the technological laboratory entered its 4th decade. Included in the fish oil program was the widest range of contract and cooperative research efforts conducted by the laboratory in its history and included such significant problems as oxidative changes, lipid metabolism, fish oil odor chemistry, nutritional properties of oxidized oils, and skin-healing properties of fish oils. In the laboratory, the research on chemical uses, reactions, and derivatives of fish oil developed various class compounds (e.g., nitrogen derivatives of fatty acids, fatty acid esters, and epoxy esters) with potential application in industry as intermediates for chemical synthesis of special industrial products. This research necessitated a close liaison by the chemists with both the fish oil industry and chemical manufacturers to select reactions and compounds of greatest interest and possible application.

The expanded laboratory research on quality criteria in conjunction with the industry cuttings demonstrated the need for better quality measurement. The distinction between freshness and spoilage criteria and the reason for using one or the other had long been a confusing area to fishery technologists. Spoilage, of course, was early assessed by both subjective and objective tests. The study of the more difficult problem of measuring freshness changes with objective methods and simpler methodology was initiated in the 60's and established the Seattle laboratory as a leader in the area. We believe that the application of these studies for quality control in frozen fish production would help assure the high quality needed for today's markets.

Another area studied was texture definition including measuring simple toughness or shear value and the water-binding or drip relations in the flesh. In the early work with Dover sole and

Pacific whiting (hake), the problem of mushy texture in some fish was resolved by the research on the protozoan parasite showing its relation to the proteolytic enzyme causing texture breakdown. In fish fillet plant studies, the importance of washing and minimizing the recontamination of the fillet was shown by conducting microbiological tests on the line in the plant.

As it turned out, this work provided the background for a major study on irradiation pasteurization of fresh fish that was supported most of this decade by the Atomic Energy Commission. The concept of using a chemical-physical means of destroying spoilage bacteria on the surface of fresh chilled fish and thereby extending its keeping quality was hardly a new one. Nevertheless, the extensive chemical, microbiological, and process research with low level gamma irradiation provided the most comprehensive base of knowledge to date on the quality changes that determine consumer acceptability of a fresh product. The extension of storage life of irradiated cod, sole, and other fish was demonstrated repeatedly; however, it seems to me that our most basic contribution lay in detailed studies of the chemistry of the flavor and texture changes in fresh fish that occur in the initial stage of quality loss long before chemical spoilage occurs. The microbiological studies on the irradiated fish first emphasized the detailed life and death story of the bacterial survivors of low level gamma irradiation. Of greatest importance in this work and the research that continues to the present date is the story of Clostridium botulinum, the possible hazard of botulism in partially processed products, and a basic understanding of the factors that determine the growth and toxicity of C. botulinum in such products. This problem more than any other problem, even the hard facts of irradiation economics, was responsible for Food and Drug Administration (FDA) actions that placed irradiation pasteurization of fish on the back burner at the conclusion of the extensive research by the Seattle and other laboratories at the end of the decade.

As a final comment to the fourth decade highlights, we should note that in 1966 Maurice Stansby left the Technological Laboratory after being Director since 1942. The new Director was Dr. Maynard Steinberg, formerly at the Gloucester Technological Laboratory.

1971-1981

In the 1970's, tuna production went out of sight with over 30 million cases valued at over 1 billion dollars. Shrimp became the most valuable landed species, and king and snow crab in Alaska made crab second in value to salmon and made Alaska first in value of U.S. landings. A community in Alaska that most people had never heard of since World War II, Dutch Harbor, became the top U.S. fishing port in value of landings. Pacific shrimp landings zoomed to new highs, then fell off. By 1980, trawl fish landings in the Northwest and Alaska were over 300 million pounds but over 40 percent went to foreign vessels under joint ventures. In 1976, the 200-mile limit became law and development of Alaska bottomfish was a bonanza or a bust depending on whom you asked. At the Seattle Technological laboratory, the Director, Maynard Steinberg, retired in August 1979 and the fourth Director for our 50-year period, John Spinelli, took over in February 1980.

Two developments had occurred in the

60's that shaped much of our technological research for the 1970's. The first was the recognition in the 1960's that the underutilized species of fish and shellfish off our coasts constituted a major food bank for future U.S. fisheries and the consumer. Species off the Northwest and Alaska included Pacific whiting, walleye pollock, and other bottomfish. Off California, anchovy and jack mackerel were included as underutilized resources. International concern for total utilization of fishery resources as food for a hungry world was expressed during the 60's and 70's in fishery conferences sponsored by the Food and Agriculture Organization (FAO) of the United Nations.

The second development was the new federal and state regulations of the 1970's on water quality, habitat protection, and the limitations on disposing of seafood processing wastes in coastal waters. These two developments brought to the industry new potentials for expansion on one hand but costly problems in plant operations on the other. As a result, the policy emphasis in the fifth decade of the technological laboratory included utilization and fishery development and the problems of quality and safety for both new and established processes.

Starting in the early 1960's, some very serious attempts were made to prepare and market relatively pure fish proteins. At that time, the primary efforts on this direction were being made in the United States, Canada, and Sweden. The end-product of this effort was, of course, fish protein concentrate (FPC). Our role in the national FPC program primarily was concerned with technical problems in FPC production at the pilot plant built in Aberdeen, Washington, and operated in 1970-71. FPC never became a viable commercial product and the story needn't be told here. Simply put, FPC was not needed in the industrialized countries and its merits were never demonstrated in third world countries. What about FPC today? It would appear that the technology to produce an inert FPC, solely a protein supplement, is too sophisticated and probably economically unsound. New approaches based on relatively old technology are beginning to show that fish can be used to supplement cereal proteins in a much simpler fashion than preparing a solvent-extracted powder.

The need for tested concepts of total utilization was still standing, of course, when the FPC program was terminated. Our research on Pacific whiting showed that total protein utilization from fishery resources requires various process alternatives for flesh and protein recovery, dehydration, stabilization, and modification of the intermediate dry or frozen product. Incorporation into modern food systems is the last and most important phase. Such concepts have been tested in our studies with Pacific whiting, rockfishes, and walleye pollock and include mechanical production of minced flesh, stabilization (as accomplished in Japanese surimi), and freezing and storage for use as an intermediate product to be used later in a variety of processed foods. The research of FPC and modified proteins has been important in building this base for alternative processing methods that industry can consider as future markets develop. The problems of species, harvest, and processing limitations aboard vessel and at the shore plant have shown that there is no universal panacea like FPC.

Actually, we have learned quite the

opposite. To utilize fully the long-neglected resources and even some of our traditional species, the fishing industry must produce food to the greatest extent practicable, but a variety of processing options must be available. Options should include processing aboard vessel, at a nearby shore plant, and intermediate processing for final production close to the markets. Selection of an option depends on the characteristics and volume of the species and the desired end product. Whether it is frozen, canned, or dried, the product must integrate with modern food production. Price and acceptability are important but also convenience, product image, and nutritive value. In a nutshell, we learned that the fishing industry must join the food industry.

Currently, our most important task is to complete the basic data on the quality, preservation, and food characteristics by species including the utilization options. Most of this has now been accomplished for Pacific whiting. Much more remains for walleye pollock, various rockfishes, flounders, and lesser species of fish and shellfish. An integral part of this technological agenda is the problem of the options for fish waste and by-catch utilization. The economic and energy outlook requires that total utilization concepts are derived also from good engineering and common sense.

CONCLUSION--FUTURE OF UTILIZATION RESEARCH

One common approach when confusion occurs in historical assessments is to gather statistics. For our review of the 48 years of Northwest and Alaska utilization research, the publication output was 615 scientific papers and technical reports, 7 patents, and numerous information reports to industry and the consumer. This sounds impressive but is not easily converted to output value. If we could convert this knowledge or the industry applications over the years to dollars on an objective basis, it would be simple to calculate the benefit/cost ratio for utilization research. How to assure objectivity in such calculations is both difficult and controversial and, for the purposes of this review, benefit/cost speculations do not seem appropriate.

It is difficult because scientific knowlege advances on a broad front and the users of research findings do not bother to give specific credit when those findings are integrated into a revenue-producing device or system. Also there are many instances that we can specifically cite where a research concept or finding lay on the shelf for many years before being rediscovered. Timing is important. Over 40 years ago, Maurice Stansby wrote a research paper on controlled atmosphere for preserving fresh fish. Today, controlled atmosphere has been rediscovered and is the "in" thing. An interesting result of our microbiological research on irradiated fish in the 60's was Dr. Melvin Eklund's knowledge of botulism and his recent finding that botulism in salmonids is responsible for recurring fingerling losses in state hatcheries. This finding will save state and federal hatcheries over 1 million dollars per year. Similarly work on flavor deterioration in irradiated foods by John Spinelli will undoubtedly be used as a quality index for frozen fish and help guarantee its quality. Six years ago, Dr. Lauren Donaldson urged that, in our work on salmonid feeds, we investigate the possibility

of extracting carotenoids from shrimp waste to use as a pigment source for pen-reared salmonids. The results of this work by John Spinelli may well lead to the development of an industry in Louisiana where 18 million pounds of crayfish waste could yield up to 2000 pounds of astaxanthin worth over 1 million dollars. It is difficult, of course, to attach a specific dollar figure on findings such as these even though the feedback shows benefits in dollars for the research.

In looking ahead, I believe Peter Drucker provided a point for management to remember: "Long range planning does not deal with future decisions but with the future of present decisions." Certainly there were major decisions made in fisheries utilization during the 70's that will affect fisheries development for many years. During the five decades of our review, it is clear that we and industry did not select all winners for fishery development; however, the benefits of research and cooperation did produce significant applications. Two important lessons stand out: (1) the need for continuity of utilization research in the basic food processes like freezing and quality measurement and (2) the long time scale for developments and process applications. These place a premium on the collected knowledge of the laboratory and the significance of our industry association for both the past and future of fishery development.

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