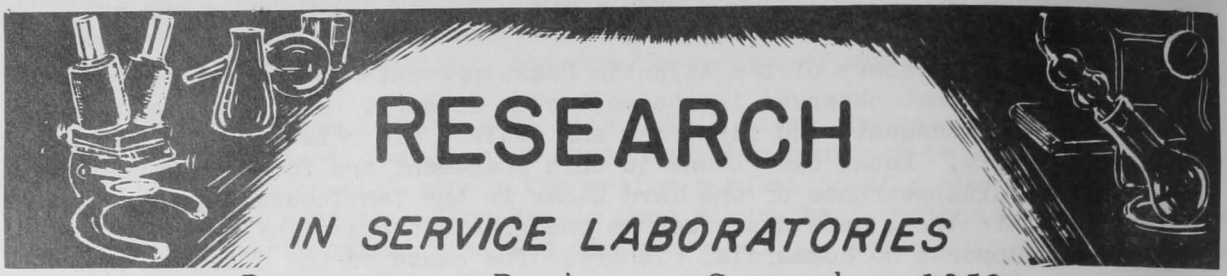


Progress on Projects, September 1952

REFRIGERATION: Freezing Fish at Sea, Defrosting, Filleting, and Refreezing the Fillets: The research trawler Delaware completed test cruises 14 and 15. Approximately 21,000 pounds of scrod haddock were caught on Georges Bank and were brine-frozen aboard the vessel. These fish were placed in commercial cold storage and will be used for further testing by the laboratory. (Boston)

* * * * *

Freezing and Storing Alaska Shrimp and Dungeness Crab: Organoleptic tests were made on seven experimental packs of frozen Alaska shrimp after 31 weeks of storage at 0° F. One lot of commercially-packed frozen shrimp was included for comparison. The purpose of the project is to determine the effect of processing and packaging methods on the flavor, texture, shrinkage, and keeping quality of the shrimp meats. The 31-week examination was made during the month and the experimental work on this phase of the project was concluded. Some of the tentative conclusions were:

1. The texture of cooked Alaska pink-shrimp (Pandalus borealis) meats varied widely within any given lot.

2. The toughening of cooked pink-shrimp meats occurred during the initial processing and did not increase materially during frozen storage at 0° F.

3. Flooding the cooked shrimp meats with brine (2-percent salt solution) prior to freezing and storage produced a product more tender than the shrimp meats packed dry in the usual commercial manner.

4. Pink-shrimp meats cooked from 1 to 4 minutes in 10-percent brine prior to packaging and freezing apparently had absorbed an excessive amount of salt as judged by taste testing. The flavor, from the standpoint of salt content, of shrimp meats cooked 1 minute in 10-percent brine and then flooded with 2-percent brine prior to freezing was satisfactory, as was the flavor of the shrimp meats cooked 1 minute in 5-percent brine.

5. Use of monosodium glutamate (3 percent by weight) in the frozen dry-packed shrimp did not improve the flavor or keeping quality of the product.

6. The storage life of frozen, dry-packed Alaska pink shrimp meats packed in moisture-vaporproof containers is from 6 to 8 months at 0° F. The storage life of frozen shrimp meats packed in dilute brine is greater than 8 months. (Ketchikan)

* * * * *

BYPRODUCTS: Vitamin Content and Nutritive Value of Fishery Byproducts: Niacin and vitamin B_{12} assays of samples of 23 lots of pilchard meal and 1 lot of tuna meal were completed. The niacin content of the lots of pilchard meal ranged

from 61 to 125 micrograms per gram of meal on the moisture-and-oil-free basis, and the vitamin B_{12} content from 0.20 to 0.38 micrograms. The niacin content of the lot of tuna meal was 174 micrograms per gram of moisture-and-oil-free meal; the vitamin B_{12} content was 0.26 micrograms. (Seattle)

* * * * *

ANALYSIS AND COMPOSITION: Composition and Cold-Storage Life of Fresh-Water Fish: The proximate composition was determined for four additional samples of Lake Michigan chub and of 16 samples of sheepshead from the upper Mississippi River. The results are presented in the following table:

Composition of Edible Portion of Lake Michigan Chub and Sheepshead

Species	Sample No.	Length	Weight	Fillet Yield	Proximate Composition			
					Moisture	Fat	Protein	Ash
		Centimeters	Grams	Percent	Percent	Percent	Percent	Percent
Lake Michigan chub (Leucichthys sp.)[1]	13	22	110	45	79.2	8.10	13.8	0.84
	14	20	85	33	78.7	4.38	15.6	1.04
	15	21	95	32	80.9	3.92	15.3	0.97
	16	20	88	37	75.1	9.18	14.5	0.77
Sheepshead (Aplodinotus grunniens)[2]	1	34	520	31	77.1	6.93	19.4	1.22
	2	33	512	35	73.6	8.21	18.7	1.04
	3	31	412	32	74.1	7.00	19.1	1.20
	4	28.5	320	30	74.1	6.43	19.1	1.09
	5	27.5	280	31	79.0	3.48	18.6	1.25
	6	27.5	305	34	76.0	4.73	19.3	1.25
	7	30.5	380	34	75.3	7.90	18.1	1.12
	8	29	395	34	69.4	9.92	18.2	1.07
	9	35	635	38	68.2	11.35	17.9	1.04
	10	36	735	35	70.4	13.09	17.2	0.99
	11	34.5	600	33	73.7	7.89	17.7	1.08
	12	31.5	445	30	77.0	4.81	18.6	1.15
	13	28	330	32	72.1	8.74	17.6	1.02
	14	28	310	33	74.1	8.25	18.2	1.00
	15	26.5	235	32	76.2	3.80	19.3	1.14
	16	33	410	26	80.0	1.87	17.6	1.10

1/CAUGHT IN JULY 1952. EVISCERATED WITH HEADS ON (DRAWN).
2/CAUGHT IN MAY 1952. ROUND (WHOLE) FISH.

(Seattle)

Technological Program Changes

Three new projects were initiated at the Seattle Fishery Technological Laboratory: (1) the cold-storage life of Pacific Coast halibut and (2) salmon, and (3) freezing, thawing, and glazing salmon for canning. This information is needed to provide the technical data to substantiate the changes recommended by the fishing industry in the Federal specifications for fresh and frozen fish and for canned salmon.

REFRIGERATION: (1) Cold-Storage Life of Halibut: The objective is to determine the length of time frozen halibut (Hippoglossus stenolepis) will remain in good condition in commercial cold-storage warehouses. Frozen and ice-glazed dressed whole halibut were obtained at three commercial fish-packing plants. The samples

were handled in the usual commercial manner by placing the fish in paper-lined boxes and storing at 0° F. or below. At intervals of storage, steaks will be cut from the dressed fish and the steak samples glazed, packaged, and further stored at 0° F. These whole dressed fish and steak samples will be examined organoleptically by a qualified taste panel at periodic intervals to determine their keeping quality.

(2) Cold-Storage Life of King and Silver Salmon: The objective is to determine the length of time frozen king (Oncorhynchus tshawytscha) and silver (O. kisutch) salmon will remain in good condition in commercial cold storage. Drawn (heads on) king and silver salmon were plate-frozen, ice-glazed, and stored in paper-lined boxes at about 0° F. At periodic intervals steaks will be cut and the steak samples will be glazed, packaged, and stored. The dressed fish and steak samples will be examined organoleptically to determine the cold-storage keeping quality.

(3) Freezing, Glazing, and Thawing Salmon for Canning: At the present time a substantial portion of the salmon caught in certain areas of Alaska are frozen in brine aboard the vessel, and transported to the State of Washington where the frozen fish are thawed and canned. Technological problems on handling the frozen fish have arisen. These affect the quality of the final canned product. The purpose of this investigation is to determine the effect of methods of freezing, holding in refrigerated brine, glazing, and thawing of the salmon upon the quality of the subsequently canned product.

Since this project was initiated after the season for sockeye salmon (O. nerka) had closed, the tests for the year will be carried out on sockeye salmon frozen aboard commercial freezer ships. Consequently, no tests during this year are contemplated on methods of brine freezing. Representative samples of brine-frozen sockeye salmon were obtained from a commercial packer. Tests are currently being carried out to (1) determine feasibility of glazing the brine-frozen fish to prevent possible changes during storage, and (2) to determine the effect of various thawing methods on the salt content of the subsequently canned fish.

Project Reviews

FREEZING FISH AT SEA, DEFROSTING, FILLETING, AND REFREEZING THE FILLETS--

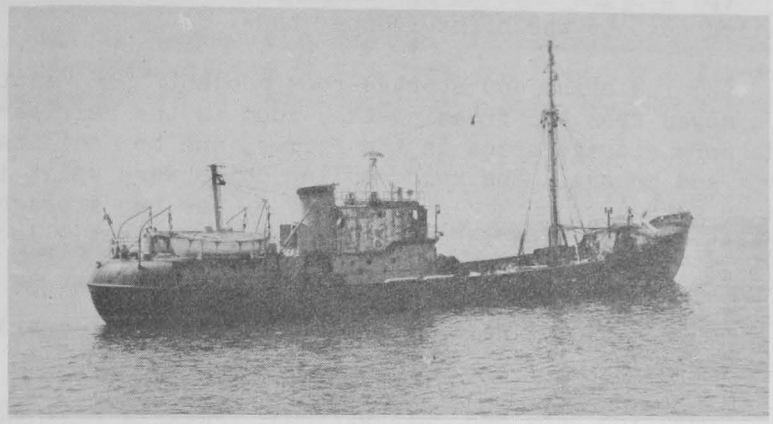
Review for Period December 1950-September 1952

The following is a summary of the over-all status of the project for the period from December 1950 to September 1952, presenting an inventory of the accomplishments, an evaluation of the original objectives in light of more recent and actual operating experiences, and plans for the continuation of research.

RESEARCH TRAWLER OPERATIONS: Vessel: The M. V. Delaware was in a run-down condition when received by the Service in December 1950. Repairs and alterations to the vessel, over and above normal maintenance, during the past 21 months included:

(a) Complete rebuilding of the main propulsion engine;
(b) Replacement of the trawl-winch Diesel engine;
(c) Enlargement and improvement of the galley, and of the forecastle and cabin quarters;
(d) Replacement of the air-compressor unit.

The vessel's basic fishing equipment was restored to the current New England trawler style by the alteration or replacement of non-standard equipment, including the echo sounder, compass, loran, radar, and heating and lighting system. The deck gear likewise was restored and most of the expendable items replaced, including trawl-winch brake system, trawl warps, trawls, and fish-hoist equipment. The crew (7 fishermen, 1 cook, and 4 officers) were indoctrinated both for government employment conditions and the project's scientific research approach, each a significant departure from their customary commercial fishing-vessel routine.



THE DELAWARE EN ROUTE TO FISHING GROUNDS.

Fishing operations are carried out at approximately half-scale as compared to commercial practice, to allow for proper testing of the refrigeration equipment during the developmental stages. Georges Bank has been the locale for all the test cruises, which average about six days each. The catch landed consisted of iced, gutted fish for control purposes; and the round brine-frozen fish as material for experimental work, quality-control tests, and for sale to commercial firms interested in testing the brine-frozen round fish. Sufficient sales have now been made to demonstrate an active interest in the product and to indicate the handling techniques that may be necessary for a larger-scale freezing-at-sea operation.

Refrigeration Equipment: A total of 15 test cruises have been undertaken, with catches up to 25,000 pounds of whole round fish per cruise. These fish, predominantly scrod haddock, were frozen at sea in sodium-chloride brine and stored in the refrigerated hold of the Delaware. The purposes of the cruises were:

(a) To obtain a supply of fish frozen at sea for use in the laboratory and pilot plant, and to provide frozen fish to interested commercial processors;

(b) To study the operation of the experimental refrigeration equipment under working conditions with a view to developing it to the point where similar equipment could be recommended to the industry.

Of special interest has been the operation of the absorption-refrigeration machine. Relatively new to this type of application, the absorption machine is claimed to have certain inherent advantages over the compressor system. Tests of the plant's efficiency, operating costs, and characteristics under full-rated load have been delayed, however, by the low capacity of the brine-cooling evaporator, and we are, therefore, not yet in a position to attest to the plant's performance under full load.

RECENT CHANGES AND ADDITIONS: Since the publication of the report "Freezing Fish at Sea--New England: Part 3 - The Experimental Trawler Delaware and Shore Facilities" (Commercial Fisheries Review, vol. 14, no. 2, February 1952, pp. 16-25), in which the vessel installation was described, a number of changes and additions have been made. These are:

(a) Additional cold-storage space for frozen fish has been provided by construction of an insulated bulkhead located two pen sections forward of the existing

cold-storage room. This new room also is equipped with cooling coils designed to keep the room temperature at 0° F.

(b) A brine make-up and storage tank of 50 cubic feet capacity has been installed next to the brine-freezer tank.

(c) The brine and storage-room coolant (or "antifreeze") circulating pumps were moved from the freezing-tank room to the refrigeration-machinery room to provide more storage space in the former, and to facilitate better maintenance of pumps and motors. The hold cooling coils were split into four parallel banks, one on each side of the center line of the two storage rooms. The flow of "antifreeze" to each bank is controlled by conveniently located valves, providing flexible control of the storage-room temperatures.

(d) Additional refrigeration controls and temperature-recording instruments were installed.

Operating Data and Observations: FREEZER PERFORMANCE: It was found that by loading the freezing tank approximately every 105 minutes with about 960 pounds of scrod haddock, the brine temperature rose about 4° F. and was then pulled down close to its original temperature in time for the next loading. Thus, the average freezing rate was about 550 pounds an hour.

STORAGE-ROOM TEMPERATURE: All-night operation of the room cooling system usually lowered the temperature to about 5° F. Opening of the bulkhead door during the storage of frozen fish caused the room temperature to rise five or more degrees, depending on the period the door was open.

HANDLING OF FISH: It has been found convenient to fill nylon mesh bags (flat dimensions 40 x 20 inches) with about 40 pounds of fish on deck, and to slide these bags down a chute rigged from the after hatch to the freezer rotor. In unloading the freezer, the bags are lifted out by hand and passed forward into the storage room where the frozen fish are emptied from the bags into the pens. The bags are then re-used.

REMOVING FROZEN FISH FROM THE BRINE FREEZER ABOARD THE DELAWARE.

FROZEN-FISH STORAGE: Measurements were made of the available space for storing frozen fish in the two refrigerated holds. After deducting working space, machinery (and access) space, and an 18-inch loading space between the ceiling and top of the fish, the net volume of the forward and after holds were found to be 985 cubic feet and 1,705 cubic feet, respectively. Using a factor of 33 pounds per cubic foot for loose-frozen fish, found to apply in loading

large boxes, the carrying capacities of these two rooms are 32,500 and 56,500 pounds, respectively.

Comments on Results: The freezing rate of 550 pounds an hour, about 55 percent of the anticipated rate, can be increased by raising the brine-cooler capacity and by reducing the loss of refrigeration in the freezing room. The first of these measures will also be necessary in order to apply a full load to the absorption machine.

Failure to maintain at 0° F. the storage-room temperature, as originally planned, is attributed to frequent door openings and to the manner in which the ammonia-vapor lines from the two evaporators (i. e., coolers) are connected. Improved fish-handling procedures and a change in piping design, incorporated into the brine-cooler modifications, can be expected to improve the storage-room temperature.

Operation of the present brine freezer, while very effective in transferring heat from fish to brine, is rather inefficient in its man-power requirements. The lack of standing space and headroom over the tank makes handling the fish bags an arduous task. Also, if sufficient fish were caught and frozen to warrant the use of the after-storage room, wherein the freezer is located, the men would be alternately working in the low temperature room and the relatively warm outside air. Their necessarily frequent passage from deck to freezing room and return would throw an excessive load on the room cooling system. These points have been amply demonstrated during the early cruises.

The data given for the present carrying capacity clearly show the need for the utmost efficiency in use of available storage space. Efficient construction of insulated linings and bulkheads is essential, along with the elimination of any equipment in the hold that could be installed elsewhere.

Under the "Pilot Plant and Shore-Processing" section of this report, observations of vessel unloading are noted. The desirability for development of an improved unloading method is indicated by the comparison with fresh-fish unloading rates. The rapid transfer of frozen fish from vessel to cold storage ashore is obviously desirable in maintaining high quality.

Outline of Future Vessel Work: BRINE COOLER: By modification or replacement of existing unit, increase cooler capacity to 20 standard refrigeration tons.

ABSORPTION MACHINE: Run tests to determine the machine's ability to handle rated freezing load, its efficiency, and cost of operation. This will require installation of metering equipment in steam-condensate and boiler-fuel lines.

BRINE FREEZER: Develop brine-freezing mechanism which can be loaded and unloaded at deck level.

STORAGE SPACE: Study the construction of refrigerated holds with a view to improving on the capacity of the existing installation. Considered in the study would be the insulating materials, construction details and materials, and cooling methods.

VESSEL UNLOADING: Develop improved methods and equipment to facilitate rapid unloading and transfer of frozen fish to cold storage.

PILOT-PLANT AND SHORE PROCESSING: The objectives of the Pilot Plant and Shore Processing section of this project as outlined in the original proposals have

been modified and elaborated as the investigations have progressed. Therefore, it might be well first, to summarize the major objectives and then, evaluate the progress made on each. In this portion of the report those objectives primarily within the scope of the laboratory or vessel-operations sections are not considered. Also, several minor incidental objectives are not mentioned.

Outline of Objectives--Original and Supplemental Combined:

A. Pilot-Plant Freezing Studies
1. Variety of freezing methods, possibly suitable for vessel operation.
2. Freezing rates of fish in brine.
3. Ratio of brine to fish necessary for optimum freezing.
4. Effect of different methods of dispersal (agitation) of fish in brine-freezing tank.

B. Pilot-Plant Thawing Studies
1. Factors affecting rate of thawing fish, especially in fresh water.
2. Commercial thawing methods and equipment.

C. Shore-Processing Studies
1. Problems of unloading and storing frozen fish.
2. Problems of handling, scaling, and filleting thawed fish.
3. Effect of prolonged storage of round-frozen fish prior to defrosting and filleting.
4. Fillet and viscera yields from round fish.
5. Changes in weight of fish during thawing.
6. Preparation of steaks from round-frozen fish.

A. Tentatively, at least, the four investigations under "Pilot-Plant Freezing Studies," are considered completed. Final reports on the bulk of the results have been prepared and accepted. One report has already been published ("Freezing Fish at Sea--New England: Part 2 - Experimental Procedures and Equipment," Commercial Fisheries Review, vol. 14, no. 2, February 1952, pp. 8-15), and the second has been accepted for publication ("Part 5 - Freezing and Thawing Studies and Suggestions for Commercial Equipment"--in press.)

The few pilot-plant trials conducted since the submission of these papers have simply confirmed the data and conclusions already reported.

On the basis of the pilot-plant studies, several recommendations were made for the design and operation of a freezing mechanism for the Delaware. In general these recommendations were followed in the designing and construction of the equipment first installed on the vessel. When the equipment was operated, and as the mechanical details were modified, the pilot-plant staff was frequently called upon to supply data and advice on the effect of various factors on the rates of freezing of fish.

It is now apparent from actual operation of the equipment that major modifications are desirable to cut down on the labor below decks. The proposed changes which would permit the bulk of the operations to be conducted on deck, are still in accordance with the initial recommendations. However, if possible, this time the moderate-size pilot-plant scale models of the freezing equipment should be given thorough trial before the final equipment is constructed and installed on the vessel.

B. The original objectives under the "Pilot-Plant Thawing Studies" have been considered from most of the major angles. A moderate amount of data has been accumulated on the factors affecting the thawing of fish in fresh water. Satisfacto

methods and equipment for commercial use have been devised. The data and recommendations are in the two reports already cited. Some of the practical information on equipment and methods was included in a short report, "Technical Note No. 21--Equipment and Procedure for Thawing Fish Frozen at Sea" (Commercial Fisheries Review, vol. 14, no. 5 (May 1952), pp. 18-19), which was based largely on the second of the larger reports.

Since submission of the above reports, the experimental work has simply tended to substantiate the conclusions and recommendations already made.

There are certain factors that have not been adequately considered and further experiments are planned for study:

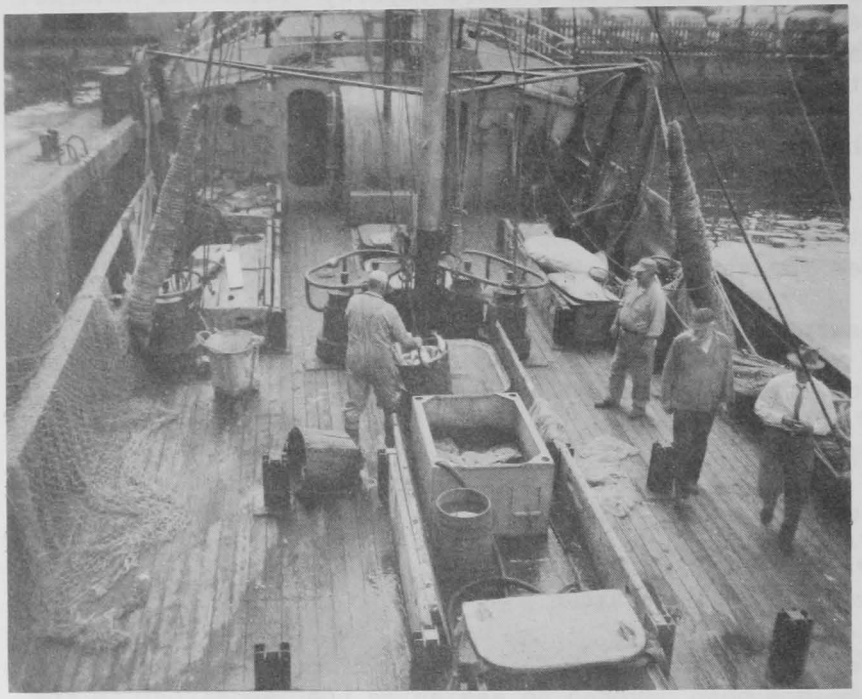
1. Methods of thawing frozen fish other than in water.
2. The effect of very rapid thawing of frozen fish in water at high temperatures, for example, near 100° F.
3. The effect of very slow thawing of frozen fish in water of near-freezing temperatures.
4. The effect of holding the fish in water for long periods, even after thawing is complete.
5. The effect of icing the fish after thawing.
6. The effect of using sea water in place of fresh water for thawing the fish.

As the determination of the exact effect on the fish of most of these factors will be difficult, some time has been devoted to assisting the laboratory in the development of taste-panel testing methods. It is not possible to detect some of these effects without more refined testing procedures.

C. The classification "Shore Processing Studies" covers a variety of investigations, some more or less overlapping into the first two classifications. None of the six studies listed in this group has been pursued far enough to warrant a full-scale final report. The results of the first experiments on commercial processing of fish which had been frozen in brine at sea were reported in "Freezing Fish at Sea--New England: Part 4 - Commercial Processing of Brine-Frozen Fish" (Commercial Fisheries Review, vol. 14, no. 2, February 1952, pp. 26-29). After over 10 months of storage, the fillets prepared from the brine-frozen haddock compare favorably with fillets from iced haddock from the same trip.

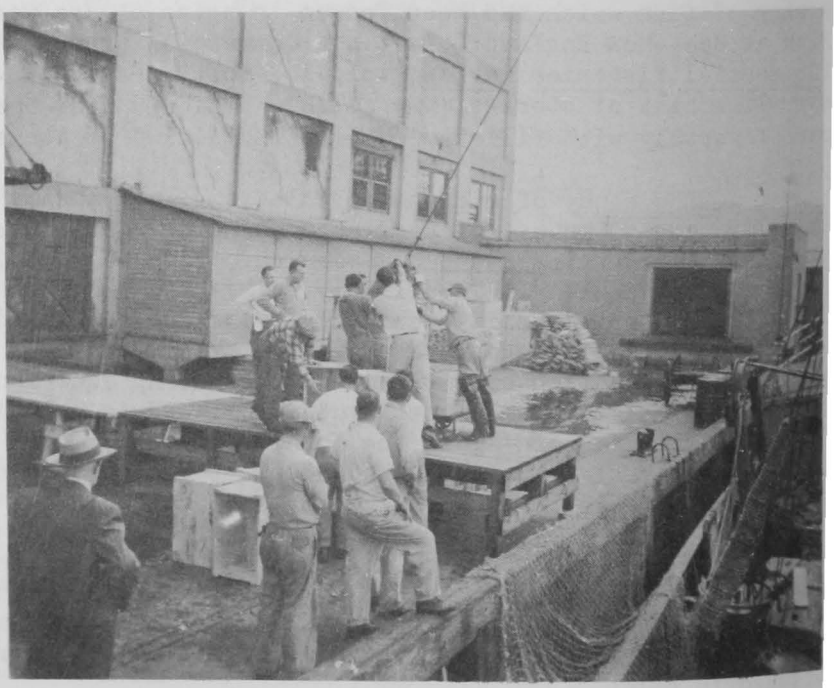
1. The study of methods of unloading and storing fish frozen at sea has been limited to the use of available handling equipment. Improvements have been made each time the Delaware has been unloaded. However, the law of diminishing returns is evident. It is unlikely that any further marked improvement in unloading rate or conditions is possible until brine-frozen fish are delivered in larger quantities. The loads delivered by a single vessel are not large enough to warrant the installation of expensive new handling equipment by cold-storage companies or by anyone else. The latest system followed in unloading the Delaware employed a vessel crew of 8 men--4 in the hold, 2 on deck, and 2 on the dock. A sustained unloading rate of about 25,000 to 30,000 pounds per half day is the most that can be expected. This is about 50 to 60 percent of the rate normal to unloading of iced fish. The handling of the frozen fish by the cold-storage crew is still highly inefficient, but as this operation is not under our control, it is not a simple matter to experiment. No unusual ideas have been developed on the storage of the fish. The cold-storage operators consider the handling of the fish in very large boxes more or less impractical. Therefore, the frozen fish are simply stacked in piles.

2. The handling, scaling, and filleting of the thawed round haddock has so far offered no special problem. Therefore, after making further observations on these operations, the information will be included in reports on another subject. So far, in all commercial trials in standard commercial processing plants, the thawed fish have been reported to handle, scale, and fillet at least as easily as iced, gutted fish. The presence of the viscera appears to simplify scaling with mechanical hand scalers. Also, with round fish it should be practical to scale the fish well with a rotating drum scaler. The filleters noted that there was less slime on the fish; this is an advantage to some and a disadvantage to others, apparently depending on their filleting styles. The filleters were all pleased with the "fresh," firm feel of the meat.



REMOVING FROZEN FISH FROM DELAWARE'S COLD-STORAGE HOLD.

3. The first study of the effect of prolonged storage of round brine-frozen fish was begun in May 1952. The best controlled series were begun in August and September 1952. No conclusions can yet be drawn on any of these experiments. Brine-frozen haddock held for up to 3½ months by private concerns have looked as though moderate drying had occurred during the storage period. However, after the fish were thawed, they were found to look good and to handle well. The fillets prepared from this haddock in storage a few months compared well with fillets prepared from iced haddock currently being delivered.



UNLOADING FROZEN FISH FROM THE DELAWARE INTO BOXES ON TEMPORARY LOADING PLATFORM.

4. The data thus far accumulated on yields of fillets have been highly encouraging--35 to 44

percent on the basis of skin-on fillets from round fish. The variation is partly due to differences in the condition of the fish (which vary somewhat according to the season). Another reason for variation is the disparity in the skills of different filleters. In order to compare fillet yields from round fish with fillet yields from iced, gutted fish, the weight of the viscera must be known. Only twice has it been possible to secure this data. In each case, on scrod haddock caught in October, the viscera recovered amounted to 10 percent of the total round weight. The contents of viscera appears to be higher in spring and summer-caught fish. Arrangements are being made to secure more complete data as often as possible.

5. In most thawing trials, the weights before and after thawing have been noted. When the fish had been in storage for less than a week and the storage temperatures and conditions had been "good," there was no significant change in weight. Brine-frozen round scrod haddock stored for one to two weeks gained approximately one percent during water-thawing at 60° F. These data must be checked in additional trials, especially after several months of storage.

6. The preparation of steaks directly from frozen round fish has been tried in an incidental way. A thorough study of this possibility is contemplated. It is also planned to investigate the possibility of preparing wrapped dressed fish or chunks.

LABORATORY: The work in the testing laboratory has been confined largely to the application of various methods that might be of value in determining and comparing the quality of frozen haddock fillets that have been prepared from brine-frozen and thawed fish in the round, and from iced, gutted fish. Test procedures have involved the use of organoleptic examinations as well as physical and chemical methods such as press drip, free drip, dry-matter content of press drip, texture, salt content, and trimethylamine content of the fillets. A somewhat detailed description of the testing procedures has been reported previously ("Freezing Fish at Sea--New England: Part 2 - Experimental Procedures and Equipment," Commercial Fisheries Review, vol. 14, no. 2, February 1952, pp. 8-15). The results of some of the preliminary laboratory tests, obtained prior to actual semi-commercial production of fillets from brine-frozen fish, have also been reported ("Technical Note No. 22--Fish Frozen in Brine at Sea: Preliminary Laboratory and Taste-Panel Tests," Commercial Fisheries Review, vol. 14, no. 7, July 1952, pp. 20-23).

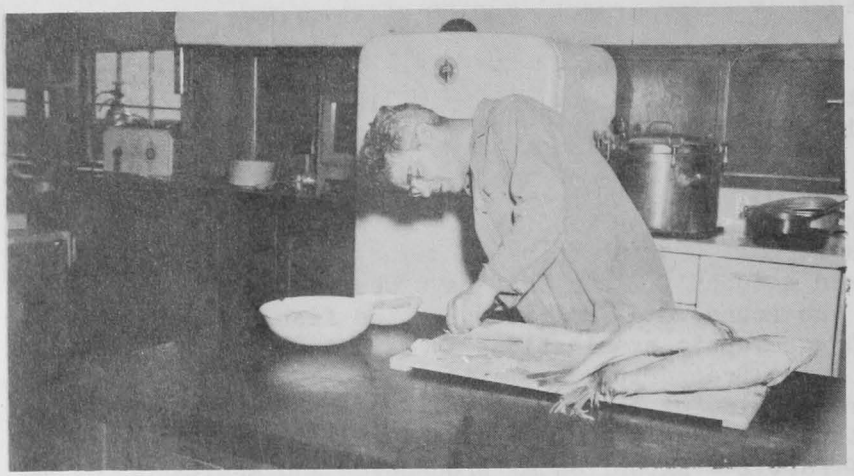
In addition to various routine tests that, in the aggregate, consume an appreciable amount of time but which nevertheless are necessary in the over-all conduct of the project, considerable time has been spent in examining the possibilities of using freezing media containing certain organic compounds and salts, other than sodium chloride, for freezing fish. Some work has been done on the histology of haddock flesh in relation to changes in cellular structure that might occur as a result of freezing once, and of thawing and refreezing. Effect of freezing on the formation of trimethylamine in fish after thawing has been given some attention. These side projects will be discussed in more detail later in this report.

Quality Evaluation of Stored Samples: Some long-range studies on quality evaluation of haddock fillets prepared from brine-frozen fish and iced fish, and held in commercial storage at -10° to 0° F. have now been under way for over 10 months. Three lots of fillets are being examined, namely those prepared from: (1) iced, gutted fish; (2) fish frozen in the round in brine, followed by thawing in water at 53° F. for 3-3/4 hours; and (3) fish frozen in the round in brine, followed by thawing in water at 72° F. for 1-3/4 hours. Examinations of the fillets have been made at intervals of 3 to 4 weeks over this storage period. Palatability tests have been made by a panel of laboratory personnel, with test samples

prepared mostly by steaming. Other tests have been made on the uncooked fillets. A random selection of three 5-pound cartons of fillets from each lot are used as the source of samples for each test in order to obtain reasonably representative results.

The results to date have indicated some changes in the quality of the three lots over the period during which they have been in storage. The changes, however, have veen practically the same for each lot--a slight decrease in palatability scores, a rather definite increase in press drip, and an increase in tenderometer readings (indicating decreased tenderness). Very little over-all change has occurred in free drip, total solids in press drip, and trimethylamine content for the three lots. At this time, the fillets are considered to be of nearly equal quality in all three lots and show no adverse effects due to refreezing.

Freezing Media Studies: During the past year, compounds to be used as substitutes for or additives to sodium-chloride brines, to enable freezing operations to be carried out at a lower temperature, have been tested. A large number of compounds were investigated. For reasons of toxicity, viscosity, hydrolysis effects, etc., the number of possibilities was reduced to a relative few. These compounds are both inorganic, such as various salts, and organic, such as carbohydrates, alcohol, and glycerol. They may be used alone or in combination with sodium chloride.



PREPARING BRINE-FROZEN FISH FOR SALT ANALYSIS.

In addition to possible toxic properties of the additives, factors which determine the cost of the brine must be considered. To be efficient as a freezing medium, a brine must afford maximum depression of the freezing-point for minimum quantities of solid substance added. Such a requirement implies that the freezing curve for the resulting medium should exhibit little or no horizontal portion or "plateau effect" with increasing concentration. Ionization or splitting of a dissolved substance into two or more charged particles, tends to increase the effectiveness of the substance. Ionization is a characteristic of inorganic, but does not occur in organic compounds (other than salts of organic acids), so that the freezing point is reduced more, per molecular weight, by inorganic than by organic additives.

The "plateau effect" is most characteristic of carbonhydrate syrups and is noticeably present in other organic media. Highly concentrated solutions are required for effective reduction of freezing points. For example, various sugar syrups require concentrations in water in the range of 50 to 60 percent (by weight) to permit low freezing temperatures to be attained.

Inorganic brines, to be commercially practical, appear to be limited to sodium chloride, magnesium chloride, or calcium chloride. The last, due to its deteriorative effect upon the meat of fish, would require some modification. These brines are characterized by efficient and relatively great reduction in freezing points, as shown in the table on page 37.

The feasibility of using calcium chloride or magnesium chloride is still being investigated. Of the two, magnesium chloride appears the most promising. Fish frozen in a eutectic (22 percent by weight) magnesium-chloride brine at temperatures of -10° F. and -20° F. are indistinguishable visually from the normal iced product. The few organoleptic tests performed thus far have evidenced no taste differences from control samples frozen in sodium-chloride brine. A sample of approximately 5,000 pounds of haddock frozen in magnesium-chloride solution is to be placed in commercial cold storage (-10° F. to 0° F.). This sample will be regularly tested chemically and organoleptically during a period of approximately one year in storage for changes in flavor, appearance, and texture.

Compound	Percentage present in water solution	Eutectic freezing temperature of solution
Sodium chloride	23.3	-6° F.
Calcium chloride (73 percent)	38.0	-36° F.
Magnesium chloride	22.0	-27° F.

The solubilities of other chlorides, when added to eutectic sodium-chloride brines, are greatly reduced, and any further depression in freezing point caused by the addition of the other chlorides is negligible. It is possible, however, to bring about a more substantial decrease in freezing point by decreasing the concentration of sodium chloride and thereby permitting increased quantities of the more efficient magnesium chloride to be added. Mixtures of this type are under investigation. Fish frozen in a mixture (15 percent by weight each of sodium and magnesium chlorides) at -10° F. have been tested organoleptically and chemically. No differences in flavor, texture, or appearance could be noted. Chemically, the penetration of salt into the meat of the fish as indicated by an increase in the chloride concentration when using the mixture was markedly reduced as compared to that for fish frozen in sodium-chloride brine. Storage of large quantities of fish frozen in these mixtures is not at present contemplated. It is felt that the results to be obtained from storage tests of fish frozen in magnesium-chloride brines will indicate whether magnesium chloride, as a substitute for or an additive to sodium-chloride brine, is usable.

Organic compounds, due to the "plateau effects" found in the freezing curves, due to their lack of ionization, and also because of relatively high costs, have not been extensively studied in this project. Much higher concentrations of organic compounds in water are required to attain a given reduction in freezing point than is the case with the more efficient inorganic salts. For example, while a 20-percent solution of sodium chloride will reach a temperature of approximately 0° F. before freezing, a 64-percent solution of sucrose is required to reach the same temperature. Not only is cost a factor in this case, but a solution of a much higher viscosity results, which retards heat transfer.

It is possible to add alcohol or glycerine to eutectic sodium-chloride brines without having the sodium chloride precipitate. Here again, however, the "plateau effect" of the freezing curve is observed. While reasonably low temperature-freezing solutions may be obtained from these mixtures, the temperatures reached are not sufficiently low, as compared to some other substances, to justify the additional cost unless found to be the only usable methods.

The addition of glucose to inorganic-salt brines has given promise of usable brines. A mixture of 12.5-percent sodium chloride and 34-percent glucose in water freezes at -10° F. Calcium chloride (25 percent) when mixed with glucose (25 percent) in water will freeze at -25° F. This solution does not cause the usual deteriorative effect upon the meat of fish found in solutions in which calcium chloride is the single dissolved component. No eutectic points have yet been found in

these calcium chloride-glucose solutions. The degree to which the temperature may be lowered is limited only by viscosity effects.

In summary, the following general statements may be made regarding immersion freezing media. The costs of sodium-chloride brine substitutes cannot possibly compete with the costs of sodium chloride. It is probable, however, that such low-temperature brines will be usable for longer periods since, for several reasons, contamination of the brine will be reduced. The possibility of the brine freezing in the heat-exchanger tubes will be minimized since the freezing point of the brine approaches the minimum temperature of the vaporizing ammonia surrounding the tubes. Lower brine temperatures will lower the degree of penetration of fish by the brine. Freezing-rates at -10° F. are approximately twice those at +10° F. Immersion periods will be proportionately shortened. Since penetration occurs, to a limited extent, even after freezing of the surface has taken place, the shortened immersion period will operate to reduce penetration of the brine into the fish.

Trimethylamine in Frozen and Thawed Fish: In developing the technique for determining the content of trimethylamine nitrogen in haddock, some results were obtained which indicated that fillets which had been previously frozen and then thawed produced trimethylamine at a much lower rate than did previously unfrozen fillets (both samples were held at above-freezing temperatures). Since the trimethylamine test is being used in this project in making quality-evaluation comparisons, it was thought advisable to conduct a side project of short duration to go further into these findings. Some samples of fresh haddock fillets and gutted haddock were held in crushed ice and removed at intervals as freshness decreased for plate-freezing and storage at 0° F. Other samples were plate-frozen immediately, without any holding period in crushed ice, and stored at 0° F., while a third series was brine-frozen and placed in 0° F. storage. After freezing and at different intervals of frozen storage, samples were placed in a household refrigerator at a temperature of about 40° F. for holding until spoilage of the samples occurred, as judged organoleptically. Trimethylamine-nitrogen determinations were made initially and at appropriate intervals during the test.

The samples held in crushed ice showed a progressive increase in trimethylamine nitrogen during the holding period, reaching a value of about 27 mg. per 100 gm. of the meat of the fish for the last of the fish that were removed from the ice to be frozen. Immediately after freezing, the values dropped to about 10 mg. Upon removal of the samples after various periods of storage up to three weeks at 0° F. and placing in the household refrigerator, no appreciable rise in trimethylamine nitrogen occurred even though the fish became badly spoiled. Similar results were obtained during spoilage of the samples that had been frozen immediately and then placed in the household refrigerator. The results indicate that trimethylamine nitrogen values used as an index of spoilage for unfrozen haddock do not appear to be valid when the fish have been previously frozen, then thawed and allowed to spoil at above freezing temperature. Under these conditions values did not rise much above 10 mg. per 100 gm. of the meat of the fish even when the fish had reached an advanced spoiled stage. A detailed report of this side project is being prepared.

Histology: Another side project which has been under way for some time is the preparation and study of sections of the meat from fish frozen once and twice. These histological studies were to be made originally to supplement the findings of other tests in evaluating the quality of the fish prepared and stored in the course of this project. At first we thought that as a result of refreezing some quality differences would occur, but none showed up. Therefore, the histological studies will be terminated shortly. Considerable difficulty has been encountered

in preparing satisfactory sections and the results obtained thus far have not been sufficiently encouraging to warrant further action at this time.

Actomyosin: Some preliminary results, at least insofar as developing the technique is concerned, have been obtained on the determination of extractable actomyosin in fish muscle. It is thought that by following changes in solubility of this substance, an indication of the degree of denaturation of the fish protein due to freezing may be obtained and these indices may, in turn, be of some value in showing possible effects of refreezing on protein breakdown. Because of the press of other work and the delay in delivery of essential laboratory equipment, very little progress has been made in conducting accurate determinations of actomyosin until quite recently. These determinations are now under way and should progress more smoothly than in the past.

Consumer Acceptance Tests: To supplement the findings in the quality-evaluation tests made in the laboratory and, more particularly, to obtain the reactions and opinions of consumers regarding the quality of fillets prepared from brine-frozen fish and from iced fish, large-scale consumer acceptance tests have been planned. Approximately 200 letters were sent out through the Massachusetts Division of Marine Fisheries, explaining the purpose of the tests and asking whether the recipients would be interested in cooperating in such tests. Although the response was less than anticipated, a sufficient number expressed a desire to participate in these tests. A number of the potential participants were visited and arrangements made to start the tests. The tests will be made in the participants' homes on samples delivered by us; the samples to be prepared for the table by the participants in any desired manner. Generally, fillets from brine-frozen fish and fillets from iced fish will be tested and compared simultaneously. A simple questionnaire signifying the preference, if any, will then be filled out and mailed to the laboratory. Plans are being discussed to expand the consumer tests to neighbors of the laboratory personnel, and to organized groups that might serve to give a representative cross-section of the consumer public.

Future Laboratory Studies: Among some problems planned for future study are organoleptic tests for seasonal effect on quality of fish frozen at sea, and of commercially-iced fish. While this, in effect, has been and is being done in connection with the various cruises made by the Delaware, the scope will of necessity be limited due to the laying-up of the boat at certain times during the year.

Another problem is to investigate procedures to reduce drip in fillets when they are thawed. It is planned, at first, to determine the effect of dipping the fillets in sodium-chloride brines of various strengths, holding the time constant. Variations of this procedure may then be tried.

Although some data have been collected on relative tenderness of the meat of brine-frozen and air-frozen fish, it is planned to supplement these findings with further data of this type.

Considerably more work should be done in developing recommended procedures for reducing brine penetration into the fish during the brine-freezing process. Factors such as temperatures of the brine, length of time the fish are held in the brine both prior to and after freezing, and possible effect of freezing before rigor and during rigor are to be considered.

Further work may possibly be done on developing freezing media that permit lower temperatures to be used in immersion freezing of the fish.

(Boston)