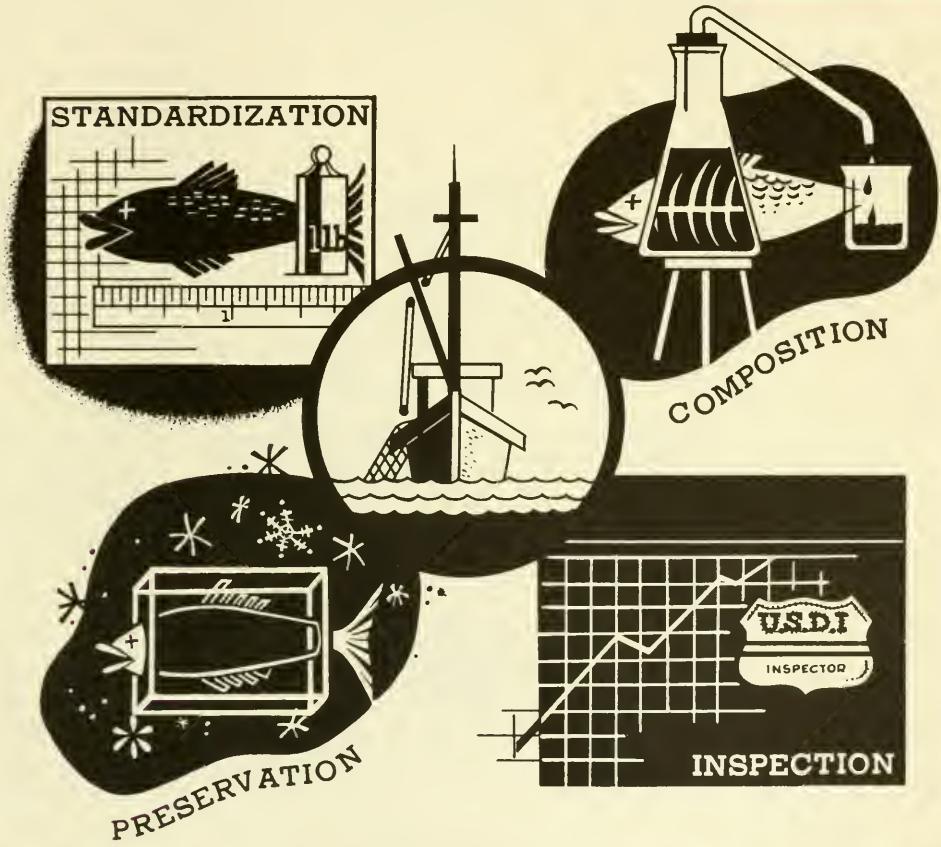
RESEARCH IN FISHERY TECHNOLOGY

Annual Report – East Boston Laboratory

June 30, 1959



United States Department of the Interior
Fish and Wildlife Service
Bureau of Commercial Fisheries

Circular 91

United States Department of the Interior, Fred A. Seaton, Secretary
Fish and Wildlife Service, Arnie J. Suomela, Commissioner
Bureau of Commercial Fisheries, Donald L. McKernan, Director

RESEARCH IN FISHERY TECHNOLOGY
ANNUAL REPORT--EAST BOSTON LABORATORY
June 30, 1959

S. R. Pottinger
Laboratory Director

A brief summation of the progress in research projects at the laboratory from July 1, 1958 to June 30, 1959.

On November 23, 1959, the laboratory moved from East Boston to Gloucester, Mass. The name was changed to Gloucester Technological Laboratory.

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BACKGROUND

The East Boston Technological Laboratory was established in July 1945. During its 14 years of existence considerable expansion of the staff and diversification of activities has occurred. The staff now comprises some 14 professional people trained in chemistry, biochemistry, engineering, fishery technology, and related fields. As of June 1959, the laboratory was still housed in old buildings at East Boston. Late in 1959, a modern laboratory building in Gloucester will be ready for occupancy. This new building will enable the Bureau of Commercial Fisheries to increase its emphasis on technological research in the New England area.

Following is a brief description of the activities at this laboratory during the period July 1958 through June 1959. This report does not thoroughly explore any one work area but instead is designed to familiarize the reader with the general laboratory research and inspection programs and the objectives of the programs.

STANDARDS AND SPECIFICATIONS

Four chemists and one fishery aid at this laboratory are directly concerned with the development of U.S. standards for grades and Federal specifications for fishery products. This team surveys current industry production practices, statistically samples and evaluates industry products, classifies and develops quality characteristics and testing methods, and holds meetings with members of industry to discuss and evaluate proposed quality requirements. Then standards are developed which serve as a quality gauge to facilitate wholesale buying and selling. In a similar fashion, Federal specifications are developed for industry and military and civil agencies. They are used to standardize Government purchases, thereby allowing industry to compete for contracts on an even and fair basis and assuring the buyers of good quality fish at regular market prices.

Figure 1.--The East Boston Laboratory

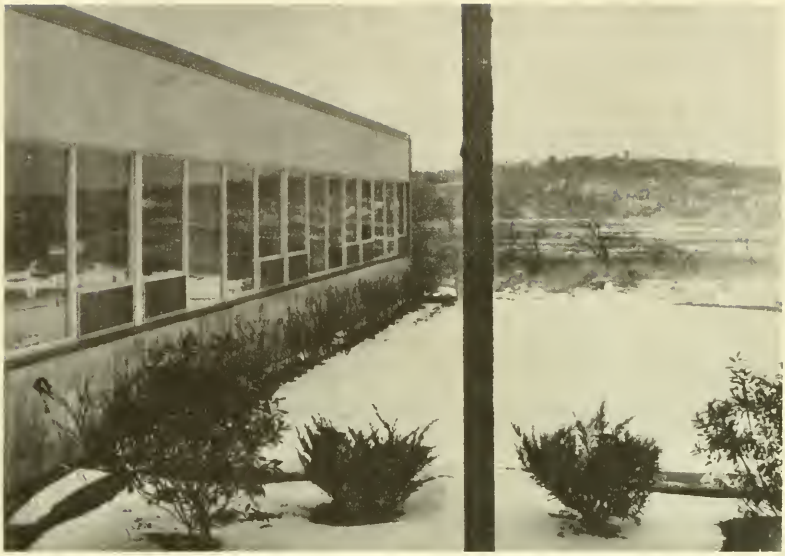

Figure 2.--The new Gloucester Laboratory

Standards Development.

During the past year development work has been carried out at this laboratory on standards for (1) frozen haddock fillets, (2) frozen cod fillets, (3) frozen raw breaded fish portions, (4) frozen ocean-perch fillets, (5) frozen fried fish portions, and (6) frozen fried scallops. The standard for frozen haddock fillets became effective March 1, 1959, and is now being used by industry. An inspectors' manual for grading haddock fillets was developed and given to the inspectors for their use. The standards for frozen cod fillets, frozen raw breaded portions, and frozen ocean-perch fillets will soon be published in the *Federal Register*, and shortly thereafter will become available for industry use. Standards for frozen fried scallops and frozen fried portions are in the final stages of development.

A grading survey of frozen fish sticks was initiated as part of the program of developing and maintaining standards to reflect current production practices. This survey, conducted 3 years after the adoption of a U. S.

Figure 3.--Chemist weighing fillets for evaluation of uniformity of fillet size.

Figure 4.--Presentation of proposed standard to industry members.

grade standard for frozen fried fish sticks, will show if there is a need for tightening of these standards.

Federal Specifications.

Specifications reflecting good production and packaging techniques were made available to Federal, civil, and military agencies for use in buying chilled and frozen fish and frozen raw breaded shrimp. Also, proposed specifications for canned tuna, lobsters (live and chilled and frozen meat), and canned clams were developed and informally presented to industry for their comments.

Figure 5.--Packaging fish sticks for frozen-storage tests.

PRESERVATION AND ENGINEERING

Four specialists in the field of fishery technology and engineering are conducting research designed to improve quality and handling of fishery products. Studies now in progress deal with the preservation of fish using improved icing, freezing, or storage techniques, and the design, development, and application of modern handling equipment for the fishing vessel and shore plants.

Preservation of Fishery Products.

The preservation research at this laboratory is designed to answer questions such as: How long can fish fillets be kept in frozen storage? What will be the effect on storage life of the fillets if the storage temperature is reduced by 10 or 20 degrees? What effect will various packaging materials have on the storage life of fishery products? How can the quality of fish landed by the vessel be improved? What is the best method for freezing fish or shellfish aboard the vessel?

An important phase of this research is to determine the rate and extent of the quality loss in frozen fishery products that occurs at temperatures below freezing. In this project, the effect of storage at various temperatures and relative humidities, and the use of packaging materials with various rates of moisture and oxygen transmission

are studied. Samples used for the test are obtained from regular commercial production or are specially prepared at the laboratory. Quality changes are determined at regular intervals by examining the frozen product for dehydration and color change, by serving cooked samples to a taste panel, and by chemical and physical tests for such factors as rancidity and texture change.

During the past year, frozen storage studies were completed on (1) haddock fillet blocks packaged with a variety of materials, (2) fish sticks prepared from these fillet blocks at intervals of frozen storage, (3) pink shrimp, commercially packed using four different methods of preparation, and (4) haddock fillets, dipped in various corn-syrup solutions before packaging and freezing. Now in progress are studies on commercially packed samples of frozen fried tuna sticks, breaded ocean-perch portions, breaded pollock portions, bay scallops, and pollock fillets. Special tests to define the quality of frozen fish were also conducted in cooperation with the National Fisheries Institute. Commercial samples of frozen haddock and ocean-perch fillets stored at three different temperatures for 9 months, were subjected to a variety of conditions to simulate commercial storage, distribution, and handling practices.

Tests, both completed and in progress, show that the frozen-storage life of fishery products can be extended by any one or a combination of the following factors: Storage temperature of 0° F. or lower, relative humidity in the storage room of 85 percent or higher, and packaging materials which allow less than 1 percent weight loss in a year of storage. Future studies are designed to determine, as exactly as possible, the extension of frozen-storage life that can be expected for a number of products using the various combinations of factors given above.

Another avenue of preservation research is concerned with the freezing of fish aboard the vessel. This technique offers promise as a means of landing uniformly high-quality fish--as compared with the very variable quality resulting from conventional iced storage, increasing utilization of vessel hold space, and leveling out production at the shore plant. Results of studies of brine-freezing of fish conducted in the past year show that the frozen-storage life of fillets prepared from both round and eviscerated brine-frozen haddock compared favorably with that of fillets prepared from very fresh iced fish. Freezing scallop meats at sea in a solution of corn-syrup solids and salt was not successful and did not produce a satisfactory product. The meats become very yellow and rancid during subsequent frozen storage. Brine-freezing of scallop meats also was unsatisfactory, resulting in excessive salt penetration into the product. Scallop meats frozen at sea in the refrigerated hold of the vessel, however, proved to be of slightly better quality than very fresh iced scallops frozen ashore immediately after being landed.

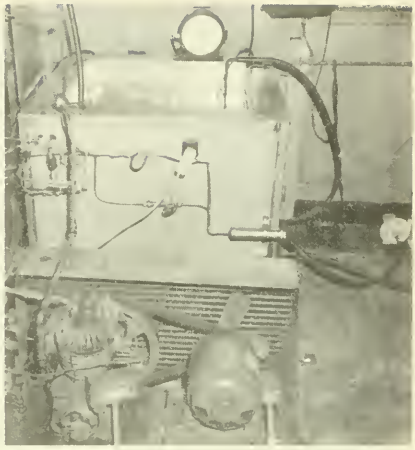

Figure 6.--The experimental refrigerated sea-water tank.

Preservation studies are in progress on the storage of fish in refrigerated sea water kept at 30° F. aboard the vessel and at the shore plant, and show considerable promise as a means of improving the quality of fish--as compared with storage in ice at 32° F.--and in reducing handling costs.

Other work in this project includes tests to determine the suitability of

fillet boxes made from wax-impregnated paperboard for storing iced fish. Encouraging results have been obtained and it is possible that these boxes may be used to replace the increasingly expensive fillet can, thus providing considerable savings to the processor with no loss of quality in the fish.

Engineering Applications.

Methods of handling fish both on the boat and at the wharf have remained substantially unchanged in the New England area for over 50 years. Many of these handling methods contribute to increased operating costs and to decreased product quality. For example, the use of harbor water in scrubbing down penboards and hold surfaces may add more spoilage bacteria than it removes, and can contribute to spoilage of the next load of fish placed in the vessel's hold. Also, pitchforks now used in unloading fish may result in tearing of the flesh with consequent loss of quality.

Figure 7.--Pitchforks puncture the fish flesh and contribute to lowering its quality.

The aim of the project is to eliminate the mishandling of fish both at sea and ashore through the application of modern engineering and sanitation techniques. One of the steps towards this goal has been the development of a mobile fish-weighing and de-icing unit during the past year. Designed primarily for unloading cod and haddock, this machine has a wire-mesh hopper into which the baskets of fish and ice are dumped as they are swung out of the vessel's hold. Much of the ice mixed in with the fish falls through openings in the hopper or the conveyor belt; the remainder is removed by hand. The conveyor carries the fish up to a box, mounted on a scale, where the fish are weighed and emptied into tote boxes for transport to the processing line. This machine eliminates at least one pitchfork operation and the need for a price allowance for ice that is normally unloaded with the fish.

Figure 8.--Dumping the weigh box of the de-icing and weighing machine.

As groundfish are gutted aboard the vessel, they are tossed into a wash box and then pitchforked to the vessel's hold. As another phase of this research, a fish wash box was developed for handling groundfish on the vessel, thus eliminating the use of pitchforks and its damage to quality. Cleaning of the vessel's hold with harbor water is not satisfactory, and many bacteria remain to contaminate further new catches of fish. To attempt to correct this condition studies were conducted on the application of chlorinated water on the vessel. A small diaphragm pump designed to meter sodium hypochlorite solution into the sea water wash line of the vessel was installed aboard a Boston fishing trawler. Sea water containing 50 to 60 parts per million of chlorine was used for washing the fish after gutting and in port for washing

the penboards and hold. The results were immediate and striking; the penboards no longer had a slimy feel after washing; and the typical fishy odor of the hold was eliminated. Many more Boston trawlers have installed this equipment, and inquiries concerning its availability and cost have been received from all over the world.

Figure 9.--The pitchfork method of de-icing haddock.

COMPOSITION AND UTILIZATION

The composition and utilization unit is staffed by five chemists who have a wide range of experience in solving fishery problems. Research is directed towards adding to the knowledge of the chemistry of fishery products in order to help solve some of the quality problems of the fishing industry. The present program consists of studies on the proximate composition of fish, the chemical constituents of the odor and flavor of fish, and the relation between protein denaturation and textural changes during the frozen storage of fish.

Composition of fish.

Information on the composition of fish enables the processor to calculate his yield and costs, and the nutritionist and dietitian to make recommendations regarding the components of normal and special diets. During the past year, studies have been conducted on the physical composition (size, weight, and

Figure 10.--The determination of the protein content of fish muscle using the Kjeldahl apparatus.

fillet yield), the proximate chemical composition (moisture, protein, fat, and ash), and the sodium and potassium content of fish as they vary between species with season of the year, and with different geographical areas. Results of studies show that fish have a low sodium content, and the methods by which fish are cooked have a profound influence on the final sodium content of the fish as they are eaten. Of all the common cooking methods tested, boiling is the most efficient in lowering the sodium content; steaming, broiling, and baking are next in order of importance. These findings have great significance to people whose physical condition requires a low sodium diet. These tests also confirm the fact that the practice of brine-dipping fillets destined for the frozen market results in an increase in the sodium content of the fillets, thus precluding their use in sodium-restricted diets. By taking advantage of these findings, industry can insure the retention of hospital kitchens as outlets for its frozen fish.

Flavor and Odor Components.

Research on flavor and odor has as its goal the detection, identification and separation of those compounds responsible for the undesirable odor and flavor changes that occur in fishery products during frozen storage. Information obtained will be used in establishing methods to minimize any undesirable changes, thereby enabling frozen fish to retain that fresh-from-the-sea flavor.

Results during the past year indicate that chemical methods can be used to detect the quantitative differences in the carbonyl content of fresh and frozen haddock and to relate this to storage age and quality. This work is progressing satisfactorily, and it is expected that as a corollary to this study a chemical test will be developed that will distinguish recently frozen fish from frozen-stored fish.

Protein Studies.

Fundamental changes in the order of arrangement of the molecules comprising the protein of the muscle of frozen-stored fish contribute to toughness and loss of quality. Solution of this problem will be an important contribution in increasing the acceptability of and the demand for frozen fish products. Research at this laboratory is aimed at identifying the chemical groups that are directly involved in bringing about these changes in protein. The hypotheses are that: (1) the increased toughness of frozen-stored fish is due to polymerization and is occurring through the formation of new disulfide linkages, and (2) the apparent dryness in the muscle of frozen-stored fish is due to a loss of function of certain molecular groups which, in fresh muscle, are free to bind large quantities of water and give to the flesh the attribute of succulence.

Figure 11.--Determining the spectra of compounds that contribute to the odor and flavor of fish.

The first hypothesis is being tested by measuring the rate of changes of the shape and weight of the protein molecules in the presence and absence of p-chloromercuribenzoic acid. This reagent is specific for sulfhydryl groups in that it attaches itself to them alone. By so doing, it prevents sulfhydryl groups from participating in reactions and therefore, should maintain the protein molecules in a monomeric state during storage. Measurements of changes in molecular shape

and weight of control and experimental extracts at different time intervals yield information on the state of the protein molecules and will help determine the correctness of this hypothesis.

Figure 12.--Measuring the viscosity of a fish muscle protein extract.

The second hypothesis will be tested by measuring the change in moisture-vapor equilibria of frozen-stored samples as a function of the degree of denaturation of the samples. This will furnish information as to whether dryness and toughness in long-time frozen-stored samples are merely different manifestations of the same phenomenon or whether they are independent phenomena taking place through similar types of reactions involving different chemical groups.

Reserach findings to date suggest that sulfhydryl groups are involved in the stability of fish muscle albumins when exposed to severe conditions of denaturation such as boiling. There is also evidence to the effect that sulfhydryl groups play a role in the solubility of globular proteins in the presence of increasing concentrations of p-chloromercuribenzoic acid.

CONTRACT RESEARCH

In cases where the high degree of specialization required cannot be furnished by the Bureau's laboratories, research work is carried out under contract by a cooperating university or research institution. All contract research projects are given close supervision by the Bureau laboratory that services the area in which the research is being conducted.

During the period covered by this report, four contract research projects have been carried out in the New England area under the supervision of the staff of this laboratory. These projects dealt with: (1) development of a device for automatically detecting bones in fish fillets, (2) bacteriological evaluation of commercial fishery products, (3) on-the-spot assistance to vessel owners and fishermen in improving the handling of fish on Massachusetts fishing vessels, and (4) a similar project on improving the handling of fish on Maine fishing vessels. The following is a brief description of the activities conducted under these projects during this past year.

Automatic Bone Inspection of Processed Fish.

Many fishery products are essentially "boneless." However, in certain products, it is almost impossible to find all of the bones by visual examination or by feel. As a result, many consumers are bone-conscious and often inspect their fish quite thoroughly to make sure it is bone free. Also, many do not buy fish because they are afraid of bones, particularly for children. Fish that were guaranteed to be boneless would increase the consumer demand for this food tremendously.

The Barkley and Dexter Laboratories in Fitchburg, Mass., under contract with the Bureau, are working on the development of a device which will automatically detect bones in fish fillets, fish sticks, and portions, and will reject from the production line those that contain bones. The major problem is to find a suitable method to obtain, define, and measure changes in resolution between the bone and flesh of these fishery products.

Investigations have been conducted using various X-ray techniques for this purpose. Specifically, survey-type

studies have been conducted using several devices. A special xicon television-type tube and various photocells have been used with little success to measure the change in intensity of X-rays emanating from the product when it is exposed to a gamma ray source. Unfortunately when using these methods, it was not possible to electrically define what little resolution was obtained.

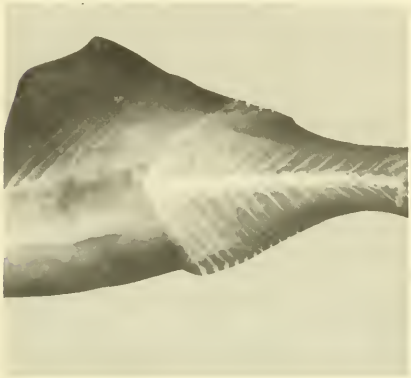

Figure 13.--X-ray picture showing bony structure of fish.

Another method, that of using certain photocells to scan the image appearing on the fluorescent screen of an X-ray unit, shows considerable promise. Results show that it is possible to obtain resolution between medium-sized bones and fish flesh. The bones in fish flesh and portion samples moving at simulated production-line speeds were picked up in the form of a readily discernible and reproducible electrical signal on a cathode ray oscilloscope. As a result of these tests, a prototype X-ray bone detection unit will be designed and constructed. This unit will be used in simulated plant tests to statistically define the resolution between fish flesh and both small and large bones.

Bacteriological Evaluation of Commercially Produced Fishery Food Products

The number of bacteria in fishery food products is often an indication of the quality of the product and of the sanitary care exercised in the commercial handling and production of the product. There are very few data on the bacteriology of commercially prepared fishery products. To obtain such data, which may provide a basis for Federal or State bacteriological standards, this laboratory conducted a survey of the various fishery products produced and marketed in the local area.

Preliminary results indicate that frozen fish fillets and precooked frozen fried fish products such as fish sticks, portions, and scallops usually have a relatively low bacterial content (average plate counts of approximately 100,000). In general, fish products purchased by the consumer are of acceptably low bacterial content.

Improved Handling of Fish on Massachusetts Fishing Vessels

The objective of this project was to improve the quality of the fish being landed in Massachusetts ports. This work was carried out under contract by the Massachusetts Division of Marine Fisheries and consisted of having an experienced commercial fisherman, referred to as a principal investigator, make trips on commercial fishing vessels in order to provide instructions in the icing and handling of the fish and in the maintenance of proper sanitary conditions.

Figure 14.--Haddock in ice aboard the vessel.

In the past year this project has been confined largely to groundfish vessels operating out of Gloucester, Mass. Vessels operating out of Boston and New Bedford were studied the previous year. During the period covered by this report, the principal investigator made trips on 17 fishing vessels and instructed the crews in the proper methods of icing, washing, and general handling of the fish and in maintaining the fish holds in a sanitary condition. Written recommendations were also furnished to the vessel owners, in which were outlined the steps that should be taken to improve handling and sanitary conditions. In addition, dockside inspections of over 36 fishing vessels were made to obtain information on the handling methods and icing protection provided.

This study has been instrumental in improving the icing, handling, and sanitary practices on some of these vessels and in providing information necessary for establishing and carrying out Bureau research programs aimed at further improving conditions on fishing vessels. The contract officially terminated during June 1959.

Improved Handling of Fish on Maine Fishing Vessels

A study similar to that described for improving the quality of fish landed by Massachusetts fishing vessels is also being carried out on Maine fishing vessels. This latter study is being conducted under contract by the Maine Department of Sea and Shore Fisheries, which has retained a principal investigator to instruct the owners and crews in the proper icing and handling of fish on the vessel and in the maintenance of proper sanitation in the fish hold.

During the past year, the principal investigator made trips on 10 fishing vessels and furnished the owners and crews of these vessels with written recommendations concerning the proper handling and icing of the catch. He also made dockside inspections of these and 22 other vessels to determine if improvements in quality results from this program. These inspections showed that in many instances the recommendations of the principal investigator are being followed, and are resulting in the landing of better quality fish. Because of the favorable results obtained, the State of Maine is planning to continue this work after termination of this contract in October of 1959.

FISHERY PRODUCTS INSPECTION AND CERTIFICATION SERVICE

The youngest member of the various units of the East Boston Laboratory is the Inspection Service which supervises the inspection and grading of fishery products in Region 3. Being a youngster, this unit suffered "growing pains," but it can now be said that the Inspection Unit has found its place in the fishing industry.

A few statistics will show how inspection has progressed. From July 1958 through June 1959, the number of plants in this region packing fishery products under the Department's Continuous Inspection Service increased from six to eight. During this same period the number of USDI inspectors increased from 8 to 14. Also, more than 40 million pounds of fishery products were packed under the continuous inspection program in this area during this period, the greatest part of which displayed the Department's Grade A shield or continuous inspection shield.

Figure 15.--Inspector grading fish sticks.

In addition, this laboratory was responsible for the inspection of over 9 million pounds of fishery products on a lot-inspection basis. This service

was performed for a variety of applicants which included processors, retail organizations, county, city, and state institutions, private and Government-operated hospitals, and passenger steampship companies.

In April of this year, a suboffice of the inspection service was officially opened in New York City. The service provided by this office was greeted with enthusiasm by its users from the very beginning, and the large volume of lot-inspection work being handled in the Metropolitan New York area has kept that office constantly bustling with activity. The greater part of the inspection work is done for several of the largest passenger steampship companies, such as the Cunard Line, the United States Lines, and the Moore-McCormack Lines. It has been learned from several sources that the inspection service has proved a valuable aid to both the producers and the purchasers of fishery products in the Metropolitan New York area.

It would be pointless to list the variety of fishery products inspected under our inspection services. Just about every form of frozen, canned, fresh, raw, cooked, uncooked, and breaded fish and shellfish has been inspected at one time or another during the year.

REPORTS OF LABORATORY RESEARCH

Information obtained in the laboratory is of no value until it is made available to industry and to other interested parties so that they can use it in their everyday operations. Distribution of pertinent research results is one of the Bureau's most important responsibilities.

A report of each study is prepared by the laboratory investigator as soon as possible after a significant phase of his work has been completed. These reports are written for all segments of the fishing industry, and are distributed to media that reach the widest possible readership, both semitechnical and scientific. During the past year, 20 reports of work conducted at this laboratory have been published. The following is a list of these reports; copies may be obtained by writing directly to the laboratory.

1. Anonymous.
   1958. U. S. Standards for Grades of Frozen Haddock Fillets. Federal Register, vol. 23, No. 246 (December), pp. 9759-9761.

2. Anonymous.
   1959. Interim Federal Specification, PP-S-00315a; Shrimp, Frozen, Raw, Breaded. Issued by General Services Administration, Federal Supply Service, April 21.

3. Anonymous.
   1959. Interim Federal Specification, PP-F-00381e; Fish, Chilled and Frozen. Issued by General Services Administration, Federal Supply Service, June 4.

4. Butler, C., J. W. Slavin, and E. J. Robertson.
   1958. Chapter 14, Fishery Products (Frozen). American Society of Refrigerating Engineers, ASRE Air Conditioning - Regrigerating Data Book, Refrigeration Applications (November - December), pp. 14-01 to 14-16, New York.

5. Christensen, A. F., K. E., Nielson, C. Butler, and J. W. Slavin.
   1958. Chapter 3, Fresh Fishery Products. American Society of Refrigerating Engineers, ASRE Air Conditioning - Refrigerating Data Book Refrigeration Applications (November - December), pp. 3-01 to 3-05, New York.

6. Mangan, George F., Jr.
   1959. Flavor and Odor of Fish - Progress Report. Commercial Fisheries Review, vol. 21, No. 6 (June), pp. 21-27 (Separate No. 552).

7. Mangan, George F., Jr.
   1959. Dicarbonyl Compounds as Components of Fish Odor. Commercial Fisheries Review, vol. 21, No. 7 (July), pp. 21,22 (Separate No. 556).

8. Mangan, George F., Joseph H. Carver, Maynard A. Steinberg, and Donald Snyder.
1958. Preparation of Dried Fish Solubles from Concentrated Press Liquors on a Laboratory Scale. Commercial Fisheries Review, vol. 20, No. 7 (July), pp. 17, 18 (Separate No. 516).

9. Mangan, G. F., C. Merritt, and J. T. Walsh.
1959. Chemical Components of the Odor of Fish. Paper presented at the 135th American Chemical Society Meeting (April).

10. Peters, John A.
1959. Salt Content of Eviscerated Haddock Frozen in Sodium Chloride Brine. Commercial Fisheries Review, vol. 21, No. 2 (February), pp. 6-9 (Separate No. 539).

11. Sereno, M. N.
1958. Time-Temperature Studies of Fishery Products by the Bureau of Commercial Fisheries. Paper presented at the annual meeting of the Canadian Department of Inspection, Ottawa, Canada (November).

12. Slavin, Joseph W.
1958. Methods of Freezing Used in the Fisheries - A review. Fishing Gazette Annual Review, vol. 75, No. 13, pp. 176, 180, 184, and 186.

13. Slavin, Joseph W.
1959. Chlorinated Sea Water Cleans and Sanitizes Fish Holds. Fishing Gazette, vol. 76, No. 1 (January), pp. 21 and 26.

14. Slavin, Joseph W., and John A. Peters.
1958. Freezing and Storing Deep Sea Lobsters - Some Tests on Cooked Whole Lobsters. Commercial Fisheries Review, vol. 20, No. 7 (July), pp. 1-6 (Separate No. 514).

15. Slavin, Joseph W., John A. Peters, and S. R. Pottinger.
1958. Studies on a Jacketed Cold-Storage Room. Food Technology, vol. 12, No. 11 (November), pp. 602-609.

16. Slavin, Joseph W., John A. Peters, and S. R. Pottinger.
1958. The Jacketed System for Freezing Fish. Quick Frozen Foods, vol. 21, No. 9 (April), pp. 122-125.

17. Slavin, Joseph W.
1958. Freezing Fish in the United States of America. Bulletin of the International Institute of Refrigeration, Meeting of Commission, 3, 4, and 5, Moscow, Russia (September), pp. 353-363.

18. Slavin, Joseph W.
1959. Icing versus Freezing. Paper presented at World Fishing Boat Congress, Rome, Italy (April).

19. Sohn, Bernard I.
1959. The Effect of Brine Dipping on the Sodium Content of Some Fishery Products. Paper presented at the Annual Meeting of the Atlantic Fisheries Technologists, Princeton, New Jersey (February).

20. Wilbour, Frederick C., Jr.
1958. Improved Handling of Fish Aboard Massachusetts Fishing Vessels. Commercial Fisheries Review, vol. 20, No. 9 (September), p. 26.

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